BL2131 Notes

Foundations in Biology II
Topics 1 to 7

This is a compilation of topics taught in BL2131.
Made by LQ

"Double the initial number of the module code, double the pain!" ~Einstein or someone idk

Links of All LQ Notes: LQ Notes Links Document

Author's Note

Please use at your own discretion, information in this set of notes may not be correct *(im not good at bio okay)*, do confirm with your Lovely Biology Teachers if you have any doubt, and if you can, drop a comment in the notes if you find a mistake.

Information marked with [confirm] need further clarification, if you have knowledge on the content, pleeeeeaaaassse help.

Everything that says "FYI" is purely for additional reading, and is not tested (at this level).

Thanks for reading and good luck! :D

Note: Topic 1 - Transport in Plants is NOT tested for EOY Exams.

Topic 1: Transport in Plants

Recap: If you need a Recap for Y1 Biology BL1131, consider referring to BL1131 Notes **Topic 7: Nutrition in Plants** before continuing.

1.1 Parts of a Leaf

Consider the **transverse** section of a Privet (*ligustrum*) plant below, in *Figure 1.1*.

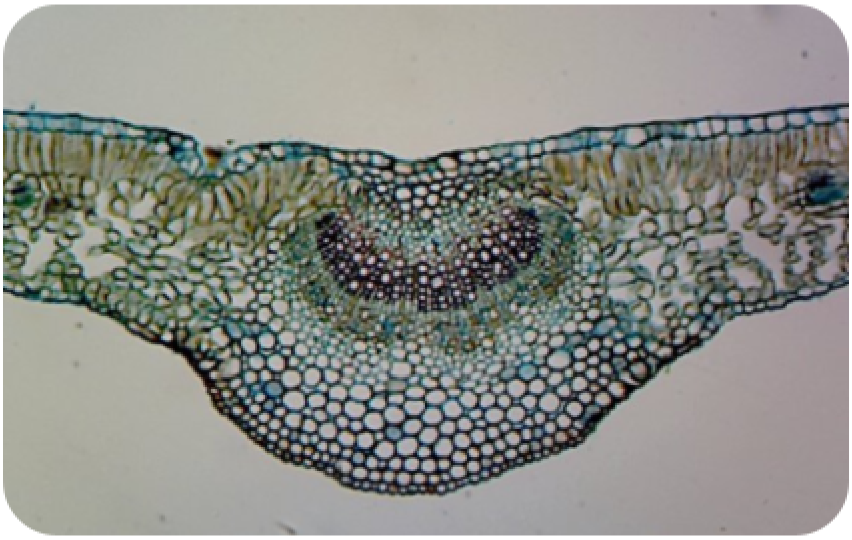


Figure 1.1: A Transverse Section of a Ligustrum Leaf

This is a typical **dicotyledonous** (or dicot, for short) leaf. We can label this transverse section as such:

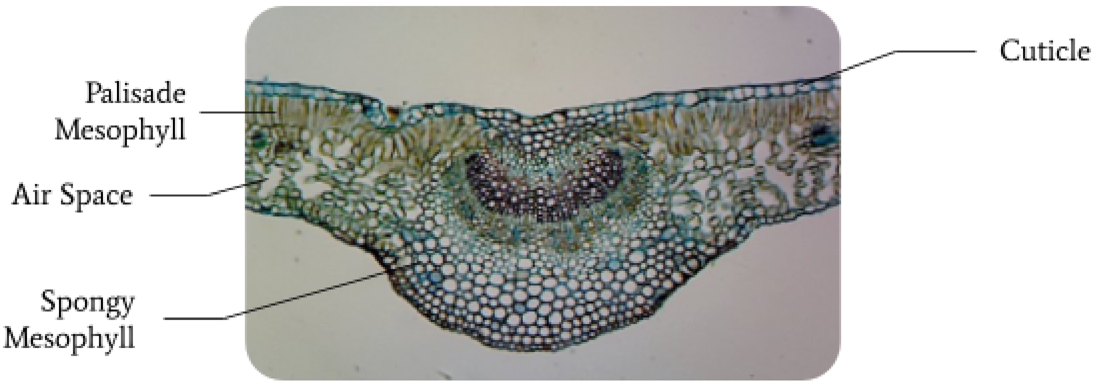


Figure 1.2: Labelled Transverse Section of Ligustrum Leaf

However, as you might notice, the stoma and vascular bundles are not labelled.

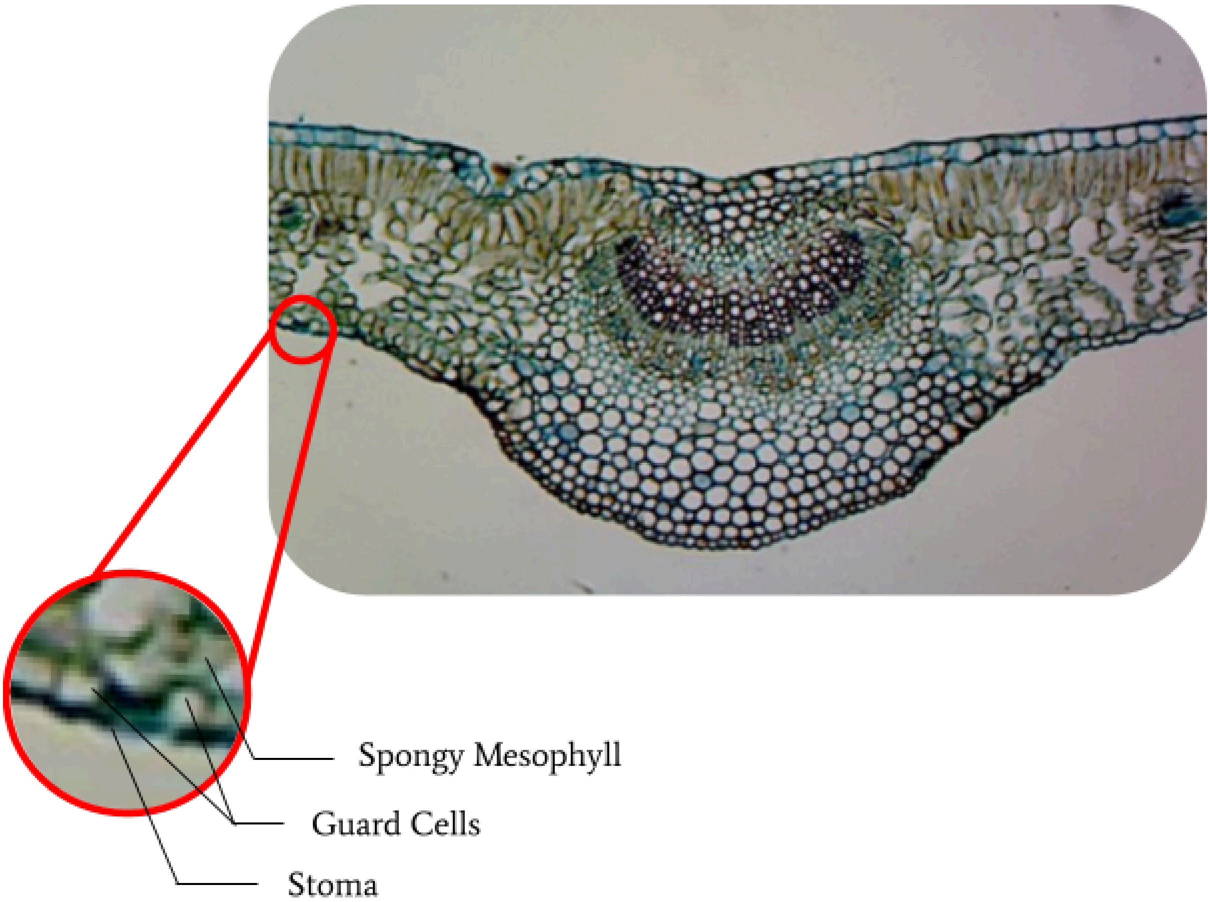


Figure 1.3: Labelled Stoma of Ligustrum Leaf

Figure 1.3 above shows the stoma of the Ligustrum Leaf.

For clarity's sake, here's a clearer image of what the stoma looks like, from an Alfalfa (*Medicago Sativa*) plant:

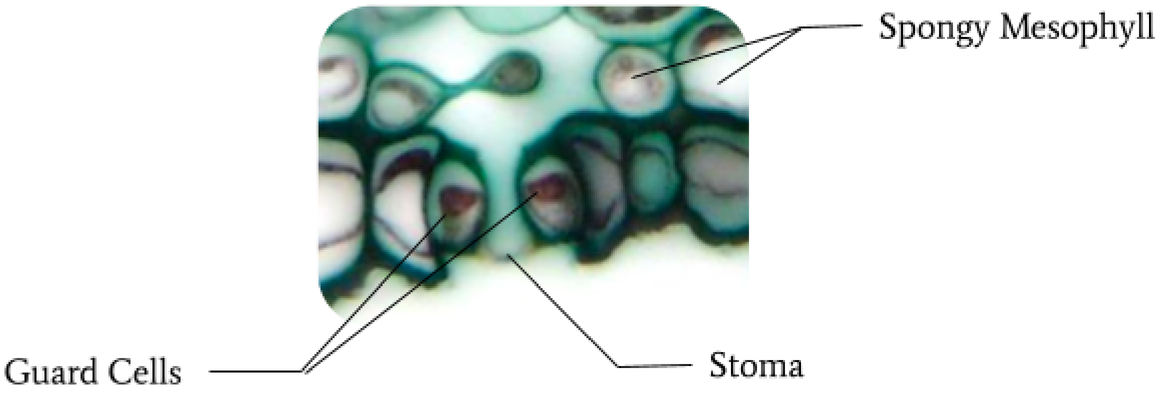


Figure 1.4: Labelled Stoma of Medicago Sativa Leaf

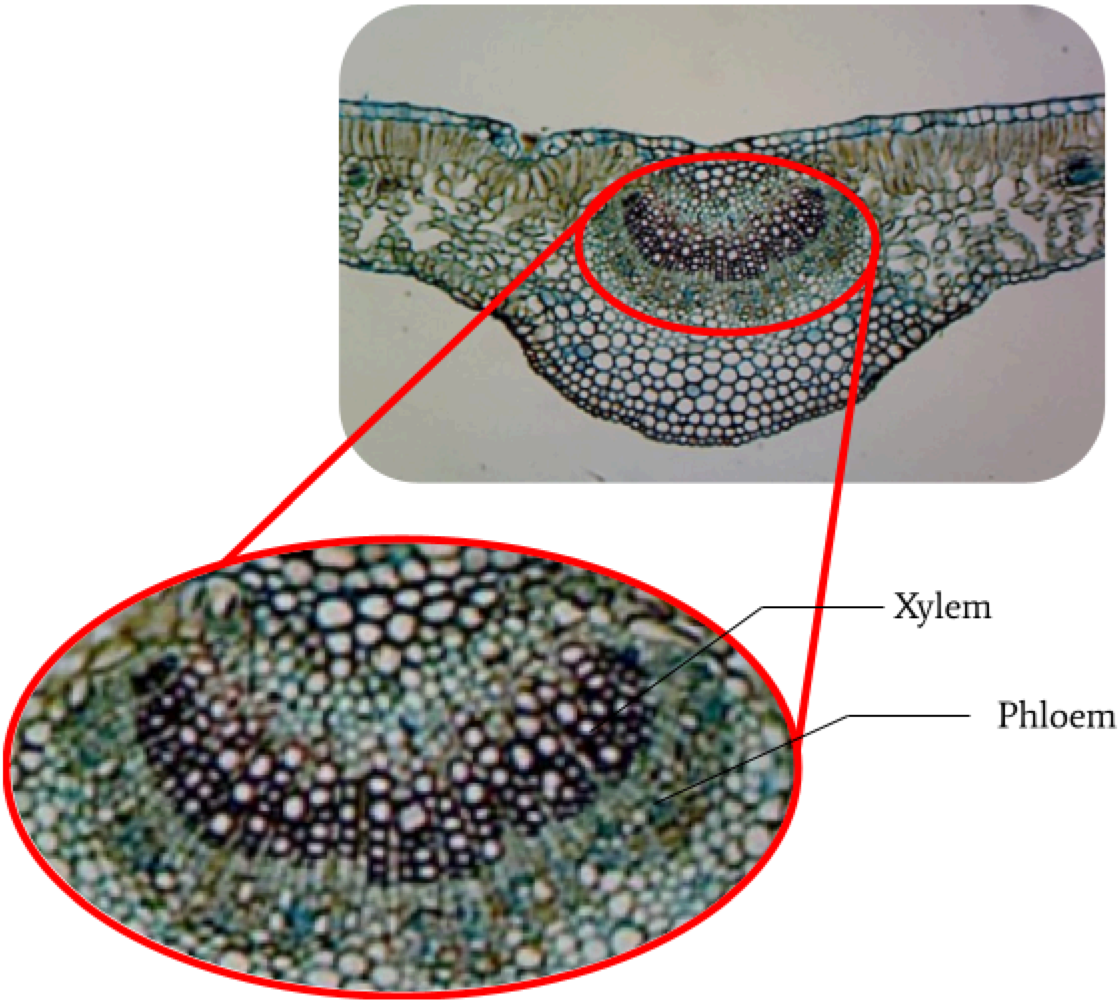


Figure 1.5: Labelled Vascular Bundle of Ligustrum Leaf

Note that the **xylem** is always **above** the **phloem** (when the leaf is positioned naturally, i.e. stomata on the bottom).

1.2 Vascular Tissues in the Stem

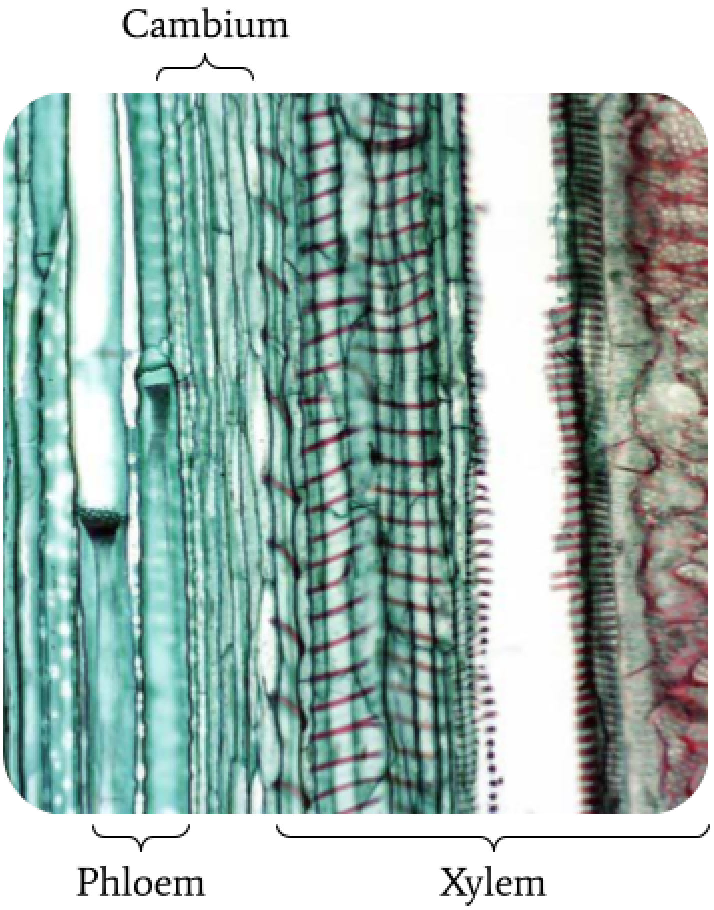


Figure 1.6: Longitudinal Section of Cucurbita Stem

Figure 1.6 above shows the Longitudinal Section of Vascular Tissues of a Squash (*Cucurbita)* Plant Stem. The xylem is always positioned closer to the centre of the stem than the phloem, as in *Figure 1.7* below:

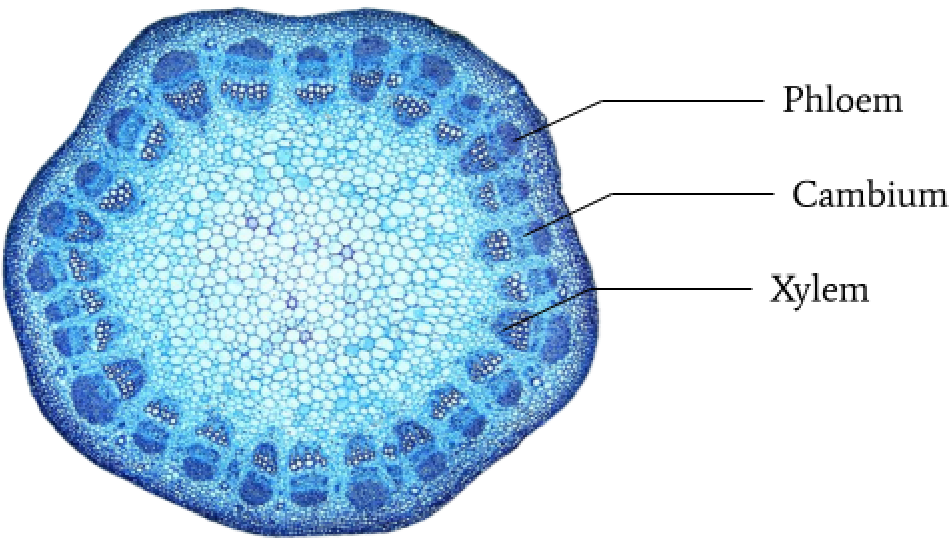


Figure 1.7: Cross Section of a Plant Stem

1.3 Vascular Tissues in the Roots

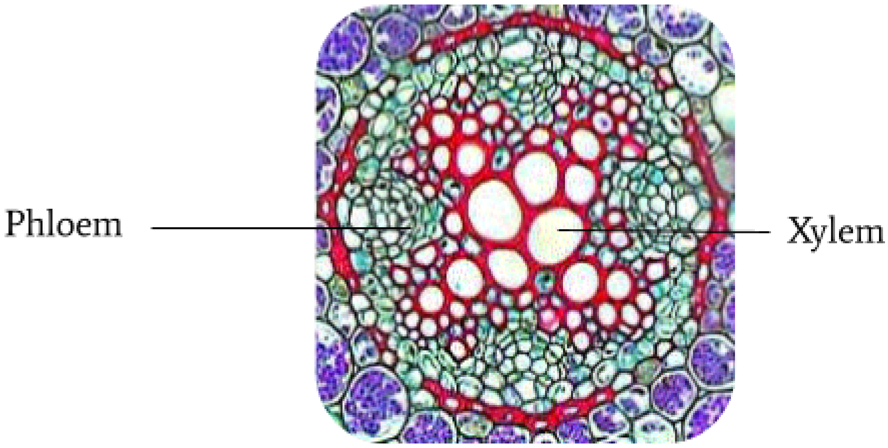


Figure 1.8: Cross Section of a Ranunculus Plant Root

Figure 1.8 above shows the xylem and phloem of a Buttercup (*Ranunculus*) Plant Root. As you can see, we can observe that the phloem and xylem are **not packed into vascular bundles** like they are in the stem or leaves.

The xylem is also **shaped** in the shape of a **star** *(or X, or cross, or whatever you call it)*.
The xylem and phloem alternate with each other.

1.4 Xylem Vessels

Xylems are the **water-carrying tubes** of a plant.

1.4.1 Function of Xylem

The xylem has 2 main functions:
1. Providing **mechanical support** for the plant; and
2. Conducting **water** and **dissolved mineral salts** from the roots to the stem and leaves.

The xylem is a **long, continuous, hollow tube**, similar to a straw, that is made up of **dead cells** fused together.

It contains no **cross-walls** or **protoplasm**. But what are cross-walls? Refer to *Figure 1.9* below.

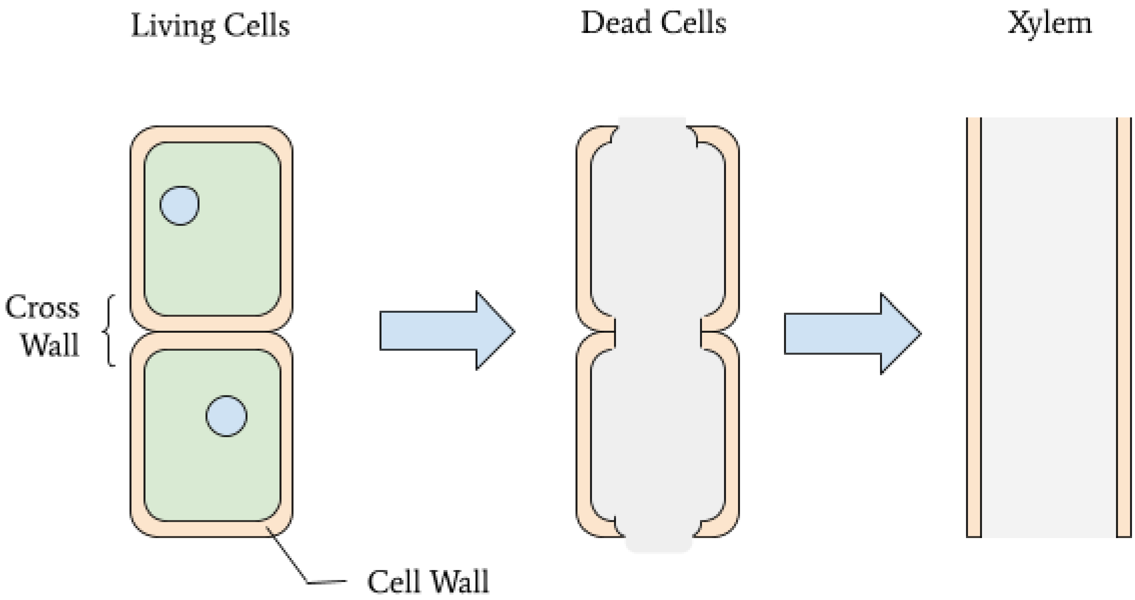


Figure 1.9: Formation of Xylem

1.4.2 Lignin

Lignin is a hard and rigid substance that is found on the walls of the xylem, which strengthens it and provides **mechanical support** for the plant. Deposits of lignin are formed on the walls of the xylem through a process called **lignification**.

Figure 1.10 below shows three lignification patterns that we need to know, where the red parts denote lignin deposits:

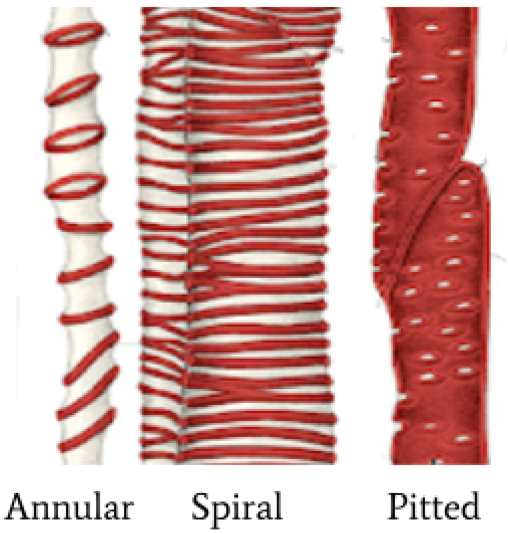


Figure 1.10: Lignification Patterns

The benefits of lignification are that the plant gets **mechanical support**, ensuring that the vessels do not collapse and hence helps in the **transport of water and mineral salts**.

1.5 Processes Involved in Transport of Water

There are three main processes involved in the transport of water - **Root Pressure**, **Capillary Action**, and finally **Transpiration Pull**.

1.5.1 Root Pressure

Root Pressure is the pressure resulting from the **constant entry** of water (by osmosis) through the roots. *Figure 1.11* below is an illustration of this:

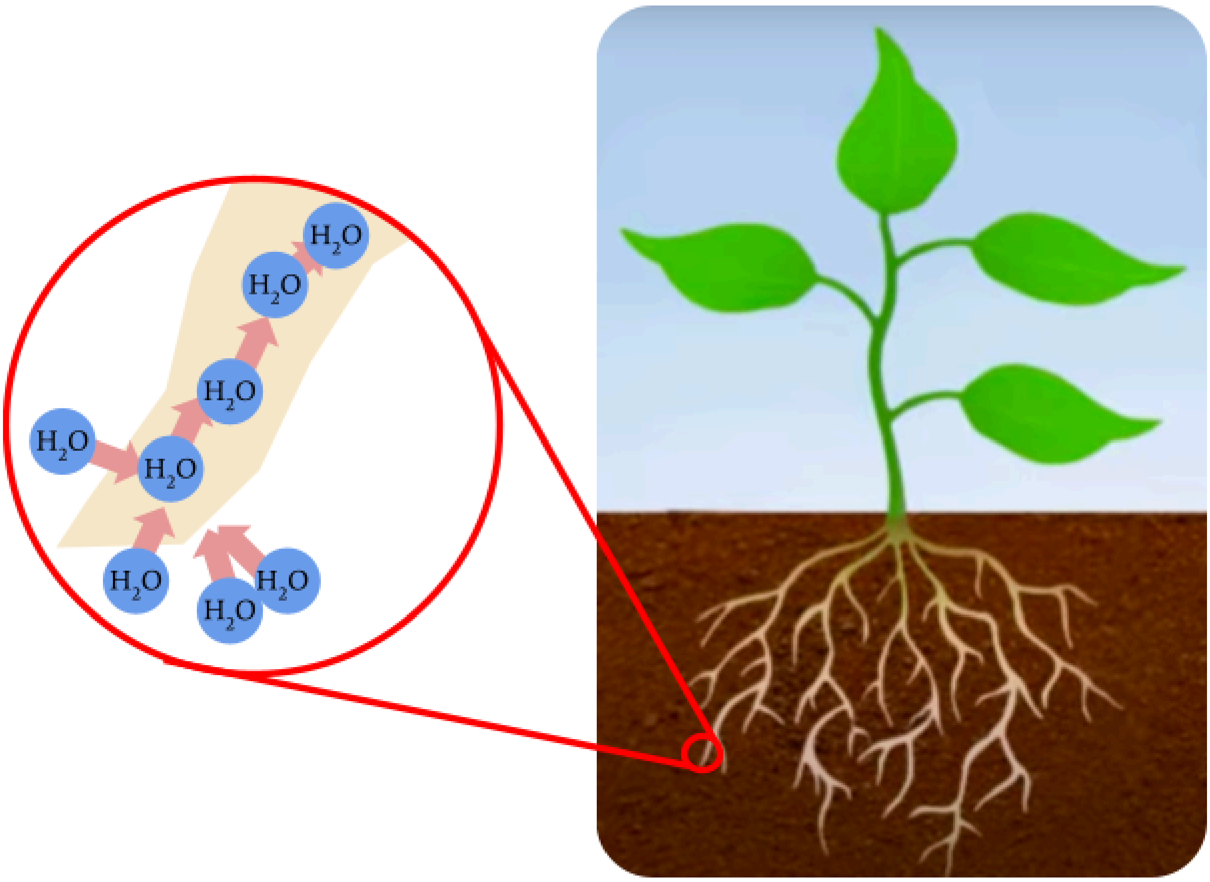


Figure 1.11: Root Pressure

As illustrated, the water molecules "push" the entire stream of water upwards as they try to enter by osmosis, as shown by the red arrows.

Illustrated by *Figure 1.12* below is the effect of root pressure.

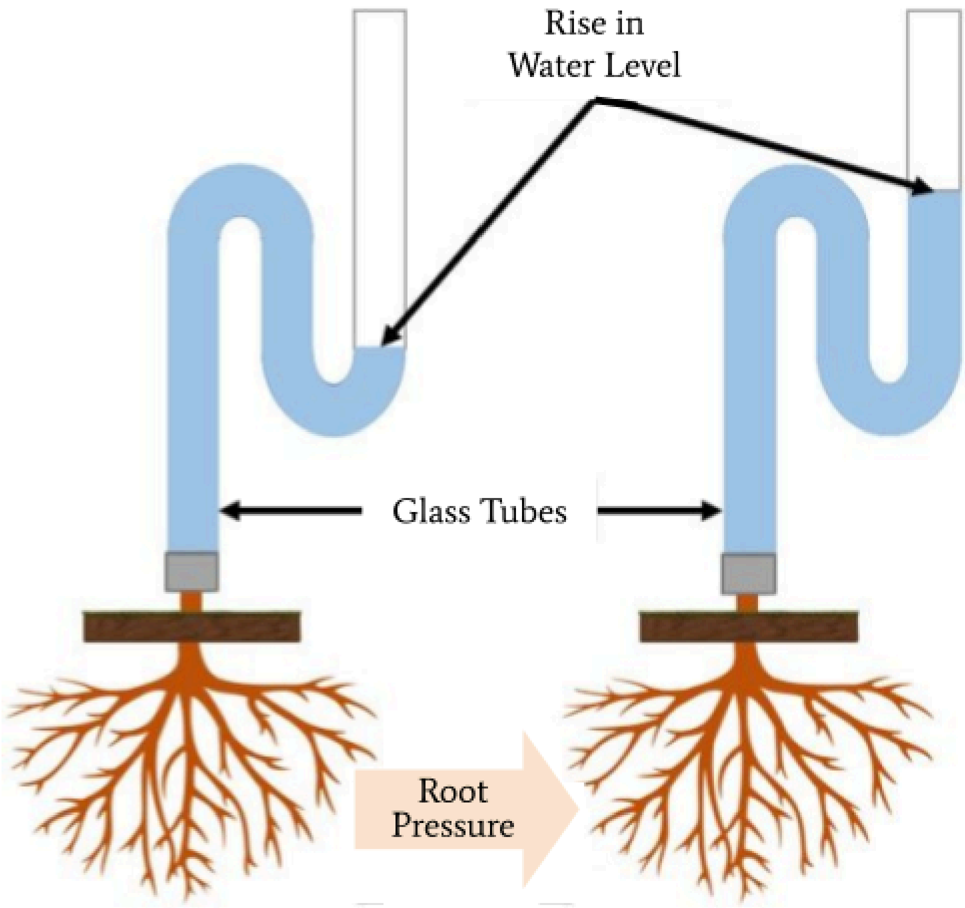


Figure 1.12: Effect of Root Pressure

1.5.2 Capillary Action

Capillary Action is dependent on the forces of **cohesion** and **adhesion**. It is defined as the **tendency of water molecules** to **move up** inside **very narrow tubes** called capillaries.

Cohesion is the attraction of water molecules to other water molecules held together. When one molecule goes up, the others are pulled up by cohesion. Refer to *Figure 1.13* below.

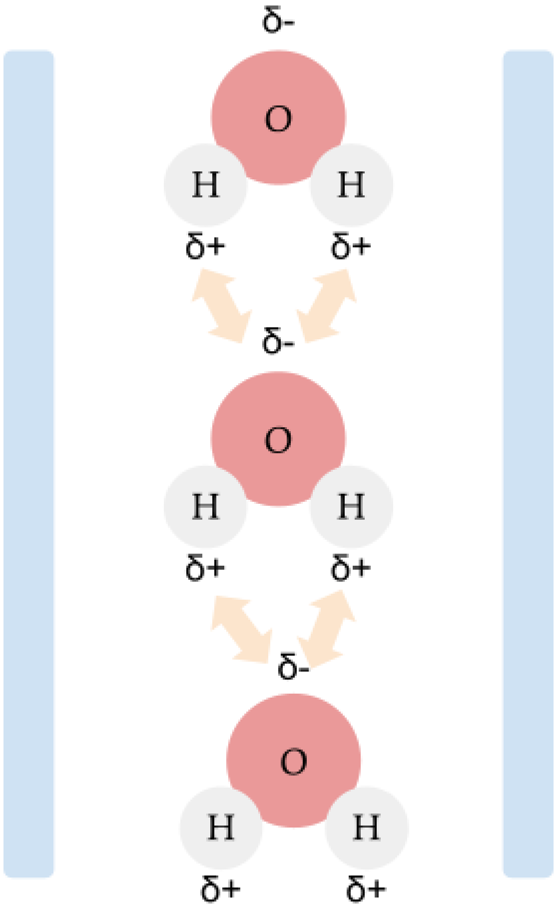


Figure 1.13: Cohesion of Water

Adhesion is the attraction of water molecules to other molecules (like the glass test tube, or the xylem walls). Refer to *Figure 1.14* below.

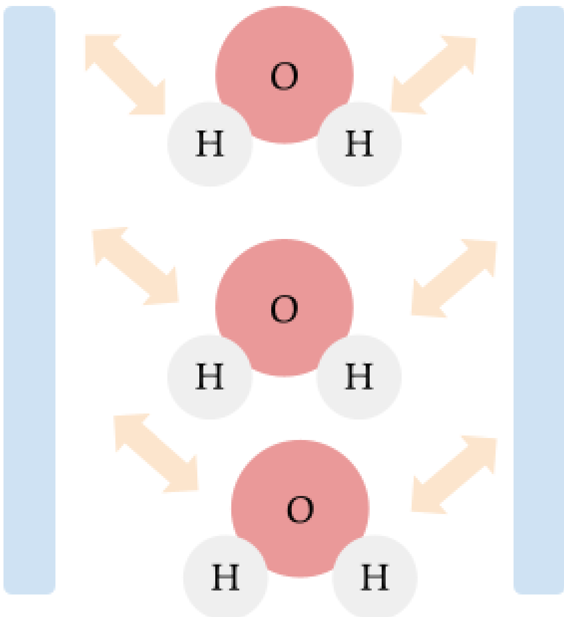


Figure 1.14: Adhesion of Water

When we consider both forces, the resultant force is called **Capillary Action**.

