

MODULE 2.1: THE CYTOSKELETON'S IMPORTANCE

Cytoskeleton: network **FIBERS** of microtubules, microfilaments, and intermediate filaments within the cytoplasm

- **Microtubules:** polymers/chains of tubulin (a protein that forms the chains) to provide shape and structure
- **Microfilaments (filaments: thread-like structures):** AKA actin *polymer* protein filaments that are in the cytoplasm
- **Intermediate filaments:** Cytoskeleton structures that provide structure support and pathways

Function: Mechanical. Structural, transport, motility and signaling functions

- Allows cell division and chromosome separation
- Organizes the cell structure
 - Anchors organelles and facilitates cellular activities
- Organelles and enzymes can attach to the cytoskeleton and move across the cell
- Maintenance and modifications of the cell's shape
 - Animal cells lack cell walls
 - Plants have cell walls so their shape is maintained by cell walls
 - The cytoskeleton is dismantled on one side of the cell and reassembled in another part
 - Very dynamic
 - Ex of maintenance: infoldings of the membranes to form phagocytosis vesicles, amoeboid movements (temporary cytoplasmic projection: pseudopodia) 🦶
- Fluorescence tagging (like coloring and dyeing) allows to show the different orientations of cytoskeleton components
 - All you need to do is excite the cell with specific wavelength
 - Different wavelengths (different colors) are specific to the 3 different fibers (3 different antibodies are linked to each fluorescent marker) 🦶
- Different types of **fibers** are recognizable because they are all made of different proteins that are associated with specific antibodies

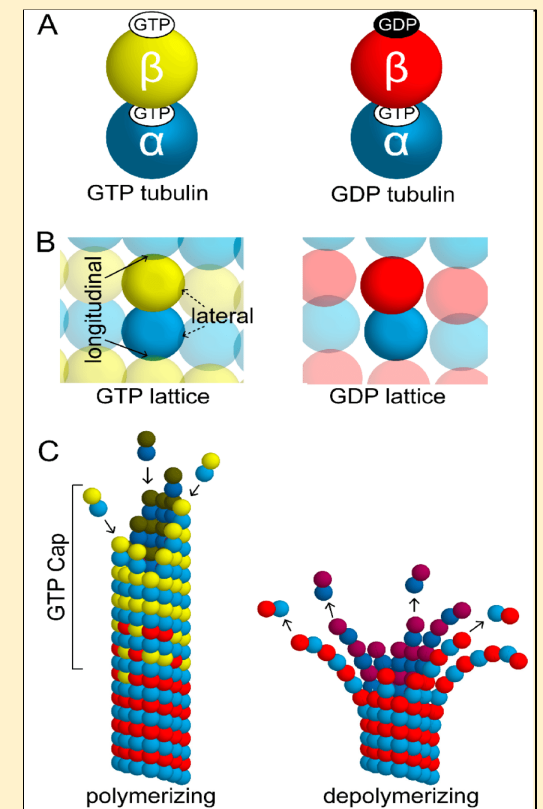
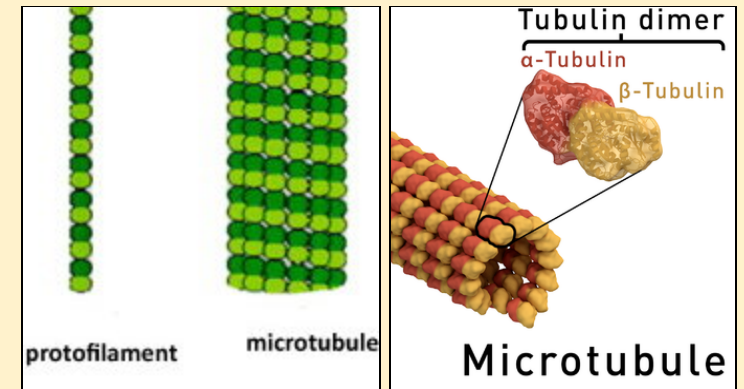
MODULE 2.2: MICROTUBULES

Microtubules: thick, hollow, rod composed of tubulin proteins to form a polymer

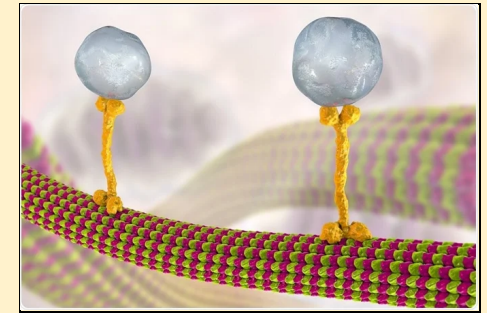
- Tubulin: a dimer (two monomers joined together to form one bigger unit)
 - α -tubulin and β -tubulin
- Has a charge orientation (polarity) of a positive and negative end
- Can grow and shrink in length from the "positive end" through polymerisation OR disassembly of the tubulin dimers
 - **Polymerisation:** The act of monomer molecules reacting with one another to form a polymer chain. Adding more tubulin to the positive end.
- The negative end is attached to the **centrosome**

Other takeaways...

