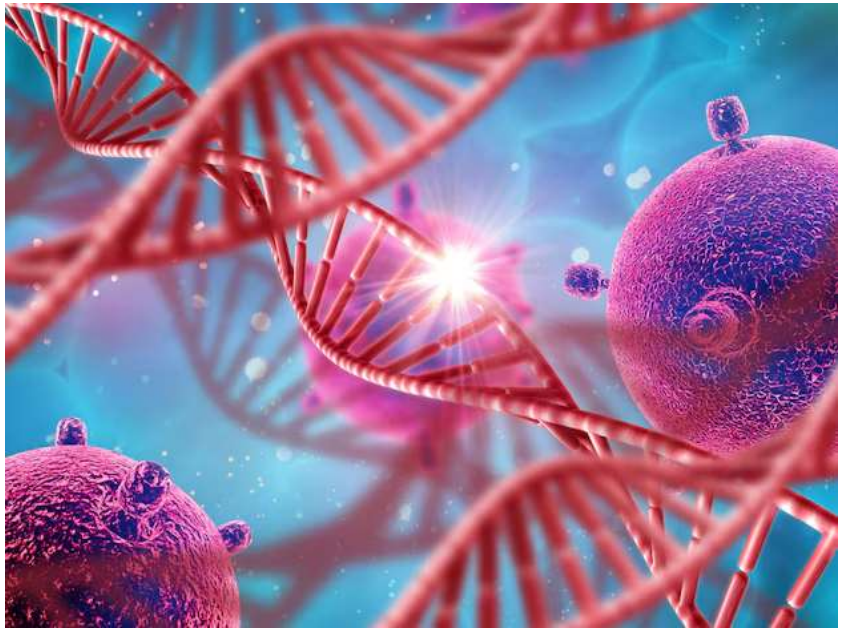
Lecture 4

General Biology & Cytology Course 2301130



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***Review*: Classification of eukaryotic cell organelles**

1. Genetic Information Processing Organelles

✓ ~~**Nucleus**~~: Stores genetic material (DNA).

✓ ~~**Nucleolus**~~: Found inside the nucleus, responsible for ribosomal RNA (rRNA) synthesis.

✓ ~~**Ribosomes**~~: Though not membrane-bound, they are crucial for translating mRNA into proteins.

2. Endomembrane System (Intracellular trafficking and synthesis)

- ✓ ~~**Endoplasmic Reticulum (ER)**~~:
  - **Rough ER**: Mentioned in previous lecture
  - **Smooth ER**: Mentioned in previous lecture
- ✓ ~~**Golgi Apparatus**~~: Mentioned in previous lecture
- ✓ ~~**Vesicles**~~: Membrane-bound transport structures that carry materials between organelles or to the cell membrane.
- ✓ ~~**Lysosomes**~~: Contain digestive enzymes to break down macromolecules, old organelles, and foreign invaders.
- ✓ ~~**Peroxisomes**~~: Involved in breaking down fatty acids and detoxifying harmful substances, including reactive oxygen species.
- ✓ **Endosomes**: Intermediate vesicular compartments formed by endocytosis, involved in sorting and transporting materials inside the cell.
- ✓ **Plasma Membrane**: Next lecture in details.

3. Energy-Related Organelles (Involved in ATP production and energy metabolism)

- **Mitochondria**: Powerhouses of the cell, responsible for producing ATP through oxidative phosphorylation. They have their own DNA and are thought to have originated from an ancient symbiotic relationship (Endosymbiotic theory).
- **Chloroplasts** (in plant cells and some algae): Responsible for photosynthesis, converting light energy into chemical energy. Like mitochondria, they contain their own DNA and are believed to have evolved through endosymbiosis.

4. Storage and Degradation Organelles

- ✓ **~~Vacuoles~~** (prominent in plant cells): Large organelles involved in storing nutrients, waste products, and maintaining cell turgor pressure.

- ✓ **~~Lysosomes~~**: Involved in intracellular digestion, breaking down waste materials and cellular debris.

- ✓ **~~Peroxisomes~~**: Involved in lipid metabolism and detoxification, producing hydrogen peroxide as a byproduct, which is then broken down.

5. Cytoskeleton and Motility Structures

- **Cytoskeleton**: Composed of microtubules, intermediate filaments, and microfilaments. It provides structural support, facilitates cell movement, and aids in intracellular transport.

- **Centrosomes and Centrioles**: Involved in organizing microtubules and play a key role in cell division.
- **Cilia and Flagella**: Microtubule-based structures involved in cell movement or moving substances across the cell surface.

6. Extracellular and Cell Communication Structures

- **Cell Wall** (in plant cells, fungi, and some protists): Rigid structure outside the plasma membrane, providing protection and structural support.

- **Extracellular Matrix (ECM)**: Network of proteins and polysaccharides outside the cell membrane, important for cell communication, adhesion, and tissue structure.

Mitochondria and chloroplasts change energy from one form to another

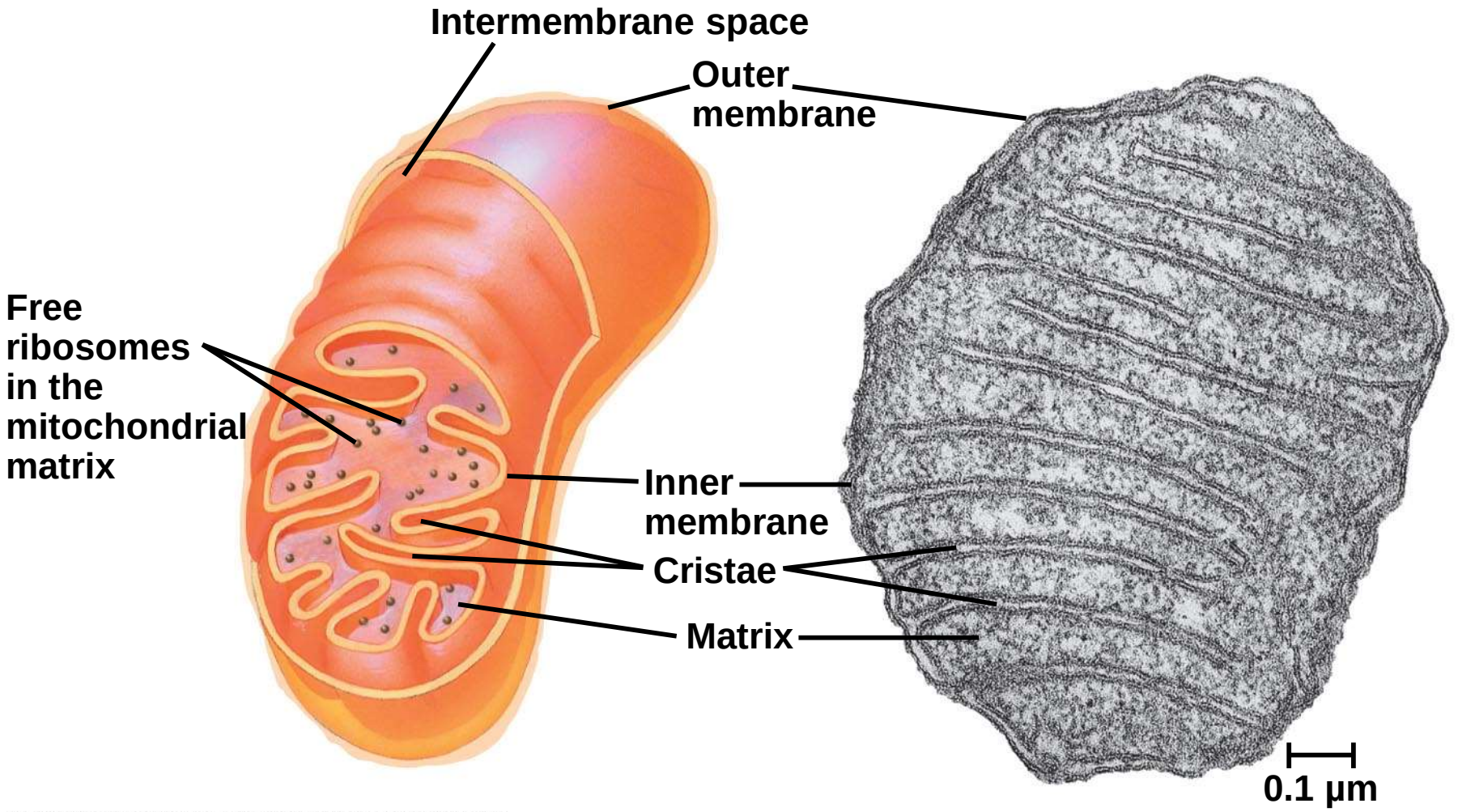
- **Mitochondria** are the sites of cellular respiration, a metabolic process that generates ATP (**Adenosine triphosphate**)
- **Chloroplasts**, found in plants and algae, are the sites of photosynthesis
- **Peroxisomes** are oxidative organelles

- Mitochondria and chloroplasts
  - Are not part of the endomembrane system
  - Have a double membrane
  - Have proteins made by free ribosomes
  - Contain their own DNA

