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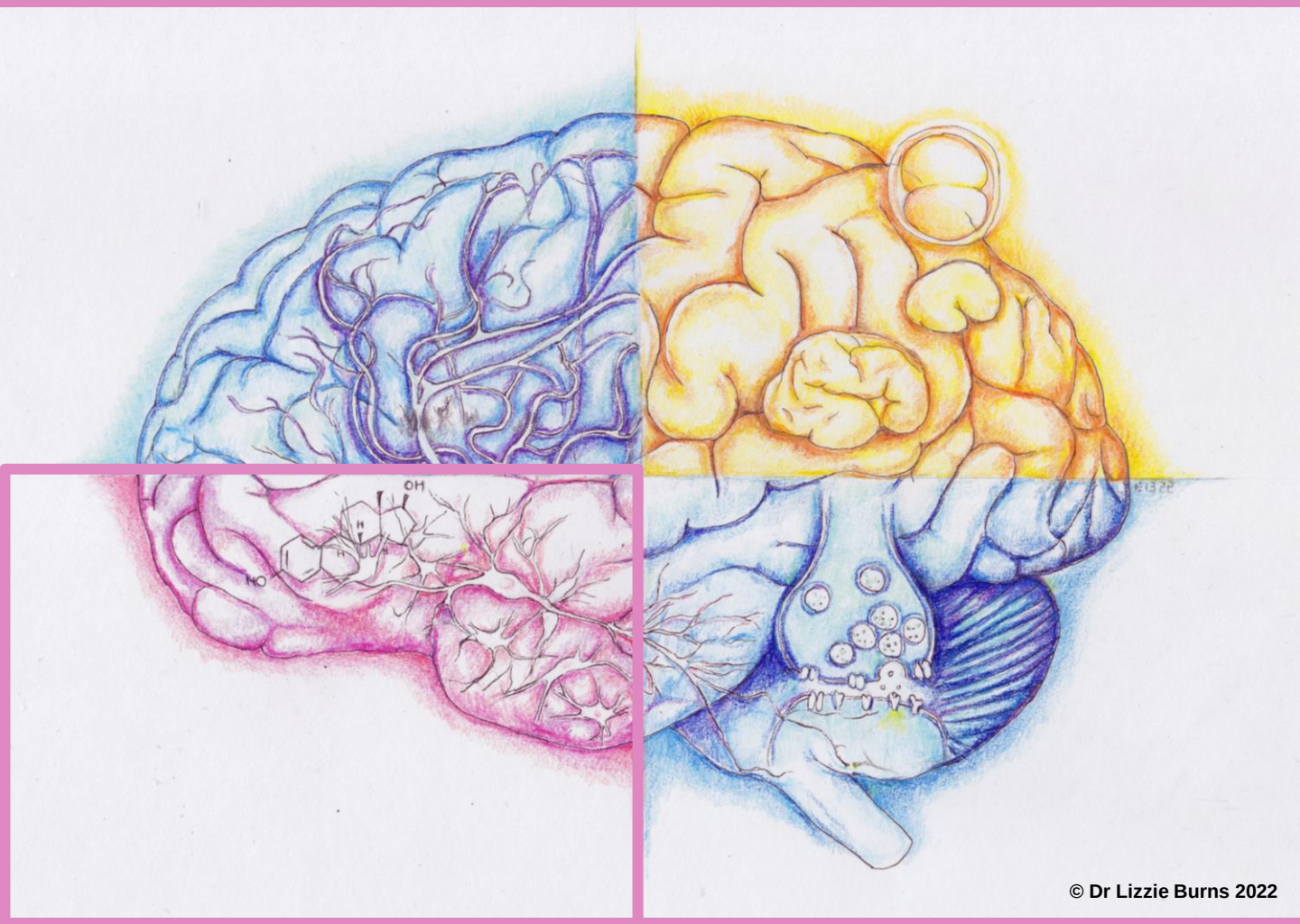


Staying in the Loop: Cell Communication

Key Stage 5
Biology

Contents

Getting Started

Subject Learning

Study Skills, Tips and Guidance

About this Pack

Who is this pack for?

- This pack was created for all students, regardless of whether this is your best or worst subject.
- It's not graded or marked by your teacher. It's a chance to explore the subject and learn in a new way that's different to the classroom.
- Each pack is written by a PhD student researching this topic and has special knowledge on the subject. When they were your age, they knew nothing about it either!
- By completing their mini-course, you will find out why it's interesting, and you will build the skills that help you improve at school.

So… why complete this pack?

- Learn new cool areas of a subject that you won't cover in the classroom
- Sharpen your academic skills, like short essay writing and interpreting data
- Experience what it's like to explore a subject freely
- Better understand what you enjoy and don't – it will help you make decisions about your future studies and career choices!

What's in this booklet?

Your RBC booklet is a pack of resources containing:

✓ More about how and why study this subject

✓ Six 'resources' each as a lesson with activities

✓ A final assignment to gauge learning

✓ Extra guidance throughout about the university skills you are building

✓ End notes on extra resources and where to find more information

Meet the Author

Name Edmond Mouofo

Area of Study and Degree Translational Neuroscience, PhD in Neuroscience

University University of Edinburgh

Where I am from

I was born in a small town called Mbouda in the West Region of Cameroon. My parents at the time lived in the capital of Cameroon, Yaoundé.

I think my subject is awesome because…

My academic mentor from Cameroon and current member of my thesis committee (Prof Alfred K. Njamnshi) often says, “If the brain doesn’t work, the rest does not matter”. This is true because although many factors contribute to our identity, the most important factor is between our ears. It is the brain. Therefore, there is nothing more exciting than studying the brain.

At school, I studied…

I studied Biology during my undergraduate, then completed a Master’s in Neurobiology. I am currently a PhD candidate at the University of Edinburgh.

A resource that inspires me…

Generally, I love reading/ watching bibliographies. When I learn about the challenges others have had to overcome, I am inspired.

One person I admire is…

I have great admiration for my mom. She has four biological children and many more adopted children. She has such a strong work ethic. I lost my dad when I was a teenager, so my mom worked up to four jobs sometimes to ensure that we always had everything we needed to succeed in our education.

Building Your Skills

Research-Based Curricula packs challenge you to build your skills in this subject and be used across any of your schoolwork.

Any time you see a badge, look out for a skill you'll be building!

These skills are the type of skills that teachers and universities look for as you progress, so see how many you know below.

Skills you may see and use in this pack.

Research *your ability to work on your own and find answers online or in other books*

Creativity *your ability to create something original and express your ideas*

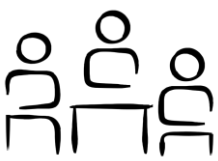
Problem solving *your ability to apply what you know to new problems*

Source analysis *your ability to evaluate sources (e.g. for bias, origin, purpose)*

Data analysis *your ability to discuss the implications of what the numbers show*

Active reading *your ability to engage with what you are reading by highlighting and annotating*

Critical thinking *your ability to think logically to build an argument clearly*

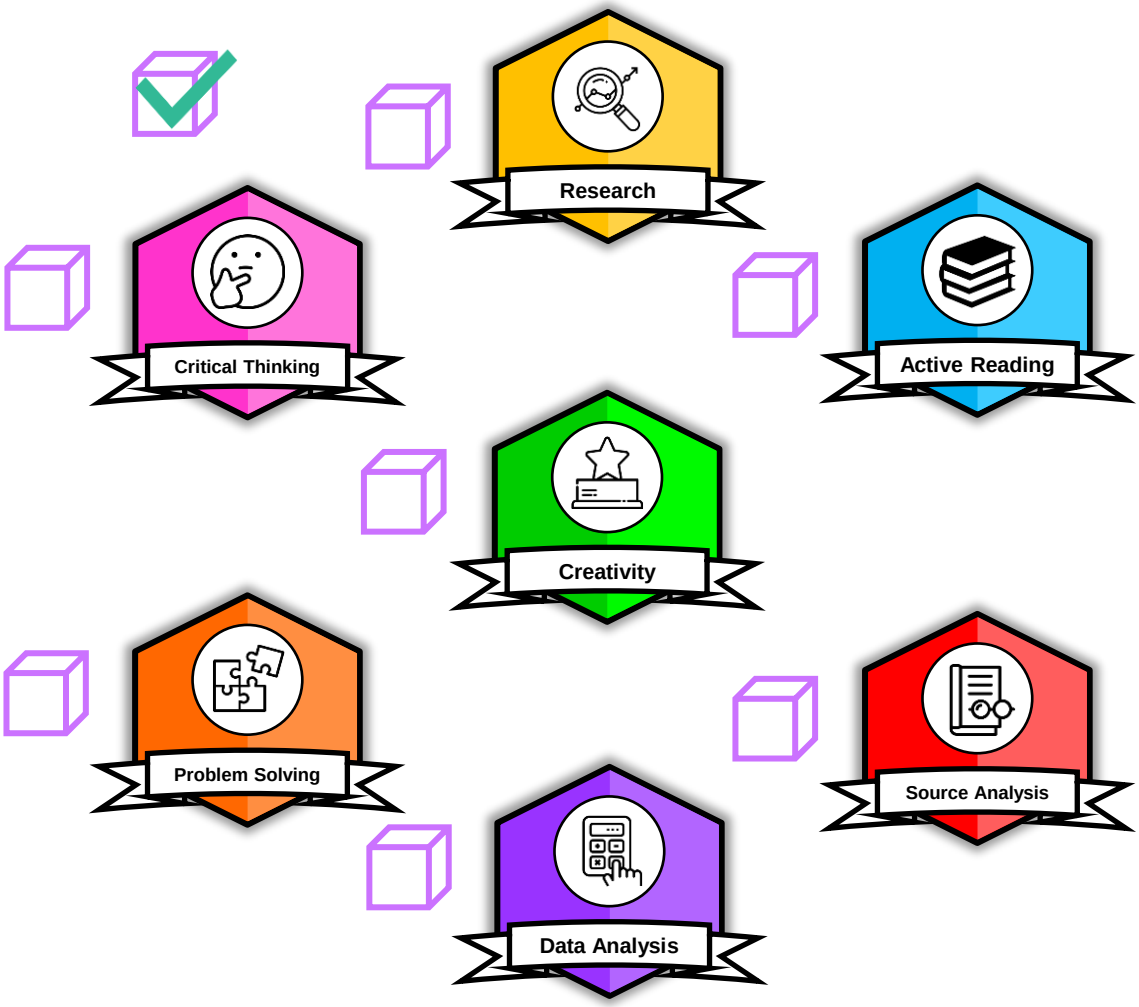


Psst! You can learn more about these skills in the Academic Study Skills section.

Your Skills Badges

As you work through this booklet, you'll have the chance to build the skills you have read on the previous page.

Make sure to revisit this page once you have mastered each skill. Tick off each skills badge below once completed!



Look out for these badges in the Data Source, Activities and Further Reading sections of each Resource. If you complete a skill more than once, write the number of times you completed it next to the badge.

When you've earned all seven skills badges, you can discuss with your teacher how to further build your skills!

Vocabulary

Be sure to use this section as you go through your booklet. If you see an emboldened word, you can find the definition here. If you are still unsure about the meaning or use of the word, we encourage you to use a dictionary or ask a teacher.

Term	Definition
Action potential	The means through which an electrical signal is carried by a nerve cell.
Cell	The cell is the smallest unit of all living things capable of maintaining life and reproducing.
Cell communication	Cell communication can also be called cell signalling. It describes the cell's ability to send, receive and process signals from its environment or other cells.
Depolarise	To make the inside of the cell more positive.
Enzyme	A substance produced by a living organism that speeds up biochemical reactions.
Gap junction	The channel between two adjacent cells that allows ions and low molecular weight substances to pass between cells enabling cells to communicate.
Hydrophilic	Hydrophilic means 'water loving'. It describes a molecule that is attracted to water. Generally, hydrophilic molecules have a charge, either positive or negative.
Hydrophobic	Hydrophobic means 'water hating'. It describes a molecule that does not mix with water.
Hyperpolarise	To make the inside of the cell more negative.
Ligand	A molecule, ion or functional group that binds to a receptor.

Vocabulary

Term	Definition
Membrane potential	The electrical charge or voltage difference between the inside and outside of the neuron.
Microscope	An instrument that magnifies an object several hundred times. It is used to view cells and their organelles.
Neuron	A specialised cell of the nervous system that consists of a cell body, axon and dendrites. It transmits nerve impulses.
Neurotransmitter	A chemical signal released by a nerve cell that can affect another nerve cell by travelling through a gap called the synapse.
Plasmodesma	Channels that pass between the cell walls of adjacent plant cells. It connects their cytoplasm and allows material to be transported from cell to cell.
Receptor	Proteins found on the surface or inside the cell that receive signals from the environment or other cells.
Search engine	A program that enables users to use key words to search for and identify items in a database.
Signal transduction	When a cell receives a signal through its receptors, it causes many changes in the cell. This process is called signal transduction.
Synapse	The junction between two nerve cells that allows nerve cells to communicate with each other either through electric or chemical signals.

When you find words you don't recognise in a resource, look up their definition. Use this page to write them down and make a note of their definition!

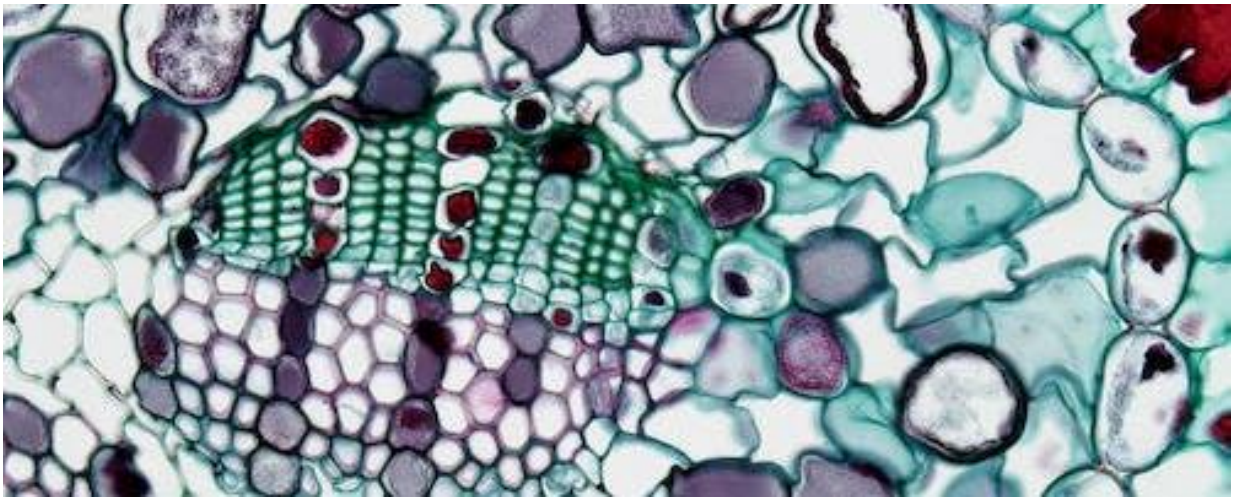
Introduction to Subject

Staying in the Loop: Cell Communication

Cell communication is essential for all biological processes as it provides the coordination necessary for multicellular organisms to function. In this coursebook, we will look at how our cells communicate with each other.

