

2.3. The cell and its environment

- ▶ Cells need to:
 - take in substances, such as **oxygen** and **glucose**, and
 - get rid of **waste products** and **chemicals** that are needed elsewhere in your body.
- ▶ Dissolved substances can move into and out of your cells across the **cell membrane** in three different ways –
 - A. **Passive**_ it takes place along a concentration gradient from high to low concentration and uses up no energy.
 - 1. **Diffusion**,
 - 2. **Osmosis** and
 - B. **Active transport**_ it takes place down concentration gradient from low to high concentration and uses up cellular energy.
 - 3. **Active transport**.

1. Diffusion

- Net (overall) movement of particles from an area of high concentration to an area of lower concentration.
 - **Concentration is a way of measuring how much (how many particles) of a substance is in one place.**
- Molecules are moving in **both directions**, there are more particles moving in the area of high concentration, and so the net (overall) movement is away from the area of **high concentration** towards the area of **low concentration**.
- Diffusion takes place **B/c** of random movement of particles of a gas or of substance in solution in water.
- All the particles are moving and bumping into each other and this moves them all around.
- Molecules are moving in both directions, there are more particles moving in the area of high concentration, and net (overall) movement is away from the area of high concentration towards low.

Rates of diffusion

- Diffusion is a relatively slow process.

Factors affecting the rate of diffusion

- **big difference in concentration between two areas**
 - ✓ If there is a big difference in concentration between two areas, diffusion will take place quickly.

- ✓ In general the bigger the difference in concentration the faster the rate of diffusion will be.
- ✓ This difference between two areas of concentration is called the concentration gradient

the overall or **net** movement = particles moving in – particles moving out

- **Increase in temperature**
 - ✓ Particles in a gas or a solution move more quickly.
 - ✓ This in turn means diffusion will take place more rapidly as the random movement of the particles speeds up.
 - ✓ at higher temperatures because the particles have more kinetic energy and so move faster.
- **The thickness of the membrane** – a shorter distance results in faster diffusion
- **The surface area of the membrane** – clearly if there is more membrane where diffusion can take place, diffusion will happen faster
- **Mass of molecules diffusing** – Heavier molecules diffuse more slowly and the reverse is true for lighter.
- **Solubility** – non polar or lipid- soluble materials pass through plasma membrane more easily than polar materials.

Diffusion in living organisms

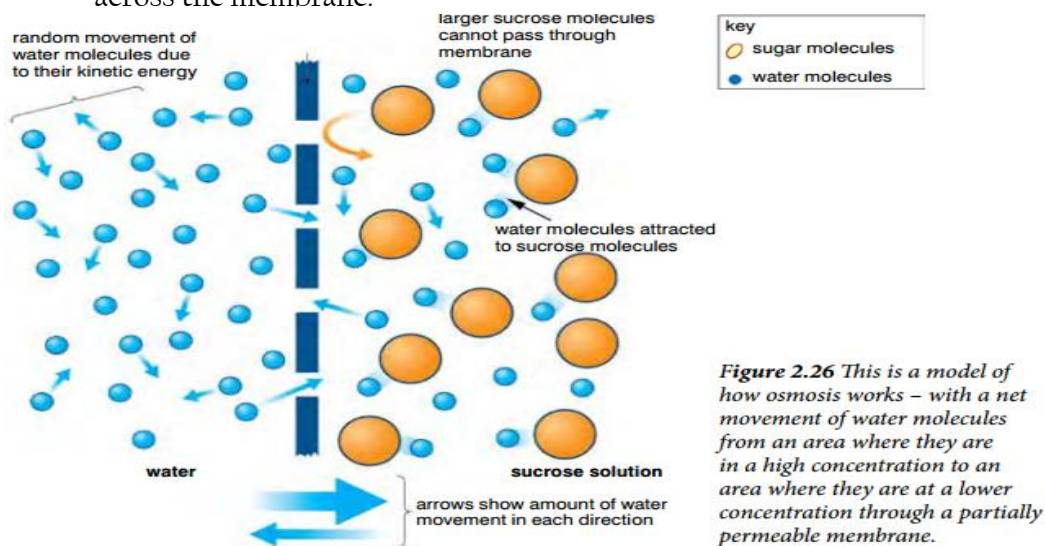
- Many important substances can move across your cell membranes by diffusion.
- Example
 - **Oxygen** from the air into your lungs into your blood and then into your body cells by diffusion.
 - Waste **carbon dioxide** produced by your cells passes out easily by diffusion.
 - Simple sugars like **glucose** and **amino acids** from the breakdown of proteins in your gut can also pass through your cell membranes by diffusion.

Adaptation of cells to make diffusion easier and more rapid across plasma membrane

- Increase the surface area of the cell membrane over which diffusion occurs_ means there is more room for diffusion to take place.
 - This is done by infolding up the membrane of a cell the area over which diffusion can take place.
 - Tissues and organs show similar adaptations to make sure that diffusion takes place as quickly as possible –
- Example
 - The air sacs of the lungs,
 - The villi of the small intestine and
 - The thin, flat leaves of plants .

2. Osmosis

- Diffusion takes place where particles can spread freely from one place to another.
- However, the solutions inside a cell are separated from those outside the cell by the cell membrane, which does not let all types of particles through.
 - Only the smallest particles can pass through freely.
- Dilute solution of sugar contains a high concentration of water (the solvent) and a low concentration of sugar (the solute).
- A concentrated sugar solution contains a relatively low concentration of water and a high concentration of sugar.
- Osmosis is a special type of diffusion where only water moves across a partially permeable membrane, from an area of high concentration of water to an area of lower concentration of water.
- A cell is basically a solution inside a partially permeable bag (the cell membrane).
 - The cell contents contain a fairly concentrated solution of salts and sugars.
 - Water moves from a high concentration of water particles (a dilute solution) to a less concentrated solution of water particles (a concentrated solution) across the membrane of the cell.
 - The sugars and salts cannot cross the membrane it is only water that is moving across the membrane.



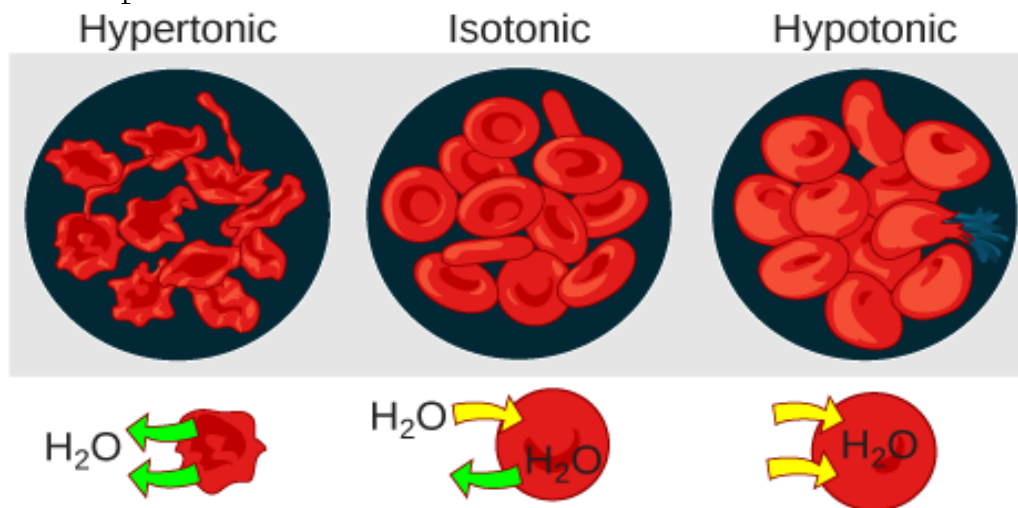
When comparing the water potential of a solution to that of a cell. We could describe it as:

- Isotonic
- Hypertonic
- Hypotonic
- **Isotonic**
 - Solution having the same water potential as the cell.
 - The cell has the same water potential as its environment; hence there is no net movement of water molecules into and out of the cell.
- **Hypertonic**
 - Solution having a lower (more negative) water potential than the cell

- Because of the cell has a relatively **higher** concentration of water, water will leave the cell, and will shrink.
- **Hypotonic**
 - Solution having a **higher (less negative)** water potential than the cell
 - The extracellular fluid has **higher concentration** of water in the solution than does the cell.

