General Zoology **Lecture 2**

Centrosome

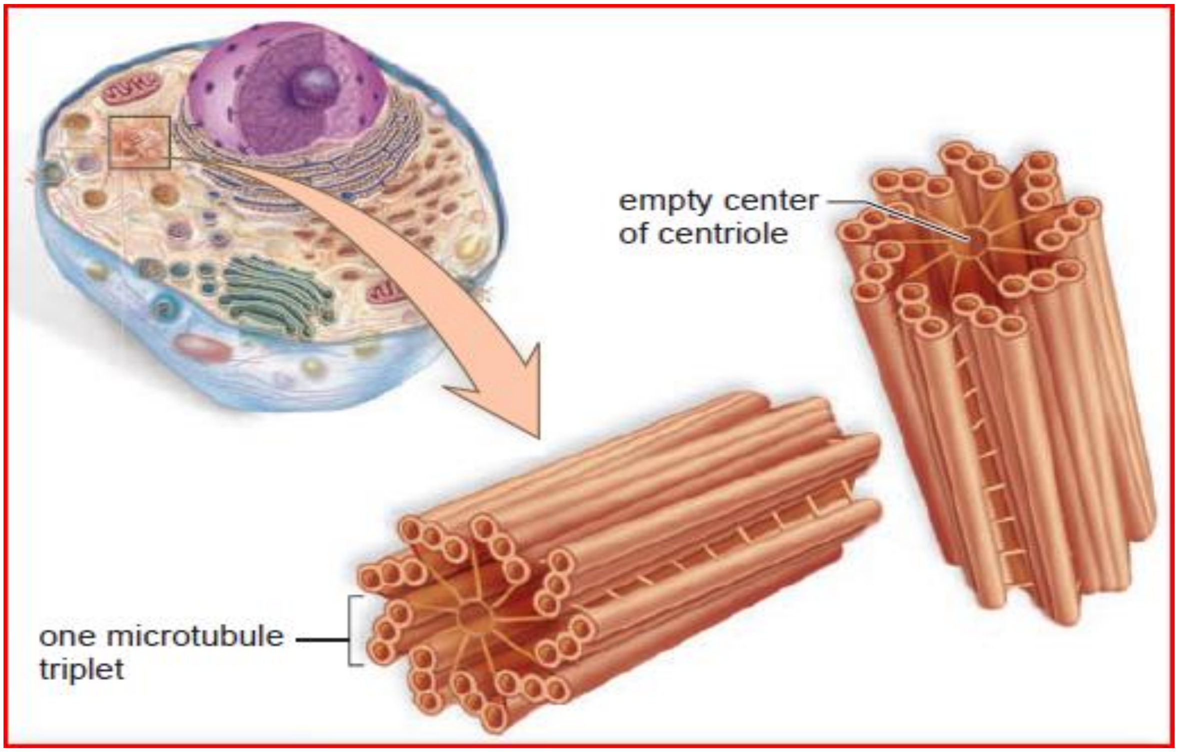
- **Centrosome has a spherical shape, often located near the nucleus.**
- **In animal cells and most protists, a centrosome contains two centrioles lying at right angles to each other.**
- **In animal cells, microtubules grow out from a centrosome and are considered a "microtubule-organising centre".**
- **It is possible that centrioles are also involved in the process by which microtubules assemble and disassemble.**
- **Before cell division, the centrosome replicates and divides in two. The two centrosomes separate and move to opposite sides of the nuclear envelope.**
- **The centrosome is most likely function to organise the mitotic spindle.**
- **The mitotic spindle is microtubules assemble into a spindle between the two centrosomes and help separate the replicated chromosomes into the daughter cells.**

