Cell Biology

Unit 5 · Lesson 3 · Junctions and matrix

The notes for Lesson 3 of Unit 5: chapters 5.7 to 5.8 of the unit book, with their figures, worked examples, exam traps and quizzes, in one file. The full unit book, with every chapter, the exam question bank and the glossary, is linked at the end.

Lesson 3 of 3 | 2 chapters | Chapters 5.7 to 5.8

About these notes

These are the notes for **Lesson 3 · Junctions and matrix** of the University free n easy video lessons on Cell Biology Unit 5, Cell Signaling and Cell Communication. They are chapters 5.7 to 5.8 of the unit book, unchanged, so a page here is the same page in the full book.

5.7 Cell junctions and cell adhesion

Cells in a tissue are not loose bags. They are bolted to each other and to the matrix below them by specialised contact points called **cell junctions**, built from **cell adhesion molecules** (CAMs) in the membrane and anchored to the cytoskeleton inside. Junctions do four jobs: seal the gaps between cells (tight junctions), hold cells together against pulling forces (adherens junctions and desmosomes), fix cells to the matrix (hemidesmosomes and focal adhesions), and let small molecules pass directly from one cell to the next (gap junctions). The skin, the gut lining and the heart all depend on them.

You need: actin filaments and intermediate filaments from Unit 3, *Cytoskeleton: microtubules, actin and intermediate filaments*.

The adhesion molecule families

1. **Cadherins**: cell–cell adhesion that needs Ca^{2+} (the name comes from "calcium-dependent adhesion"). A cadherin usually binds the same cadherin on the next cell (homophilic binding). E-cadherin holds epithelial cells together.
2. **Integrins**: two chains, α and β, that bind the extracellular matrix (fibronectin, laminin, collagen) outside and the cytoskeleton inside. They also send signals in both directions.

3. **Selectins**: bind sugar groups on other cells, also Ca^{2+}-dependent. They let white blood cells roll along the wall of a blood vessel during inflammation.
4. **Immunoglobulin-superfamily CAMs**: Ca^{2+}-independent, such as N-CAM in nerve tissue and ICAM-1 on blood-vessel lining, which binds the integrins of white blood cells.

The junctions of an epithelial cell, from top to bottom

1. **Tight junction** (occluding junction): a belt near the top where rows of the proteins **claudin** and **occludin** seal neighbouring membranes together. It stops fluid leaking between cells, so material must pass through the cells by transporters. It also acts as a fence that keeps apical and basolateral membrane proteins apart.
2. **Adherens junction**: just below, a belt of cadherins linked inside through **catenins** to a ring of actin filaments. It holds cells together and lets a sheet of cells fold, as in forming the neural tube.
3. **Desmosome**: a button-like spot weld. The desmosomal cadherins (desmogleins and desmocollins) link through plaque proteins such as plakoglobin and desmoplakin to **intermediate filaments** (keratin in skin). Desmosomes are common in tissues under mechanical stress, such as skin and heart muscle.
4. **Gap junction**: a cluster of channels joining the cytoplasm of two cells. Six **connexin** proteins form a **connexon** (hemichannel) in one membrane; two connexons dock to form a complete channel. Ions and small molecules such as sugars, amino acids, nucleotides, cAMP, IP_3 and Ca^{2+} pass, but proteins and nucleic acids do not. Textbooks usually quote a size cut-off near 1,000 daltons; measured limits vary with the connexin type and are often lower. Gap junctions let heart muscle cells contract together by passing ions.
5. **Hemidesmosome**: at the base, integrins (α6β4) bind laminin in the basal lamina and link inside to keratin filaments. **Focal adhesions** are the matching actin-linked integrin contacts of cells such as fibroblasts.

Plants have no gap junctions. Their cells connect through **plasmodesmata**, channels through the cell wall lined by the plasma membrane, which allow larger molecules than gap junctions, including some proteins and RNAs.

