Cell-Cell Interactions

B.Sc Sem 3 Microbiology

MB-302 Unit-1

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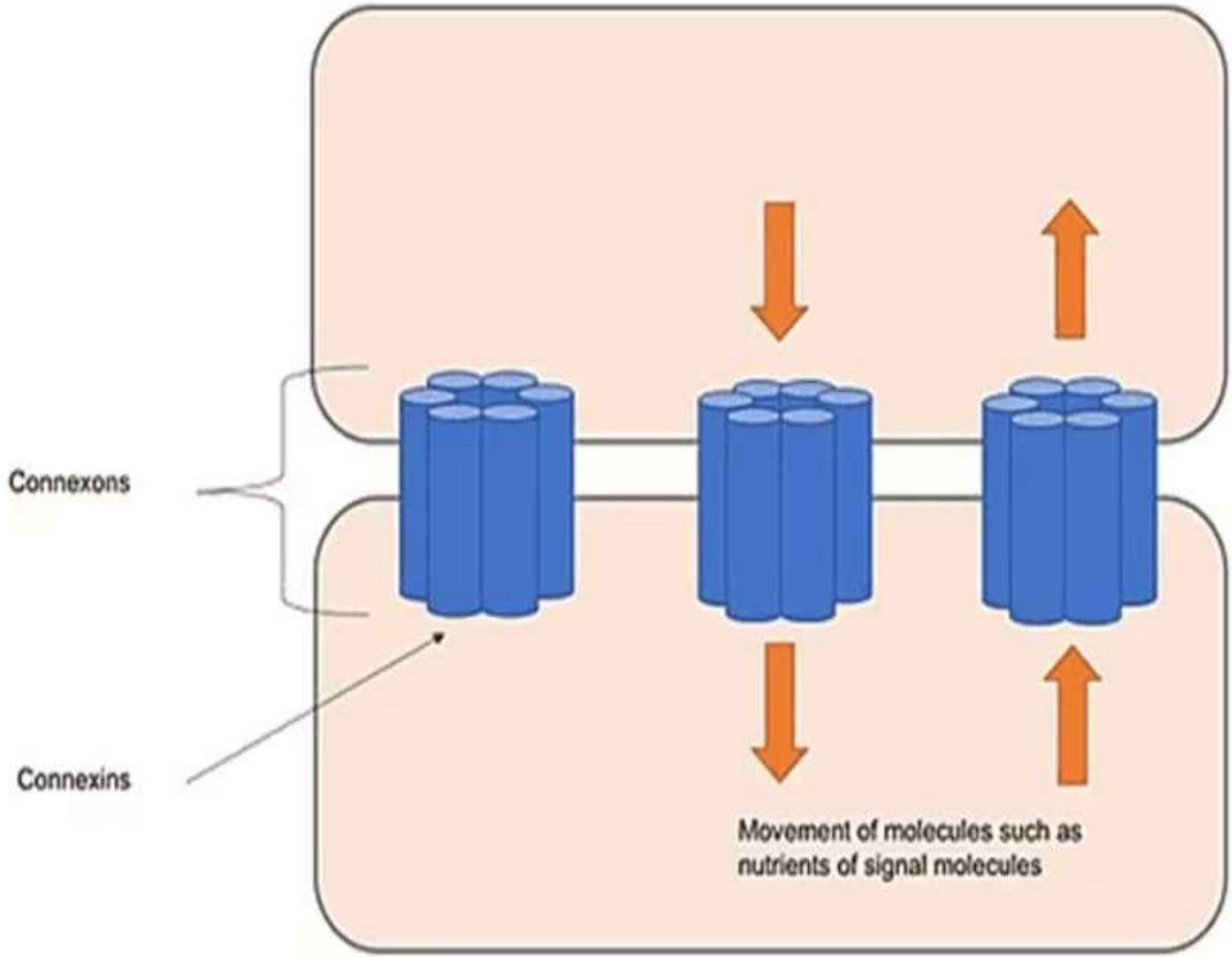
Introduction

- Cell–cell interaction refers to the **direct interactions between cell surfaces that play a crucial role in the development and function of multicellular organisms**.
- These interactions allow cells to communicate with each other in response to changes in their microenvironment.
- There are many different ways that cells can connect to each other.
- The four main ways for cells to connect with each other are: **gap junctions, tight junctions, adhesion junctions and plasmodesmata**.