Figure 1.15: Effect of Capillary Action

1.5.3 Transpiration Pull

Transpiration pull is the **suction force** caused by transpiration which results in water moving up the xylem in a stream of water called the **transpiration stream**.

<u>**Recall:**</u>

Transpiration is the loss of water from the **aerial parts** of a plant, especially through the **stomata** of leaves.

The effect of Transpiration Pull is demonstrated in *Figure 1.16* below, where the orange arrows denote the water molecules diffusing out of the stoma, and the green arrows denote **Transpiration Pull**.

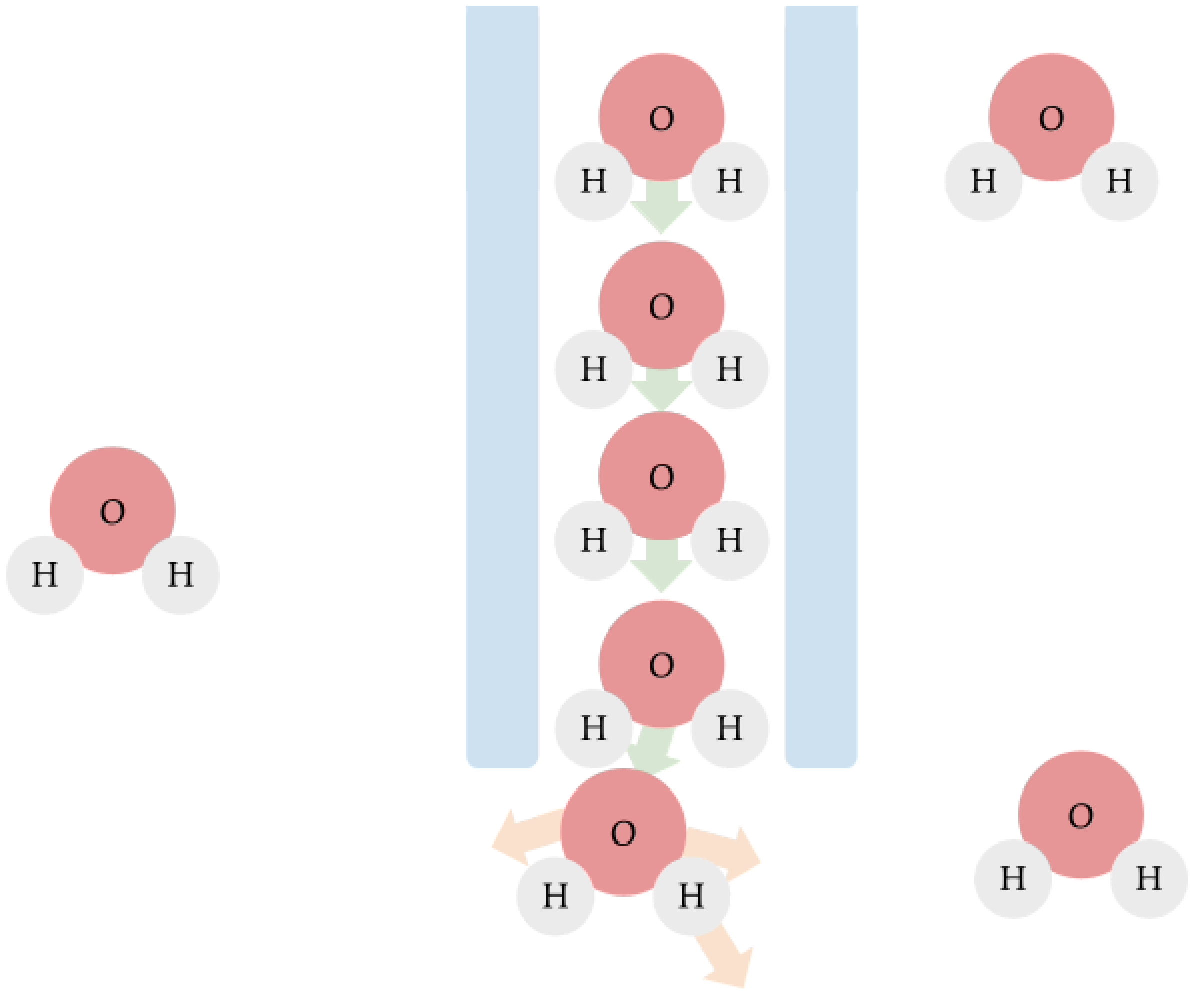


Figure 1.16: Diffusion and Transpiration Pull

1.6 Phloem Vessels

The phloem is the **food-carrying tube** in a plant.

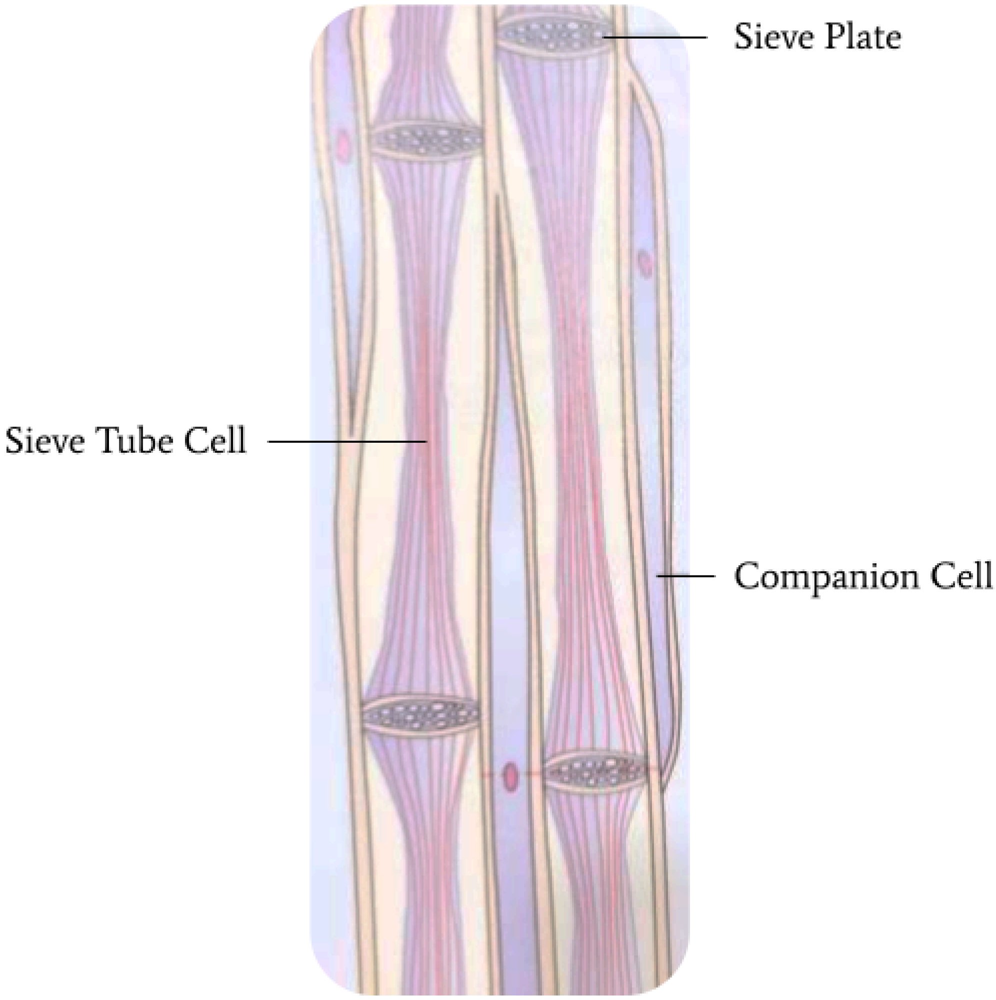


Figure 1.17: Longitudinal Section of Phloem

The phloem consists of **Companion Cells**, **Sieve Plates** and **Sieve Tube Cells** (also known as Sieve Tube Elements).

The phloem conducts **manufactured food** from the green parts of the plant (i.e. parts with chlorophyll; mostly the leaves) to the rest of the plant in the form of **Sucrose** and **Amino Acids**. This process is called **Translocation of Food.**

Translocation occurs from **Sugar Sources** (for example, leaves) to **Sugar Sinks** (for example, roots, fruits, etc.).

1.6.1 Aphid Feeding Experiment

Aphids have a mouthpart called a **stylet**, which acts like a mini syringe, pulling the phloem sap out of the phloem. The flow of the phloem sap can then be tracked by using aphids at different points between a source and a sink.

Research found that the concentration of sugar near sugar sinks is lower, and the pressure of the phloem sap is higher near sugar sources.

FYI: This supports a hypothesis known as the **Pressure Flow Hypothesis**, which is not tested.

1.6.2 Ringing Experiment

Ringing, or **Girdling**, is the removal of the layer of bark containing the phloems.

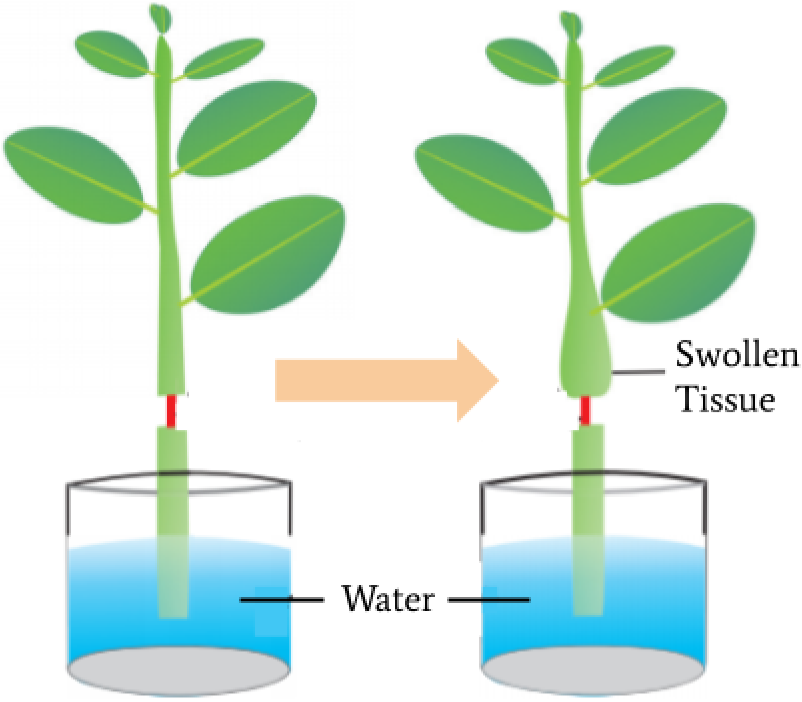


Figure 1.18: Girdling Experiment

After time, the manufactured food from the leaves can no longer be transported down to the roots, which also shows the path which food travels in.

The food accumulates just above the ring that was removed, creating a swollen region. This also lowers the water potential of the cells in that region, allowing water to enter and swell the area further.

1.6.3 Radioactive Carbon Experiment

Carbon is most commonly found as Carbon-12, ${}^{12}_{6}C$. However, there is a radioactive isotope of carbon, Carbon-14, ${}^{14}_{6}C$, written as: ${}^{14}C$. Carbon-14 can then form radioactive carbon dioxide, written as: ${}^{14}CO_2$.

We supply the plant with radioactive carbon dioxide using a container as in *Figure 1.19* below:

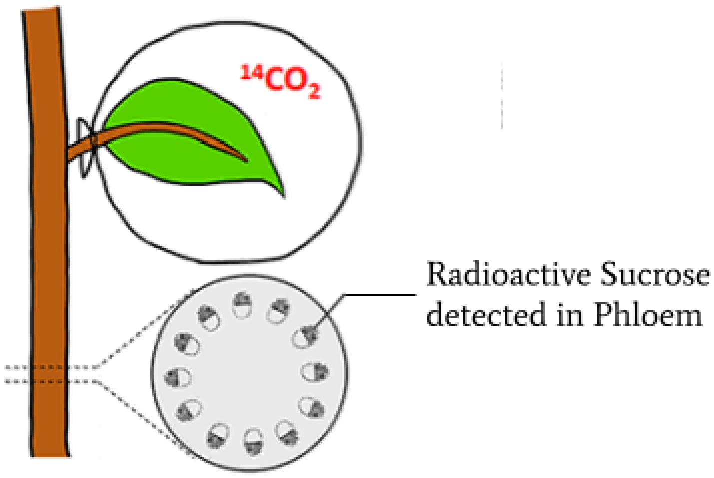


Figure 1.19: Supplying Radioactive Carbon Dioxide to Leaf

This special radioactive carbon dioxide is then used in photosynthesis, creating radioactive glucose, and then radioactive sucrose as it is transported.

This radioactive sucrose in the stem can then be captured by an **X-ray**, which allows the places where radioactive sucrose are transported to to be captured, thereby pinpointing the translocation flow.

1.6.4 Sieve Tube Cells

Sieve Tube cells have **very little protoplasm**, which **reduces the resistance** to the flow of substances within the phloem.

Simply, it means there is barely anything inside the cells to block the way of food being transported.

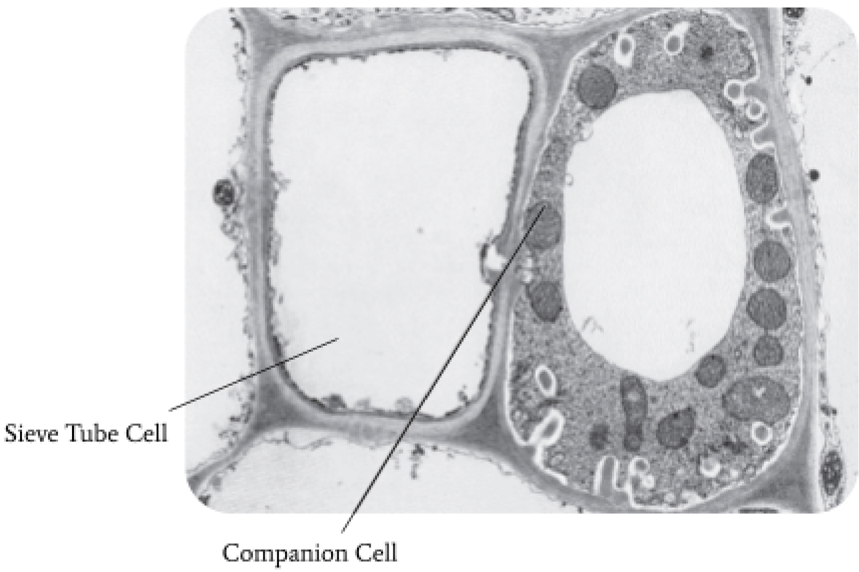


Figure 1.20: Sieve Tube Cell and Companion Cell

As we can see from *Figure 1.20* above, the Sieve Tube Cell is mostly empty, while the Companion Cell is filled with organelles.

1.6.5 Sieve Plates

Sieve Plates have **pores**, which are the tiny holes running through them.

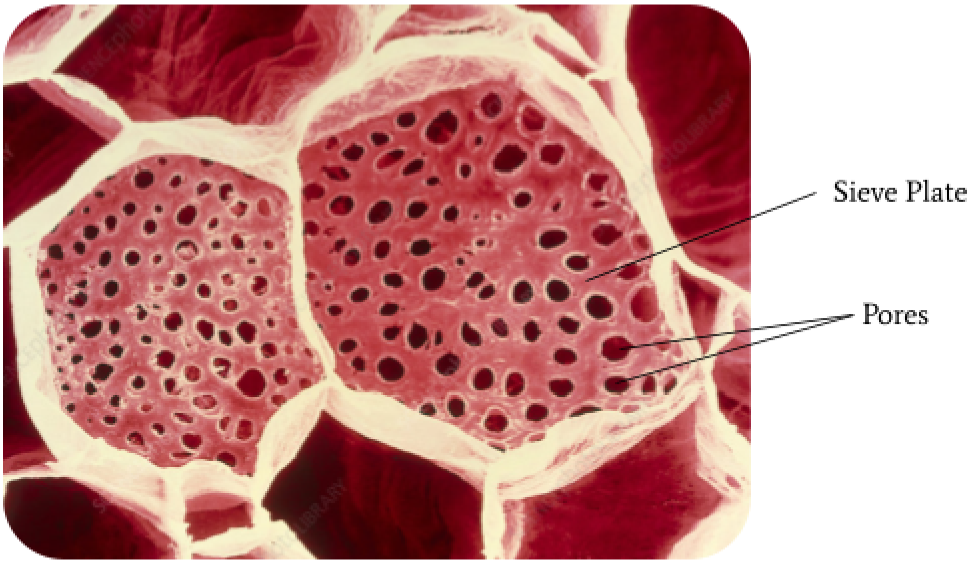


Figure 1.21: Sieve Plate

These pores within the sieve plates allow for **rapid flow of manufactured food substances**.

The sieve plates also act as a barrier to prevent the loss of sap when the phloem is cut or damaged, often by an insect or herbivorous animal. (FYI: This is done by the formation of a substance known as Callose.)

1.6.6 Companion Cells

Since Sieve Tube Cells have most of their organelles removed, they naturally don't have mitochondria to release energy. Hence, another cell nearby, called the **companion cell**, supplies it with energy to keep it alive and for the loading of sucrose into the sieve tubes (see *Figure 1.22*).

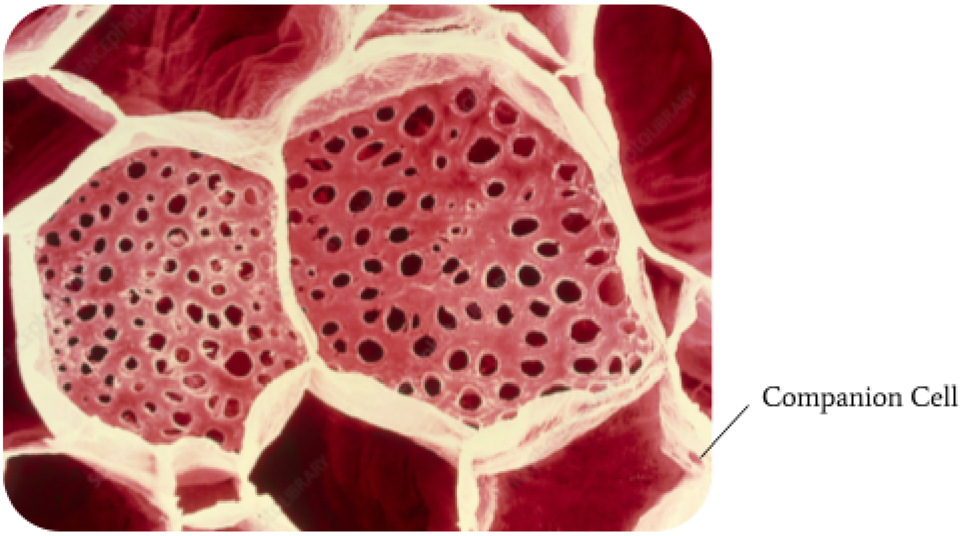


Figure 1.22: Companion Cell

The companion cell is considerably tinier than the sieve tubes, as shown in *Figure 1.22* above.

These cells have **numerous mitochondria** to provide energy for the **loading of sucrose** into the sieve tubes, i.e., "pushing" the sucrose through the sieve plate. Companion cells also provide **nutrients** to the sieve tubes to keep them alive.

1.7 Cortex and Pith (FYI)

Well, it's supposed to be FYI only, but somehow it got tested in a worksheet so :/

In the stem, there is also the **cortex** and the **pith**, which are both used for **storage of starch**, mainly. Refer to *Figure 1.23* below:

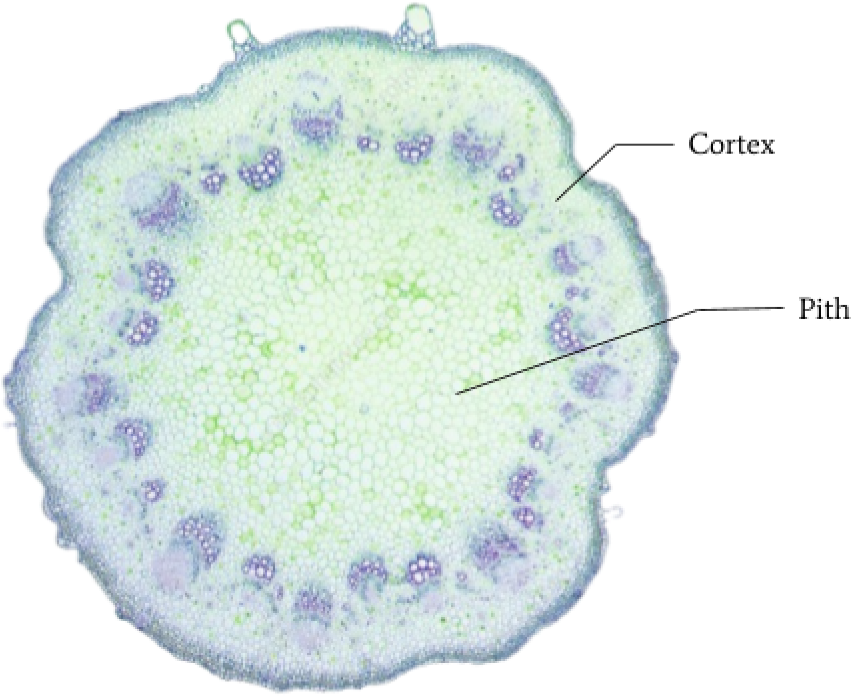


Figure 1.23: Cross-Section of Sunflower Stem

The root also has a **cortex**, which is used for a similar purpose. Refer to *Figure 1.24* below:

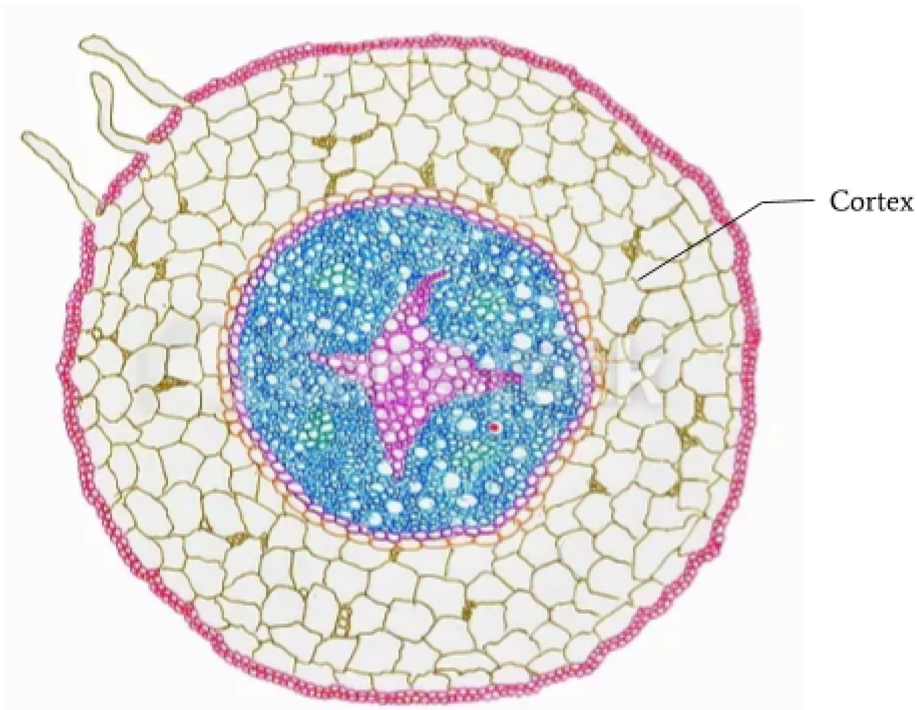


Figure 1.24: Cross Section of Dicot Root

1.8 Boundary Layer

Around the leaves of a plant, there exists a Boundary Layer, which is a layer of **unstirred** (i.e. calm) **air**. In this region, the wind is weaker and both the humidity and the temperature are higher.

A thinner boundary layer would result in a more abrupt change from the **unstirred air** to the **bulk air** (i.e. surrounding, normal air), which would also then increase the diffusion gradient of water.

Hence, a **thinner boundary layer** would cause water to **diffuse out of the stomata**, as a result of transpiration, **faster**.

Furthermore, a thinner boundary layer also causes carbon dioxide to diffuse into the stomata faster and increase transfer of heat.

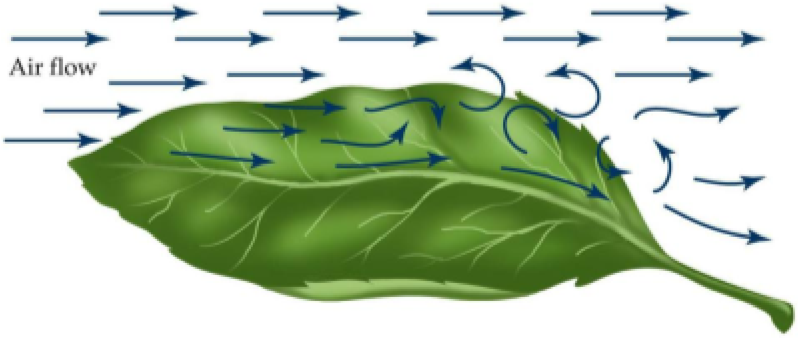


Figure 1.25: Boundary Layer of a Leaf

1.9 Factors Affecting Rate of Transpiration

There are 4 main factors affecting rate of transpiration:

1. **Humidity**
2. **Wind**
3. **Temperature**
4. **Light**

When the atmosphere is **more humid**, the **concentration gradient of water** is less steep, so diffusion and hence transpiration occurs at a **slower rate**.

When the wind is **stronger**, the water vapour accumulating on the outside of the stomata (in the boundary layer) is blown away, hence increasing the **concentration gradient of water**, so diffusion and hence transpiration occurs at a **higher rate**.

When the **temperature is higher**, the **rate of evaporation increases**, so transpiration occurs at a **higher rate**.

When there is **more light**, the stomata will open and become wider, **increasing the rate** of transpiration.

1.10 Temporary Wilt

A normal plant is held up by the **turgor pressure** in the leaf mesophyll cells, which is why leaves don't crumple up usually.

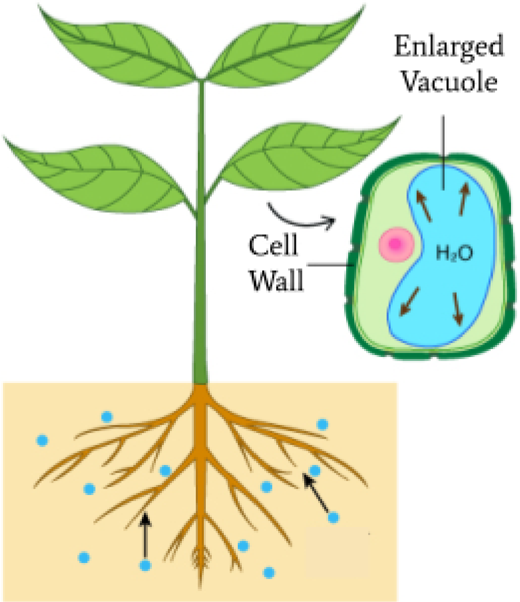


Figure 1.26: Turgor Pressure due to Accumulation of Water

However, when the rate of transpiration exceeds the rate of absorption of water by the roots (i.e. too much water is lost), the mesophyll cells **lose water** and lose their **turgor pressure**. Hence, the cells and the leaf become flaccid.

This is called **wilting**.

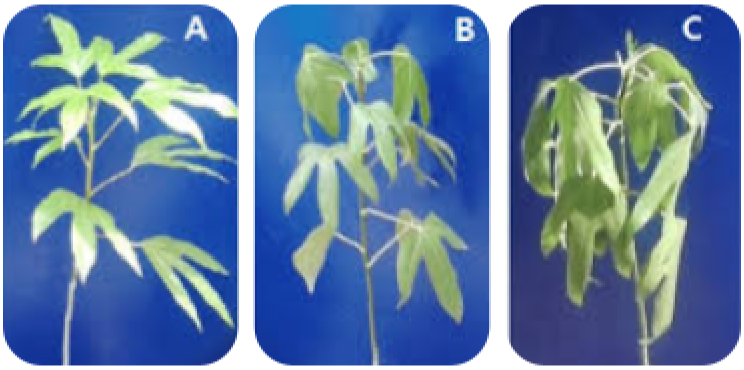


Figure 1.27: Wilting of a Plant

Refer to *Figure 1.27* above. This shows a plant (*Dendropanax Morbiferus*) wilting from picture A to B to C. As we see, in C, the leaves have become flaccid and are drooping down.

1.10.1 Benefits of Wilting

When a leaf folds up, the **surface area exposed to sunlight is reduced**. Excessive loss of water also causes the guard cells to become flaccid, which causes the **stomata to close**. These two factors reduce the **transpiration rate** (i.e. reduces water loss). The plant is also **cooled**.

1.10.2 Disadvantages of Wilting

The rate of **photosynthesis** is **reduced**, since less carbon dioxide can enter the plant when the stomata is closed. Furthermore, the surface area of leaves exposed to sunlight decreases, which also reduces the rate of photosynthesis.

Topic 2: Transport in Humans

2.1 Why a Transport System?

We know that cells do not need a transport system, as nutrients can directly diffuse in, and waste can directly diffuse out, so why do we need one?

uwucellular

Well, in a **Unicellular Environment** (*uni - one; unicellular - single celled*), the movement of substances can occur by simple **diffusion**, because no part of the cell is too far from the external environment.

However, in a **Complex Multicellular Organism,** a transport system is needed to transport substances from one part of the body to another because many cells are located **deep in the body, far from the external environment**, too far for substances to be transported by diffusion.

For example, for mammals, a transport system consisting of **blood, blood vessels,** and a **heart** was developed.

2.2 Composition of Blood

Here is the composition of blood:

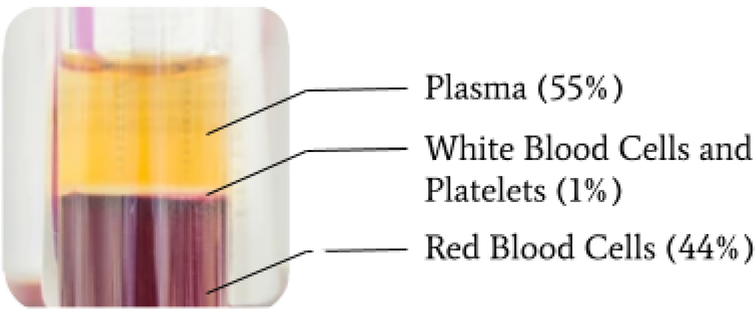


Figure 2.1 - Composition of Blood

2.3 Plasma

Plasma is a yellow substance which consists of **90% water** and **10% proteins, mineral salts, food substances, waste products and hormones.**

Its function is to **transport materials** throughout the body.

2.4 Red Blood Cells

Red Blood Cells, also known as **erythrocytes**, have a **biconcave shape**, as shown in *Figure 2.2* below.

Figure 2.2: Biconcave shape of Red Blood Cell

This biconcave shape **increases Surface Area to Volume Ratio** to increase rate of **uptake of oxygen**.

Red Blood Cells are filled with a red pigment **Haemoglobin** (or Hemoglobin) for binding oxygen. Haemoglobin is broken down in the **spleen and liver**.

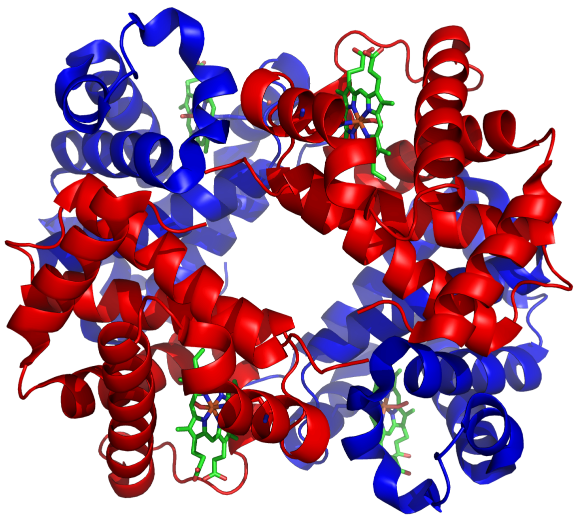


Figure 2.3: Haemoglobin

Red Blood Cells do not have a **nucleus**, so as to carry more Haemoglobin to carry more oxygen.

Red Blood Cells are **elastic** to enable cells to squeeze through blood capillaries.

Red Blood Cells are **synthesised in the bone marrow** and are **broken down in the spleen and liver.**

2.5 White Blood Cells

White Blood cells, also known as **leucocytes,** have an irregular shape and contain a nucleus, as shown in *Figure 2.4* below:

Figure 2.4: A White Blood Cell

White Blood Cells are **colourless** as they do not contain haemoglobin.

