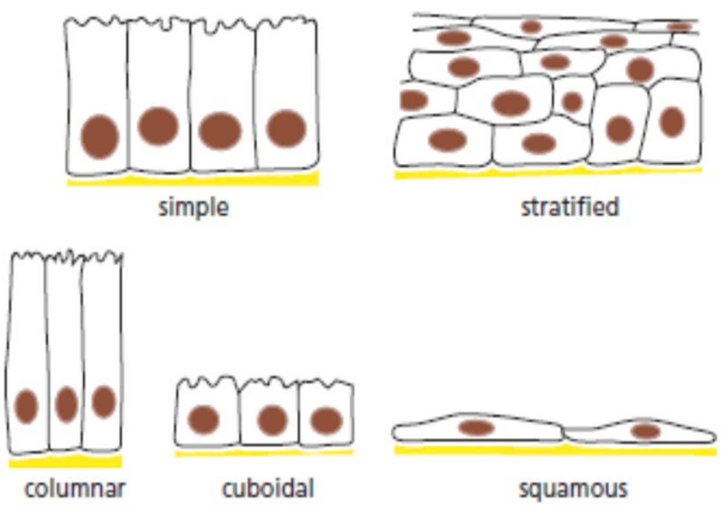
Epithelial Sheets and Cell Junctions

TYPES OF EPITHELIA



Functions of Epithelia

1. Epithelia cover the external surface of the body and line all its internal cavities.
2. Cells joined together into an epithelial sheet create a barrier, which has the same significance for the multicellular organism that the plasma membrane has for a single cell. It keeps some molecules in, and others out; it takes up nutrients and exports wastes.
3. It contains receptors for environmental signals.
4. it protects the interior of the organism from invading microorganisms and fluid loss.
5. Some secrete specialized products such as hormones, milk, or tears.

Epithelial Sheets – its anatomy

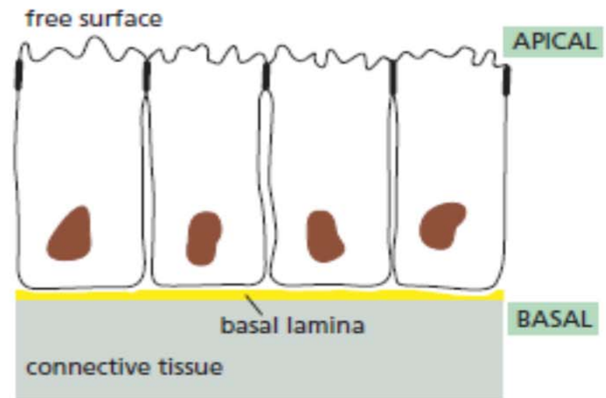
1. An epithelial sheet has two faces:

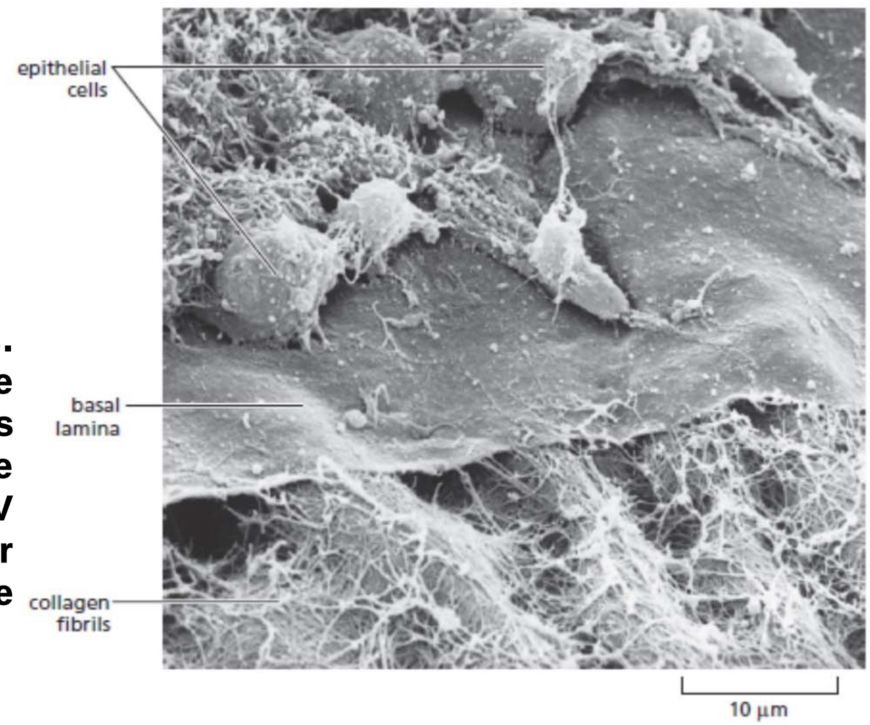
the **apical surface** is free and exposed to the air or to a watery fluid;

the **basal surface** is attached to a sheet of connective tissue called the **basal lamina**.

2. The basal lamina consists of a thin, tough sheet extracellular matrix, composed mainly of a specialized type collagen (**type IV collagen**) and a protein called **laminin**.