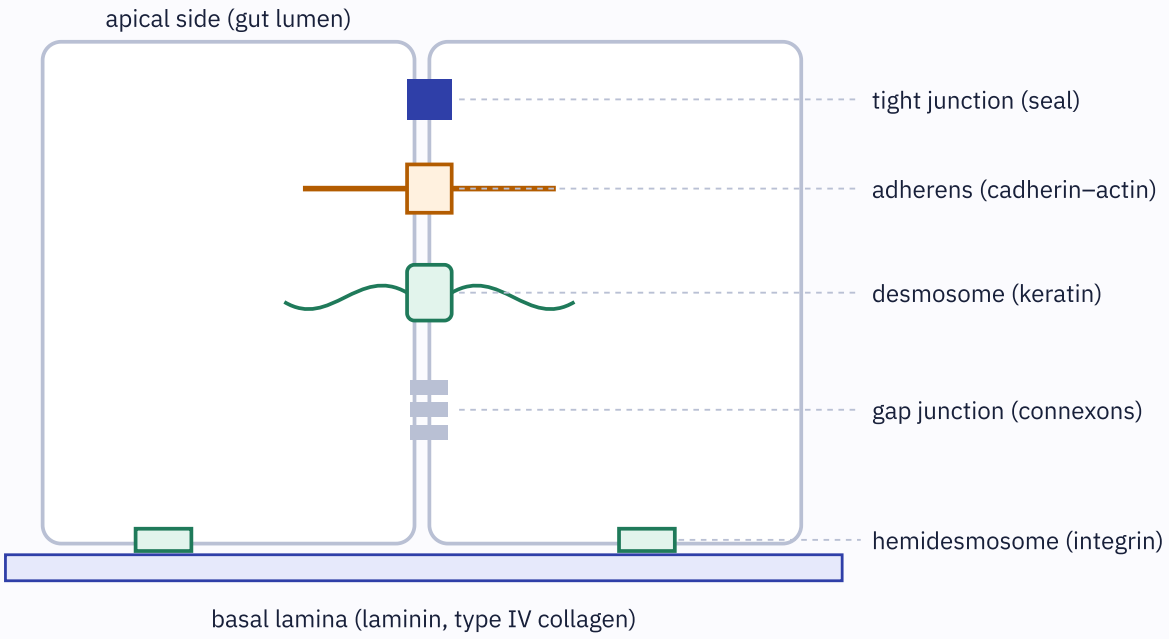


Figure 5.7.1 The junctions between two gut epithelial cells, in their usual order from the lumen (top) to the basal lamina (bottom). Orange lines are actin, green curves are intermediate filaments. Notice that the two anchoring junctions use different filaments: adherens junctions use actin, desmosomes and hemidesmosomes use intermediate filaments.

WORKED EXAMPLE

Question (6 marks). Interpret each experiment. (a) A sheet of epithelial cells falls apart when EDTA (which removes Ca^{2+}) is added, and re-forms when Ca^{2+} is restored. (b) A fluorescent dye of 400 daltons injected into one heart muscle cell appears in its neighbours within minutes, but a 10,000-dalton fluorescent protein stays in the injected cell. (c) An electron-dense tracer added to the gut lumen stops at a point near the top of the spaces between the cells. (d) A patient's own antibodies against desmoglein 3 cause skin blisters.

1. (a) Cell–cell adhesion depends on Ca^{2+}, so it is mediated by **cadherins** (adherens junctions and desmosomes). Removing Ca^{2+} makes cadherins lose their shape and binding.
2. (b) The cells are connected by **gap junctions**. Small molecules pass through connexon channels; a protein is far too large.
3. (c) The tracer is stopped by **tight junctions**, which seal the space between cells at the apical end.
4. (d) Desmoglein 3 is a desmosomal cadherin. Antibodies block it, **desmosomes** fail, and skin cells separate under friction. This disease is pemphigus vulgaris.