Osmosis in animals

- If a cell uses up water in its chemical reactions, the cytoplasm becomes more concentrated. The external solution is hypotonic and more water will immediately move in by osmosis.
- Similarly if the cytoplasm becomes too dilute because water is produced during chemical reactions. The external solution becomes hypertonic and water will leave the cell by osmosis, restoring the balance.
- However osmosis can also cause some very serious problems in animal cells.
 - If the solution outside the cell is much more dilute than the cell contents (hypotonic) then
 - Water will move into the cell by osmosis, diluting the cytoplasm.
 - The cell will swell and may eventually burst.
 - On the other hand, if the solution outside the cell is much more concentrated than the cell contents (hypertonic) then
 - Water will move out of the cell by osmosis, the cytoplasm will become too concentrated and the cell will shrivel up.
 - This is why homeostasis and maintaining constant internal conditions will important.



Osmosis in plants

- Plants rely on osmosis to support their stems and leaves.
- In plants, osmosis making the cytoplasm swells and press against the plant cell walls.
- This swollen state is called turgor.

- So for plants it is important that the fluid surrounding the cells always has a higher concentration of water (it is a more dilute solution of chemicals or hypotonic) than the cytoplasm of the cells, to keep osmosis working in the right direction.
- If the surrounding fluid becomes more concentrated than the contents of the plant cells (hypertonic),
 - Water will leave the cells by osmosis.
 - The vacuole shrinks and the cell becomes much less rigid – it is flaccid.
 - If water continues to leave the cell by osmosis, eventually the cytoplasm pulls away from the cell walls and the cell goes into a state known as plasmolysis.
- If conditions are very dry,
 - The plant cannot take enough water up through the roots from the soil.
 - The cells are no longer rigid and the plant wilts.
 - Many of the chemical reactions slow down and so the plant survives until more water is available.
 - But only for so long – if the osmotic situation is not put right fairly quickly, most plants will die.

Active transport

- There are three main ways in which substances are moved into and out of cells.
 - **Diffusion** is the passive movement of substances and it depends on a concentration gradient in the right direction to work.
 - **Osmosis** depends on a concentration gradient of water and a partially permeable membrane. Only water moves in osmosis.
 - Active transport allows cells to move substances from an area of low concentration to an area of high concentration, completely against the concentration gradient.
 - The only way you can do this is to use energy produced by respiration. The process is known as active transport.
 - In other words, if a cell is making lots of energy, it can carry out lots of active transport.
 - Cells like root hair cells and your gut lining cells, which are involved in a lot of active transport, usually have lots of mitochondria

The importance of active transport

There are some situations where active transport is particularly important.

- Plants absorb mineral ions in the soil which usually found in very dilute solutions_ more dilute than the solution within the plant cells.
- Glucose is always moved out of your gut and kidney tubules into your blood, even when it is against a large concentration gradient, so this relies on active transport.

3.2 The digestive system

Our body need:

- **Carbohydrates** provide the body with an energy source for respiration.
- **Proteins** for building new cells and repairing old ones.
- **Lipids** are also an energy source and they provide a way of storing spare energy.

However, in the form that they are usually eaten neither carbohydrates, proteins nor fats are useful to the body.

These large molecules cannot be absorbed into the bloodstream and used by your body so they need to be broken down into smaller, simpler, soluble molecules.

❖ **The link between what comes in and what the body needs is the digestive system.**

The human body needs small, soluble molecules to use in all the reactions of metabolism such as releasing energy and making new larger molecules.

This is the main job of the digestive system – food substances are broken down into small soluble molecules as they pass through the gut.

Large molecules that make up the carbohydrates, proteins and fats are built up from small molecules that are joined together by **condensation reactions**, with a molecule of **water** being lost each time.

When these large molecules are broken down during digestion it involves the opposite process – **hydrolysis (splitting with water)** reactions.

The working of your digestive system is based on two things:

1. **The physical (or mechanical) breakdown of the food:**
 - This breaking down occurs in two main ways.
 - Your teeth bite and chew the food .
 - Then your gut, which is a muscular tube, squeezes the food and physically breaks it up,
 - By breaking the food up in this way, there is a much larger surface area for the digestive enzymes to work on.
2. **The chemical breakdown of the food:**
 - Controlled by enzymes.

More about enzymes

- Biological catalysts that usually work best under very specific conditions of temperature and pH.
- It made of protein
- Like any catalyst are not affected by the reaction they speed up, so they can be used many times.

- Enzymes are very specific
- Enzyme can be:
 - Intracellular enzymes _ work inside your cells.
 - Extracellular enzymes _ secreted into organs of your body such as the gut where they catalyse specific reactions. Eg. Digestive enzyme
- Enzyme names usually (but not always) end in –ase,
Example
 - Amylase breaks down starch,
 - Lipase breaks down fats,
 - Catalase breaks down hydrogen peroxide

The working of the gut

The human digestive system composed of different processes.

1. Ingestion

- The first stage in digestive system.
- It is taking foodstuff into your body through the mouth.

2. Digestion

- The chemical and physical breakdown of complex organic molecule that begins in the oral cavity and extends to the small intestine.

3. Absorption

- The transport of digested nutrients from the small intestine to the cell of the body through finger like projection called villi in the small intestine.

4. Egesting

- The removal of food waste from the body.
 - Egestion is removal of food digestion wastes
 - Excretion the process through which metabolic waste is expelled

The teeth

- Your teeth, physically breaking down food and providing a greater surface area for digestive enzymes to work on.
 - This process is known as **mastication**.

There are 4 types of teeth

A. Incisors

C. Premolar

B. Canine

D. Molars

The shape of different teeth means they are ideally suited to their different functions.

- The **incisors** and **canines** are used for **biting** while the **premolars** and **molars** are used for **chewing** and **crushing** food

All of your teeth have a similar make-up. Parts of the teeth include:

1. Enamel

- Non-living, the hardest white outer part of the tooth

2. Dentine

- Not hard as enamel, but it is still very hard, being similar to bone.
- It is hard tissue that contains microscopic tubes

3. Pulp cavity

- It is the center of the tooth, which contains nerves and blood vessels.
- 4. **Cement**
 - Held the teeth in place.
 - Keeps your teeth firmly in place and allows a certain amount of flexibility as you are chewing.
- 5. **Roots**
 - Part of the tooth that extends into the bone and holds the tooth in place.
 - It makes up approximately two thirds of the tooth.
- 6. **Crown**
 - The top portion of the tooth that is visible.

Moving the food on

- ▶ The saliva coated chunk of food (known as a **bolus**) moves to the back of your throat to be swallowed.
 - Swallowing is a **reflex action** that takes place when food reaches the back of your throat.
- ▶ As you swallow, your epiglottis closes over the trachea, preventing food going down into your lungs; you can't swallow and breathe in at the same time.
- ▶ When your food is swallowed it travels down the **esophagus** or gullet, squeezed along by muscular contractions known as **peristalsis**.

Stomach churning activity

- At the lower end of the esophagus your food passes through a ring of muscle called a sphincter into your stomach.
- This sphincter
 - Its contraction closes the opening to the stomach, while its relaxation allows food to enter.
 - Usually closed except when you are swallowing food, or being sick.
- The stomach is a muscular bag that produces
 - Protease enzymes (Pepsin) to digest protein.
 - Relatively concentrated solution of hydrochloric acid.
 - **HCL**
 - Kills most of the bacteria that are taken in with our food.
 - Also helps indirectly in the breakdown of the protein in your food, because pepsin works best in acid conditions.
 - Also makes a thick layer of mucus, which protects the muscle walls from being digested by the protease enzymes and attacked by the acid.
- After a time – usually between 1-4 hours – a paste of partly digested food is squeezed out of the stomach through another sphincter (**pyloric sphincter**) into the first part of the small intestine known as the duodenum.
 - **pyloric sphincter**- regulates the movement of food and stomach acids into the small intestine.

As soon as it arrives the food is mixed with two more liquids: **bile** and **enzymes**.

Bile

- Bile is a greenish-yellow alkaline liquid that is produced in the liver.
- It is made by the liver cells and then stored in the gall bladder until it is needed.

The bile does two important jobs:

- It **neutralizes** the acid from the stomach and makes the semi-digested food alkaline.
 - This is ideal for the enzymes in the small intestine, which work most effectively in an alkaline environment.
- Bile also **emulsifies** the fats in your food – it breaks down large drops of fat into smaller droplets.
 - This provides a much bigger surface area of fats for the lipase enzymes to work on to break down the fats completely into fatty acids and glycerol.

Enzymes

- The **duodenum** cannot make its own enzymes, but this doesn't matter because they are supplied by the pancreas.
- Some parts of the pancreas make the hormone insulin, which helps to control your blood sugar levels.
- The rest of the pancreas makes and stores enzymes that digest carbohydrates, proteins and fats.

The rest of the small intestine (**Jejunum and Ileum**) is a long (6–8 m) coiled tube that produces carbohydrase, protease and lipase enzymes of its own.

- The tube is coiled up to fit inside the body cavity.

