CELL AND MOLECULAR BIOLOGY

Unit: II

MITOCHONDRIA

- The mitochondria are thread-like or granular cytoplasmic organelles (Gr.mito thread chondrion = granule).
- They contain many enzymes and coenzymes which are responsible for energy metabolism.
- They are described as the power plants or power houses of cells.
- The mitochondria play main roles in cellular respiration and energy production.
- The mitochondria were first observed by Flemming and Kolliker in 1882.
- These organelles were first called bioblasts by Altmann. Later, the term mitochondrion was introduced by Benda in 1898.

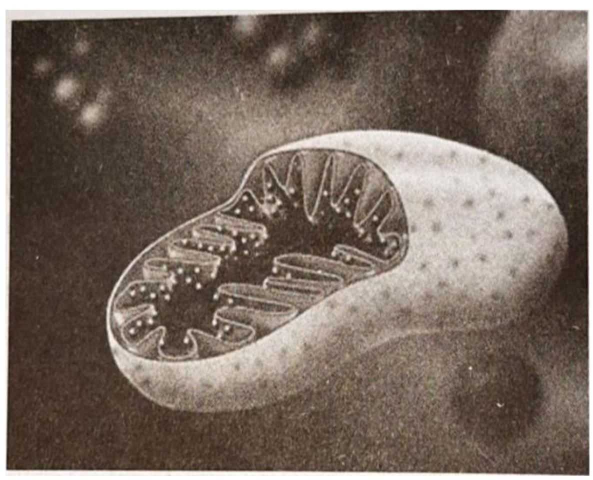

Fig: Mitochondria.

- Mitochondria are found both in plant and animal cells.
- The mitochondria may be filamentous or granular in shape.
- The shape of mitochondria may change from one cell to another depending upon the physiological conditions of the cell.
- They may be rod-shaped, club-shaped, ring-shaped, rounded or vesicular.

- The size of the mitochondria is highly variable. In most cells, their length varies from microns and their width from 0.2 to 1.0 micron.

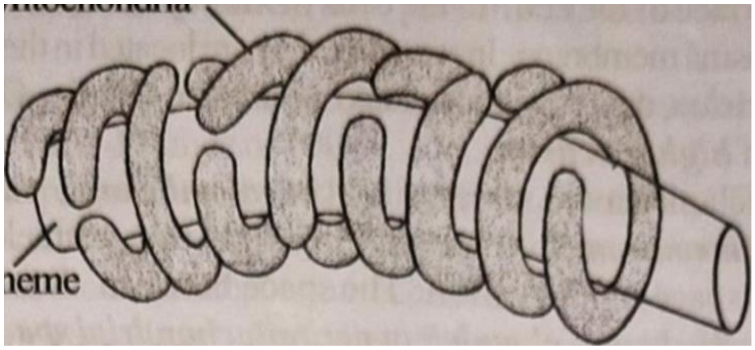

Fig : Mitochondria in sperm tail.

- The smallest mitochondrion is seen in yeast.
- The largest mitochondria are found in the oocytes of amphibia.
- The number is particularly related to the functional state of the cell.
- If the metabolic activity is high, the number ofmitochondria is also high.
- A small number indicates cells of low metabolic activity.
- The giant Amoeba (Chaos chaos) contains 50,000 mitochondria whereas the egg ofsea urchin contains 1 1 ,50,000 mitochondria

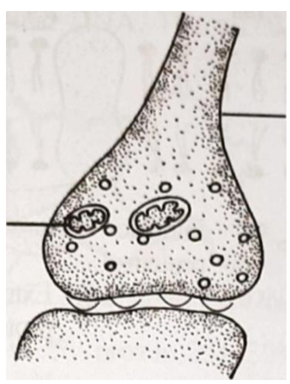

Fig: Mitochondria (in neurons).