The topics within this pack will include:

Resource One	*Introduction to cell communication*
Resource Two	*Signalling molecules and pathways*
Resource Three	*Contact-dependent cell communication*
Resource Four	*Short distance cell communication*
Resource Five	*Long distance cell communication*
Resource Six	*Studying cell communication*



Resource One Overview

Topic

Introduction to cell communication

Key Stage 5 Subject Area

Many proteins are enzymes, and Transport across cell membranes (Biology)

Objectives

By completing this resource, you will be able to:

- ✓ Describe the general features of plant and animal cells.
- ✓ Understand why the cell membrane is central to cell communication.
- ✓ List the types of cell communication.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Resource Two**

Resource One
Data Source

Section A

Cells communicate like we do

Can you think of instances in school when you wanted to send a message to a specific person or group? If the message was for a friend sitting by you in class, you wrote a short note and gave it to them or whispered directly into their ears so that no one else read or heard it. At other times, you may have turned to a small group of friends sitting by you to invite them to your birthday party, and your voice only reached this group. What if you wanted a larger group of people to listen to you? Maybe you stood in front of the classroom and spoke loud enough for everyone to hear you, or you reached out for your phone and made a status update on your social media profile for even more people to see.

Even though the **cells** that make up our bodies do not have to organise birthday parties and invite other cells, the mechanism by which cells talk with each other is similar to how people communicate. **Cell communication** is essential for all biological processes as it provides the coordination necessary for multicellular organisms to function.

Figure 1: How we communicate

Cell communication is only possible because the cell has special structures that enable this function.

Resource One
Data Source

Section B

Structure of a cell

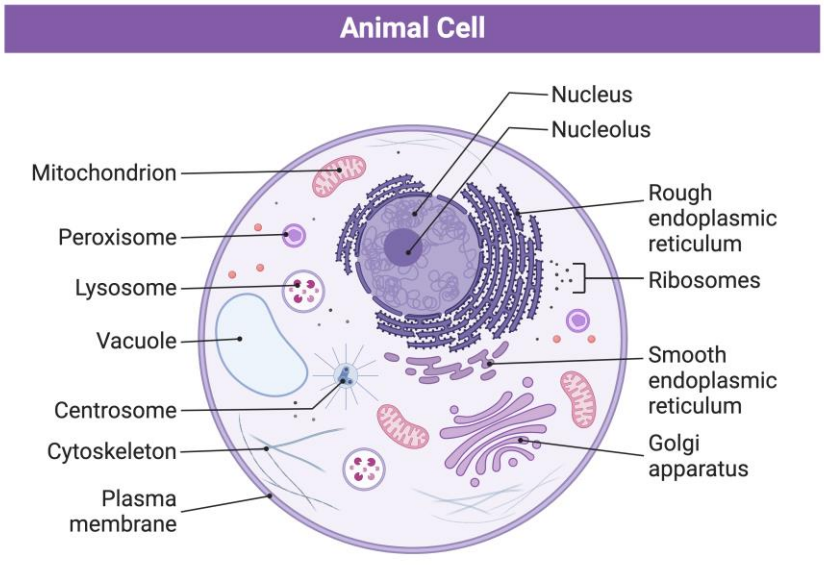
Cells are the building blocks of all living organisms, including humans, animals and plants. A cell is the smallest unit that can live on its own and is capable of reproducing itself.

Cells are often surrounded by a membrane called the plasma/ cell membrane, which separates the cell's content (intracellular) from the material outside (extracellular) the cell. The cell membrane is constituted of a bilayer of lipids and proteins, with carbohydrates, portions of glycolipids and glycoproteins. The proteins in the cell membrane serve as structural support, provide channels/ carrier molecules, and act as **receptor** sites. The cell membrane plays a vital role in cell communication by controlling the exchange of substances between the intracellular and extracellular spaces.

Active Reading

The nucleus is the control centre of the cell. It is formed by a nuclear membrane that surrounds the cell's genetic material. The cytoplasm is fluid in the cell containing all cell organelles, which all have specific structures and functions in the cell.

Figure 2: Structure of an animal cell

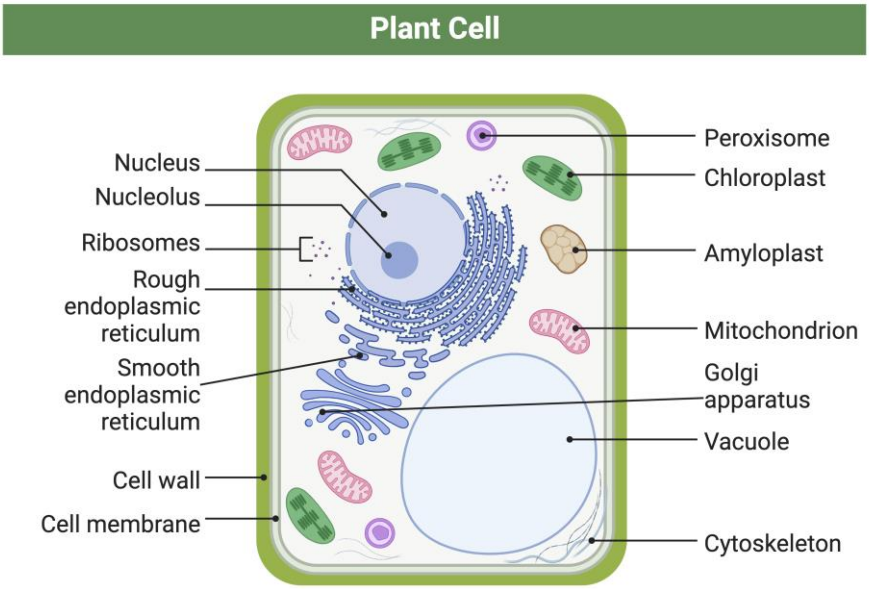


Source Analysis

Resource One
Data Source

Section B

Figure 3: Structure of a plant cell



Source Analysis

Section C

Mechanisms of cell communication

Even though both plant and animal cells have similar organelles (see Figures 2 and 3), they have a few differences. These differences arise because these cells have different needs. For example, a cell wall surrounds plant cells. They also have chloroplasts which are needed to carry out photosynthesis. Similarly, different mechanisms of cell communication enable the cells in our bodies to meet different needs.

The different types of cell communication can be classified according to the type of signalling molecules involved and the distance between the origin of the cell into five signalling pathways: autocrine, paracrine, contact-dependent, endocrine and synaptic communication.

Resource One
Data Source

Section C

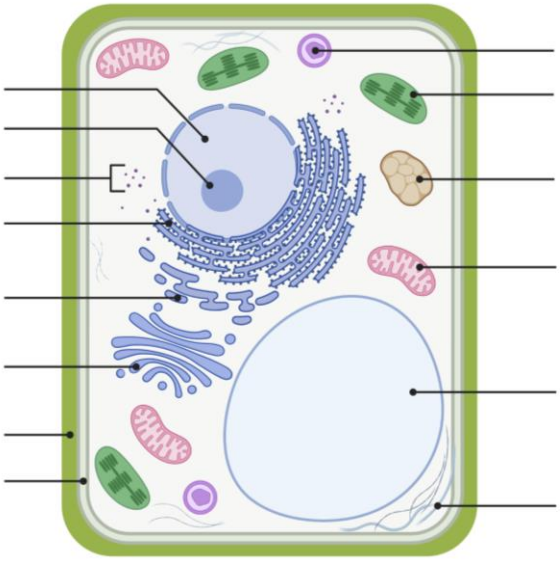
1. **Autocrine communication** involves the release of signalling molecules that target the same cell from which they were released.
2. In **paracrine communication**, on the other hand, a cell releases signalling molecules that act on neighbouring cells.
3. **Contact-dependent communication** can occur when cells are next to each other either through receptors on the plasma membrane to bind to each other or through **gap junctions**. Gap junctions are protein channels in the membrane, allowing the direct transfer of signals from cell to cell by forming bridges between them.
4. **Endocrine communication** uses signalling molecules called hormones, released by endocrine cells, that travel through the bloodstream to reach all body parts.
5. **Synaptic communication** occurs at the junction between **neurons** called **synapses** with the help of signalling molecules called **neurotransmitters.**

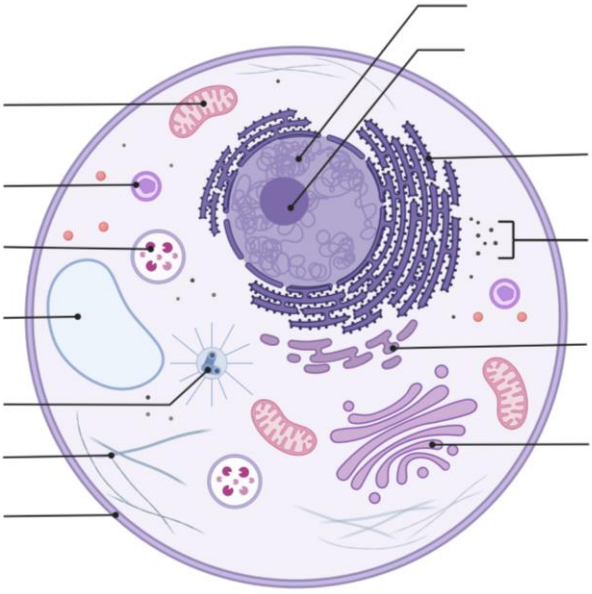
Even though the coursebook focuses on internal communication, our bodies can communicate with our environment through our senses, including sight (vision), hearing, touch, taste and smell. The cellular mechanisms that make this higher level of communication possible depend on the cell to cell communication mechanisms discussed in the coursebook.

Resource One Activities

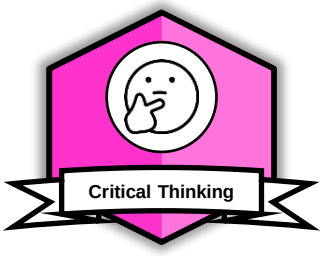
Activities

1. Identify and label the following diagrams.





2. Why is the cell membrane necessary for cell communication?
3. How do we classify the different types of cell communication?
4. List five different mechanisms of cell communication.
5. Why is it important to have different mechanisms of cell communication?



6. Is signalling in single-celled organisms more complicated than in multicellular organisms? Yes/ No. Briefly justify your answer.

Tip: *Further research is needed to answer question 6.*

Resource One
Further Reading

Explore

- https://training.seer.cancer.gov/anatomy/cells_tissues_membranes/cells/structure.html#:~:text=A%20cell%20consists%20of%20three,but%20distinct%20structures%20called%20organelles.
- https://doctorlib.info/physiology/medical/10.html

References

- Essentials of Cell Biology (2004 Garland Science)

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/

Resource Two Overview

Topic

Signalling molecules and pathways

Key Stage 5 Subject Area

Receptors, and Transport across cell membranes (Biology)

Objectives

By completing this resource, you will be able to:

- ✓ State the stages of cell signalling.
- ✓ Compare and contrast the different types of signalling molecules.
- ✓ List the different types of receptors.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Resource Three**

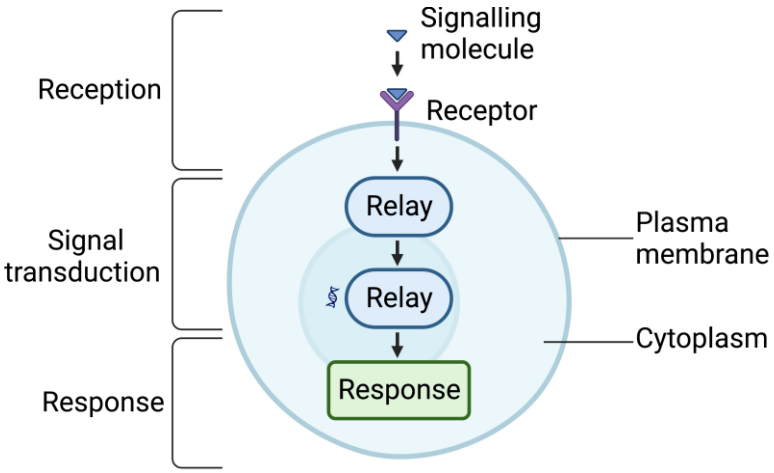
Resource Two
Data Source

Section A

Stages of cell signalling

Cell communication or signalling involves the production of a signal (which can be chemical or physical) by a cell, which will be received by a target cell. There are three stages of **signal transduction** (see Figure 4), namely, reception, transduction, and cell response.

Figure 4: Stages of cell signalling



Source Analysis

1. **Reception:** The signalling molecule (**ligand**) binds to a specific receptor on a target cell and causes this receptor to change its shape. **Hydrophilic** ligands bind to receptors at the cell's surface, while **hydrophobic** ligands are transported into the cell, where they attach to intracellular receptors.

Active Reading

2. **Transduction:** The changes occurring in the receptor after ligand binding. The molecules involved in these changes are called relay molecules. This process often involves activating proteins by removing or adding phosphate groups or releasing small molecules or ions that can act as messengers.

3. **Cellular response** always follows after transduction. The response can be varied, taking place in the nucleus or cytoplasm, resulting in **enzyme** catalysis, protein synthesis and cytoskeleton rearrangements.

Resource Two
Data Source

Section B

Signalling molecule categories

A signalling molecule (ligand) is a molecular messenger released by a signalling cell and transmitted to a target cell with proteins called receptors that can identify and specifically bind to ligands. Some ligands are membrane bound ligands. These remain bound to the cell surface and mediate contact-dependent signalling. Other ligands can be secreted and, therefore, called secretory ligands.

1. **Hydrophobic ligands** can pass through the lipid bilayer of the plasma membrane and interact with receptors in the cytoplasm. Members of this class of ligands include steroid hormones (such as oestradiol, a female sex hormone and testosterone, a male sex hormone), thyroid hormones, and Vitamin D. Hydrophobic signals require soluble carrier proteins to travel through the bloodstream.

2. **Hydrophilic ligands** are water soluble. Since they must pass through the cell membrane, their receptors are often found on the cell surface and membrane. Hydrophilic ligands are diverse and include proteins, peptides, hormones such as adrenaline, and small molecules. Hydrophilic signals can travel freely through the bloodstream.

3. **Nitric Oxide:** A subcategory of hydrophobic ligands includes gases such as nitric oxide (NO). NO acts over short distances because it has a short lifespan and plays a crucial role in smooth muscles like blood vessels where the vessel dilation. It can diffuse freely across the plasma membrane and bind to internal receptors.

Resource Two
Data Source

Section C

Receptors

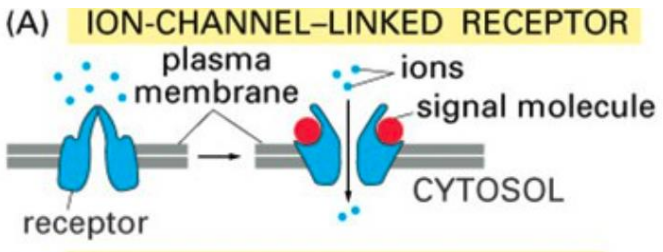
Receptors are proteins found on the surface or within cells that bind specifically to a signalling molecule and cause a cellular response by interacting with a cellular effector. Receptors can be divided into two broad categories based on their location in the cell: cell surface receptors (transmembrane) and internal receptors.