EXAM TRAPS

- Desmosomes link to intermediate filaments, not actin. Adherens junctions link to actin.
- Hemidesmosomes use integrins, not cadherins, because they bind the matrix, not another cell.
- Tight junctions seal; they do not allow molecules through like gap junctions. Do not swap the two.
- Six connexins make one connexon (half a channel); two connexons make one gap-junction channel.
- Favourite question: "Classify cell junctions with a neat diagram." Use three groups: occluding (tight), anchoring (adherens, desmosome, hemidesmosome, focal adhesion), communicating (gap junction, plasmodesmata).

CHECK YOURSELF

– REMEMBER **Name the proteins that form tight junctions.** 2 marks

Claudins and occludin.

– REMEMBER **Which adhesion molecules need Ca^{2+}?** 2 marks

Cadherins and selectins (integrins need divalent cations too, but the classic Ca^{2+}-dependent cell–cell molecules are the cadherins).

– UNDERSTAND **Give two functions of tight junctions.** 2 marks

They seal the space between cells so solutes cannot leak across the sheet, and they act as a fence keeping apical and basolateral membrane proteins separate.

– UNDERSTAND **How is a gap junction channel built?** 3 marks

Six connexins form a connexon in each cell's membrane; connexons of two neighbouring cells dock end to end, forming a continuous aqueous channel between the two cytoplasms.

– APPLY **Why do heart muscle cells need gap junctions?** 3 marks

Ions pass through gap junctions, so the electrical excitation spreads quickly from cell to cell and the heart muscle contracts together.

– ANALYZE **Loss of E-cadherin is common in tumours that spread. Explain why.** 4 marks

E-cadherin holds epithelial cells together. Without it, cells detach from their neighbours, can move away and invade, which is a step towards metastasis.

BEYOND THE SYLLABUS

Junctions are also signalling hubs: β-catenin, part of the adherens junction, doubles as a transcription co-activator in the Wnt pathway, and integrins sense matrix stiffness, a field called mechanobiology. Researchers engineer leaky or tight barriers in "organ-on-a-chip" models of the gut and blood–brain barrier. This is not for the exam; search "mechanotransduction integrins" and "epithelial–mesenchymal transition".

5.8 Extracellular matrix and cell wall

Outside the plasma membrane, most cells build a structure of their own. Animal cells secrete an **extracellular matrix** (ECM): a network of protein fibres in a hydrated sugar gel that gives tissues strength, holds cells in place and carries signals. Plant, fungal and bacterial cells build a rigid **cell wall** instead, which resists the pressure of water entering by osmosis. The materials differ (collagen in animals, cellulose in plants, peptidoglycan in bacteria, chitin in fungi), but the idea is the same: a fibre for strength set in a filler.

You need: integrins and hemidesmosomes from Chapter 5.7, and plant versus animal cells from Unit 1.

The animal extracellular matrix

1. **Collagen**, the most abundant protein in mammals, gives tensile strength (resistance to pulling). Three polypeptide chains wind into a **triple helix**. Every third residue is glycine, giving a repeating Gly-X-Y sequence in which X is often proline and Y often hydroxyproline. Glycine, the smallest amino acid, is the only one that fits in the crowded centre of the helix. Hydroxyproline is made after translation by prolyl hydroxylase, an enzyme that needs vitamin C; without vitamin C collagen is weak and the disease scurvy follows (bleeding gums, poor wound healing). Type I collagen forms fibrils in skin, bone and tendon; type IV forms a sheet-like network in the basal lamina.
2. **Elastin** gives stretch and recoil to skin, lungs and large arteries.
3. **Glycosaminoglycans** (GAGs) are long unbranched chains of repeating disaccharides, strongly negative because of sulfate and carboxyl groups. Hyaluronan, chondroitin sulfate, heparan sulfate and keratan sulfate are examples. Except hyaluronan, GAGs are attached to core proteins as **proteoglycans**, such as aggrecan in cartilage. Their negative charges attract cations and water, forming a gel that resists compression, which is why cartilage cushions joints.