Table 3.5 *Enzymes of the human digestive system*

Type of enzyme	Where it is found in the gut	What does it act on?	What are the breakdown products?
Carbohydrase, e.g. amylase, maltase	Salivary glands, pancreas, small intestine	Starch, maltose	Glucose
Protease, e.g. pepsin, trypsin	Stomach, pancreas and small intestine	Protein	Amino acids
Lipase	Pancreas and small intestine	Lipids (fats and oils)	Fatty acids and glycerol

Absorption

Digestion end products (glucose, amino acids, fatty acids and glycerol), they leave the small intestine by diffusion and go into the blood supply to be carried around the body to the cells that need them.

Factors that make absorption of digested food efficient

- Villi_ many finger-like projections of the lining and each individual villus in turns has micro villi to increase the surface area for diffusion.
- The villi also have a rich blood supply that carries away the digested food molecules and maintains a steep diffusion gradient.

- The diffusion distances are very small, and
- The whole process takes place in a water-based solution.

During absorption

- The glucose molecules and amino acids go directly into the blood.
- The fatty acids and glycerol move initially into the lacteals, which are part of the lymph system.
- The lymphatic fluid with its load of fatty acids and glycerol then eventually drains into the blood as well.
- Once the digested food molecules have all been taken into the blood they are taken in the hepatic portal vein to the liver, which processes some of the food.
- ❖ The remaining products of digestion are carried around the body to the cells where they are needed.
- ❖ They are built up into the molecules required by the cells. This is known as **assimilation**

Large intestine

- Portion of alimentary canal b/n the small intestine and the anus.
- Function absorption of water and formation of faeces (thick paste).
- In this wide, thin-walled tube water is absorbed back into bloodstream by diffusion.
- Parts of large intestine, appendix, cecum, colon, and rectum.
- The appendix is a finger-shaped pouch attached to the cecum.
- The cecum is the first part of the large intestine. The colon is next. The rectum is the end of the large intestine (stores stool).
- The time it takes to digest a meal completely will depend on a variety of things- in particular,
 - the size of meal you eat
 - the type of food it contains

Issues of digestive health

Constipation

- A condition in which the faeces remains in your large intestine for too long, too much water is removed from them and become compacted, hard and difficult to evacuate.
- The most common causes are
 - ▶ Lack of fiber in the diet and
 - ▶ Not drinking plenty of water
- It can be usually treated by:
 - Eating more fibre food (provide the muscle of the gut more material to work on)
 - Drinking more plenty water
 - Sometimes taking laxatives .

Diarrhea

- ▶ If an infection causes the gut to contract more strongly or more rapidly than usual, the faeces that are produced may be very loose and watery. This is known as **diarrhea**.
- ▶ Often this condition clears up within 24 hours, but if it persists – diarrhea can be fatal as it causes dehydration of the tissues.
- ▶ Treatment_ giving the sufferer frequent drinks of water with rehydration salts.
 - ▶ These replace the fluids that are being lost and keep the body tissues hydrated until the immune system overcomes the infection.

Food hygiene

- ▶ Bacteria growing on food that you eat can make you very ill and even kill you.
- ▶ For example
 - ▶ raw meat and raw eggs can contain bacteria such as **salmonella** that cause diarrhea and sickness (vomiting).

3.3 The respiratory system

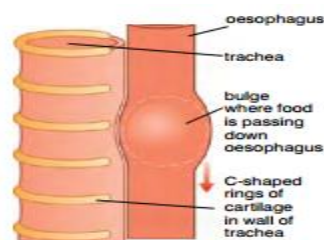
- The human respiratory system composed of the following structures

Your nose

- Contains the nasal passages, which have
 - a large surface area
 - a good blood supply_ warm inhaled air
 - lots of hairs and lining that secrete mucus_ filter dust and small particles and moisten the surface
- air we take in is already warm, clean and moist before it gets into the delicate tissue of our lungs.

Trachea

- It has a series of incomplete rings of cartilage (shaped like the letter C) that support it and hold it open.
- Your esophagus and trachea run next to each other so as a bolus (lump) of food moves down your esophagus it presses against your trachea.
- The lining of your trachea secretes mucus, which like the surface of the nose collects bacteria and dust particles.
- The cells that line the trachea are also covered in hair-like cilia that beat to move the mucus with any trapped micro-organisms and dirt away from your lungs and towards your mouth. This mucus is then either swallowed and digested or coughed up.



Larynx or Voice box

- It sits at the top of your trachea.
- Connects the pharynx to the trachea
- Helps regulate the amount of air that enters and leaves the lungs.
- Produce the sound that you use in speech.

Bronchi (sing. Bronchus)

- The trachea splits into two tubes; the left and right bronchi, one leading to each lung.
- The bronchi are also supported by rings of cartilage.
- Inside your lungs; the bronchi divide into smaller tubes known as the bronchioles.

Bronchioles

- Are much smaller than the bronchi, dividing into ever smaller tubes until they reach the main structures of the lungs- the alveoli (sing. Alveolus).

Alveolus

- It is the tiny air sac in the lungs.
- It is lined by a delicate moist membrane, has many blood capillaries, and is the site of exchange of respiratory gases.
- There are millions of these tiny air sacs giving a massive surface area for the main exchange of gases in the lungs to take place.

How is air brought into your lungs?

- This is brought about by movements of the ribcage, which you can see and feel, and movements of the diaphragm, which you can't.
- The breathing movements are brought about by two different sets of muscles that change the pressure in the chest cavity.

When we breathe in, (inhalation)

- our ribs move up and out
- Muscles of the diaphragm contract so flattens from its normal domed shape.
- Intercostal muscles between the ribs contract, pulling them upwards and outwards.
 - The diaphragm is a sheet of muscle separating the thorax and the abdomen.

We have two sets of intercostal muscles.

External intercostal muscles

- In normal, quiet breathing we use only our external intercostal muscles, which lift our ribs.

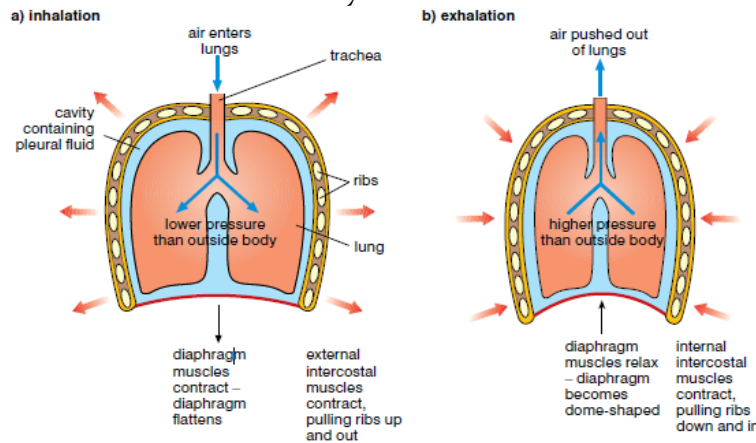
Internal intercostal muscles

- We use internal intercostal muscle,
 - ✓ If we need to breathe out deliberately, forcing the air out of our lungs, or when we are exercising really hard.
 - ✓ It pulls the ribs down hard and squeezes more air out of your lungs.
 - ✓ These two movements increase the volume of your chest (thorax).
 - ✓ This in turn means the pressure inside the chest is lower than the pressure of the air outside. As a result air moves into the lungs.

When we breathe out (Exhalation)

- intercostal and diaphragm muscles relax,
- The ribs drop and the diaphragm domes up.
- The volume of the thorax is decreased,

- The pressure inside your chest increases as the air is squeezed and forced out of your lungs. You breathe out.
- ❖ Movement of air in and out of the body is known as **ventilation** of the lungs



- ▶ The mechanism of gas exchange in the alveoli depends on:
 - large surface area,
 - moist surfaces,
 - short diffusion distances (gases in the air and the gases dissolved in the blood are only separated by two cell layers, a distance of only about a thousandth of a millimeter),
 - a rich blood supply maintaining steep concentration gradients.
- ▶ The blood that the heart pumps to the lungs has come from the active body tissues and is
 - low in oxygen and
 - relatively high in carbon dioxide.
- ▶ Oxygen is constantly moved into the blood, but more deoxygenated blood immediately replaces it.

What affects your breathing rate?