Active Reading

1. **Cell surface receptors** are attached to the cell membrane. They bind ligands that cannot cross the cell membrane often because they are hydrophilic or large, making diffusion through the cell membrane difficult. The three main types of cell surface receptors include:

A. **Ligand gated ion channel receptors** bind a ligand and open a channel through the membrane to allow specific ions (such as sodium, potassium, calcium, magnesium and hydrogen) to pass through. This is possible due to conformational changes in the protein structure of the channel that result from the binding of a ligand to the extracellular region of the channel.

Figure 5: Ion channel receptors



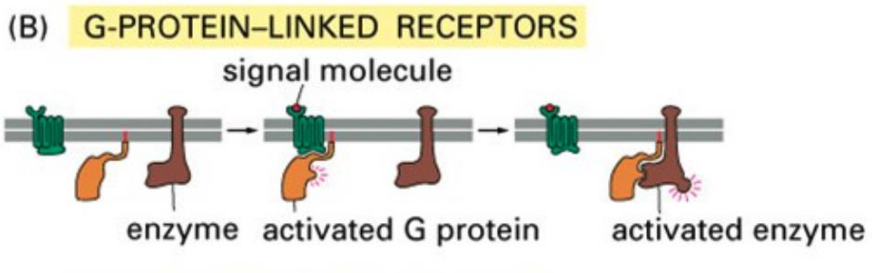
Source Analysis

B. **G protein coupled receptors (GPCR)** are the largest and most diverse cell surface receptors. GPCRs interact with G proteins in the plasma membrane resulting in conformational changes that activate a separate enzyme or ion channel.

Resource Two
Data Source

Section C

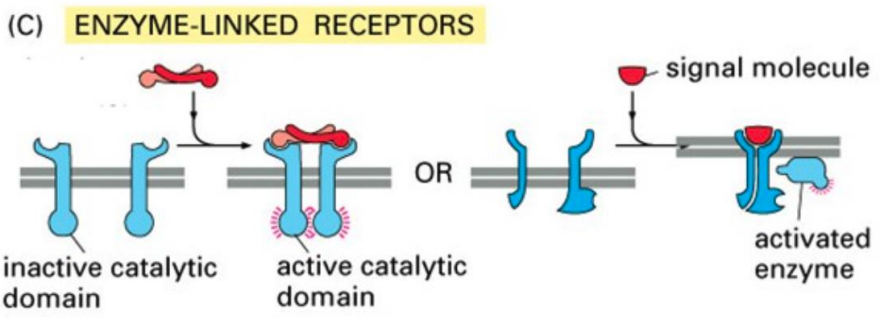
Figure 6: G protein coupled receptors



Source Analysis

C. **Enzyme coupled receptors** have two domains. The ligand binds to the extracellular domain, while the intracellular domain is associated with an enzyme that can be activated, resulting in a downstream reaction in the cell, causing a response.

Figure 7: Enzyme coupled receptors



Active Reading

2. **Internal receptors** are also called intracellular or cytoplasmic receptors. They are found in the cytoplasm or nucleus and are targeted by hydrophobic ligands that can diffuse across the plasma membrane. Examples of internal receptors include nuclear receptors. These receptors possess a hormone-receptor complex with an exposed DNA binding domain and can activate gene transcription.

Resource Two
Activities

Activities

1. What is a signal transduction pathway?
2. List and briefly describe the different stages of cell signalling.
3. What are the differences between hydrophobic and hydrophilic ligands?
4. What are cell surface receptors?
5. List three main types of cell surface receptors.

Resource Two
Further Reading

Explore

- https://www.wikiwand.com/en/Cell_signaling
- https://www.youtube.com/watch?v=9sF_h-bAnIE

References

- XMiller EJ, Lappin SL. Physiology, Cellular Receptor. [Updated 2022 Sep 14]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK554403/
- https://www.wikiwand.com/en/Cell_signaling

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/
- https://slideplayer.com/slide/4663463/

Resource Three Overview

Topic

Contact-dependent cell communication

Key Stage 5 Subject Area

Cell recognition and the immune system, and Receptors (Biology)

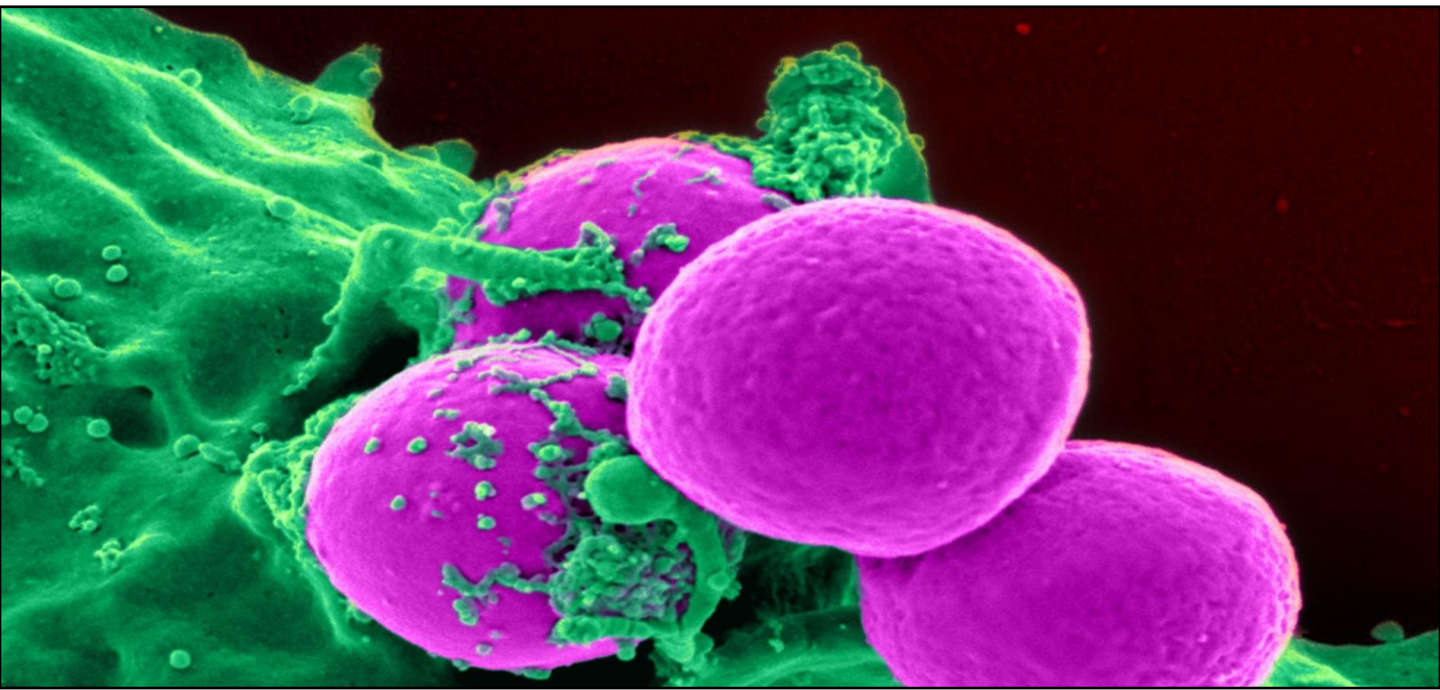
Objectives

By completing this resource, you will be able to:

- ✓ Define gap junctions.
- ✓ Describe how contact-dependent cell communication occurs in the immune system.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Resource Four**



Resource Three
Data Source

Section A

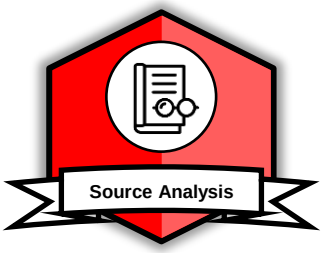
Gap junctions and plamodesmata

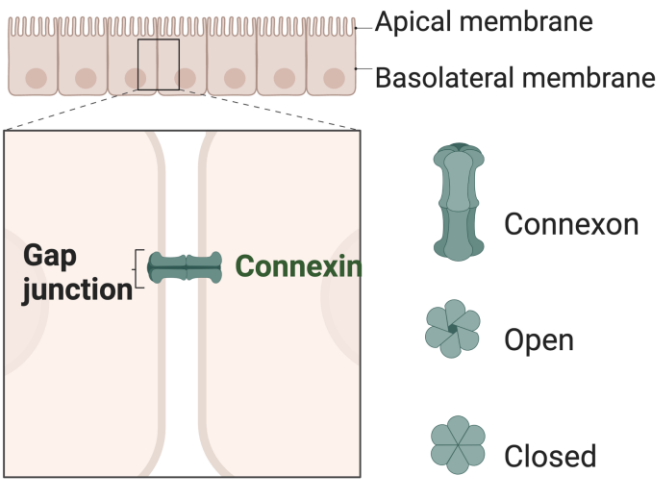
The cells that make up living organisms constantly receive signals from their environment and respond accordingly. One means by which cells communicate is through intercellular channels found clustered in specialised regions of the plasma membrane called gap junctions.

In higher plants, the functionally equivalent structures are called plasmodesmata (singular, **plasmodesma**).

In animals, gap junctions are formed when six membrane proteins called connexins reassemble an elongated doughnut structure called a connexon. There are several types of connexins. This diversity enables gap junctions to choose which molecules can pass through based on the molecule's size or electrical charge. Gap junctions can permit the exchange of molecules up to 1500 Daltons (a Dalton is a unit of measurement used to measure atoms' mass). In cells that can be electrically excited, like cardiac muscle cells and neurons, gap junctions permit the exchange of ions creating a metabolic syncytium or ensuring the rapid spread of **action potential**.

Figure 8: Gap junction





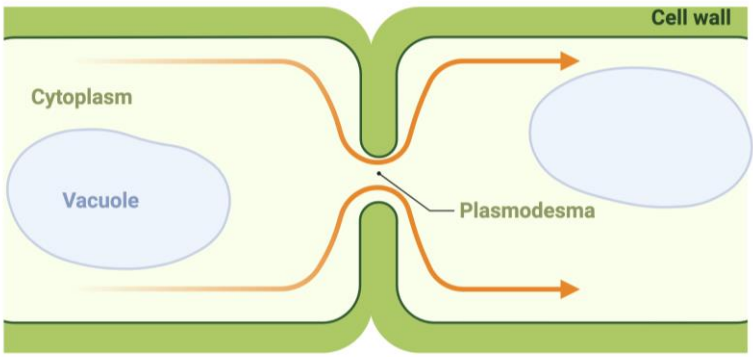
Resource Three
Data Source

Section A

Other small molecules or second messengers diffuse across gap junctions in none excitable cells contributing to cell and tissue functions such as regulation of growth, differentiation (young, immature cells grow into specific cell types), developmental signalling and cell synchronisation.

In plant cells, plasmodesmata (PD) ensure the continuity between adjacent cells. PD are tube-like membrane-lined channels formed from the association between the plasma membrane and endoplasmic reticulum. They enable large hydrophilic molecules to travel faster by passing through the cell membrane. PD also transport proteins, including transcription factors, RNA and even viral particles, from cell to cell.

Figure 9: Plasmodesmata



Section B

Contact-dependent communication in macrophages

Our immune system protects our bodies from invaders such as germs, bacteria, viruses, fungi and toxins produced by these invaders. This is possible because the different cells of our immune system can talk with each other. Macrophages are immune cells that play an important role in recognising and eliminating bacteria. They sometimes also participate in anti-inflammatory responses, tissue repair and homeostasis. While they can be found in every tissue-organ system, in the central nervous system (CNS), there are two main types of macrophages: microglia and CNS-associated macrophages (CAMs).

Resource Three
Data Source

Section B

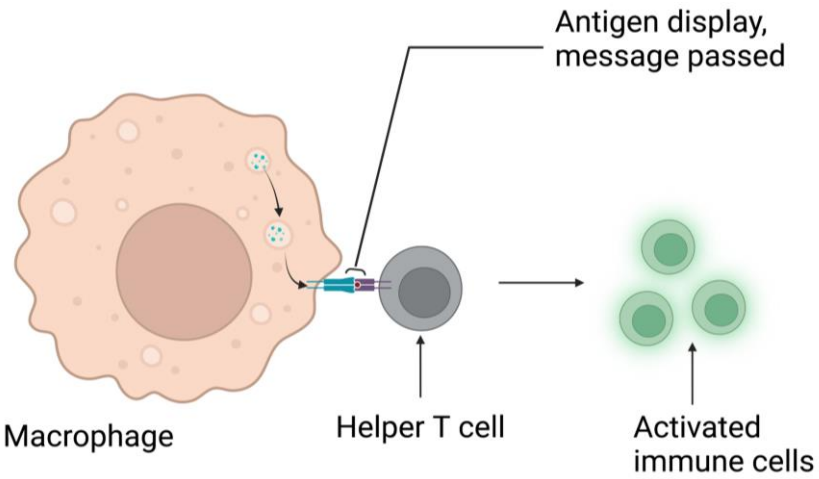
Active Reading

As the name implies, microglia have a small body (around 7–10μm) located in the brain tissue. CNS-associated macrophages, also known as border associated macrophages, are found in the CNS interfaces such as the meninges, perivascular space and choroid plexus. Microglia are the only CNS immune cells in close contact with neurons. Microglia promote vessel growth and maintain neurons during the embryo's development by guiding their migration. They also support other glial cells (non-neuronal cells) oligodendrocytes, remove debris and promote regeneration.

Macrophages can contact depend or direct cell signalling with other immune cells. When macrophages come in contact with foreign agents, pathogens or antigens in our bodies, they ingest them. In the endosome, these antigens interact with Major histocompatibility complex class II (MHC II) molecules forming an antigen-MHC class II, which will be presented on the macrophage cell surface membrane. The macrophage can therefore signal any immune cell with receptors to recognise the antigen presented by the MHC II.

Figure 10: MHC II as an example of contact-dependent communication

Source Analysis



Resource Three Activities

Activities

1. Which of the following are found only in plant cells?
   A. Gap junctions
   B. Desmosomes
   C. Plasmodesmata
   D. Tight junctions
2. Name two important functions of gap junctions.
3. Can gap junctions discriminate which molecules they allow to pass through? Yes/ No. Briefly justify your answer.