- The mitochondria are covered by two membranes, namely an outer and an inner mitochondrial membranes, each measuring about 60Å in thickness
- The central space of the mitochondria is called the inner chamber.
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Electron Transport System or Respiratory Chain

- It is a system of enzymes and coenzymes, where the reduced coenzymes like F NADH are oxidized (FAD, NAD) to release energy.
- The energy released in electron system is used for the synthesis of ATP.
- The synthesis of ATP is called o phosphorylation. The electron transport system occurs in the inner membrane mitochondria.
- The electron transport system contains mainly six components

1. NAD
2 FAD a and
3. NADH
4. FADH
5. Cytochrome
6. Cytochrome

- The oxidation of FADH and NADH occurs by the following steps:

1. The initiation of electron transport system is the removal of hydrogen from the (NADH or FADH) by the enzyme dehydrogenase. The hydrogen atom becomes ionized' protons (+) and electrons (-).

$$2H \longrightarrow 2H^+ \text{ (Proton)} + 2e^- \text{ (Electron)}$$

2. The hydrogen ion reduces the coenzyme NAD.

NAD + 2H+——---+ NADH + H+

3. The NADH is oxidized into NAD by transferring its hydrogen ion to FAD which acts as hydrogen carrier

4. The cytochtome oxidase finally discharges electrons to oxygen. This oxygen unites with hydrogen ions forming water.

ADP + Pi + Energy ATP

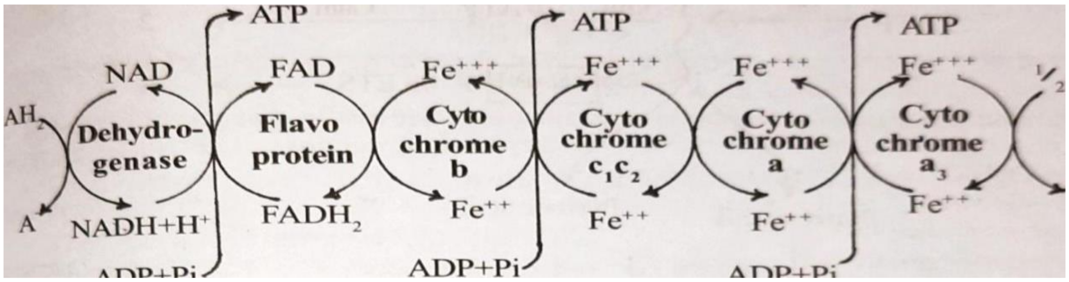

Fig: Electron transport system.

- The process of ATP formation occurring during the oxidative reactions of Krebs' cycle is known as oxidative phosphorylation

Synthesis of ATP in Krebs Cycle

- In Krebs cycle, only one molecule of ATP is synthesized directly. It is produced when succinyl COA is converted into succinic acid.

Synthesis of ATP in Electron Transport System

- The ETS oxidizes the NADH and FADH released during glycolysis, oxidative decarboxylation and Krebs cycle. The NADH and FADH molecules produced during the metabolism ofa glucose molecule are as follows:

l. Glycolysis	NADH -2
2. Oxidative decarboxylation	NADH = 1
3, Krebs cycle	NADH=4
	FADH = I

- When one molecule of NADH molecule is oxidised in ETS, 3 molecules of ATP are synthesized. Similarly, when one molecule of FADH is oxidized in ETS, 2 molecules of ATP

ENDOPLASMIC RETICULUM

- Endoplasmic reticulum is a network of membrane bound cavities, vesicles and tubule, distributed throughout the cytoplasm.
- It is concerned with the biosynthesis of proteins and lipids.
- It is more concentrated in the endoplasm than in the ectoplasm. Hence the name. e It is the cytoskeleton of the cell.
- It is a cytoplasmic vesicular system.
- Since this network is more concentrated in the endoplasm of the cytoplasm, the name endoplasmic reticulum was proposed.
- De Robertis, Nowinski and Saez have coined another term, the cytoplasmic vacuolar system for these membrane bound cavities present in the cytoplasm.

Functions of Endoplasmic Reticulum

Endoplasmic reticulum performs the following functions:

1. Mechanical support

The endoplasmic reticulum divides the fluid content of the cell into different compartments by which it gives mechanical support to the cell. Hence it is known as the cytoskeleton of the cell.

2, Transport

Endoplasmic reticulum acts as a kind of circulatory system, involved in the import, export and intacellular circulation of various substances.

By this process, proteins, lipids, enzymes, etc. are transported to the various parts of the cell.

3. Protein Synthesis

Ribosomes are protein factories. Amino acids are assembled on ribosomes to polypeptide chains.

The ribosomes attached to the endoplasmic reticulum are more protein synthesis than the free ribosomes lying in the cytoplasm.

The endoplasmic reticulum provides space for the attachment of ribosomes.