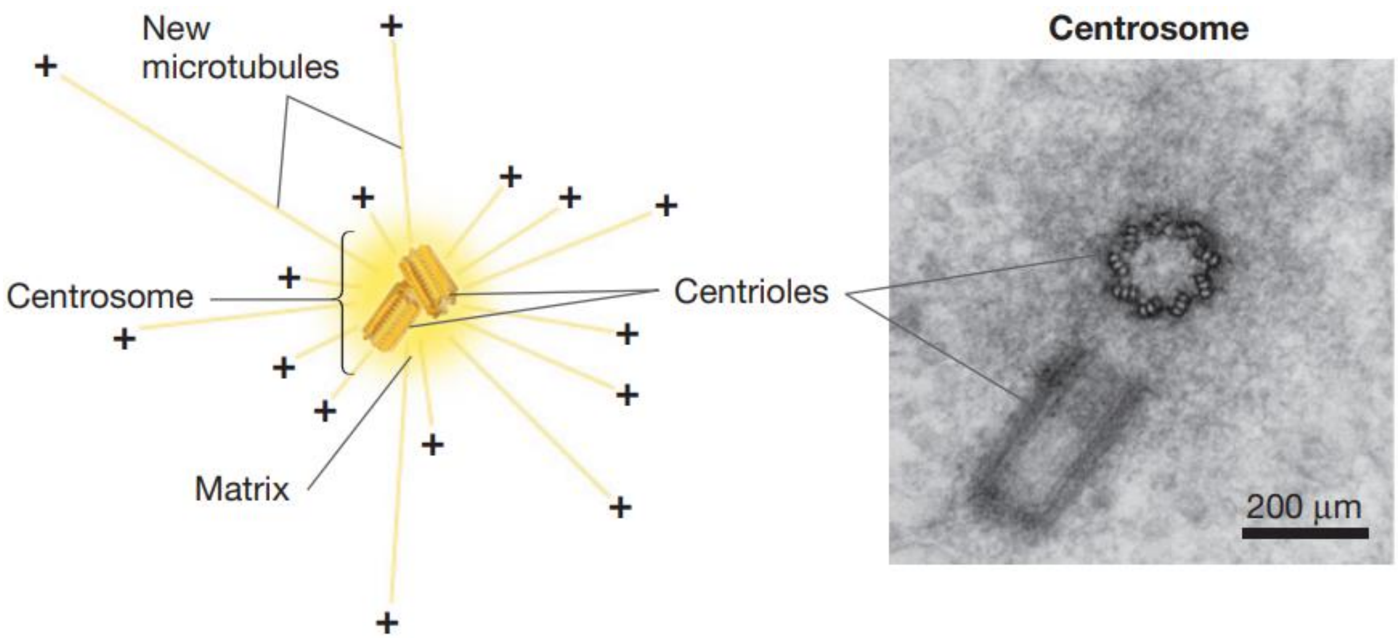
Centriole

- **Centrioles [in Greek: *centrum*, centre].**
- **Each centriole is about 0.25 µm in diameter.**
- **Centrioles are short cylinders with a (9 + 0) pattern of microtubule triplets—nine sets of three microtubules are arranged in an outer ring, but the centre of a centriole does NOT contain a microtubule.**

Cilia and Flagella

- **Flagella (singular, *flagellum*) (*flagello* means whip).**
- **Cilia (singular, *cilium)* (means eyelash, hair).**
- **In eukaryotes, a specialised arrangement of microtubules is responsible for the beating of flagella and cilia, which their microtubules containing extensions, project from some cells.**
- **They are act as locomotor appendages in the sperm of animals, algae, and some plants have flagella.**





- **When cilia or flagella extend from cells that are held in place as part of a tissue layer, they can move fluid over the surface of the tissue.**
- **In a woman's reproductive tract, the cilia lining the oviducts help move an egg toward the uterus.**

- Motile cilia usually occur in large numbers on the cell surface while flagella are usually limited to just one or a few per cell.
- Cilia are shorter, about 2-20 µm long.
- Flagella are longer, 10-200 µm.

Beating pattern in Cilia and Flagella

- Flagella and cilia differ in their beating patterns.
- Flagellum has an undulating motion that generates force in the same direction as the flagellum's axis.
- Cilia work like oars, with alternating power and recovery strokes generating force in a direction perpendicular to the cilium's axis, much as the oars of a crew boat extend outward at right angles to the boat's forward movement.

