Shree H. N. Shukla College of Science
(Affiliated to Saurashtra university)
Nr. Lalpari Lake, B/H Marketing Yard, Rajkot-360 003

F.Y. B.Sc. (Sem. II) (CBCS)

BIOCHEMISTRY

[201]: CELL BIOLOGY

Unit 4
Cell-Cell Interaction

Prepared By

KISHAN VACHHANI

CELL-CELL INTERACTIONS AND CELL MATRIX INTERACTION

CELL-CELL INTERACTION

- **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. This ability to send and receive signals is essential for the survival of the cell.
- Interactions between cells can be stable such as those made through cell junctions. These junctions are involved in the communication and organization of cells within a particular tissue.
- Others are transient or temporary such as those between cells of the immune system or the interactions involved in tissue inflammation. These types of intercellular interactions are distinguished from other types such as those between cells and the extracellular matrix.
- The loss of communication between cells can result in uncontrollable cell growth and cancer.
- Stable cell-cell interactions are required for cell adhesion within a tissue and controlling the shape and function of cells. These stable interactions involve cell junctions which are multiprotein complexes that provide contact between neighbouring cells.
- Cell junctions allow for the preservation and proper functioning of epithelial cell sheets.
- These junctions are also important in the organization of tissues where cells of one type can only adhere to cells of the same tissue rather than to a different tissue.

RECEPTOR PROTEINS IN DIRECT-CONTACT SIGNALLING

- Receptor proteins on the cell surface have the ability to bind specific signaling molecules secreted by other cells.
- Cell signalling allows cells to communicate with adjacent cells, nearby cells (paracrine) and even distant cells (endocrine).
- This binding induces a conformational change in the receptor which, in turn, elicits a response in the corresponding cell.
- These responses include changes in gene expression and alterations in cytoskeleton structure. The extracellular face of the plasma membrane has a variety of proteins, carbohydrates, and lipids which project outward and act as signals.
- Direct contact between cells allows the receptors on one cell to bind the small molecules attached to the plasma membrane of different cell. In eukaryotes, many of the cells during early development communicate through direct contact.[5]
- Synaptic signalling, an integral part of nervous system activity, occurs between neurons and target cells. These target cells can also be neurons or other cell types (i.e., muscle or gland cells).
- Protocadherin, a member of the cadherin family, mediate the adhesion of neurons to their target cells at synapses otherwise known as synaptic junctions. In order to for communication to occur between a neuron and its target cell, a wave of depolarization travels the length of the neuron and causes neurotransmitters to be released into the synaptic junction.

- These neurotransmitters bind and activate receptors on the post-synaptic neuron thereby transmitting the signal to the target cell. Thus, a post-synaptic membrane belongs to the membrane receiving the signal, while a pre-synaptic membrane is the source of the neurotransmitter. In a neuromuscular junction, a synapse is formed between a motor neuron and muscle fibres.
- In vertebrates, acetylcholine released from the motor neuron acts as a neurotransmitter which depolarizes the muscle fibre and causes muscle contraction. A neuron's ability to receive and integrate simultaneous signals from the environment and other neurons allows for complex animal behaviour.