- ▶ The average resting breathing rate for an adult human being is around 12–14 breaths per minute. This does not use up all of the capacity of your lungs.
- ▶ When you are breathing normally at rest, you take about 500 cm³ of air in and out each time you breathe – this is only about 15% of your possible maximum.
- ▶ This is known as your **tidal volume** of air.
- ▶ The **vital capacity** of your lungs is the absolute maximum amount of air you can take into or breathe out of your lungs.
- ▶ Anything that increases the oxygen requirements of your body will tend to increase your breathing rate. The main factors known to have an effect are:

Exercise

- ▶ When you begin to exercise,
 - ▶ Your muscles start contracting harder and faster.
 - ▶ Muscles need more glucose and oxygen to supply their energy needs.
 - ▶ muscles also produce increased amounts of carbon dioxide
 - ▶ So during exercise, when muscular activity increases, your breathing rate increases and you breathe more deeply.

Anxiety

- ▶ When you are anxious your body reacts as if you are in danger and need extra oxygen. As a result, your breathing rate will increase.

Drugs

- ▶ Drugs, whether they are medicines, legal or illegal, may affect your breathing rate – sometimes fatally.
- ▶ Khat, amphetamines and cocaine, for example, can cause your breathing rate to increase dramatically, whereas depressants can cause the breathing rate to drop alarmingly and even stop.

Environmental factors

- ▶ If conditions are particularly hot, your body has to work very hard to keep cool and you may find your breathing rate increases.

Altitude (height above sea level)

- ▶ The higher you go above sea level, the lower both the atmospheric pressure and the oxygen levels in the air.
- ▶ Once you go above 3650 m above sea level, there is a noticeable lack of oxygen and your breathing rate will increase to try and keep your oxygen levels up.
- ▶ Many people feel ill at altitude although you may begin to acclimatize, getting more air into your lungs with every breath as well as producing more red blood cells to carry oxygen.
- ▶ People who are born and live at high altitudes have an increased lung volume with many more alveoli, as well as more blood capillaries and red blood cells to pick up the oxygen from the air.

Weight

- Excess **weight** can also affect your breathing rate.
- It can be difficult to breathe deeply because of the fat around the abdominal organs, which makes it difficult for the diaphragm to lower properly.

Smoking

- The effect of smoking on the lungs and the rest of the body
- Every cigarette smoked produces around 4000 chemicals that are inhaled into the lungs.
- **Nicotine** is the addictive drug found in tobacco smoke.
- **Carbon monoxide** is a very poisonous gas found in cigarette smoke.
- It takes up some of the oxygen carrying capacity of the blood – after smoking a cigarette up to 10% of a smoker's blood will be carrying carbon monoxide rather than oxygen.
- This can lead to a shortage of oxygen for the smoker, and the effect is most marked in pregnant women.
- Smoking in pregnant women can lead to
 - premature births,
 - low birth weight babies and
 - Stillbirths where the baby is born dead.

Smoking-related diseases

Bronchitis (inflammation and infection of the bronchi)

- Tar is a sticky black chemical in tobacco smoke that is not absorbed into the bloodstream, accumulates in the lungs, turning them from pink to grey. It makes smokers more likely to develop **bronchitis**.

Chronic obstructive pulmonary diseases (COPD)

- The build-up of tar in the delicate lung tissue can also lead to a breakdown in the alveolar structure.
- In these COPD the structure of the alveoli break down and much larger air spaces develop.
- This reduces the surface area of the lungs. As a result the person affected is always short of oxygen and feels breathless.

Lung Cancer

- Tar is also a major carcinogen (a cancer causing substance).
- Tobacco smoking is also linked to cancers of the throat, mouth and larynx – the whole respiratory tract is affected.
- The chemicals in tobacco smoke also affect the heart and blood vessels, making it more likely that blood vessels will become blocked, causing heart attacks, strokes and thrombosis.

3.5 The circulatory system

- Small, single-celled organisms rely on simple diffusion to exchange materials between the outside world and the inside of their cells.
- However, as animals get larger and are made up of more and more cells, simple diffusion alone is not enough to supply the body needs; there is simply not enough surface area available for the exchanges to take place.
- So a more complex transport system is required to supply the needs of the body cells and remove the waste material they produce - **transport systems**
- The human transport system is the **blood circulation system**. It has **three** elements –
 - The pipes (**blood vessels**),
 - The pump (the **heart**) and
 - The medium (the **blood**).
- All mammals have a similar system.

A double circulation

We have a **double circulation**,

Pulmonary circulation

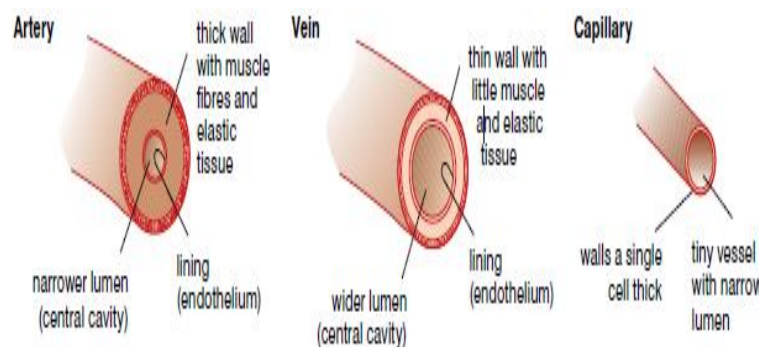
- Blood flows from the heart to the lungs and back again

Systemic circulation

- Blood is pumped from the heart all around the body and back again.
- ▶ A double circulation is very important in warm-blooded, active animals like ourselves because:
 - It is very efficient.
 - It lets our blood get fully oxygenated in the lungs before it is sent off to the different parts of the body.
- ▶ In animals like fish that have a single circulation, as soon as the blood has picked up oxygen it starts to lose it again to the tissues, so very few parts of the body receive fully oxygenated blood.

The blood vessels

- ▶ In the human body we have three main types of blood vessels, **arteries**, **veins** and **capillaries**; they are all carrying the same blood.



Arteries

- ▶ Carry blood away from the heart so they have to be able to withstand the pumping of the heart forcing the blood out into the circulation.
- ▶ This is usually oxygenated blood so it is bright red.
- ▶ Arteries have thick walls that contain muscle and elastic fibres,
 - They can stretch as the blood is forced through them and go back into shape afterwards.
- ▶ Have a pulse in them.
 - The pulse is the surge of blood from the heart when it beats.
- ▶ Narrower lumen (central cavity)
- ▶ Because the blood in the arteries is under pressure, it is very dangerous if an artery is cut.
- ▶ The only arteries that carry deoxygenated blood are:
 - The pulmonary and umbilical arteries which carry the blood away from your heart to your lungs, and away from a foetus into the placenta respectively

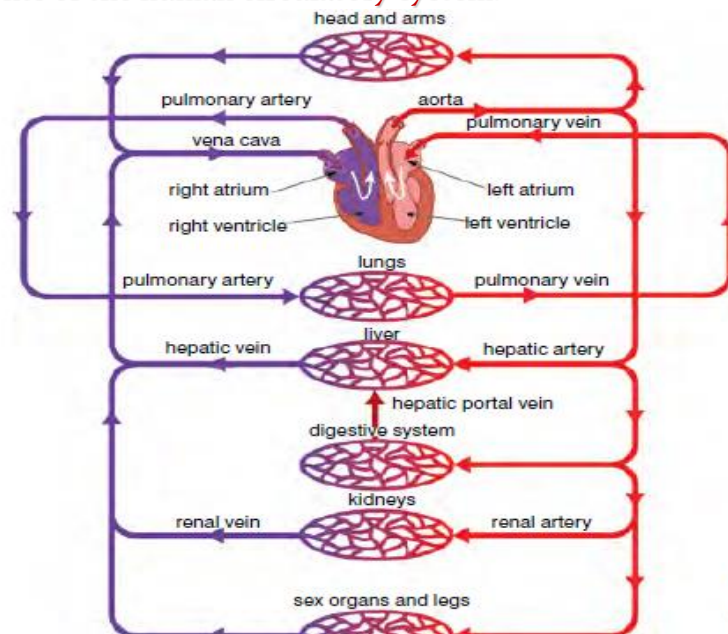
Veins

- ▶ The **veins** carry blood towards your heart – it is usually low in oxygen and so is a deep purple-red colour.
- ▶ They have:
 - much thinner walls than arteries
 - Blood in them is under much lower pressure.
 - Wider lumen(central cavity)
 - They do not have a pulse, but they often have valves to prevent the back-flow of blood as it moves from the various parts of the body back to the heart.
- ▶ The only veins that carry bright red blood are
 - Pulmonary veins, which carry oxygenated blood back from your lungs to the left-hand side of your heart, and
 - Umbilical vein, which carries oxygenated blood from the placenta back to the developing fetus.