The synthesized proteins are collected by the endoplasmic reticulum. They and transported to other parts of the cell by the endoplasmic reticulum.

4. Formation of Microbodies

Microbodies are small granular bodies filled with an electron dense granule rich in peroxidase.

They include peroxisomes and glyoxysomes. They are formed in yeast, liver, kidney and higher plants.

Microbodies remain in close association with endoplasmic reticulum.

Endoplasmic buds off microbodies. In some instances, microbodies show connections with endoplasmic

5. Synthesis of Cholesterol and Steroid Hormones

Endoplasmic reticulum is the major site for the synthesis of cholesterol, the precursor for steroid hormones.

In the testis, ovary and adrenal cortex, the smooth endoplasmic reticulum plays the major role in the synthesis of steroid hormones.

6. Glycosylation

Glycosylation is the addition of carbohydrate units to other cellular macromolecules

It leads to the formation of glycoproteins, mucopolysaccharides, glycolipids, glycogen, etc•

Almost all secretory proteins are in the form of glycoproteins. Glycoprotein is formed of proteins and carbohydrates.

Proteins are synthesized on the ribosomes attached to the endoplasmic reticulum. The proteins transferred to the lumen of endoplasmic reticulum.

In the endoplasmic reticulum, carbohydrate units are linked to the polypeptide chain byglycosylation.

The glycosylation is catalyzed by the enzyme glycosyl transferase.

7. Detoxification

Detoxification refers to the reduction of toxic properties of chemicals such as drugs and pollutants. Detoxification occurs in the endoplasmic reticulum of liver cells.

Detoxification involves biochemical reactions by which harmful materials are converted into harmless substances suitable for excretion by the cell.

The detoxification reactions include oxidations, reductions, hydrolysis or conjugation to soluble molecules.

8. Lipid Synthesis

ER synthesizes triglycerides andphospholipids. It also stores lipids.

9. Glycogenolysis

The conversion of glycogen into glucose is called glycogenolysis.

It takes place inside the ER. The ER contains an enzyme calledglucose-6-phosphatase. It converts glucose-6-phosphate into glucose which is transported to the blood.

10. Storage of Calcium ions (Ca++)

ER stores calcium ions. In sarcoplasmic reticulum (ER of muscle cell), the calcium ion concentration is higher than that of cytosol. When the muscle is stimulated, ER releases rapidly large amount of Ca++ into the cytosol. This brings about muscle contraction. During relaxation, Ca44 ions are pumped into the ER from the cytosol.

GOLGI COMPLEX

- Golgi complex is a stack of membranous flattened sacs and vesicles concerned with cell secretion.
- It was first described by Camillo Golgi (1898) in the nerve cells of barn owl.
- The Golgi complex has been variously named as Golgi body, dictyosome, lipochondrion, internal reticular apparatus, canalicular system and tropho-spongium by various workers.

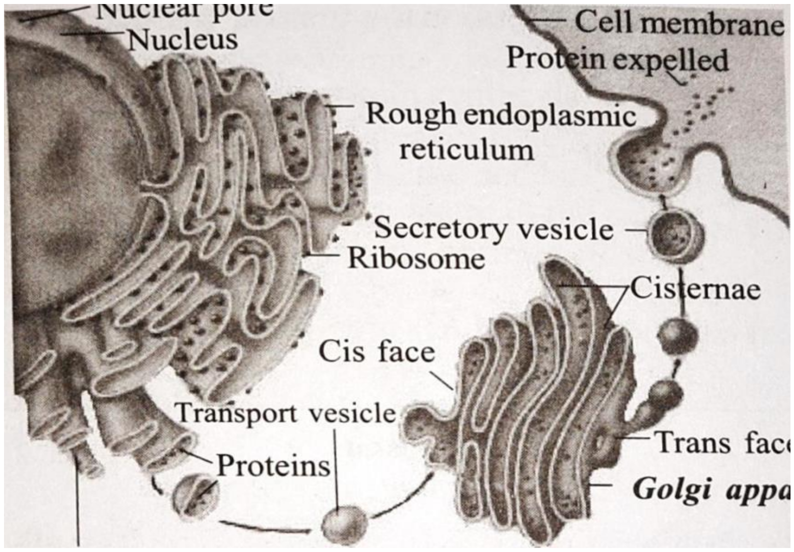

Fig: Golgi complex

- Generally, the term dictyosome is used for the Golgi body of invertebrates and plants.
- The Golgi is located in the cytoplasm.
- It is a cell membrane bound organelle.