White Blood Cells are also **mobile** as they are able to move, change their shape and squeeze through walls of thin blood capillaries.

Leucocytes can be further subdivided into two types - Phagocytes and Lymphocytes, which have different functions.

2.5.1 Lymphocytes

Lymphocytes produce **antibodies** that **protect the body** from diseases.

When a pathogen (i.e. harmful foreign particle) enters the bloodstream, lymphocytes are **stimulated to produce antibodies**.

Antibodies are specialised **Y-shaped** proteins, as shown in *Figure 2.5* below:

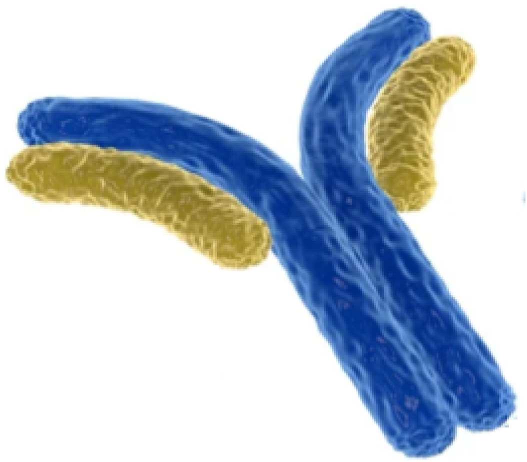


Figure 2.5: An Antibody

These antibodies **bind to antigens** on **bacteria and viruses** like a lock and key (similar to enzyme lock-and-key hypothesis). This causes the bacteria and viruses to clump together in a process known as **agglutination**, as shown in *Figure 2.6* below.

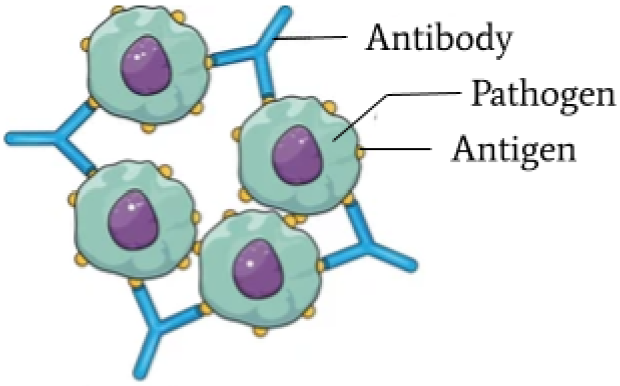


Figure 2.6: Agglutination

The **clumped pathogens** are then ingested by **Phagocytes** by **Phagocytosis**, as covered in Section 2.5.2 below.

2.5.2 Phagocytes

Phagocytes **surround and engulf foreign particles** like bacteria by **phagocytosis**.

Phagocytes can destroy foreign bodies like **Bacteria**, **Viruses**, **Toxins**, **Allergens**, and other **Pathologically Altered Cells of Organisms**.

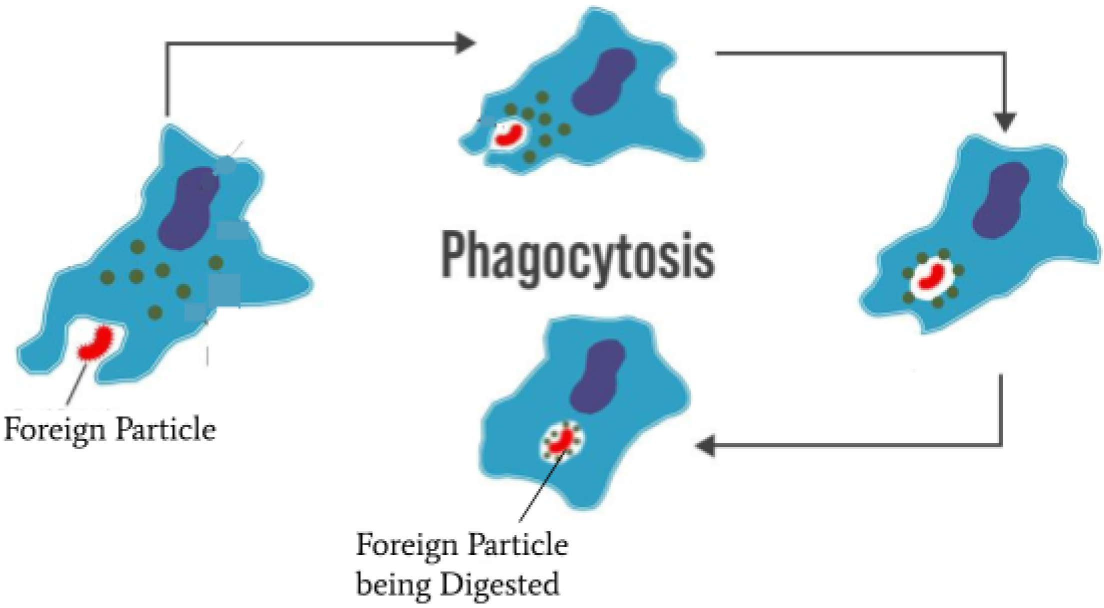


Figure 2.7: The process of Phagocytosis

2.6 Platelets

Platelets, also known as **thrombocytes**, are membrane-bound fragments of cytoplasm. Their main function is **blood clotting.**

When platelets are **damaged**, they release an enzyme known as **thrombokinase**, and this begins the process of **Blood Clotting** (Refer to Section 2.7 below).

2.7 Blood Clotting

The main purpose for Blood Clotting is to prevent **excessive blood loss** and prevent **pathogens from entering** the blood through the wound.

Blood Clotting, also known as **Coagulation of Blood**, is a 3-step process, known as a **Cascade Reaction**, as one reaction sets off the next.

It starts with Damaged Tissue Platelets releasing **Thrombokinase**, which is an enzyme.

Thrombokinase, along with the Ca^{2+} ion, catalyses the reaction converting the **inactive enzyme Prothrombin** to its **active form, Thrombin**.

Thrombin then catalyses the reaction converting **soluble Fibrinogen** into **insoluble Fibrin**.

Fibrin is like a net that blocks off the wound, while Prothrombin and Fibrinogen are **Clotting Factors**, along with White Blood Cells and Red Blood Cells. These substances help to block the wound.

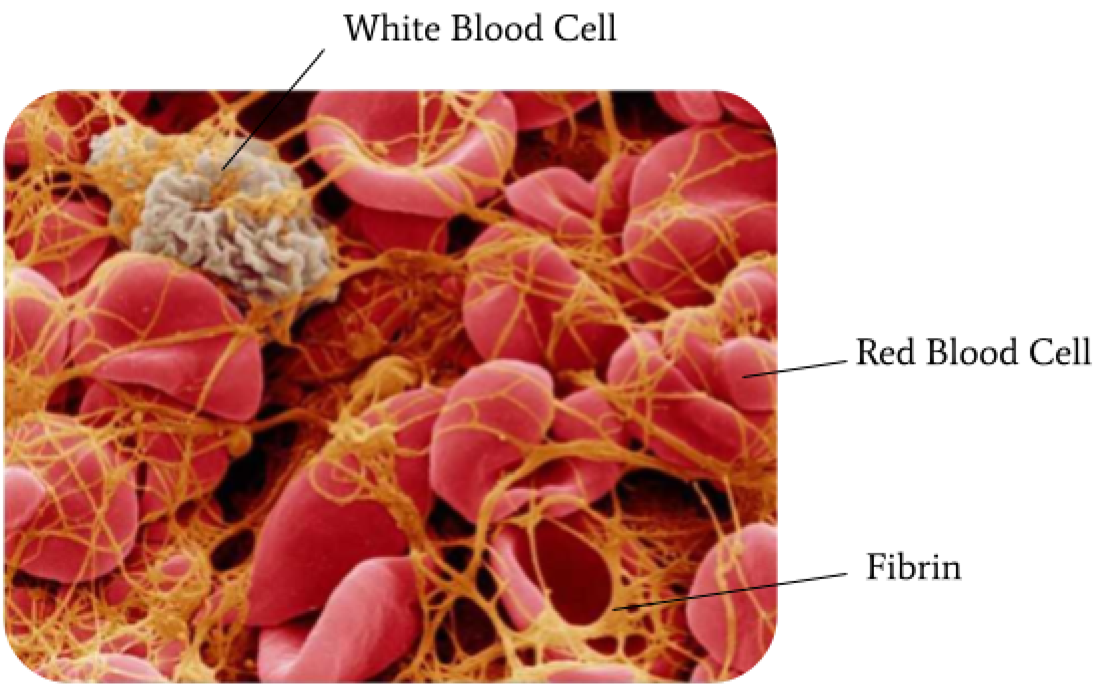


Figure 2.8: Clotting of Blood

Figure 2.9 below shows a summary of the Coagulation Cascade.

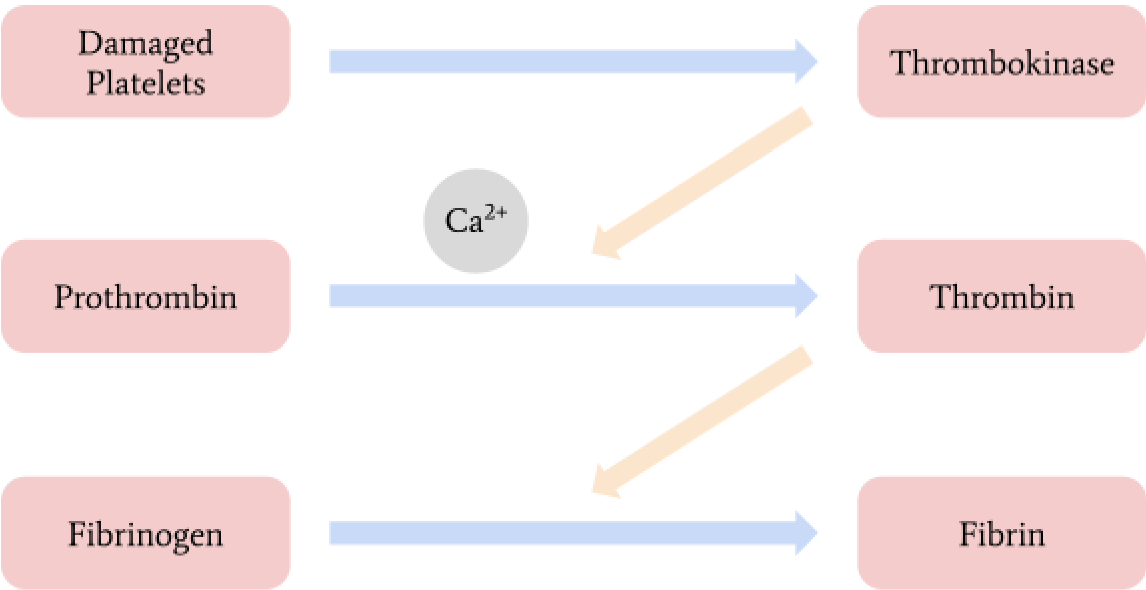


Figure 2.9: Coagulation Cascade

2.8 Functions of Blood

Blood has 3 key functions:

1. To act as a **transport medium** carrying many substances from one part of the body to another;
2. To **protect** the body against disease-carrying organisms (known as **pathogens**); and
3. To **coagulate** (i.e. the clotting of blood) at wounds by sealing the wound.

2.8.1 Substances Transported by Blood

Table 2.10 below shows some substances transported by blood:

Substance Transported		Source	Destination
Digested Food Products		Small Intestine	Liver, then to All Other Parts of Body
Excretory Products (i.e. waste)	Nitrogenous Waste	All Parts of Body	Kidney
	Carbon Dioxide	All Parts of Body	Lungs
Hormones		Glands	Target Cells & Organs
Heat		Respiring Body Tissue	All Parts of Body
Oxygen		Lungs	All Parts of Body

Table 2.10: Substances Transported by Blood

2.8.2 Gaseous Exchange

Figure 2.11 below shows the process of **Gaseous Exchange** in the air-sac (also known as alveolus).

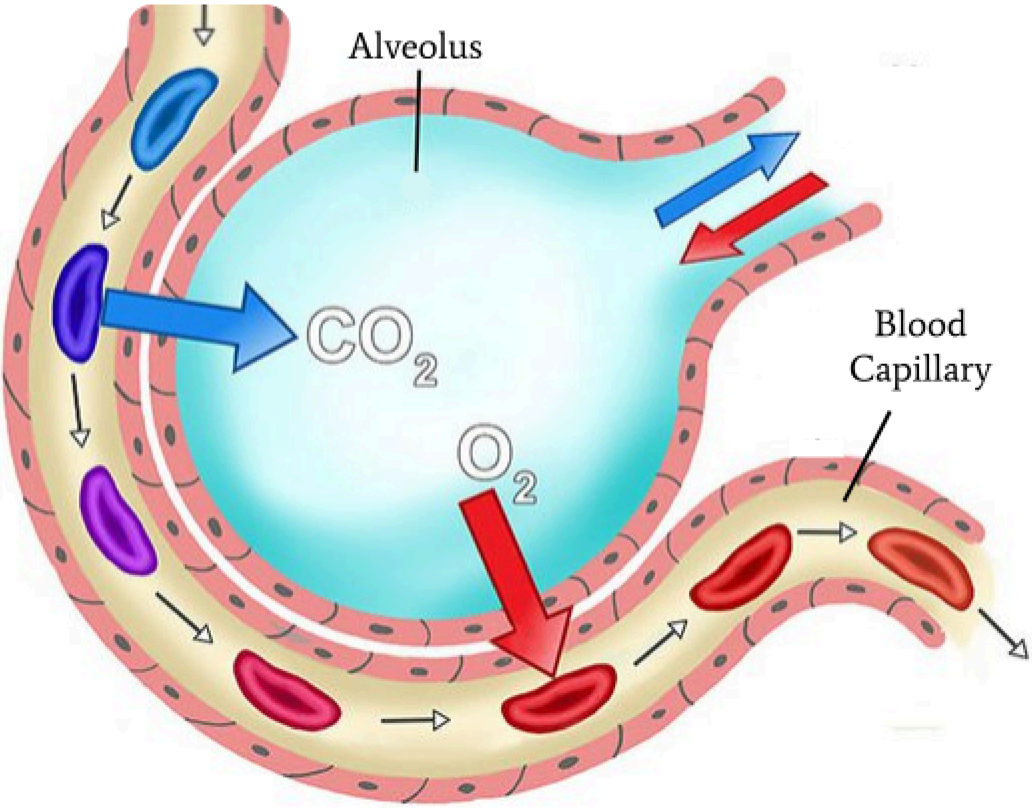


Figure 2.11: Gaseous Exchange in the Alveolus

2.8.3 Transport of Oxygen

As the blood passes through lungs, O_2 diffuses from the air sacs in the lungs into the blood. The O_2 then combines with Haemoglobin in the red blood cells to form **Oxyhaemoglobin**.

Taking a unit of Haemoglobin as Hb, the formula for Oxyhaemoglobin is then $Hb \cdot 4O_2$.

This process is easily **reversible**. As the blood leaves the lungs and passes through a tissue that lacks oxygen, the oxyhaemoglobin breaks apart into **Oxygen** and **Haemoglobin**, and the Oxygen is then supplied to the tissue by **diffusion**.

While 98.5% of Oxygen is transported in the form of Oxyhaemoglobin, Oxygen can also dissolve in the plasma of blood, which is how the remaining 1.5% of Oxygen is transported.

2.8.4 Transport of Carbon Dioxide

Carbon Dioxide can be transported in 3 main ways in the blood.

Firstly, it can be **dissolved in and transported in the plasma** directly.

This accounts for about 7% of CO_2 transported.

Secondly, it can be transported as the **Hydrogen Carbonate Ion** in the plasma.

CO_2 first diffuses into the Red Blood Cell, where it reacts with H_2O to form Carbonic Acid, H_2CO_3. This reaction is catalysed by an enzyme present in Red Blood Cells, **Carbonic Anhydrase.**

Then, Carbonic Acid dissociates to form Hydrogen Ion, H^+, and Hydrogen Carbonate Ion (also known as Bicarbonate Ion), HCO_3^-.

HCO_3^- can then be transported in the plasma.

The chemical equations are:

$$H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$$

This accounts for 70% of CO_2 transported.

Lastly, it can be transported by **Haemoglobin**.

Taking a unit of Haemoglobin as Hb, the reaction is $CO_2 + Hb \rightarrow Hb \cdot CO_2$.
This form of Haemoglobin, $Hb \cdot CO_2$, is known as **Carbaminohaemoglobin**.

This accounts for 23% of CO_2 transported.

2.9 Steps to Wound Healing (FYI)

The first step is **Haemostasis** (or Hemostasis), which involves coagulation of blood (i.e. clotting of blood).
The second step is **Inflammation**, where pathogens are attacked and destroyed.
The third step is **Proliferation**, where the epidermis (outer skin tissues) is repaired.
The final step is **Remodelling**, where collagen, a protein, is rearranged within the dermal layer.

2.10 The Human Heart

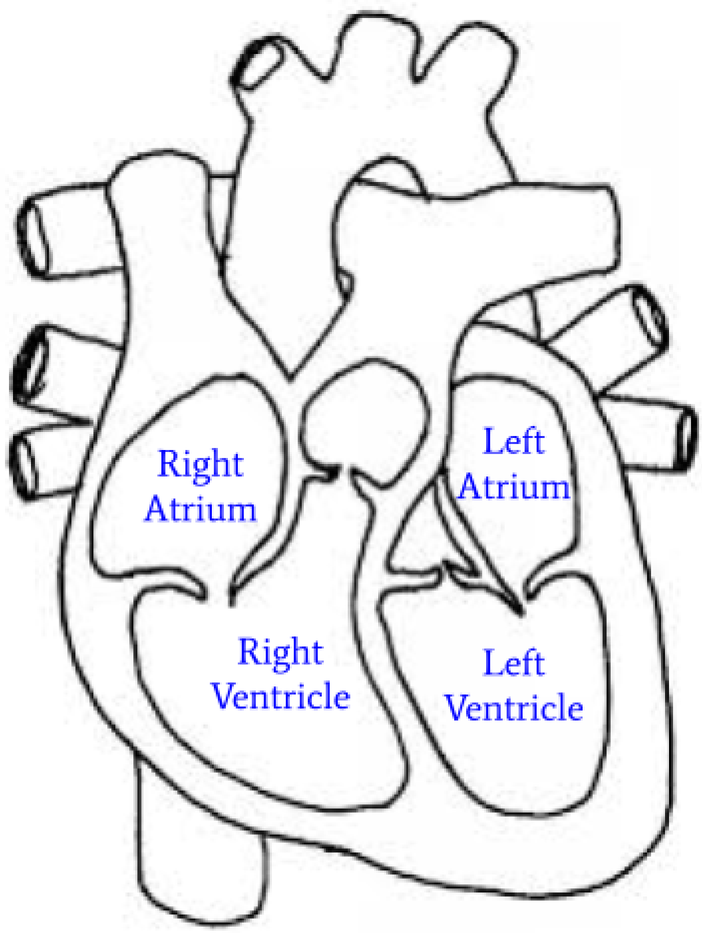


Figure 2.12: Four Main Chambers of the Heart

Figure 2.12 above shows the **four main chambers** of the heart.

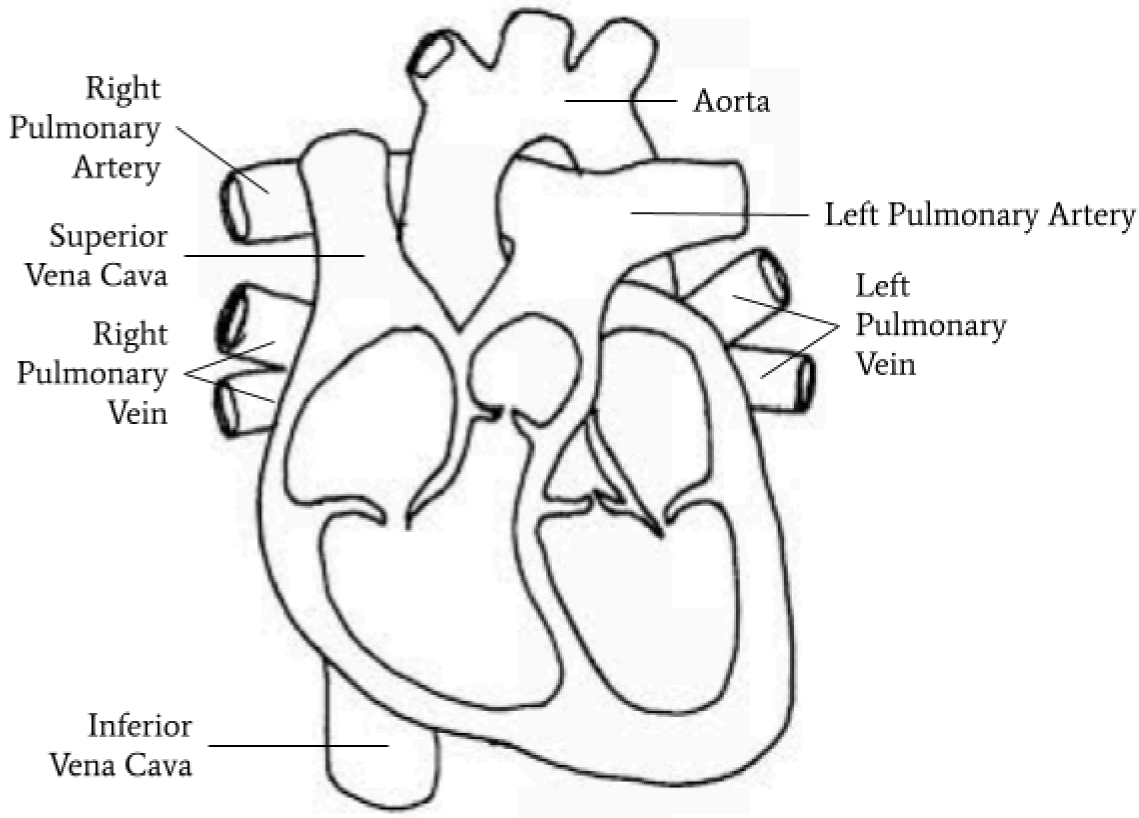


Figure 2.13: Major Blood Vessels of the Heart

Figure 2.13 above shows the major blood vessels related to the heart.

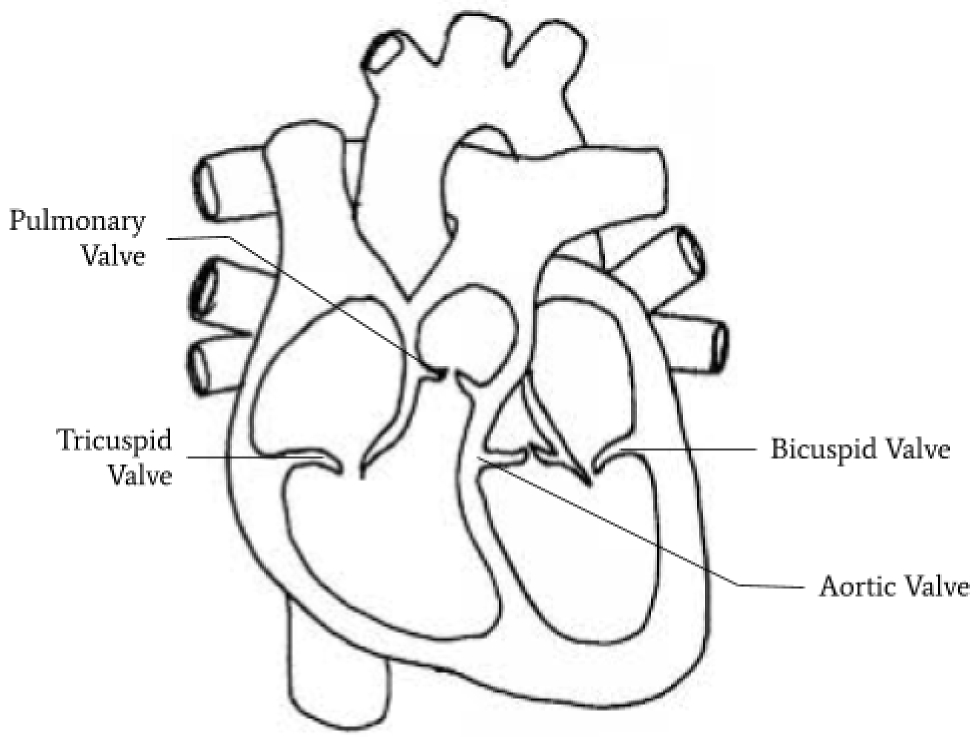


Figure 2.14: Four Valves of the Heart

Figure 2.14 above shows the four main valves of the heart.

With reference from *Figure 2.11*, *Figure 2.12* and *Figure 2.13* above,

Deoxygenated Blood first enters the **Right Atrium,** through the **Superior and Inferior Vena Cava,** then enters the **Right Ventricle** through the **Tricuspid Valve** *(also known as the Right Atrioventricular Valve).*

Blood then enters the **Pulmonary Artery** through the **Pulmonary Valve** *(also known as the Right Semi-Lunar Valve).*

The deoxygenated blood travels through the **Pulmonary Artery** into the lungs, where gaseous exchange occurs, turning the blood into **Oxygenated Blood**.

The Oxygenated Blood returns to the heart and enters the **Left Atrium** through the **Pulmonary Veins**, then enters the **Left Ventricle** through the **Bicuspid Valve** *(also known as the Left Atrioventricular Valve, or the Mitral Valve).*

Blood then enters the **Aorta** through the **Aortic Valve** *(also known as the Left Semi-Lunar Valve).* The blood is then distributed all around the body through the **Aorta**.

Figure 2.14 shows some miscellaneous parts (FYI), in the heart.

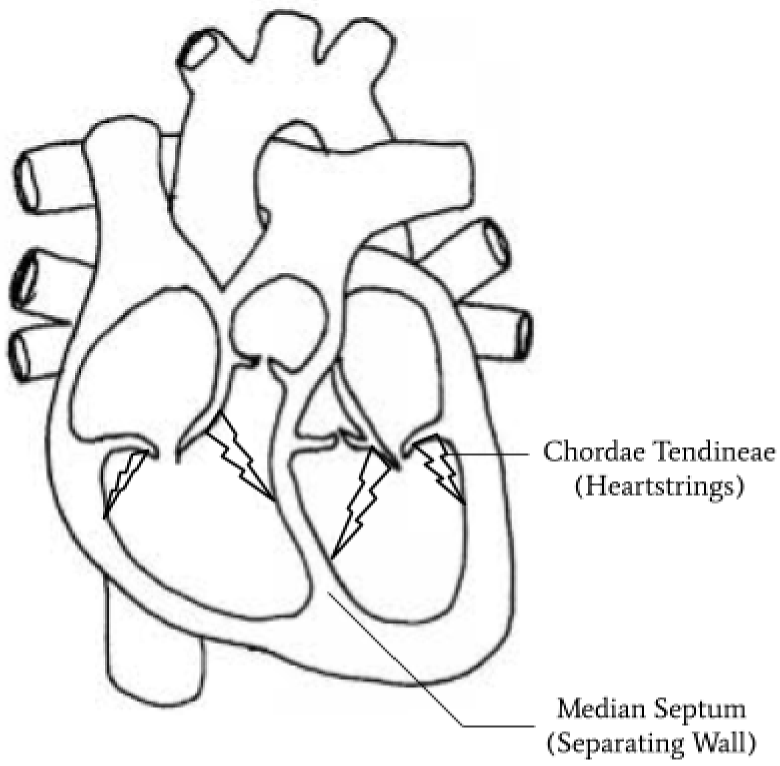


Figure 2.14: Miscellaneous Parts of the Heart

2.11 Blood Groups

Some people have Red Blood Cells with **antigens** present. There are two types of antigens that can be present, **Antigen A** and **Antigen B**.

One person's blood can have either one of these antigens, neither, or both. These types of blood are known as **blood groups**.

These are the four possible "types" of blood cells:

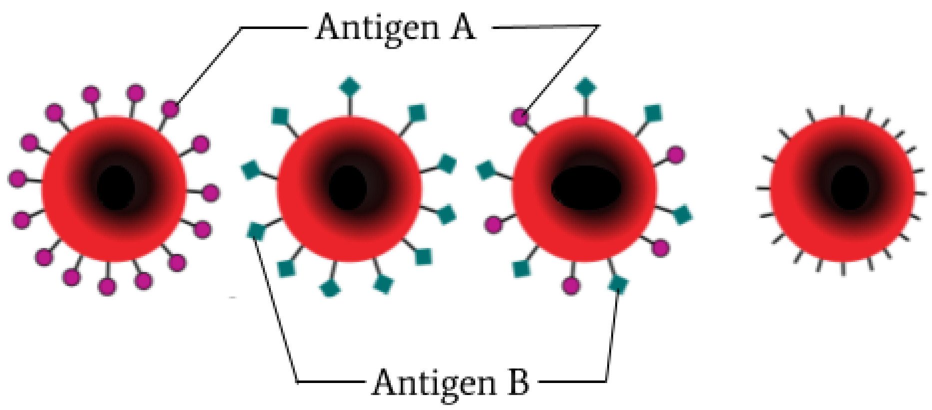


Figure 2.15: Antigens on Red Blood Cells

We then name the blood group based on what antigens are present. For example, if the blood cells have Antigen A but not Antigen B, the blood group is known as **Blood Group A**.

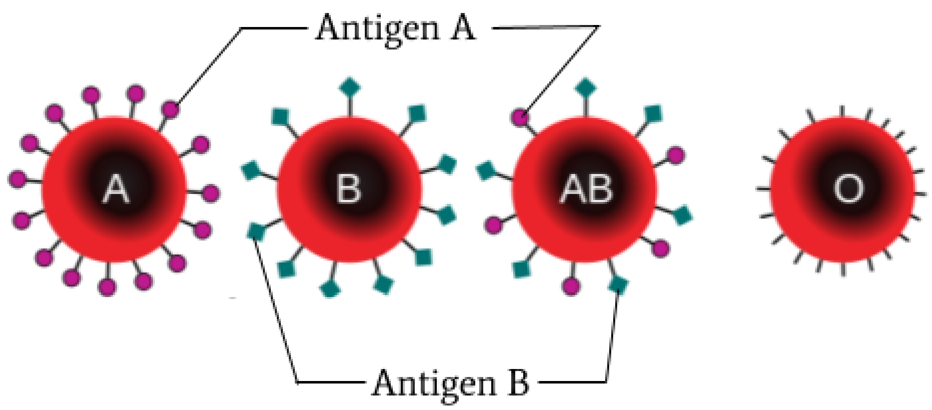


Figure 2.16: Blood Groups

We call the blood group with neither antigen **Blood Group O**.

2.11.1 Antibodies and Blood Groups

If a person's Red Blood Cell does not contain Antigen A, then their blood plasma will contain the Antibody known as **Anti-A**.

Similarly, if a person's Red Blood Cell does not contain Antigen B, then their blood plasma will contain the Antibody known as **Anti-B.**

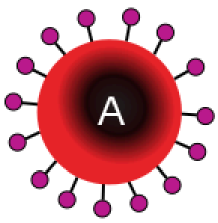
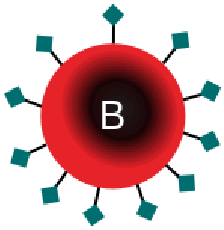
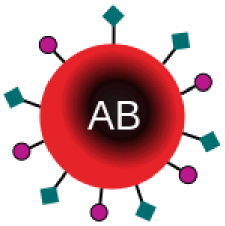
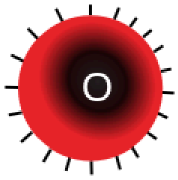
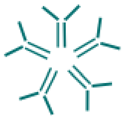
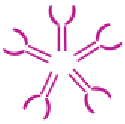
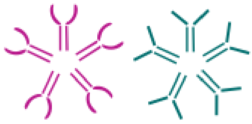
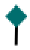
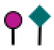
	Group A	Group B	Group AB	Group O
Red blood cell type				
Antibodies in plasma	 Anti-B	 Anti-A	None	 Anti-A and Anti-B
Antigens in red blood cell	 A antigen	 B antigen	 A and B antigens	None

Table 2.17: Antibodies and Antigens Present in Blood

2.11.2 Blood Donors and Recipients

Sometimes, patients require blood donations, but not all blood groups are compatible with others. Blood Groups with **Antigen A** cannot be compatible with those with **Anti-A Antibody**. Similarly, Blood Groups with **Antigen B** cannot be compatible with those with **Anti-B Antibody**.

This is because **Agglutination** will occur in the blood. Refer to **Section 2.11.3** below.

For example, a person with Blood Group A, which contains the **Antibody Anti-B**, cannot receive blood from a person with Blood Group B, since it contains **Antigen B**.

On the other hand, for example, a person with Blood Group A can receive blood from a person with Blood Group O.

Table 2.18 below summarises which Blood Groups are compatible with which Blood Groups.