3. Laminin provides adhesive sites for integrin molecules in tl basal plasma membranes of epithelial cells, and it thus serves linking role like that of fibronectin in other connective tissues.

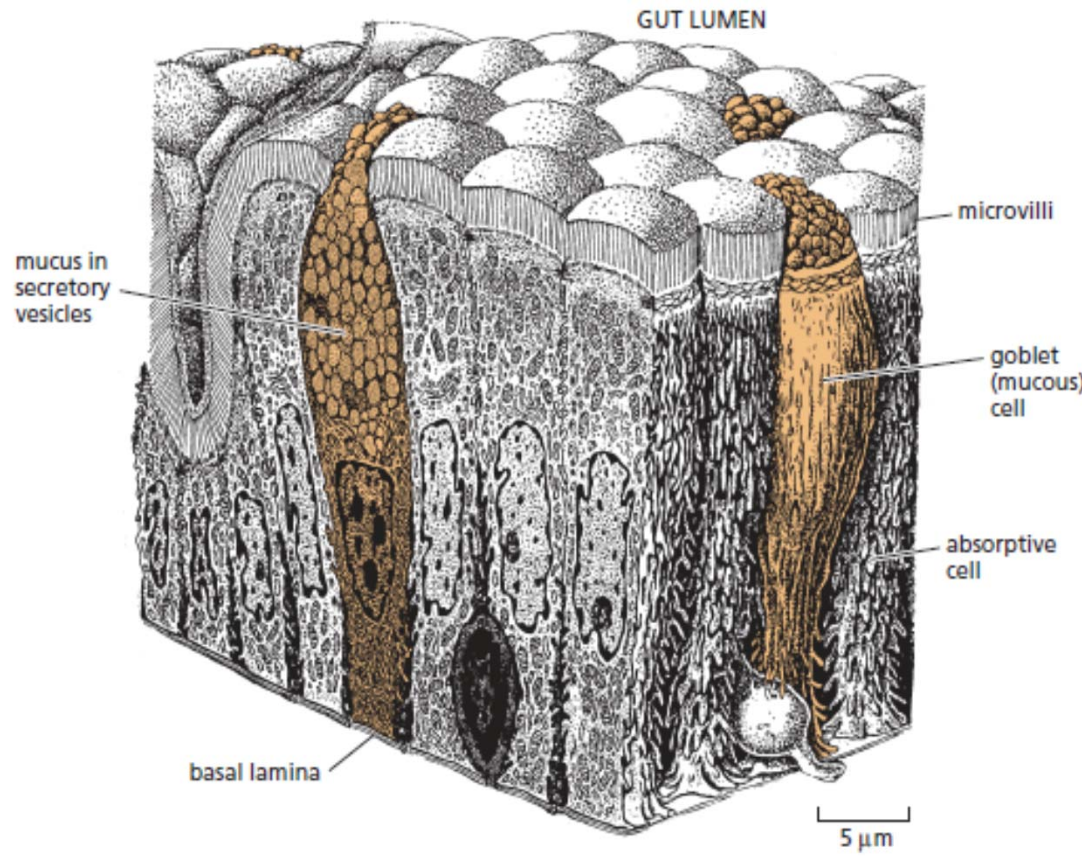




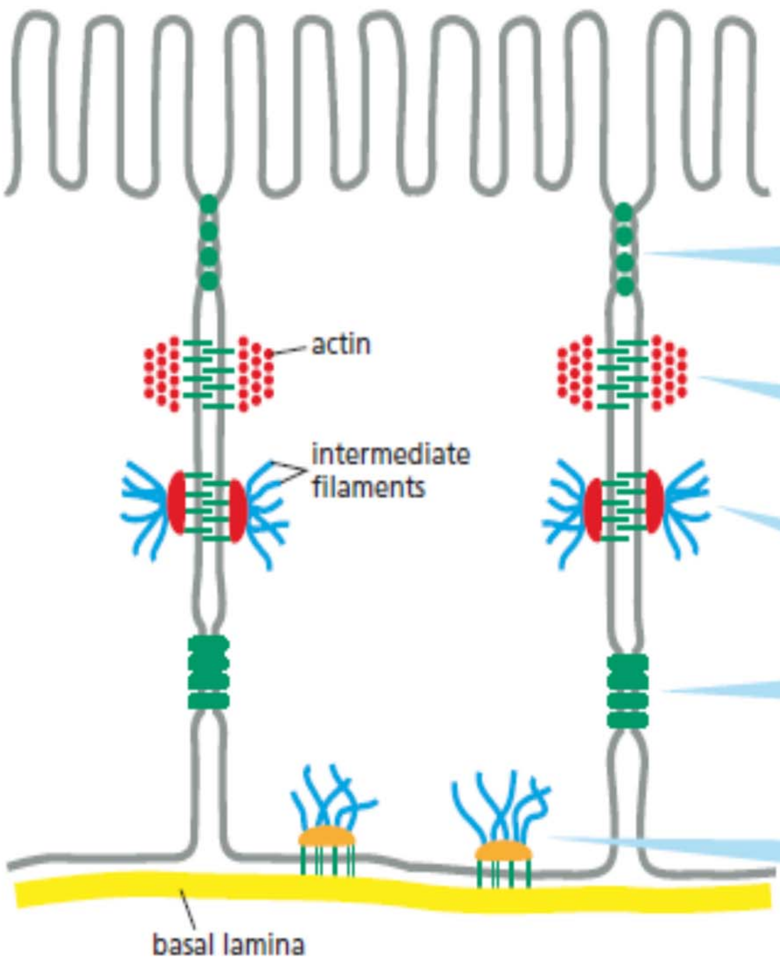
The basal lamina supports a sheet of epithelial cells. Scanning electron micrograph of a basal lamina in the cornea of a chick embryo. Some of the epithelial cells have been removed to expose the upper surface of the mat-like basal lamina, which is woven from type IV collagen and laminin proteins. A network of other collagen fibrils in the underlying connective tissue interacts with the lower face of the lamina.