PLANT CELL-CELL INTERACTIONS

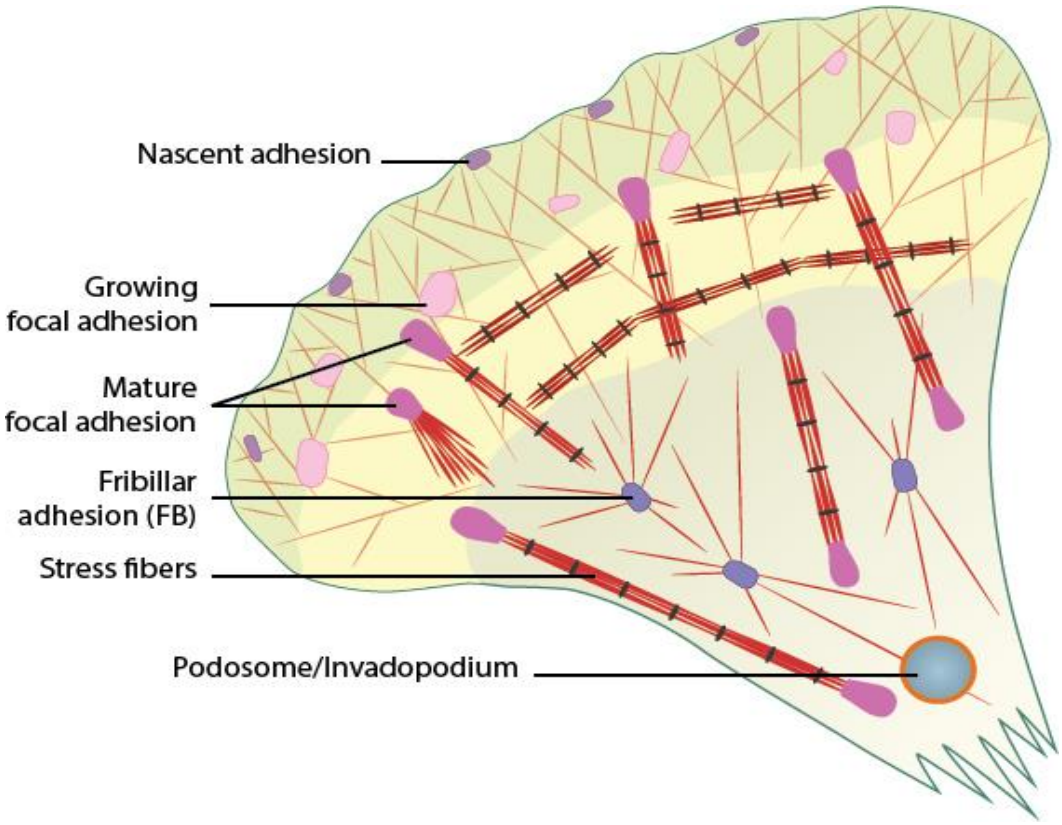
- Plant cells are surrounded by cell walls which are barriers for cell-cell communication. This barrier is overcome by specialized junctions called plasmodesmata.
- They are similar to gap junctions, connecting the cytosol of adjacent cells. Small molecules (<1000 Da), such as ions, amino acids, and sugars, can diffuse freely through plasmodesmata.
- These small molecules include signalling molecule and transcription factors. The size of the channel is also regulated to allow molecules up to 10,000 Da in size. The permeability of these channels is dependent on many factors, including Ca2+ concentration.
- An increase in cytosolic Ca2+ concentration will reversibly limit passage through the plasmodesmata. Unlike gap junctions, the cell membranes of adjacent cells merge to form a continuous channel called an annulus.
- Additionally, within the channel, there is an extension of the endoplasmic reticulum, called a desmotubule, which spans between the cells. The cell-cell interactions facilitated by plasmodesmata play an important role in development of plant cells and tissues and defence against viral infection.

CELL- MATRIX INTERACTION

THE EXTRACELLULAR MATRIX AND THE BASAL LAMINA

- Cell-matrix adhesion is the interaction of a cell with the extracellular matrix, mediated by multi-protein adhesion structures such as focal adhesions, fibrillar adhesions and podosomes.
- The ECM is a network of extracellular molecules which are secreted locally to ensure cell and tissue cohesion. The ECM also serves as a reservoir for extracellular signalling molecules that control cell growth, migration, and differentiation.
- The major classes of ECM molecules are proteoglycans, collagens and multi-adhesive matrix proteins (e.g., **laminin**, **fibronectin**). In mammals, the ECM is commonly known as "connective tissue". ECM components are linked to each other through diverse protein and carbohydrate-binding domains. For stability in tissues, cells are linked to the ECM through cell adhesion receptors (e.g., **integrins**).
- A specialized form of extracellular matrix that underlies the basal side of polarized epithelial cell sheets to separate them from the underlying connective tissue is the basal lamina.

- Basal laminae (plural) also surround individual muscle cells, fat cells, and cells lining peripheral nerve cell axons (i.e., Schwann cells). The basal lamina is thin and flexible, and is composed of closely packed matrix molecules that lack significant volume.
- The basal lamina components are synthesized and deposited by the cells on either side: the epithelial cells and the cells within the underlying bed of connective tissue (i.e., fibroblasts).
- The basal laminae form a cohesive network and mechanical connection between cells and their external environment. Force-driven signals originating between the basal lamina components (i.e., fibronectin) and linked cell adhesion receptors (i.e., integrins) is communicated to the interior of cells through a mechanotransduction system to influence cell polarity, metabolism, fate, and migration.
- The key constituents found in the basal lamina are glycoproteins (i.e., laminin, collagen) and proteoglycans (i.e., **perlecan**), however, the precise composition varies from tissue to tissue and various other molecules (e.g. fibronectin) can also be found.
- **What are cell-matrix adhesions?**