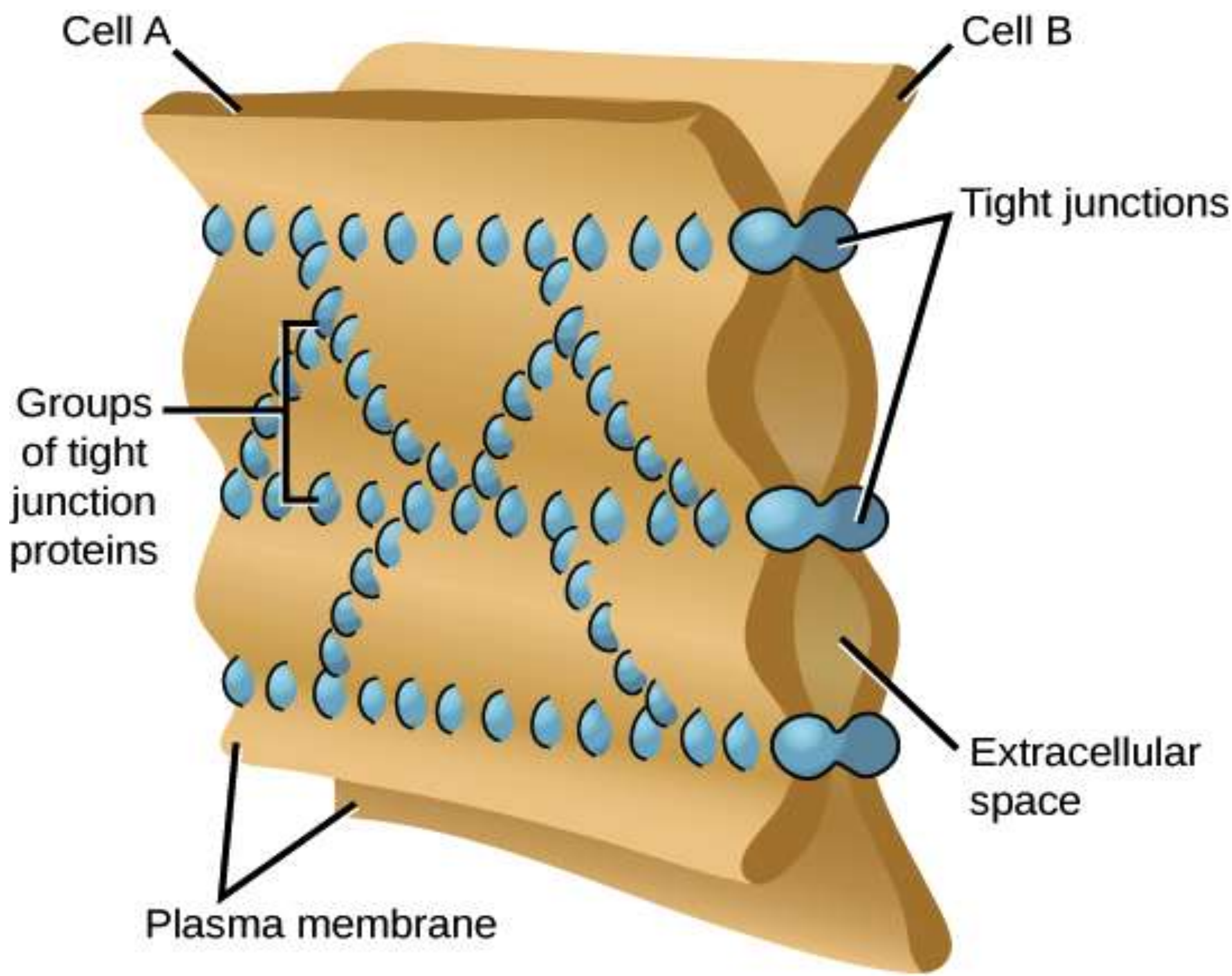
1. Gap junctions

- Gap junction channels are formed as a result of the **connexins** that create the **connexons,** and they are permeable to particular ions. these are transmembrane proteins that are organized in six-membered groups on the surface of the cell membrane.
- These channels not only serve to keep cells together and preserve structural stability, but they also facilitate the transport of ions and tiny molecules throughout the cytoplasms of neighboring cells.
- This allows gap junctions to participate in cell signaling by controlling the flow of molecules across signaling pathways.
- Gap junctions are capable of responding in a variety of ways such as modifying the number of channels available in the junction.
- Gap junctions are particularly important in cardiac muscle: the electrical signal to contract spreads rapidly between heart muscle cells as ions pass through gap junctions, allowing the cells to contract in tandem.


Connexons
Connexins
Movement of molecules such as
nutrients of signal molecules

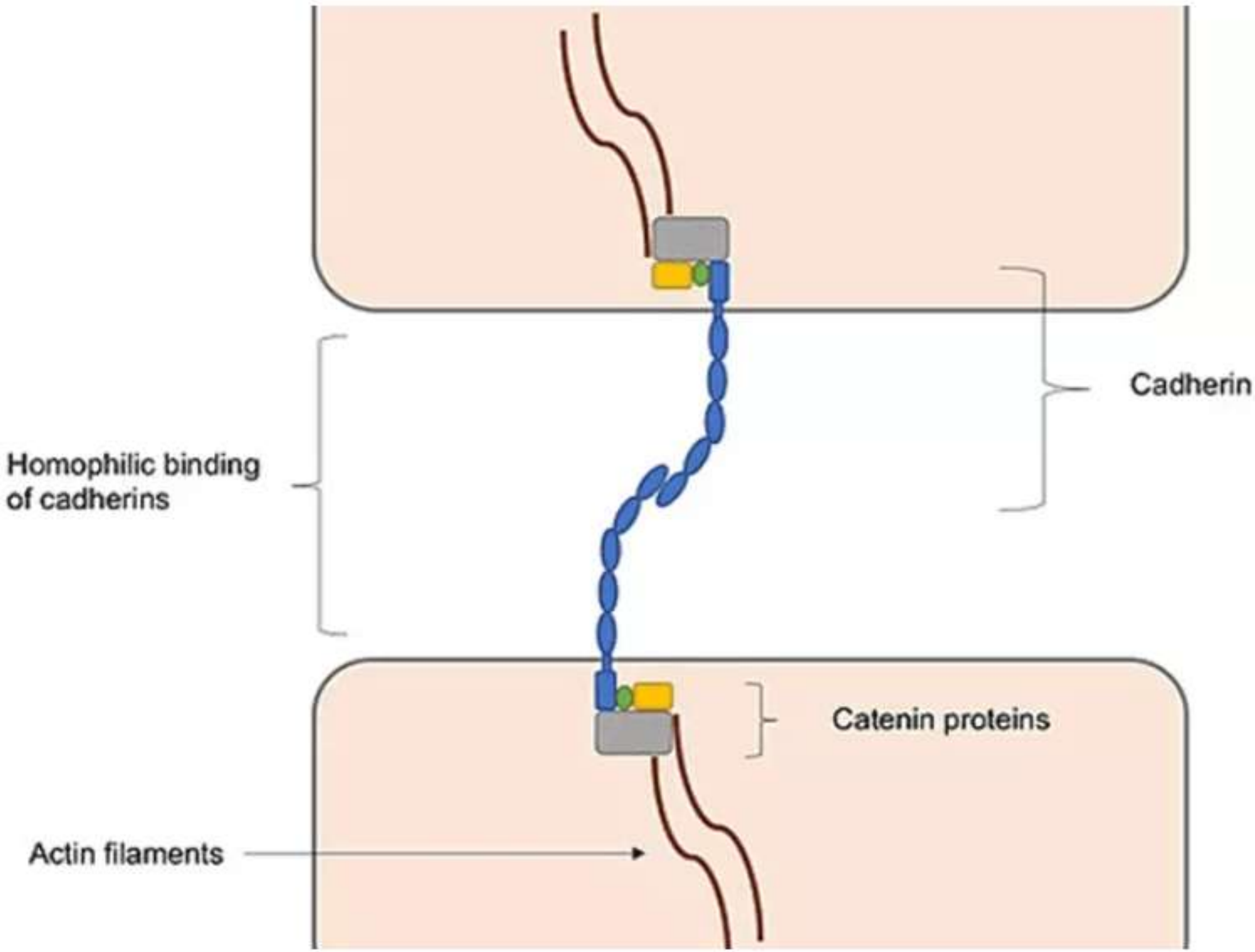
2. Tight junctions

- A tight junction is a type of connection that is present in epithelial and endothelial tissues.
- Tight junctions serve as barriers, closing gaps and controlling the passage of molecules and extracellular fluids between cells.
- At the site of a tight junction, cells are held tightly against each other by many individual groups of tight junction proteins called **claudins**, each of which interacts with a partner group on the opposite cell membrane. The groups are arranged into strands that form a branching network, with larger numbers of strands making for a tighter seal.
- The purpose of tight junctions is to keep liquid from escaping between cells, allowing a layer of cells to act as an impermeable barrier. For example, the tight junctions between the epithelial cells lining your bladder prevent urine from leaking out into the extracellular space.
- To maintain the structure of the tight junction, scaffold proteins bind to the intracellular domains of these tight junction proteins.