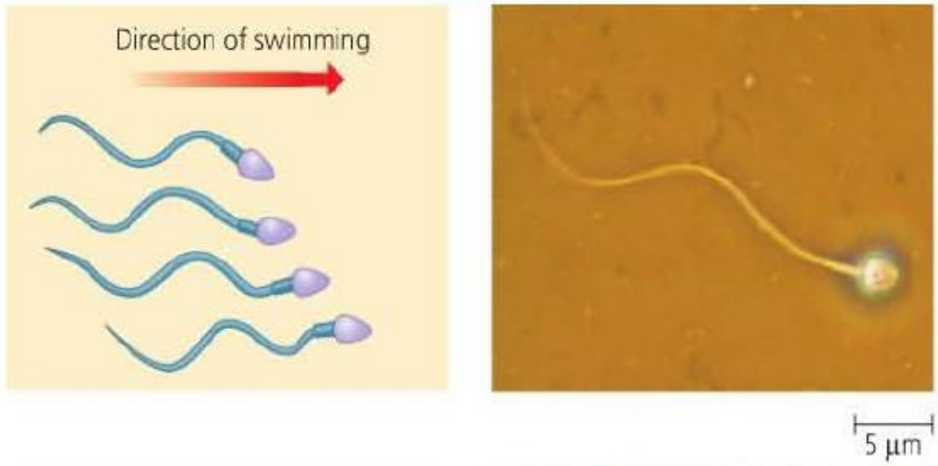
Structure of Cilia and Flagella

- In eukaryotic cells, cilia are much shorter than flagella, but they have a similar construction.
- Both are membrane bounded cylinders enclosing a matrix area.
- In the matrix are nine microtubule doublets arranged in a circle around two central microtubules; this is called the (9 + 2) pattern of microtubules.
- Cilia and flagella move when the microtubule doublets slide past one another.

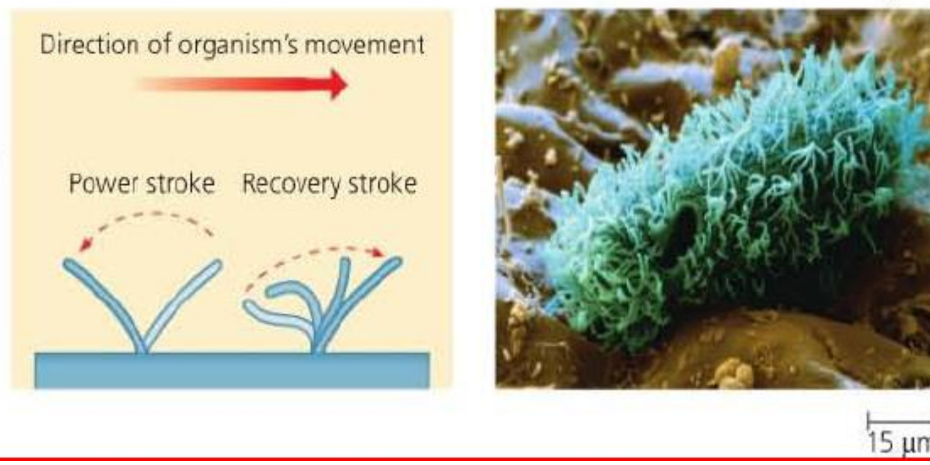
Structure of Basal body

- Each cilium and flagellum have a basal body which is an organelle that lies at the base of cilia and flagella.
- It may direct the organisation of microtubules within these structures.
- It has microtubule pattern similar centriole (nine microtubule tribelets arranged in a circle, but without central microtubules; (9 + 0) pattern.
- Cilia and flagella are believed to be derived from basal body.
- Each triplet microtubule of basal body joins doublet microtubule of a cilium or flagellum.

(a) Motion of flagella. A flagellum usually undulates, its snakelike motion driving a cell in the same direction as the axis of the flagellum. Propulsion of a human sperm cell is an example of flagellate locomotion (LM).