Functional Polarity of Epithelial Sheets

Functionally polarized GUT LUMEN cell types line the intestine. Absorptive cells, which take up nutrients from the intestine, are mingled in the gut epithelium with goblet cells (brown), which secrete mucus into the gut lumen. The absorptive cells are often called brush-border cells, because of the brush-like mass of microvilli on their apical surface; the microvilli serve to increase the area of apical plasma membrane for the transport of small molecules into the cell. The goblet cells owe their gobletlike shape to the mass of secretory vesicles that distends the cytoplasm in their apical region.



Types of cell junctions found in animal epithelia



name	function
tight junction	seals neighboring cells together in an epithelial sheet to prevent leakage of extracellular molecules between them; helps polarize cells
adherens junction	joins an actin bundle in one cell to a similar bundle in a neighboring cell
desmosome	joins the intermediate filaments in one cell to those in a neighbor
gap junction	forms channels that allow small, intracellular, water-soluble molecules, including inorganic ions and metabolites, to pass from cell to cell
hemidesmosome	anchors intermediate filaments in a cell to the basal lamina

Tight Junctions

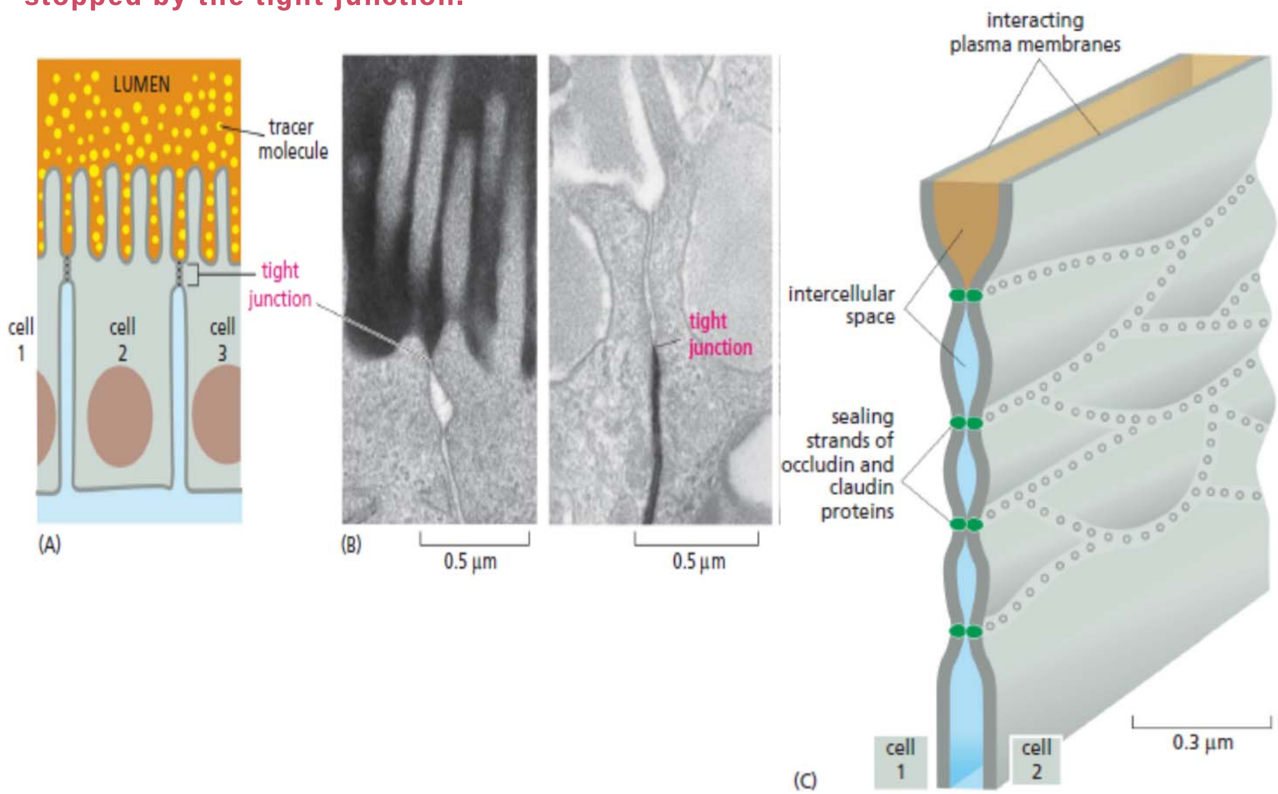
- The sealing function is served (in vertebrates) by tight junctions. **These junctions seal neighboring cells together so that water-soluble molecules cannot easily leak between them.**
- The tight junction is formed from proteins called **claudins** and **occludins,** which are arranged in strands along the lines of the junction to create the seal.