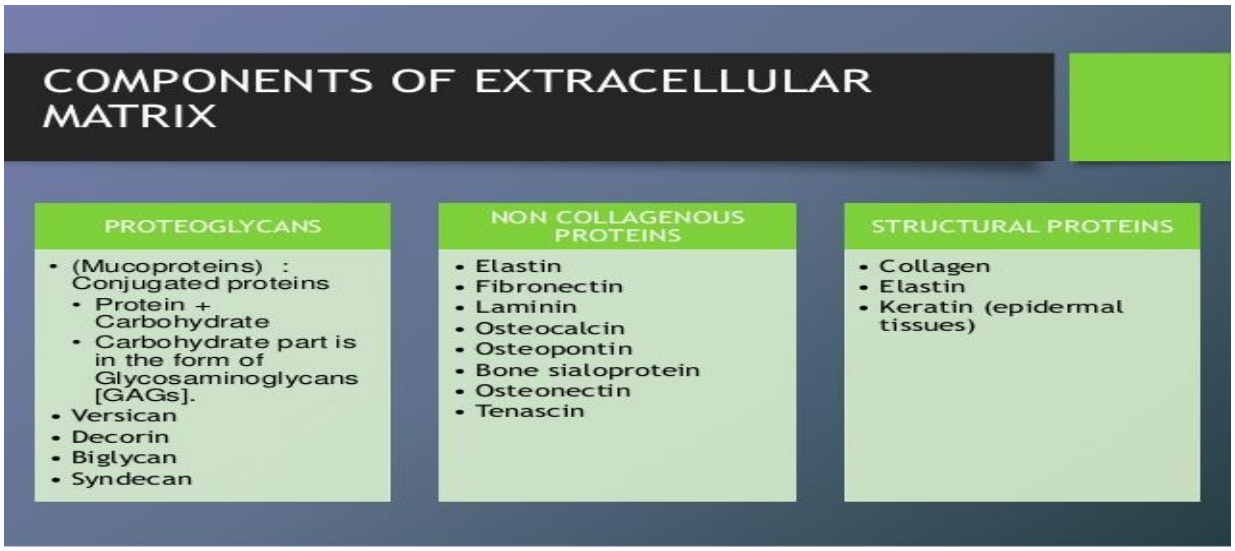
- Cell-matrix adhesion complexes include nascent adhesions, focal adhesions (growing and mature), fibrillar adhesions, stress fibres, and podosomes/invadopodia.
- Cell-matrix interactions are mediated by adhesion receptors and lead to the formation of multi-protein adhesion structures that interact with the actin cytoskeleton at the cell interior; collectively, they are called cell-matrix adhesion complexes (CMACs).
- These adhesions act as vital information processing centers that enable cells to sense numerous extracellular signals that convey information about the chemistry, geometry, and physical properties of the ECM (reviewed in).

- The substrate type or chemical composition (reviewed in), its rigidity , and the surface topography (reviewed in) influence force-induced events through CMACs, and mechanosensitive cells transmit this information through subsequent mechanotransduction pathways and signaling cascades to influence diverse processes such as the cell shape, polarity, fate, motility and deposition and/or restructuring of ECM components

COMPONENTS OF EXTRACELLULAR MATRIX

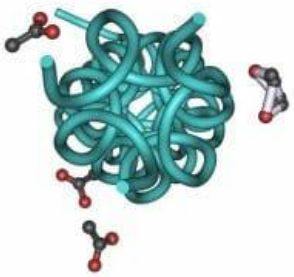
EXTRACELLULAR MATRIX DEFINITION

- The extracellular matrix can be thought of as a suspension of macromolecules that supports everything from local tissue growth to the maintenance of an entire organ.
- These molecules are all secretions made by neighbouring cells. Upon being secreted, the proteins will undergo scaffolding. Scaffolding, in turn, is a term used to describe the ephemeral structures that form between individual proteins to make more elaborate protein polymers.
- These rigid, albeit temporary protein structures will lend the matrix a viscous consistency. One can think of the extracellular matrix as essentially a cellular soup, or gel mixture of water, polysaccharides (or linked sugars), and fibrous protein.
- This leads us to another category of molecule found within the extracellular matrix called the proteoglycan. The proteoglycan is a hybrid cross of a protein and a sugar, with a protein core and several long chain sugar groups surrounding it.
- All of the molecular groups that make up these macromolecules will lend them special properties that will dictate the kind of hydrophobic or hydrophilic interactions they can participate in.
- Much like the ephemeral interactions they form in this aqueous solution, the actual structures of the proteins themselves are notably dynamic. The molecular components found within their structures are always changing.
- The remodelling they undergo is certainly aided by protease enzymes found in the matrix and can be modified by post-translational changes. The extracellular matrix has a functional value in buffering the effects of local stressors in the area. But we will discuss many more of the functions the matrix serves in detail below.