Resource Three
Further Reading

Explore

- https://doi.org/10.1038/sj.jid.5700770.
- https://www.youtube.com/watch?v=5MoIg5lWLXA

References

- Kambayashi, T., Laufer, T. Atypical MHC class II-expressing antigen-presenting cells: can anything replace a dendritic cell?. *Nat Rev Immunol* **14**, 719–730 (2014). https://doi.org/10.1038/nri3754

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/

Resource Four Overview

Topic

Short distance cell communication

Key Stage 5 Subject Area

Nervous coordination, and Transport across cell membranes (Biology)

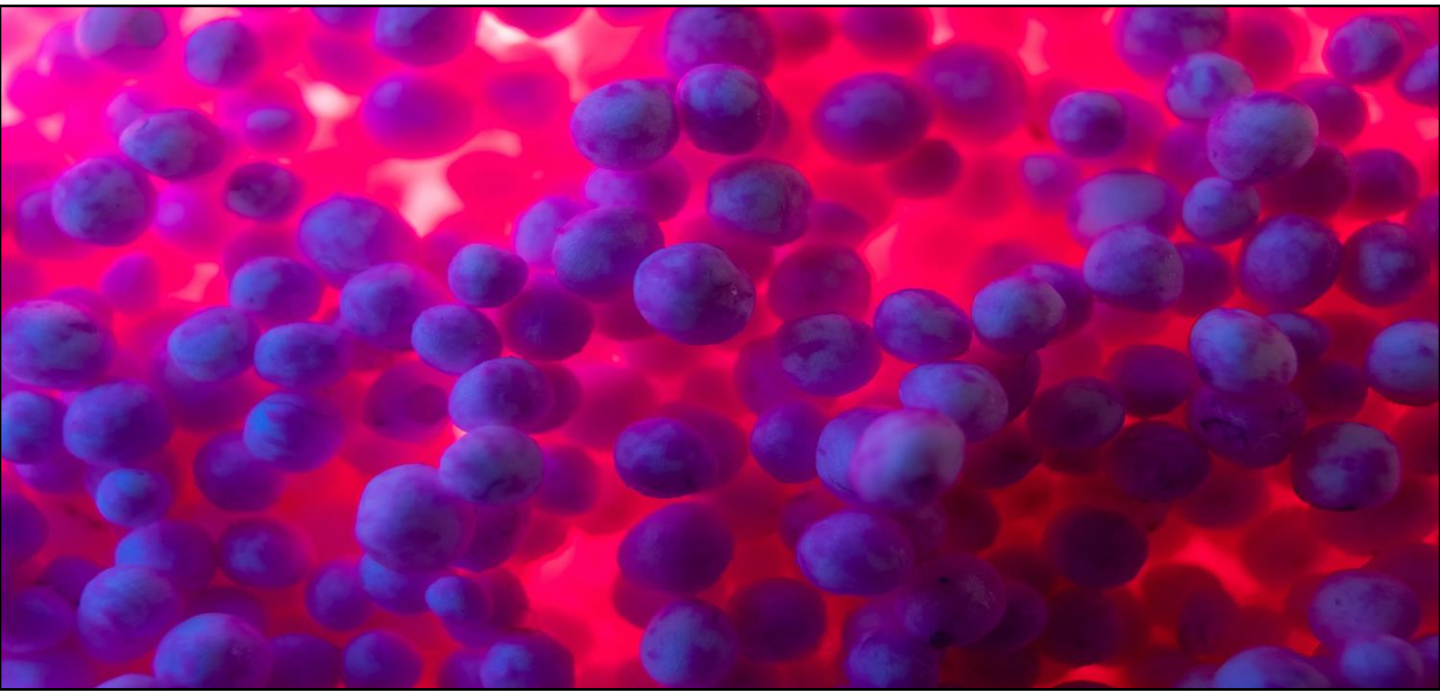
Objectives

By completing this resource, you will be able to:

- ✓ Define paracrine signalling.
- ✓ Describe the differences between electrical and chemical synapses.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Resource Five**



Resource Four
Data Source

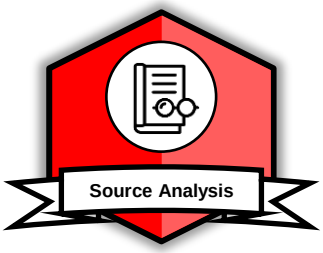
Section A

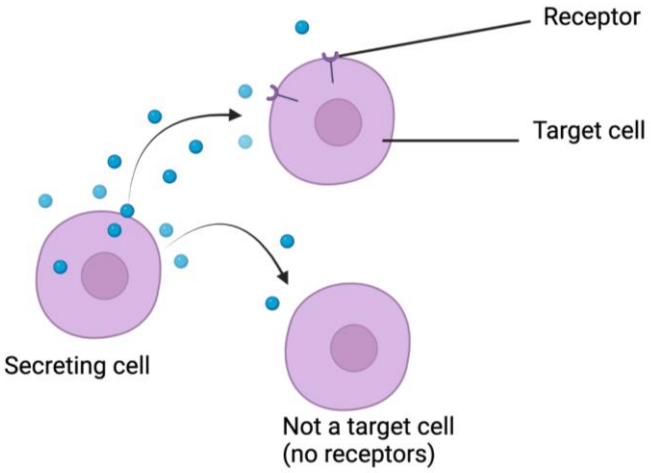
Paracrine signalling

Sometimes in your classroom, you want to pass a message to the people sitting near you. So you call their attention and speak just loud enough for only them to hear. When cells do the same, we call it paracrine signalling.

Paracrine signalling is a system of cell communication that allows cells to communicate with each other by releasing signalling molecules that can bind to and activate neighbouring cells. How far the paracrine signal travels determines the number of surrounding cells which will be reached. Paracrine signals are often short-lived because they are quickly broken down by enzymes or taken up by the neighbouring cells once a localised effect has been accomplished.

Figure 11: Illustration of paracrine signalling





Section B

Paracrine signalling of ATP

A common molecule in our bodies that can act as a paracrine signal is ATP (adenosine triphosphate).

When wounding occurs, the damaged cells spill out their ATP content which acts as a danger signal to the surrounding cell. This leads to the activation of the healing process as the healthy surrounding cells are stimulated to release the growth factors required for the healing process.

Resource Four
Data Source

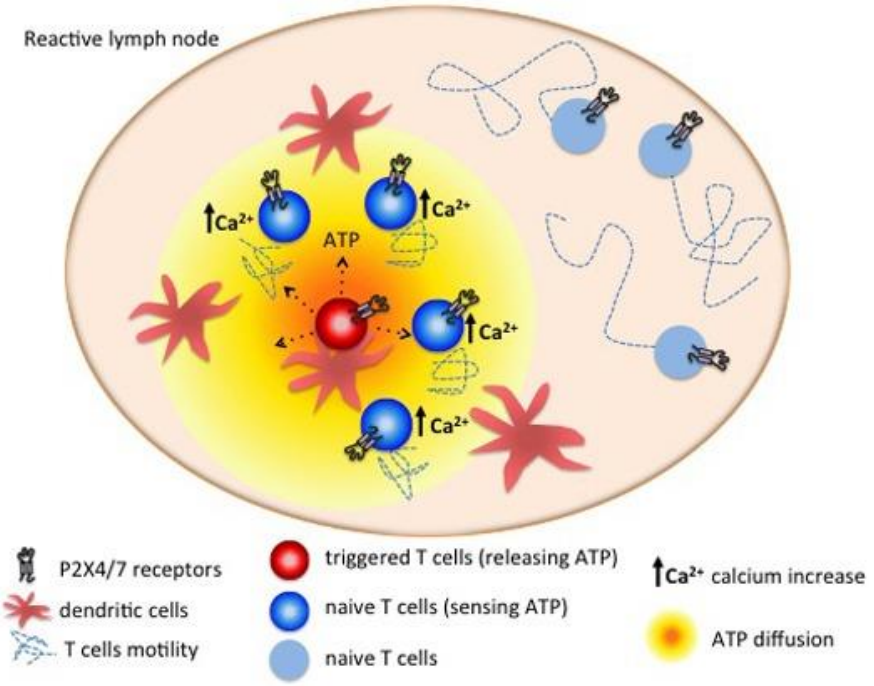
Section B

Lymph nodes are small, kidney-shaped organs of the lymphatic system and adaptive immune system containing clusters of specialised cells that protect our bodies by filtering lymphatic fluid and destroying invaders.

Active Reading

We just noted the participation of ATP paracrine signalling in wound healing. In reactive lymph nodes, ATP is released by stimulated T cells (antigen-triggered T cells). ATP acts as a paracrine signal through P2X4 and P2X7 receptors to induce calcium waves in non-adhering bystander T cells (non-stimulated T cells nearby). This ultimately alarms the neighbouring lymphocytes and reduces their motility.

Figure 12: ATP as a paracrine signal in T cells



Source Analysis

Naïve cells have not come in contact with an antigen. These cells are activated by paracrine signalling.

Resource Four
Data Source

Section C

Paracrine signalling at the synapse

Synapses are connections between neurons that allow electrical signals to pass from one neuron to the next. There are two types of synapses, namely electrical synapses and chemical synapses.

1. An **electrical synapse** connects neighbouring neurons through specialised channels called gap junctions. They have a 3 to 5 nm (nanometre) synaptic cleft (the gap between presynaptic and postsynaptic compartments). They allow electrical signals to travel quickly through them with diminished signal strength and are only excitatory. When talking about electrical synapses, we often specify 'electrical', while chemical synapses are called synapses.

2. A **chemical synapse** transmits information through chemical messengers (signalling molecules) called neurotransmitters secreted by the presynaptic neuron. The impulse can only flow in one direction, from the presynaptic neuron to the postsynaptic neuron. In chemical synapses, the synaptic cleft is about 20 nm wide. There is no signal strength loss even though the transmission speed is slower (several milliseconds). Synapses permit neurons to receive impulses from multiple sources. When a neuron receives impulses simultaneously from more than one source, it is termed spatial summation. When a neuron receives repeated impulses shortly after each other from a single source, it is called temporal summation. Once the postsynaptic neuron has processed all incoming inputs from the presynaptic neurons, an action potential will be triggered if the threshold voltage is reached. Based on the type of neurotransmitter released by the presynaptic neuron, a synapse can either excite (cause to do more of an action) or inhibit (stop an action) the postsynaptic neuron.

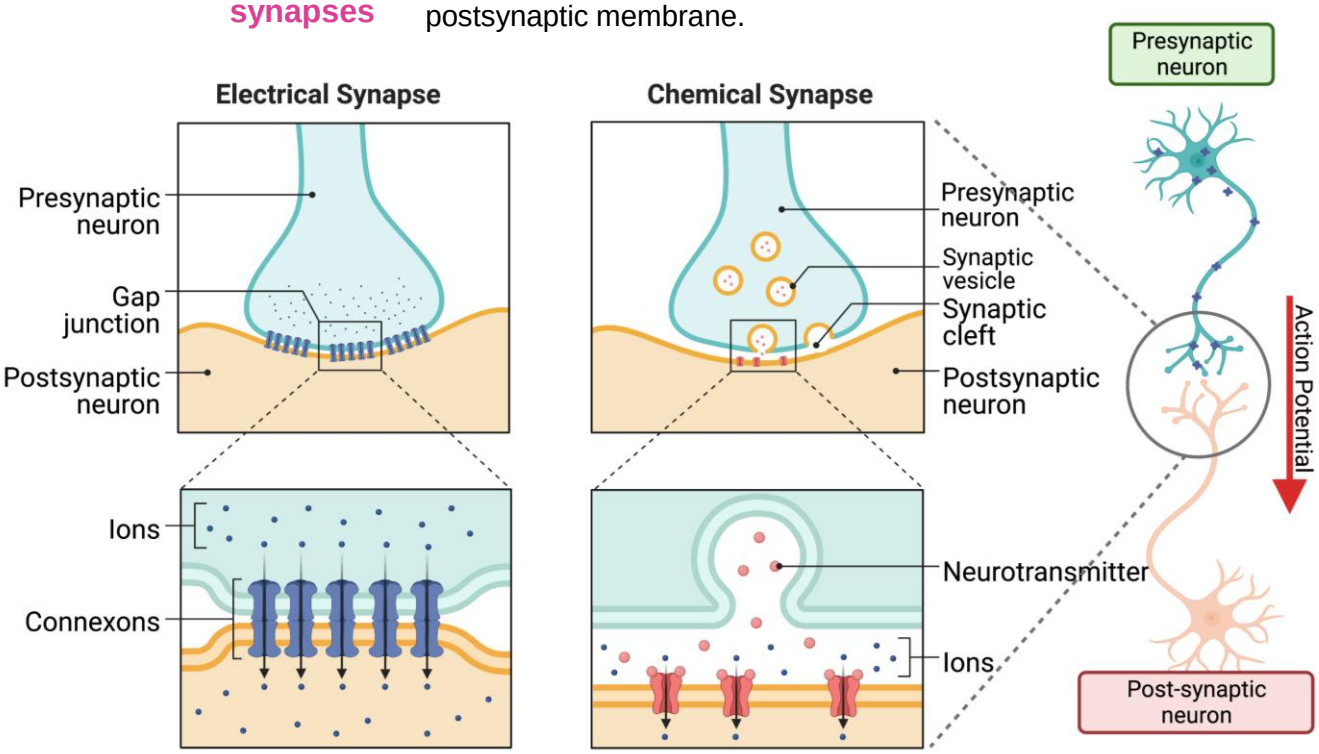
Resource Four
Data Source

Section C

When an electrical impulse arrives at the axon terminal, it causes calcium ions (Ca2+) uptake into the neurons by activating voltage-gated channels. The Ca2+ permits neurotransmitter release into the synaptic cleft as synaptic vesicles fuse to the presynaptic membrane. Once in the synapse, the neurosynaptic vesicles travel to the postsynaptic membrane, where they bind to receptors leading to **depolarisation** or **hyperpolarisation** of the postsynaptic membrane.

The synapse converts the action potential from a presynaptic neuron into a chemical signal through neurotransmitters. Once these neurotransmitters are released into the synaptic cleft and bind to postsynaptic receptors, the chemical signal is converted back to an electrical signal as charges flow across the postsynaptic membrane.

Figure 13: Electrical vs chemical synapses



Resource Four Activities

Activities

1. What are synapses?
2. What are the unique features of chemical synapses compared to those of electrical synapses?
3. What are the unique features of electrical synapses compared to those of chemical synapses?
4. Why is signalling at the synapse considered paracrine?

Tip: *Further research is needed to answer question 4.*

Resource Four
Further Reading

Explore

- https://www.studysmarter.co.uk/explanations/biology/cell-communication/paracrine-signaling/
- https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/a/the-synapse#:~:text=Neurons%20communicate%20with%20one%20another,ions%20flow%20directly%20between%20cells.

References

- Wang CM, Ploia C, Anselmi F, Sarukhan A, Viola A. Adenosine triphosphate acts as a paracrine signaling molecule to reduce the motility of T cells. EMBO J. 2014 Jun 17;33(12):1354-64. doi: 10.15252/embj.201386666. Epub 2014 May 19. PMID: 24843045; PMCID: PMC4194124.
- L Naomi Handly, Anna Pilko, Roy Wollman (2015) Paracrine communication maximizes cellular response fidelity in wound signaling eLife 4:e09652 https://doi.org/10.7554/eLife.09652

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/
- Wang CM, Ploia C, Anselmi F, Sarukhan A, Viola A. Adenosine triphosphate acts as a paracrine signaling molecule to reduce the motility of T cells. EMBO J. 2014 Jun 17;33(12):1354-64. doi: 10.15252/embj.201386666. Epub 2014 May 19. PMID: 24843045; PMCID: PMC4194124.