Functions:

- Without tight junctions to prevent leakage, the pumping activities of absorptive cells such as those in the gut would be futile, and the composition of the extracellular fluid would become the same on both sides of the epithelium.
- Tight junctions also play a key part in maintaining the polarity of the individual epithelial cells in two ways.

1. The tight junctions around the apical region of each cell prevents diffusion of proteins within the plasma membrane and so keeps the apical domain of the plasma membrane different from the basal (or basolateral) domain.

2. In many epithelia, the tight junctions are sites of assembly for the complexes of intracellular proteins that govern the apico-basal polarity of the cell interior.



Tight junctions allow epithelial cell sheets to serve as barriers to solute diffusion. (A) Schematic drawing showing how a small, extracellular tracer molecule added on one side of an epithelial cell sheet cannot traverse the tight junctions that seal adjacent cells together. (B) Electron micrographs of cells in an epithelium where a small, extracellular tracer molecule (dark stain) has been added to either the apical side (on the left) or the basolateral side (on the right); in both cases the tracer is stopped by the tight junction.

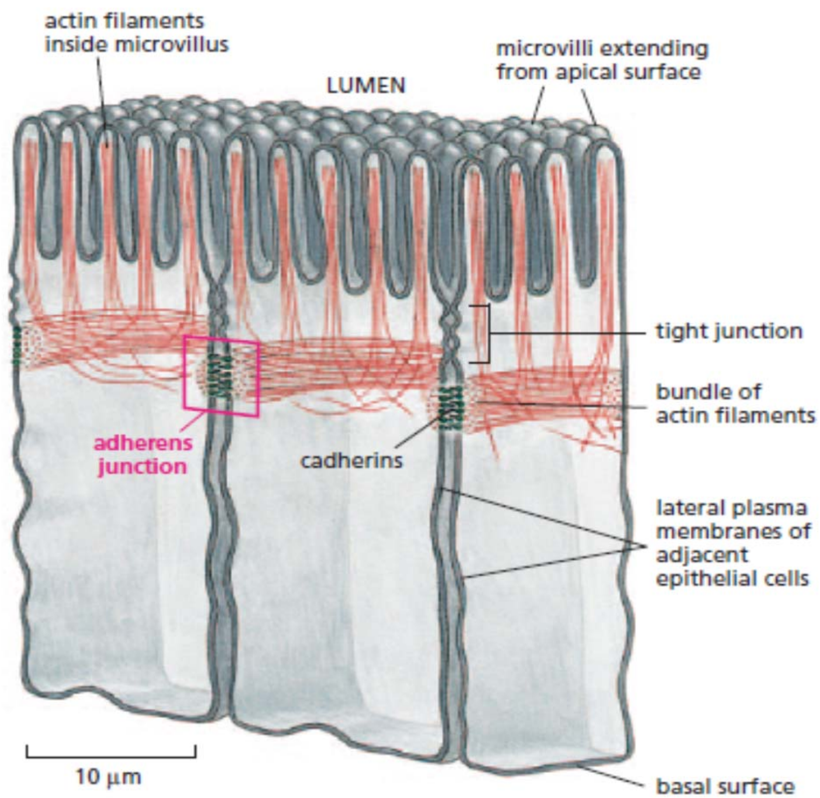
(C) A model of the structure of a tight junction, showing how the cells are sealed together by branching strands of transmembrane proteins, called claudins and occludins (green), in the plasma membranes of the interacting cells. Each type of protein binds to the same type in the apposed membrane.

Adherens Junction

1. Built around transmembrane proteins that belong to the **cadherin** family: a cadherin molecule in the plasma membrane of one cell binds directly to an identical cadherin molecule in the plasma membrane of its neighbor. Such binding of like-to-like is called **homophilic binding**.

2. Inside the cell, they are attached, via linker proteins, to cytoskeletal filaments—either actin filaments or keratin intermediate filaments. As cells touch one another, their cadherins become concentrated at the point of attachment.

3. Cadherin binding also **requires** that **Ca2+** be present in the extracellular medium—hence the name.



Adherens junctions form adhesion belts around epithelial cells in the small intestine. A contractile bundle of actin filaments runs along the cytoplasmic surface of the plasma membrane near the apex of each cell. These bundles are linked to those in adjacent cells via transmembrane cadherin molecules