Blood Recipient	Blood Donor			
	A	B	AB	O
A	✔	✖	✖	✔
B	✖	✔	✖	✔
AB	✔	✔	✔	✔
O	✖	✖	✖	✔

Table 2.18: Blood Recipient and Donor

2.11.3 Agglutination in the Blood

When both Antigen A and Antibody Anti-A, or both Antigen B and Antibody Anti-B are present, agglutination (Refer to **Section 2.5.1**) will occur, as the antigens and antibodies bind to each other.

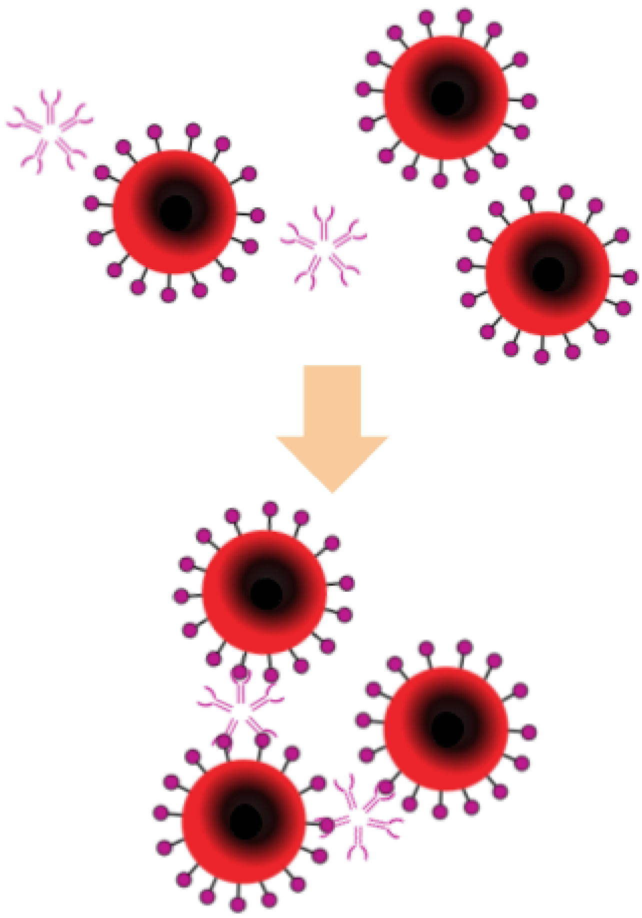


Figure 2.19: Agglutination of Red Blood Cells

This causes the Red Blood Cells to stop being able to function properly. Furthermore, agglutinated red blood cells can **clog blood vessels** which can prevent the circulation of blood in the body.

This can have **fatal consequences**.

2.12 Blood Vessels

A **vein** is a blood vessel carrying blood **towards** the heart. An **artery** is a blood vessel carrying blood **away from** the heart. A **capillary** is a microscopic blood vessel that links **arteries** to **veins**.

2.12.1 Arteries

Arteries are typically oxygen-rich, except for the **Pulmonary Arteries**.

It has thick muscular walls to prevent it from **rupturing** when there is an influx of blood at high pressure. Its muscles contract and relax to cause **constriction** and **dilation** of the artery.

It has a **small lumen** relative to its diameter. It has elastic fibres which can stretch and spring back, which helps to maintain the pulse.

2.12.2 Veins

Veins are typically deoxygenated, except for the **Pulmonary Veins**. It is thinner than an artery, and has a **large lumen** relative to its diameter.

Only **veins** have valves within them, as shown from *Figure 2.20* below. This prevents backflow of blood as the blood pressure is lower in the veins.

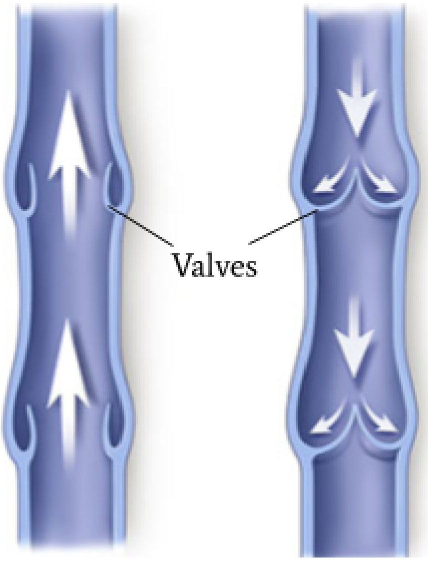


Figure 2.20: Valves in the Veins

2.12.3 Capillaries

It is only one-cell thick endothelium to make it partially permeable and to reduce diffusion distance of substances. It has the **largest lumen** relative to its diameter. *Figure 2.21* below shows how capillaries are connected to arteries and veins.

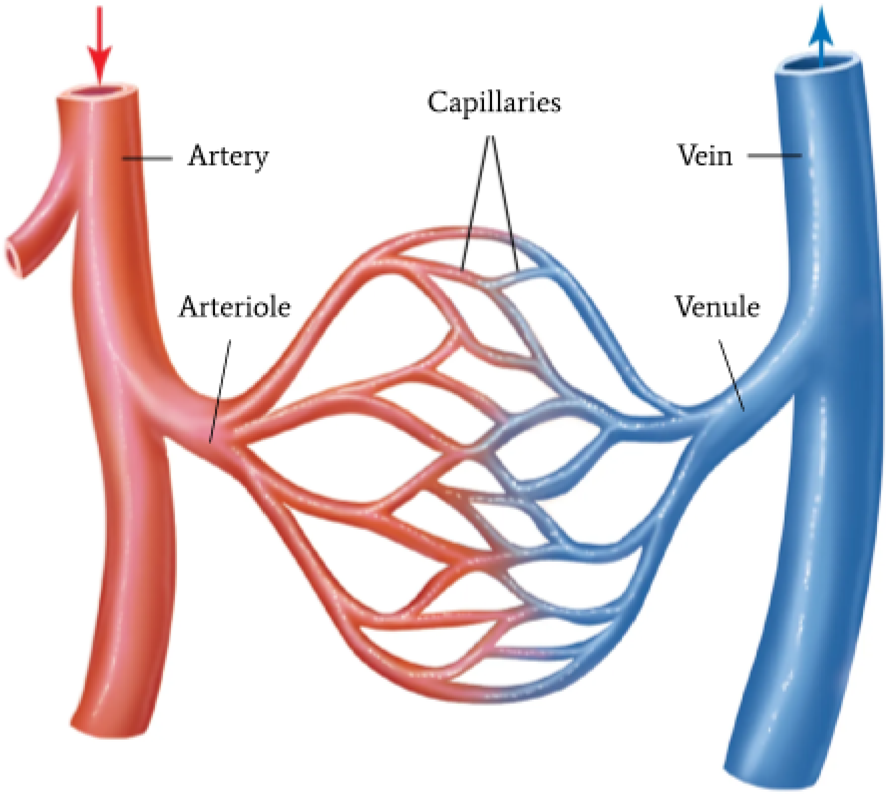


Figure 2.21 - Capillaries

The network of capillaries increases **surface area to volume ratio** and **total cross-sectional area**, to allow for efficient movement of substances between blood and cells.

2.13 The Cardiac Cycle

A **systole** refers to when the atrium/ventricle is **contracting**.
A **diastole** refers to when the atrium/ventricle is **relaxed**.

2.13.1 Phases of the Cardiac Cycle

The cardiac cycle is made up of three steps:

1. Atrioventricular Diastole (~0.4s)
2. Atrial Systole & Ventricular Diastole (~0.1s)
3. Ventricular Systole & Atrial Diastole (~0.3s)

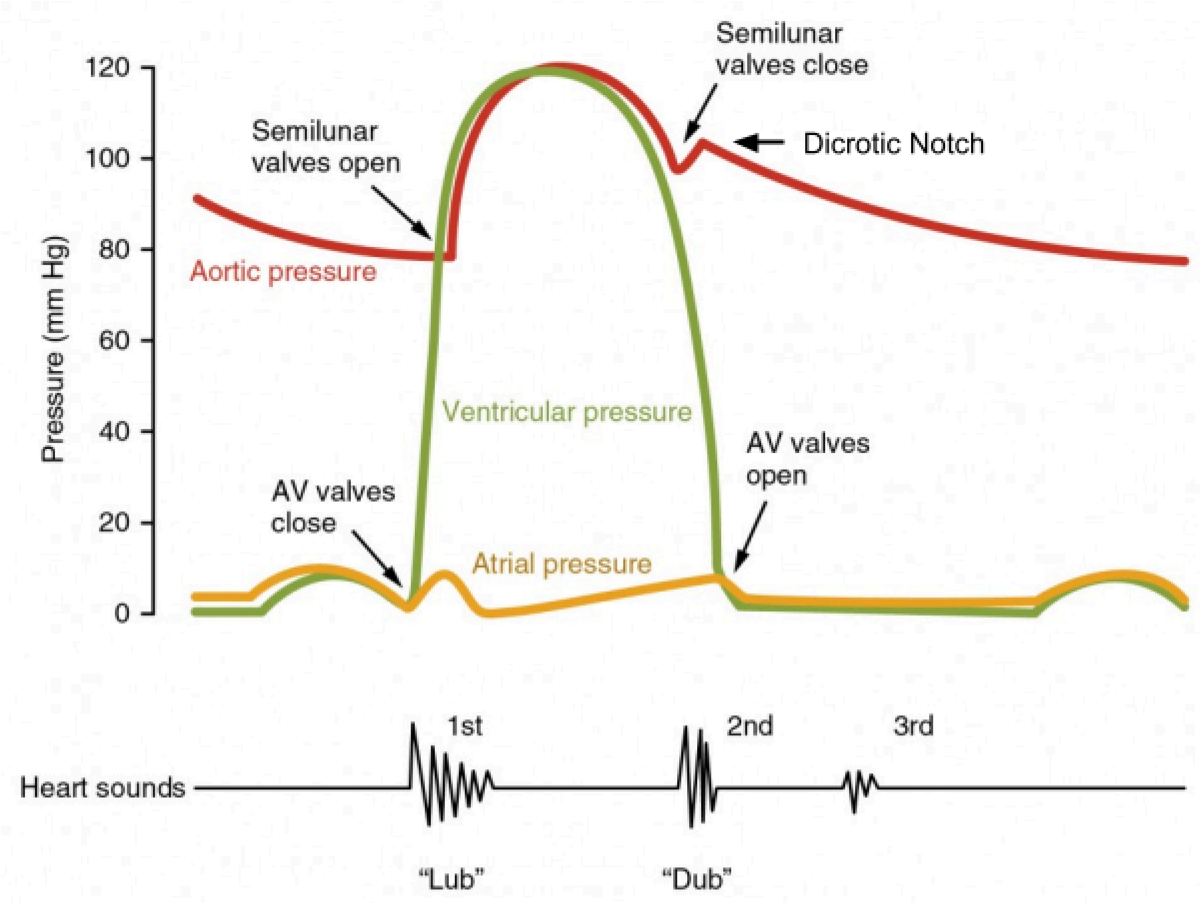


Figure 2.22 - Blood Pressure against Time graph

For Sections 2.13.2 to 2.13.4, refer to *Figure 2.22* above.

2.13.2 Atrial Systole

During Atrial Systole, the **atria** *(plural of atrium)* **contracts**, forcing the blood inside the atrium to enter the **ventricles**. During this time, the **AV Valves** are open, and the **Semi-lunar Valves** are closed.

2.13.3 Ventricular Systole

During Ventricular Systole, the **atrium relaxes** and the **ventricles contract**. This causes the blood pressure of the ventricles increases to be greater than that of the atria and the aorta/pulmonary arteries, which forces the **AV Valves** to close, and the **Semi-lunar Valves** to open.

As the **AV Valves** close, backflow of blood is prevented and a "lub" sound is produced.

The wall of the aorta **stretches** to accommodate the high pressure of blood exiting from the left ventricle, pushing blood into systemic circulation.

2.13.4 Atrioventricular Diastole

The ventricles begin to **relax** as the **Semi-lunar Valves close** to prevent backflow of blood. This produces a "dub" sound. The pressure in the ventricles drops to be lower than that of the atria, causing the **AV Valves** to **open.**

At this time, there is a slight increase in aortic pressure as the walls of the aorta spring back to maintain the driving force to push blood into systemic circulation, causing what is known as the **dicrotic notch** on the blood pressure-time graph (Refer to *Figure 2.22* above).

During Atrioventricular Diastole, blood passively flows into the heart from the veins into the **atria**, and then through the **AV Valves** into the **ventricles**.

2.14 Coronary Heart Disease

Coronary Arteries lie on the surface of the heart and **supply** the muscles of the heart with **oxygenated blood,** since the walls of the heart are too thick for the muscles to directly obtain blood from the chambers.

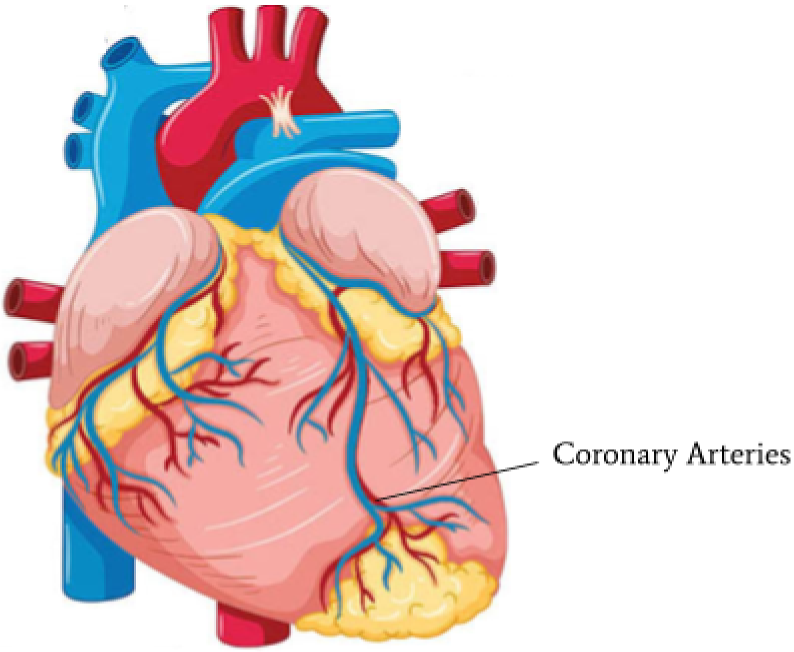


Figure 2.23 - Coronary Arteries

Excess **cholesterol** can build up along the sides of the inner arterial walls, causing blockages and disrupting blood flow. This causes the lumen of arteries to become **narrower** and is known as **atherosclerosis**.

A blood clot can then form in the Coronary Arteries, a process known as **thrombosis**. This reduces blood flow to the heart muscles, which receive less oxygen and nutrients. This causes sections of the heart muscles to weaken and become damaged, possibly leading to a **heart attack**.

Topic 3: Respiration

"BREATHE AIR" ~Andrew Tate

3.1 Why is Respiration Important?

Living things respire because they require **energy** to sustain life. Energy is required for processes like growth, cell division (reproduction), movement, and excretion.

Living organisms first **break down** food into simpler food molecules through **digestion**, then use these molecules to release energy through **respiration**.

3.2 Aerobic Respiration

Aerobic Respiration takes place as the following reaction:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} + 6\,O_2 \rightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

It is the breakdown of food substances in the **presence** of oxygen. It results in the release of a large amount of energy in the form of ATP and it gives out carbon dioxide and water as waste products. Energy is also released as heat.

It occurs in the **mitochondria of all cells**.

FYI: Adenosine Triphosphate (ATP)

This is the structure of Adenosine Triphosphate.

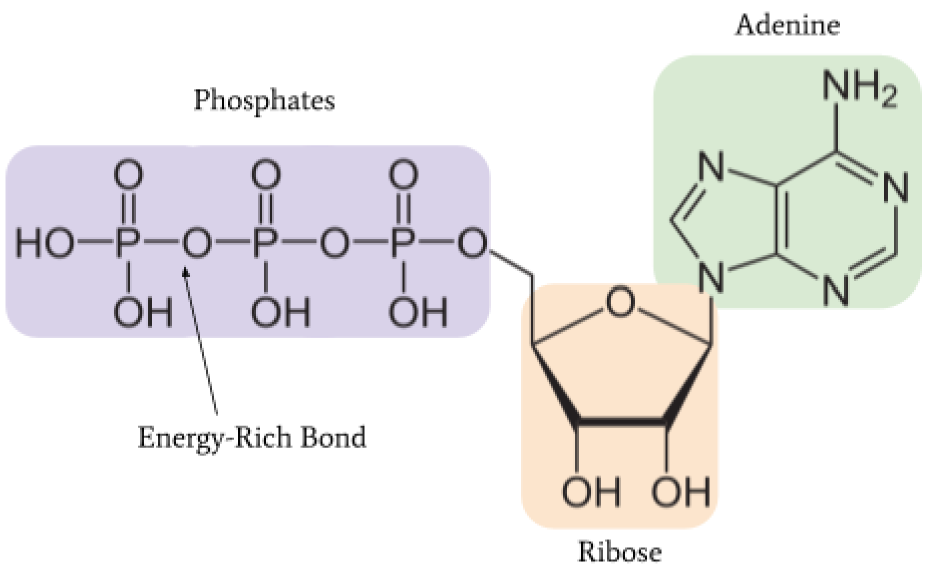


Figure 3.1 - Adenosine Triphosphate

The final phosphate is said to have an Energy-Rich bond and when broken, releases a lot of energy. The reaction to break this bond is:

$$ATP + H_2O \rightarrow ADP + P_i + Energy$$

Where ADP is Adenosine Diphosphate:

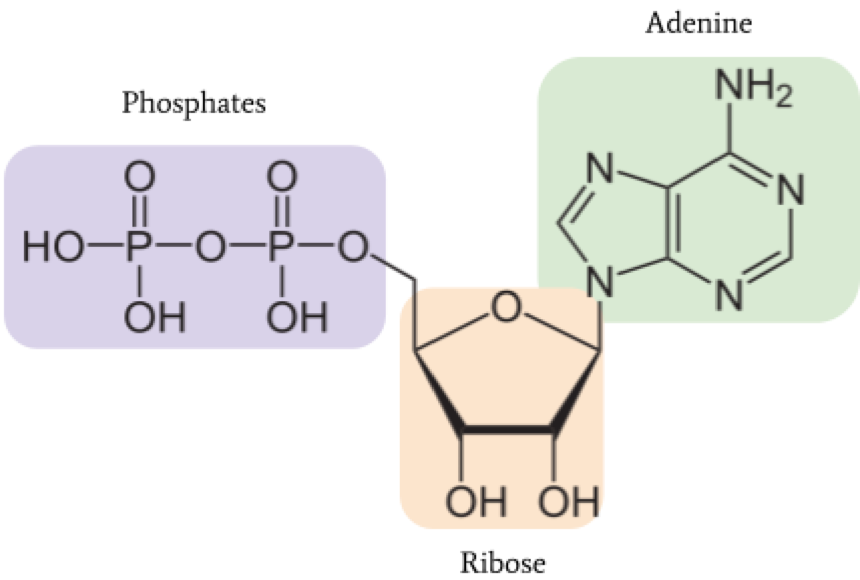


Figure 3.2 - Adenosine Diphosphate

...and P_i is an inorganic phosphate (usually in the form of $H_2PO_4^-$ or HPO_4^{2-})[confirm]

3.3 Anaerobic Respiration

Anaerobic Respiration takes place in the following reaction in humans:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \rightarrow 2\,\underset{\text{(lactic acid)}}{C_3H_6O_3} + \text{Energy}$$

Anaerobic Respiration is the breakdown of food substances in the **absence of oxygen**. It releases significantly less energy than aerobic respiration. (**FYI:** around 19 times less!)

Less energy is released as heat in anaerobic respiration than in aerobic respiration.

3.3.1 Anaerobic Respiration in Yeasts

In yeast, anaerobic respiration takes place in a slightly different reaction:

$$\underset{\text{(glucose)}}{C_6H_{12}O_6} \rightarrow 2\,CO_2 + 2\,\underset{\text{(ethanol)}}{C_2H_5OH} + \text{Energy}$$

This reaction cannot happen in humans as ethanol is toxic to humans, but not to yeasts.

3.4 Photosynthesis vs Respiration

Photosynthesis is like the "reverse reaction" of Respiration.

Respiration	Photosynthesis
Energy is **used**	Energy is **released**
Oxygen is **used**	Oxygen is **released**
Carbon Dioxide is **released**	Carbon Dioxide is **used**
Water is **released**	Water is **used**
Catabolic process ("breaking down")	**Anabolic** process ("building up")
Occurs all the time, independent of **chlorophyll** and **light**	Occurs only in cells containing **chlorophyll** and under presence of **light**
Results in **loss** of dry mass	Results in **gain** of dry mass

Table 3.3 - Respiration vs Photosynthesis

Table 3.3 above illustrates why photosynthesis and respiration are "opposites".

3.5 Respiration During Exercise

During exercise, the muscles **contract vigorously** to enable movement. Both the **rate of respiration** and **heart rate** increase to enable more oxygen to reach the muscles.

If there is not enough oxygen to produce the energy required, an **oxygen debt** results as **anaerobic respiration** takes place to provide the energy required. This can cause **lactic acid** to accumulate in the muscle cells, which can lead to **fatigue and muscle pain**.

In the liver, some lactic acid is oxidised by enzymes present to release some energy, converting the rest of the lactic acid back into **glucose**.

When all the lactic acid has been converted back to glucose, the **oxygen debt** is said to be **repaid** as glucose is transported back to the muscles.

3.6 The Human Respiratory System

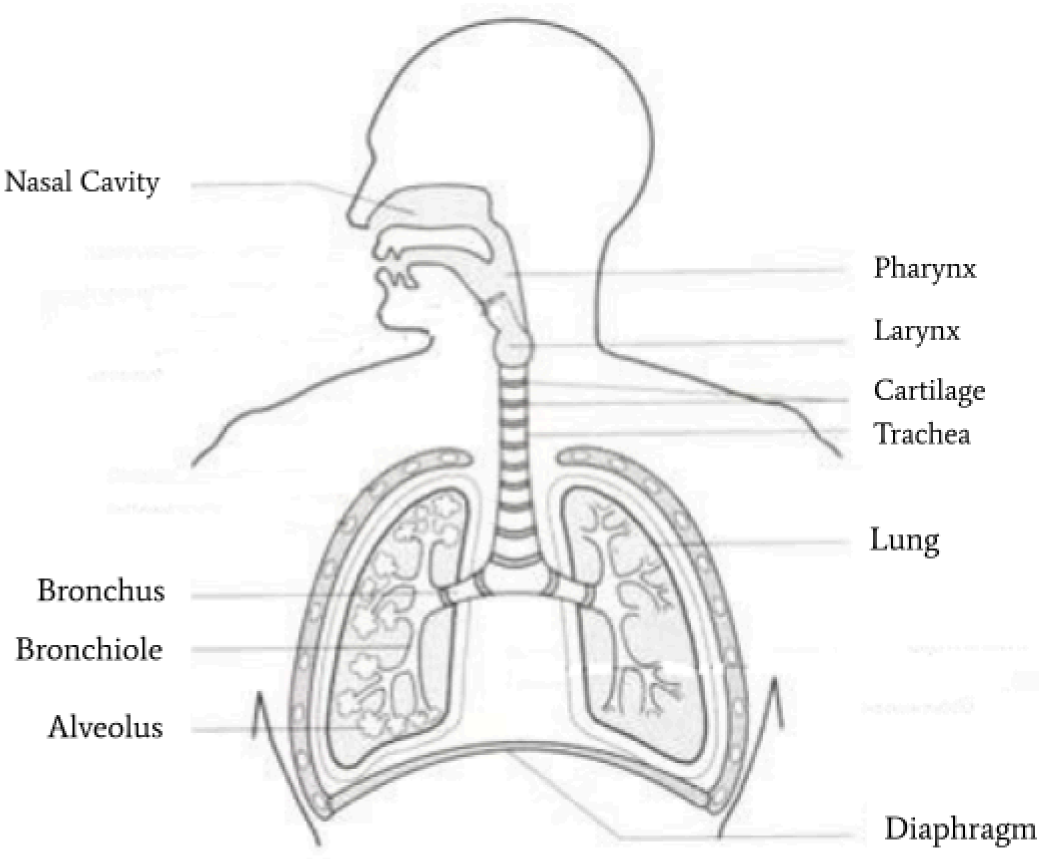


Figure 3.4: The Human Respiratory System

3.6.1 Nasal Cavity

The fringe of **hair** and **mucous layer** on the walls of the nasal cavity **trap dust and foreign particles**. As the air passes through the air passages, it is warmed and moistened.

3.6.2 Trachea

The trachea, also known as the windpipe, is supported by **C-shaped** rings of cartilage that ensures that the trachea is **always open**.

3.6.3 Walls of Trachea and Bronchi

The walls of trachea have **gland cells**, which **secrete mucus that trap dust**, and **ciliated cells**, which have **cilia** that sweep the trapped dust particles and bacteria up the bronchi and trachea back into the **pharynx**.

3.6.4 Lungs

In the lungs, the bronchial tubes divide repeatedly to form **bronchioles**, which end in an **alveoli**.

3.6.5 Alveoli

Alveoli are the site of gas exchange. The numerous alveoli in the lungs increase **Surface Area to Volume Ratio** for higher rate of gaseous exchange.

The alveoli are also **well-supplied with blood capillaries**, which contain a constant flow of blood to enable the efficient exchange of gases.

The alveolar surface is coated with a **thin film of water**, and the wall of an alveolus is **one-cell thick**.

3.6.6 Ribs

Ribs **support the chest wall**, and have two main sets of muscles - internal intercostal muscles, and external intercostal muscles, as seen in *Figure 3.5* below.

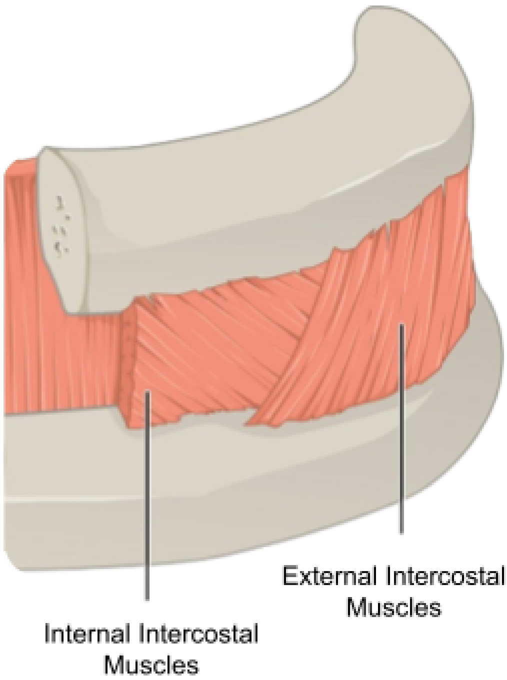


Figure 3.5: Intercostal Muscles in the Ribs

FYI: Humans have 12 pairs of ribs! Yay!

3.6.7 Diaphragm

The diaphragm is a **dome-shaped** muscle and elastic tissue that can **contract and relax** to change the volume of the **thoracic cavity** (chest cavity).

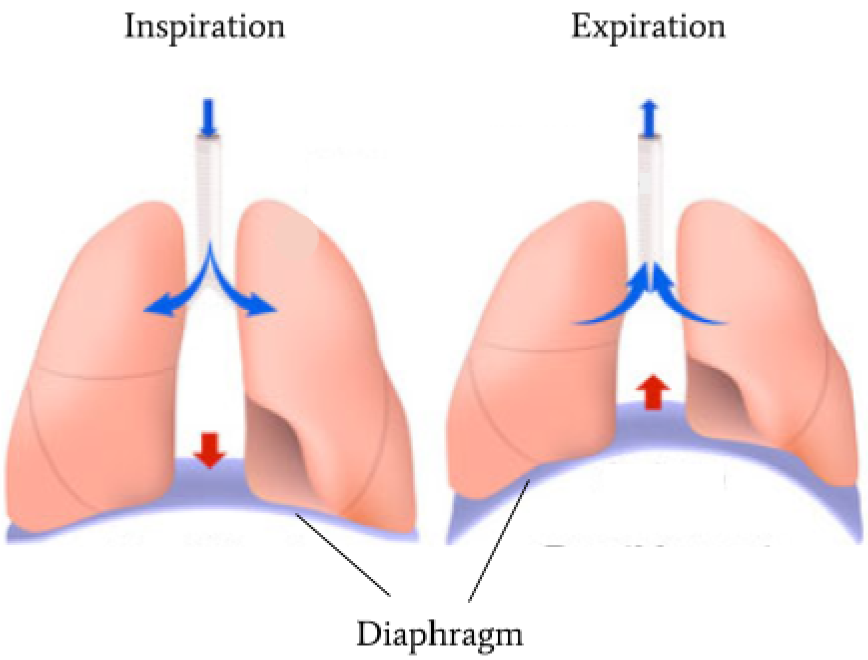


Figure 3.6: Contraction and Relaxation of Diaphragm

3.7 Breathing in Humans

Breathing consists of two parts - **Inspiration** (Breathing in) and **Expiration** (Breathing out).

Tip: Remember that the **diaphragm** and the **external intercostal muscles** perform the same action (contract or relax) at the same time, while the **internal intercostal muscles** perform the opposite.

3.7.1 Inspiration

During inspiration, the diaphragm **contracts** and **flattens**. Around the same time, the external intercostal muscles **contract** and the internal intercostal muscles **relax**, moving the rib cage **upwards** and **outwards**.

The thoracic volume **increases**, **decreasing pressure** in the lungs to below that of the surrounding air, so air is drawn into the lungs.

3.7.2 Expiration

During expiration, the diaphragm **relaxes** and **arches up**. Around the same time, the external intercostal muscles **relax** and the internal intercostal muscles **contract**, moving the rib cage **downwards** and **inwards**.

The thoracic volume **decreases**, compressing the lungs and **increasing pressure** in the lungs, forcing the air out of the lungs.

3.8 Chemicals Present in Tobacco Smoke

We all know that smoking can have many **adverse effects** on your health. This is because tobacco smoke contains chemicals such as **Nicotine, Carbon Monoxide and Tar**, as well as certain other **Irritants**.

3.8.1 Nicotine

Nicotine is highly **addictive** and makes blood **clot** more easily, increasing risk of heart disease.

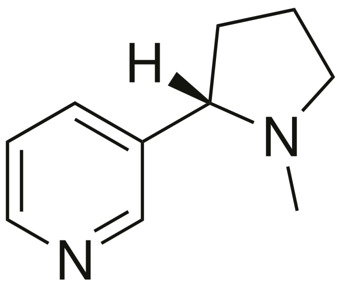


Figure 3.7: Nicotine

3.8.2 Carbon Monoxide

Carbon Monoxide decreases the ability of red blood cells to transport **oxygen**, as it binds strongly with **haemoglobin** to form **carboxyhaemoglobin**. This bond is typically too strong to be broken so the haemoglobin is just stuck in this form and can no longer bind with oxygen.

It also increases the rate at which fats are deposited on the **inner arterial walls** and increases the risk of **atherosclerosis** (Refer to Section 2.14).

3.8.3 Tar

Tar is a **carcinogenic** (cancer-causing) chemical that **paralyses** the cilia lining in air passages and reduces the **efficiency** of gaseous exchange.

3.8.4 Other Irritants

These irritants **paralyse** the cilia lining in air passages and increase the risk of **Chronic Bronchitis** and **Emphysema** (Refer to Section 3.9 below).

3.9 Diseases Caused by Tobacco Smoke

We focus on three conditions caused by tobacco smoke - **Chronic Bronchitis**, **Emphysema** and **Lung Cancer**.

3.9.1 Chronic Bronchitis

Chronic Bronchitis refers to **infection** of the **bronchi**.

In patients with Chronic Bronchitis, the epithelium lining the airways is **inflamed**. The cilia lining the airways are **paralysed** and **breathing difficulties** are often developed.

There is also **excessive mucus secretion**, leading to **persistent coughing** as a natural response to try to clear the mucus.

3.9.2 Emphysema

Emphysema refers to damage to the **alveoli** of the lungs, in which the alveoli could be collapsed, destroyed, narrowed, overinflated or stretched.

In patients with Emphysema, the partition walls of alveoli eventually **break down** due to violent coughing, resulting in the **reduction** of surface area of alveoli available for gaseous exchange.

The lungs also lose their **elasticity** as the elastic fibres of the lungs are damaged, and become constantly inflated with air.

Symptoms of emphysema include **severe coughs, breathing difficulties** and **wheezing**.

3.9.3 Lung Cancer

In heavy smokers, lung cancer can develop due to uncontrolled **division** of cells producing **outgrowths** or **lumps** of tissues.

Topic 4: Heredity

Actually fun biology?!!

4.1 Basic Definitions

Chromosomes are formed from **chromatin**, which is found in the nucleus of a cell.

- Chromosomes come in homologous pairs, where one is from the father, and one is from the mother.
- Humans have 23 pairs of chromosomes.
- Each chromosome can split into two identical **sister chromatids** during cell division.