Mitochondria: Chemical Energy Conversion

- Mitochondria are in nearly all eukaryotic cells
- They have a smooth outer membrane and an inner membrane folded into **cristae**
- The inner membrane creates two compartments: **intermembrane space** and **mitochondrial matrix**
- Some metabolic steps of cellular respiration are catalyzed in the mitochondrial matrix
- Cristae present a large surface area for enzymes that synthesize ATP

Fig. 6-17

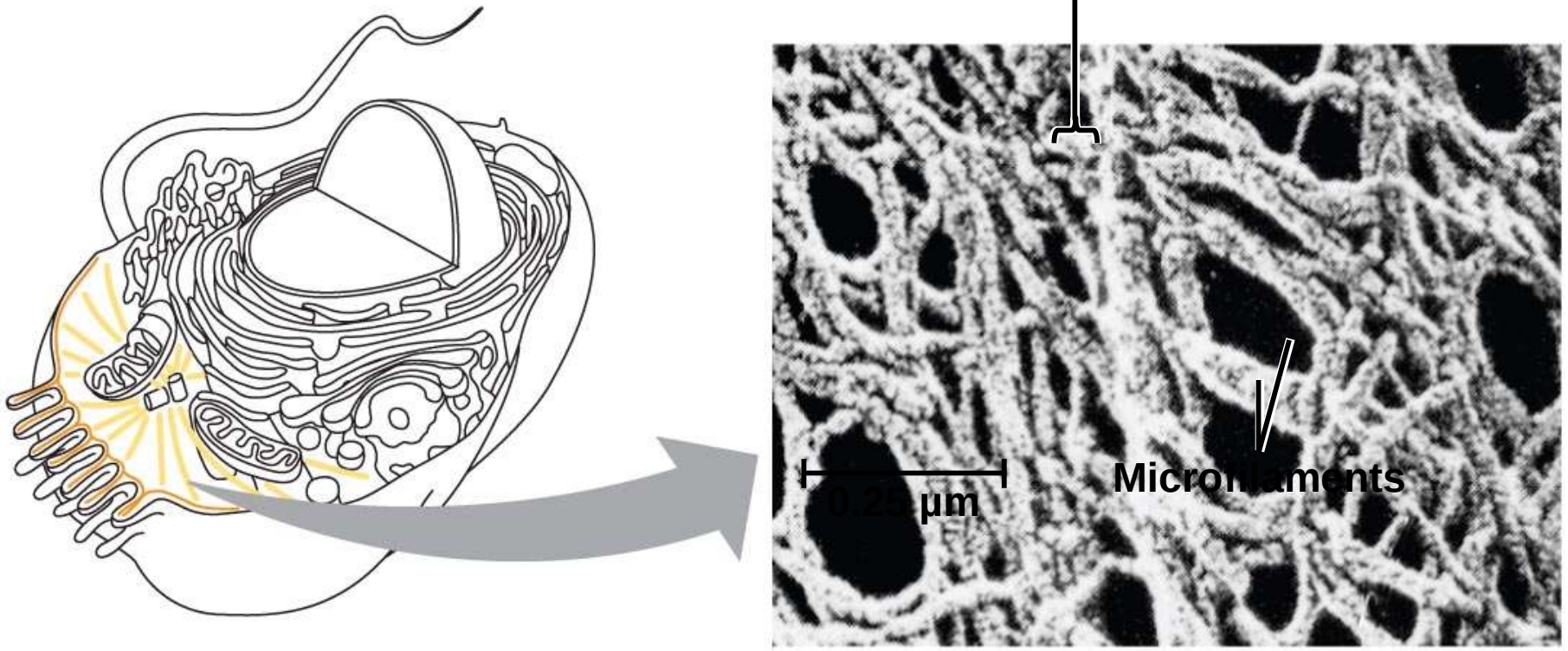


Peroxisomes: Oxidation

- Peroxisomes are specialized metabolic compartments bounded by a single membrane
- Peroxisomes produce hydrogen peroxide and convert it to water.
- Oxygen is used to break down different types of molecules.

Cytoskeleton

- The **cytoskeleton** is a network of fibers extending throughout the cytoplasm
- It organizes the cell's structures and activities, anchoring many organelles
- It is composed of three types of molecular structures:
  1- Microtubules
  2- Microfilaments
  3- Intermediate filaments



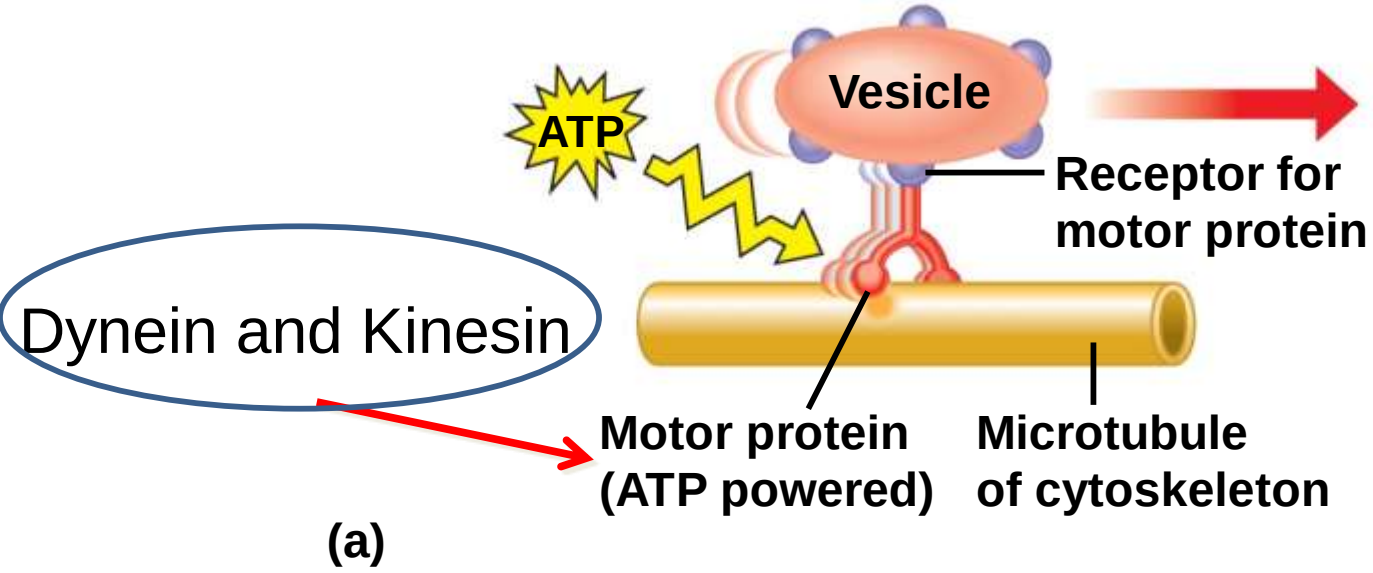
Roles of the Cytoskeleton:

1- The cytoskeleton helps to support the cell and maintain its shape

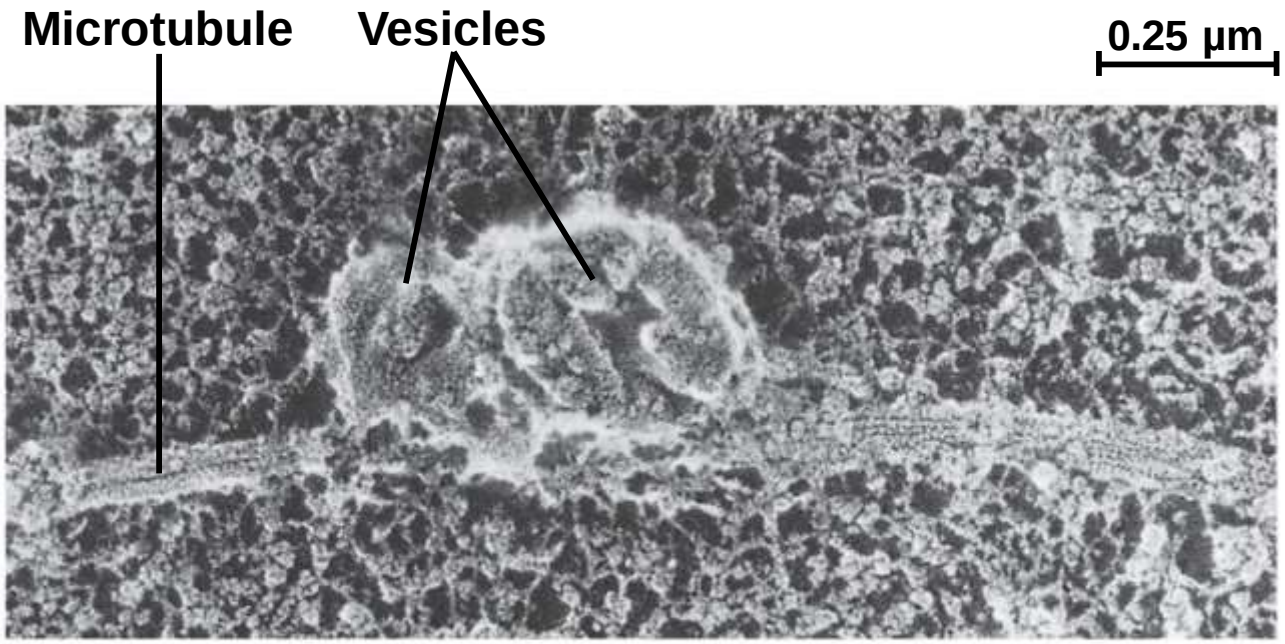
2- It interacts with **motor proteins** to produce motility