Cell A
Cell B
Tight junctions
Groups of tight junction proteins
Extracellular space
Plasma membrane

3. Adhesion junctions

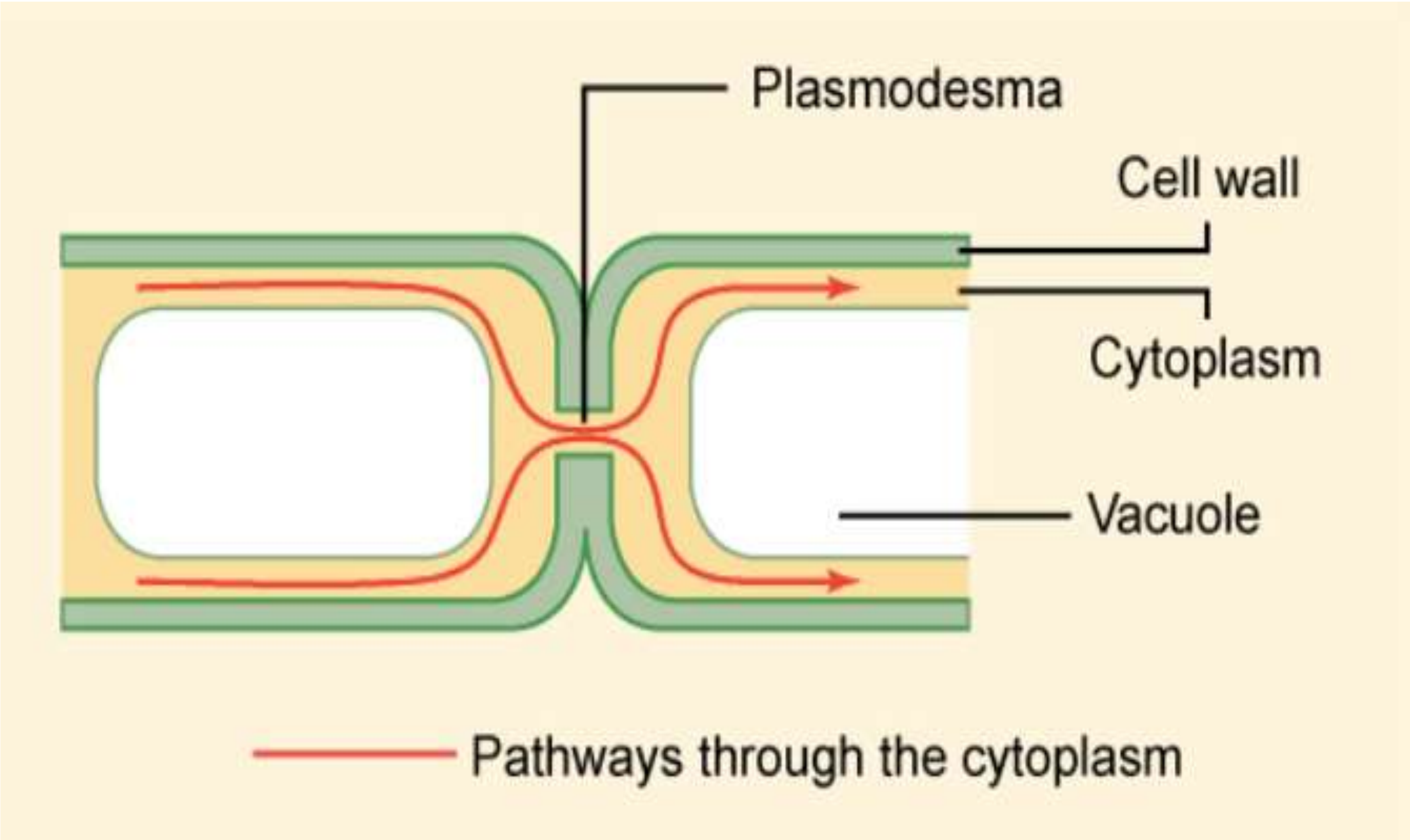
- Adherens junctions are largely responsible for maintaining the shape of tissues and retaining cells together.
- Cadherins connect cells via their cytoplasmic domain, which shares a fundamental calcium-sensitive region. When the extracellular domains of cadherins come into touch with calcium ions, they undergo a structural change an inactive flexible shape to a more rigid form.
- Cadherin intracellular domains are also highly conserved since they form complexes with catenin-like proteins.
- Between actin and cadherin filaments, these protein complexes behave as connective tissue.
- Interactions with actin filaments, which are involved in the formation of adherens junctions and the creation of adhesions, may facilitate cadherin clustering.
- cadherin clusters promote actin filament polymerization, which aids in the development of adherens junctions by connecting to cadherin–catenin complexes.