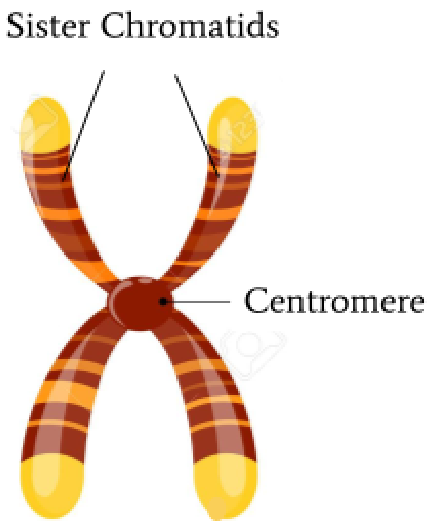


Figure 4.1 - Chromosome

A **gene** is a **section of DNA** at a specific location on a chromosome which contains certain **information** that **determines a trait**. It can be **duplicated** and **controls the production of one protein**. It is inherited from **parent** to **child**.

A **Mendelian trait** is a trait determined by **one gene**.

The **ploidy level** of cells describes the number of chromosomes present.
In **diploid cells**, we say its ploidy level is 2n, and in **haploid cells**, we say its ploidy level is n.

A **somatic cell** is any non-sex cell. In humans, somatic cells are always **diploid**.

A **gamete** is a sex cell. In humans, gametes are always **haploid**.

4.2 Sexual vs Asexual Reproduction

Sexual reproduction is the process involving the fusion of **nuclei** to form a **zygote** and the production of **genetically dissimilar** offspring **from two parents**.

Asexual reproduction is the process resulting in the production of **genetically identical offspring** from **one parent**.

In general, **sexual reproduction** takes more time than **asexual reproduction.**

4.3 Mitosis

Cells can undergo **Mitosis** to produce two **identical** daughter cells. Each daughter cell has the **same number of chromosomes** (same ploidy level) as the parent cell.

FYI: The Mitotic Phase consists of 5 stages - Prophase, Metaphase, Anaphase, Telophase (which are referred to collectively as Mitosis) and Cytokinesis.

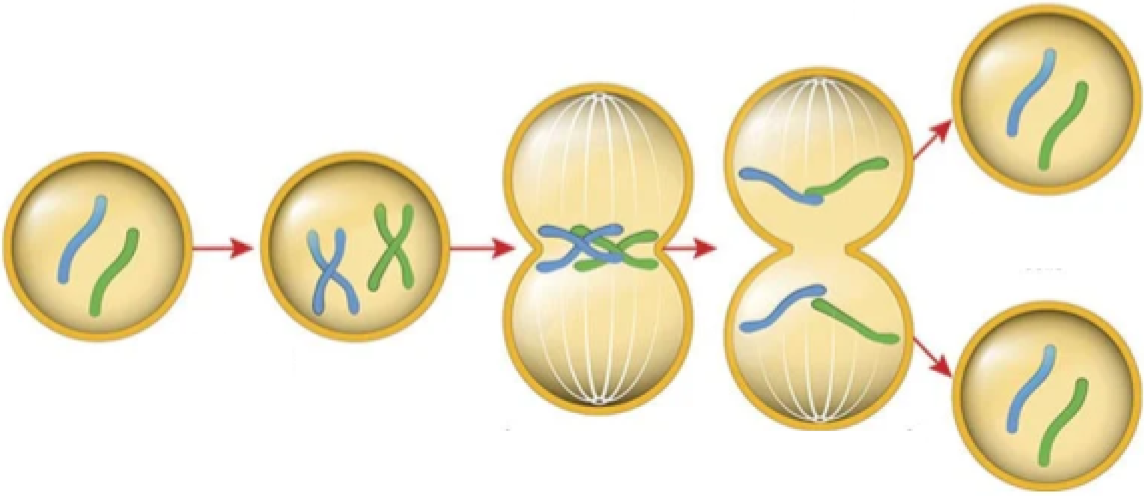


Figure 4.2 - Mitosis

Mitosis is considered as **Asexual Reproduction**.

Mostly, only **diploid cells** reproduce by Mitosis.

4.3.1 Functions of Mitosis

Mitosis allows for **growth**, increasing the number of cells within the organism.
Mitosis also allows for **renewal and repair**, where the cells and tissues lost in the processes of **wear and tear** are **regenerated**.

4.4 Meiosis

Cells can also undergo cell division through **Meiosis.** The cells that reproduce through meiosis are typically **sex cells**, and it causes the haploid gametes produced to have half the number of chromosomes from its parent cells.

In humans, a sex cell from the father will undergo meiosis to form **4 sperm cells**.

On the other hand, a sex cell from the mother will undergo meiosis to form 4 cells, **one** of which becomes an **egg cell** and the other three are non-functional cells termed polar bodies.

4.4.1 Why half the chromosome number?

The cells generated must be haploid in order to ensure that the number of chromosomes over **successive generations** through sexual reproduction **remains constant**.

4.4.2 Genetic Variation

Since meiosis occurs with sexual reproduction, there is crossing over of genes between the paternal cell and the maternal cell, which causes **genetic variation** in the **daughter cells**.

4.5 Homozygous, Heterozygous, whaaaaat???

Since each chromosome comes in a **homologous pair,** where one chromosome comes from the Mother, and one comes from the Father, for every gene on one chromosome, there is **essentially another copy** of this gene on the other chromosome in the pair.

This means, there are two **alleles** (that can be different!) for every gene that controls a trait!

Normally, a gene has two alleles, or "versions" - the **dominant** one, and the **recessive** one. We denote by "T" the dominant allele and by "t" the recessive allele.

The word homozygous refers to having two copies of the same allele (TT or tt), while heterozygous means having one of each (Tt, order doesn't matter).

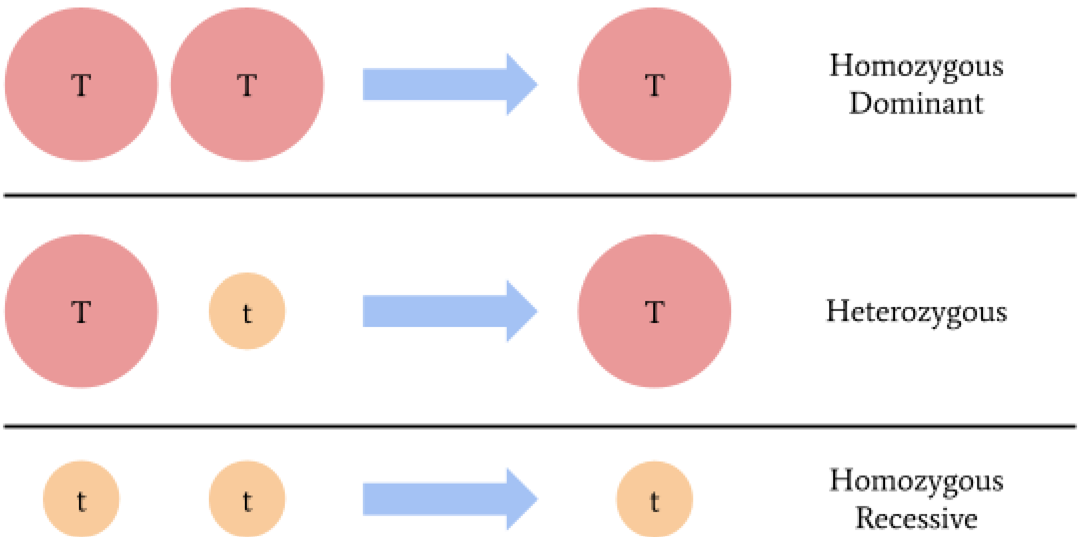


Figure 4.3 - The Three Configurations of Alleles

As seen in ***Figure 4.3*** above, if we have a dominant allele present, the dominant allele always dominates and will take priority over the recessive allele. Hence in Homozygous Dominant and Heterozygous cases, we say that the **dominant allele is expressed**.

Similarly in Homozygous Recessive environments, we say the **recessive allele is expressed.**

4.6 Punnett Squares

Punnet Squares and **Genetic Diagrams** are tools to determine and explain **genotypes** (the genetic makeup of an organism) **and phenotypes** (the observable traits of an organism) arising from **genetic crosses**.

When the **dominant and recessive alleles** are expressed, we can expect **slightly different phenotypes**.

For example, for the allele controlling height of a pea plant, where the dominant allele is the "Tall" allele, if the dominant allele is expressed, we expect the plant to be tall. On the other hand if the recessive allele is expressed, we expect it to be dwarf. See the example below.

Worked Example

Consider a **pure-bred tall** and **pure-bred dwarf** plant. Given that the allele for dwarfism is recessive, explain why all the offspring produced are **tall**, by means of a **Punnett Square**.

Solution

Let the alleles representing dwarf and tall be t and T respectively. Then we construct a Punnett Square:

Parents

TT × tt

Gametes	t	t
T	Tt	Tt
T	Tt	Tt

Figure 4.4 - Punnett Square

Notice that each of the Tt's are constructed by taking one allele from each parent. That is, we take the topmost row and leftmost column of each cell.

Gametes	t	t
T	Tt	Tt
T	Tt	Tt

Figure 4.5 - Construction of Punnett Square

From this, we see that the genotypes of all the offspring are Tt, which means that the phenotypes of the offspring will all be **tall**.

4.7 Genetic Diagrams

A Genetic Diagram is like a more comprehensive version of a Punnett Square, that shows the intermediary steps of how genes work.

Using the same example from before, we propose a Genetic Diagram.

Worked Example

Consider a **pure-bred tall** and **pure-bred dwarf** plant. Given that the allele for dwarfism is recessive, explain why all the offspring produced are **tall**, by means of a **Genetic Diagram**.

Solution

Pure-bred simply means homozygous. Let the alleles representing dwarf and tall be t and T respectively. Then we construct a Genetic Diagram:

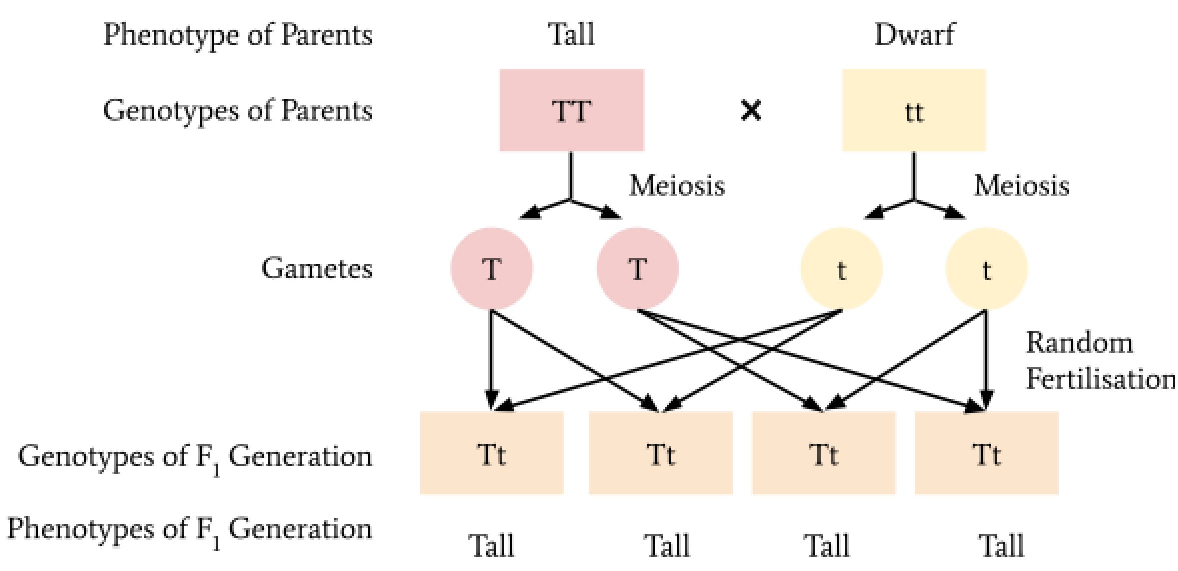


Figure 4.6 - Genetic Diagram

F_1 Generation (First Filial Generation) means the plants produced by cross-breeding of the parents. Do remember that the fertilisation arrows **must** point from different parents, and should not repeat.

Of course, the colours are not needed, but do take note the shapes (rectangle vs circle). Circles are only used for **gametes**.

Worked Example

An allele controls whether a person has black or red hair. The allele for black hair is dominant. It is given Male A is heterozygous, and Female B has red hair. What is the probability a child from A and B has red hair?

Solution

If B has red hair, it means the recessive allele has been expressed, so she must be **homozygous recessive**. Now we can construct a Genetic Diagram.

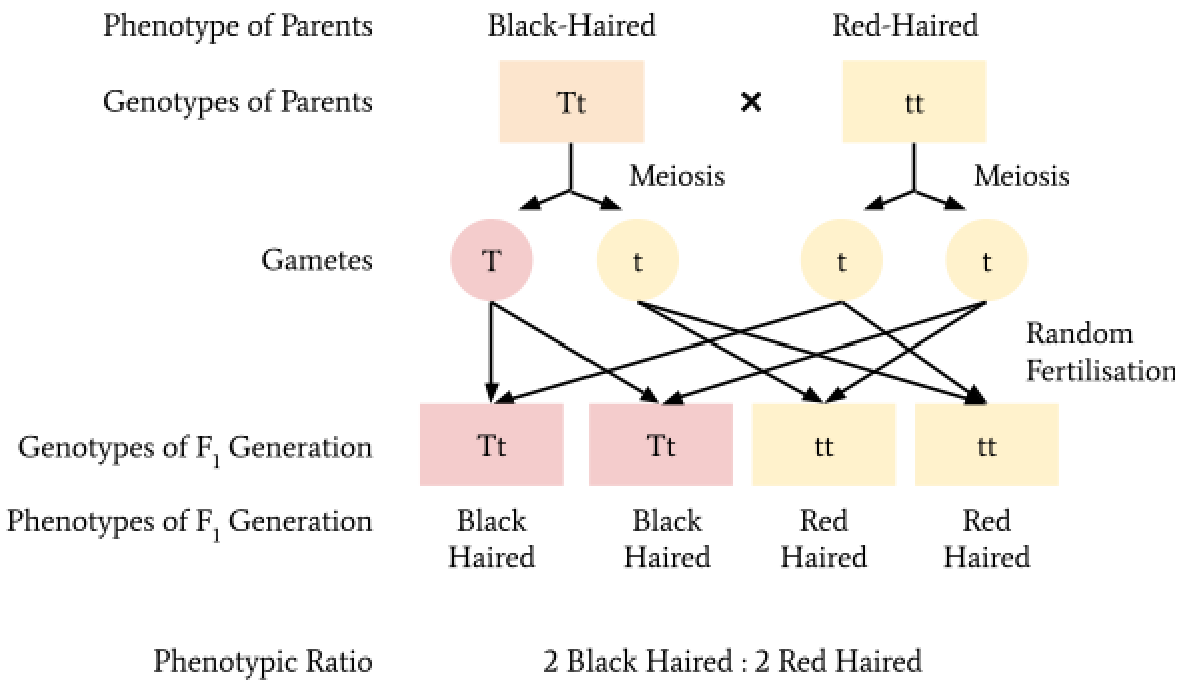


Figure 4.7 - Genetic Diagram

The probability that a child of A and B has red hair is then $2 \div (2+2) \times 100\% = 50\%$.

4.8 Co-dominance and Incomplete Dominance

Sometimes, the allele isn't just split into dominant and recessive. There are actually 3 cases. The dominant-recessive case in the previous examples are known as **Complete Dominance**.

Co-dominance refers to how two alleles can be expressed together and are equally expressed in heterozygous environments, while **Incomplete Dominance** refers to how two alleles' effects can be "mixed" together in heterozygous environments.

For example, consider two flowers and denote by C^R the allele for red flowers, and C^W the allele for white flowers. The three cases of dominance can be shown below:

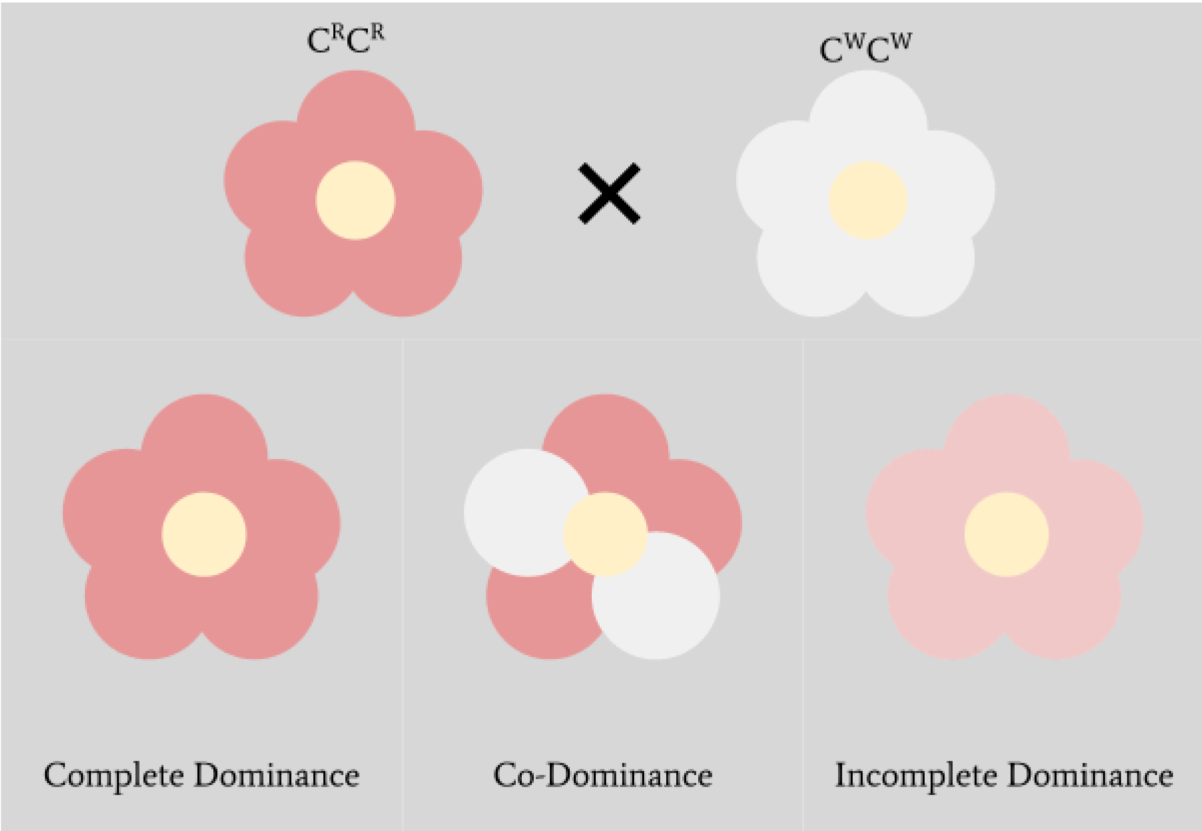


Figure 4.8 - Complete, Incomplete and Co-Dominance

4.9 Multiple Alleles

We have only explored genes with exactly 2 alleles. What if there are more? A gene is said to have **multiple alleles** if it has more than 2 alleles ("versions").

4.9.1 ABO Blood Group

If you need a recap on Blood Groups, you may refer to Section 2.11 - Blood Groups.

The ABO Blood Group System is one we need to be familiar with for BL2131. We denote by I^A the presence of antigen A, by I^B the presence of antigen B and I^O the presence of neither.

I^A and I^B are **co-dominant** to each other, while I^O is **recessive** to both I^A and I^B.

Blood Group	Possible Alleles
A	I^AI^O (heterozygous) or I^AI^A (homozygous dominant)
B	I^BI^O (heterozygous) or I^BI^B (homozygous dominant)
AB	I^AI^B (co-dominant)
O	I^OI^O (homozygous recessive)

Table 4.9 - Blood Groups and their Alleles

From this, we can construct genetic diagrams to find the possible blood types of children, if we know the parents' alleles. For example, 2 parents with Blood Type O will only produce children of Blood Type O.

Topic 5: Reproduction in Plants

Boo. No, I'm not trying to scare you. Just booing this chapter. It's halloween now :3

5.1 Parts of the Flower

Here are some parts of a typical flower that we need to know.

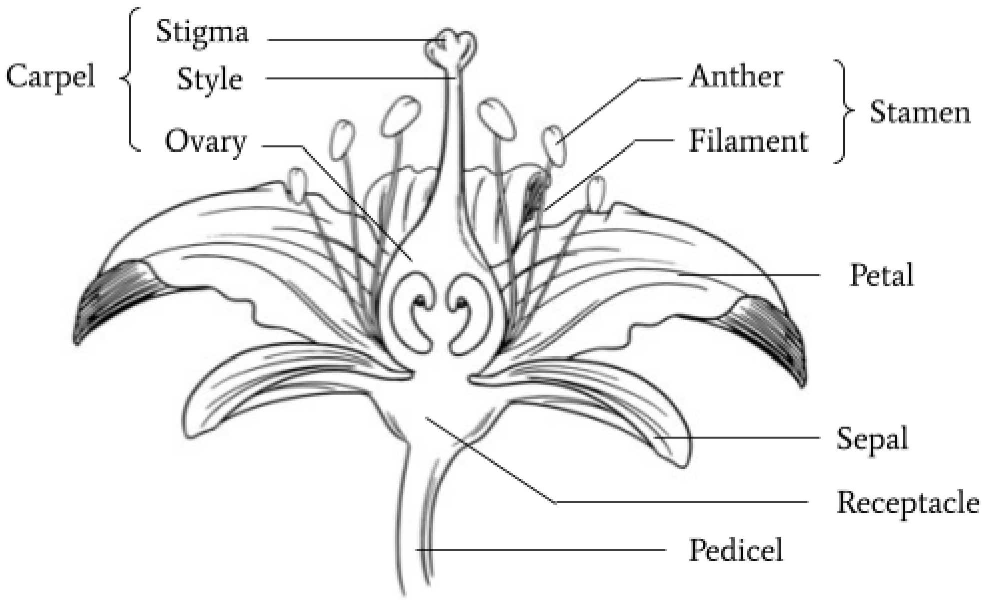


Figure 5.1: Longitudinal Section of Flower

5.1.1 Collective Nouns

Here are the collective words of the flower parts:

Singular	Collective
Petal	Corolla
Sepal	Calyx
Stamen	Androecium
Carpel	Gynoecium

Table 5.2

Also, a cluster of flowers is also referred to as an **inflorescence**.

5.2 Sepal

The sepal (collective: calyx) is a modified leaf that **protects the flower in the bud stage**. Some flowers have another layer outside the calyx called the **epicalyx**.

5.3 Petal

The petal (collective: corolla) is a modified leaf, and in insect-pollinated flowers, it is brightly **coloured to attract insects** for pollination, and provides a **landing platform** for insects.

Sometimes, the petals have **nectar guides** to guide the insect towards the nectar to increase the chance of pollination.

5.4 Stamen

The stamen is the **male reproductive parts** of the flower. *(A way to remember this is "sta<u>men</u>")* The stamen is made up by an anther and a filament, and all the stamens together make up the **androecium** (plural: androecia) of the flower.

The filament keeps the anther **upright** in a position **suitable to disperse pollen grains**, and the anther **produces** pollen grains.

The longitudinal section of the anther reveals **two** anther lobes, with **two** pollen sacs **each**.

In the centre, there is a **vascular bundle** comprising a xylem and phloem.

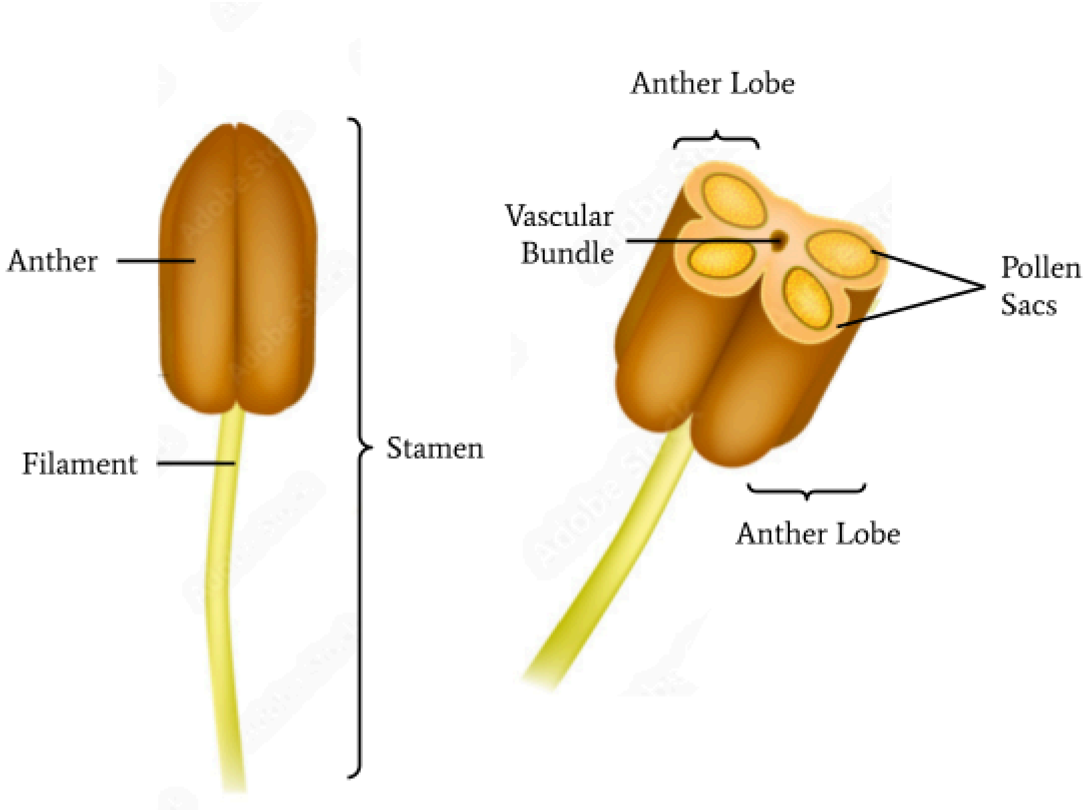


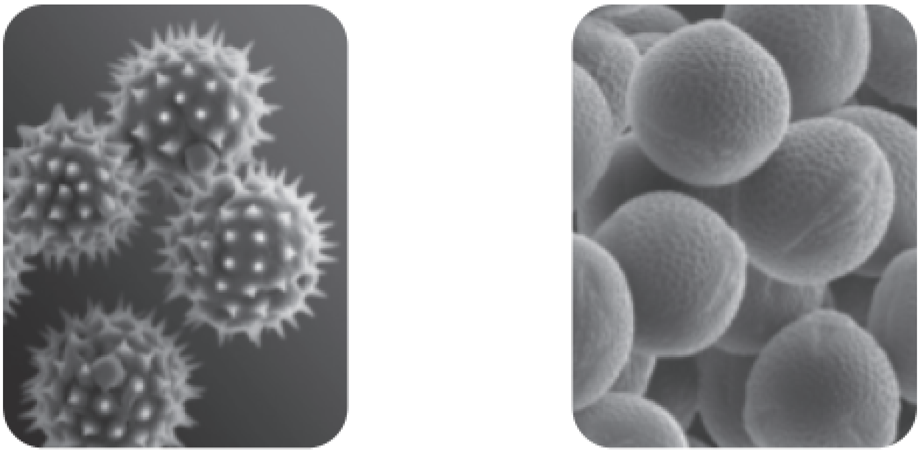
Figure 5.3 - Stamen and its Longitudinal Section

5.4.1 Pollen Grain

Pollen grains contain a **haploid** set of **chromosomes**.

Each pollen grain has two nuclei - the **generative nucleus** and the **tube nucleus** (also known as the vegetative nucleus).

As seen in *Figure 5.4* below, insect-pollinated flowers have pollen grains with **rough** surfaces to stick to the insect's body. They are also **larger** and **less numerous**. On the other hand, wind-pollinated flowers have pollen grains that are **smaller**, **smoother**, and **more numerous**.



Insect Pollinated

Wind Pollinated

Figure 5.4 - Pollen Grains under Microscope

5.5 Carpel

The carpel is the **female reproductive parts** of the flower.
The carpel is made up of at least one stigma, a style and an ovary, and all the carpels (usually just one) make up the **pistil** or **gynoecium**.

The stigma is where the pollen grains land. When the stigma matures, it secretes a **sugary fluid** which **stimulates** the **growth** of any pollen grains that land on it.

The style **connects** the stigma to the ovary, holding the stigma upright in a position to trap pollen grains.

The ovary contains one or more **ovules**. Each ovule contains an ovum and the definitive nucleus, and is connected to the **placenta** by a stalk called the **funicle**. The ovum has a haploid set of chromosomes.

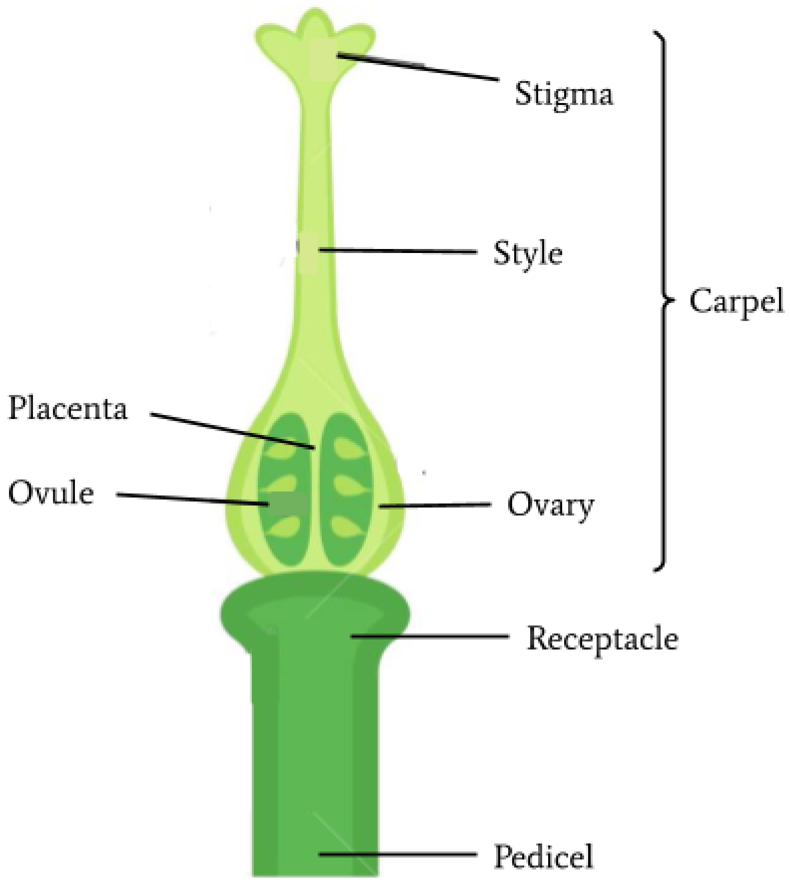


Figure 5.5 - Carpel of Flower

5.6 Pollination

Pollination is the transfer of **pollen grains** from an **anther** to a **stigma**. If the anther and stigma are from flowers of the **same** plant, it is **self-pollination**. Otherwise, it is **cross-pollination**.

In self-pollinated plants, the flowers are **bisexual** (with both male and female reproductive parts in the same flower) with anther and stigmas **maturing at the same time**. The **stigmas** are typically situated directly below the **anthers.**

On the other hand, in cross-pollinated plants, the flowers can be **dioecious** (with two types of flowers, either male or female reproductive parts) or **bisexual/monoecious**. The anther and stigmas **mature at different times**, and the stigma is situated some distance away from the anthers.

We focus on insect-pollinated and wind-pollinated plants.

In insect-pollinated plants, typically, the insect brushes its back against the anther of one flower while trying to collect nectar, causing **pollen grains to be stuck onto it**. When the insect visits the next flower, it brushes its back against the flower's stigma, completing pollination.

In wind-pollinated plants, the reproductive parts are often **long** and **pendulous**, sticking out of the flower. This allows the pollen to be **carried away** by the **wind** more easily, and allows the **large**, **feathery** stigma to capture the pollen more easily.

5.6.1 Advantages and Disadvantages of Self vs Cross Pollination

Here are some advantages and disadvantages of self-pollination and cross-pollination. Advantages are marked in Green while Disadvantages are marked in Red. *(sorry Ethan Tan)*

Point	Self-Pollination	Cross-Pollination
Beneficial Qualities	All Beneficial Qualities are inherited	Can be inherited from both parents
Number of Parent	Only one	Multiple
Reliance on External Factors	Not reliant on external factors	Requires Wind/Insects
Likeliness	More likely to take place	Less likely to take place
Speed	Faster	Slower
Wastage of Pollen and Energy	Less wastage	More wastage
Genetic Variation	Less Genetic Variation	More Genetic Variation
Harmful Recessive Alleles	More likely to be expressed in offspring	Less likely to be expressed in offspring
Disease	More susceptible to disease	Less susceptible to disease
Seeds	Seeds survive for a shorter period before germination	Seeds can survive longer before germination

Table 5.6 - Advantages and Disadvantages of Self and Cross Pollination

5.7 Clitoria Ternatea (Butterfly Pea)

Figure 5.7 below is the petal of the Butterfly Pea flower (*Clitoria Ternatea*), which is a local insect-pollinated flower.