Resource Five Overview

Topic

Long distance cell communication

Key Stage 5 Subject Area

Receptors (Biology)

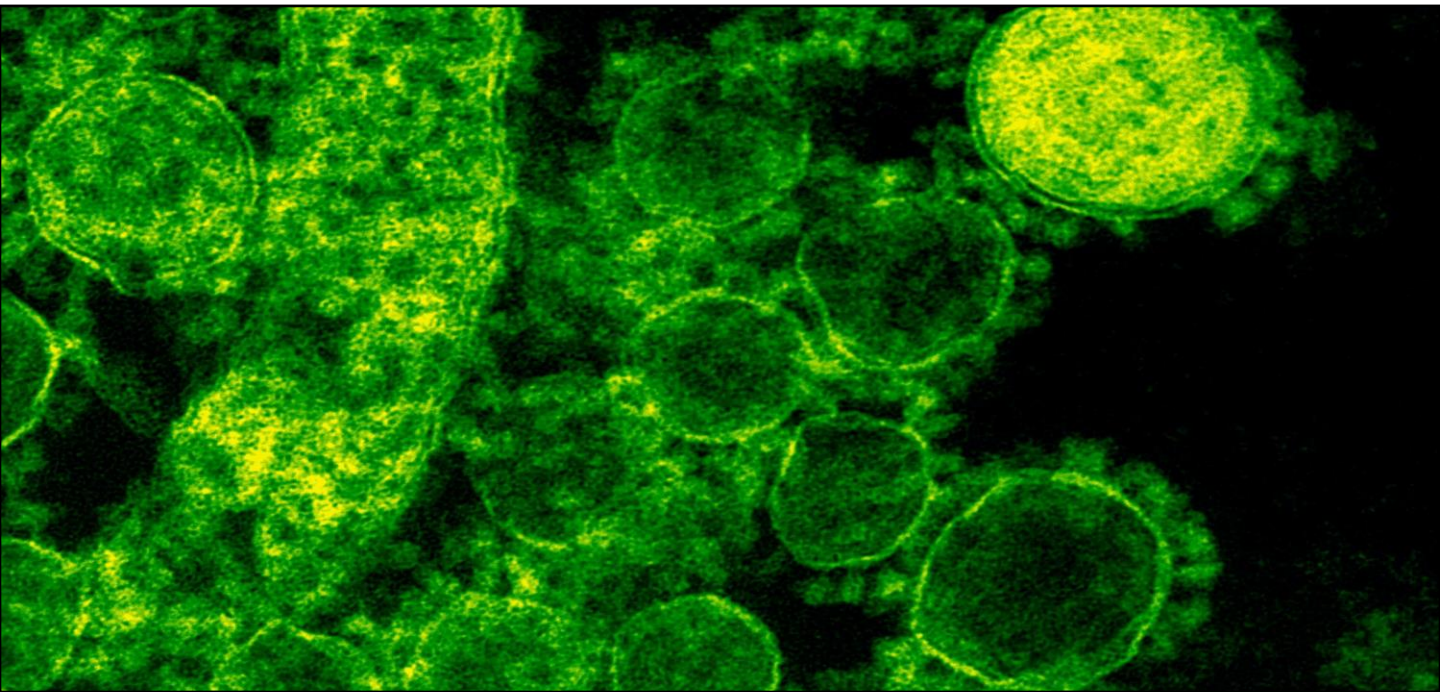
Objectives

By completing this resource, you will be able to:

- ✓ Recognise the different endocrine glands and the hormone they secrete.
- ✓ Understand saltatory conduction.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Resource Six**



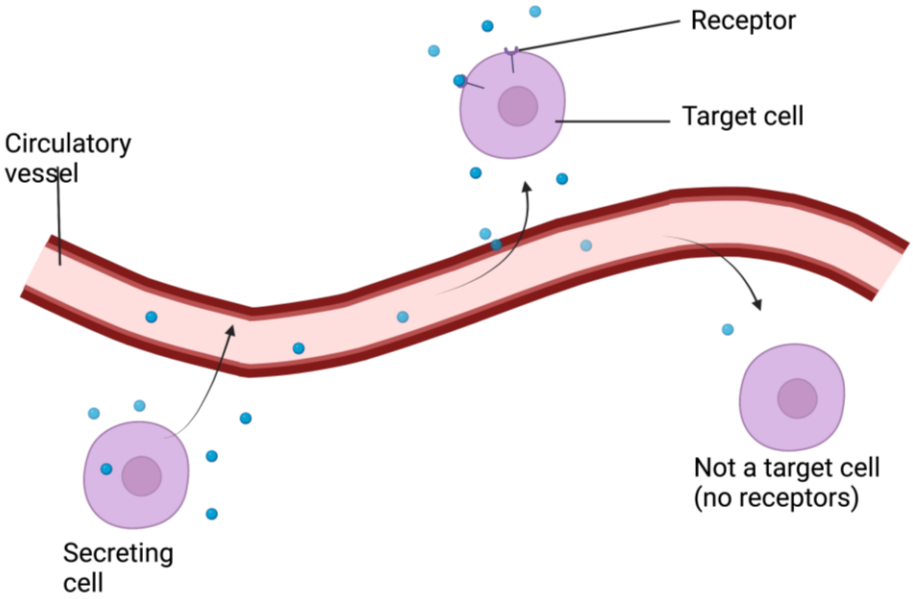
Resource Five
Data Source

Section A

Hormonal/ endocrine signalling

We have seen how cells send signals either to themselves or over short distances. Sometimes, cells also need to communicate over long distances. This type of cell communication which requires that the signals are produced by one part of the body and travel through the bloodstream to reach targets far away is called endocrine signalling.

Figure 14: Endocrine signalling



Source Analysis

Endocrine signalling is also called hormonal signalling because the signalling molecules which are produced by an endocrine gland are called hormones. They affect many processes, including growth and development, reproduction, mood, sexual function and metabolism.

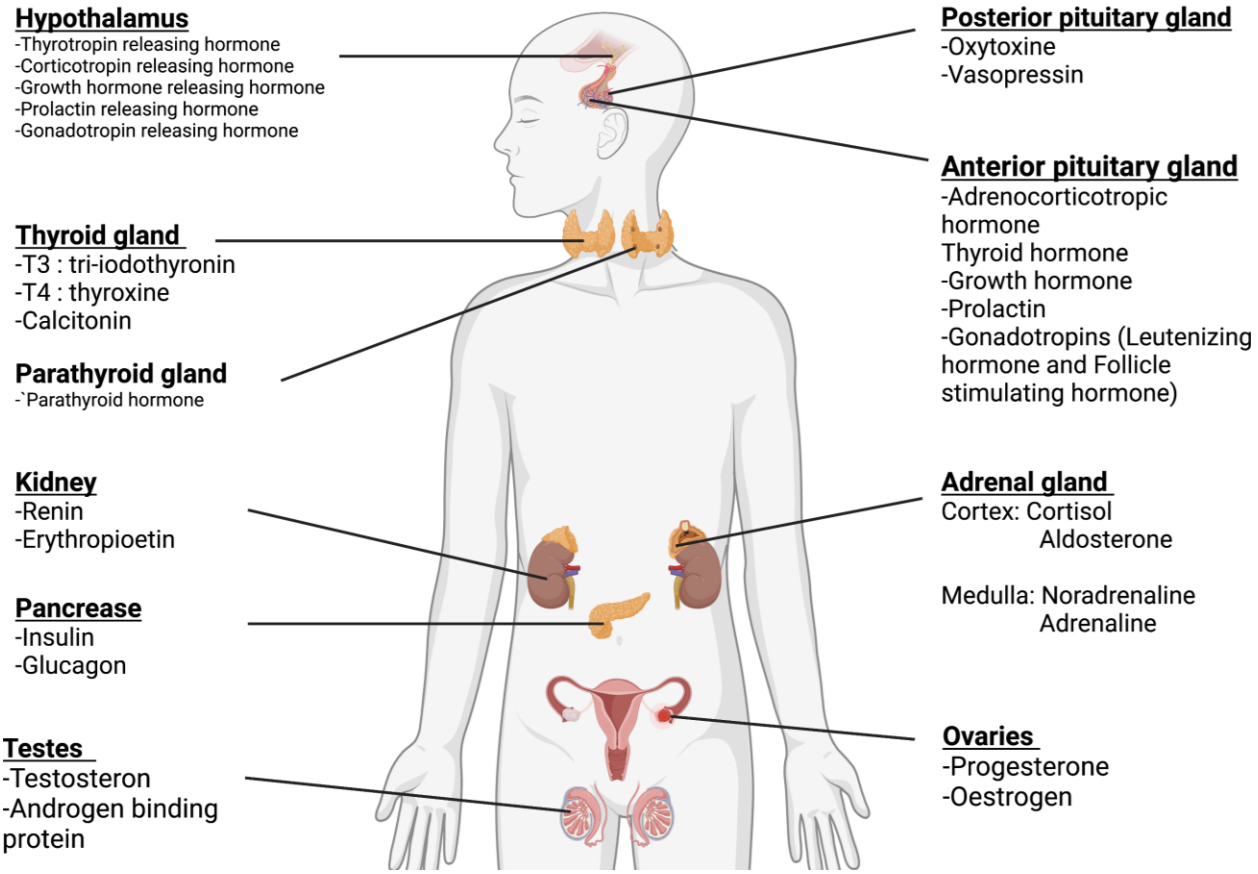
Active Reading

The major endocrine glands are the pituitary (anterior and posterior), pineal, thymus, thyroid, pancreas and adrenal gland. Our reproductive organs, ovaries and testes also produce a few hormones.

Resource Five
Data Source

Section A

Figure 15: Endocrine glands and hormones



Section B

Saltatory conduction

Active Reading

Generally, neurons have a cell body from which extends dendrites and an axon. The dendrites are tree-like structures that receive signals from other neurons and conduct a nerve impulse towards the cell body, while the axon is a nerve fibre that conducts electrical impulses away from the cell body (soma). In some neurons, axons are wrapped in a layer of fatty material called myelin sheath that provides biological electrical insulation. Since there are gaps with no myelin sheath along the axon called nodes of Ranvier, the electrical impulse can move from node to node. This type of conduction is called saltatory conduction. Myelinated axons can conduct an impulse 20 times faster than non-myelinated axons.

Resource Five
Data Source

Section B

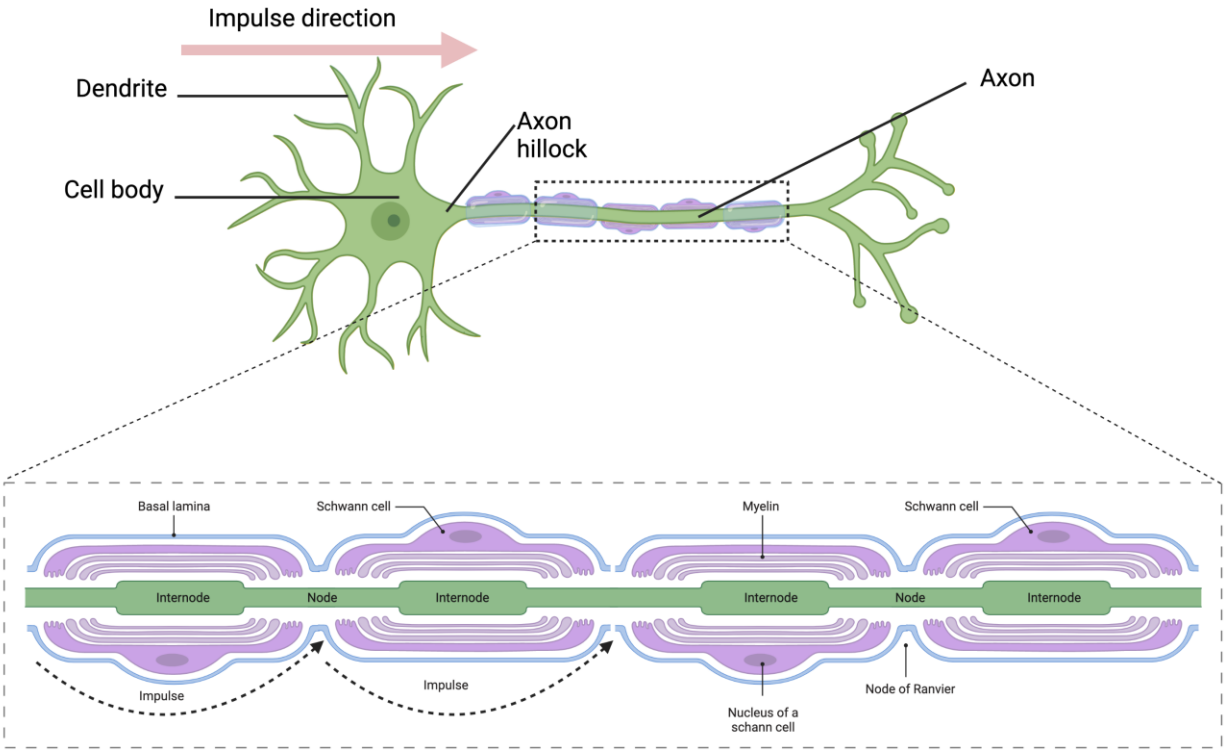
To understand how this conduction works, we must first understand **membrane potentials**.

Neurons differ in the charge between the inside and outside of their membranes. When the neuron is at rest, the inside is more negative than the outside, leading to a resting membrane potential of around -70 mV. At rest, sodium and chloride ions are more prevalent outside the cell, while potassium and organic anion are more prevalent inside. The plasma membranes of neurons have ionic pumps, such as the sodium-potassium pump, which transport proteins. At rest, this transport protein pumps out three sodium ions for every two potassium ions it pumps in. Potassium ions can also easily diffuse across the plasma membrane through ion channels until they reach an equilibrium. These two factors contribute to maintaining a negative resting potential.

During an action potential, there is a rapid and momentary reversal of the membrane potential. This is because when neurotransmitters found in synaptic vesicles bind to the postsynaptic membrane receptors, they cause the membrane potential to become more positive, a process called depolarisation. If this reversal meets the threshold membrane potential (-55 mV), voltage sensitive sodium channels open up, leading to even bigger depolarisation as sodium ions rush into the neuron. As the membrane potential becomes positive, the sodium channels close up, and the potassium channels open, driving a loss of potassium, repolarisation of the membrane and even a hyperpolarisation (the membrane become temporarily more negative than the resting potential). This hyperpolarisation is known as the refractory period. When the potassium channels close, the membrane returns to a resting potential where it can be activated again.

Resource Five
Data Source

Section B **Figure 16: Myelin structure and saltatory conduction**



The appearance of the jumping from one node to the next (from where we have the name saltatory conduction comes) comes from the fact that action potentials slow down at nodes of Ranvier and speed at myelinated portions of the axon. The nodes of Ranvier are rich in sodium channels which open in response to action potentials travelling down the axon allowing for positive sodium ions to rush in. This influx of sodium ions boosts the action potential while the insulation provided by the myelin sheath prevents the dying out by leakage as the action potential travels through the axon.

Resource Five
Activities

Activities

1. What is endocrine signalling?
2. Why are endocrine signals transmitted more slowly that paracrine signals?
3. List five endocrine glands.
4. Give one example of a hormone produced by each of the glands mentioned in response to question 3.

Resource Five
Further Reading

Explore

- https://www.studysmarter.co.uk/explanations/biology/cell-communication/endocrine-signaling/
- https://www.youtube.com/watch?v=-SPRPkLoKp8

References

- Purves D, Augustine GJ, Fitzpatrick D, Hall WC, Lamantia AS, McNamara JO, White LE. Neuroscience. 4th ed. Sunderland, MA. Sinauer Associates; 2008.

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/

Resource Six Overview

Topic

Studying cell communication

Key Stage 5 Subject Area

Methods to study cells (Biology)

Objectives

By completing this resource, you will be able to:

✓ Describe tools used by scientists to study cell communication.