Capillaries

- ▶ Link the other two types of blood vessels.
- ▶ Take the blood into all the organs and tissues of the body.
- ▶ It is site of the exchange of substances within the body.
- ▶ Blood from the arteries passes into the capillaries
- ▶ Capillaries have
 - ▶ Very thin walls (single cell thick) and a massive surface area.
 - ▶ Narrow lumen
- ▶ In the same way substances produced by the cells such as carbon dioxide pass into the blood through the walls of the capillaries and flowing back into veins to be returned to the heart and recirculated around the body.

The main components of the human circulatory system.



The human heart

- ▶ a bag of reddish-brown muscle that beats right from the early days of our development in the uterus until the end of our life.
- ▶ The heart is made up of
 - Two pumps that beat at the same time.
 - ▶ Blood can be delivered to the body about 70 times each minute.
 - Cardiac muscle, which can contract and relax more or less continuously without fatiguing.
- ▶ The walls of the heart are almost entirely muscle.
- ▶ Coronary arteries, supply glucose and oxygen and the carbon dioxide carried away in the coronary veins, which feed back into the right atrium.

Atria

- relatively thin wall,
- can stretch to contain a lot of blood.

Ventricles

- much thicker wall, as they have to pump the blood out through the major blood vessels.
- ❖ The muscle walls of the left-hand side of the heart are thicker than on the right.
 - ✓ B/c it has to pump blood around the whole body whilst the right-hand side pumps only to the lungs.

The working of the heart

- ▶ The two sides of the heart fill and empty at the same time to give a strong, co-ordinated beat.
 - Deoxygenated blood, comes into the right atrium of the heart from the veins of the body.
 - The atrium contracts and forces blood into the right ventricle.

- The right ventricle contracts and forces blood out of the heart and into the lungs where it is oxygenated – it picks up oxygen.
- Oxygenated blood returns to the left-hand side of the heart from the lungs and the left atrium fills up.
- The left atrium contracts forcing blood into the left ventricle.
- The left ventricle contracts forcing oxygenated blood out of the heart and around the body.
- ▶ Inside the heart there are many different **valves**. Their names describe their appearance
 - bicuspid (two parts) – b/n left atrium and ventricle
 - tricuspid (three parts) and – b/n right atrium and ventricle
 - semi lunar (half-moon) -heart valve at the base of the aorta and the pulmonary artery
- ▶ The noise of the heartbeat we can hear through a stethoscope is actually the sound of these valves transporting the surging blood.
 - **Diastole** is when the heart muscles relax and it fills with blood.
 - **Systole** is when the heart muscles contract and force the blood out of the heart.
- ▶ **At systole**
 - The blood pressure is at its highest
 - Higher of the two readings taken.
- ▶ **At diastole**
 - the pressure is lower
 - It is the lower reading.
- ▶ A normal blood pressure is 120 mmHg/80 mmHg – usually quoted as: 120 over 80 or 120/80.
- ▶ Your blood pressure will vary through the day and depending on what you are doing.
- ▶ Blood pressure is used as a measure of the health of both **the heart** and the **blood vessels**.

The flexible heart

- ▶ When we are resting our heart beats steadily at around 70 beats every minute.
- ▶ However, during physical exercise muscles need more food and oxygen to work, and so the heart needs to supply more blood.
- ▶ It does this in two ways.
 - The heart beats faster – the pulse rate can easily go up from rest to 120 or even 140 beats a minute.
 - The heart can also increase the amount of blood pumped out at each heartbeat.
- ▶ If people do lots of physical exercise and are fit, their heart responds by becoming bigger and stronger.
- ▶ Because their heart pumps more blood with each beat, fit people tend to have relatively slow resting heartbeats – some are as low as 50 beats a minute.
- ▶ Your heart doesn't beat with a steady rhythm all the time – it responds to all the needs of your body.

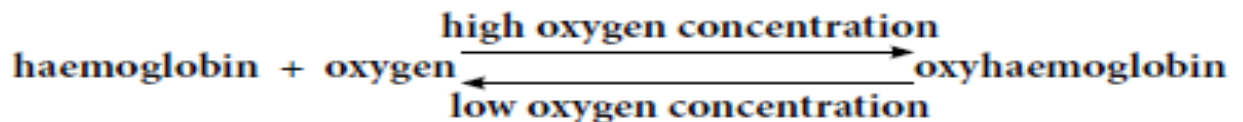
The blood

- ▶ It is the transport medium.
- ▶ Complex mixture of cells and liquid.

- ▶ It consists of a liquid called the plasma, which carries RBC, WBC and platelets and other things like Carbon dioxide, urea

Red blood cells (RBC)/erythrocytes

- ▶ One of the main components of your blood.
- ▶ There are more red blood cells than any other type of blood cell.
- ▶ They are superbly adapted to carrying oxygen around your body.
- ▶ The RBC can do this because:
 - they are packed with a special red substance called **haemoglobin**, which picks up oxygen.
- ▶ In a high concentration of oxygen, such as in the lungs, the haemoglobin reacts with oxygen to form **oxyhaemoglobin**.
 - This is bright scarlet, which is why most arterial blood is bright red.
- ▶ In areas where the concentration of oxygen is lower, such as the cells and organs of the body, the reaction reverses.
- ▶ The **oxyhaemoglobin** splits to give purple-red haemoglobin (the colour of venous blood) and oxygen. The oxygen then passes into the cells where it is needed by diffusion.



How RBC adapted to its role?

- Once they are mature they lose their nucleus. There is more room to carry extra haemoglobin – another adaptation to their all-important function.
- Because they have no nucleus, the red cells only live 100–120 days in your body, so they are constantly being replaced.
- RBC have a unique shape – they form biconcave discs_ gives them a large surface area to volume ratio.
- They are relatively thin, giving short diffusion distances.
- Red blood cells also have a thin surface membrane for ease of diffusion. This allows them to squeeze easily through the very narrow capillaries.

WBC /leukocytes

- They are much bigger than the RBC and there are fewer of them.
- They have a nucleus and form part of the body's defence system against microbes.
- Some white blood cells:
 - **lymphocytes** _ form antibodies against microbes whilst others
 - **Phagocytes** _ engulf invading bacteria.

Platelets/thrombocytes

- They are small fragments of cells and they are very important in helping your blood to clot at the site of a wound.
- When platelets arrive at a wound site they are involved in the formation of a network of protein threads.
- The clotting of the blood is a very important process.
 - It prevents you from bleeding to death from a simple cut.

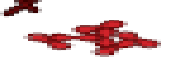
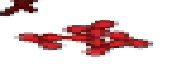
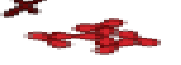
- It also protects your body from the entry of bacteria and other pathogens (disease-causing micro-organisms) through an open wound, and protects the new skin from damage as it grows.

Human blood groups

- ▶ Antigen special protein on the surface of all cells that allow cells to recognize other cell. They allow cells to recognize each other and also to recognize cells from different
- ▶ If the cells of your immune system recognize a foreign antigen on a cell in your body, they will produce **antibodies** and destroy the foreign cells.
- ▶ A number of different antigens are found specifically on the surface of the RBC. This gives us the different human blood groups.
- ▶ There are several different blood grouping systems, but the best known is the ABO system.
- ▶ In this system there are two possible
 - antigens on the red blood cells – antigen A and antigen B.
 - antibodies in the plasma, known as antibody a and antibody b.
- ▶ Unlike most other antibodies, these antibodies are present in your body all the time. They are not made in response to a particular antigen.
- ▶ Four combinations of antibodies and antigens which give rise to the four ABO blood groups.

Blood group	Antigen on red blood cells	Antibody in the plasma
A	A	b
B	B	a
AB	AB	none
O	none	ab

- ▶ If the blood from different blood groups is mixed together, there may be a reaction between the antigen and the complementary antibody which makes the red blood cells stick together (agglutinate).
- ▶ For example,
 - blood group O has no antigens so it can be given to anyone, but someone who has blood group O has both antibodies so they can only receive group O blood!
 - On the other hand someone with blood group AB which has no antibodies can receive any type of blood!

Recipient Donor	O (antibodies a and b)	A (antigen A, antibody b)	B (antigen B, antibody a)	AB (antigens A and B)
O (antibodies a and b)	✓ 	✓ 	✓ 	✓ 
A (antigen A, antibody b)	✗ 	✓ 	✗ 	✓ 
B (antigen B, antibody a)	✗ 	✗ 	✓ 	✓ 
AB (antigens A and B)	✗ 	✗ 	✗ 	✓ 

Two common problems of the circulatory system

Anaemia

- ▶ If you are anaemic you have too few RBC in the body, or the levels of the oxygen-carrying red pigment haemoglobin in your blood are too low.
- ▶ Cause
 - The most common is a lack of iron in the diet.
- ▶ Symptoms
 - Tiredness and lack of energy, because your body cells are constantly deprived of oxygen.
- ▶ Girls are more likely to be anaemic than boys because they lose iron each month in their menstrual bleeding.
- ▶ Women are more likely to be anaemic than men because of the demands of pregnancy
- ▶ Anyone who suffers an injury and bleeds a lot, or who has internal bleeding for any cause, is also likely to become anaemic if they do not have a blood transfusion and a diet rich in iron.