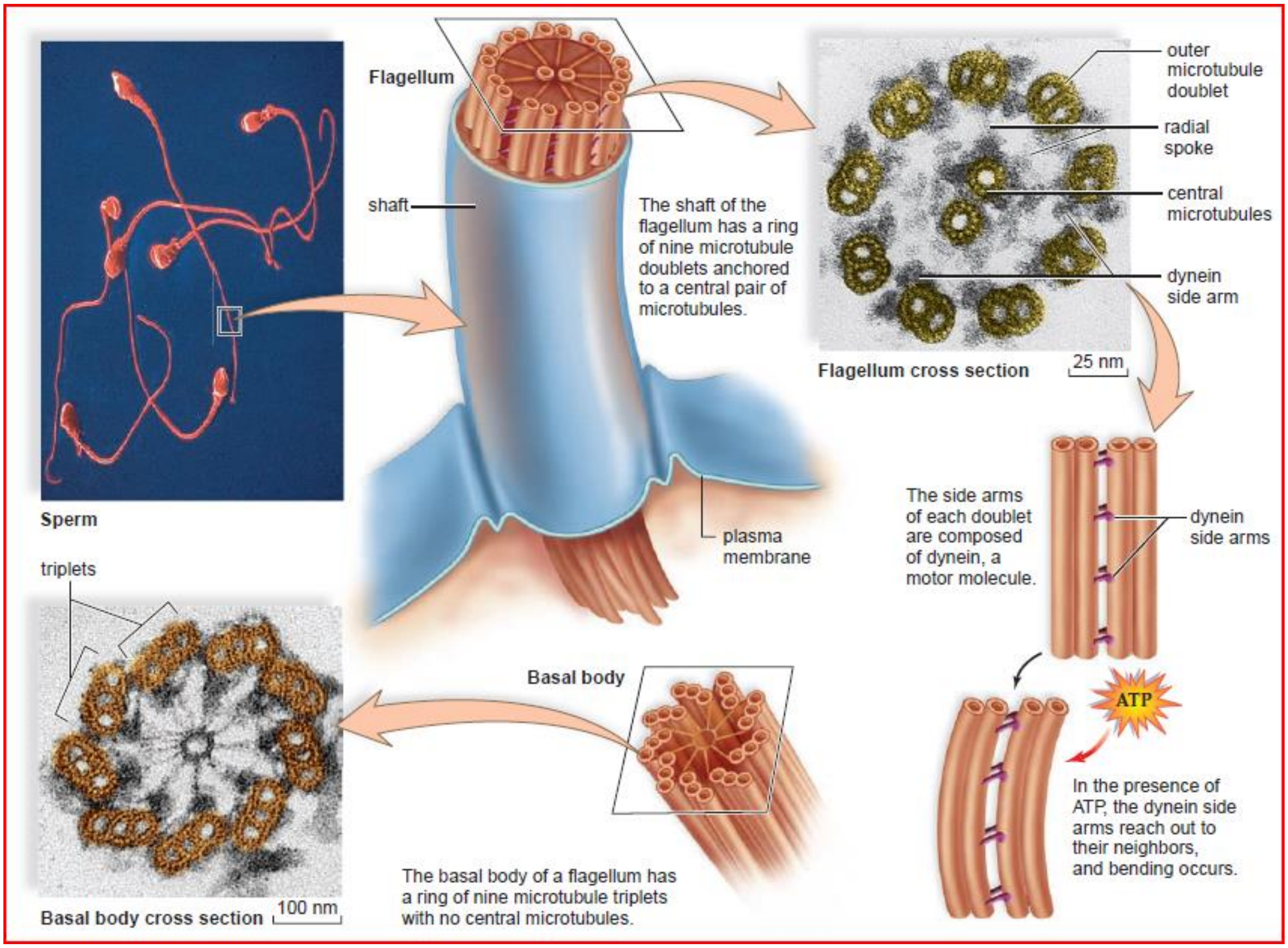


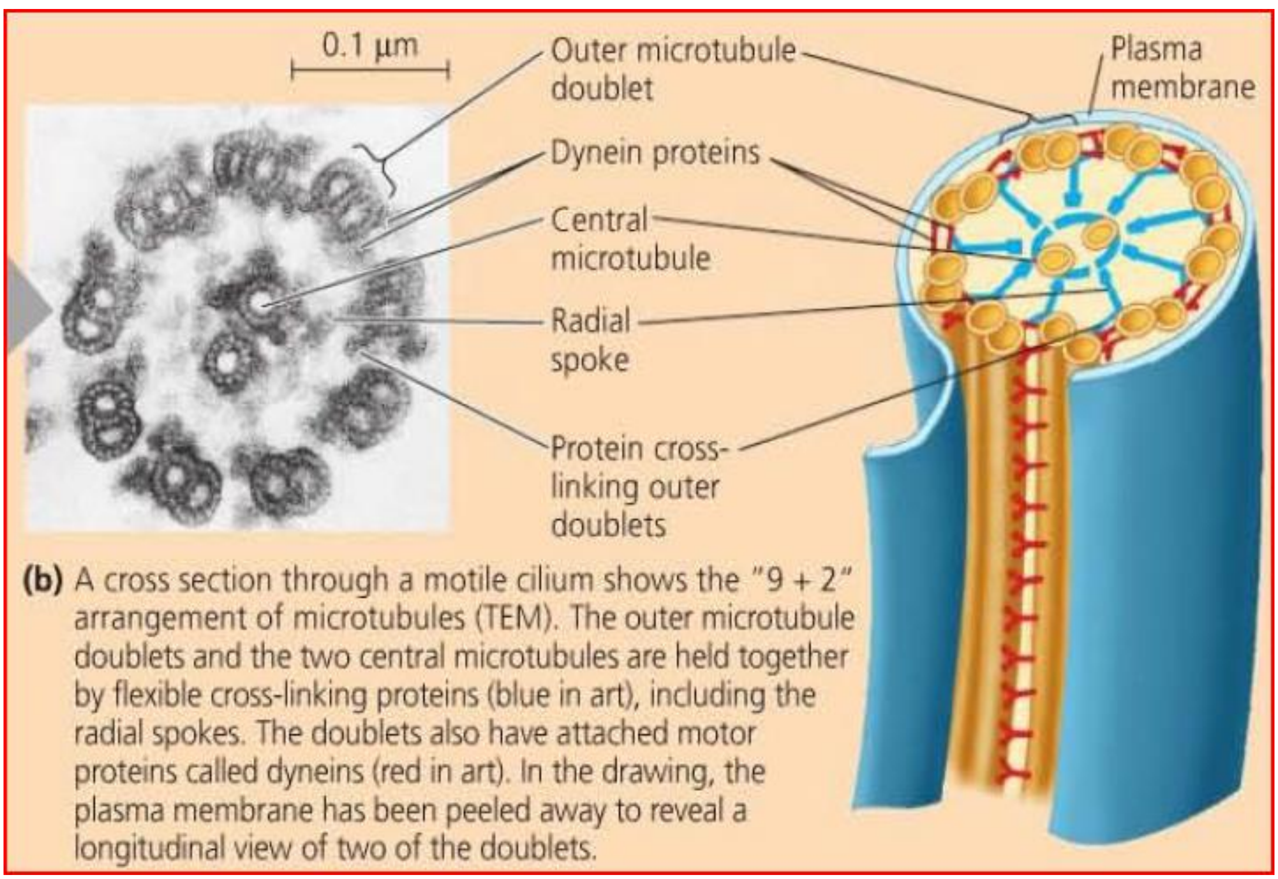
(b) Motion of cilia. Cilia have a back-and-forth motion. The rapid power stroke moves the cell in a direction perpendicular to the axis of the cilium. Then, during the slower recovery stroke, the cilium bends and sweeps sideways, closer to the surface. A dense nap of cilia, beating at a rate of about 40 to 60 strokes a second, covers this *Colpidium*, a freshwater protozoan (colorized SEM).