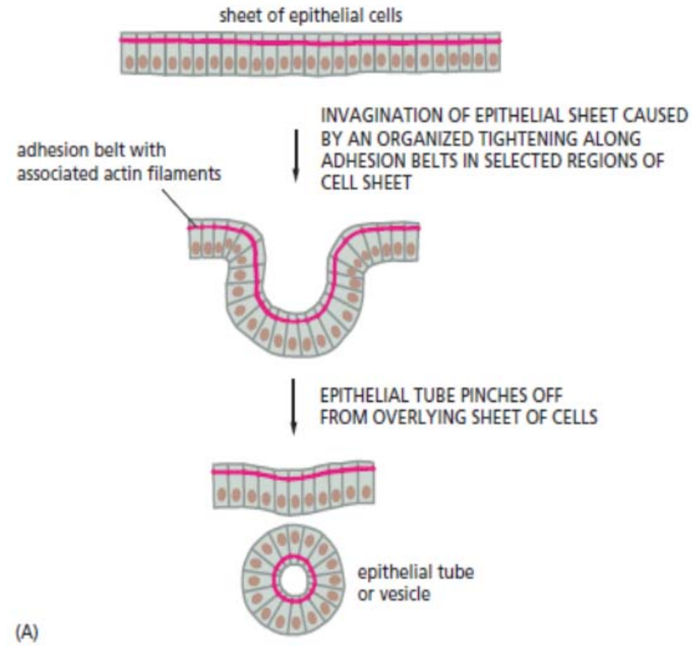
Adherens Junction- Functions

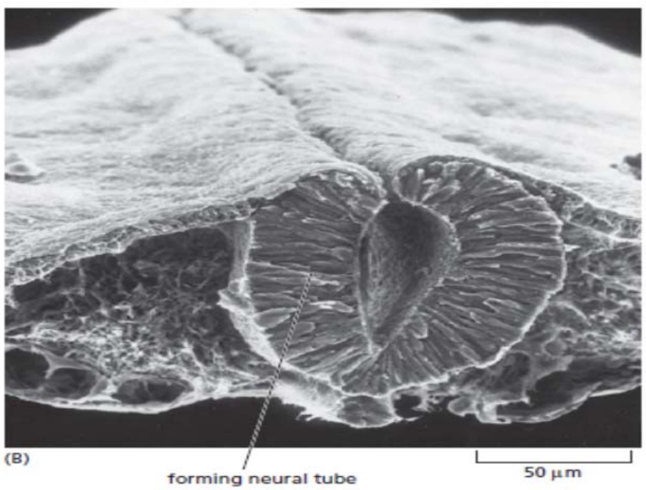
Epithelial sheets can bend to form a tube or a vesicle during animal fetal development.

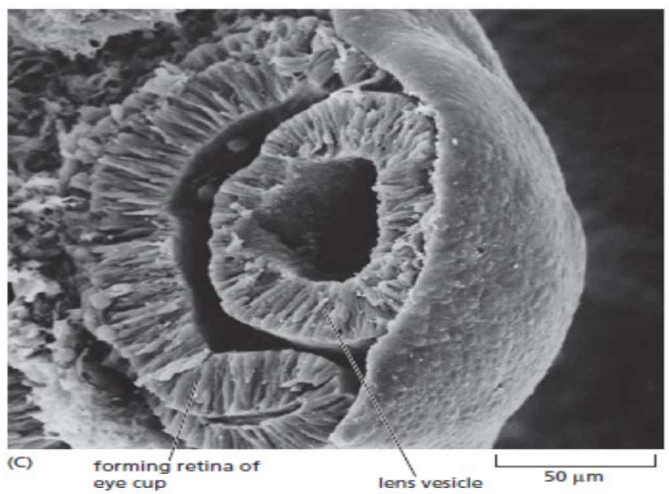
Contraction of apical bundles of actin filaments linked from cell to cell via adherens junctions causes the epithelial cells to narrow at their apex. Depending on whether the contraction of the epithelial sheet is oriented along one axis, or is equal in all directions, the epithelium will either roll up into a tube or invaginate to form a vesicle.

(A) Diagram showing how an apical contraction along one axis of an epithelial sheet can cause the sheet to form a tube.

(B) Scanning electron micrograph of a cross-section through the trunk of a two-day chick embryo, showing the formation of the neural tube