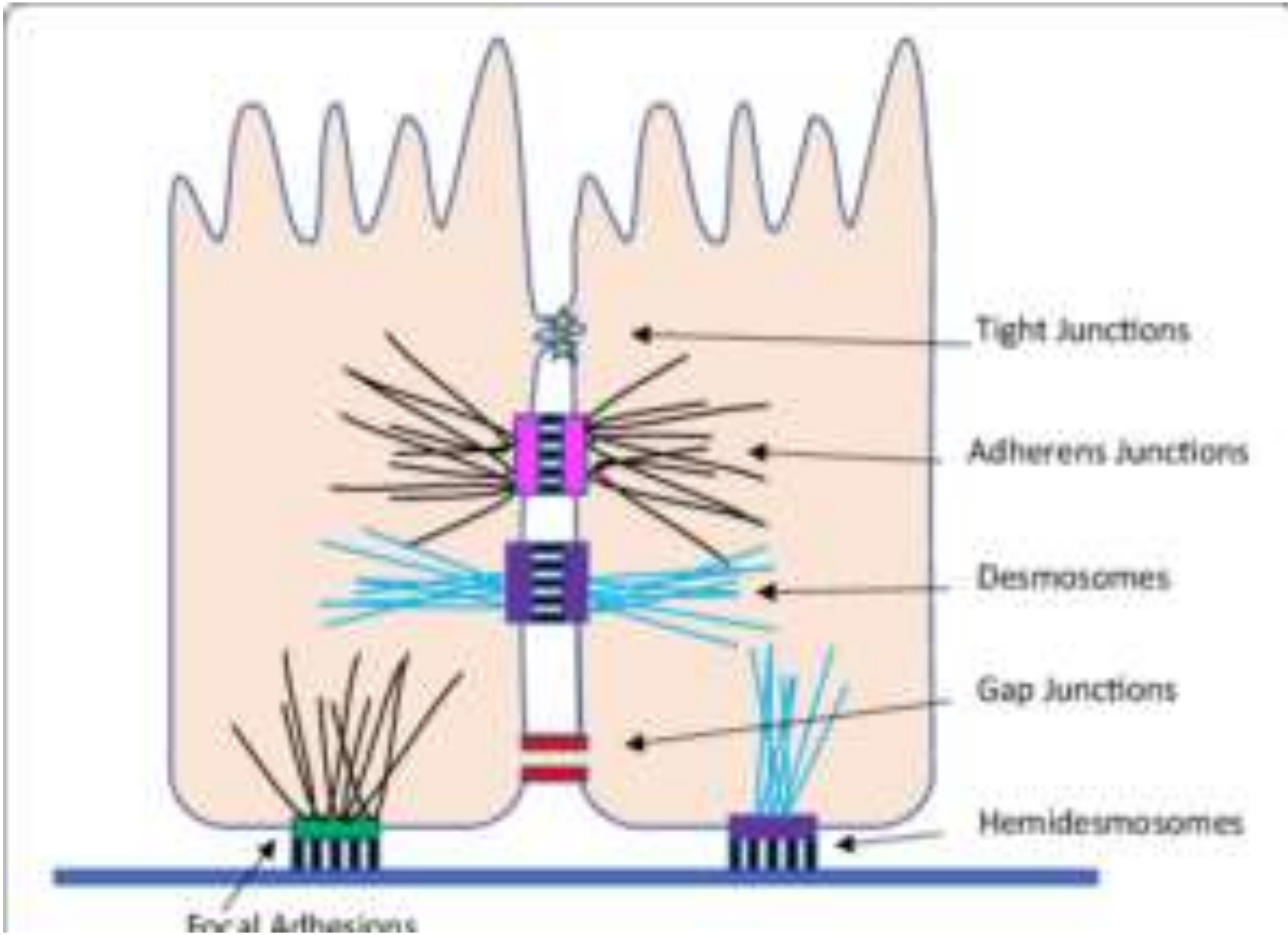


Cadherin
Homophilic binding of cadherins
Catenin proteins
Actin filaments

4. Plasmodesmata

- Plant cells, surrounded as they are by cell walls, don’t contact one another through wide stretches of plasma membrane the way animal cells can.
- However, they do have specialized junctions called **plasmodesmata** , places where a hole is punched in the cell wall to allow direct cytoplasmic exchange between two cells.
- Plasmodesmata are lined with plasma membrane that is continuous with the membranes of the two cells.
- Each plasmodesma has a thread of cytoplasm extending through it, containing an even thinner thread of endoplasmic reticulum.
- Molecules below a certain size move freely through the plasmodesmal channel by passive diffusion.
- The size exclusion limit varies among plants, and even among cell types within a plant.


Plasmodesma
Cell wall
Cytoplasm
Vacuole
Pathways through the cytoplasm

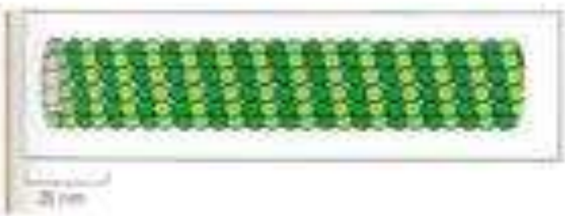

Tight Junctions
Adherens Junctions
Desmosomes
Gap Junctions
Hemidesmosomes
Focal Adhesions

Cytoskeleton

- The cytoskeleton of a cell is made up of **microtubules, actin filaments, and intermediate filaments**.
- These structures give the cell its shape and help organize the cell's parts. In addition, they provide a basis for movement and cell division.
- The cytoskeleton assists in the transportation of communication signals between cells.
- It assists in the formation of vacuoles.
- Chromosome manipulation during mitosis and meiosis, and organelle migration.
- It forms cellular appendage-like protrusions, such as cilia and flagella, in some cells.

Filaments Of The Cytoskeleton

- Actin Filaments
  - Helical polymers of protein actin



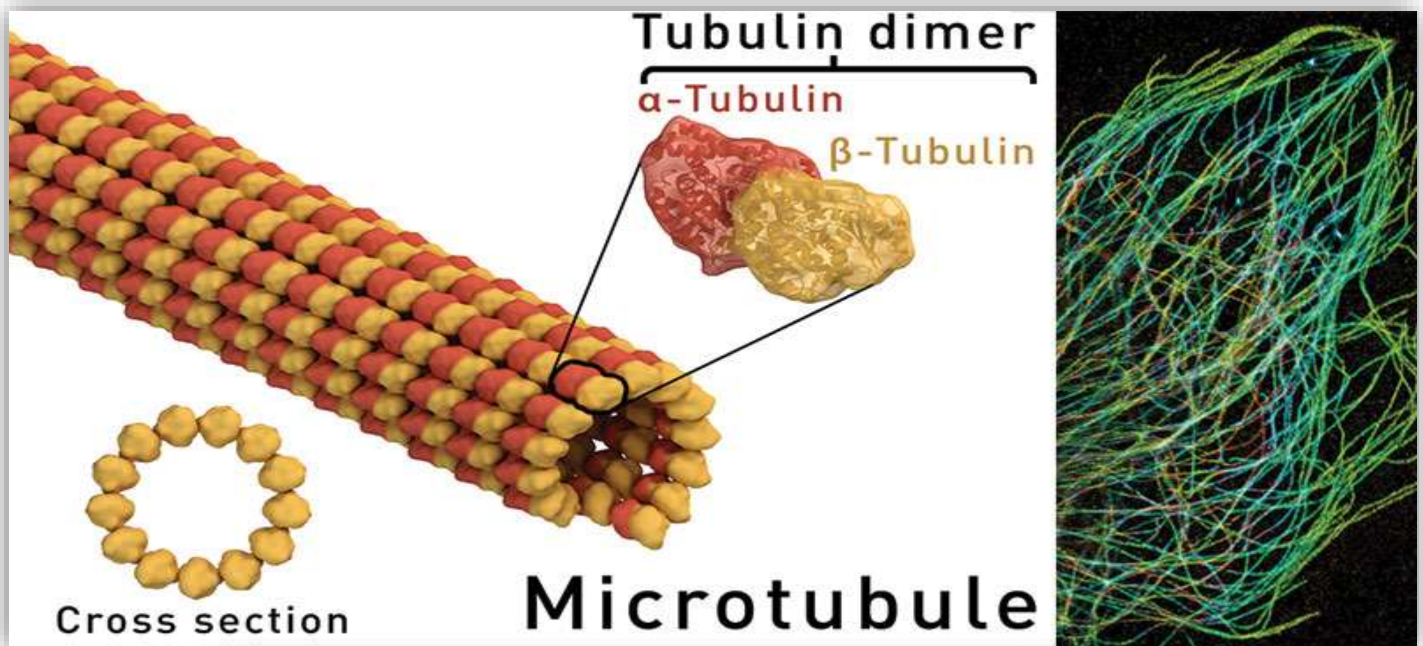
- Microtubules
  - Hollow cylinders of protein tubulin