4. **Adhesive glycoproteins** connect cells to the matrix. **Fibronectin** carries an Arg-Gly-Asp (**RGD**) sequence that integrins recognise. **Laminin** is the main adhesive protein of the basal lamina.
5. The **basal lamina** (basement membrane) is a thin mat of type IV collagen, laminin and proteoglycans under every epithelium. It supports the epithelium, filters (in the kidney glomerulus) and guides cells during repair.

The ECM is constantly remodelled. **Matrix metalloproteinases** (MMPs) cut matrix proteins during growth and wound healing; cancer cells use them to invade. The matrix also stores growth factors and signals to cells through integrins, linking this chapter back to the signalling chapters of this unit.

The plant cell wall

The **primary wall** is laid down while the cell grows. It is made of **cellulose microfibrils** (long chains of glucose joined by β-1,4 bonds, bundled into crystalline fibres) cross-linked by **hemicelluloses** such as xyloglucan and embedded in **pectin**, a gel of acidic polysaccharides. Cellulose is made at the plasma membrane by cellulose synthase complexes, which move along tracks set by cortical microtubules underneath. Between neighbouring cells lies the **middle lamella**, rich in pectin (calcium pectate), which glues them together. After growth stops, many cells add a thick **secondary wall** inside the primary wall, with more cellulose and often **lignin**, which makes wood hard and waterproof. Plasmodesmata cross all these layers.

Bacterial and fungal walls

The bacterial wall is **peptidoglycan** (murein): chains of alternating N-acetylglucosamine (NAG) and N-acetylmuramic acid (NAM), joined by β-1,4 bonds and cross-linked by short peptides. **Gram-positive** bacteria have a thick peptidoglycan layer that holds the crystal violet stain. **Gram-negative** bacteria have a thin layer between two membranes, the outer one carrying lipopolysaccharide (LPS). Penicillin blocks the transpeptidase enzymes that make the peptide cross-links, and lysozyme in tears cuts the NAM–NAG bond. Fungal walls are made mainly of **chitin** (a polymer of NAG) and glucans.