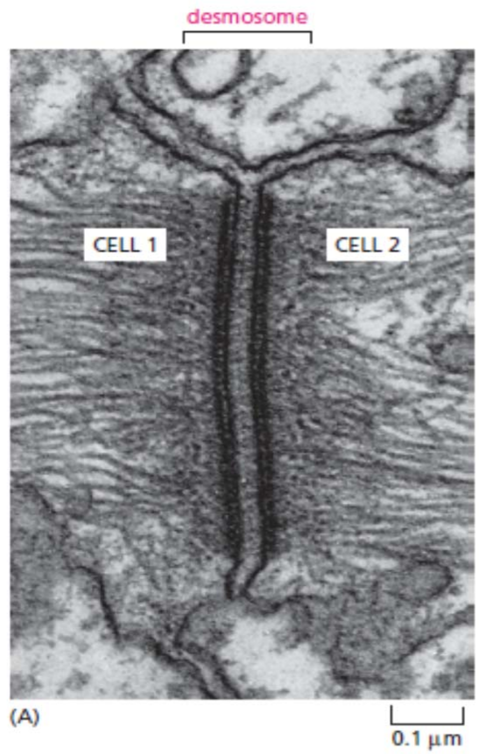




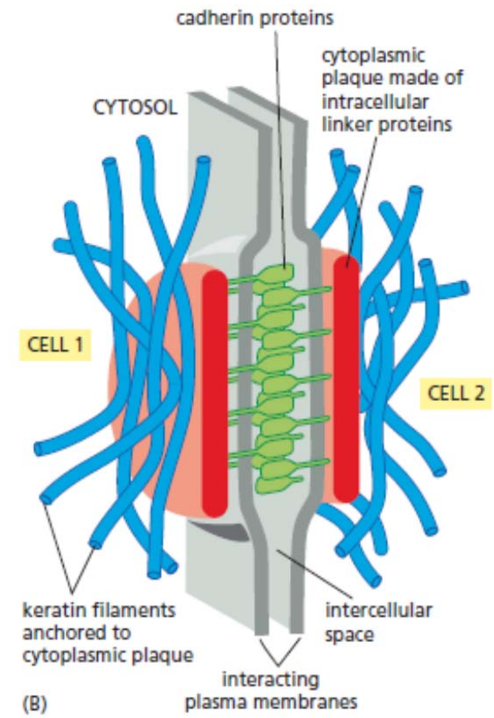
(C) Scanning electron micrograph of a chick embryo showing the formation of the eye cup and lens. A patch of surface epithelium overlying the forming eye cup has become concave and has pinched off as a separate vesicle—the lens vesicle—within the eye cup. This process is driven by an apical narrowing of epithelial cells in all directions.

Desmosomes

- A different set of cadherin molecules connects to keratin filaments— the intermediate filaments found specifically in epithelial cells.
- Bundles of ropelike keratin filaments crisscross the cytoplasm and are “spot-welded” via desmosome junctions to the bundles of keratin filaments in adjacent cells. This arrangement confers great tensile strength on the epithelial sheet and is characteristic of tough, exposed epithelia such as the epidermis of the skin.
- **Desmosomes link the keratin intermediate filaments of one epithelial cell to those of another.**



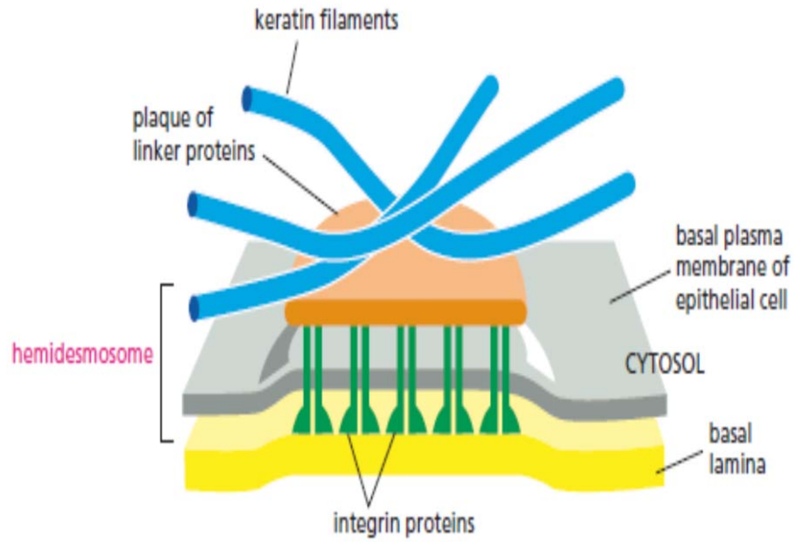
(A) An electron micrograph of a desmosome joining two cells in the epidermis of newt skin, showing the attachment of keratin filaments.



(B) Schematic drawing of a desmosome. On the cytoplasmic surface of each interacting plasma membrane is a dense plaque composed of a mixture of intracellular linker proteins. A bundle of keratin filaments is attached to the surface of each plaque. The cytoplasmic tails of transmembrane cadherin proteins bind to the outer face of each plaque; their extracellular domains interact to hold the cells together