Instructions

1. **Read the data source**
2. **Complete the activities**
3. **Explore the further reading**
4. **Move on to Final Reflection Activity**

Resource Six
Data Source

Section A

Finding Biomedical Sciences research

We began the coursebook with an example of human communication. Even though cells do not talk as we humans do, we saw how cells communicate can be similar to how we communicate.

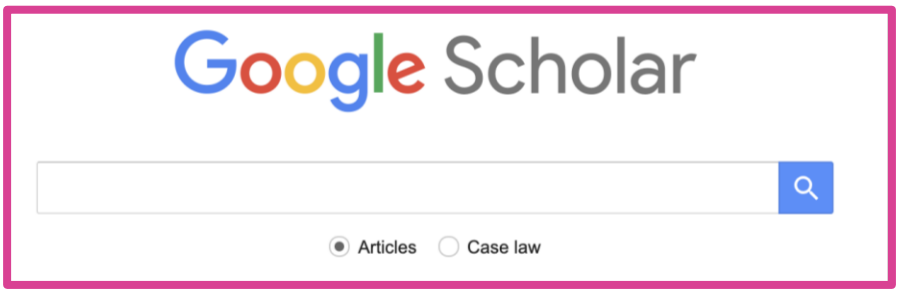
To summarise, cells produce signalling molecules which can travel to target cells. Once in the target cells, these signals can cause an effect. The nature of these signals can be electrical or chemical, and the distance these signals travel varies case by case.

What if we want to study further? The next step will be for you to have a look at the websites below:

https://scholar.google.com/

https://pubmed.ncbi.nlm.nih.gov/

Figure 17: Finding resources



Resource Six
Data Source

Section A

PubMed and Google Scholar are tools (**search engines**) which can enable us to search for scholarly literature. PubMed accesses a database for Life Sciences, and Biomedical Sciences called MEDLINE. Google Scholar returns search results across several disciplines.

To carry out an effective search, you must first identify concepts central to your research and use these concepts as key terms in your search. Your search will yield scientific articles with a title, authors, an abstract (a summary) and the full article. Each article will have a digital object identifier, a string of numbers, letters and symbols linked to that specific article.

Even though PubMed and Google Scholar are free, your search will sometimes yield paid articles.

As you begin to read scientific articles, you may need help understanding their content. However, this will improve with time as your knowledge increases.

Each article has four main sections:

- Introduction – why is the research important?
- Methods – how was the research carried out?
- Results – what were the findings?
- Discussions – what do the results mean?

You may find other important elements in an article, including references, ethics statements, author contributions and funding acknowledgement.

Resource Six
Data Source

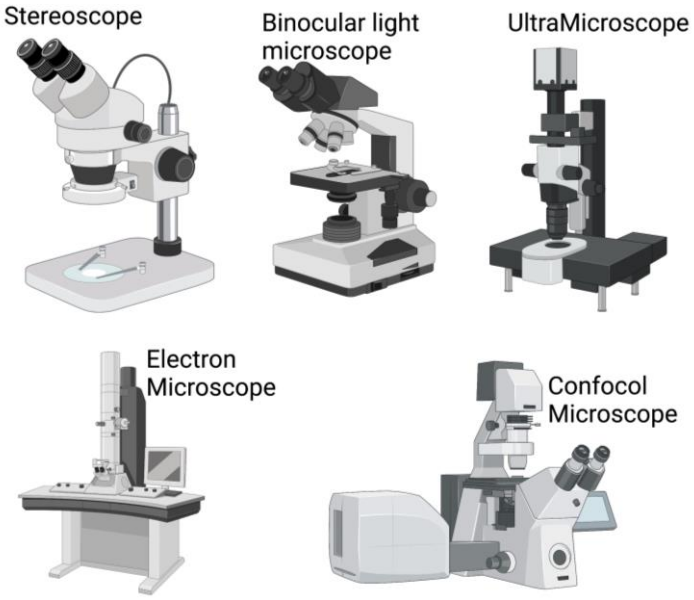
Section B

Tools used to study cell communication

When reading scientific articles, you'll learn about different tools researchers use to study cell communication, such as visualising cells and identifying proteins.

1. **Visualising cells:** Mammalian cells have a diameter of 10 to 100 micrometres (µm). A micrometre is a unit of length equal to one millionth of a metre, while a nanometre is equal to one billionth of a metre. Since cells are so small, we have to employ different cellular imaging methods to visualise them. **Microscopes** permit us to visualise these extremely small objects.

Figure 18: Microscope types



Source Analysis

Active Reading

Generally, microscopes are made up of several lenses that bend light rays passing through them to make the observed object look bigger. To look at intact cells, phase-contrast microscopes are used, while fluorescent microscopes (ultramicroscopes) are useful to visualise single molecules or organelles. Confocal microscopes can help us make high-quality images and 3D reconstructions of cells.

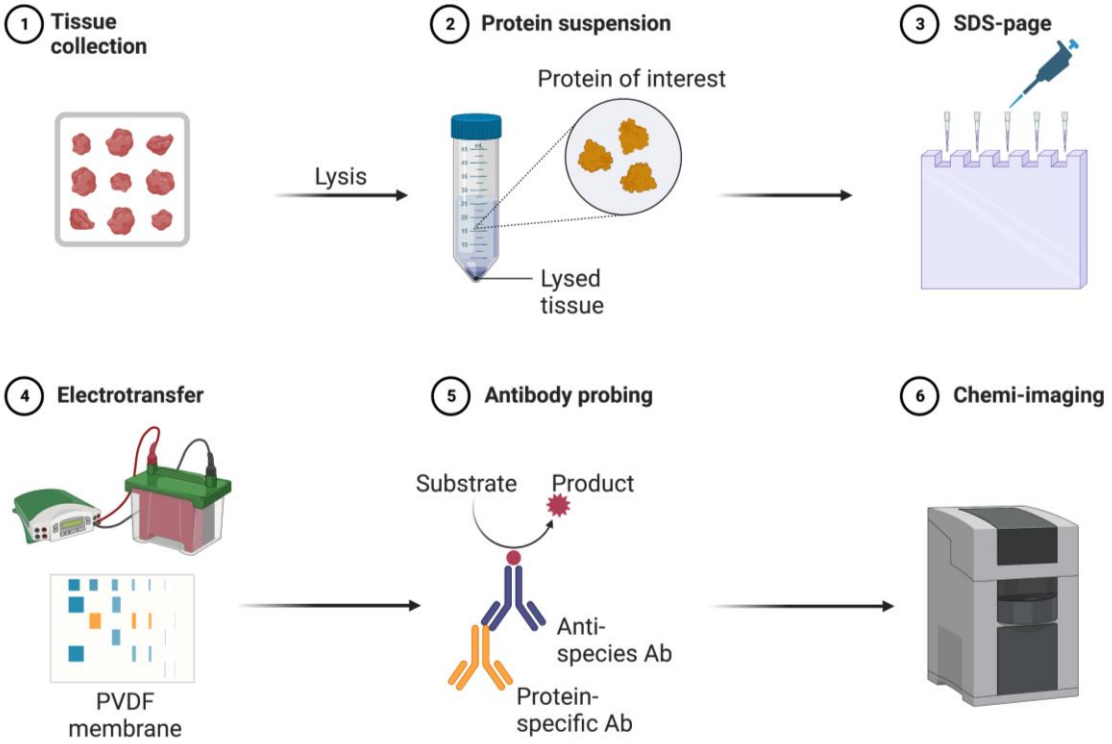
Resource Six
Data Source

Section B

2. **Identifying proteins:** Proteins are large complex molecules linked to hundreds to thousands of amino acids. Proteins participate in every activity required for cell structure and function. According to their functions, the different types of proteins include antibodies, enzymes, messengers, transport and structural proteins.

In my work as a PhD candidate, one of the proteins I am studying is called Tau. Tau is a structural protein that is a microtubule binding protein that is important for the normal function of axons. In Alzheimer's disease, Tau accumulates in the neurons and interferes with the normal functions of the neurons and ultimately causes the neurons to die. To quantify how much Tau has accumulated in any given tissue (I often use brain tissue), I used a Western Blot technique (see Figure 19).

Figure 19: Western blot



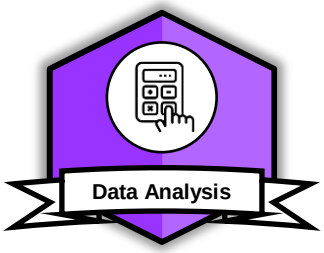
Resource Six
Data Source

Section B

Briefly, the steps western blot steps begin with tissue collection. Sometimes the tissue is fresh, and other times, it is frozen. The tissue must then be mashed with a lysis buffer to extract the protein. The resulting mixture of proteins is separated by molecular weight using gel electrophoresis. The charged protein molecules are transported across the SDS page by an electric field during this process. After the proteins have been separated in the gel, they are transferred to a solid support membrane that can then be used for protein detection with specific antibodies.

In my case, I used an antibody for Tau. However, before I applied the antibody, I blocked the membrane by adding a blocking solution. The blocking solution prevented the antibody from binding to any site other than the protein of interest in the membrane. Even after applying the antibody (the primary antibody), I could not visualise the protein. I had to use a secondary antibody (tagged with a reporter enzyme or fluorophore) that bound to the primary antibody. This enabled me to detect the protein using digital imaging equipment.

Resource Six
Activities



Activities

1. Student must identify relevant articles by following the steps outlined below:

   A. Visit the PubMed search engine and search using the search term ‘Cell communication’ and ‘mammals’.

   B. Repeat the above search on Google Scholar.

   C. How many results do you have in PubMed and Google scholar?

   D. Why do you think the results are different in both search engines?

   E. From your PubMed results, select one of the free articles. You will see the label ‘Free PMC article’ below the title.

   - Can you see the list of authors? Yes/ No
   - Can you see the abstract? Yes/ No
   - Click on the DOI – this should bring you to the full text of the article. Can you access the full text? Yes/ No

Resource Six
Further Reading

Explore

- https://pubmed.ncbi.nlm.nih.gov/help/
- https://www.cmu.edu/student-success/other-resources/handouts/comm-supp-pdfs/imrd-structuring-your-paper.pdf
- https://www.open.edu/openlearn/science-maths-technology/biology/introduction-microscopy/content-section-0?intro=1

References

- https://medlineplus.gov/genetics/understanding/howgeneswork/protein/
- Mahmood T, Yang PC. Western blot: technique, theory, and trouble shooting. N Am J Med Sci. 2012 Sep;4(9):429-34. doi: 10.4103/1947-2714.100998. PMID: 23050259; PMCID: PMC3456489.

Image Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/

Final Reflection Activity

Further Guidance

Below are links to a two-day webinar on Neuroscience research and career for students. This webinar was organised by Sophie Sanford, a student at the UK Dementia Research Institute at Cambridge University.

Day 1: Making it Brain Neuroscience and Career Webinar for students

https://www.youtube.com/watch?v=i5lWI3XBCrM&t=4s&ab_channel=UKDementiaResearchInstitute-UKDRI

Day 2: Making it Brain Neuroscience and Career Webinar for students

https://www.youtube.com/watch?v=7PXNXdFm6DU&t=1615s&ab_channel=UKDementiaResearchInstitute-UKDRI

- Have a look at the time stamps on page 53 to see what each recording contains.
- Choose one session on Day 1 and one session on Day 2 that you'd like to watch.
- Present a 5-minute summary of both sessions to your class.

Tip: *If you have enough time, watch the rest of the webinar!*

Final Reflection Activity

Further Guidance

Day 1 Time stamps	Day 2 Time stamps
0:00:00 Introduction with Sophie Sanford (UK Dementia Research Institute student at Cambridge University)	0:00:00 Introduction with Sophie Sanford (UK Dementia Research Institute student at Cambridge University)
0:02:35 Dr Aitana Sogorb-Esteve (Race Against Dementia ARUK Fellow and Emerging Leader, UK Dementia Research Institute at UCL) *What can blood tell us about dementia? Tools to explore the brain from the outside.*	0:02:30 Prof Selina Wray (UCL) *Building a brain in a dish: How stem cells can help us understand dementia*
0:27:00 Dr Lucia Li (Emerging Leader, UK DRI at Care, Research & Technology) *In the bathroom at 3am? Using smart tech to look after patients after they've left hospital*	0:21:50 Screening *Follow me around the lab*
0:57:50 Dr Zoeb Jiwaji (Clinical Lecturer, UK Dementia Research Institute at the University of Edinburgh) *Being a doctor and a scientist* 1:05:25 Sumi Bez (UK Dementia Research Institute student at UCL) *Being a scientist: From dyslexia to neuroscientist*	0:27:00 Dr Dayne Beccano-Kelly (UK Dementia Research Institute at Cardiff University) *Once upon a time at the synapse: The story of how identifying early changes in the brain could stop Parkinson's disease*
1:14:15 Nan Fletcher-Lloyd (UK Dementia Research Institute student at Care, Research & Technology) *Disabled, queer, and a woman in STEM*	0:50:15 Dr Soyon Hong (UK Dementia Research Institute Group Leader at UCL) *It takes two to tango: How immune and nervous cells work together for healthy brains*
1:21:20 Live Q&A with speakers	1:10:30 Q&A with speakers

Reference List

Journal Articles

- Kambayashi, T., Laufer, T. Atypical MHC class II-expressing antigen-presenting cells: can anything replace a dendritic cell?. *Nat Rev Immunol* 14, 719–730 (2014). https://doi.org/10.1038/nri3754
- Meşe G, Richard G, White TW. Gap junctions: basic structure and function. J Invest Dermatol. 2007 Nov;127(11):2516-24. doi: 10.1038/sj.jid.5700770. PMID: 17934503 .
- XMiller EJ, Lappin SL. Physiology, Cellular Receptor. [Updated 2022 Sep 14]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK554403/
- Wang CM, Ploia C, Anselmi F, Sarukhan A, Viola A. Adenosine triphosphate acts as a paracrine signaling molecule to reduce the motility of T cells. EMBO J. 2014 Jun 17;33(12):1354-64. doi: 10.15252/embj.201386666. Epub 2014 May 19. PMID: 24843045; PMCID: PMC4194124.
- L Naomi Handly, Anna Pilko, Roy Wollman (2015) Paracrine communication maximizes cellular response fidelity in wound signaling eLife 4:e09652 https://doi.org/10.7554/eLife.09652
- Mahmood T, Yang PC. Western blot: technique, theory, and trouble shooting. N Am J Med Sci. 2012 Sep;4(9):429-34. doi: 10.4103/1947-2714.100998. PMID: 23050259; PMCID: PMC3456489.

Reference List

Books

- Essentials of Cell Biology (2004 Garland Science)
- Chapter 36 - Approaches and methods to study cell signaling: Linguistics of cellular communication, Advances in Protein Molecular and Structural Biology Methods, Academic Press, 2022, https://doi.org/10.1016/B978-0-323-90264-9.00036-2.

Images Sources

- Diagrams were generated with Biorender (https://app.biorender.com/)
- https://www.pexels.com/
- https://doi.org/10.15252/embj.201386666
- https://labs.openai.com/

More Subject Resources

A Deeper Look into Cell Communication

Read

- https://training.seer.cancer.gov/anatomy/cells_tissues_membranes/cells/structure.html#:~:text=A%20cell%20consists%20of%20three,but%20distinct%20structures%20called%20organelles.
- https://doctorlib.info/physiology/medical/10.html
- https://www.wikiwand.com/en/Cell_signaling

Watch

- https://www.youtube.com/watch?v=5MoIg5lWLXA
- https://www.khanacademy.org/science/biology/human-biology/neuron-nervous-system/v/anatomy-of-a-neuron

Study Skills, tips & Guidance

This section includes helpful tips to help you complete this pack and improve your study skills for school.