- Inside the cell, vesicles can travel along "monorails" provided by the cytoskeleton

3- Recent evidence suggests that the cytoskeleton may help regulate biochemical activities



(a)

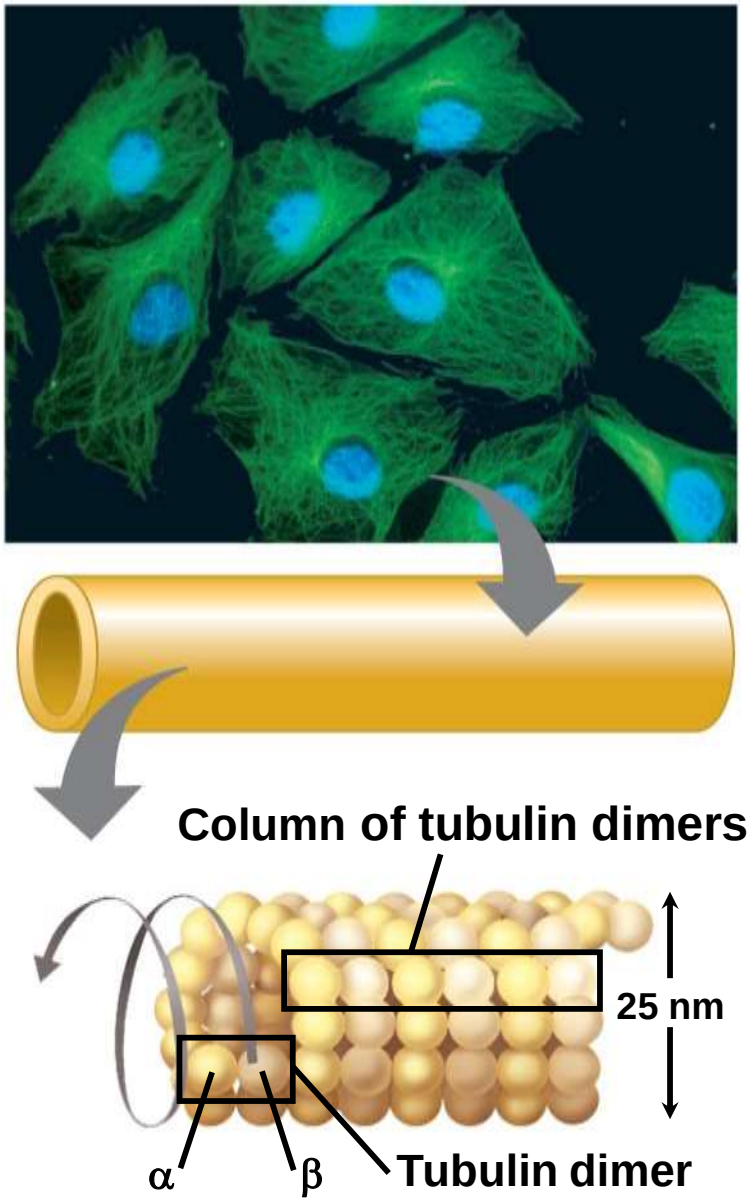


(b)

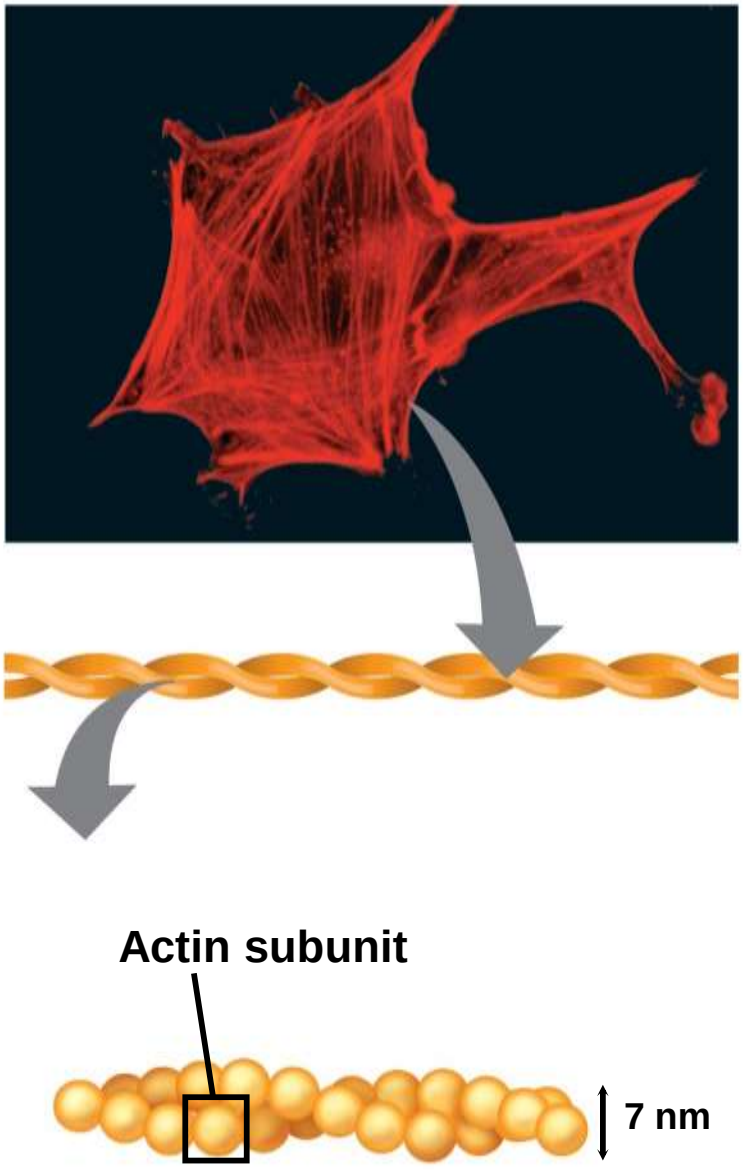
Components of the Cytoskeleton

- Three main types of fibers make up the cytoskeleton:
  - ***Microtubules*** are the thickest of the three components of the cytoskeleton
  - ***Microfilaments***, also called actin filaments, are the thinnest components
  - ***Intermediate filaments*** are fibers with diameters in a middle range

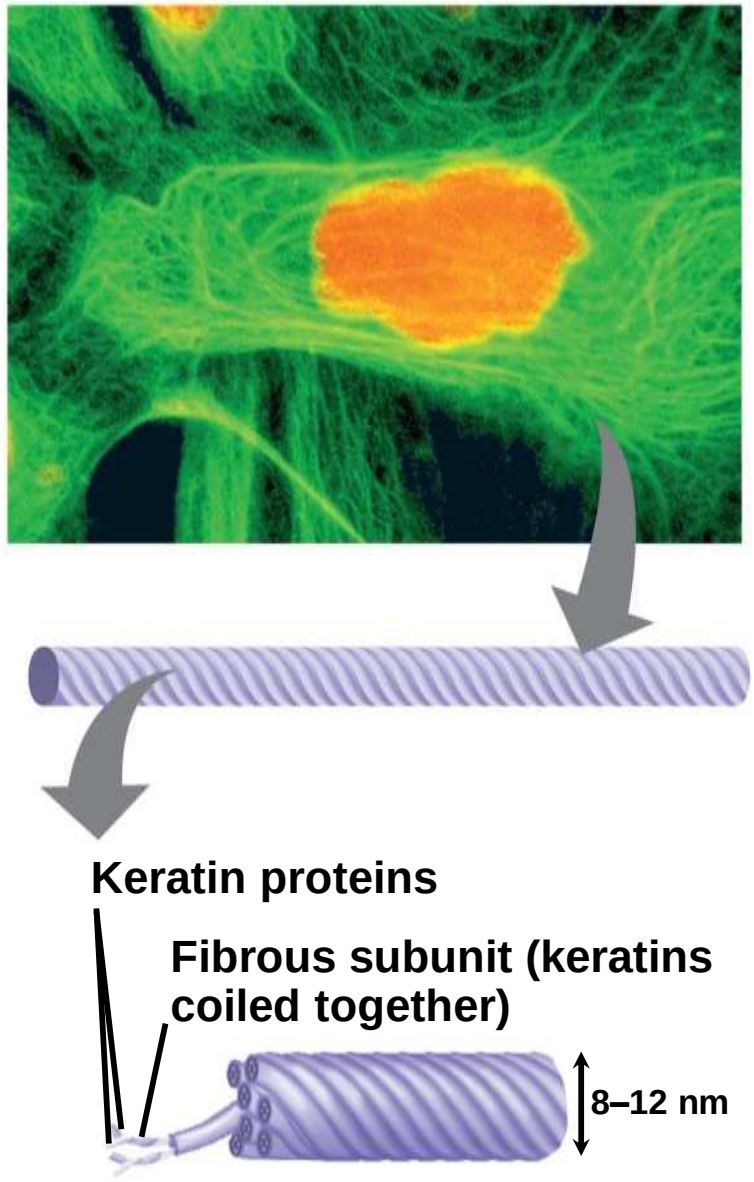
Property	Microtubules (Tubulin Polymers)
Structure	Hollow tubes; wall consists of 13 columns of tubulin molecules
Diameter	25 nm with 15-nm lumen
Protein subunits	Tubulin
Main functions	Maintenance of cell shape Cell motility Chromosome movements in cell division Organelle movements