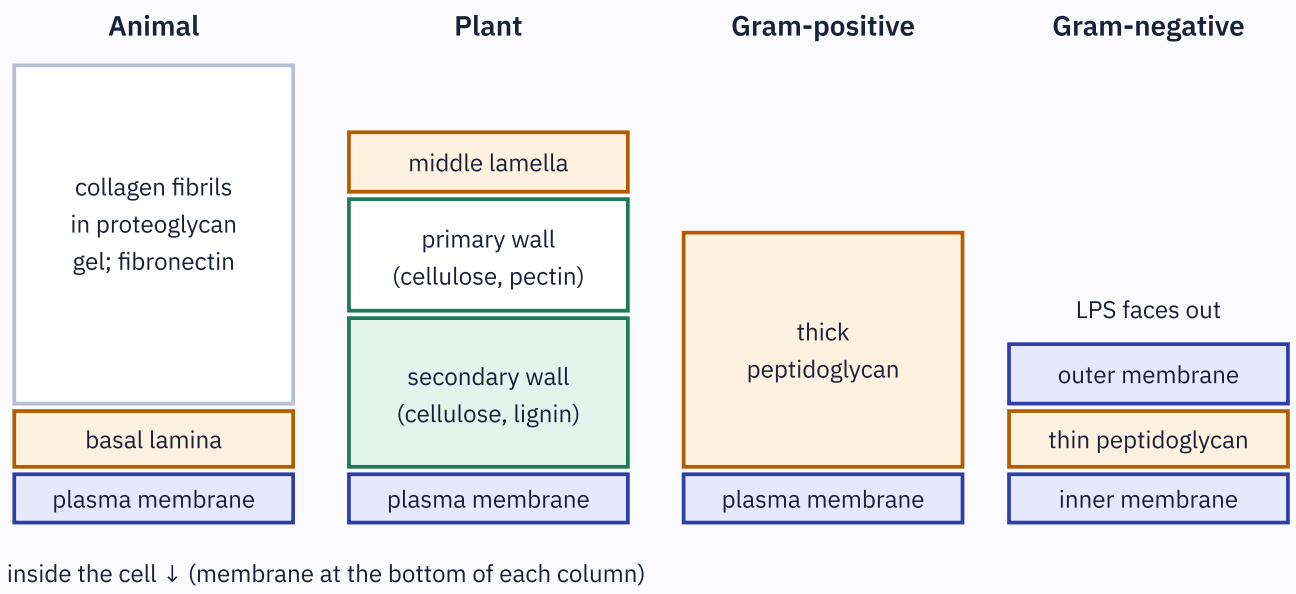


Figure 5.8.1 What lies outside the plasma membrane in four kinds of cell, membrane at the bottom. Notice that the plant secondary wall is laid down inside the primary wall, nearest the membrane, and that the Gram-negative wall has a second membrane outside its thin peptidoglycan.

WORKED EXAMPLE

Question (6 marks). (a) A synthetic collagen-like peptide is $(\text{Pro-Hyp-Gly})_{10}$. How many residues and how many glycines does one chain have, and how many glycines are in its triple helix? Why must glycine be every third residue? (b) Predict the result of treating each sample with the enzymes given: plant leaf tissue with pectinase alone; plant leaf tissue with cellulase plus pectinase in an osmotically balanced solution; a Gram-positive bacterium with lysozyme in water.

1. (a) Each repeat has 3 residues, so 10 × 3 = 30 residues per chain, of which 10 are glycine. The triple helix has 3 chains, so 3 × 10 = 30 glycines.
2. Glycine has only a hydrogen as its side chain. In the triple helix every third residue faces the crowded central axis, and only glycine is small enough to fit there.
3. (b) Pectinase dissolves the pectin of the middle lamella, so the cells separate from each other but keep their walls (this is how single cells are prepared from leaves).
4. Cellulase plus pectinase removes the whole wall, giving **protoplasts**: wall-less cells that survive only because the solution is osmotically balanced.
5. Lysozyme cuts the NAM–NAG bonds of the thick peptidoglycan; without its wall the bacterium takes in water and bursts (lyses) in water.

EXAM TRAPS

- The secondary wall is inside the primary wall, not outside it. It is added between the primary wall and the membrane.
- Collagen gives tensile strength; proteoglycans resist compression. Do not swap them.
- Cellulose is β-1,4 linked glucose; starch is α-1,4. The bond type, not the sugar, makes the difference.
- Gram-positive means thick peptidoglycan and no outer membrane; Gram-negative means thin peptidoglycan with an outer LPS membrane.
- Favourite question: "Describe the components of the extracellular matrix and their functions." List collagen, elastin, GAGs and proteoglycans, fibronectin and laminin, with one function each.

CHECK YOURSELF

– REMEMBER **Name the repeating tripeptide pattern of collagen.** 1 mark

Gly-X-Y, with X often proline and Y often hydroxyproline.

– REMEMBER **What are the layers of a plant cell wall, from outside in?** 2 marks

Middle lamella, primary wall, secondary wall, then the plasma membrane.

– UNDERSTAND **Why does vitamin C deficiency weaken connective tissue?** 3 marks

Prolyl hydroxylase needs vitamin C to make hydroxyproline. Without it, collagen chains form unstable triple helices and weak fibres, causing scurvy.

– UNDERSTAND **How do proteoglycans make cartilage resist compression?** 3 marks

Their GAG chains are densely negatively charged, so they attract cations and hold large amounts of water, forming a gel that pushes back when squeezed.

– APPLY **Why is penicillin harmless to human cells?** 2 marks

It blocks the transpeptidases that cross-link peptidoglycan. Human cells have no peptidoglycan and no such enzymes.

– APPLY **A cell line lacks the integrins that recognise RGD. Predict its behaviour on a fibronectin-coated dish.** 3 marks

The cells cannot bind fibronectin's RGD sequence, so they attach poorly, do not spread, and lose integrin-dependent survival signals.