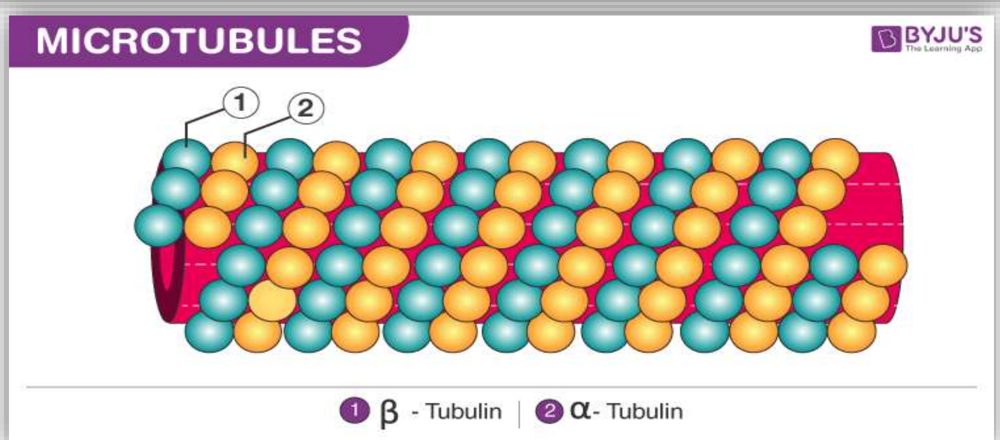
- Intermediate filaments
  - Ropelike fibers of intermediate filament proteins

1. Microtubules

- **Microtubules are microscopic, hollow tubes made of alpha and beta tubulin that are a part of the cell's cytoskeleton.**
- **Structure of Microtubules**
- Microtubules are made of subunits called tubulin.
- They are long fibers about 24 nm in diameter.
- In cross-section, each microtubule appears to have a dense wall of 6 nm thickness and light or hollow center.
- In cross-section, the wall of a microtubule is made up of 13 globular subunits, called protofilaments, about 4 to 5 nm in diameter.
- Chemically, they are composed of two kinds of protein subunits: α-tubulin (tubulin A) and β-tubulin (tubulin B), each of M.W. 55,000 daltons.
- The wall of a microtubule is made up of a helical array of repeating α and β tubulin subunits.
- Assembly studies have indicated that the structural unit is an αβ dimer of 8 nm length.
- Thus, all microtubules have a defined polarity: their two ends are not structurally equivalent.

Structure of Microtubules





Microtubule Function

- They move vesicles, granules, organelles like mitochondria, and chromosomes via special attachment proteins.
- Along with microfilaments and intermediate filaments, they form the cytoskeleton of the cell, as well as participate in a variety of motor functions for the cell.
- Cell Division:- Microtubules play a major role in forming the mitotic spindles. These mitotic spindles organize and separate the chromosomes during cell division.
- Transportation of specific organelles within the cell via microtubule “roadways” or “conveyor belts.”

2. Intermediate Filaments

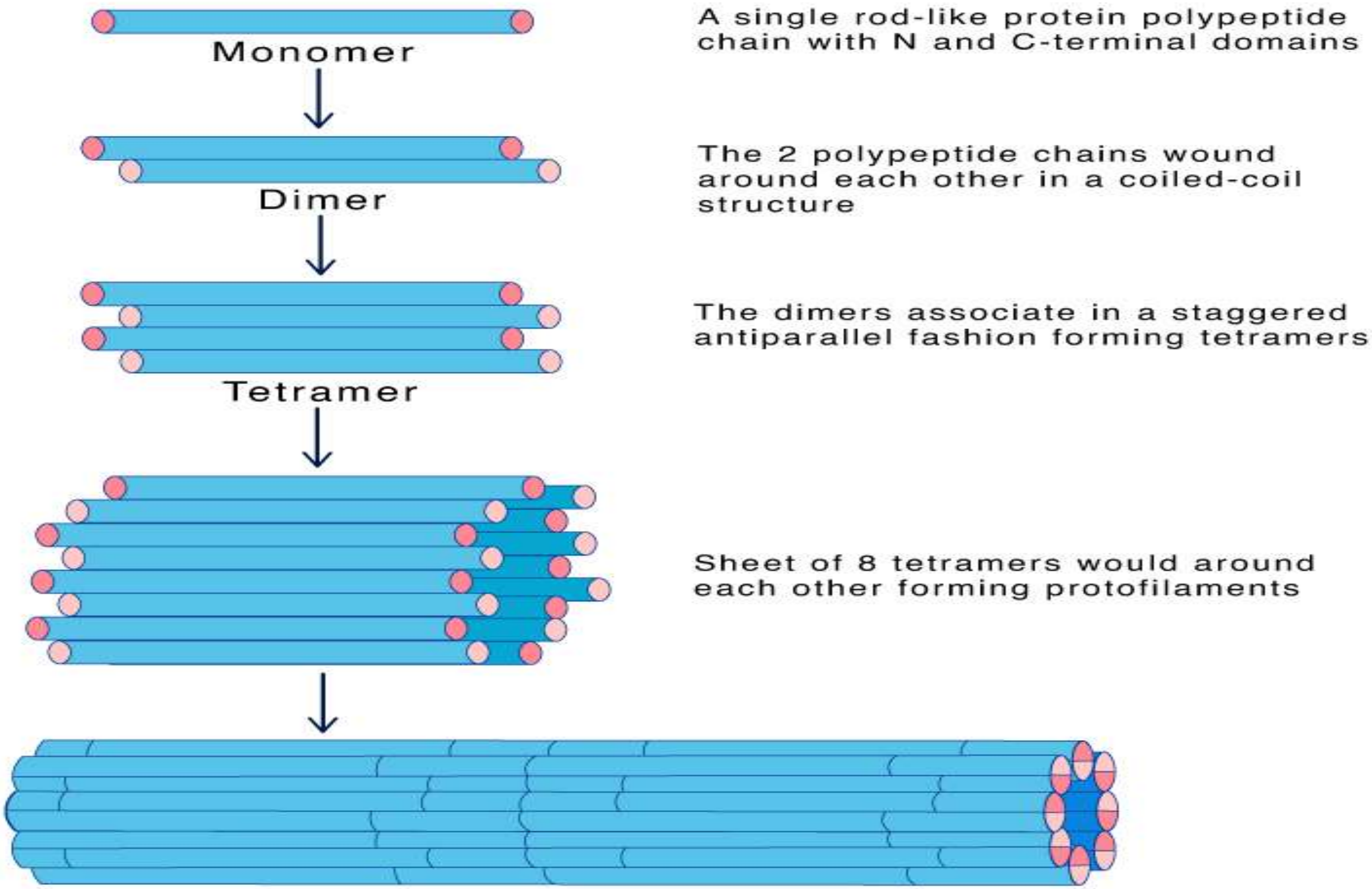
- Intermediate filaments (IFs) are one of the primary components of the cell cytoskeleton, along with microtubules and microfilaments.
- They are made of multiple strands of fibrous proteins wound together, each consisting of amino acids arranged in a chain.
- IFs are dynamic, motile elements that interact with a range of cellular proteins to function.
- They are the most stable cytoskeletal component and thus provide mechanical strength to cells and tissues.
- They form an extensive network in the cytoplasm of most animal cells, extending from a ring surrounding the nucleus to the plasma membrane.
- However, IFs are absent in plants and fungi.