Structure of Cilia and Flagella

- **In flagella and motile cilia, flexible cross-linking proteins (called Nexin protein), evenly spaced along the length of the cilium or flagellum, connect the outer doublets to each other and the two central microtubules of (9 + 2) pattern.**
- **Each outer doublet also has pairs of protruding proteins spaced along its length and reaching toward the neighbouring doublet; these are large motor proteins called dynein.**
- **Dynein proteins are responsible for the bending movements of the cilia and flagella.**
- **Dynein molecule performs a complex cycle of movements caused by changes in the shape of the protein, with ATP providing the energy for these changes.**

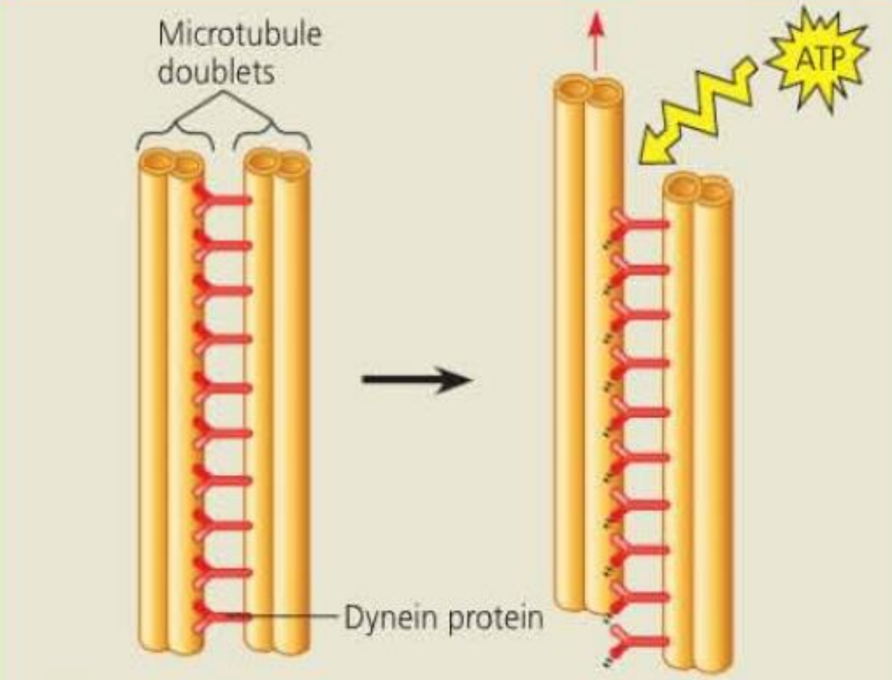




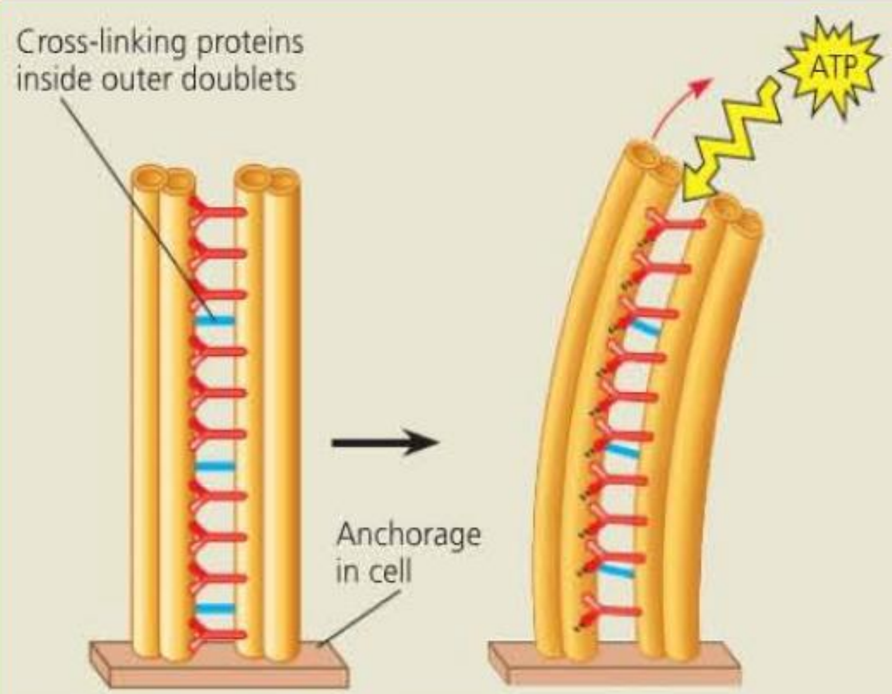
(b) A cross section through a motile cilium shows the "9 + 2" arrangement of microtubules (TEM). The outer microtubule doublets and the two central microtubules are held together by flexible cross-linking proteins (blue in art), including the radial spokes. The doublets also have attached motor proteins called dyneins (red in art). In the drawing, the plasma membrane has been peeled away to reveal a longitudinal view of two of the doublets.

The mechanics of dynein movement

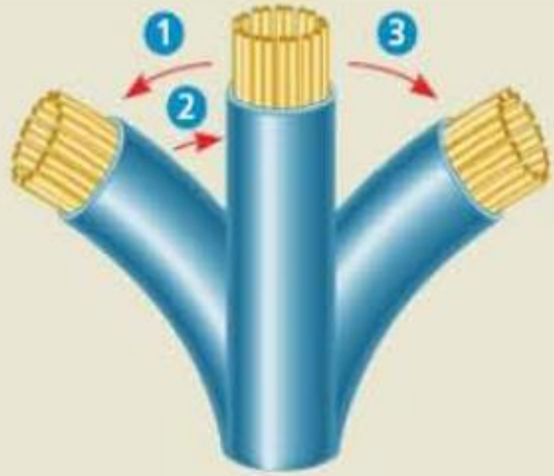
- **The mechanics of dynein-based bending involve a process that resembles walking.**
- **Dynein protein has two "feet" that "walk" along the microtubule of the adjacent doublet, one foot maintains contact while the other releases and reattaches one step further along the microtubule.**
- **Without any restraints (No cross-linking proteins = Nexin proteins) on the movement of the microtubule doublets, one doublet would continue to "walk" along and slide past the surface of the other, elongating the cilium or flagellum rather than bending it.**
- **For lateral movement of a cilium or flagellum, the dynein "walking" must have something to pull against, as when the muscles in your leg pull against your bones to move your knee.**
- **In cilia and flagella, the microtubule doublets seem to be held in place by the cross-linking proteins just inside the outer doublets and by the radial spokes and other structural elements. Thus, neighbouring doublets cannot slide past each other very far.**
- **Instead, the forces exerted by dynein "walking" cause the doublets to curve, bending the cilium or flagellum.**



(a) Effect of unrestrained dynein movement. If a cilium or flagellum had no cross-linking proteins, the two feet of each dynein along one doublet (powered by ATP) would alternately grip and release the adjacent doublet. This "walking" motion would push the adjacent doublet up. Instead of bending, the doublets would slide past each other.