EXTRACELLULAR MATRIX COMPONENTS

- The extracellular matrix is mostly made up of a few key ingredients: water, fibrous proteins, and proteoglycans. The main fibrous proteins that build the extracellular matrix are collagens, elastin, and laminins. These are all relatively sturdy protein macromolecules.
- Their sturdiness lends the extracellular matrix its buffering and force-resisting properties that can withstand environmental pressures without collapsing.
- Collagen is actually a main structural component of not only the matrix, but also of multicellular animals. Collagen is the most abundant fibrous protein made by fibroblasts, making up roughly one third of the total protein mass in animals.
- In the matrix, collagen will give the cell tensile strength and facilitate cell-to-cell adhesion and migration. Elastin is another fibre that will lend tissues an ability to recoil and stretch without breaking. In fact, it is because elastin and collagen bind and physically crosslink that this stretching is limited to a certain degree by collagen.
- Fibronectin is first secreted by fibroblast cells in water soluble form, but this quickly changes once they assemble into an un-dissolvable meshwork. Fibronectin regulates division and specialization in many tissue types, but it also has a special embryonic role worth mentioning where it will aid in the positioning of cells within the matrix.
- Laminin is a particularly important protein. It is particularly good at assembling itself into sheet-like protein networks that will essentially be the ‘glue’ that associates dissimilar tissue types. It will be present at the junctions where connective tissue meet muscle, nerve, or epithelial lining tissue.



The image depicts a computerized illustration of the three-dimensional structure of collagen protein

Roles of fibrous protein:

- **Collagen** – stretch resistance and tensile strength (i.e. scar formation during wound healing)
- **Elastin** – stretch and resilience
- **Fibronectin** – cell migration and positioning within the ECM, and cell division and specialization in various tissues
- **Laminin** – sheet-like networks that will ‘glue’ together dissimilar types of tissue

- On the contrary to fibrous proteins that resist against stretching, proteoglycans will resist against compression. This refers to the forces pushing down on the tissue that would otherwise "squash" or collapse it. This ability stems from the glycosaminoglycan group in the proteoglycan. Glycosaminoglycan, or GAGs, are chains of sugar that will vary and thus lend the molecules different chemical properties.
- Moreover, GAGs are the most highly negatively charged molecule animal cells produce. This charge will attract GAGs to positively charged sodium ions. In living tissue, water follows the movement of sodium.
- This will bring us to a situation where water and GAGs will attract as well, which will lend water within the extracellular matrix a characteristic resistance to compression.

COLLAGEN AND NONCOLLAGEN COMPONENTS

- **Collagen** (/ˈkɒlədʒən/) is the main structural protein in the extracellular matrix found in the body's various connective tissues. As the main component of connective tissue, it is the most abundant protein in mammals, making up from 25% to 35% of the whole-body protein content.
- Collagen consists of amino acids bound together to form a triple helix of elongated fibril[2] known as a collagen helix. It is mostly found in connective tissue such as cartilage, bones, tendons, ligaments, and skin.
- Depending upon the degree of mineralization, collagen tissues may be rigid (bone) or compliant (tendon) or have a gradient from rigid to compliant (cartilage). Collagen is also abundant in corneas, blood vessels, the gut, intervertebral discs, and the dentin in teeth.
- In muscle tissue, it serves as a major component of the endomysium. Collagen constitutes one to two percent of muscle tissue and accounts for 6% of the weight of strong, tendinous muscles.
- The fibroblast is the most common cell that creates collagen. Gelatine, which is used in food and industry, is collagen that has been irreversibly hydrolysed.
- Collagen has many medical uses in treating complications of the bones and skin.
- The name *collagen* comes from the Greek κόλλα (*kólla*), meaning "glue", and suffix -γέν, -*gen*, denoting "producing".[6][7] This refers to the compound's early use in the process of creating glue from boiling the skin and tendons of horses and other animals.
- Over 90% of the collagen in the human body is type I collagen.
- However, as of 2011, 28 types of collagens have been identified, described, and divided into several groups according to the structure they form. All of the types contain at least one triple helix.