Functions of Golgi Apparatus

Golgi complex performs the following ftmctions in living cells:

1. Formation of Acrosome
   - The acrosome ofsperm is developed from Golgi apparatus during spematogenesis.
   - During spermiogenesis, a vacuole appears in the Golgi apparatus. Inside the vacuolea dense granule called proacrosomal granule develops.
   - The vacuole and proacrosomal ganule gradually enlarge.
   - The entire apparatus moves towards the nucleus and gets attached to the tip of the nucleus.
   - The granule is now called acrosomal granule and the entire structure is called acrosome. It spreads over the nucleus as a cap.
2. Cell Wall Formation

- Golgi complex is involved in cell wall formation in plant cells. During cytokinesis, the Golgi vesicles accumulate in the equatorial plane and help in the formation of cellplate.
- The materials present in the Golgi apparatus help in the formation of cell wall. The polysaccharide of cell wall is formed in the Golgi complex and is transported to the cell wall.

3. Plasma Membrane Formation
    - Golgi complex involves in the formation of plasma membrane.
    - During exocytosis, the secretory vesicles formed from Golgi complex fuse with the plasma membrane.
    - The membrane of the vesicle becomes incorporated into the plasma membrane.
    - Due to exocytosis, the surface area of plasma membrane increases. But endocytosis removes segments of plasma membrane.
    - The exocytosis and endocytosis maintain the normal size of plasma membrane. This helps in the renewal of the membrane constituents.
    - In addition, the Golgi complex synthesizes the carbohydrate components of the plasma membrane.
4. Biogenesis of Lysosomes
    - Golgi complex is involved in the formation of primary lysosomes.
    - The cisternae of Golgi complex in turn bud off small vesicles called primary lysosomes.
    - The primary lysosomes fuse with pinosomes or phagosomes to form secondary lysosomes
5. Membrane Trafficking
    - Golgi complex carries out a trafficking function in the transport of biosynthetic products.
    - They are transported within the cells (intracellular transport) or to outside the cells (intercellular transport).

- The intracellular transport includes the delivery of products from endoplasmic reticulun to Golgi complex or from the Golgi complex to lysosomes or plasma membrane.
- The intercellular transport includes secretion of synthetic products to the outside by exocytosis.

6. Secretion
   - Secretion is the process of elaborating and releasing a specific product from the cell.
   - The mucous cells secrete mucous; the salivary gland cells secrete saliva; The sebaceous cells secrete oil; the sweat gland cells secrete sweat; the tear gland cells secrete tears; exocrine gland cells secrete enzymes, endocrine gland cells secrete hormones; the plasma cells secrete antibodies; Nerve cells secrete neurotransmitters, mammary gland cells secrete milk
   - Secretion is done by the Golgi complex. Golgi complex functions as a transporting chamel from the site of synthesis to the outside.
7. Mucous Secretion
   - The intestinal cells (goblet cells) secrete mucous into the lumen of intestine. The mucous is synthesized by the Golgi complex of goblet cells and is then secreted into the intestine. Mucous secretion involves the following steps.
     - Protein is synthesized on the ribosomes ofendoplasmic reticulum.
     - The protein move into the lumen ofendoplasmic reticulum.
     - From the endoplasmic reticulum, the proteins are packed in small vesicles.
     - These vesicles are transported to the cis -face ofcisternae (Golgi complex).
     - The vesicles fuse with the cisternae.
     - The proteins are transported from one cisterna to other towards the trans- face.
8. Concentration and Storage of Secretory Products

- The Golgi cisternae have the ability to concentrate the secretory products by losing water drough the membrane.
- The secretory vesicles can store the secretory product until the product is demanded.

9. Glycosylation
   - Glycosylation is the linking ofcarbohydrate units with macromolecules.
   - Glycosylation produces complex carbohydrates such as glycoproteins, mucopolysaccharides, glycolipids, glycogen, etc.