It also includes a few fantastic, easy-to-use resources to know what to do next and where else you can look for more information on the subject.

Helpful information you will find in this section:

1. Cornell Notes
2. Academic Terminology (keywords)
3. Academic Writing Style
4. Referencing
5. How to Evaluate Your Sources
6. Subject Guidance
7. University Guidance

Psst! Learning these tips to improve your school skills could help you do better in exams and make assignments easier!

You can use the tips and web links in this section throughout your pack!

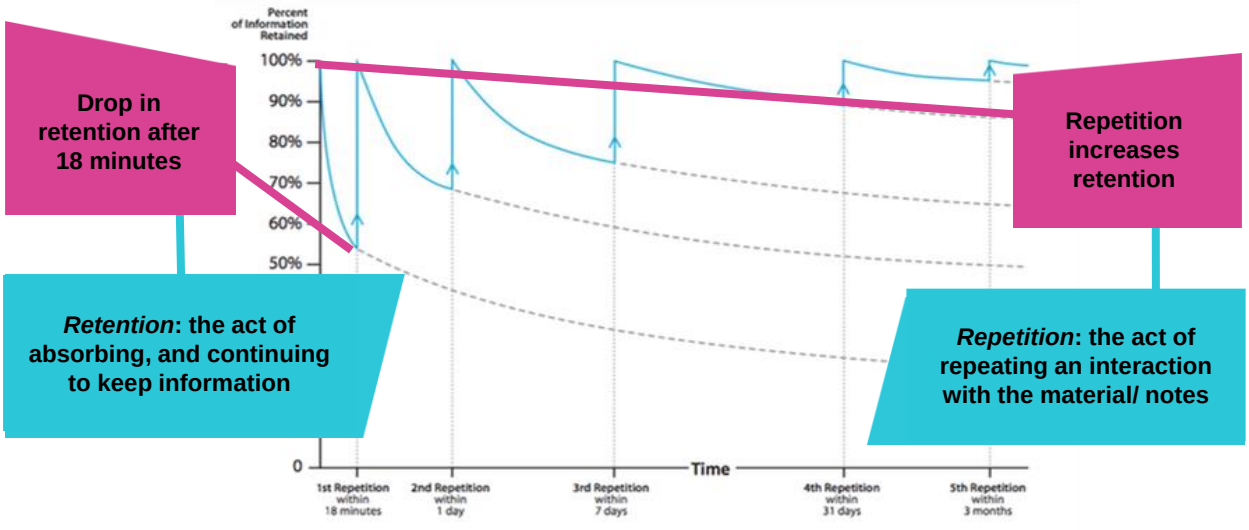
Academic Study Skills

Cornell Notes

Why is good note-taking important?

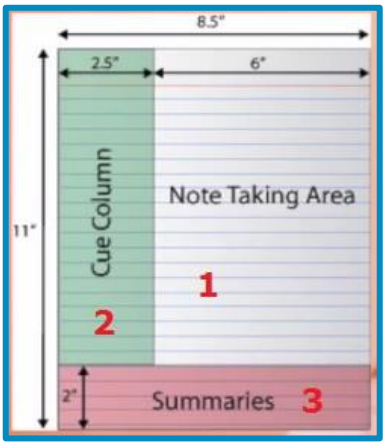
If you forget new information almost as quickly as you hear it, even if you write it down, you tend to lose nearly 40% of new information within 24 hours of first reading or hearing it.

However, if we take notes effectively, we can retain and retrieve almost 100% of the information we receive. Consider this graph on the rate of forgetting with study/ repetition:



Learning a new system

The Cornell Note System was developed in the 1950s at the University of Cornell in the USA. The system includes interacting with your notes and is suitable for all subjects. There are three steps to the Cornell Note System.



Step 1: Note-Taking

1. ***Create Format:*** Notes are set up in the Cornell Way. This means creating three boxes like the ones on the left. You should put your name, date, and topic at the top of the page.
2. ***Write and Organise:*** You then take your notes in the 'note taking' area on the right side of the page. It would be best if you organised these notes by keeping a line or a space between 'chunks'/ main ideas of information. You can also use bullet points for lists of information to help organise your notes.

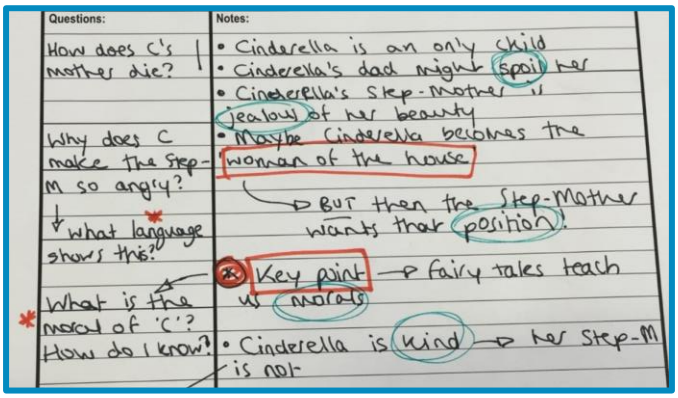
Academic Study Skills

Cornell Notes

Step 2: Note-Making

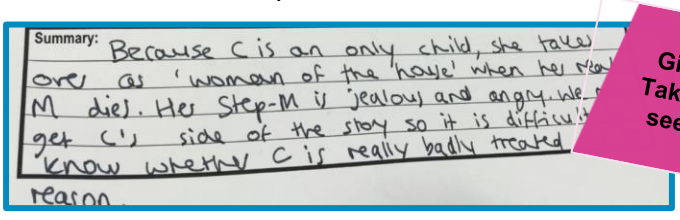
1. ***Revise and Edit Notes***: Go back to box 1, the note-taking area and spend some time revising and editing. You can do this by highlighting 'chunks' of information with a number or a colour; circling all keywords in a different colour; highlighting main ideas; adding new information in another colour.
2. ***Note Key Idea:*** Go to box two on the left-hand side of the page and develop some questions about the main ideas in your notes. The questions should be 'high level'. This means they should encourage you to think deeper about the ideas. Example 'high level' questions would be:
    - Which is the most important/ significant reason for…
    - To what extent…
    - How does the (data/ text/ ideas) support the viewpoint?
    - How do we know that…

Here is an example of steps 1 and 2 for notes on the story of Cinderella



Step 3: Note-Interacting

1. ***Summary:*** Go to box three at the bottom of the page, summarise the main ideas in box one, and answer the essential questions in box 2.



Give the Cornell Note-Taking System a try and see if it works for you!

Academic Study Skills

Key Words

Below is a series of key terms you will come across from teachers and tutors as you go through school, especially as you enter upper secondary.

Knowing these will help you understand what you are being asked to do!

- ***Analyse:*** When you analyse something, consider it carefully and in detail to understand and explain it. To analyse, identify the main parts or ideas of a subject and examine or interpret the connections between them.
- ***Comment on:*** When you comment on a subject or the ideas in a subject, you say something that gives your opinion or an explanation.
- ***Compare:*** To compare things means to point out their differences or similarities. A comparison essay would involve examining the qualities/ characteristics of a subject and emphasising the similarities and differences.
- ***Contrast:*** When you contrast two subjects, you show how they differ when compared with each other. A contrast essay should emphasise striking differences between two elements.
- ***Compare and contrast:*** To write a compare and contrast essay, you would examine the similarities and differences between two subjects.
- ***Criticise:*** When you criticise, you make judgments about a subject after thinking about it carefully and deeply. Express your judgement concerning the correctness or merit of the factors under consideration. Give the results of your analysis and discuss the limitations and contributions of the factors in question. Support your judgement with evidence.
- ***Define:*** When you define something, you show, describe, or state clearly what it is and what it is like; you can also say its limits. Do not include details but do include what distinguishes it from the other related things, sometimes by giving examples.
- ***Describe:*** To describe in an essay requires you to give a detailed account of a subject's characteristics, properties or qualities.
- ***Discuss:*** To discuss in an essay, consider your subject from different points of view. Examine, analyse and present considerations for and against the problem or statement.

Academic Study Skills

Key Words

- ***Evaluate:*** When you evaluate in an essay, decide on your subject's significance, value, or quality after carefully studying its good and bad features. Similar to assess. Use authoritative (e.g. from established authors or theorists in the field) and, to some extent, personal appraisal of both contributions and limitations of the subject.
- ***Illustrate:*** If asked to illustrate in an essay, explain the points that you are making clearly by using examples, diagrams, statistics, etc.
- ***Interpret:*** In an essay that requires you to interpret, you should translate, solve, give examples, or comment upon the subject and evaluate it in terms of your judgement or reaction. Explain what your subject means. Similar to explain.
- ***Justify:*** When asked to justify a statement in an essay, you should provide the reasons and grounds for the conclusions you draw from the statement. Present your evidence in a form that will convince your reader.
- ***Outline:*** Outlining requires that you explain ideas, plans, or theories in a general way, without giving all the details. Organise and systematically describe the main points or general principles. Use essential supplementary material, but omit minor details.
- ***Prove:*** When proving a statement, experiment or theory in an essay, you must confirm or verify it. You must evaluate the material and present experimental evidence and/ or logical argument.
- ***Relate:*** To relate two things, you should state or claim the connection or link between them. Show the relationship by emphasising these connections and associations.
- ***Review:*** When you review, critically examine, analyse and comment on the major points of a subject in an organised manner.

Write any other keywords you come across below. Ask your teacher to explain their meaning or use a dictionary to find out.

Academic Study Skills

Academic Writing Style

What is academic writing?

'Academic writing' is a specific way of writing when communicating research or discussing a point of view. You will most often do this in essays and reports.

Academic writing has a logical structure and uses formal language. Unlike creative or narrative writing, academic writing uses different sources of information to support what is being said (see next page about various sources).

Top Academic Writing Tips

Do's

- Do use words you know the meaning of and are confident using.
- Remember, words don't have to be complicated to be clear!
- Do write words out fully, e.g., do not, cannot, does not, it would.
- Use the third person point of view
- Minimise the use of informal adjectives, such as cool, amazing and wonderful.

Don'ts

- Do not use contractions, e.g., don't, can't, doesn't, it'd.
- Do not use public speaking phrases like "We can all agree that…" and "As I previously mentioned…".
- Do not use conversational phrases, such as 'literally' or 'basically' too often.
- Do not use slang or jargon, for example, 'awks', 'lit', 'woke'.
- Do not use words that express value judgements, e.g., crazy, ridiculous, terrible. Suitable synonyms are surprising, unjustified or distressing.

Academic Study Skills

Academic Writing Style

Expressing your opinion in academic writing

In academic writing, it is best practice to express an opinion without writing in the first person.

Rather than saying, 'In my opinion, this proves that you can express your opinion by saying:

- 'Based on (insert fact/ theory/ finding) it shows that….';
- 'The graph here indicates that…';
- 'The aforementioned problems in Smith's argument reveal that…';
- 'Such weaknesses ultimately mean that…'; and so on.

Signposting

Signposting guides your reader through different sections of your writing. It lets those who read your writing know what is being discussed and why and when your piece is shifting from one part to another. This is crucial for clear communication with your audience.

Signposting stems for a paragraph which expands upon a previous idea	Signposting stems for a paragraph which offers a contrasting view
Building on from the idea that ... (mention the previous idea), this section illustrates that ... (introduce your new idea).	However, another angle on this debate suggests that ... (introduce your contrasting idea)
To further understand the role of ...(your topic or your previous idea), this section explores the idea that ... (introduce your new idea)	In contrast to evidence which presents the view that ... (mention your previous idea), an alternative perspective illustrates that ...
Another line of thought on ... (your topic or your previous idea) demonstrates that ...	However, not all research shows that ... (mention your previous idea). Some evidence agrees that ...

Academic Study Skills

Referencing

What is a reference or referencing?

A reference is just a note in your assignment that tells your reader where particular ideas, information or opinions that you have used from another source have come from. It can be done through ‘citations’ or a ‘bibliography’.

You must include references in your writing assignments when you get to university. As well as being academic good practice, referencing is very important because it will help you to avoid plagiarism.

Plagiarism is when you take someone else’s work or ideas and pass them off as your own. Whether plagiarism is deliberate or accidental, the consequences can be severe. You must be careful to reference your sources correctly.

Why should I reference?

Referencing is essential in your work for the following reasons:

- It gives credit to the authors of any sources you have referred to or been influenced by.
- It supports the arguments you make in your assignments.
- It demonstrates the variety of sources you have used.
- It helps prevent you from losing marks or failing due to plagiarism.

When should I use a reference?

- You should use a reference when you:
- Quote directly from another source.
- Summarise or rephrase another piece of work.
- Include a specific statistic or fact from a source.

Academic Study Skills

Referencing

How do I reference?

There are several different ways of referencing, but most universities use the Harvard Referencing Style. Please speak with your teacher about which style they want you to use because the most important thing is that you remain consistent!

The two main aspects of referencing you need to be aware of are:

1. In-text citations

These are used when directly quoting a source. They are in the body of the work after you have referred to your source in your writing. They contain the surname of the source's author and the year it was published in brackets.

- E.g. *Daisy describes her hopes for her infant daughter, stating, "I hope she'll be a fool—that's the best thing a girl can be in this world, a beautiful little fool." (Fitzgerald, 2004).*

2. Bibliography

This is a list of all the sources you have referenced in your assignment. In the bibliography, you list your references by the numbers you have used and include as much information as possible about the reference. The list below gives what should be included for different sources.

- ***Websites:*** Author (if possible), *title of the web page*, 'Available at:' website address, [Accessed: date you accessed it].
  - E.g. *'How did so many soldiers survive the trenches?',* Available at: http://www.bbc.co.uk/guides/z3kgjxs#zg2dtfr [Accessed: 11 July 2019].

- ***Books:*** Author surname, author first initial, (year published), *title of book*, publisher
  - E.g. Dubner S. and Levitt, S., (2007) *Freakonomics: A Rogue Economist Explores the Hidden Side of Everything,* Penguin Books

- ***Articles:*** Author, *'title of the article'*, where the article comes from (newspaper, journal, etc.), date of the article.
  - E.g. Maev Kennedy, *'The lights to go out across the UK to mark First World War's centenary',* The Guardian Newspaper, 10 July 2014.

Academic Study Skills

Referencing

Is it a source worth citing? Use these tips to question your sources before referencing them.

- ***Currency – the timelines of the information:*** When was it published or posted? Has it been revised or updated? Does your topic require current information, or will older sources also work?
- ***Relevancy – the importance of the information for your needs:*** Does the information relate to your topic or answer your question? Have you looked at a variety of sources? Who is the intended audience?
- ***Authority - the source of the information:*** Who is the author/ publisher/ source/ sponsor? What are the author's credentials? Is the author qualified to write on the topic?
- ***Accuracy – the reliability and correctness of the source:*** Does evidence support the information? Has the information been reviewed or refereed? Can you verify whether it is a personal or professional source? Are there errors?
- ***Purpose – the reason the information exists:*** Does the author clarify the intentions/ purpose? Is the information fact opinion or propaganda? Are there biases? Does the viewpoint appear objective?