(b) Effect of cross-linking proteins. In a cilium or flagellum, two adjacent doublets cannot slide far because they are physically restrained by proteins, so they bend. (Only two of the nine outer doublets in Figure 6.24b are shown here.)



(c) **Wavelike motion.** Synchronized cycles of movement of many dyneins probably cause a bend to begin at the base of the cilium or flagellum and move outward toward the tip. Many successive bends, such as the ones shown here to the left and right, result in a wavelike motion. In this diagram, the two central microtubules and the cross-linking proteins are not shown.

Motor proteins

- **Motor protein is a protein that interacts with the cytoskeleton (microtubule and microfilament) and other cell components, producing movement of the whole cell or parts of the cell.**
- **It converts chemical energy into mechanical work by the hydrolysis of ATP.**

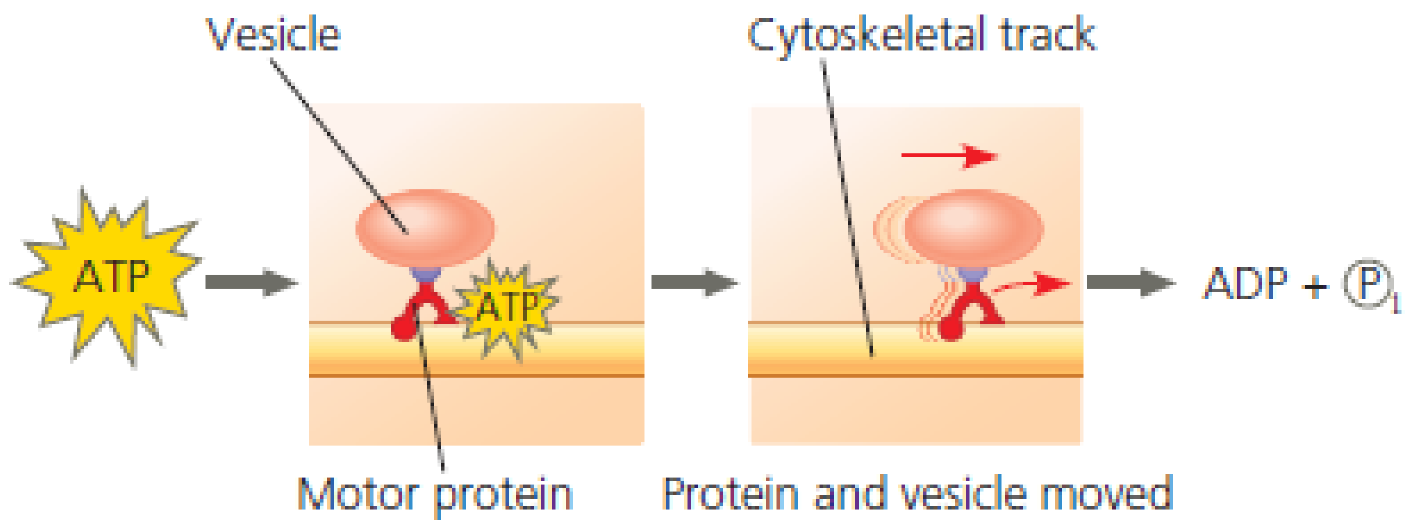
$$\text{ATP} \longrightarrow \text{ADP} + \text{Pi}$$

- **Many types of motor proteins are present within the cell such as kinesin, dynein, and myosin (muscle).**