10. Sulphation
    - Golgi complex is involved in the metabolism ofsulphate.
    - The goblet cells ofintestine secrete mucigen. Mucigen is a mucopolysaccharide made up of protein, sugar and sulphate.
    - The Golgi complex adds sulphate to the glycoprotein produce mucigen.
11. Lipid Packaging and Secretion
    - The intestinal cells use their Golgi apparatus for the absorption of monoglycerides and fat] acids.
    - The endoplasmic reticulum synthesizes triglycerides from monoglycerides and fattyacids.
    - The Golgi complex concentrates and transports the lipids synthesized in the endoplasmic reticulum to the plasma membrane and intercellular space.

LYSOSOMES

- Lysosomes are membrane bound tiny bags filled with digestive enzymes. They are concerned with intracellular digestion. They were discovered by de Duve in 1955.
- A lysosome is a lytic body. It is capable of lysis.
- Lyso means digestive, soma means body.
- It can destroy a cell in which it releases its enzymes. Hence, it is often called suicidal bag.
- As the lysosome digests the components ofthe cells, it is often referred to as the tract of the cell (de Duve, 1963).
- It is a cell organelle.
- Lysosomes were first by named as pericanalicular bodies because of their location in 1955.
- Lysosomes are usually spherical in shape; but they are ilTegular in certain meristematic cells of roots.
- The size of the lysosomes usually ranges from 0.2 micron to 0.8 micron in diameter.
- Lysosomes are large spherical as 8 microns dense bodies in mammalian filled with kidney large number cells and of dense leucocytes granules having hydrolytic enzymes.
- The interior of the lysosome is acidic with apH of4.8, but the pH ofthe surrounding cytosol is 7.2.
- The low pH is maintained by pumping protons (H+) from the cytosol.
- Lysosomes are polymorphic structures because their contents vary with the stages of digestion. On this basis, the lysosomes can be differentiated into four types. They are the following:

1. Primary Lysosomes:

- These are small sac-like structures enclosing enzymes synthesized by the Golgi body or endoplasmic reticulum. Since they store enzymes, they are also said to be storage granules. The enzymes present in primary lysosomes are acid hydrolases.

2. Secondary Lysosomes (Digestive Vacuoles):

- These are formed by the fusion of primary lysosomes with phagosomes. They contain engulfed materials and enzymes. The materials are progressively digested by the enzymes.

3. Residual Body:

The secondary lysosomes with undigested wastes are called residual lysosomes. The digested materials are diffused into the cell cytoplasm through the lysosomal membrane.

4. Autophagic Vacuoles:

Autophagic vacuoles are also called autophagosomes. These are special type of lysosomes, which are formed when the cells feed on their own intracellular.

Chemistry

- Lysosomes contain a wide variety of enzymes. About 50 enzymes have been isolated.
- The enzynes are enclosed by a membrane. All enzymes are acid hydrolases.
- Oxidative enzymes are completely absent from lysosomes. These enzymes remain inactive inside the lysosomes.
- The membrane is punctured; all enzymes are released and become active. The following are the enzymes located inside the lysosomes:

l. Acid ribonuclease	9. Peptidase
2. Acid deoxyribonuclease	
3. Acidphosphatase	10. Beta -galactosidase
4. Acidphosphodiesterase	ll. Beta-glucuronidase
5. Esterase	12. Alpha - mannosidase
6. Phospholipase	13. Alpha - glucosidase
7. Cathepsin	14. Sulphatase.

8. Collagenase

The lysosomal enzymes are classified into six main types. They are following:

1. Nucleases
2. Phosphatases
3. Sulphatases
4. Lipases
5. Proteases
6. Glycosidases

1. Nucleases

- Nucleases act on nucleic acids. They hydrolyze nucleic acids into nucleotides.
- The nucleases are of two types, namely ribonuclease and deoxyribonuclease.

$$\text{Nucleic acid} \xrightarrow{\text{Nuclease}} \text{Nucleotides}$$

- Ribonuclease acts on RNA and deoxyribonuclease acts on DNA.

2. Phosphatases

- Phosphatases hydrolyze phosphate compounds. Phosphatases include acidphosph and acidphosphodiesterases. atqq

3. Sulphatases

- Sulphatases break down sulphate esters into fragments.

4. Lipases

- Lipases hydrolyze lipids into fatty acids and glycerol. They include esterases phospholipases.

5. Proteases

- Proteases hydrolyze proteins into amino acids. Proteases include cathepsin, collag andpeptidases.