- Diameter: 25nm - 15nm lumen
- Main functions:
 - Maintain cell shape (compression-resisting girders)
 - Cell motility (as in cilia or flagella)
 - Chromosome movements in cell division; organelle movements
- **Fibroblast:** type of cell in loose connective tissue that secretes the protein ingredients of the extracellular matrix (ex: collagen)
 - Produces collagen
- GTP-tubulin molecule can be added on top of each other to create a **protofilament**
 - Protofilaments are the main constituents of microtubules
- GTP-**BETA**-tubulin can turn into GDP-tubulin via **hydrolysis** (addition of water)
 - **GTP**-ALPHA-tubulin is always **GTP** bound, never **GDP**
 - **GTP** bound dimers make strong bonds
 - **GDP**-Beta-tubulin make weak bonds, making them easier to break
 - This is at the plus end
 - The process of the microtubule breaking down is called **catastrophe**
 - **GTP cap:** area in which **GTP** hydrolysis has not occurred yet
- **Catastrophe:** when hydrolysis rate is faster than the addition rate. Dimers can't keep up.
- **Rescue:** Vise versa. When dimer addition is faster than hydrolysis
- GDP tubulin to GTP tubulin:
 - Transfer of phosphate group from free GTP (not associated with tubulin) molecule in cytosol to make GDP



- Involved in the movement of organelles, vesicles, and enzymes across the cell
 - Movements are caused by **motor proteins** powered by ATP (converts chemical energy to mechanical energy)
- Motor proteins (yellow diagram) : Connect the cytoskeleton (the microtubule) and the vesicle (clear diagram) which has the motor protein receptor
 - It kind of walks along the microtubule
- 2 different types of motor proteins
 - BOTH can displace vesicles, but in **different directions**
 - ONE vesicle can have BOTH types of motor proteins **at the same time**, but only **ONLY ONE** will actually attach to the microtubule

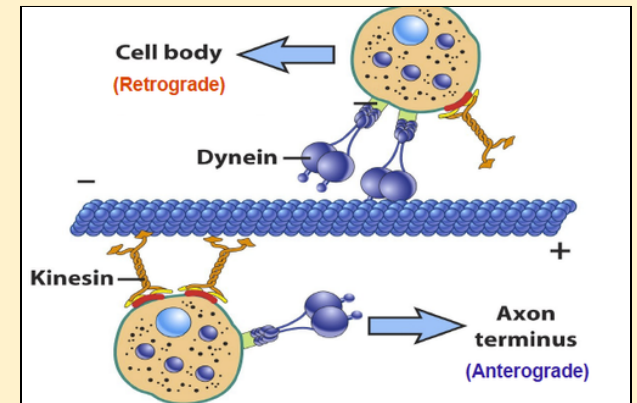


Dynein Motor Protein

- Moves loads towards the **minus** end of microtubules

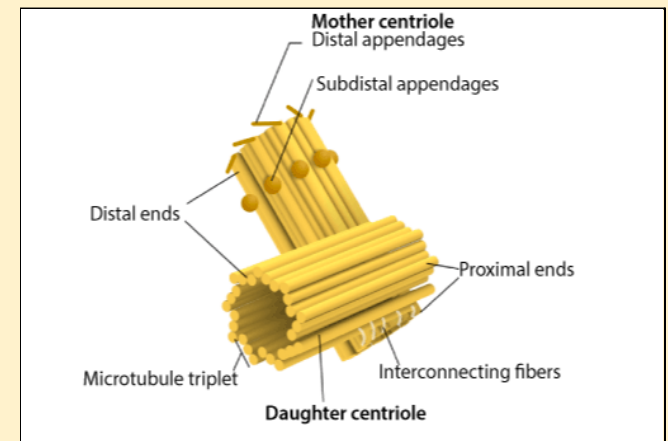
Kinesin Motor Protein

- Moves loads towards the **plus** end of microtubules



More about microtubules...