Property	Microfilaments (Actin Filaments)
Structure	Two intertwined strands of actin
Diameter	7 nm
Protein subunits	Actin
Main functions	Maintenance of cell shape Changes in cell shape Muscle contraction Cytoplasmic streaming Cell motility Cell division



Property	Intermediate Filaments
Structure	Fibrous proteins supercoiled into thicker cables
Diameter	8–12 nm
Protein subunits	One of several different proteins of the keratin family
Main functions	Maintenance of cell shape Anchorage of nucleus and certain other organelles Formation of nuclear lamina



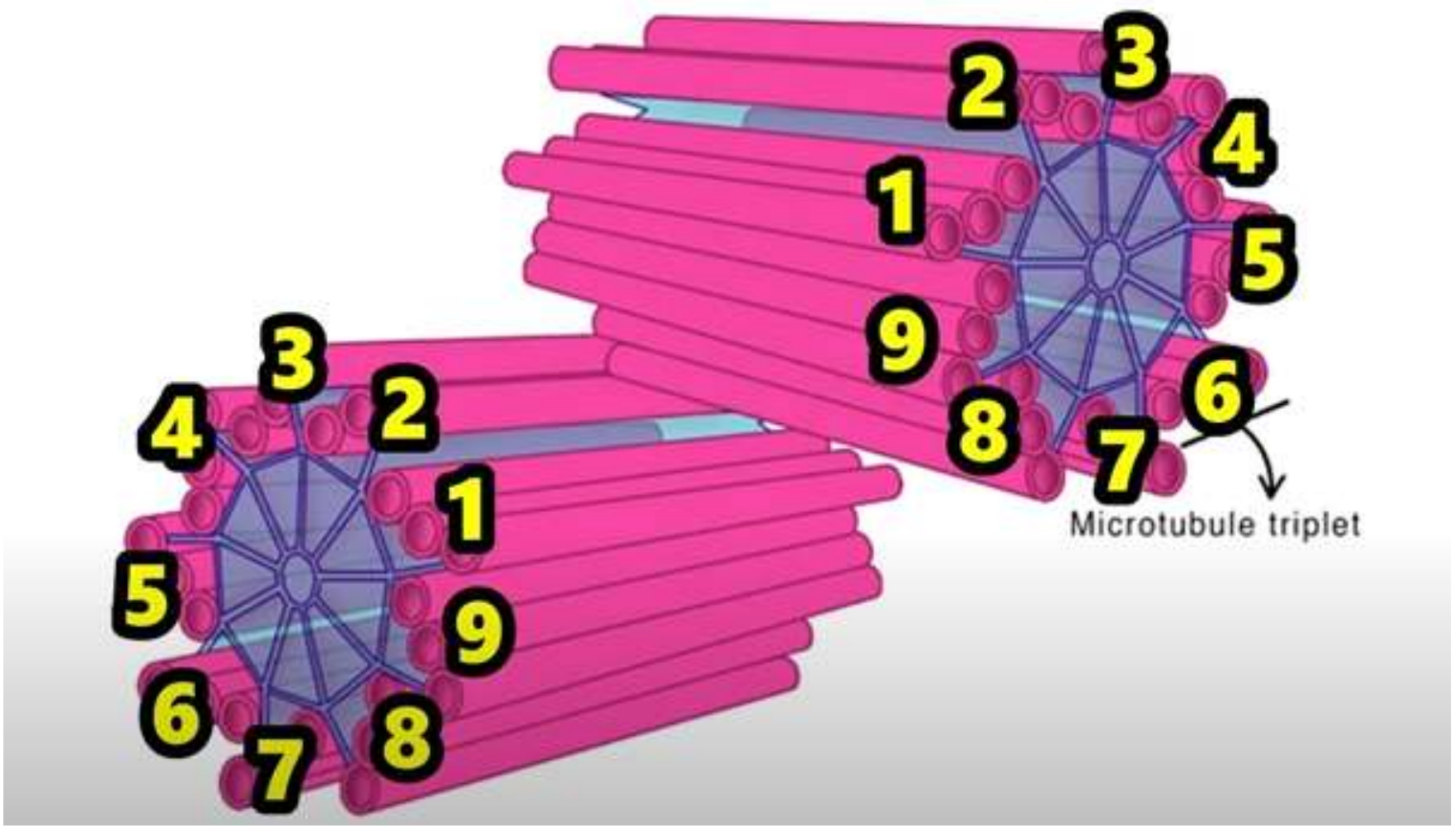
Microtubules

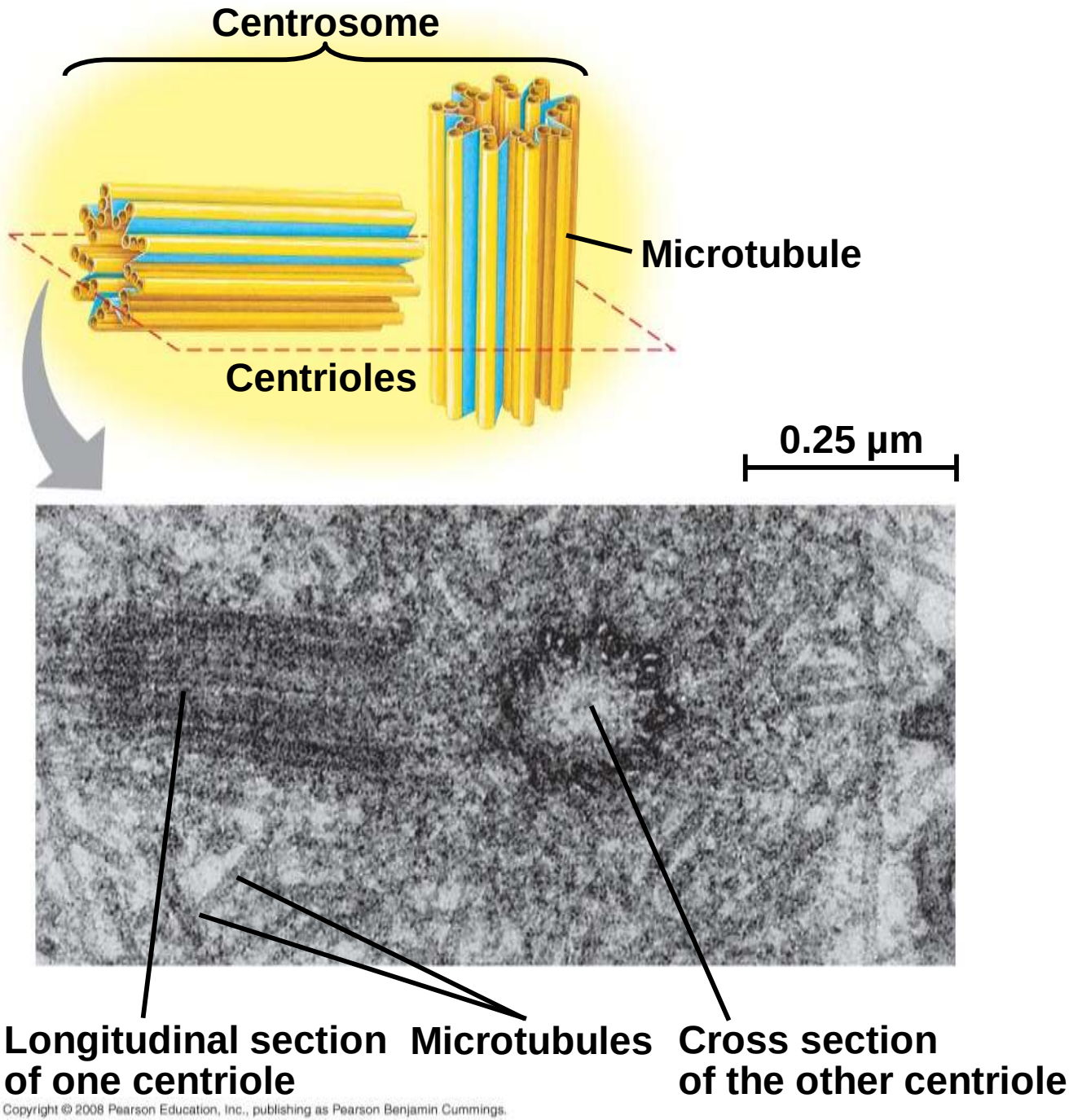
- **Microtubules** are hollow rods about 25 nm in diameter and about 200 nm to 25 microns long
- Functions of microtubules:
  - Shaping the cell
  - Guiding movement of organelles
  - Separating chromosomes during cell division