Hypertension

- It is the medical name for high blood pressure.
- Blood pressure is considered high if the systolic pressure is greater than 140 mmHg or the diastolic pressure is greater than 90 mmHg.
- For 90% of the cases of hypertension, the cause is unknown.
- For the other 10%, hypertension is a symptom of another disease, such as:
 - Chronic kidney diseases or diseases in the arteries supplying the kidney.
 - Chronic alcohol abuse.
 - Hormonal disturbances or tumours.
- There are a number of factors that can increase the risk of you developing hypertension. Many of these factors:
 - narrower or rigid blood vessels
- These factors include: increasing age, being overweight, excessive salt intake, excessive, consumption of alcohol, sedentary (inactive) lifestyle, smoking, kidney diseases, diabetes and certain medicines, such as steroids.
- There is also evidence to suggest that hypertension may be genetic (i.e. run in the family).

Unit 5: Classification

5.1 Principles of classification

- ▶ This **great variety** of life is called **diversity or biodiversity**.
- ▶ This **grouping of similar living things** is known as classification.
- ▶ Biologists classify living things for the following reasons:

1. **To simplify their study.**
2. **To bring order out of chaos or confusion.**
3. **To try to understand how life originated.**

What is a species?

- The most common and widely used definition of a species is:
 - *A group of organisms that can breed successfully with one another to produce fertile offspring.*

The classification system

- ▶ The process of classifying living organisms is known as **taxonomy**, and the system we use groups living things into categories called **taxa**.
- ▶ The main taxonomic categories are **kingdom, phylum (or for plants, division), class, order, family, genus and species**.
- ▶ The largest groups into which living organisms are divided are the kingdoms.
- ▶ Kingdoms are subdivided into phyla, each phylum into classes, each class into orders, each order into families, each family into genera and each genus into species.
- ▶ The **species** is the smallest unit of classification. There will be many different types of organisms

Naming living things

Aristotle (384-322 BC)

- Taxonomy began with the work of Aristotle, a philosopher who lived in Ancient Greece.
- He even tried to give everything **a scientific name with two parts to it – he called humans ‘rational animals’**.

Carl Linnaeus

- Taxonomy became a serious science with the work of Carl Linnaeus in the 18th century
- He developed the **binomial system of nomenclature** for organisms, which he published in a book called *The System of Nature*.
 - **Binomial** means two names.
- He suggested a way of organising living organisms from the kingdoms downwards.
- ▶ The two names of an organism are in **Latin**.
 - ▶ Even in the time of Linnaeus, Latin was no longer spoken anywhere in the world.
 - ▶ However, it was the language of scholars everywhere.
- ▶ So, for example, the wolf with so many names in Ethiopia is known to all scientists as *Canis simensis* – so no one gets confused.

Simple rules for writing scientific names

- The first name is the name of the genus to which the organism belongs.
 - It is written with a capital letter.
 - Sometimes the name of the genus is reduced to just the capital letter,
 - Example *H. sapiens*, *C. simensis*.
- The second name is the name of a species to which the organism belongs.
 - It is written with a small letter.
- The two names are underlined when handwritten or in italics when printed.

Living things are classified and named for the following main reasons:

1. To create an internationally accepted way of referring to a particular living thing.
2. To avoid confusion created by different languages.
3. To help in simplifying classification and study of living things.

- ▶ To reach those names, the organism needs to be completely classified from the kingdom downwards.

5.2 The five kingdoms

What is a kingdom?

- ▶ A kingdom is the largest **taxon** and consists of all the other **taxa**. In the modern classification, There are five kingdoms namely:
 1. Monera (bacteria)
 2. Protista (also known as the protocista)
 3. Fungi
 4. Plantae
 5. Animalia
- ▶ This system of classification is known as the five-kingdom system.

Kingdom Monera

- ▶ Include all of the **bacteria**, as well as the **blue-green algae**.
- ▶ Are all single-celled organisms
- ▶ They do not have a separate nucleus (they are **prokaryotic**).
- ▶ They are all **microscopic** and they reproduce by simply splitting in two.
- ▶ Some of them can make their own food by photosynthesis, but many of them are heterotrophic – they rely on other organisms to provide their food.
 - **Examples**
 - *Mycobacterium tuberculosis*
 - *Haemophilus ducreyi*
 - All pathogenic bacteria
 - Bacteria that do good include those in the soil and in your gut

Kingdom Protista

- ▶ Are all microscopic single-celled organisms that do have a nucleus – they are **eukaryotic** cells.
- ▶ They include plant-like organisms that **can move** around and animal-like organisms that **cannot move**.
- ▶ Make up much of the plankton found in the oceans and are the basis of the food supply for all the organisms in the sea.
- ▶ Some protista cause serious disease in human beings.
- ▶ Examples
 - ▶ *Plasmodium falciparum*_ Causes malarial disease
 - ▶ *Entamoeba histolyca*_ Causes amoebic dysentery
 - ▶ *Trypanosoma*_
- ▶ Dinoflagellates are protista that cause bioluminescence in the seas and oceans when they produce a greenish light.

Kingdom Fungi

- ▶ Large and very successful group – there are around 80 000 species.
- ▶ Vary in size from single-celled yeasts to enormous puffballs.
- ▶ Eukaryotic and usually multicellular.
- ▶ They are heterotrophic
 - Many fungi are **saprotrophs**_ they feed on dead material.
 - Saprophytic fungi usually produce huge numbers of spores, which float on the wind to other dead material.
 - They play a vital role within ecosystems as decomposers.
 - Examples:
 - *Rhizopus* (bread mould),
 - *Mucor* and
 - *Penicillium* (the fungus that produces the antibiotic penicillin).
 - Fungi can be parasites.
 - They attack plants more than animals, although some fungi, such as
 - *Candida albicans* (thrush)
 - *Tinea pedis* (athlete's foot)
 - Mildews cause enormous damage to plants.
 - Some fungi are **mutualists**. This means they live in close association with another organism and both benefit.
 - Examples are
 - Lichens, which are a combination of a fungus and green algae or blue-green bacteria, and
 - Mycorrhizae, an association between a fungus and the roots of a plant.
 - Yeast, which makes injera rise and allows us to make alcohol, is one of the few single-celled fungi.

Kingdom Plantae

- ▶ Includes from tiny mosses to giant trees.
- ▶ So far botanists have identified around 300 000 living plant species, and over 80% of these are flowering plants.
- ▶ Plants are enormously important –
 - Source of the fossil fuel coal
 - They provide:
 - Food, oxygen, building materials, clothing, medicines and many other things.
- ▶ The main characteristics of all plants include:
 - Eukaryotic cells.
 - Multicellular organisms.
 - Chlorophyll and carry out photosynthesis.
 - Predominantly land dwelling.
 - Most have a waxy cuticle that helps to prevent drying out.
- ▶ Plant divisions are the same as animal phyla. The four most important divisions are:
 - Bryophyta – the mosses and liverworts
 - Pteridophyta (Filicinophyta) – the ferns
 - Gymnospermae (Coniferophyta) – the conifers
 - Angiospermae (Angiospermophyta) – the true flowering plants

Division Bryophyta (mosses and liverworts)

- The simplest land plants.
- They do not have a true root system.
- They are non-vascular (do not have xylem and phloem).
- A large percentage of bryophytes live in tropical rainforests.
- The best examples of bryophytes are mosses like:
 - *Etodon concinnus*, found in the Bale Mountains
 - *Funaria* spp.
- A moss plant has a simple, slender stem.
- Have thin simple leaves, which are only one cell thick.
- Mosses also have simple root-like structures called rhizoids that have slender filaments and attach the mosses to the soil but without any strength.

Division Pteridophyta

- Plants have true leaves, stems and roots.
- Fern stems have rhizomes, which grow horizontally just below the surface of the soil.
- Their stems contain vascular tissue similar to that found in flowering plants, and so do their roots.
- They produce spore-forming bodies on the underside of the fronds.
- The spores are dispersed by wind. However, they still rely on water for reproduction, which limits where they can live.
- Most ferns live in damp, shady places. However, some ferns – such as *Pteridium* spp (commonly known as bracken) – are an exception because they can grow and do well in full sunlight.