Structure of intermediate filaments

- IFs are so named because they have a diameter of about 10 nm.
- They are thicker than actin filaments (about 7 nm) and thinner than microtubules (about 25 nm) or muscle myosin filaments.
- Each IFs monomer consists of a central α-helical rod domain of approximately 310 amino acids, flanked by amino- and carboxy-terminal domains.
- The central domain varies among intermediate filament proteins in size, sequence, and secondary structure.
- Intermediate Filament protein classes:-
- Type I and II: **Keratins**
- Type III: **Desmin**, **vimentin**
- Type IV: **Neurofilaments**
- Type V: **Lamins**

Intermediate Filaments

Structure & Assembly



A rope-like **intermediate filament** bundle (~10 nm)

Functions

- The primary function of IFs is to provide structural support to the cell. The tight association between their protofilaments helps in:
- Regulating cell shape in association with some other proteins such as cadherins and integrin
- Integrating the cytoskeleton
- Regulating some key signaling pathways
- Providing high tensile strength in durable structures such as hair, scales, and fingernails
- Maintaining the alignment of myofilaments and sarcomeres in skeletal muscles
- Apart from structural functions, IFs also have a significant role in cell-type-specific functions and regulate gene expressions and mitosis.

Actin filaments

- **Actin filaments**, also known as microfilaments, are the smallest protein fiber in the cytoskeleton, about 7nm in diameter.
- Actin filaments play an important role in many cellular processes, such as the following:

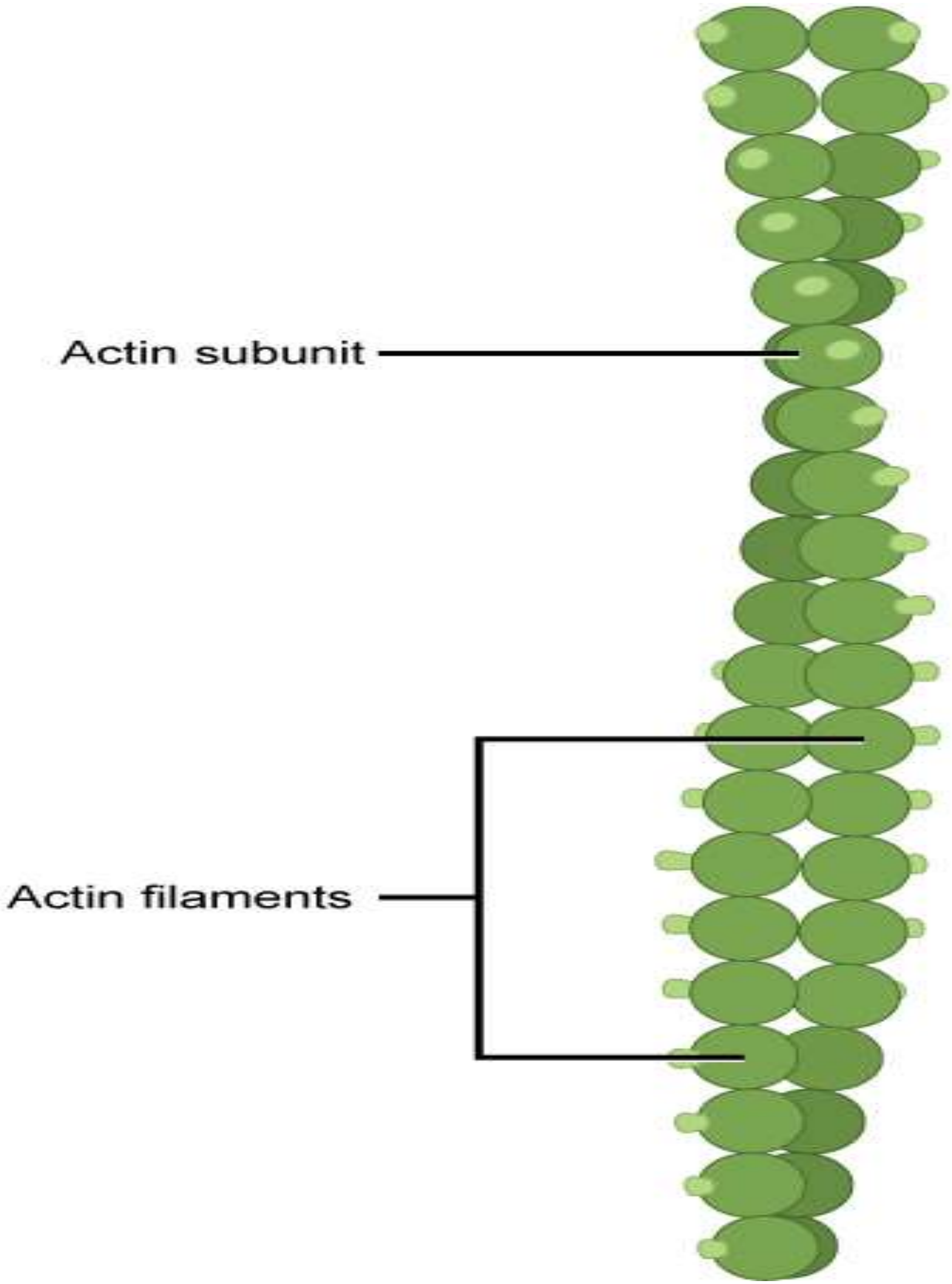
1. Cell division
2. Cell motility
3. Cell morphology
4. Plasma membrane structure
5. Contractility

- Actin can exist in two forms, globular (g-actin) or filamentous (f-actin).
- **G-actin** is a monomer protein attached to the nucleotide ATP, adenosine triphosphate. ATP is cellular energy and can be used to power cellular processes.
- ATP is hydrolyzed to ADP, adenosine diphosphate, and inorganic phosphate when g-actin polymerizes to form filamentous actin, or **f-actin**. The hydrolysis of one phosphate group releases energy.