Figure 5.7 - Clitoria Ternatea Flowers

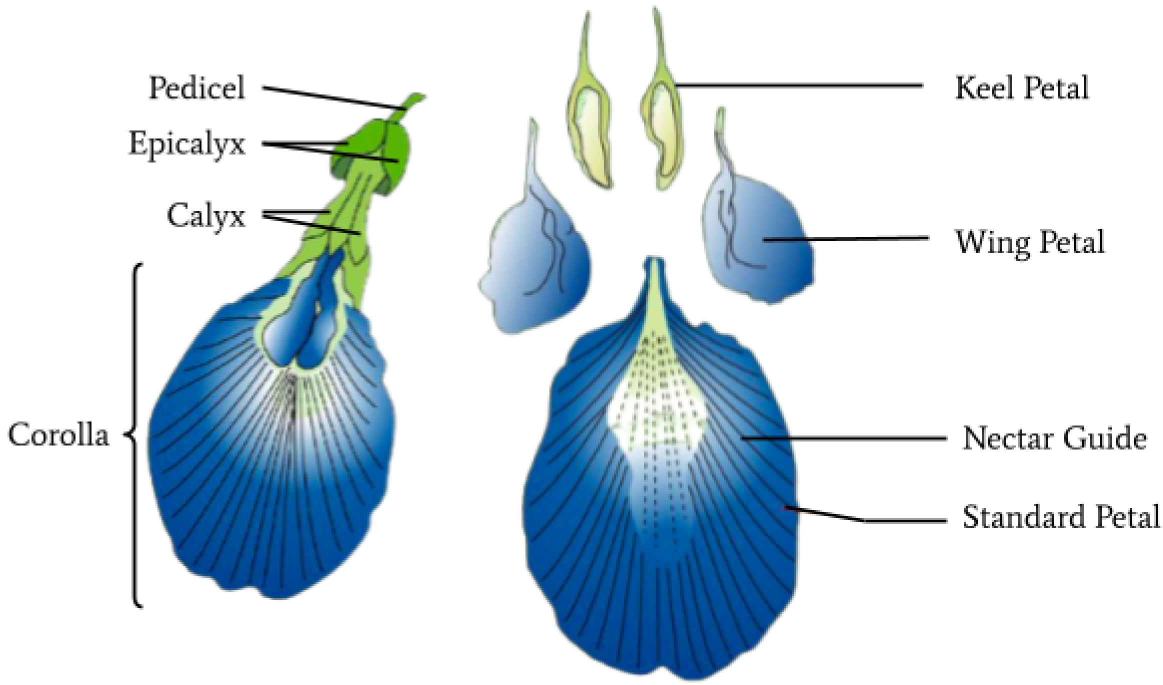


Figure 5.8 - Clitoria Petals

When the insect lands on the standard petal, it **follows the nectar guides** and forces the wing petals open.

The insect's back then forces the keel petals upwards, revealing the reproductive parts of the flower inside. This allows **pollen grains** to stick to the insect's back, allowing for pollination.

5.8 Ischaemum Muticum (Murainagrass)

Ischaemum Muticum is another local species of plant we should be familiar with. It is a wind-pollinated plant, as can be seen from the pendulous anthers and the feathery stigma in *Figure 5.9* below.

Figure 5.9 - Ischaemum Muticum

5.9 Fertilisation

Recall that fertilisation is the **fusion** of a **male gamete** with a **female gamete** to form a **zygote**.

5.9.1 Inside the Ovule

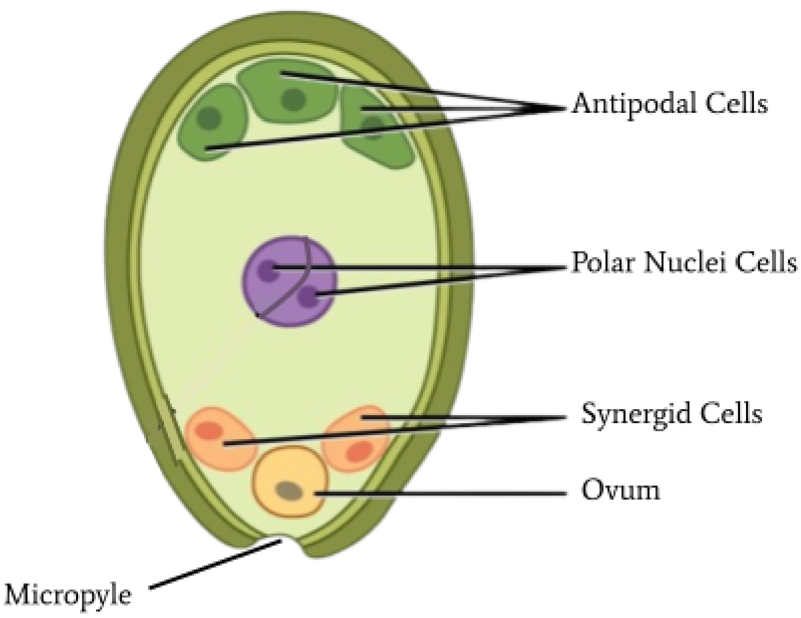


Figure 5.10 - Ovule

Figure 5.10 above shows the cells present inside the ovule. All these cells are formed through **meiosis** and are all **haploid**.

5.9.2 The Pollen Tube

When a pollen grain lands on a mature stigma, the sugary fluid stimulates the pollen grain to **germinate**, as a **pollen tube** grows out of it. The pollen tube secretes **enzymes** that **digest** the tissues of the stigma and style, allowing the pollen tube to grow towards the ovary, or specifically the **micropyle**, which is the opening of the ovule.

At this point, the **tube nucleus** is the one "leading" the pollen tube, as the **generative nucleus** follows behind.

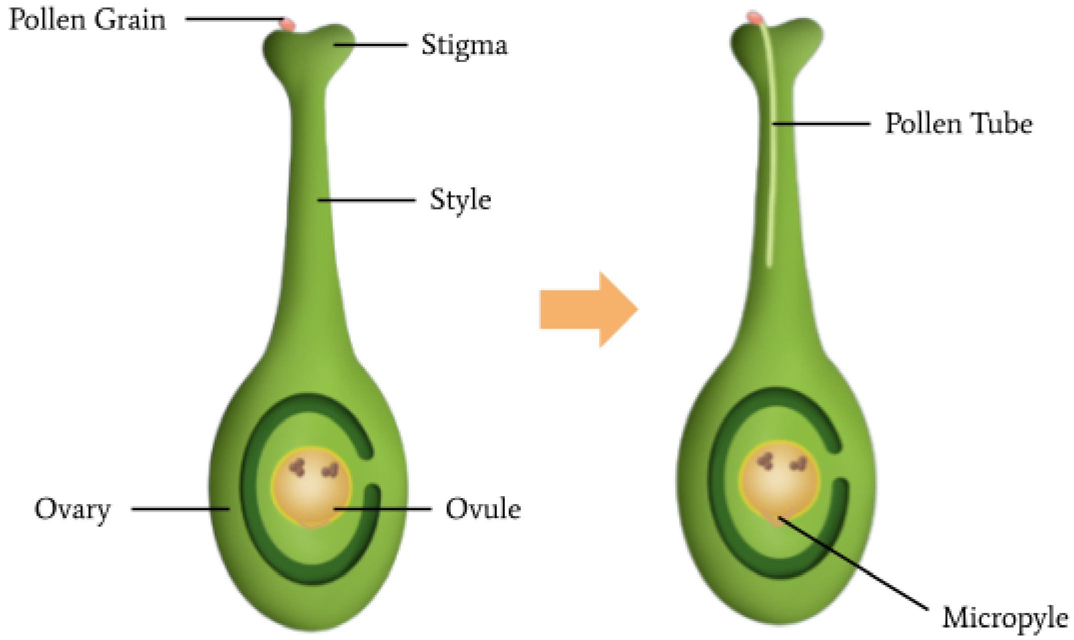


Figure 5.11 - Growth of Pollen Tube

Eventually, the pollen tube reaches the ovary and enters an ovule through the micropyle, as shown in *Figure 5.12* below. At this point, the tube nucleus has finished its job and disintegrates.

Figure 5.12: Pollen Tube entering Micropyle

5.9.3 Double Fertilisation

The generative nucleus undergoes mitosis to form two haploid sperm cells.

One of the sperm cells fuses with the ovum to form a diploid zygote. **Fertilisation** has occurred.

The other sperm cell fuses with the two haploid polar nuclei cells, and forms a **triploid (3n) endosperm nucleus**, which supplies nutrients. This is **Double Fertilisation.**

In summary, we say that most **flowering plants** (also known as angiosperms) undergo **Double Fertilisation.** Double Fertilisation **saves energy** such that plants do not waste energy in forming endosperms for ovules that would not get fertilised.

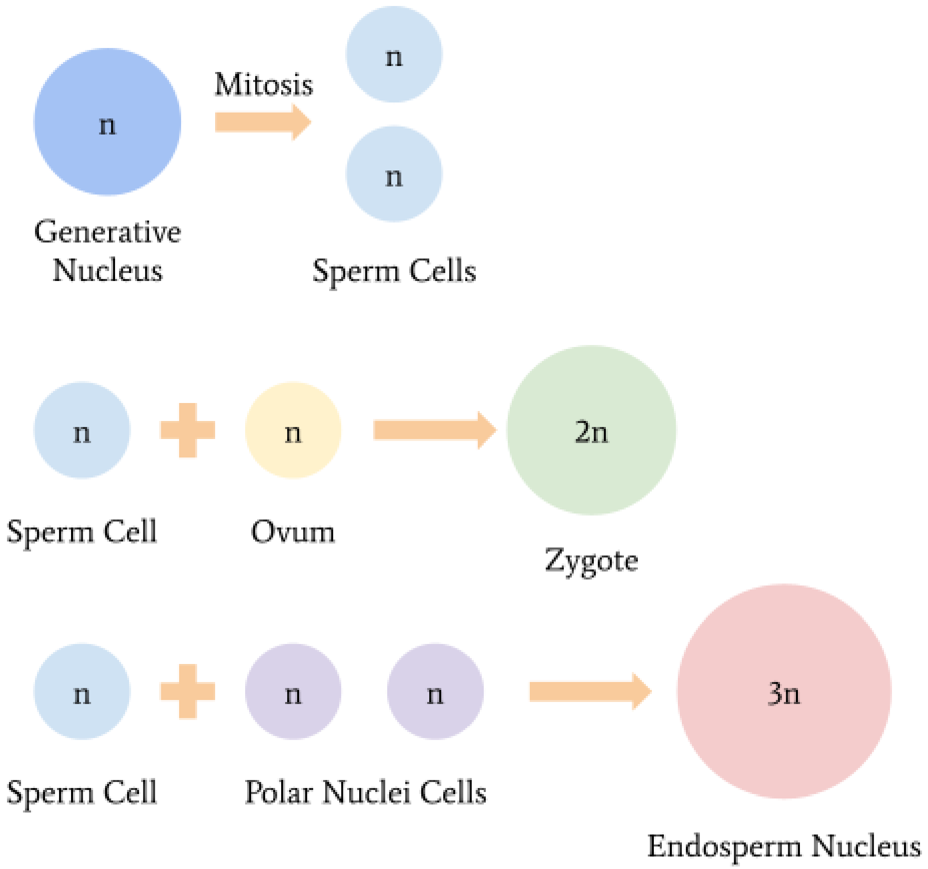


Figure 5.13: Double Fertilisation in Angiosperms

5.9.4 Post-Fertilisation Changes

Table 5.14 below summarises the post-fertilisation changes.

Before	After
Ovule	Seed
Zygote	Embryo
Endosperm Nucleus	Endosperm
Ovule Stalk	Seed Stalk
Ovary	Fruit
Ovary Wall	Fruit Wall (Pericarp)
Stigma, Style and Sepal	Wither or modified to help in fruit dispersal
Stamens, Petals	Wither and fall off

Table 5.14: Post-Fertilisation Changes

Topic 6: Reproduction in Humans

Teaching repro to 14-year-olds… hmm…

6.0 Notation

In the rest of these notes, let **GnRH**, **FSH** and **LH** denote Gonadotropin-Releasing Hormone, Follicle Stimulating Hormone and Luteinising Hormone respectively.

Symbol		Meaning
Blue Box	Gonads	Organ
Orange Box	GnRH	Hormone
Red Arrow	A → B	A Secretes B
Orange Arrow	A → B	A Stimulates B
Green Arrow	A → B	A Develops Into B
Circle	2n	Cell

Table 6.0: Notation for Chapter 6

6.1 Puberty

Puberty refers to the period of **rapid development** during which a person gains the ability to reproduce. During puberty, the **sex organs mature,** and **sex hormones** are **released**.

6.1.1 Puberty in Boys vs Girls

Puberty is a time of **physical**, **emotional** and **social changes** for teenagers. Specifically, *Table 6.1* below highlights some of the changes that occur.

Question	Boys	Girls
When does Puberty occur?	Around 14 Years Old	Around 10-12 Years Old

What visible changes occur?	Larynx (Voice Box) **Enlarges** Voice **Deepens** Penis and Testes **enlarge** **Growth** of Beard, Facial Hair, Pubic Hair, Armpit Hair, etc.	**Menstruation** Begins **Growth** of Pubic Hair Breasts and Uterus **Enlarge** Hips **Broaden**
What other changes occur?	**Sex organs mature** and start **producing sperms**.	**Sex organs mature** and **ova** (eggs) are produced, beginning of **ovarian** cycle
What causes these changes?	Increased levels of **testosterone** produced in the **testes**.	Increased levels of **oestrogen** and **progesterone** produced in the **ovaries**.

Table 6.1: Effects of Puberty

6.1.2 What Triggers Puberty?

The term "Gonads" refers to the **Testes** in Males, and **Ovaries** in Females.

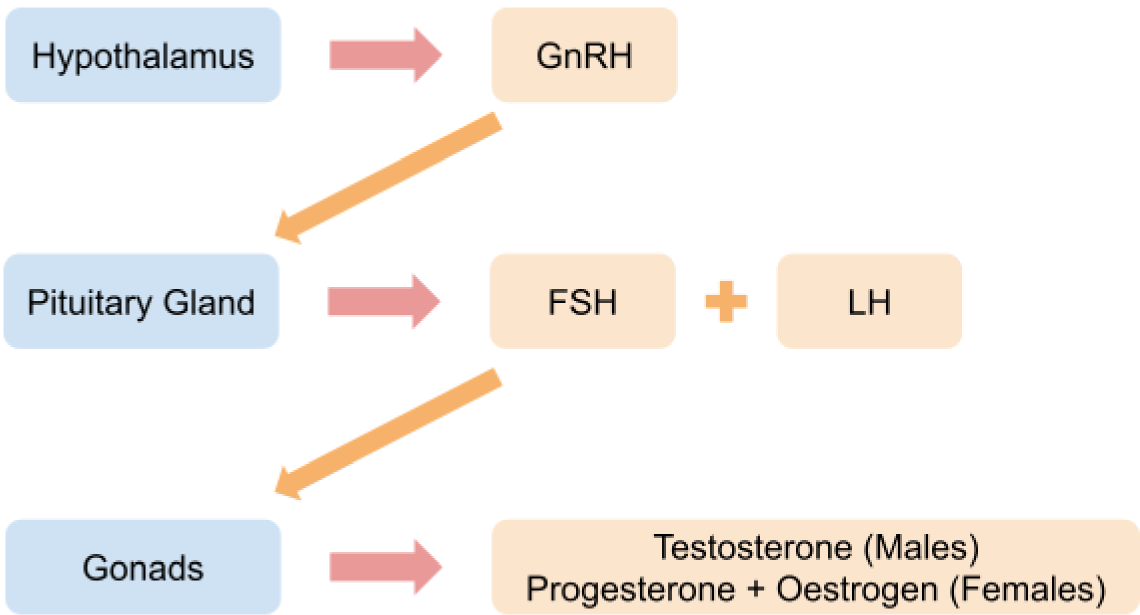


Figure 6.2: How is Puberty Triggered?

Common Misconceptions:

✖ FSH, LH, Progesterone and Oestrogen are only found in Females
✖ Testosterone is only found in Males
✔ All 5 hormones are present (in varying levels) in both Males and Females.

6.1.3 Gametogenesis

Puberty also causes the gonads to start producing gametes through a process called **Gametogenesis.** It starts with the division of a Germ Cell (parent cell) into two cells by **Mitosis**.

These cells then further divide through **Meiosis**.

Spermatogenesis (Production of Sperm) occurs in males, while **Oogenesis** (Production of Ova/Eggs) occurs in females. Refer to *Figure 6.3* below.

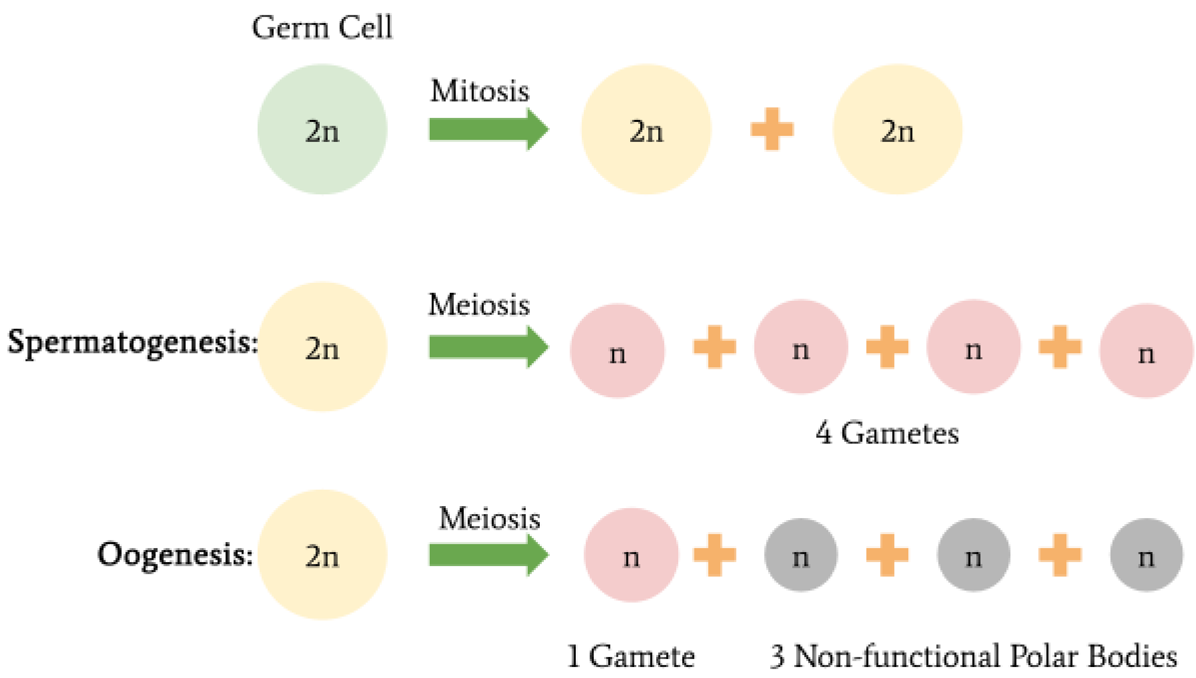


Figure 6.3: Gametogenesis

6.2 The Male Reproductive System

Figure 6.4 below shows the Male Reproductive System.

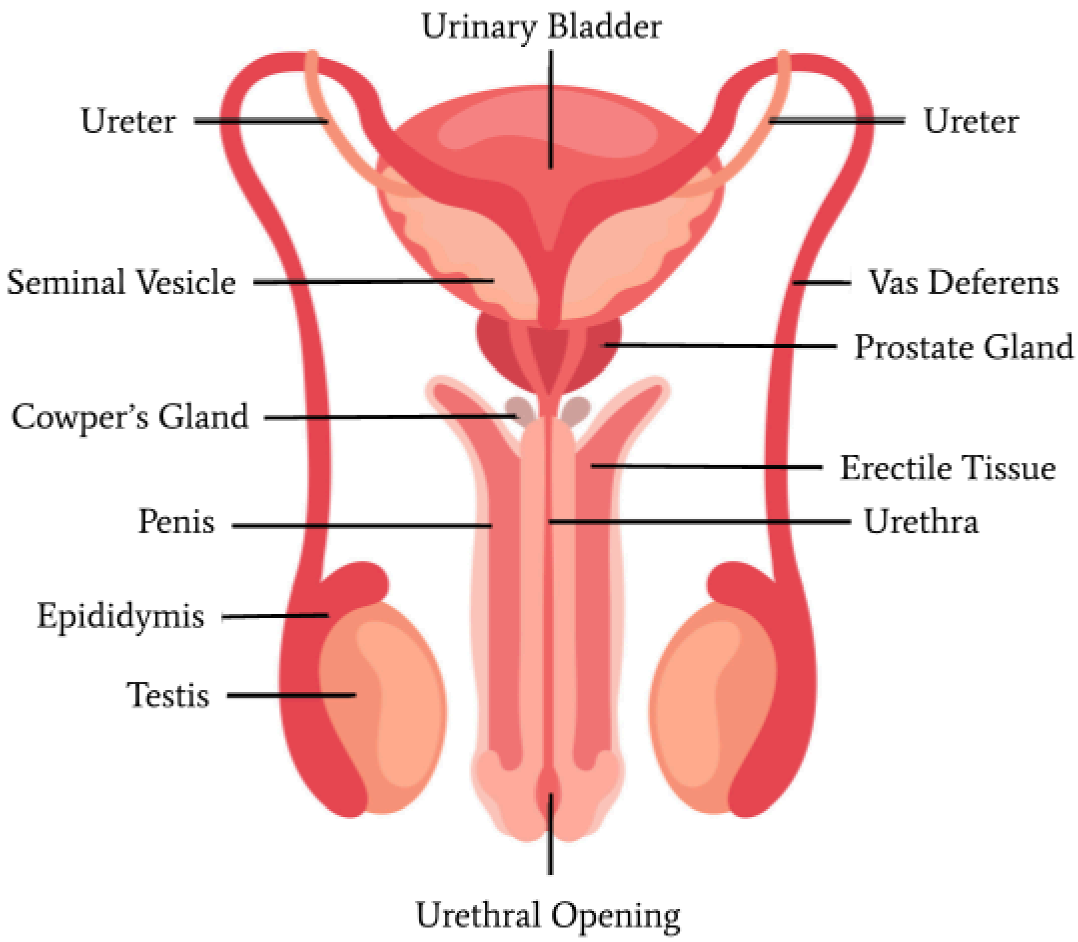


Figure 6.4: Male Reproductive System

6.2.1 Testis

The testis (plural: testes) produces **sperms** and **sex hormones** like **testosterone**.

6.2.2 Scrotum

The scrotum is a **sac of skin** located outside the abdominal cavity that **holds** and **supports** the **testes**. It helps to maintain a lower temperature for the development of sperms.

The optimal temperature for sperm development is **33 to 34 °C**.

6.2.3 Epididymis

The epididymis is a **coiled duct** next to the **testis.** It stores **inactive sperms temporarily,** before they are transported into the **vas deferens**.

6.2.4 Vas Deferens

The vas deferens (ductus deferens, sperm duct) conducts sperms from the **testis** to the **penis**.

6.2.5 Seminal Vesicle, Cowper's Gland and Prostate Gland

These three organs **release fluids** that contain **nutrients** and **enzymes** needed to activate sperm cells, creating a fluid called **semen**.

The **Seminal Vesicle** also temporarily stores sperms before they are released into the **urethra**.

6.2.6 Urethra

Urethra conducts **semen** from the **vas deferens** or **urine** from the **urinary bladder** to the **penis**.

Note: The Urethra is unable to do these two things at the **same time**, just one at a time.

6.2.7 Penis

The penis is the **erectile organ** that becomes hard as it is filled with blood during **sexual intercourse**, such that when it enters the vagina, it is able to deposit **sperm-containing semen**.

6.2.8 Spermatic Cord

The spermatic cord is a **cord-like structure** containing **blood vessels** which **supplies blood** to the testis.

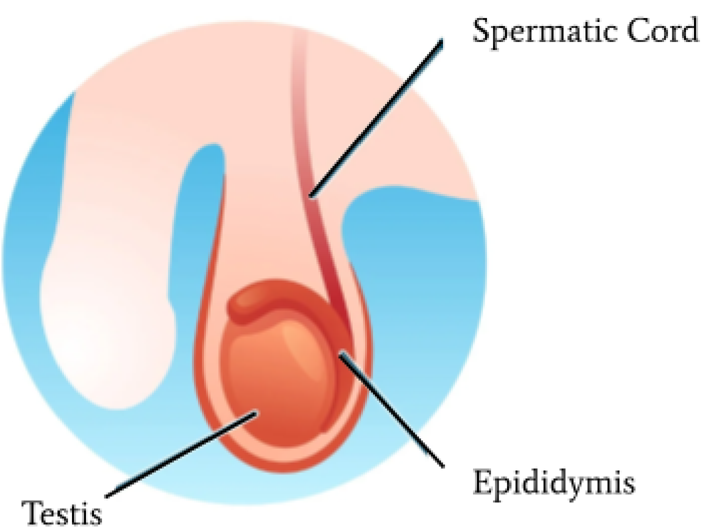


Figure 6.5: Spermatic Cord

6.2.9 Vasectomy

Vasectomy is a procedure by which the **vas deferens** is either tied up (temporary) or cut (permanent). It is a **contraceptive method** (that is, it prevents pregnancy) that prevents sperms from reaching the **urethra**, preventing **fertilisation**.

6.3 The Female Reproductive System

Figure 6.6 below shows the female reproductive system.

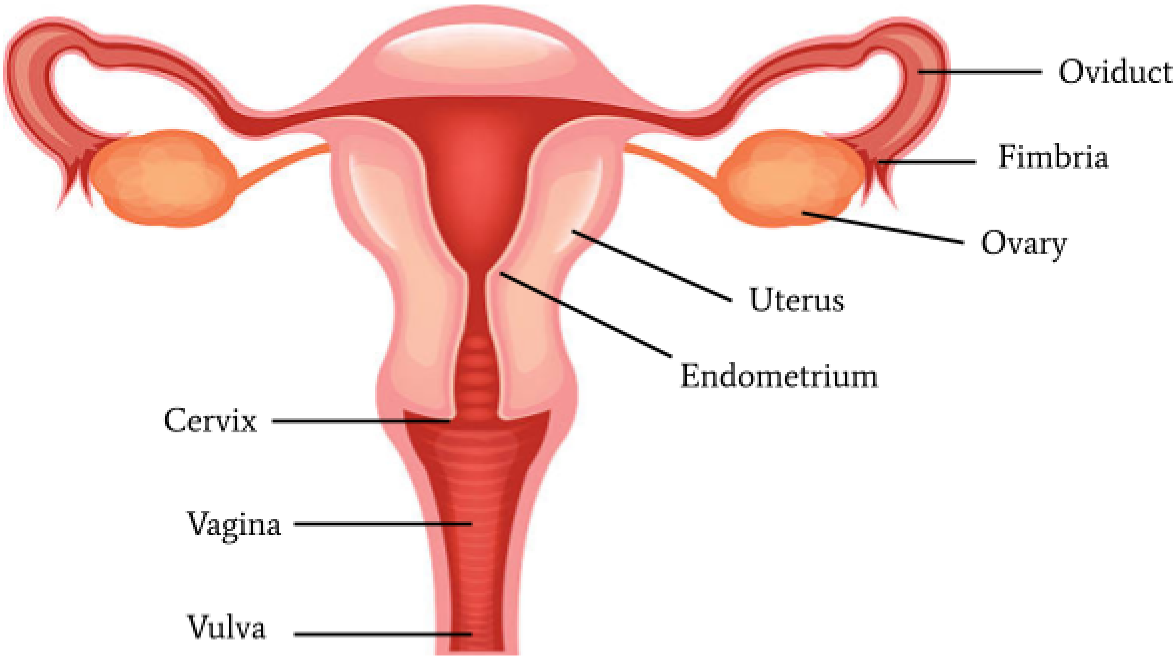


Figure 6.6: Female Reproductive System

6.3.1 Ovary

The ovary produces the **ovum** (egg, plural: ova) and female sex hormones such as **oestrogen** and **progesterone**.

6.3.2 Fimbria

The fimbria is the **opening** of the **ovary**, and has cilia that sweep the eggs into the oviduct.

6.3.3 Oviduct

The oviduct, also known as the **fallopian tube**, is a narrow muscular tube that conducts mature eggs from the ovary to the uterus, with the **cilia** present on its surface.

By right, the oviduct should be the **site of fertilisation**.

6.3.4 Uterus

The uterus (or womb) is a **muscular chamber** where the **fetus** develops during pregnancy. It is often described as having the shape of an **inverted pear**.

6.3.5 Endometrium

The endometrium (or uterine lining) is the **outer muscular layer** of the uterus, and is the site of **implantation.**

6.3.6 Cervix

The cervix is a **circular ring of muscles** that closes off the lower end of the uterus, which allows **menstrual blood** to flow out into the vagina during **menstruation**. See 6.8 Menstrual Cycle.

6.3.7 Vagina

The vagina is the **birth canal**. It is also the **receptacle** for **semen**, where semen is deposited. Furthermore, it is where **menstrual blood** flows out.

6.3.8 Tubal Ligation

Tubal Ligation is similar to a vasectomy, but it is for females instead of males.

It is a **contraceptive method** (that is, it prevents pregnancy) where the **oviduct** is **tied** (temporary) or **cut** (permanent).

6.4 Sperm

Sperms (spermatozoa) are produced by the **testes**. They contain 3 main parts - the **head, middle piece**, and **tail**. Refer to *Figure 6.7* below.

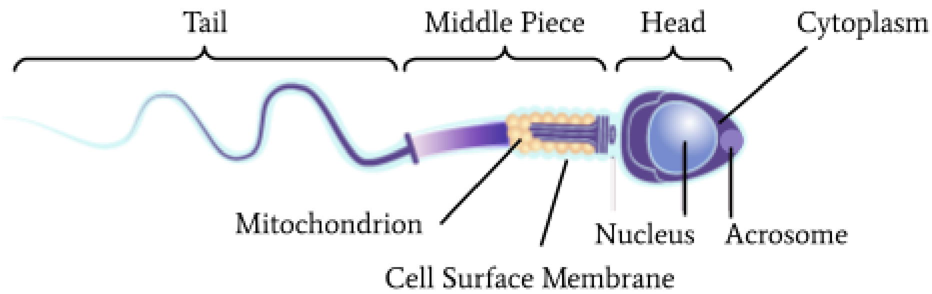


Figure 6.7: Sperm

Sperms are produced **throughout the entire lifetime** of a male after puberty. Sperms are quite small, around 55 to 65 μm (micrometer: 1 μm = 10^{-6} m) in length, and 3.5 μm in width.

The acrosome contains an enzyme called **acrozyme**, which is able to digest the **jelly coat** and **cell membrane** of a **mature egg** to allow the sperm to penetrate into the egg, in order for fertilisation to occur.

The nucleus contains one **haploid** set of **chromosomes**.

The tail is also called a **flagellum,** and allows the sperm to move. We say the sperm is **motile**.

Common Misconceptions:

✖ Motility is the same as Mobility

✔ Motility refers to something being able to move **on its own**, while mobility refers to something moving either **on its own** or by **external assistance** (e.g. by wind).

6.5 Ovum

The ovum (egg, oocyte) is produced by the **ovary**. Refer to *Figure 6.8* below.

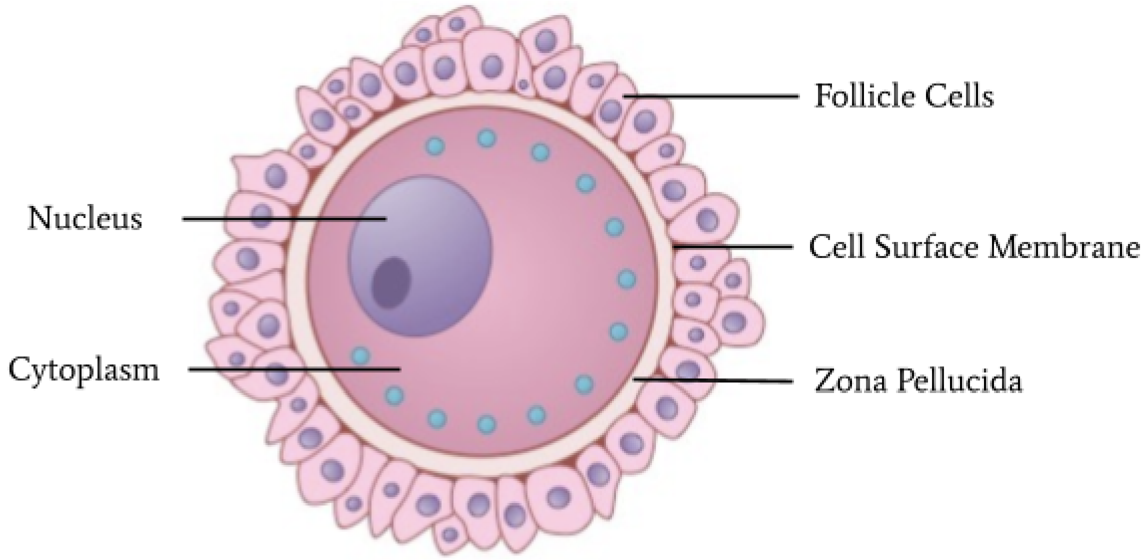


Figure 6.8: Ovum

The **ova** are **present** in the ovaries of a female **at birth**. Eggs are released into the oviducts from puberty to when a female reaches 45-55 years of age. At that age, we say that **menopause** has occurred.