The number of types shows collagen's diverse functionality.

- Fibrillar (Type I, II, III, V, XI)
- Non-fibrillar
    - FACIT (Fibril Associated Collagens with Interrupted Triple Helices) (Type IX, XII, XIV, XIX, XXI)
    - Short chain (Type VIII, X)
    - Basement membrane (Type IV)
    - Multiplexin (Multiple Triple Helix domains with Interruptions) (Type XV, XVIII)

  - MACIT (Membrane Associated Collagens with Interrupted Triple Helices) (Type XIII, XVII)
  - Microfibril forming (Type VI)
  - Anchoring fibrils (Type VII)

- The five most common types are

  - Type I: skin, tendon, vasculature, organs, bone (main component of the organic part of bone)
  - Type II: cartilage (main collagenous component of cartilage)
  - Type III: reticulate (main component of reticular fibers), commonly found alongside type I
  - Type IV: forms basal lamina, the epithelium-secreted layer of the basement membrane
  - Type V: cell surfaces, hair, and placenta

NON-COLLAGEN COMPOUNDS

PROTEOGLYCANS

- Glycosaminoglycans (GAGs) are carbohydrate polymers and mostly attached to extracellular matrix proteins to form proteoglycans (hyaluronic acid is a notable exception; see below).
- Proteoglycans have a net negative charge that attracts positively charged sodium ions (Na^+), which attracts water molecules via osmosis, keeping the ECM and resident cells hydrated. Proteoglycans may also help to trap and store growth factors within the ECM.
- Described below are the different types of proteoglycans found within the extracellular matrix.

HEPARAN SULPHATE

- Heparan sulphate (HS) is a linear polysaccharide found in all animal tissues. It occurs as a proteoglycan (PG) in which two or three HS chains are attached in close proximity to cell surface or ECM proteins.
- It is in this form that HS binds to a variety of protein ligands and regulates a wide variety of biological activities, including developmental processes, angiogenesis, blood coagulation, and tumour metastasis.
- In the extracellular matrix, especially basement membranes, the multi-domain proteins perlecan, agrin, and collagen XVIII are the main proteins to which heparan sulphate is attached.

CHONDROITIN SULPHATE

- Chondroitin sulphates contribute to the tensile strength of cartilage, tendons, ligaments, and walls of the aorta. They have also been known to affect neuroplasticity.

KERATAN SULPHATE

- Keratan sulphates have a variable sulphate content and, unlike many other GAGs, do not contain uronic acid. They are present in the cornea, cartilage, bones, and the horns of animals.

HYALURONIC ACID

- Hyaluronic acid (or "hyaluronan") is a polysaccharide consisting of alternating residues of D-glucuronic acid and N-acetylglucosamine, and unlike other GAGs, is not found as a proteoglycan. Hyaluronic acid in the extracellular space confers upon tissues the ability to resist compression by providing a counteracting turgor (swelling) force by absorbing significant amounts of water.
- Hyaluronic acid is thus found in abundance in the ECM of load-bearing joints. It is also a chief component of the interstitial gel. Hyaluronic acid is found on the inner surface of the cell membrane and is translocated out of the cell during biosynthesis.
- Hyaluronic acid acts as an environmental cue that regulates cell behaviour during embryonic development, healing processes, inflammation, and tumour development. It interacts with a specific transmembrane receptor, CD44

ELASTIN

- Elastin, in contrast to collagens, give elasticity to tissues, allowing them to stretch when needed and then return to their original state. This is useful in blood vessels, the lungs, in skin, and the ligamentum nuchae, and these tissues contain high amounts of elastin.
- Elastin is synthesized by fibroblasts and smooth muscle cells. Elastin are highly insoluble, and tropoelastins are secreted inside a chaperone molecule, which releases the precursor molecule upon contact with a fibre of mature elastin.
- Tropoelastins are then deaminated to become incorporated into the elastin strand. Disorders such as cutis laxa and Williams syndrome are associated with deficient or absent elastin fibres in the ECM

TIGHT JUNCTIONS

- Tight junctions are multi-protein complexes that hold cells of a same tissue together and prevent movement of water and water-soluble molecules between cells.
- In epithelial cells, they function also to separate the extracellular fluid surrounding their apical and basolateral membranes.[1] These junctions exist as a continuous band located just below the apical surface between the membranes of neighbouring epithelial cells.
- The tight junctions on adjacent cells line up so as to produce a seal between different tissues and body cavities.
- For example, the apical surface of gastrointestinal epithelial cells serves as a selective permeable barrier that separates the external environment from the body.
- The permeability of these junctions is dependent on a variety of factors including protein makeup of that junction, tissue type and signaling from the cells.