- Another example of a Pteridophyta is the fern *Dryopteris* spp

Spermatophytes/ seed-bearing plants

- Most successful of all land plants because of the following characteristic features that they possess:
 - ✓ Well-developed roots stem and leave.
 - ✓ Well-developed vascular tissues.
 - ✓ The male gametes are contained within pollen grains and the female gamete is contained within the embryo sac.

Division Gymnospermae

- Commonly known as the conifers or ‘naked seed plants’.
- About **one third of the world’s forests** are coniferous
- They are usually the dominant vegetation in **cold and mountainous regions**.
- Some conifers have **developed relatively fleshy** tissue around their seeds (e.g. juniper), but the majority produce **bare cones**.
- The main characteristics of the Gymnospermae are:
 - Their **seeds are not enclosed in fruits**.
 - Small **needle-shaped leaves** with a **thick waxy cuticle**.
 - They are **evergreen** so they can photosynthesize all year long.
 - The reproductive structures are found in **cones**.
- ▶ A conifer tree produces two different types of cone.
 - ▶ The male cone forms huge numbers of pollen grains that are blown by wind to a female cone.
 - ▶ Fertilization results in a small winged seed.
 - ▶ The genus *Pinus* (for example, *Pinus sylvestris*, *Pinus resinosa*, *Pinus radiata*) is a good example of a conifer.
 - ▶ They are **evergreen** – they maintain their leaves throughout the year, even in temperate climates. This means they shed and replace a few leaves all the time rather than spending part of the year leafless and dormant.
 - ▶ Conifers have been imported and planted in East Africa because of their importance as a source of timber and for ornamental purposes.

Division Angiospermae

- ▶ The flowering plants are the **biggest group of land plants** on the Earth.
- ▶ Their reproductive structures are carried in **flowers**.
 - The biggest flowers in the world belong to *Rafflesia arnoldii* and they can be as much as a metre across.
 - The smallest belong to *Wolffia globosa* and they are less than 2 mm across.
- ▶ Whatever the size of the flowers, they carry the reproductive parts of the plant.
- ▶ The main characteristics of the angiosperms are:
 - They have flowers as reproductive organs.

- They have their seeds enclosed in a fruit.
- They have well-developed xylem and phloem tissue.

Subdivisions of Angiosperms

Class Monocotyledons (monocots)

- ▶ The main characteristics of the monocotyledons are:
 - The embryo has a single seed leaf (cotyledon).
 - Leaves are generally long and thin with parallel veins.
 - The stem contains scattered vascular bundles.
 - In general, monocots do not reach great sizes (palms are the exception to this).
 - They are often wind pollinated.

Examples grasses, orchids, maize.

Class Dicotyledons (dicots)

- ▶ The main characteristics of the dicotyledons are:
 - The embryo has two seed leaves (cotyledons).
 - The leaves are often relatively broad and have a network of veins.
 - The stem contains a ring of vascular tissue.
 - Some dicots reach great sizes.
 - They are often insect pollinated.
- ▶ Examples: sunflowers, peas, beans, mangos are dicotyledons.

Kingdom Animalia

Includes the animals:

- ▶ There are at least two million species of animals alive today.
- ▶ Multicellular and heterotrophic – they feed on other organisms.
- ▶ They differ from the other four kingdoms in that:
 - They exhibit locomotion - can move their bodies from one place to another
 - Their cells do not have cell walls.
 - They have nervous systems so they are sensitive to their surroundings.

There are 33 animal phyla, but here we shall only consider the main ones.

- Porifera (sponges)
- Coelenterata (cidaria)
- Platyhelminthes (flatworms)
- Nematoda (roundworms or nemathelminthes)
- Annelida (segmented worms)
- Mollusca (soft-bodied animals)
- Echinodermata (spiny-skinned animals)
- Arthropoda (joint-footed animals)
- Chordata

Invertebrates

Vertebrate

Invertebrates_ do not have a backbone.

Vertebrates – all the animals which have a spinal cord enclosed in a backbone of vertebrae.

Phylum Porifera – the sponges

- The simplest invertebrates.
- Only the young move – the adults are permanently attached to a surface on the sea bed.
- They are hollow filter feeders, and the body cavity is connected to its external environment by pores.
- There is little co-ordination or control.
- They range in size from a few millimeters to 2m and are supported by a series of calcareous spicules. (skeletal system made of CaCO_3 or silicon)
- The sponges are an evolutionary dead end and have no other close living relatives.
- Definite digestive, respiratory and circulatory system are absent.
- Canal system is present. Canal is water intake, respiratory and nutritive.

Phylum Coelenterata

- ▶ Include some exceptionally beautiful creatures and also some very poisonous ones.
 - Example_ Sea anemones, hydra, jelly fish and coral
- ▶ Soft bodies with a ring of tentacles for capturing prey.
- ▶ Stinging cells on their tentacles for poisoning or immobilizing prey and predators.
- ▶ Two layers of cells in their bodies that surround a central cavity.
- ▶ Only one opening, the mouth, and their bodies have radial symmetry.

Phylum Platyhelminthes – flatworms

- ▶ show a relatively high level of organisation.
- ▶ range from 1 mm to 30 cm in length.
- ▶ possess a front end where the mouth, major sense organs and the main integrating region of the nervous system is sited.
- ▶ flattened bodies with a mouth but no anus.
- ▶ no body cavity and rely on diffusion for everything.
- ▶ They are hermaphrodites – they contain both male and female sex organs.
- ▶ They live in other animals as parasites or are free-living in fresh water.
- ▶ Examples *Planaria* spp (which live in fresh water), tapeworms and liver flukes like *Fasciola hepatica*.

Phylum Nematoda (nematelminthes) – roundworms

- ▶ most numerous animals in the world.
- ▶ it has been estimated that there are around 5 billion roundworms in the top 7 cm of an acre of soil.
- ▶ found in almost all environments, from the deepest ocean floor to the Antarctic.
- ▶ have narrow, thread-like bodies, which are pointed at both ends and bilaterally symmetrical.
- ▶ Their bodies are not segmented and are round in cross-section, which is how they get their name.

- ▶ They **don't have a circulatory system** but they do have a **complete digestive system with both mouth and anus**.
- ▶ Example__ *Ascaris*, Filariidae

Phylum Annelida

- ▶ body divided into regular segments with structures and organs repeated along the body.
- ▶ they have a closed blood circulatory system.
- ▶ they are hermaphrodites and they have bristle like structures called **chaetae** to help them move. they are found in moist soil and water and most are free-living.
- ▶ Example earthworm, *Lumbricus terrestris*, *Hirudo* spp, the medicinal leech.

Phylum Mollusca

- ▶ have a wide range of lifestyles and include the most intelligent of the invertebrate species.
- ▶ Octopi and squid have well developed brains.
- ▶ they may have shells or be shell-less, live in the sea, or in fresh water or on land.
- ▶ the main features
- ▶ a soft muscular foot with a soft body, which is often protected by the shell.
- ▶ their bodies are divided into head, foot and visceral mass and they are not segmented.
- ▶ they breathe through gills.
 - Examples slugs and snails

Phylum Echinodermata

- ▶ The skin contains many spines.
- ▶ Although they appear very simple they have a mouth (on the lower side), a gut and an anus (on the upper side).
- ▶ They are all marine animals, and move around using **tube feet**. The adults have five arms, but the larval stages do not. Examples_ sea urchins, starfish and brittle

Phylum Arthropoda

- ▶ This phylum gets its name from two Greek words, *arthron* – joint, and *podos* – foot.
- ▶ they cannot grow very large.
- ▶ an external exoskeleton made of chitin that prevents excessive water loss but also limits their growth.
- ▶ are animals with segmented bodies and jointed limbs.
- ▶ well-developed nervous system and a complete gut from the mouth to anus.
- ▶ divided into a number of classes according to the number of limbs, presence and number of antennae and number of body parts.
- ▶ These include **insecta**, **crustacea**, **arachnida**, **diplopoda** and **chilopoda**.

The insecta

- ▶ live almost everywhere, although most are land-based.
- ▶ three body parts; head, thorax and abdomen.

- ▶ three pairs of jointed legs on the thorax along with one or two pairs of wings. On their head they have a pair of antennae and one pair of compound eyes.
- ▶ Insects include flies, butterflies and moths, beetles, wasps and bees and many other common groups.