Academic Study Skills

Evaluating Your Sources

What is a source?

When you learn new things, you might get information from different places. These places are called sources. Some sources are more reliable than others. For example, information in a textbook written by an expert is more reliable than the information in a non-expert's social media post.

How do you decide which source to use? From newspaper articles to books to tweets, this provides a brief description of each source type and breaks down the factors to consider when selecting a source.

Twitter

A platform for millions of concise messages on a variety of topics.

Blog

Blogs (e.g. WordPress) are an avenue for sharing both developed and unpublished ideas and interests with a niche community.

Youtube

A collection of millions of educational, inspirational, eye-opening and entertaining videos.

Newspaper

A reporting and recording of cultural and political happenings that keeps the general public informed. Opinions and public commentaries can also be included.

Journal

A collection of analytics reports that outline the objectives, background, methods, results and limitations of new research written for and by scholars in a niche field.

Academic book

The information presented is supported by clearly identified sources. Sometimes each chapter has a different author.

Encyclopaedia

Books or online – giving information on many different subjects. Some are intended as an entry point into research; some provide detailed information and onwards references.

Popular magazine

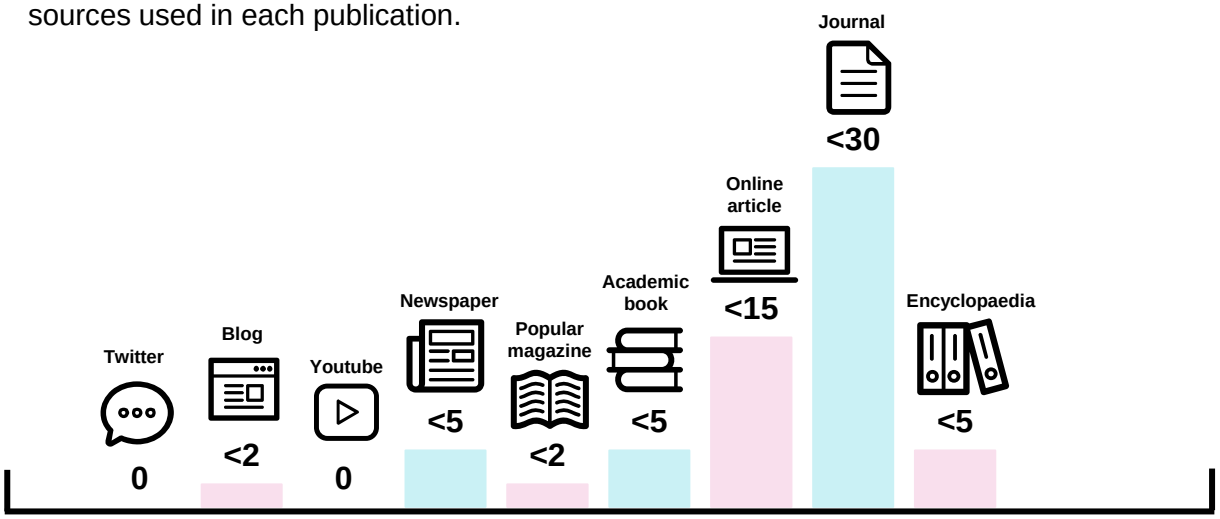
A glossy compilation of stories with unique themes intended for specific interests.

Academic Study Skills

Evaluating Your Sources

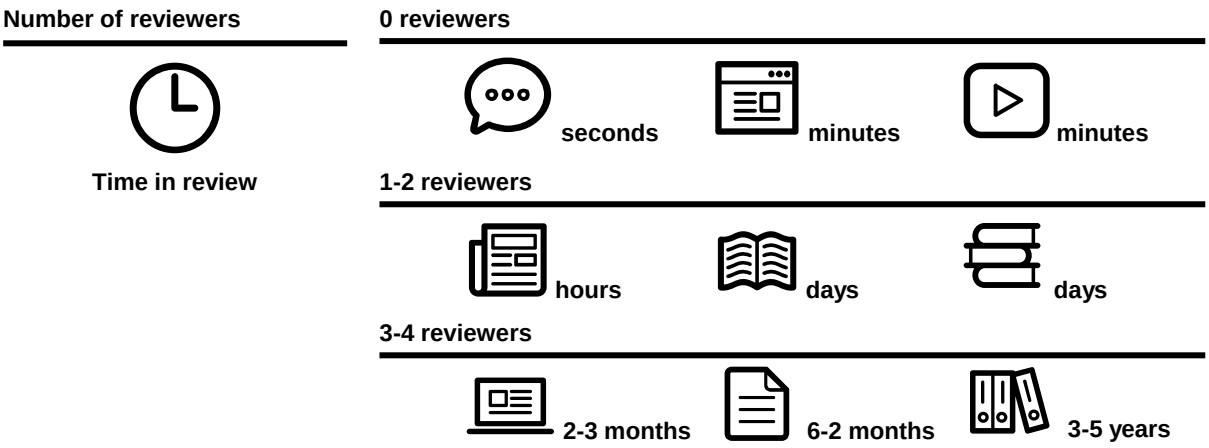
Number of outside sources

When an author used many outside sources in their writing, they demonstrate familiarity with ideas beyond their own. As more unique viewpoints are pulled into a source, it becomes more comprehensive and reliable. This shows the typical number of outside sources used in each publication.



Degree of review before a source is published

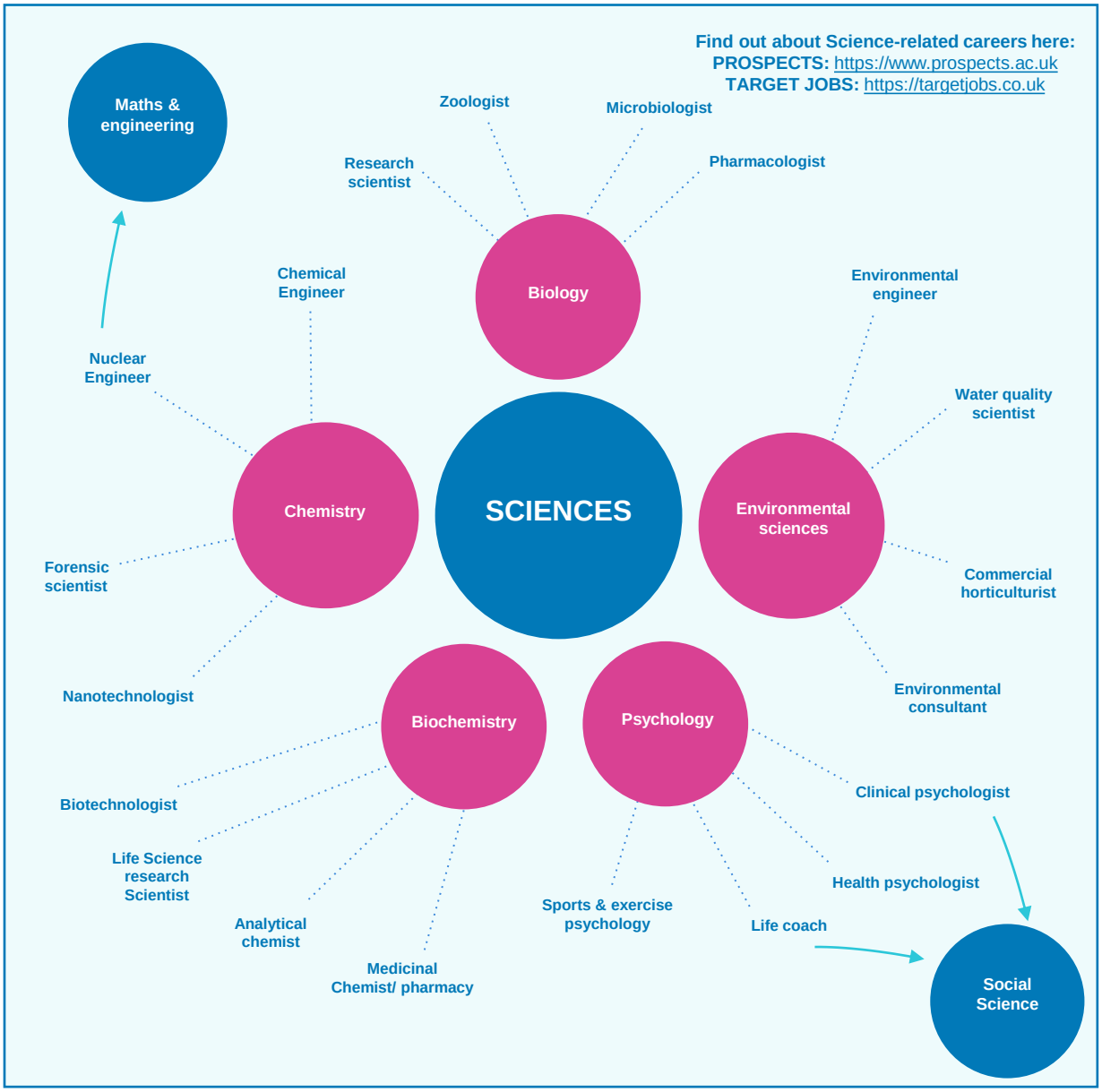
Two factors contribute to the amount of inspection a source receives before it might be published: the number of reviewers fact-checking the written ideas and the total time spent by reviewers as they fact-check. The more people involved in the review process and the longer the review process takes, the more credible the source is likely to be.



What's next?

Sciences subject maps & jobs

A degree in Sciences gives Students access to many career choices. Students who study sciences go on to pursue their Master's degree in Science. However, a significant portion of them also start looking for jobs in the fields of Cancer Research, Stem Cell technology and other positions in this space.



What's next?

University Guidance

Different people go to university for different reasons. You might have a particular job in mind or want to study a subject you are passionate about.

Whatever your motivations, going to university can help improve your career prospects and develop your confidence, independence and academic skills.

Choosing a course and university

Choosing the right course to study is important, so research the options available to you. Here are some top tips:

- You don't have to choose a course you have already studied; many courses don't require prior knowledge of the subject. You can apply skills gained from school studies to a new field.
- The same subject can be taught differently depending on your chosen course and university. Search university websites to learn more about the course content, teaching styles and assessment types.
- When choosing a university, think about what other factors are important to you. Do you want to study at a campus university or be based in a city center? What accommodation options are there? Does the university have facilities for any extracurricular activities you're involved in?
- To research your options, look at university prospectuses and websites and see if there are opportunities to speak to current students who can give you a real insight into what life is like there.

What's next?

University Guidance

Exploring careers and subject options

- Find job descriptions, salaries and hours, routes into different careers, and more at **https://www.startprofile.com/**
- Research career and study choices, and see videos of those who have pursued various routes at **http://www.careerpilot.org.uk/**
- See videos about what it's like to work in different jobs and for different organisations at **https://www.careersbox.co.uk/**
- Find out what different degrees could lead to, how to choose the right course for you, and how to apply for courses and student finance at **https://www.prospects.ac.uk/**
- Explore job descriptions and career options, and contact careers advisers at **https://nationalcareersservice.direct.gov.uk/**
- Discover which subjects and qualifications (not just A levels) lead to different degrees and what careers these degrees can lead to at **http://www.russellgroup.ac.uk/media/5457/informed-choices-2016.pdf**

Other useful resources

- **https://www.ucas.com/**
- **https://www.whatuni.com/**
- **https://www.opendays.com/**
- **https://www.thecompleteuniversityguide.co.uk/**

You may or may not have thought about studying at university.

Don't worry – you have plenty of time to think about this and explore your options if you would like to go!

What's next?

University Guidance

UCAS and the university application process

All applications for UK degree programmes are made through **UCAS**. There is lots of information on the UCAS website to guide you through the process and what you need to do at each stage.

Apply	• Applications **open in September** the year before you plan to start university. • You can apply for up to **five courses.** • The deadline for most courses is **25 January**.
Decisions	• Some courses may require an interview, portfolio or admissions test in addition to a UCAS application. Check individual university website details. • Check UCAS Track which will be updated with decisions from the universities you have applied for, and to see your deadline for replying to any offers. • You should choose a firm (or first) choice university and an insurance choice. If you already have your exam results or a university thinks your application is particularly strong, you might receive an **unconditional offer**.
Results	• If you're holding a conditional offer, then you will need to wait until you receive your exam results to have your place confirmed. • Clearing & Adjustment allows you to apply to courses which still have vacancies if you didn't meet the conditions of your offer, have changed your mind about what or where you want to study, or have met and exceeded the conditions of your offer and would like to look at alternate options.

Personal statements

An important part of your application is the personal statement. The personal statement allows you to tell universities why they should offer you a place.

Here are a few top tips for making your personal statement stand out:

- You can only submit one personal statement, so it's important that you are consistent in your course choices. Make sure you have done your research to show your understanding of the subject area and your passion for it.

What's next?

University Guidance

Personal Statement (cont.)

- Start by brainstorming all your skills, experience and attributes. Once you have everything written down, you can begin to be selective – you only have 47 lines so won't be able to include everything.
- The ABC method: action, benefit and course can be a useful way to help demonstrate your relevant experience and how it applies to the course you're applying for.

Personal Statement do's and don'ts

Read the tips below from real life professors and admissions staff in university Science departments, on the 'do's' and 'don'ts' of what to include in your personal statement.

Science

- Tell us why you want to study Science.
- What area of Science fascinates you?
- Demonstrate your interest by telling us what you have recently read, watched or listened to and how they helped your understanding of Science.
- Describe how your school or individual work has equipped you with the necessary knowledge and ability to be a successful Science student.

Other useful resources

- An easy template to start practising your personal statement: **https://www.ucas.com/sites/default/files/ucas-personal-statement-worksheet.pdf**
- Untangle UCAS terminology at **https://www.ucas.com/corporate/about-us/who-we-are/ucas-terms-explained**
- Discover more about the application process including when to apply and how to fill in your application on the **UCAS website.**
- Read more useful advice about what to include in your personal statement on **UCAS**, **the Complete University Guide** and **The UniGuide.**
- Attend one of the Physiological Society 's **virtual sessions** to find out more about applying and personal statements.

Insight into the Physiological Society

About us

As the largest network of physiologists in Europe, with academic journals of global reach, The Physiological Society continues a 150-year tradition of being at the forefront of the life sciences.

The Physiological Society supports the advancement of Physiology by promoting collaboration between Physiologists worldwide, organising world-class conferences and publishing the latest developments in their scientific journals.

Research in Physiology helps young people to understand how the body works in health, what goes wrong in disease, and how the body responds to the challenges of everyday life.

To find out more and join our community, visit physoc.org/join.

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LinkedIn The Physiological Society

The Neurosparks Project

The Physiological Society funded the development of this resource pack as of the Neurospark Project.

The Neurosparks Project produced four digital resource packs for Key Stage 5 students that centre around the overarching theme of 'Our Electric Bodies'.

Resource packs were written by PhD researchers, each incorporating six chapters of research-inspired subject content, as well as university study skills materials, information advice and guidance, and careers-linked motivational content, for young people.

Click here to download these curriculum-linked, interdisciplinary, and free resources for under-served young people.

The front cover of this resource pack was designed by Dr Lizzie Burns (@DrLizzieBurns). For more information, contact scienetolife@yahoo.co.uk.

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