- Tight junctions are made up of many different proteins. The four main transmembrane proteins are occludin, claudin, junctional adhesion molecules (JAMs) and tricellulins.
- The extracellular domains of these proteins form the tight junction barrier by making homophilic (between proteins of the same kind) and heterophilic interactions (between different types of proteins) with the protein domains on adjacent cells. Their cytoplasmic domains interact with the cell cytoskeleton to anchor them.

GAP JUNCTIONS

- Gap junctions are the main site of cell-cell signaling or communication that allow small molecules to diffuse between adjacent cells. In vertebrates, gap junctions are composed of transmembrane proteins called connexins.
- They form hexagonal pores or channels through which ions, sugars, and other small molecules can pass. Each pore is made of 12 connexin molecules; 6 form a hemichannel on one cell membrane and interact with a hemichannel on an adjacent cell membrane.
- The permeability of these junctions is regulated by many factors including pH and Ca^{2+} concentration.

DESMOSOME

- Of the three types of anchoring junctions, only two are involved in cell-cell interactions: adherens junctions and desmosomes. Both are found in many types of cells.
- Adjacent epithelial cells are connected by adherens junctions on their lateral membranes. They are located just below tight junctions. Their function is to give shape and tension to cells and tissues and they are also the site of cell-cell signaling.
- Adherens junctions are made of cell adhesion molecules from the cadherin family. There are over 100 types of cadherins, corresponding to the many different types of cells and tissues with varying anchoring needs. The most common are E-, N- and P-cadherins.
- In the adherens junctions of epithelial cells, E-cadherin is the most abundant.
- Desmosomes also provide strength and durability to cells and tissues and are located just below adherens junctions. They are sites of adhesion and do not encircle the cell.
- They are made of two specialized cadherins, desmoglein and desmocollin. These proteins have extracellular domains that interact with each other on adjacent cells.
- On the cytoplasmic side, plakins form plaques which anchor the desmosomes to intermediate filaments composed of keratin proteins. Desmosomes also play a role in cell-cell signaling.

HEMIDESMOSOMES

- **Hemidesmosomes** are very small stud-like structures found in keratinocytes of the epidermis of skin that attach to the extracellular matrix.
- They are similar in form to desmosomes when visualized by electron microscopy, however, desmosomes attach to adjacent cells. Hemidesmosomes are also comparable to focal adhesions, as they both attach cells to the extracellular matrix.

- Instead of desmogleins and desmocollins in the extracellular space, hemidesmosomes utilize integrins. Hemidesmosomes are found in epithelial cells connecting the basal epithelial cells to the lamina lucida, which is part of the basal lamina.
- Hemidesmosomes are also involved in signaling pathways, such as keratinocyte migration or carcinoma cell intrusion.
- Hemidesmosomes can be categorized into two types based on their protein constituents.
- Type 1 hemidesmosomes are found in stratified and pseudo-stratified epithelium. Type 1 hemidesmosomes have five main elements: integrin α6β4, plectin in its isoform 1a, i. e. P1a, tetraspanin protein CD151, BPAG1e, or bullous pemphigoid antigen isoform e, and BPAG2 (also known as BP180 or type 17 collagen).
- Type 1 hemidesmosomes are found in stratified and pseudostratified epithelial tissue. Type 2 hemidesmosomes contain integrin α6β4 and plectin without the BP antigens.
- Hemidesmosomes have two membrane-spanning components: Integrin α6β4 and Plectin 1a.
- Integrin α6β4 operates as a laminin-332 receptor. Integrin α6β4 is composed to two α and β subunit dimers. The larger β4 subunit has domains that bind to fibronectin III and calcium.
- The α6 subunit binds to extracellular BP180, CD151 and laminin-322. When integrin α6β4 binds to Plectin 1a and BPAG1, it associates with the keratin intermediate filaments in the cytoskeleton.
- Hemidesmosomes are linked to keratin by plectin isoform 1a from the plakin protein family.
- Plectin is a 500 kDa protein with a long, rod-like domain and a domain at the end that contains an intermediate filament binding site. BPAG2, or (bullous pemphigoid antigen 2), is a transmembrane protein that exists adjacent to integrins, BPAG2 has domains that bind to plectin, integrin β4 subunit in the cytoplasm and integrin α6 and laminin-332 in the extracellular space.
- CD151, a protein of the tetraspanin superfamily, resides on the cell surface of keratinocytes and vascular endothelium. CD151 aids in hemidesmosome formation. BPAG1e is an antigen with multiple isoforms that binds to integrin α6β4, BPAG2 and keratin 5 and 14.
- The main role of BPAG1e is for hemidesmosome stability.