Centrosomes and Centrioles

- In many cells, microtubules grow out from a **centrosome** near the nucleus.
- The centrosome is a “microtubule-organizing center”
- In animal cells, the centrosome has a pair of **centrioles**, each with nine triplets of microtubules arranged in a ring

Each Centriole consist of Nine sets of triplet Microtubules



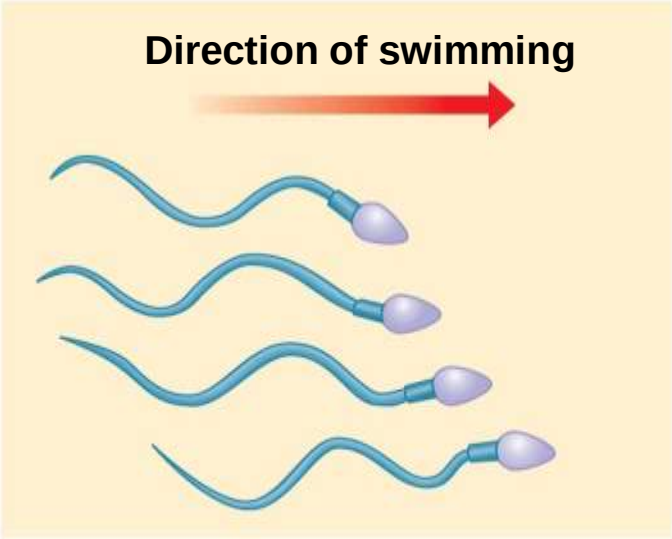


Cilia and Flagella

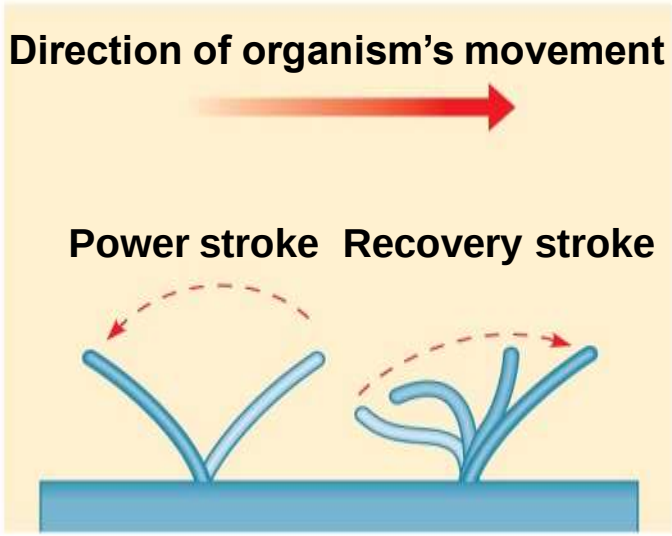
- Centrioles forming the Cilia and Flagella.
- Microtubules control the beating of **cilia** and **flagella**, locomotor appendages of some cells.
- Cilia and flagella differ in their beating patterns.
- **Cilia** are short, hair-like structures that cover the surface of certain cells and can be either:

➢ **Motile** (moving) like in Respiratory Tract cells, Fallopian Tube cells, and Ependymal cells in the brain help circulate cerebrospinal fluid.

➢ or **non-motile** (sensory): have a sensory role, acting as antennae to detect environmental signals. E.g: Olfactory Neurons, Retinal Photoreceptor Cells and Kidney Tubule Cells

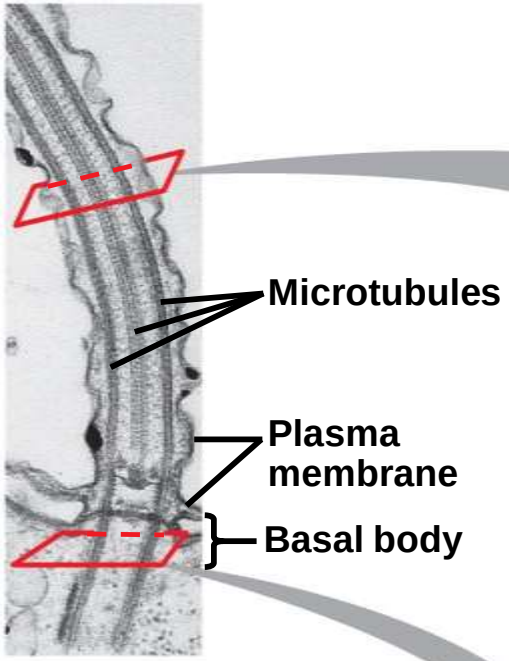


(a) Motion of flagella

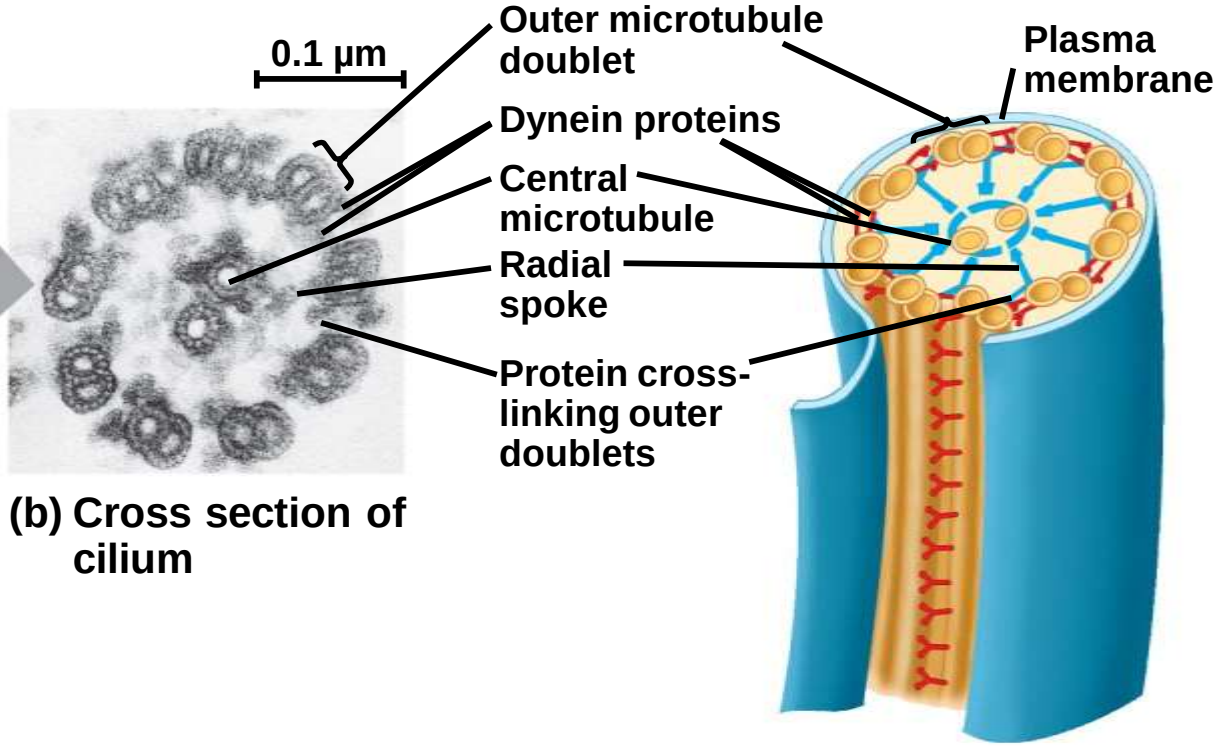


(b) Motion of cilia

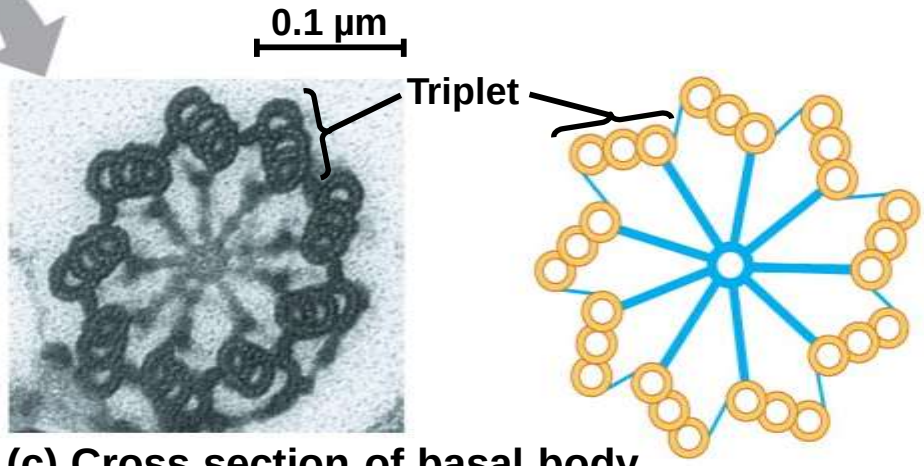
- Cilia and flagella share a common ultrastructure:
  - A core of microtubules sheathed by the plasma membrane
  - A **basal body** that anchors the cilium or flagellum
  - A motor protein called **dynein**, which drives the bending movements of a cilium or flagellum