Hemidesmosomes

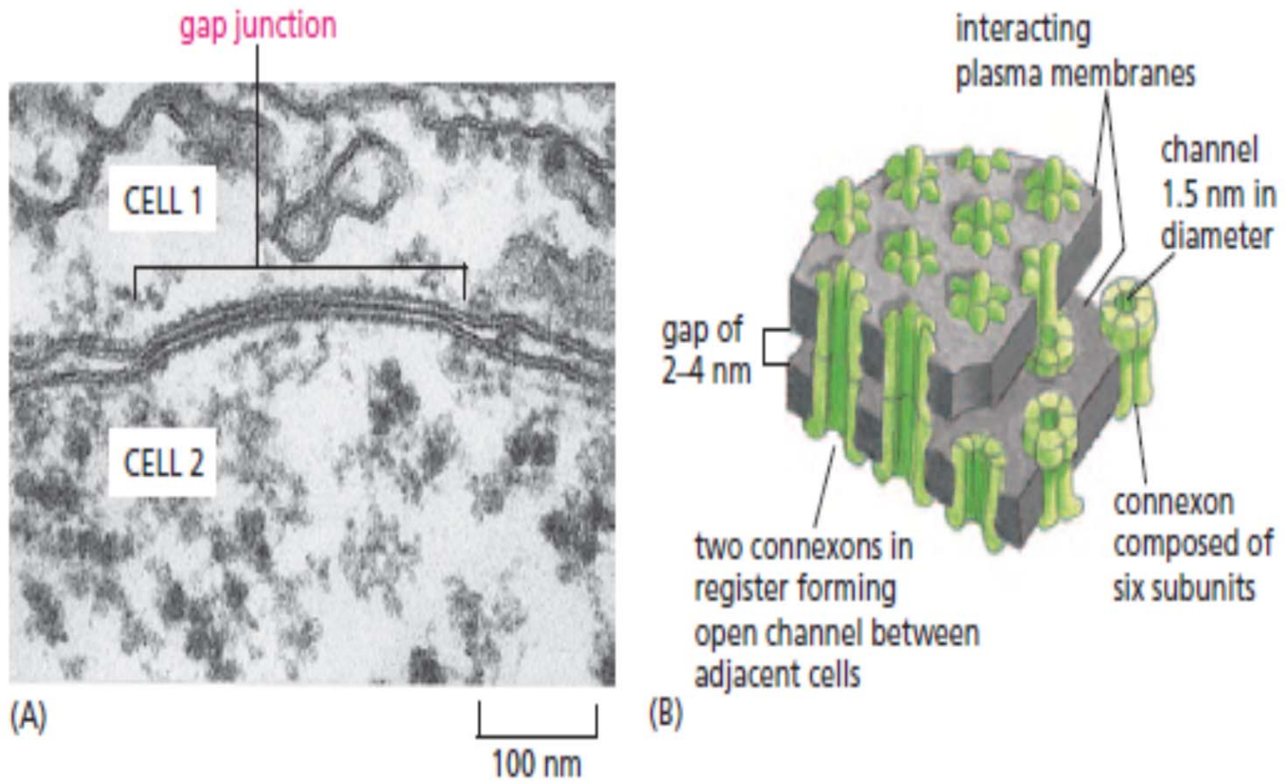
- It is not enough for epidermal cells to be firmly attached to one another: they must also be anchored to the underlying connective tissue.
- The anchorage is mediated by integrins in the cells' basal plasma membranes.
- The extracellular domains of these integrins bind to laminin in the basal lamina.
- Inside the cell, the integrin tails are linked to keratin filaments, creating a structure that looks superficially like half a desmosome. These attachments of epithelial cells to basal lamina beneath them are therefore called hemidesmosomes.



Hemidesmosomes anchor the keratin filaments in an epithelial cell to the basal lamina. The linkage is mediated by transmembrane integrins

Gap Junctions

- Found in virtually all epithelia and in many other types of animal tissues.
- In the electron microscope, this gap junction appears as a region where the membranes of two cells lie close together and exactly parallel, with a very narrow gap of 2–4 nm between them.
- The gap, however, is not entirely empty; it is spanned by the protruding ends of many identical, transmembrane protein complexes that lie in the plasma membranes of the two apposed cells.
- These complexes, called connexons, are aligned end-to-end to form narrow, water-filled channels across the two plasma membranes .



Gap junctions provide neighboring cells with a direct channel of communication. (A) Thin-section electron micrograph of a gap junction between two cells in culture. (B) A model of a gap junction. The drawing shows the interacting plasma membranes of two adjacent cells. The apposed membranes are penetrated by protein assemblies called connexons (green), each of which is formed from six identical protein subunits. Two connexons join across the intercellular gap to form an aqueous channel connecting the cytosols of the two cells.

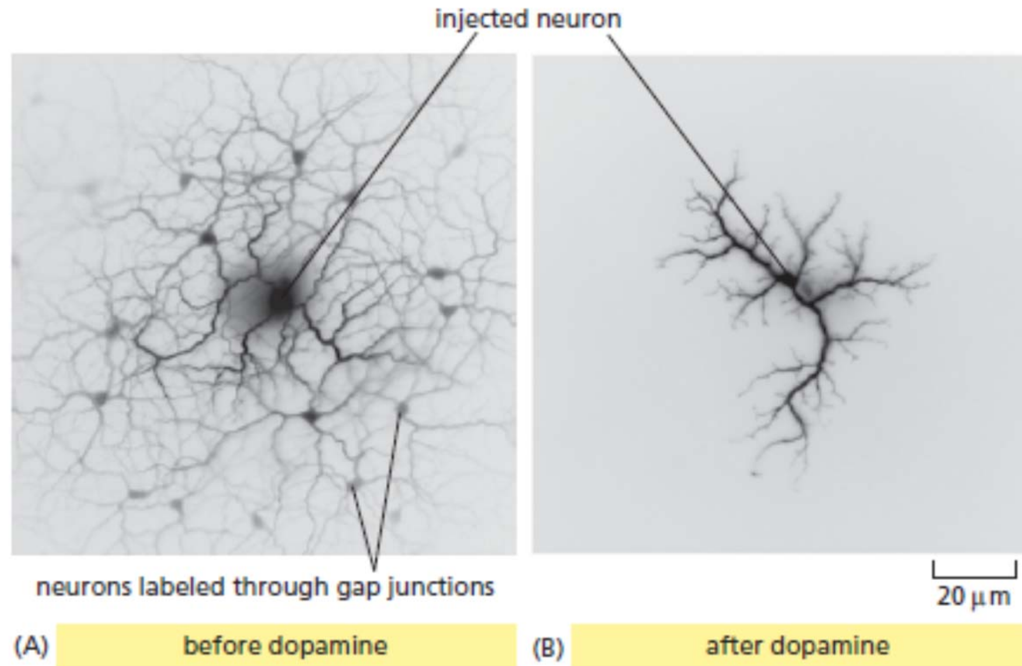
Gap Junctions- Functions

1. The channels allow inorganic ions and small, water-soluble molecules (up to a molecular mass of about 1000 daltons) to move directly from the cytosol of one cell to the cytosol of the other. This creates an electrical and a metabolic coupling between the cells.