Structure and function of Actin filaments

- Actin filaments are made of g-actin that has been assembled into f-actin strands.
- Two filaments twist together to form a microfilament strand.
- Actin is a highly conserved protein across evolution and is the most abundant protein in eukaryotic cells.
- They have a diameter of about 7 nm, combined in a structure that resembles a double helix. Because they are made of actin monomers.
- Many of the functions carried out by actin are in conjunction with actin-binding proteins. Some examples of actin-binding proteins include:

1. **Profilin:-** cell development, cytokinesis, membrane trafficking, and cell motility.
2. **Cofilin:-** important role in severing actin filament, nucleating, depolymerizing, and bundling activities
3. **Gelsolin:**-binds to the ends of actin filaments, preventing monomer exchange
4. **Spectrin:-**maintaining the stability and structure of the cell membrane and the shape of a cell.
5. **Myosin:-**Muscle contraction thus results from an interaction between the actin and myosin filaments that generates their movement relative to one another.


Actin subunit
Actin filaments

Association of Actin Filaments with the Plasma Membrane

- A network of actin filaments and other cytoskeletal proteins underlies the plasma membrane and determines cell shape: example, rbc.
- Actin bundles also attach to the plasma membrane to anchor cell-cell and cell-substratum contacts.
- The major protein provides the structural basis for the cortical cytoskeleton in erythrocytes is the actin-binding protein spectrin. spectrin is a tetramer consisting of two chains.

Figure 11.11 Association of the erythrocyte cortical cytoskeleton with the plasma membrane

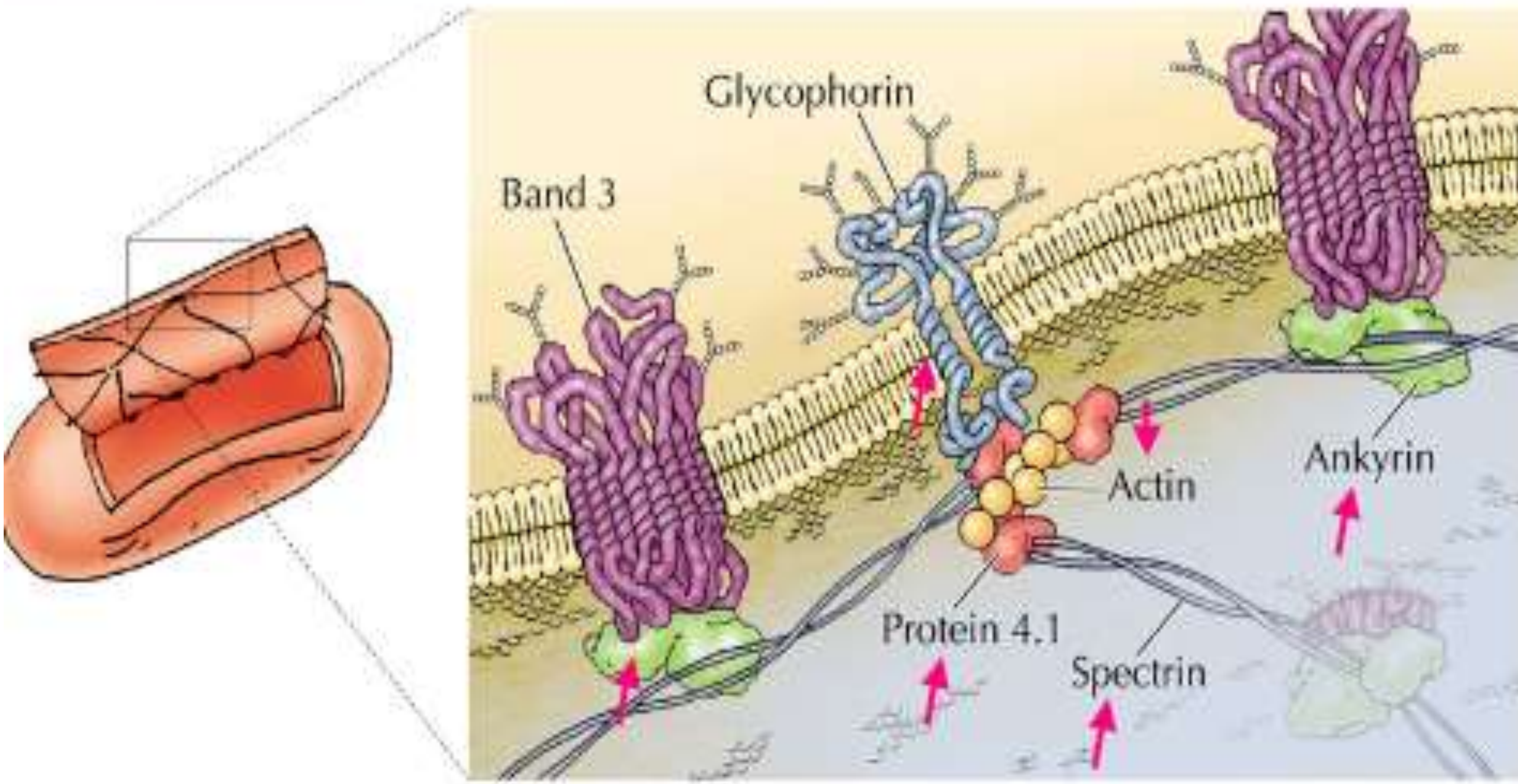
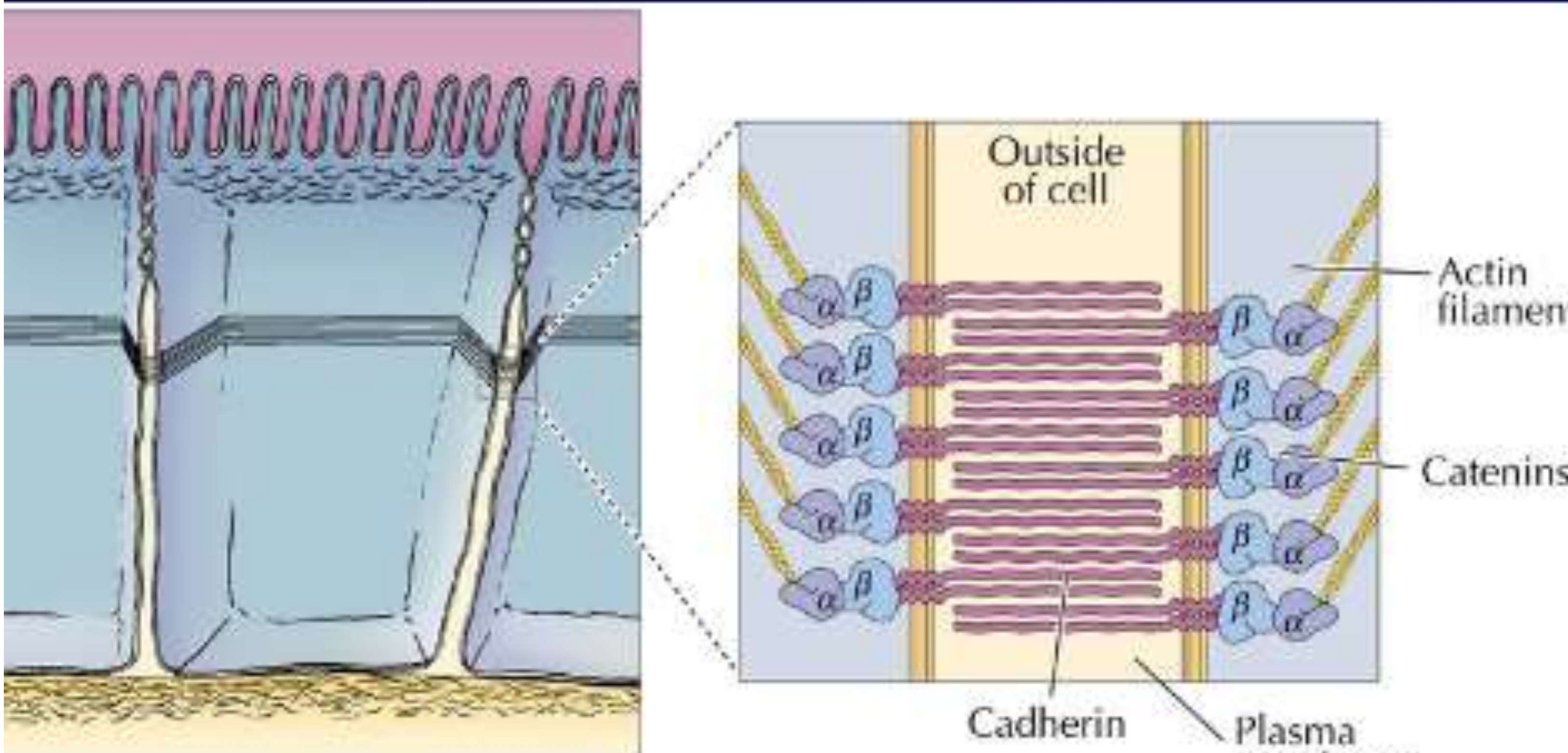