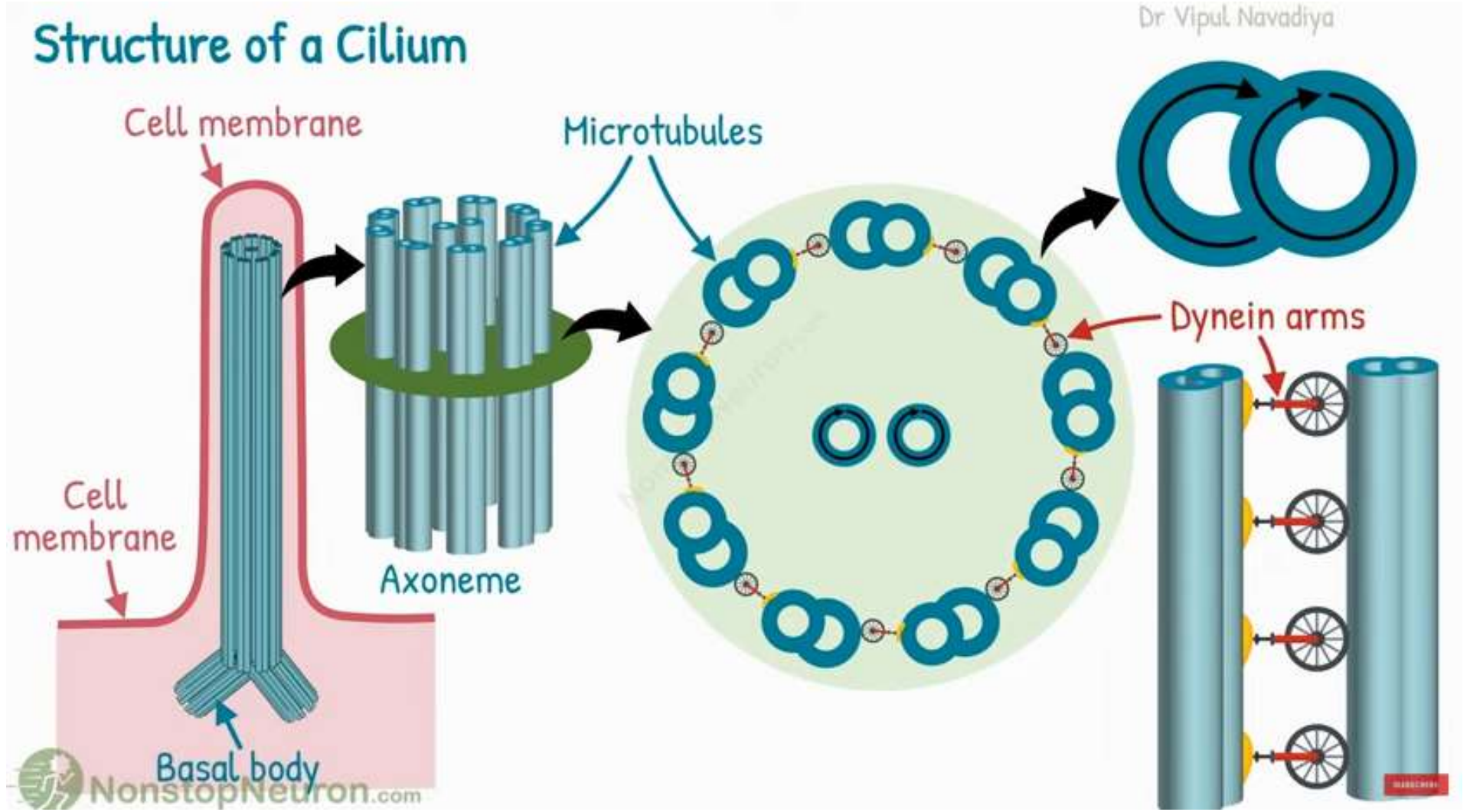
(a) Longitudinal section of cilium



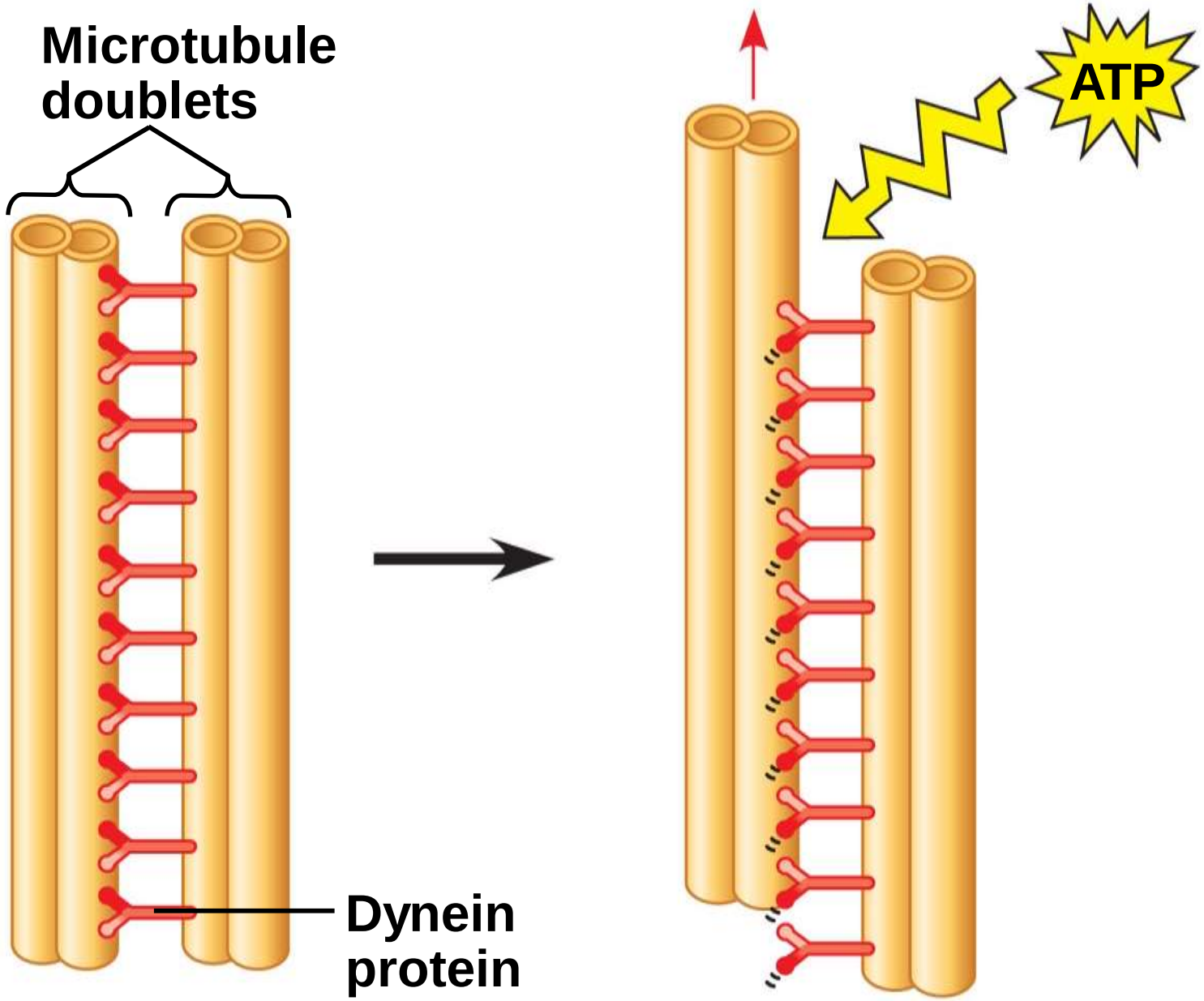
(b) Cross section of cilium



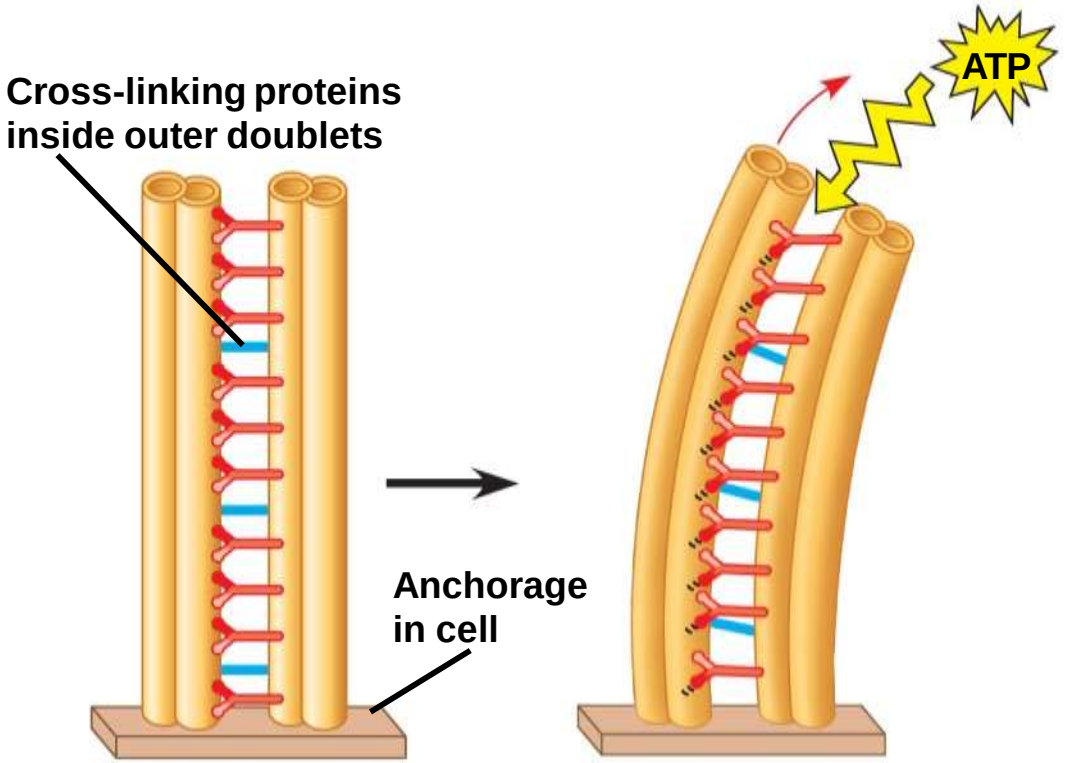
(c) Cross section of basal body


Structure of a Cilium
Dr Vipul Navadiya
Cell membrane
Microtubules
Dynein arms
Cell membrane
Axoneme
Basal body
NonstopNeuron.com

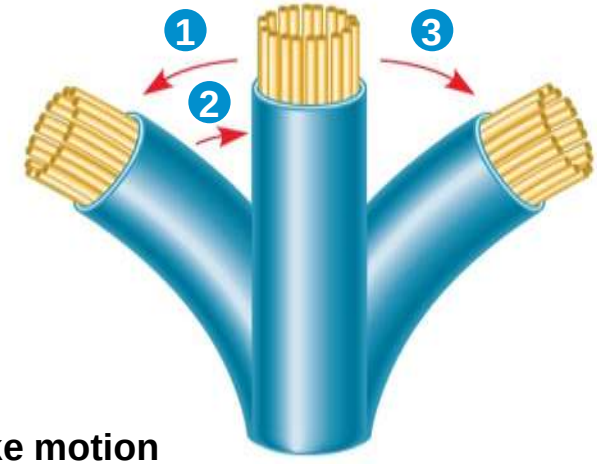
- How dynein “walking” moves flagella and cilia:
  - Dynein arms alternately grab, move, and release the outer microtubules
  - Protein cross-links limit sliding
  - Forces exerted by dynein arms cause doublets to curve, bending the cilium or flagellum



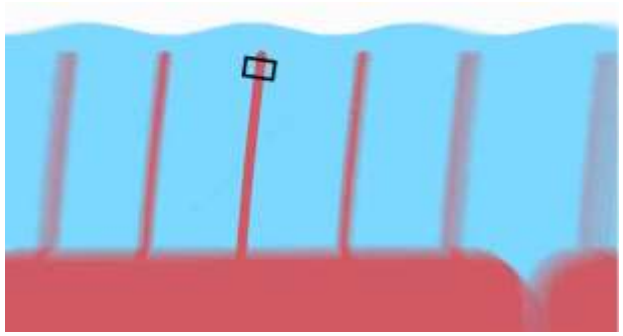
(a) Effect of unrestrained dynein movement