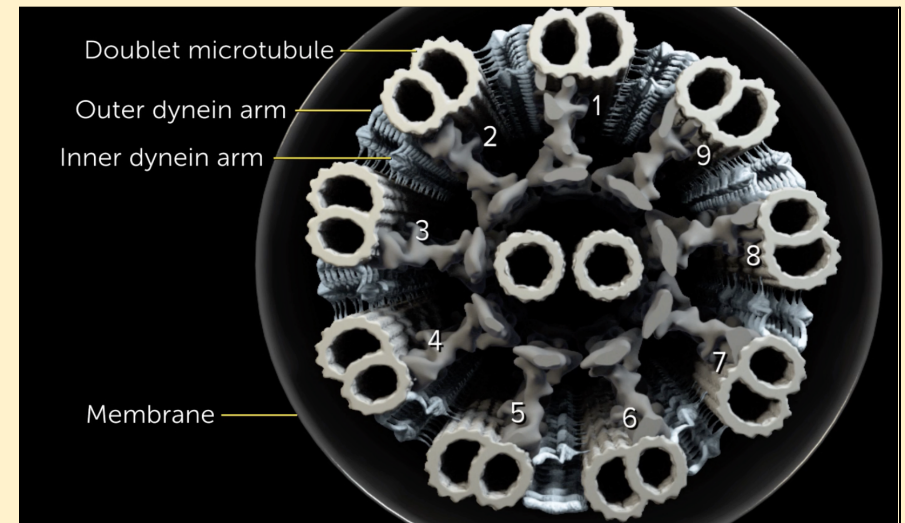
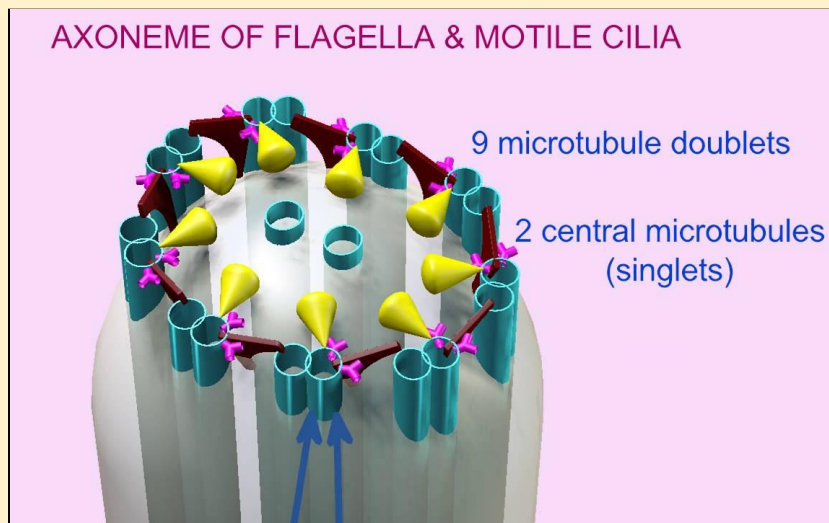
- Are involved in the separation of chromosomes during mitosis
 - Radiate from the centrosome
- Centrosome:** structure present in the cytoplasm of animal cells near the nucleus that functions as a **microtubule-organizing center (MTOC)** and is important during cell division
 - Centrosome has 2 **centrioles** that are perpendicular to one another
 - Centriole:** *cylindrical structure in the centrosome of an animal cell that is composed of 9 microtubule triplets ("9+0 arrangement")*
 - 9 triplets of microtubules that form a **SINGLE CENTRIOLE**
 - 0: refers to the number of microtubules we can see on the inside of the centriole
 - After mitosis, the 2 centrioles separate, and each is replicated for the next cell cycle
 - Only 1 centrosome per daughter cell, then there will be 2 after duplication eventually



Flagella and Cilia

- Microtubules are involved in the beating of flagella and cilia
- Both cilia and flagella are appendages in eukaryotic cells that contain microtubules and are used in locomotion (flagella and cilia) or used to move fluid around and feed (JUST cilia)
 - **Flagella:** long and few of them
 - **Cilia:** short and a lot of them
- Both have a core (**axoneme**) made of 9 outer doublet microtubules and 2 inner single microtubules (9+2 arrangement).
 - These microtubules are covered by the plasma membrane
 - The movement of cilia and flagella are related to the movement of microtubules on each
 - The sliding of the doublets
 - The sliding of the microtubules onto each other depends on a motor protein (dynein)
 - Dynein link the adjacent microtubules
 - One side of dynein are active while the other is not, and they keep alternating, this is why the structure bends and moves left to right
 - Like rowing a boat: if you row only on one side, you're gonna only move in one direction. You must alternate
- A loss or shortening of cilia (axoneme)
 - Cilia get rid of viral particles (in the trachea for example), so there will be an accumulation of viral particles that cannot be cleared
 - Can lead to an infection
 - The mean clearance speed of viral particles decreases as they are cleared