The nucleus of the ovum contains one **haploid** set of **chromosomes**.

The ovum is unable to move on its own, and hence we say its **non-motile**. However, it is able to move as the **cilia** brushes it along the fallopian tube. Hence, despite being non-motile, it is **mobile**. (Recall the difference between mobility and motility!)

Factor	Sperm	Ovum
Motility	Motile	Non-motile
Size	Small	Large
Shape	Long, has a head, middle piece and tail	Circular
Number	~300 million are released at once	1 is released at a time

Table 6.9: Differences between Sperm and Ovum

6.6 Fertilisation

Recall that fertilisation is the fusion of a male gamete with a female gamete to form a zygote. In humans, it is the fusion of a sperm with an egg to form a zygote.

6.6.1 The Path Taken by the Sperm

Figure 6.10 below shows the path taken by the sperm, from its production in the testes to the site of fertilisation, the oviduct.

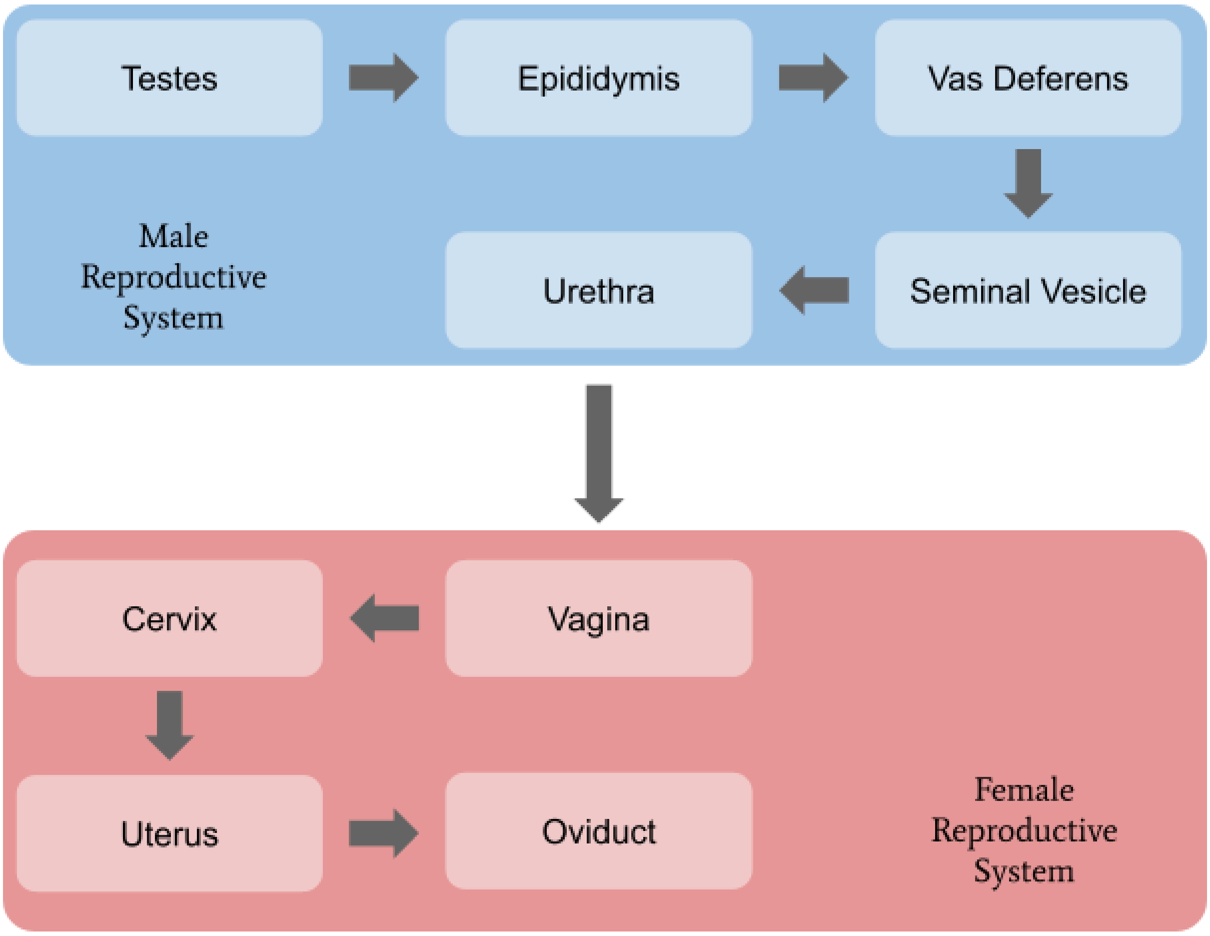


Figure 6.10: Path Taken by Sperm

6.6.2 Sperm Penetrating the Egg

The sperms first swim towards the egg. When some sperms eventually reach the egg, they **scatter** the **follicle cells**, possibly using **enzymes** they secrete. One sperm secretes **acrozyme** to digest the zona pellucida, passing through the cell membrane and entering the cytoplasm of the egg.

The sperm and egg nuclei fuse to form a **zygote**. Fertilisation has occurred. This triggers the egg to form a **protective fertilisation envelope** around it, preventing any other sperm from entering, since acrozyme is ineffective against this protection envelope.

6.6.3 Post-fertilisation

After fertilisation, the zygote undergoes mitosis, eventually forming a **blastocyst**, which is a ball of cells. Around day 7, the blastocyst reaches the uterus and implants itself onto the thickened **endometrium**.

This blastocyst will eventually develop into an embryo, and into a fetus.

6.7 Ovarian Cycle

Since birth, a female's ovaries contain many immature eggs known as **follicles**. These follicles are **diploid**, and form a matured, **haploid ovum** by **oogenesis**.

A mature egg is released into the **oviduct** in regular intervals due to the **ovarian cycle**, which consists of 3 parts - **Follicular Phase**, **Ovulation Phase** and **Luteal Phase**.

6.7.1 Follicular Phase

The hypothalamus secretes GnRH, which stimulates the Pituitary Gland to secrete FSH and LH. In the follicular phase, FSH stimulates a **primary follicle** to develop into a **Graafian follicle,** while secreting **oestrogen** throughout. The **oestrogen** is used for the **repair** and **growth** of the **endometrium** in the **uterus**.

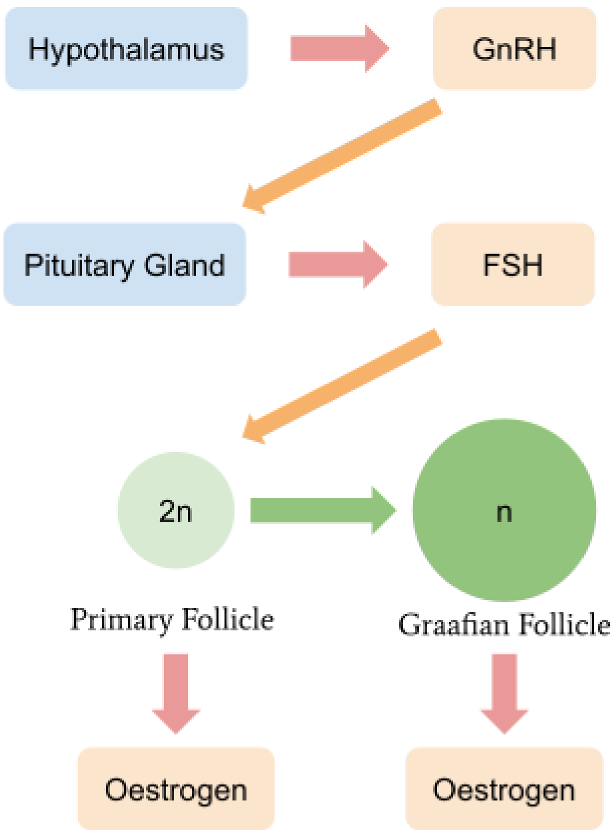


Figure 6.11: Follicular Phase

As the Graafian follicle develops, **oogenesis** occurs as a **mature haploid ovum** develops. At the same time, high levels of **oestrogen** causes the **pituitary glands** to secrete LH.

6.7.2 Ovulation Phase

High levels of LH eventually causes the **Graafian follicle** to **rupture**, releasing the **haploid ovum** into the **oviduct** through the **fimbria**. This occurs around Day 14 of the 28-day **Ovarian/Menstrual Cycle**. We extend *Figure 6.11* as such:

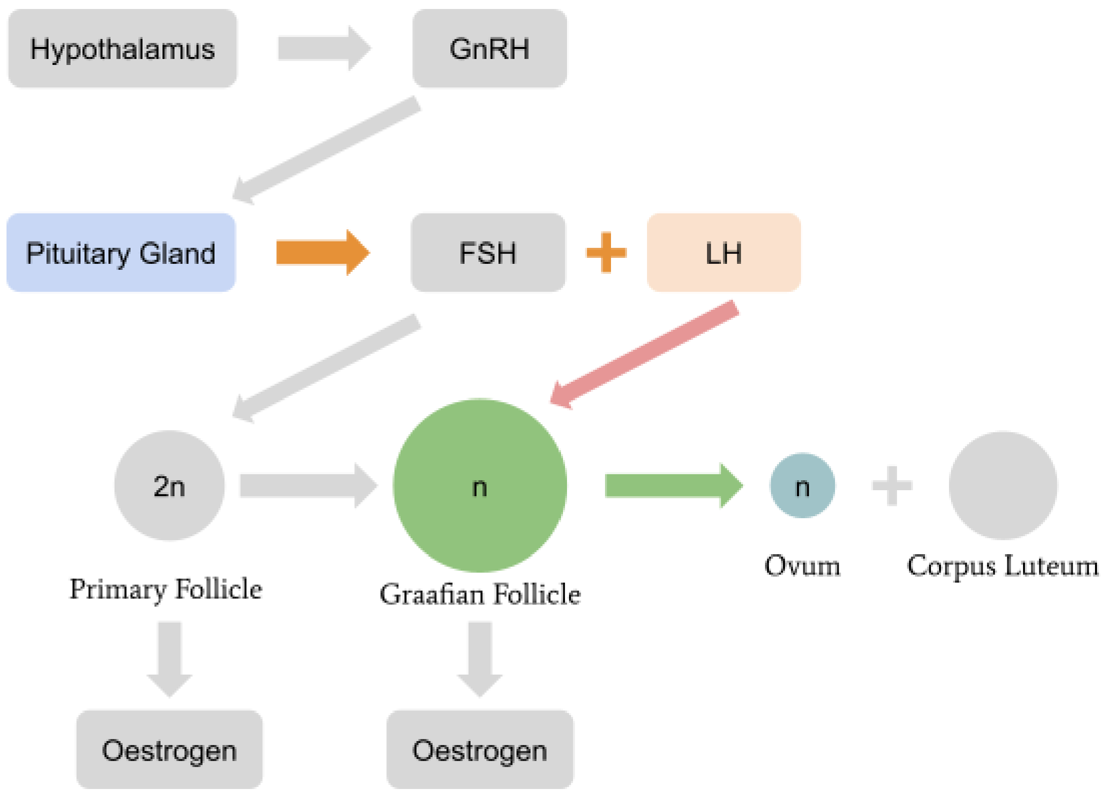


Figure 6.12: Ovulation Phase

6.7.3 Luteal Phase

As the ovum is released in the ovulation phase, something else called the **corpus luteum** forms alongside it. The **corpus luteum** produces **oestrogen** and **progesterone**.

The oestrogen causes the **endometrium** to grow thicker, while the **progesterone maintains** the thickness of the **endometrium**, so that implantation of embryo can occur if fertilisation is successful.

The high levels of **progesterone** and **oestrogen** causes **negative feedback**, decreasing the amount of FSH and LH secreted. Specifically, **high levels of oestrogen** inhibit FSH production, and **high levels of progesterone** inhibit FSH and LH production[confirm].

This negative feedback ensures that only one ovum is released at a time by **inhibiting** the **development** of more **primary follicles**. Refer to *Figure 6.13* below.

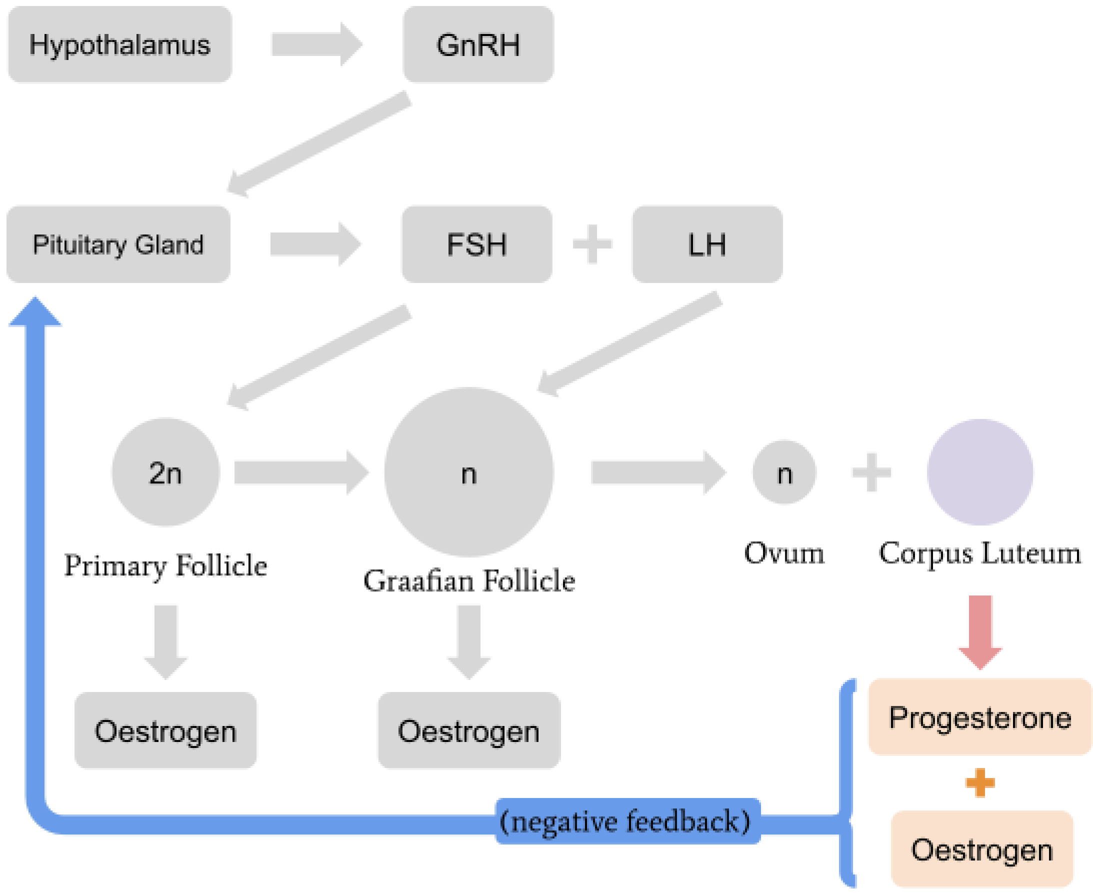


Figure 6.13: Luteal Phase

Finally, the corpus luteum breaks down if no successful fertilisation occurs, causing a sharp decline in **progesterone** and **oestrogen** levels. As progesterone is what **maintains** the **thickness** of the endometrium, this causes the **endometrium** to begin **breaking down** as well, which leads to **menstruation**.

However, if **fertilisation** is successful, the corpus luteum **DOES NOT** break down.

Instead, it continues to produce **oestrogen** and **progesterone** so that the endometrium grows thicker and maintains the endometrium thickness until the placenta develops, when the placenta takes over the production of these hormones.

Figure 6.14 below is a summary of the ovarian cycle.

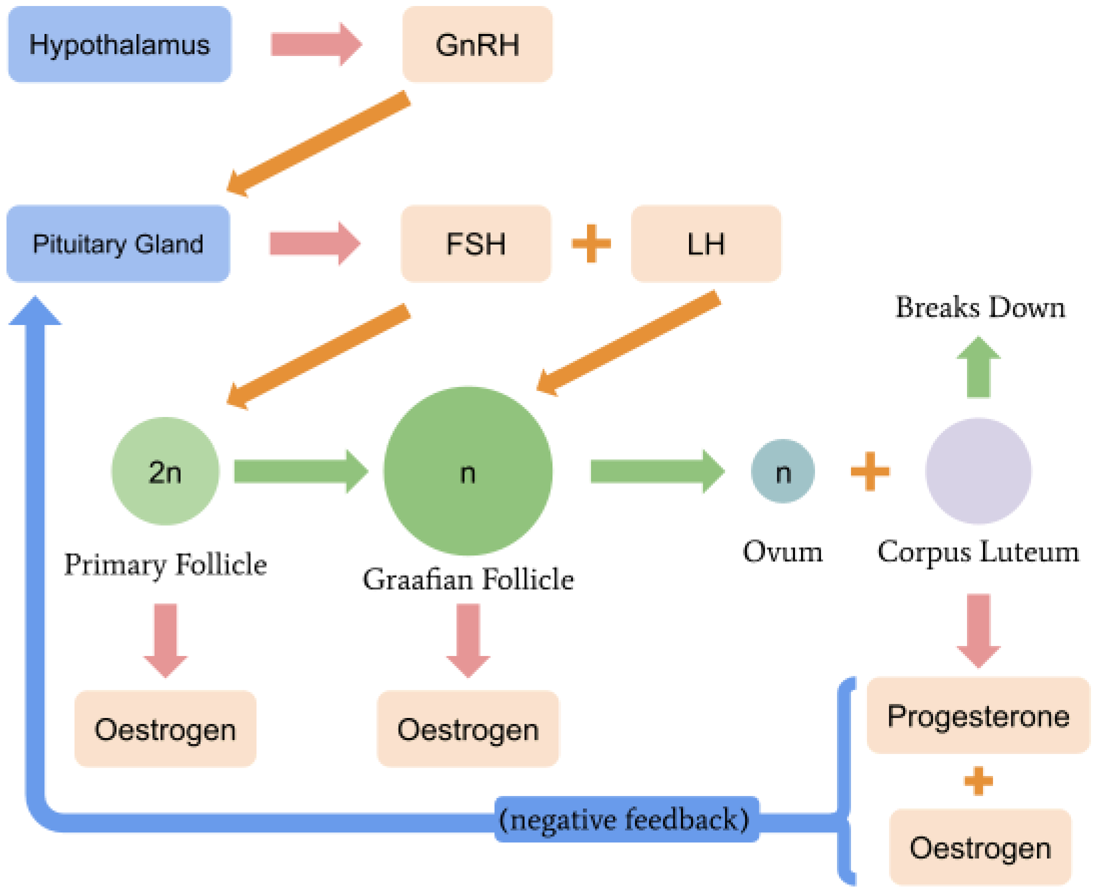


Figure 6.14: Summary of Ovarian Cycle

6.8 Menstrual Cycle

Instead of focusing on what happens in the ovary like the ovarian cycle, the menstrual cycle focuses on the changes in the **uterus** over the same duration.

The menstrual cycle consists of 4 stages over 28 days - Menstrual Phase, Proliferative Phase, Ovulation and Secretory Phase.

6.8.1 Menstrual Phase (Day 1 - Day 5)

In the menstrual phase, **menstruation** occurs as the shedding of **endometrium**, **degenerated egg** and **blood from the endometrium** takes place. They are removed through the **vagina**.

Around the same time, the pituitary gland begins to secrete FSH into the bloodstream to restart the ovarian cycle.

6.8.2 Proliferative Phase (Day 6 - Day 13)

During this phase, high levels of FSH causes the primary follicles to secrete **oestrogen**, and the high levels of **oestrogen**, allows for repair and growth of **endometrium.** The high levels of **oestrogen** also stimulates the pituitary gland to secrete **LH.**

6.8.3 Ovulation (Day 14)

On Day 14, high levels of **LH** trigger **ovulation** and the ovary releases a **mature haploid ovum**. This ovum remains viable for up to 3 days (but typically 24 hours). For comparison, sperm remains viable for up to 3 days (but typically 48 hours) in the female reproductive tract.

Hence, the optimum time for sexual intercourse such that the chance of fertilisation is maximum is around Day 13 to 16 of the ovarian cycle.

6.8.4 Secretory Phase (Day 15 - Day 28)

During the secretory phase, the **endometrium** of the uterus is **thickened** by the **high levels of oestrogen** and is **maintained** by the **high levels of progesterone**, to prepare for implantation if fertilisation occurs.

6.9 Contraceptive Pills

Contraceptive Pills typically contain **progesterone** and **oestrogen**. High levels of **oestrogen** and **progesterone** cause **negative feedback** to be sent to the **hypothalamus**, which suppresses the **FSH** and **LH** production from the **pituitary glands**.

Hence, no **primary follicles** are able to mature and develop into **Graafian follicles** and no **ovulation** occurs. Thus **fertilisation** will not occur and no **conception** takes place.

6.10 Placenta

The placenta is a **temporary organ** that consists of both **maternal tissue** and **embryonic tissue**. It is temporary as it will be shed off after giving birth.

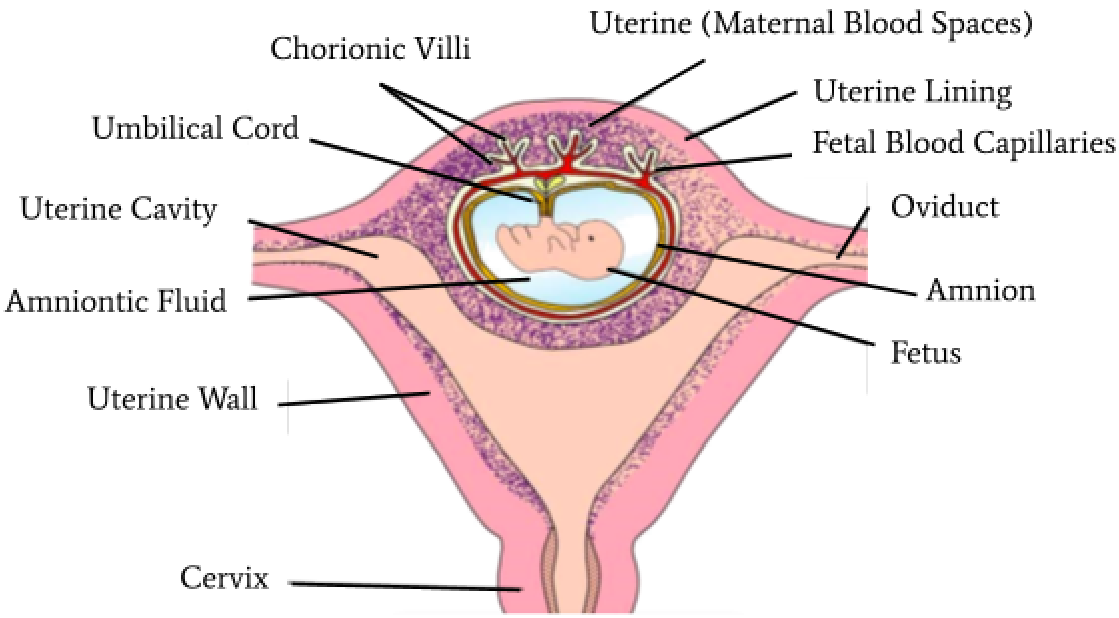


Figure 6.15: Placenta in Uterus

Figure 6.15 above shows the placenta in the uterus, while *Figure 6.16* below shows the placenta in more detail.

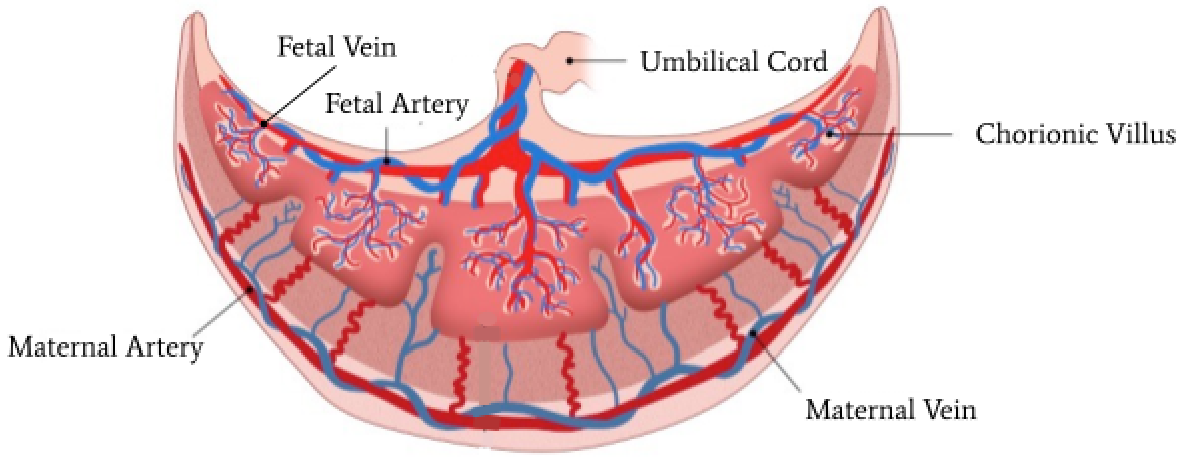


Figure 6.16: Placenta

Let's zoom in further. Refer to *Figure 6.17* below.

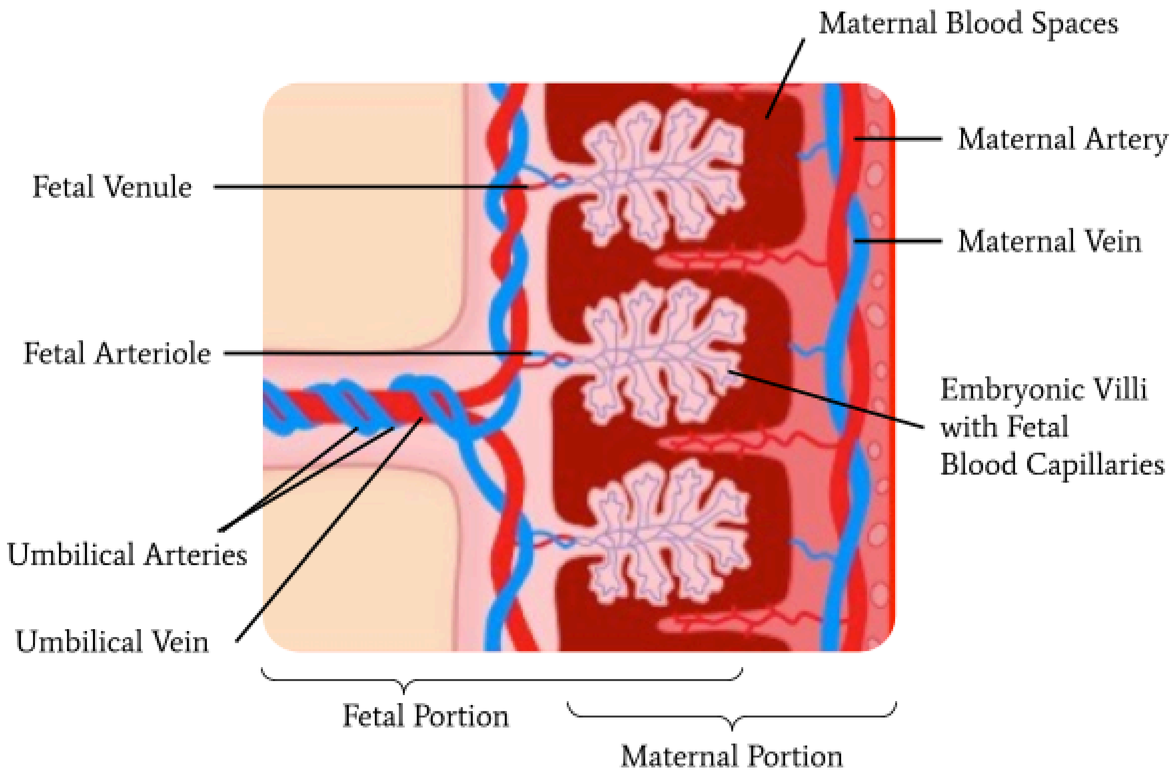


Figure 6.17: Zoomed in Placenta

Notice that in the mother's blood, we mark the arteries red (oxygen-rich) by convention, and the veins blue (oxygen-poor). On the other hand, in the fetal portion, we mark the arteries in blue and the veins in red. This means, the veins carry oxygen-rich blood instead of the arteries and vice versa.

6.10.1 Functions of Placenta

The placenta **secretes oestrogen** and **progesterone**, to **suppress** the pituitary gland from producing **FSH** and **LH** so that no ovulation would occur, and to **maintain** the thickness of the **endometrium.**

The placenta is the **site of exchange** of substances between the mother and the fetus.

The placenta allows **antibodies** to diffuse from the mother's blood into the fetus' blood to protect the fetus against disease.

6.10.2 Diffusion Through the Placenta

The substances transported from Mother to Fetus are **hormones, oxygen** and **nutrients.**
The substances transported from Fetus to Mother are **hormones, waste products** like carbon dioxide and urea.

For example, oxygen from the maternal blood pools diffuses into the chorionic villi and into the fetal venule, which then connects to the umbilical vein, which carries the oxygen towards the fetus.

The villi in the placenta described in this process are similar to the alveoli found within the lungs or the villi found within the intestines. These structures have an increased surface area to allow for faster diffusion.

6.10.3 Adaptations of Placenta

Table 6.18 below shows the adaptations of the placenta.

Feature	Function
Maternal blood directly bathes the entire surface of the chorionic villi	Constant diffusion is ensured by maintaining a high concentration of oxygen and nutrients.
There is continuous blood flow in fetal capillaries and maternal blood spaces	To maintain a constant diffusion gradient.
Chorionic villi have highly folded structure to increase Surface Area to Volume Ratio	Increased rate of diffusion.
Maternal blood not confined in blood vessels but found in maternal blood spaces	Facilitates efficient diffusion.

Table 6.18: Adaptations of Placenta

6.10.4 Why don't the Maternal and Fetal Blood Mix?

If the maternal and fetal blood mixes directly, the maternal blood pressure would be too high and could cause damage to the organs and blood vessels of the fetus.

Furthermore, the mother and fetus could have different blood types, so if the maternal and fetal blood mix directly, agglutination could occur.

6.10.5 Umbilical Cord

The umbilical cord usually contains **two umbilical arteries** and **one umbilical vein**, and is connected to the **fetal capillaries** in the placenta.

Exchange of substances between the Mother and Fetus also must pass through the umbilical cord.

<u>Application Question</u>

(Biology Matters Chapter 18, Let's Review, Q4(c) Modified)

Figure 6.19 below is the cross section of an umbilical cord. Name the structures P and Q and justify your answer with explanations.

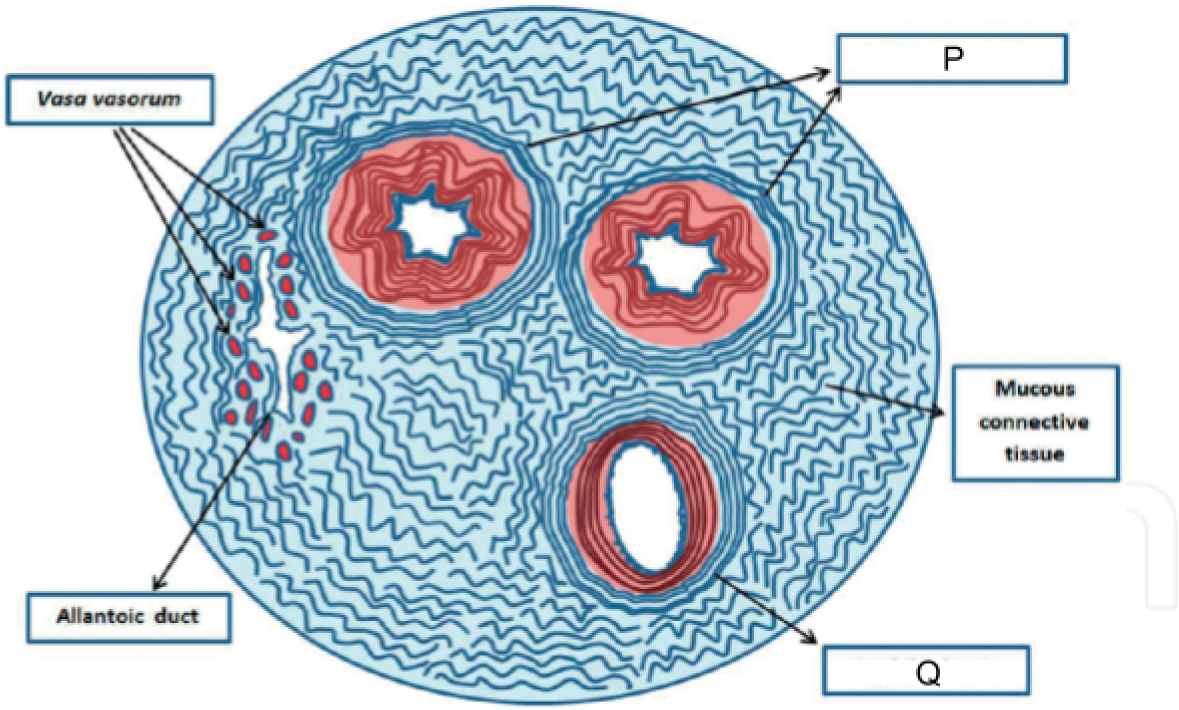


Figure 6.19: Cross Section of Umbilical Cord

Solution:[verify]

P and Q are the **umbilical arteries** and the **umbilical vein** respectively.