Gap junctions between cardiac muscle cells, for example, provide the electrical coupling that allows electrical waves of excitation to spread synchronously through the heart, triggering the coordinated contraction of the cells that produces each heart beat.

2. Gap junctions in many tissues can be opened or closed in response to extracellular or intracellular signals.

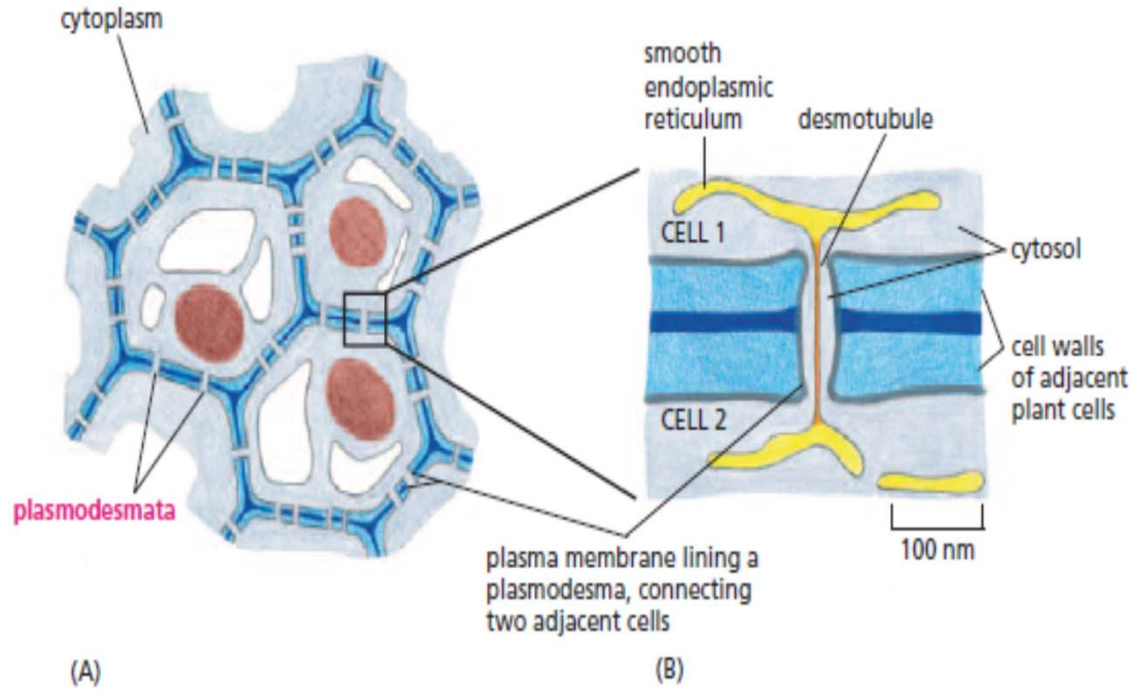
The neurotransmitter dopamine, for example, reduces gap-junction communication within a class of neurons in the retina in response to an increase in light intensity (Figure 20–30). This reduction in gap-junction permeability alters the pattern of electrical signaling and helps the retina switch from using rod photoreceptors, which are good detectors of low light, to cone photoreceptors, which detect color and fine detail in bright light.



Extracellular signals can regulate the permeability of gap junctions. (A) A neuron in a rabbit retina (center) was injected with a dye that passes readily through gap junctions. The dye diffuses rapidly from the injected cell to label the surrounding neurons, which are connected by gap junctions. (B) Treatment of the retina with the neurotransmitter dopamine prior to dye injection decreases the permeability of the gap junctions and hampers the spread of the dye.

Plasmodesmata

1. Plant tissues lack all the types of cell junctions found in animals. Their cells are held together by their cell walls.
2. However, they have a functional counterpart of the gap junction.
3. The cytoplasms of adjacent plant cells are connected via minute communicating channels called plasmodesmata, which span the intervening cell walls.
4. In contrast to gap-junction channels, plasmodesmata are cytoplasmic channels lined with plasma membrane.
5. Thus in plants, the cytoplasm is, in principle, continuous from one cell to the next.



Functions:

Inorganic small molecules, and even macromolecules—including some proteins and regulatory RNAs—can pass through plasmodesmata. The controlled traffic of transcription regulators and regulatory RNAs from one cell to another is important in plant development.

Plant cells are connected via plasmodesmata. (A) The cytoplasmic channels of plasmodesmata pierce the plant cell wall and connect the interiors of all cells in a plant. (B) Each plasmodesma is lined with plasma membrane common to the two connected cells. It usually also contains a fine tubular structure, the desmotubule, derived from smooth endoplasmic reticulum.