LOOK
AT BLUE



New Topic

MODULE 2.3: MICROFILAMENTS AND INTERMEDIATE FILAMENTS

Microfilaments

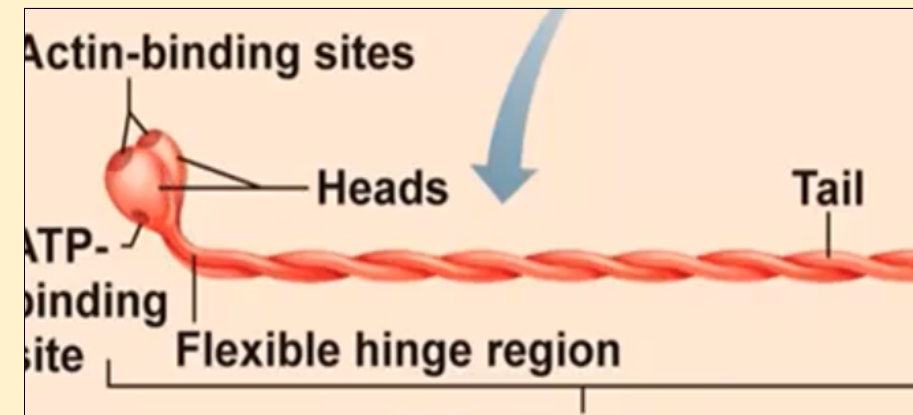
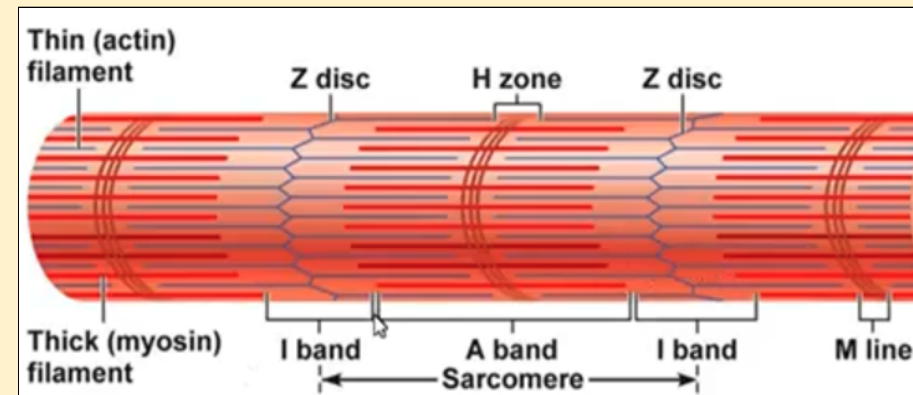
- AKA actin filaments (actin is a polymer protein)
 - Made of actin proteins that act alone **or** with myosin to cause cell contraction
- Much smaller than microtubules
 - 7nm
- Microfilaments form a network and can be branched
- Double chain of actin subunits
- Resist compression and maintains the shape of the cell (the cortex: thin region directly beneath the plasma membrane)
- Can be important in motility and cell division
 - Chloroplasts can walk across microfilaments
 - Can also push the cytosol to create “cytoplasmic streaming in plant cells”
- Can interact with a protein **myosin** to cause muscle cells to contract

Muscle Contraction

- The sliding of microfilaments (thin) onto each other
 - This is powered by myosin
 - Sliding of actin filaments against myosin filaments
- Sarcomere of muscle have Z lines
 - **Sarcomeres** go from Z - disc to Z - disc. (it's like a unit)
 - They are composed of 2 main protein filaments: actin and myosin
 - **Actin**: thin filaments (see blue I bands and in A band)
 - **Myosin**: thick filaments (see red width of A band)
- If the head of myosin filaments contract, actin filaments get closer to one another
 - This is the shortening of the cell
 - Contraction uses ATP

Thick (myosin) filaments have...