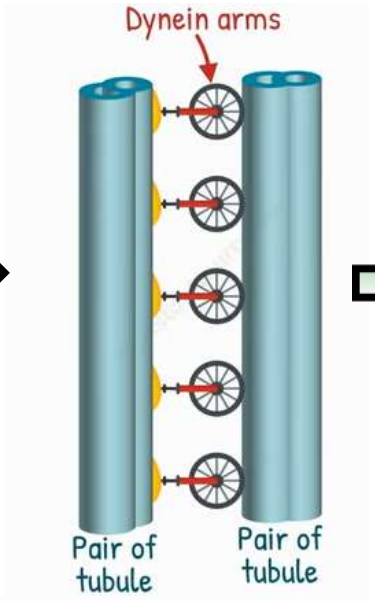


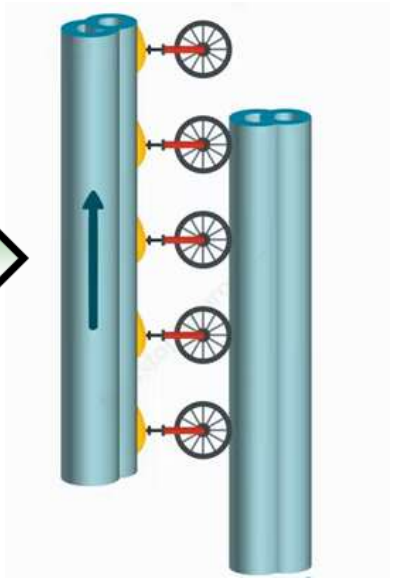
(b) Effect of cross-linking proteins

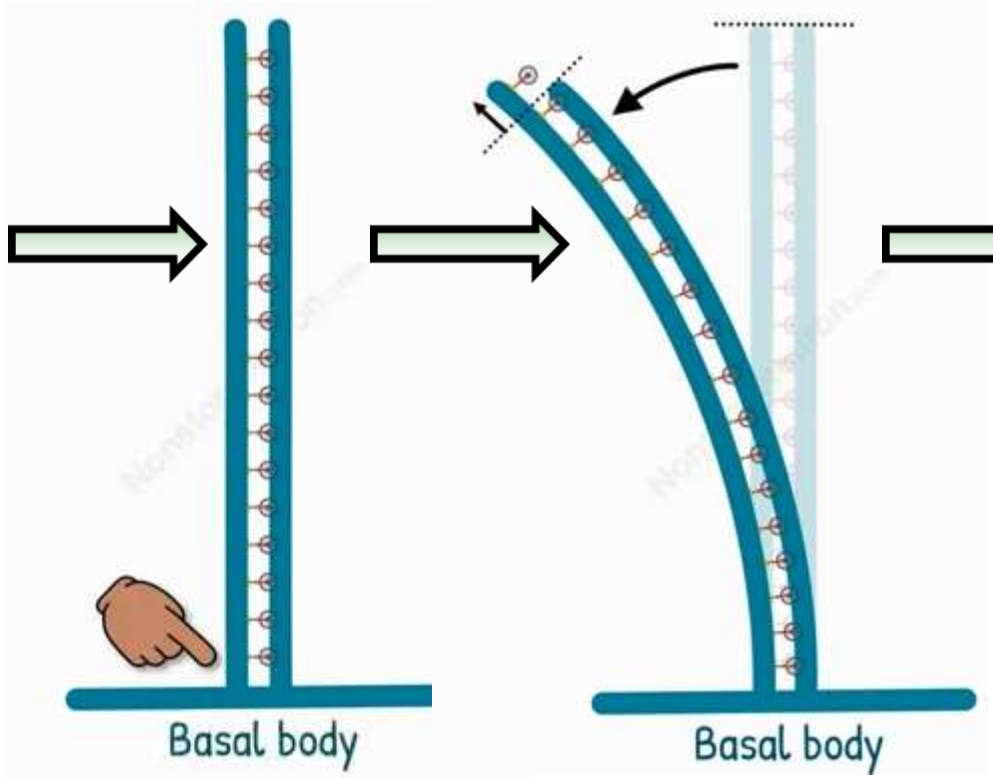


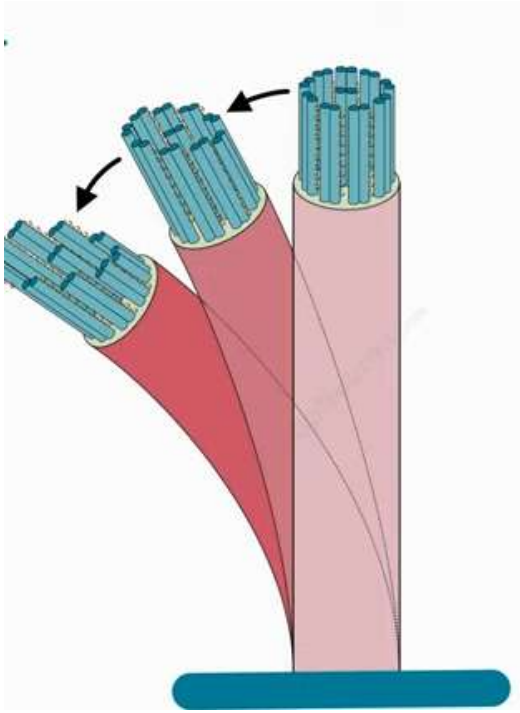
(c) Wavelike motion




Dynein arms
Pair of tubule
Pair of tubule

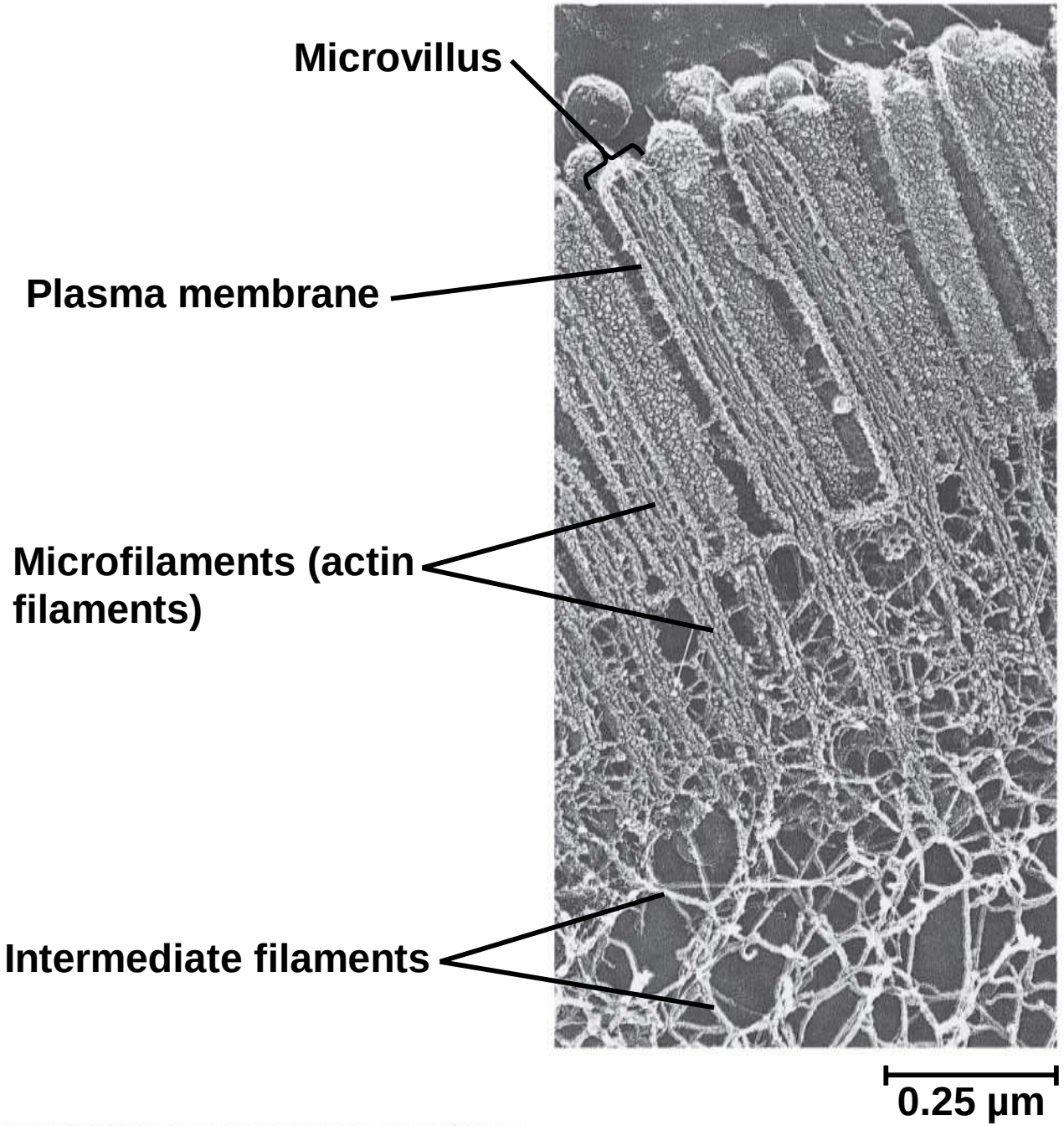



Basal body
Basal body

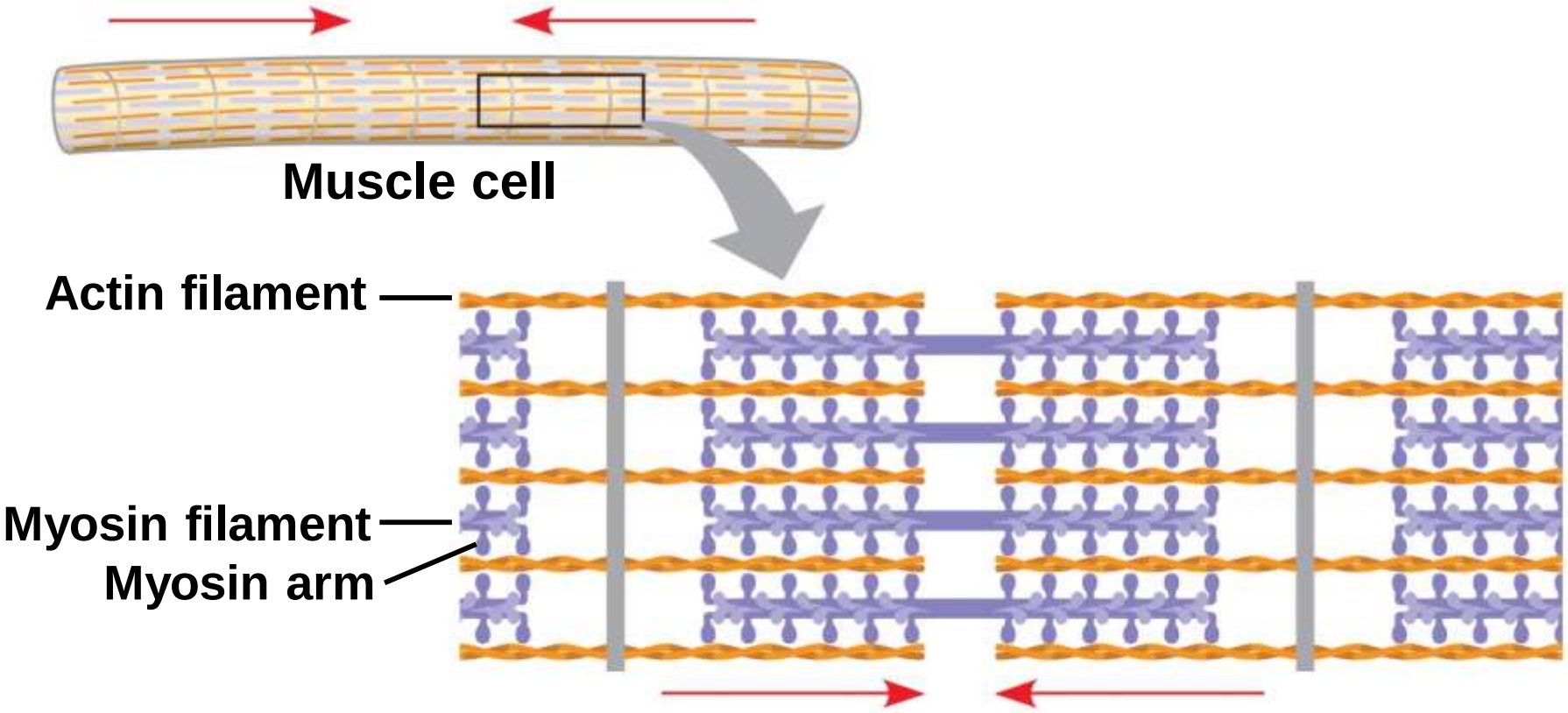


Microfilaments (Actin Filaments)

- The structural role of microfilaments is to bear tension, resisting pulling forces within the cell.
- They form a 3-D network called the **cortex** just inside the plasma membrane to help support the cell's shape.
- Bundles of microfilaments make up the core of microvilli of intestinal cells.



- Microfilaments that function in cellular motility contain the protein **myosin** in addition to actin
- In muscle cells, thousands of actin filaments are arranged parallel to one another
- Thick filaments composed of myosin interdigitate with the thinner actin fibers.



(a) Myosin motors in muscle cell contraction

- **Cytoplasmic streaming** is a circular flow of cytoplasm within cells.
- This streaming speeds distribution of materials within the cell.
- Less obvious in animal cells, it can occur in large cells like **oocytes**, where streaming helps distribute organelles and signaling molecules.

Intermediate Filaments

Function:

1. They support cell shape and fix organelles in place.
2. Cell-Cell and Cell-Matrix Interactions.
3. Nuclear Envelope Stability: form a meshwork called the nuclear lamina inside the inner nuclear membrane, helping maintain the shape of the nucleus and organizing nuclear contents.