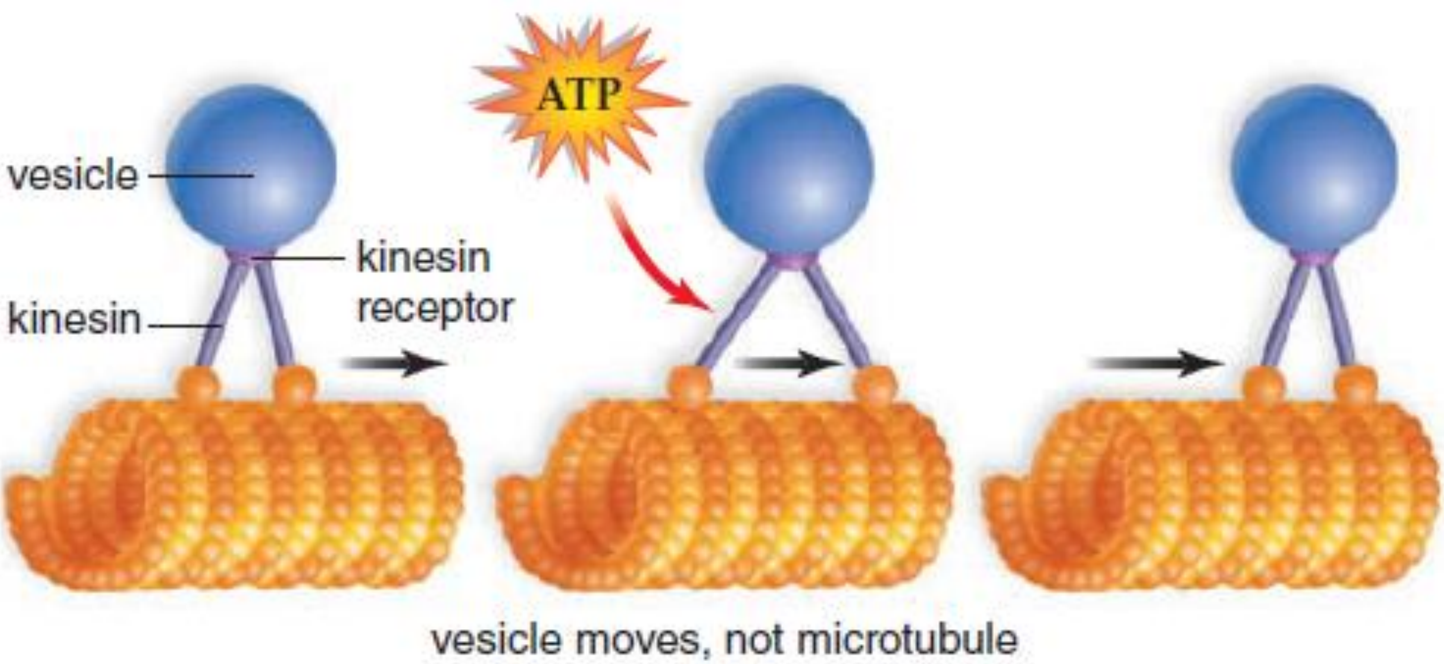
Role of Kinesin and dynein

- **Kinesin and dynein play essential roles in intracellular transport such as movements of vesicles and membrane-bound organelles, formation of mitotic spindle, and separation of chromosomes during mitosis and meiosis and other cargo along microtubules in cells. Dynein also powers bending motions of eukaryotic flagella and cilia.**

- **The direction movement of a transport vesicle in the cell depends on the type of motor protein that used microtubules track in their movement.**
- **Kinesin motor protein binds a transport vesicle and moves (pulls) it along microtubule from centrosome toward the periphery of the cell (plasma membrane).**
- **Dynein motor protein binds transport vesicles and move from cell periphery towards centrosome (near the nucleus).**



(b) Mechanical work: ATP binds noncovalently to motor proteins and then is hydrolyzed.



Definitions:

Centrosome: The structural organising centre in cytoplasm, located near the nucleus, where all microtubules originate, therefore it regards as a microtubule organizing centre. Each contains two centrioles.

Centriole: A pair of short cylinders, composed of nine triplet microtubules in a ring with a pattern (**9+0**); found at the center of a centrosome; divides and organises spindle fibers for chromosome movement during animal cell division.

Cilia: Short, hair-like projection from plasma membrane, specialised for movement or moving fluid past the cell; it is formed from a core of nine outer doublet microtubules and two inner single microtubules (**9+2** arrangement), occurring usually in larger numbers.

Flagella: Long, whip-like projection from plasma membrane, specialised for movement. Eukaryotic flagella have a core with nine outer doublet microtubules and two inner single microtubules (**9+2** arrangement). Cells may have a single or few.

Basal body: Organelle that lies at the base of cilia and flagella and may direct the organisation of microtubules within these structures. It has the same circular arrangement of microtubule triplets as centrioles (without central microtubule, **9+0** pattern). Each triplet microtubule joins the doublet microtubule of a cilium or flagellum.

Motor protein: Protein that interacts with the cytoskeleton (microtubule and microfilament) and other cell components, producing movement of the whole cell or parts of the cell. It converts chemical energy into mechanical work by the hydrolysis of ATP.

Dynein: A type of motor protein that performs basic transportation tasks in the cell. Converts chemical energy stored in an ATP molecule into mechanical energy that moves material through the cell microtubules. It helps move chromosomes during cell division and also plays a part in the movement of eukaryotic flagella and cilia.

Kinesin: A type of motor protein, that plays essential roles in intracellular transport such as movements of vesicles. It binds a transport vesicle and moves (pulls) it along microtubule from centrosome toward the periphery of the cell (plasma membrane).