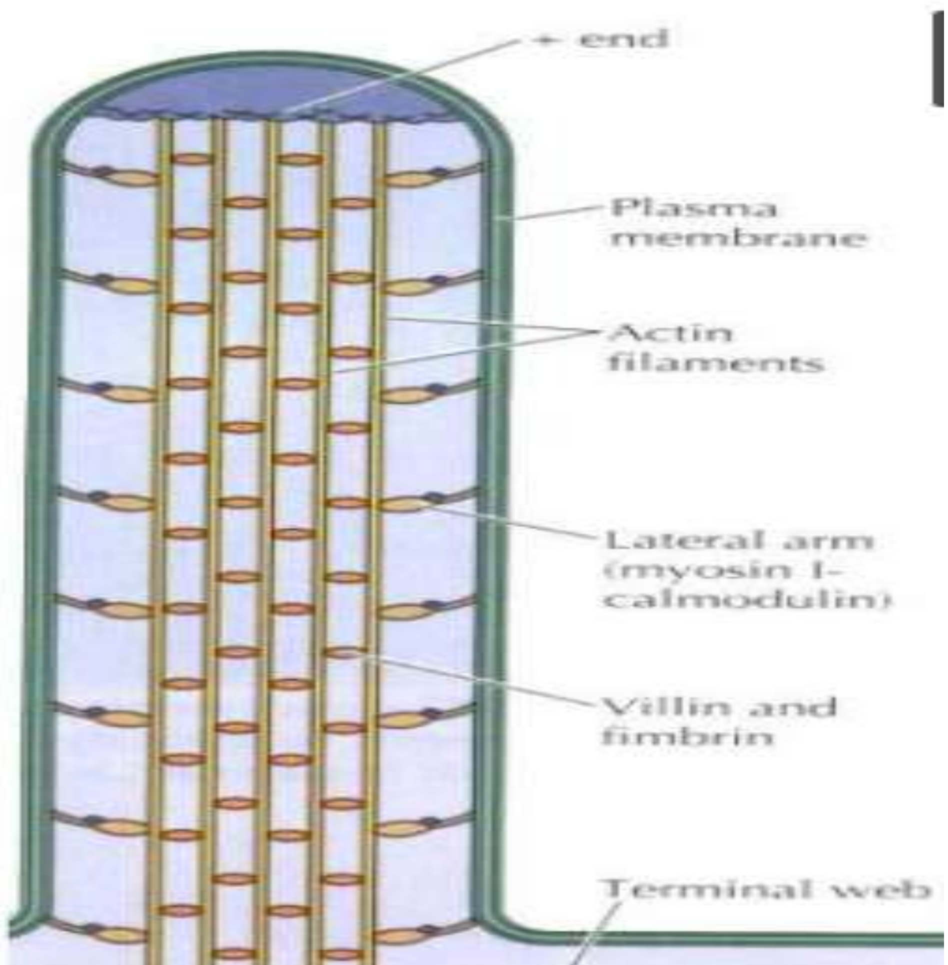
Figure 11.14 Attachment of actin filaments to **adherens junctions**



Protrusions of the Cell Surface

- Cellular protrusions are **highly dynamic structures involved in fundamental processes,including cell migration and invasion**.
- Each of the ~ 1000 microvilli contain several dozen microfilaments with their + ends facing outward;
- they are tightly packed together by actin-bundling proteins and are connected to the inner surface of the plasma membrane by lateral crosslinks composed of calmodulin and myosin.
- They project into the dense actin network within the cell.
- Microvilli increase the surface area of cells such as those lining the intestine and kidney.
- That are responsible for phagocytosis and cell locomotion.

Structure of microvilli



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