6. Glycosidases

- Glycosidases hydrolyze polysaccharides into monosaccharides. They include galactosidase, - glucuronidase, mannosidase, a- glucosidase, etc. The interior of the lysosome is acidic. The pH is 4.8.

Functions of Lysosomes

The lysosomes have the following functions:

1,Heterophagy Heterophagv is the lysosomal digestion of foreign materials. It is an intracellular digestion.

In heterophagy, the cells digest the foreign or extracellular food materials.

These food materials are taken into the cells by endocytosis such as phagocytosis or pinocytosis.

- The food materials are enclosed in vesicles called phagosomes or pinosomes.
  - These vesicles move towards lysosomes and fuse with the primary lysosome to form a digestive vacuole called secondary lysosome.
  - The vacuole now moves to the plasma membrane.
  - The enzymes of lysosomes digest the food materials in the digestive vacuole.
  - The digested food materials diffuse into the cytoplasm through membrane of digestive vacuole.

CENTROSOME

- Centrosome is a cell organelle containing two centrioles surrounded by an amorphouy mass of pericentriolar material.
- It is the microtubule organizing centre. It is not at all a membrane bound structure.
- It is an omganelle concerned with cell division. It is otherwise called cell centre.
- It was discovered by Beneden in 1887. It was named by Boveri in 1988.
- The centrosome is located near the nucleus in the cytoplasm. In Metazoa, it lies outside the nucleus, but in Protozoa, it lies inside the nucleus.
- Centrosomes are found in all eukaryotic animal cells and in the cells of some lower plants like algae, fungi, bryophytes, ferns and gymnosperms. They are absent from higher plants (angiosperms), prokaryotes, diatoms and yeast. Amoeba also does not contain centrosome.
- It divides into two during cell division.
- During mitosis, they move to opposite poles.
- As mitosis proceeds a cluster of microtubules called spindlefibres grow from each centosome.

- The centrosome is cylindrical in shape. It is 0.15 to 0.25 micron in diameter and 0.3 to 2.0 micron in length.
- The centrosome consists of three components, namely
    1. Centrioles
    2. Centmsphere
    3. Spindlefibres.

Centrioles

Centrioles are microtubule producing organelles involved in cell division.

- They are located in the cytosol near the nucleus.
- A cell contains two centrioles lying at right angles to each other.
- Each centriole is a hollow cylinder opening at both the ends.
- The two centrioles are surrounded by an amorphous substance called centrospheres or pericentriolar material.
- The entire structure formed of centrosphere and two centrioles is called centrosome.
- A group of spindle fibres radiate from the centrosome.
- The interphase cell contains only one centrosome with two centrioles.
- They are present in all animal cells and plant cells except Angiosperms.
- They are absent from diatoms, yeast, Angiosperms and Amoeba.
- Each centrosome contains two darkly staining cylindrical bodies called centrioles.
- The wall of each centriole is formed of nine triplet microtubules.
- Each triplet is formed of three microtubules.
- They are named as A, B and C from the inner side.
- The triplets remain lightly tilted to about 400 to the radius of the cylinder.
- The microtubules are 200-250Å in diameter and are arranged parallel to one another
- The C tubule is slightly shorter than the other two tubules.
- Each microtubule is formed of 12-13 globular subunits.

- TheA microtubule ofone triplet is connected to the Cmicrotubule ofanother triplet by a dense material called linker.
- The A - Clinkers cause the tilt ofthe triplets.
- The proximal end of the centriole has a cart wheel structure. It consists of a central hub and nine spokes. Each spoke is connected to the A microtubule of the triplet.
- Near the outer end ofeach spoke, there is a thickening called X often called foot.
- There is another thickening called Y located between the X thickenings.
- The Y-thickening is known as connective.
- The Y thickening is connected with the X thickenings and linkers.
- The microtubules of centriole are formed of three important chemical substances, namely

  l. Tubulin (protein)

  2. Lipid and

  3. ATPase enzyme.

Functions

Centriole has the following functions:

I. The centrioles help in the formation of spindle fibres during cell division.

2. In spermatozoan, the distal centriole develops into the axial filament of flagellum.

3. The basal bodies ofcilia and flagella develop from the centrioles.

4. In lower animals and plants, they are concerned with ciliary and flagellar movements.

5. They produce microtubules.

6. In lower forms, they are used to locate the directions of signal sources.