- ❖ Rod like tail (2 heavy chains) (twisted together)
- ❖ 2 globular heads (ends of heavy chains) (contain ATPase)
- ❖ 4 light chains / cross bridges
 - Business ends of the thick filaments (bind to actin for muscle contraction) 🦶



Intermediate filaments

- 8-12nm
- Made of many proteins such as keratin
- Strong and flexible filaments of intermediate size (between microtubules and microfilaments)
- Provide mechanical support of the cell against physical stress
 - Intermediate filaments are only found in the cells of some animals, including vertebrates (ex: keratin found in epithelium, scales, hair, nails, feathers, horns, claws, hooves, skin etc)
 - Intermediate filaments are more permanent (not disassembled and reassembled as much as microtubules and microfilaments)
 - They do not often change in size
 - Can bear tension (like microfilaments, maintain the shape of a cell and the nucleus (nuclear lamina) and fix the position of organelles)

New Topic

MODULE 2.4: CELL JUNCTIONS

Cell junction: a cellular structure that provides contact or adhesion between neighboring cells (or between a cell and **extra**cellular matrix)

Plasmodesmata: only found in plants

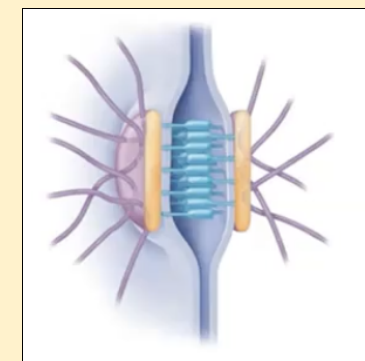
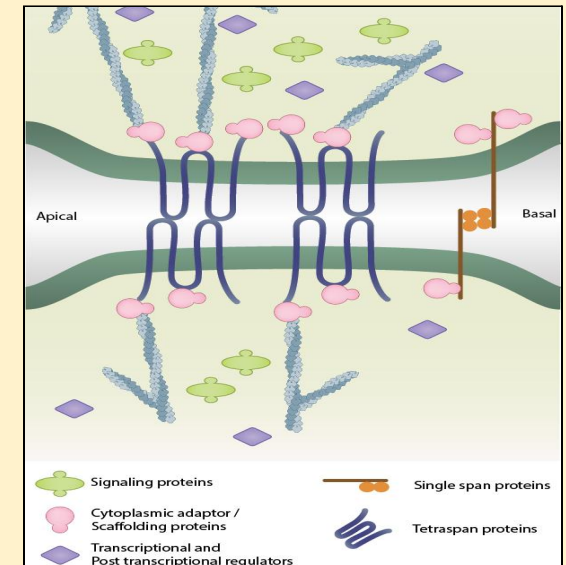
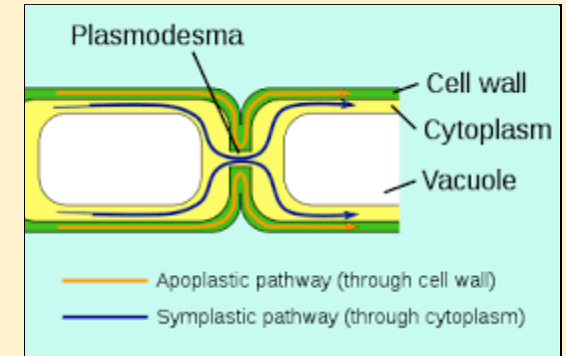
- ❖ Neighboring cells of multicellular organisms adhere and communicate with one another
- ❖ Plants: neighboring cells are connected by cytoplasmic channels called **plasmodesmata**
 - They go through the cell walls, making the membrane continuous between cells
 - Allow the continuity of the cytosol
 - Many substances can pass from one cell to another
 - Ex; sugar, nucleic acid

Tight junctions: found in animal cells

- ❖ Plasma membranes of adjacent cells are bound together by proteins
- ❖ Prevents leakage of fluid through the epithelium layers
 - Impermeability
 - Prevents any substance to penetrate skin, since it's an impermeable layer
- ❖ Ex: epithelial cells (like skin cells or enterocytes) or endothelial cells (like blood vessel cells)

Desmosomes: found in animal cells

- ❖ Anchor the different adjacent cells together through transmembrane proteins (that belong to the cadherins family) which are linked to **intermediate filaments**
 - **Cadherins:** play a part in the evolution of multicellular organisms
- ❖ Keep adjacent cells tight together, especially in tissues that can stretch
- ❖ Interactions between membrane proteins of both cells



Gap junctions: found in animal cells

- ❖ Similar to plasmodesmata in plant cells
- ❖ 6 proteins (connexins) form a channel and allow the communication of adjacent cells
 - Each of those connexin is made of multiple transmembrane domains
 - 6 connexins form a connexon
 - Line up with each other to let molecules go through
 - Letting through ions and small molecules such as amino acids, sugars
- ❖ Ex: heart muscle cells