FOCAL ADHESIONS

- Focal adhesions are integrin-containing, multi-protein structures that form mechanical links between intracellular actin bundles and the extracellular substrate in many cell types.
- Focal adhesions are large, dynamic protein complexes through which the cytoskeleton of a cell connects to the ECM. They are limited to clearly defined ranges of the cell, at which the plasma membrane closes to within 15 nm of the ECM substrate.
- Focal adhesions are in a state of constant flux: proteins associate and disassociate with it continually as signals are transmitted to other parts of the cell, relating to anything from cell motility to cell cycle. Focal adhesions can contain over 100 different proteins, which suggests a considerable functional diversity.
- More than anchoring the cell, they function as signal carriers (sensors), which inform the cell about the condition of the ECM and thus affect their behavior.

- In sessile cells, focal adhesions are quite stable under normal conditions, while in moving cells their stability is diminished: this is because in motile cells, focal adhesions are being constantly assembled and disassembled as the cell establishes new contacts at the leading edge, and breaks old contacts at the trailing edge of the cell.
- One example of their important role is in the immune system, in which white blood cells migrate along the connective endothelium following cellular signals to damaged biological tissue.

PLASMODESMATA

- **Plasmodesmata** (singular: **plasmodesma**) are microscopic channels which traverse the cell walls of plant cells and some algal cells, enabling transport and communication between them.
- Plasmodesmata evolved independently in several lineages, and species that have these structures include members of the Charophyceae, Charales, Coleochaetales and Phaeophyceae (which are all algae), as well as all embryophytes, better known as land plants.
- Unlike animal cells, almost every plant cell is surrounded by a polysaccharide cell wall. Neighbouring plant cells are therefore separated by a pair of cell walls and the intervening middle lamella, forming an extracellular domain known as the apoplast.
- Although cell walls are permeable to small soluble proteins and other solutes, plasmodesmata enable direct, regulated, symplastic transport of substances between cells. There are two forms of plasmodesmata: primary plasmodesmata, which are formed during cell division, and secondary plasmodesmata, which can form between mature cells.
- Similar structures, called gap junctions and membrane nanotubes, interconnect animal cells and stromules form between plastids in plant cells.

PLASMODESMATAL PLASMA MEMBRANE

- A typical plant cell may have between 10^3 and 10^5 plasmodesmata connecting it with adjacent cells equating to between 1 and 10 per μm^2 Plasmodesmata are approximately 50–60 nm in diameter at the midpoint and are constructed of three main layers, the plasma membrane, the *cytoplasmic sleeve*, and the *desmotubule*. They can transverse cell walls that are up to 90 nm thick.
- The plasma membrane portion of the plasmodesma is a continuous extension of the cell membrane or plasmalemma and has a similar phospholipid bilayer structure.
- The cytoplasmic sleeve is a fluid-filled space enclosed by the plasmalemma and is a continuous extension of the cytosol.
- Trafficking of molecules and ions through plasmodesmata occurs through this space. Smaller molecules (e.g. sugars and amino acids) and ions can easily pass through plasmodesmata by diffusion without the need for additional chemical energy.
- Larger molecules, including proteins (for example green fluorescent protein) and RNA, can also pass through the cytoplasmic sleeve diffusively.

- Plasmodesmatal transport of some larger molecules is facilitated by mechanisms that are currently unknown. One mechanism of regulation of the permeability of plasmodesmata is the accumulation of the polysaccharide callose around the neck region to form a collar, thereby reducing the diameter of the pore available for transport of substances.
- Through dilation, active gating or structural remodelling the permeability of the plasmodesmata is increased. This increase in plasmodesmata pore permeability allows for larger molecules, or macromolecules, such as signaling molecules, transcription factors and RNA-protein complexes to be transported to various cellular compartments.