– ANALYZE **Compare the animal ECM with the plant cell wall as "fibre in a filler" composites.** 4 marks

Animal: collagen fibres (tension) in a proteoglycan gel (compression), flexible and remodelled by MMPs, linked to cells by integrins. Plant: cellulose microfibrils (tension) in hemicellulose and pectin, rigid, resisting turgor pressure, stiffened by lignin in secondary walls. Both pair a strong fibre with a hydrated filler.

BEYOND THE SYLLABUS

Tissue engineers grow cells on scaffolds made from collagen, hyaluronan or decellularised organs, which keep the native ECM after the cells are washed away. Plant cell walls are the raw material of second-generation biofuels, where lignin is the main barrier to breaking cellulose into sugar. This is not for the exam; search "decellularised scaffold" and "lignocellulose pretreatment" to read further.

Key terms of this lesson

TERM	MEANING OR FORMULA	CHAPTER
Junction types	Occluding (tight); anchoring (adherens, desmosome, hemidesmosome); communicating (gap junction, plasmodesmata)	5.7
Collagen	Triple helix, Gly-X-Y repeat; hydroxyproline needs vitamin C	5.8
Peptidoglycan	NAG–NAM chains (β-1,4) cross-linked by peptides; thick in Gram-positive	5.8

Glossary (terms used in this lesson)

Basal lamina Thin mat of type IV collagen, laminin and proteoglycans under an epithelium.

Cadherin Ca^{2+}-dependent cell–cell adhesion protein of adherens junctions and desmosomes.

cAMP Cyclic AMP; second messenger made by adenylyl cyclase, activates PKA.

Connexon Ring of six connexins forming half of a gap-junction channel.

Desmosome	Spot junction linking the intermediate filaments of neighbouring cells.
Fibronectin	Matrix glycoprotein with an RGD sequence that integrins bind.
Glycosaminoglycan	Long negatively charged disaccharide chain that holds water in the matrix.
Integrin	αβ transmembrane receptor that binds the matrix and links to the cytoskeleton.
IP_3	Inositol 1,4,5-trisphosphate; releases Ca^{2+} from the ER.
Middle lamella	Pectin-rich layer cementing neighbouring plant cells.
Peptidoglycan	Bacterial wall polymer of NAG and NAM cross-linked by peptides.
Proteoglycan	Core protein carrying GAG chains; resists compression.
Tight junction	Claudin–occludin seal between epithelial cells near their apical end.

The full unit book

Every chapter of Unit 5, the unit summary, the exam question bank with model answers and the full glossary: Cell Biology · Unit 5 · Cell Signaling and Cell Communication (one file, works offline).

Sources and further reading

- Alberts B. et al., *Molecular Biology of the Cell*, Garland Science / W. W. Norton: the chapters on cell signalling and on cell junctions and the extracellular matrix (from memory; check the edition you are prescribed).
- Lodish H. et al., *Molecular Cell Biology*, W. H. Freeman: the chapters on signal transduction and on integrating cells into tissues (from memory; check).
- Karp G., *Cell and Molecular Biology: Concepts and Experiments*, Wiley: the chapters on cell signalling and on interactions between cells and their environment (from memory; check).
- Cooper G. M., *The Cell: A Molecular Approach*, Sinauer / Oxford University Press: the chapter on cell signalling (from memory; check).
- Alberts B. et al., *Molecular Biology of the Cell*, 4th edition (2002), "General Principles of Cell Communication", free on NCBI Bookshelf: ncbi.nlm.nih.gov/books/NBK26813 (source of the hormone and acetylcholine concentrations and the nitric oxide half-life used in Chapter 5.1).
- Wikipedia, "Gap junction": en.wikipedia.org/wiki/Gap_junction (consulted for the connexon structure and the range of size limits quoted in Chapter 5.7).

Syllabus: the University free n easy universal syllabus, built from top universities' syllabi.

Built for the University free n easy YouTube channel from the universal syllabus of Cell Biology (Oct 2026). Written with top universities' syllabi and standard textbooks; check a formula against your prescribed book before an exam, and report mistakes on the channel.