The umbilical arteries have a smaller lumen relative to their diameters, carrying blood which flows at a **higher blood pressure** from the baby to the mother as compared to the umbilical vein, which have a larger lumen relative to its diameter, carrying blood which flows at a **lower blood pressure** from the mother to the baby.

Hence, the umbilical arteries have **thicker walls** than the umbilical veins to **prevent them from rupturing** when an influx of high pressure blood occurs.

6.10.6 Amniotic Sac and Fluid

The **amniotic sac** is a bag of fluid, called the **amniotic fluid**, in a female's uterus where the unborn baby develops and grows. This fluid is **sterile** and must not be exposed to the outside world.

Most of the **amniotic fluid** comes from the **mother's blood** by diffusion.

After the first 3 months, the fetus also begins to **excrete urine** into the sac to fill the amniotic cavity. The fetus then **swallows** the fluid and the cycle repeats.

The **amnion** is the outer membrane of the **amniotic sac**.

6.10.7 Functions of Amniotic Fluid

The amniotic fluid has many functions, namely:
- **Supports** and **cushions** the fetus
- **Protects** the fetus from physical **injury** by **absorbing shock**
- Allows the fetus to **move freely** during growth
- Assists in **regulating** fetal body **temperature**
- **Lubricates** the vagina during birth

6.11 Human Chorionic Gonadotropin (FYI)

hCG, short for **Human Chorionic Gonadotropin**, is a hormone that is secreted by cells in the placenta when successful fertilisation occurs, and hCG levels remain high during most of the pregnancy.

hCG **maintains the corpus luteum** and prevents it from breaking down, which keeps **progesterone** and **oestrogen** levels consistently **high**.

High levels of **progesterone** ensures that the thickness of endometrium is maintained and ensures that **menstruation** does not occur, and at the same time inhibiting **FSH** and **LH** production.

High levels of **oestrogen** also inhibits **FSH** production.

The inhibition of **FSH** and **LH** prevents more primary follicles to develop into Graafian follicles and prevents further ovulation.

Figure 6.19 below highlights how well the female reproductive system is designed, by showing how all of the hormones interact with one another in many ways.

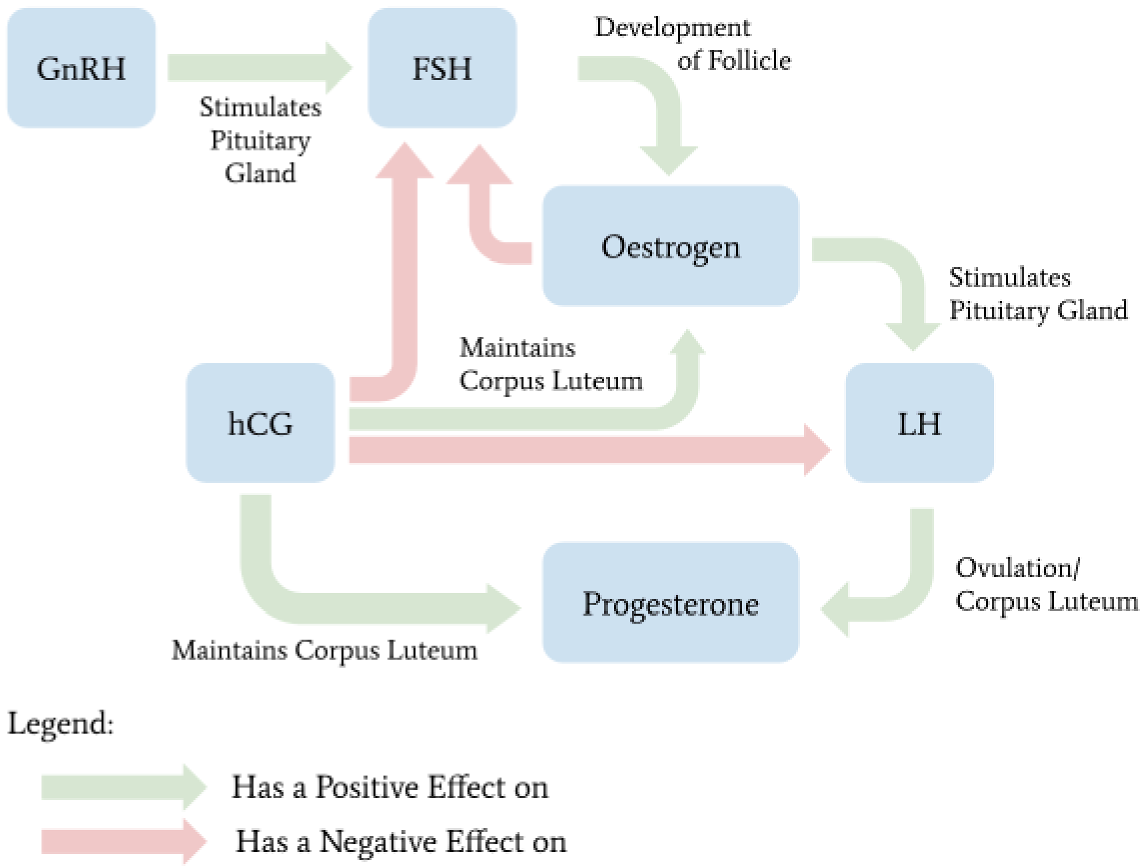


Figure 6.20: Interaction of Hormones in the Female Reproductive System

Topic 7: Homeostasis and Thermoregulation

is that a PC2131 reference (ew phys)

7.1 Maintaining Thermal Balance

There are 4 main processes that are involved in **heat loss** or **heat gain**: Evaporation, Radiation, Conduction, Convection.

Thermal Balance is important as exercise requires **energy**, **releasing heat** as a byproduct in the body. If thermal balance isn't maintained, this could lead to **heat injury** like **heatstroke**.

Furthermore, because Singapore is **humid**, the rate of **evaporation** is lowered, which leads to **less heat loss**. **Humidity** is a very **crucial factor** that must be considered carefully in answering questions about Thermal Balance.

7.1.1 Evaporation

Heat is lost as **latent heat of vaporisation**. More accurately, heat is conducted from our skin and used to evaporate water in sweat (or other liquids) present on the surface of our skin.

7.1.2 Radiation

Objects **exchange radiation** with each other, and **hotter objects** tend to **lose heat** to **cooler objects**.

7.1.3 Conduction

Conduction is the **direct transfer of heat** when objects of different temperatures come into contact. Again, **hotter objects** tend to **lose heat** to **cooler objects**.

7.1.4 Convection

Convection can be described in terms of **convection currents**, but more simply it happens when a stream of **air** or **fluid** is **cooler** than **body surface temperature**.

7.2 Heat in the Body

When **respiration** occurs, **heat** is produced as a **byproduct.**

This heat must then be **distributed** from the **active muscles** to everywhere around the body, to ensure that not too much heat is collected at one location. But how?

The active muscles transfer heat to the blood in surrounding blood vessels by **conduction**, causing the muscles to lose heat, and the blood to gain heat. As the blood then flows into the blood vessels that surround the other body organs, it loses heat by **conduction** again to the body organs, evenly distributing the heat.

7.2.1 Core Temperature and Skin Temperature

Refer to *Figure 7.1* below.

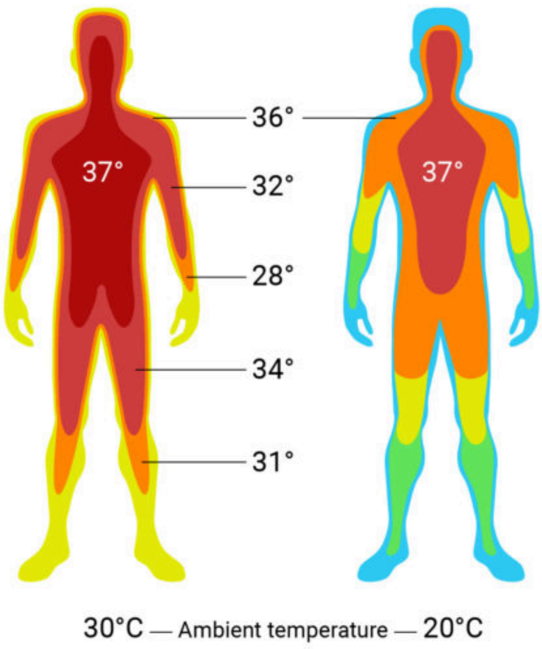


Figure 7.1: Core vs Skin Temperature

As we can see, the core temperature (that is, the temperature around your face and chest region) should always be maintained at around 37 °C.

One of the reasons for this is that many processes such as digestion require **enzymes**, and many enzymes have an **optimal temperature** of around 37 °C.

If the temperature gets too high, the enzymes are **denatured** and no longer work, and if the temperature gets too low, the enzymes are **not as effective**.

We can also see that the core temperature is usually higher than the skin temperature. This is why **oral thermometers** (which measure core temperature) usually have a higher reading than **thermometers which measure skin temperature.**

7.2.2 Hair in Mammals

Many mammals (including us!) have layers of **fur** or **hair**, or **blubber** with adipose tissue (body fat). These adaptations **trap air**, which is a **poor conductor of heat.** This reduces heat loss by **conduction** and **convection**.

7.3 Homeostasis

Homeostasis refers to **maintaining** a relatively **stable internal environment** regardless of **changes** in the **external environment**, which requires energy, obtained from **respiration**.

At the organism level, it gives the organism **independence** from reliance on the **external environment**, and enables it to travel between highly variable environments.

At the cellular level, it helps the cell maintain optimal **pH**, **temperature** and **water potential** for **enzymatic reactions** like **digestion** and **cellular respiration**, so it is more efficient.

7.4 What is Thermoregulation?

Thermoregulation is a process where animals maintain an **internal temperature** within a **tolerable range** as the external environment changes.

Thermoregulation is achieved by **striking a balance** between the **heat gain** and **heat loss** mechanisms in the body.

The **hypothalamus** is the control centre of thermoregulation.

7.4.1 How does the Hypothalamus Work?

The hypothalamus receives **signals** from **receptors**, such as **thermoreceptors** or **pressure receptors** present in our skin. It compares these signals with the **set-point** ("optimum value").

It then decides on the appropriate **response**, sending **signals** to **effectors** (the organs that carry out the instructions to restore balance). The effectors then produce a **response** to **change** the **controlled condition**. This is called a self-regulatory **corrective mechanism**.

7.4.2 Negative and Positive Feedback

Negative Feedback refers to when the **response reduces** the **stimulus**. (e.g. when it is too hot, the body performs actions to reduce body temperature)

Positive Feedback refers to when the **response amplifies** the **stimulus**. (e.g. apples ripen, producing ethylene, stimulating more apples to ripen, causing more ethylene, and so on…)

Figure 7.2 below summarises this idea.

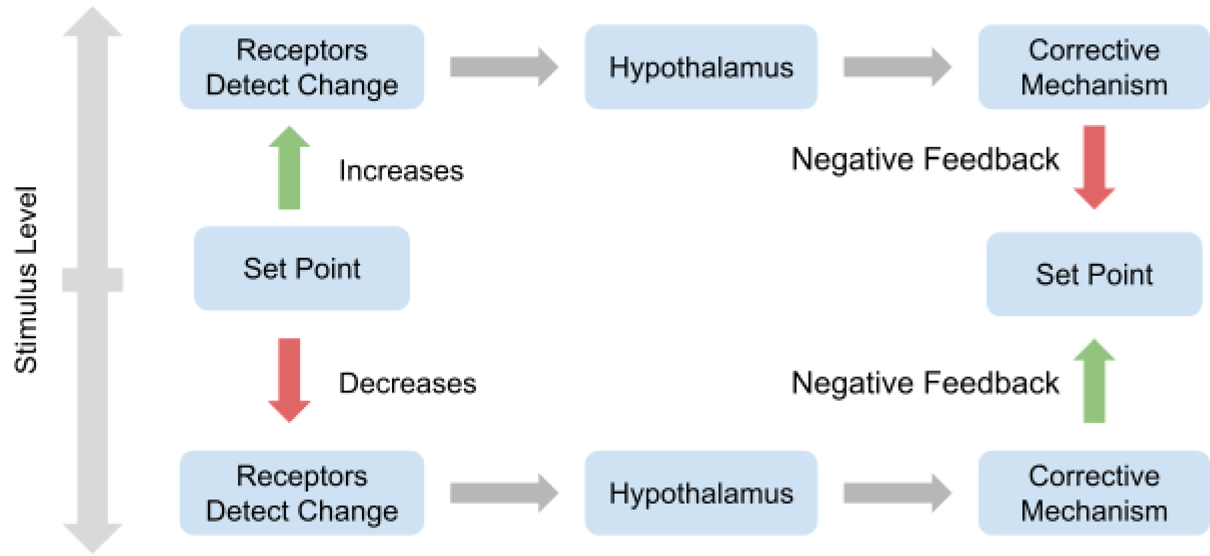


Figure 7.2: Homeostasis

7.4.3 Examples of Positive Feedback

As mentioned earlier, ripening of apples is an example of **positive feedback**, since the **ethylene** gas produced by ripe apples stimulates more apples to ripen, which, in turn, produces **more ethylene**, as shown in *Figure 7.3* below.

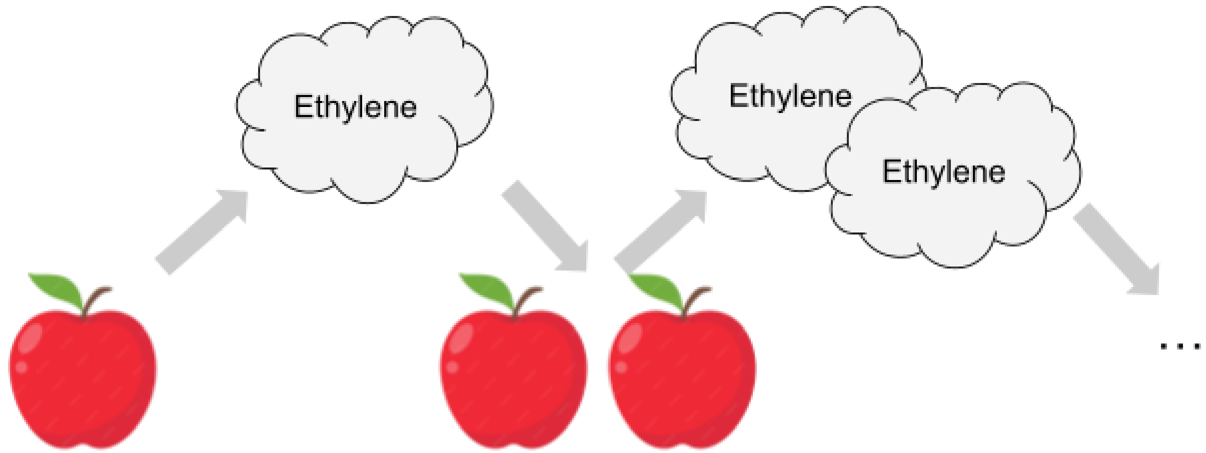


Figure 7.3: Apples Ripening

Another example is childbirth, where a positive feedback loop occurs as the baby's head pushes against cervix, which causes signals to be transmitted to the brain, causing the brain to stimulate the **pituitary gland** to secrete **oxytocin**, which leads to **uterine contractions**, and pushes the baby's head against the cervix more.

The feedback loop is shown in *Figure 7.4* below.

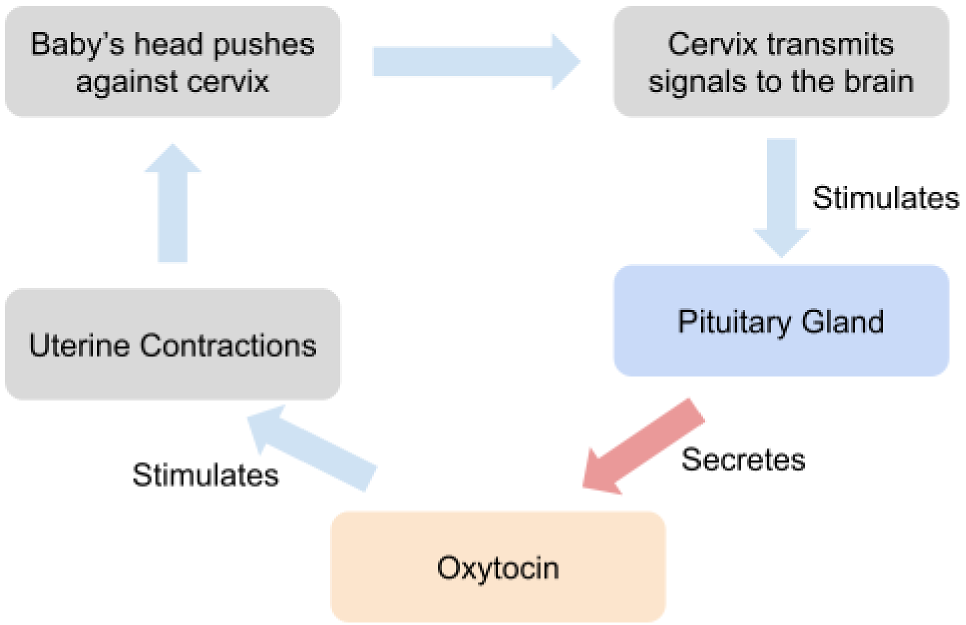


Figure 7.4: Childbirth

The last example provided in the notes is **milk production**, shown in *Figure 7.5* below.

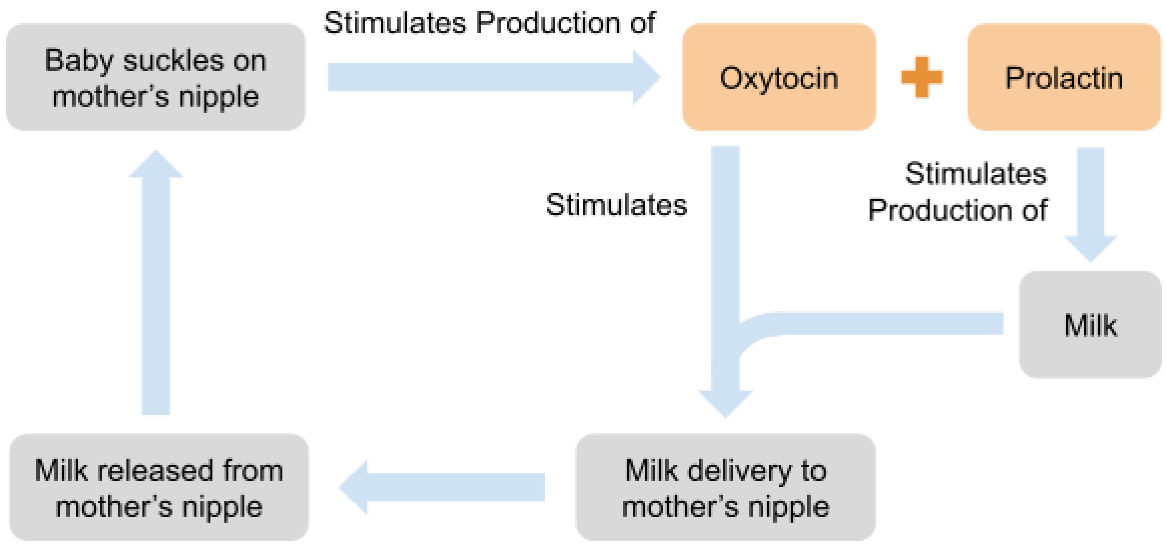


Figure 7.5: Milk Production

7.5 Skin Structure

Figure 7.6 below shows a human's skin structure. Human skin consists of 3 main sections: the **epidermis**, the **dermis**, and the **subcutaneous layer**.

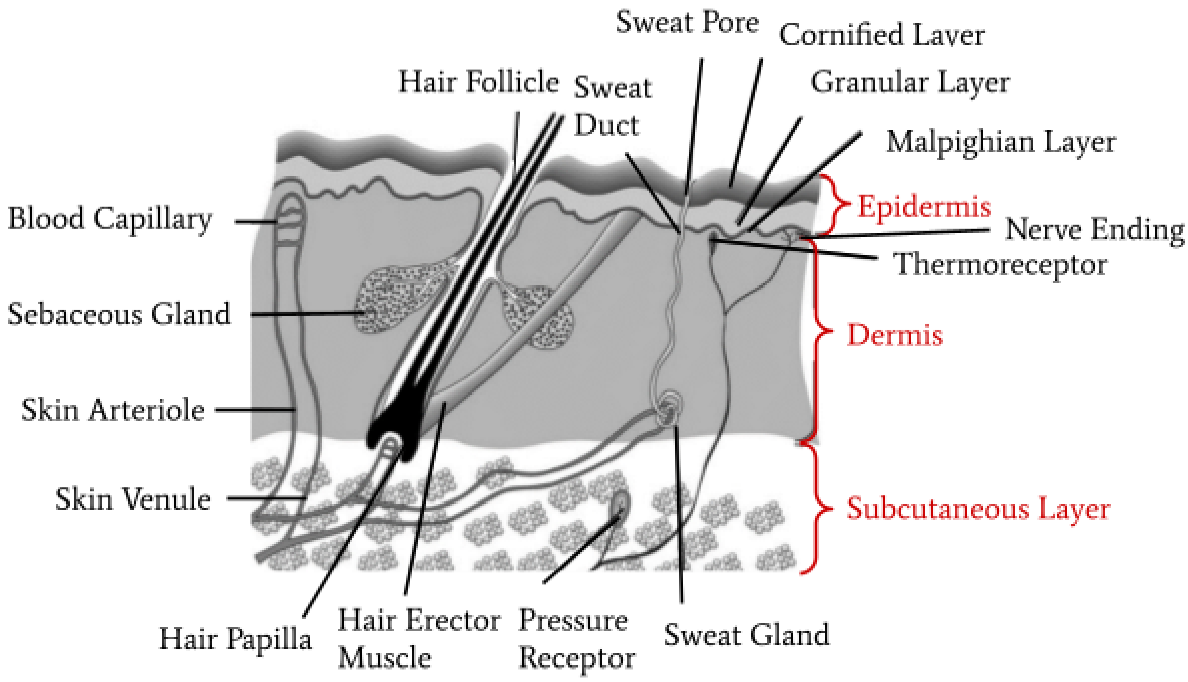


Figure 7.6: Skin Structure

7.5.1 Cornified Layer

The **cornified layer** is the **outermost layer** of the epidermis, consisting of **dead dry cells** with **keratin deposits**. Dead skins are constantly shed from the surface.

FYI: Keratin helps to form hair, nails, and epidermis! How useful! :D

7.5.2 Granular Layer

The **granular layer** is the **middle layer** of the epidermis, consisting of **living cells** that **move up constantly** when they become dry and dead to replace the cells that are shedded from the cornified layer.

7.5.3 Malpighian Layer

The **malpighian layer** is the **innermost layer** of the epidermis, made of actively **dividing cells** that contain **melanin**, the **pigment** that contributes to the colour of **human skin, hair** and **eyes**.

Dark-skinned people have **more melanin** in their skin than light-skinned people.

Melanin is produced by cells called **melanocytes**.

7.5.4 Blood Vessels in the Dermis

The dermis is found below the **malpighian layer**, and has **numerous blood capillaries** supplying blood to the skin.

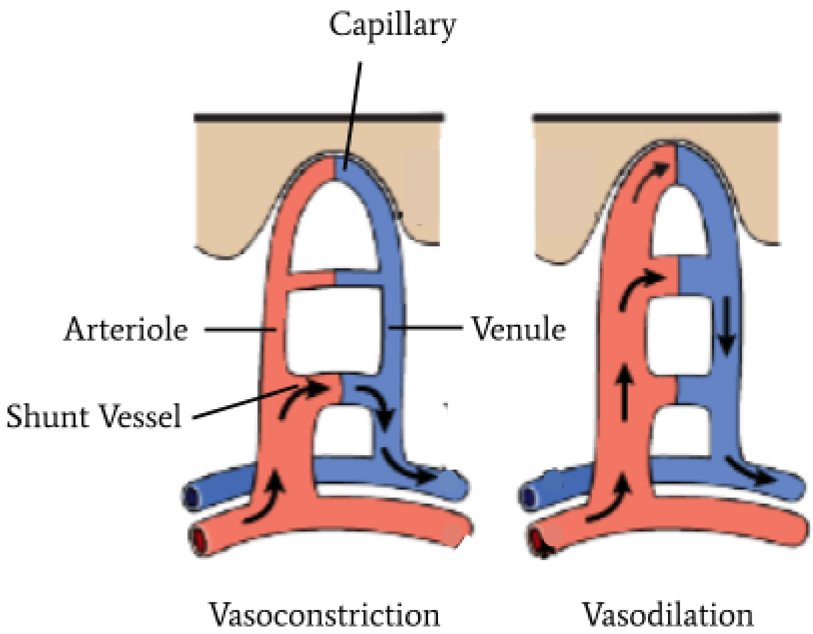


Figure 7.7: Vasoconstriction and Vasodilation

The arterioles in the dermis can constrict in a process called **Vasoconstriction**. When the arterioles constrict, the **shunt vessels dilate**, and the blood flow through the **capillaries** are reduced, while the blood flow through the **shunt vessel** is increased.

The **shunt vessel** is a way for the **blood to bypass capillaries** in **certain areas**.

On the other hand, the arterios can also dilate, called **Vasodilation**. When the arterioles dilate, the **shunt vessels constrict**, and the blood flow through the capillaries are increased, while the blood flow through the **shunt vessel** is decreased.

Since the capillaries are closer to the surface of the skin, if more blood flows through the capillaries, more heat will be lost by **conduction** from the **blood** to the **surroundings**. On the other hand, when less blood flows through the capillaries, less heat is lost by **conduction**.

This is one of the **thermoregulatory mechanisms** of the human body.

7.5.5 Hairs and Hair Erector Muscles

Hairs are embedded within the **dermis**. The **malpighian layer** sinks into parts of the **dermis** to form **Hair Follicles**.

Hair Papilla are found at the base of **hair follicles** and consist of **blood capillaries** and **nerves**.

Hair Erector Muscles, also known as *arrector pili*, contract and relax, causing hairs to stand up and lie flat respectively. When the hair erector muscles contract, **goosebumps** also form.

7.5.6 Sebaceous Gland

Sebaceous Glands are found in the **dermis** and open into each **hair follicle**. These glands secrete **sebum**, which is an oily substance that **lubricates** the hair, keeps the skin **soft** and **prevents microbial growth**.

7.5.7 Sweat Gland

Sweat Glands are **richly surrounded** by **blood capillaries**, secreting **sweat** which flows through the **sweat duct** and out the **sweat pore** to the skin surface. Sweat is another **thermoregulatory mechanism** of the human body.

7.5.8 Subcutaneous Layer

Subcutaneous fat is found below the dermis. The subcutaneous layer consists of **adipose**, which are cells which **store fats**.

7.5.9 Metabolic Wastes

We say a substance is **excreted** if the substance is a metabolic waste. Hence, we say that the **sweat pores excrete sweat**, but we don't say that the **sebaceous glands excrete sebum,** because sebum isn't considered as a metabolic waste.

More specifically, metabolic wastes are substances like **carbon dioxide** and **urea**, where urea (shown in *Figure 7.8* below) is a nitrogenous organic compound that is commonly found in urine and sweat.

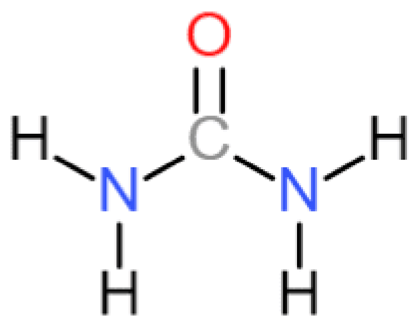


Figure 7.8: Urea

7.6 Corrective Mechanisms for Thermoregulation

Table 7.8 below gives some examples of corrective mechanisms for thermoregulation. Notice that the effects on a hot day are typically the opposite to those on a cold day, and all of these effects are considered **negative feedback**.

Corrective Mechanism	On a hot day	On a cold day
Arterioles and Shunt Vessels	**Vasodilation** to increase heat lost by **conduction**.	**Vasoconstriction** to decrease heat lost by **conduction**.
Sweat Gland	**More active sweat glands** to increase heat lost through **evaporation** by removing latent heat of vaporisation.	**Less active sweat glands** to decrease heat lost through **evaporation** by removing latent heat of vaporisation.
Hair Erector Muscles	Hair erector muscles **relax** to allow hairs to **lie flat**.	Hair erector muscles **contract** to make hairs **stand up**, trapping an insulating layer of warm air over the skin, reducing heat lost by **conduction** and **convection**.
Metabolic Rate	Rate of metabolic activities like respiration **decreases** so that **less heat is produced**.	Rate of metabolic activities **increases** so that **more heat is produced**.
Skeletal Muscles	-	**Reflex contraction** of skeletal muscles generates heat, increasing body temperature, through **shivering**.

Table 7.9 - Corrective Mechanisms for Thermoregulation

7.7 Skin Shenanigans: Alcohol and Showers

Here are two commonly asked questions.

Application Question 1: LQ the Alcoholic

(BL2131 Revision Worksheet 8 Homeostasis and Thermoregulation Q8 Modified)

LQ is climbing a mountain in -10 °C weather. He then has the urge to drink alcohol. Explain why drinking alcohol would make LQ feel warm initially. A while later, he died due to hypothermia. Explain how the alcohol contributed to LQ losing more heat.

Application Question 2: LQ the Showering Scientist

(BL2131 2023 EOY Revision Package Homeostasis and Thermoregulation Q30 (c) Modified)

LQ has come back to life! Maybe reincarnation is real. Either way, he becomes a scientist with core body temperature 38.3 °C. One day, he is showering while monitoring his core body temperature. Under 35 °C water, his temperature decreased to 37.3 °C after 10 minutes. The next day, with the same starting temperature and duration, under 15 °C water, his temperature only decreased to 37.6 °C. Account for this difference, with explanation.

Solutions can be found on the next page.

Solution to Question 1

When LQ drinks alcohol, the alcohol enters his bloodstream, which causes his skin arterioles to **vasodilate**. This diverts blood flow to and **increases blood flow in the skin capillaries**, which are **closer** to the **thermoreceptors**. Hence, more **warm blood** passes near the thermoreceptors, causing LQ to feel **warm initially**.

Over time, since the alcohol causes LQ's skin arterioles to **vasodilate**, **more blood** is diverted to and flows in the **skin capillaries**, which is **closer** the **cooler external environment**. Hence **more heat is lost** to the environment by conduction, (convection, radiation and evaporation) and LQ's body **loses too much heat** (which causes him to die due to hypothermia).

Solution to Question 2

When LQ showers at 15 °C, his thermoreceptors detect his skin temperature **decreasing rapidly** below the set-point, signalling to the hypothalamus to start **thermoregulatory mechanisms** to reduce heat loss. On the other hand, when LQ showers at 35 °C, his skin temperature remains above the set-point, so **no thermoregulatory mechanisms** occur.

In the 15 °C shower, the hypothalamus signals to the skin arterioles to **vasoconstrict** and the shunt vessels to **vasodilate**, diverting blood from and **decreasing blood flow** in the blood **capillaries**, which **decreases heat lost by conduction**. On the other hand, in the 35 °C shower, no vasoconstriction of the skin arterioles occur, so more blood flows to the blood capillaries and **more heat is lost by conduction**.

Furthermore, in the 15 °C shower, the hypothalamus also signals to the muscles to begin shivering, which consists **involuntary vigorous contraction and relaxation of muscle**s, which requires **energy** from **respiration**. Hence metabolic rate increases, and **heat is produced as a byproduct of respiration**. On the other hand, **shivering does not occur in the 35 °C shower**.

Hence, LQ loses more heat in the 35 °C shower over 10 minutes than in the 15 °C shower.

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Way too many sources.

Good luck for Bio <3