DESMOTUBULE

- The **desmotubule** is a tube of appressed (flattened) endoplasmic reticulum that runs between two adjacent cells.
- Some molecules are known to be transported through this channel, but it is not thought to be the main route for plasmodesmatal transport.
- Around the desmotubule and the plasma membrane areas of an electron dense material have been seen, often joined together by spoke-like structures that seem to split the plasmodesma into smaller channels. These structures may be composed of myosin and actin, which are part of the cell's cytoskeleton.
- If this is the case these proteins could be used in the selective transport of large molecules between the two cells.

MYOSIN

- High amounts of myosin proteins are found at the sites of plasmodesmata. These proteins are involved in directing viral cargoes to plasmodesmata.
- When mutant forms of myosin were tested in tobacco plants, viral protein targeting to plasmodesmata was negatively affected. Permanent binding of myosin to actin, which was induced by a drug, caused a decrease in cell to cell movement. Viruses are also able to selectively bind to myosin proteins.

MICROTUBULES

- Microtubules are also are also an important role in cell to cell transport of viral RNA.
- Viruses use many different methods of transporting themselves from cell to cell, and one of those methods associating the N-terminal domain of its RNA to localize to plasmodesmata through microtubules.
- Tobacco plants injected with tobacco movement viruses that were kept in high temperatures there was a strong correlation between TMV movement proteins that were attached to GFP with microtubules.
- This led to an increase in the spread of viral RNA through the tobacco

CELL WALL

- A cell wall is an outer layer surrounding certain cells that is outside of the cell membrane. All cells have cell membranes, but generally only plants, fungi, algae, most bacteria, and archaea have cells with cell walls.
- The cell wall provides strength and structural support to the cell, and can control to some extent what types and concentrations of molecules enter and leave the cell. The materials that make up the cell wall differ depending on the type of organism. The cell wall has evolved many different times among different groups of organisms.
- Cell Wall Functions
- The cell wall has a few different functions. It is flexible, but provides strength to the cell, which helps protect the cell against physical damage.
- It also gives the cell its shape and allows the organism to maintain a certain shape overall.
- The cell wall can also provide protection from pathogens such as bacteria that are trying to invade the cell.
- The structure of the cell wall allows many small molecules to pass through it, but not larger molecules that could harm the cell.

ROLE OF CELL INTERACTION IN DEVELOPMENT

- **Cell adhesion** is the process by which cells interact and attach to neighbouring cells through specialised molecules of the cell surface. This process can occur either through direct contact between cell surfaces such as cell junctions or indirect interaction, where cells attach to surrounding extracellular matrix, a gel-like structure containing molecules released by cells into spaces between them.
- Cells adhesion occurs from the interactions between cell-adhesion molecules (CAMs), transmembrane proteins located on the cell surface.
- Cell adhesion links cells in different ways and can be involved in signal transduction for cells to detect and respond to changes in the surroundings.
- Other cellular processes regulated by cell adhesion include cell migration and tissue development in multicellular organisms.
- Alterations in cell adhesion can disrupt important cellular processes and lead to a variety of diseases, including cancer and arthritis.
- Cell adhesion is also essential for infectious organisms, such as bacteria or viruses, to cause diseases

EUKARYOTES

- Plants cells adhere closely to each other and are connected through plasmodesmata, channels that cross the plant cell walls and connect cytoplasms of adjacent plant cells.
- Molecules that are either nutrients or signals required for growth are transported, either passively or selectively, between plant cells through plasmodesmata.
- Protozoans express multiple adhesion molecules with different specificities that bind to carbohydrates located on surfaces of their host cells.

- cell–cell adhesion is key for pathogenic protozoans to attach en enter their host cells. An example of a pathogenic protozoan is the malarial parasite (*Plasmodium falciparum*), which uses one adhesion molecule called the circumsporozoite protein to bind to liver cells, and another adhesion molecule called the merozoite surface protein to bind red blood cells.
- Pathogenic fungi use adhesion molecules present on its cell wall to attach, either through protein-protein or protein-carbohydrate interactions, to host cells[31] or fibronectins in the extracellular matrix.

PROKARYOTES

- Prokaryotes have adhesion molecules on their cell surface termed bacterial adhesins, apart from using its pili (fimbriae) and flagella for cell adhesion.
- Adhesins can recognise a variety of ligands present on the host cell surfaces and also components in the extracellular matrix.
- These molecules also control host specificity and regulate tropism (tissue- or cell-specific interactions) through their interaction with their ligands.