The crustacean

- are mainly aquatic.
- They vary in size from very small, for example water fleas, to quite large, for example lobsters and crabs.
- two body parts – a cephalothorax (head fused with thorax) and abdomen.
- The body is often protected by a tough covering called a carapace.
- They have more than four pairs of jointed legs, two pairs of antennae and simple eyes. In some members, the eyes are on stalks.
- Crustaceans include *Daphnia*, crab, prawn, shrimp, barnacle, water flea, lobsters, woodlice and crayfish.
 - The chilopoda – the centipedes – and the diplopoda – the millipedes –
 - are often confused. In fact some scientists put them all in one group. They both have long bodies with many segments and lots of legs

Table 5.3 Differences between centipedes and millipedes

Centipedes	Millipedes
Have flattened bodies	Cylindrical bodies
Have brightly coloured bodies	Dull-coloured bodies
Have few or less segments	Have more segments
Have one pair of limbs per segment	Have two pairs of limbs per segment
Carnivorous (feed on other animals)	Herbivorous
Have poisonous claws for paralyzing their prey	Have claws for biting and chewing plant material

The arachnida (the spiders)

- are mainly terrestrial although some are aquatic.
- They have two body parts – a cephalothorax (fused head and thorax) and the abdomen – with no antennae.
- They have eight legs in four pairs. Arachnids have simple eyes but often up to eight of them. Spiders spin silken webs.

Examples of arachnids include spiders, ticks, scorpions and mites.

Phylum Chordata

- ▶ The term chordata is derived from the term **notochord**.
- ▶ A **notochord** is a flexible rod-like structure, made of cartilage, which runs along the dorsal side of the body. It provides support to the body.
- ▶ Animals in the phylum Chordata have the following three features in common:
 - They have a **notochord** at some stage of their lifecycle.
 - They have a **hollow nerve cord**, which is a group of nerves forming a hollow tube. This is located above the notochord.
 - They have **gill slits** during early stages of development that are later replaced by lungs and gills.

Vertebrates

- ▶ Vertebrate animals have a vertebral column/backbone. In addition, they also have the following features:
 1. An internal skeleton (endoskeleton) made of bone or cartilage.
 2. A closed blood circulatory system consisting of blood vessels.
 3. A well-developed nervous system.
 4. Two pairs of limbs.
 5. Kidneys as excretory organs.
- ▶ Vertebrate animals form the largest group of the phylum Chordata and they are divided into five classes:
 - Pisces – the fish
 - Amphibia – the amphibians
 - Reptilia – the reptiles
 - Aves – the birds
 - Mammalia – the mammals

Class Pisces

- ▶ These are the fishes. They are **aquatic**, i.e. they live in water, except the mudskipper and lung fish, which can spend short periods breathing in air.
- ▶ They have **streamlined bodies** with scales on their skin.
- ▶ They use **gills for gaseous** exchange and **have fins for swimming**.
- ▶ They have a **lateral line system for hearing** and most fish are **dark on the dorsal** (back) side and **lighter on the ventral side**.
- ▶ Fish are **ectothermic** – they rely on heat from their environment to regulate their body temperature.
- ▶ The class Pisces is divided into two subclasses:
 - **Bony fish (teleosts)** – examples include *Tilapia*, Nile perch, cod, mackerel and catfish.
 - **Cartilaginous fish (elasmobranchs)** – examples include sharks, skates and rays.

Class Amphibia

- ▶ This class includes the amphibians (frogs, toads, newts and salamanders).

- ▶ The word **amphibian** comes from two Greek words *amphi*, which means both, and *bios*, which means life.
- ▶ This means that amphibians spend part of their lives (as larvae or tadpoles) in water and part of it (as adults) on land.
- ▶ The amphibians were the **first vertebrates to colonise the land**.
- ▶ They have simple **sac-like lungs** (which are not very efficient) and smooth, moist skin, which is also used as a respiratory surface.
- ▶ Their lifecycle includes **metamorphosis**, and they need water for successful reproduction as fertilisation is external and the larval form (tadpole) is aquatic.
- ▶ Gills are only present in the larval forms.
- ▶ Amphibians are **ectothermic** – they rely on heat from their environment to regulate their body temperature.

Table 5.6 Differences between a frog and a toad

Frog	Toad
Has a smooth skin	Has a rough skin
Has a moist skin	Has a dry skin
Has more webbed feet	Has less webbed feet
Has a brightly coloured body	Has a dull-coloured body
Has a more streamlined body	Has a less streamlined body
Has extra-long hind legs	Has hind legs that are not extra long

Class Reptilia

- ▶ The **reptiles** are
 - **mainly terrestrial animals**
 - for many millions of years **dominant group of animals on the Earth**.
 - **dry skin with scales**
 - gas exchange takes place exclusively in **the lungs**.
 - **developed internal fertilisation** and they lay eggs on land in a leathery shell.
 - Some reptiles even keep the eggs within their body and give birth to fully developed young.
 - The **gill slits** that are a chordate feature are **seen only in embryonic development** in the reptiles, and reptiles have no external ears.
 - Reptiles are **ectothermic** – they rely on heat from their environment to regulate their body temperature.

Examples include snakes, crocodiles, Nile crocodile, lizard.

Class Aves

These are the birds.

- Birds have **feathers** over most of their body, and **scales on their legs**.
- The **forelimbs** are adapted as **wings**, which most birds use to fly.

- The **sternum or breastbone has been enlarged into a big keel** shape for the attachment of the wing muscles, particularly in those birds that fly.
 - This forms the tasty meat that is so good to eat!
- The **jaws are toothless and are covered by a horny beak.**
- Birds reproduce using well-developed eggs with a hard shell.
- Birds have **light skeletons**, which makes it easier for them to fly.
- They are also **endothermic**, which means they use heat produced by their own metabolism to regulate their body temperature.
- Of the main chordate features, only the hollow nerve cord remains in an adult bird, although the others can be seen at stages during the development of the embryo in the egg.

Class Mammalia

- ▶ **Mammals** are the best known of all animals.
- ▶ Mammals differ from other chordates in a number of ways.
 - A true mammal produces milk for its young in mammary glands,
 - has a high internal body temperature and regulates its own body temperature.
 - Mammals sweat to help control their body temperature.
 - A mammal has hair on the skin and external ears.
 - Most mammals also produce live young which have developed for a time within the body of the mother in a structure called the uterus.
 - As with the birds, chordate features are only plainly visible in the embryos.
 - The mammals range in size from tiny shrews to elephants and whales.
 - The ways in which they control their body temperature and reproduce inside their bodies have made it possible for them to live almost everywhere on the earth.
 - We human beings are just one example of this most highly developed phylum of animals.

Subdivisions of mammals

- ▶ Mammals are classified according to the way their young are produced. There are three sub-classes of mammals:
 - **Egg-laying mammals** – lay eggs, e.g. duck-billed platypus.
 - **Marsupials** – produce immature young, which are nourished by milk in the pouch, e.g. kangaroo, koala bear, opossum.
 - **Higher mammals** – produce fully developed young, which are nourished by milk from the mammary glands, e.g. rats, cows, elephants, cats, monkeys and humans.
- ▶ Mammals are a very successful group of animals, which give us the biggest animals in most of the habitats on the Earth.
- ▶ There are even flying mammals, as bats have been adapted to fly through the air on their leathery wings!

Homeostasis

- Homeostasis is maintenance of normal internal conditions in a cell or an organism by means of self-regulating mechanisms.
 - Feedback mechanisms involving both the nervous and hormonal systems play an enormous role in maintaining homeostasis.
- Most of these control systems in the body are examples of negative feedback. This means:
 - When levels of a substance in the body rise, changes are made which lower the levels again.
 - When levels of a substance fall, changes are made so that it rises again to the original levels.
- Homeostasis is essential for proper body function to ensure survival of the organism.
- Some of the main threats to stable state inside your body
 - ¶ Your daily glucose intake may varies
 - ¶ Whenever you respire, poisonous waste build up in your body that change the pH of your blood or may kill you.
 - ¶ Whenever you exercise you produce heat from your muscle that can increase your core body temperature.
 - ¶ The amount of water and salt you take in vary greatly throughout the day.

Controlling temperature (temperature regulation)

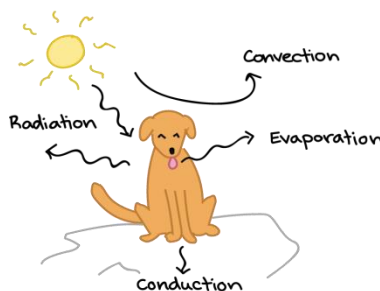
Heat:

- ▶ It is a form of energy which is produced in a number of ways including by:
 - The sun
 - Artificial heating systems.
 - The chemical reactions in the body.

Temperature:

- ♥ It is a way of measuring hotness or coldness (the effect of heat energy) on a relative scale.
- ♥ Wherever we go and whatever we do our body temperature is maintained at the temperature (around 37 °C) at which our enzymes work best.
- ♥ It is not the temperature at the surface of an organism which matters – the skin temperature can vary **enormously** without causing harm.

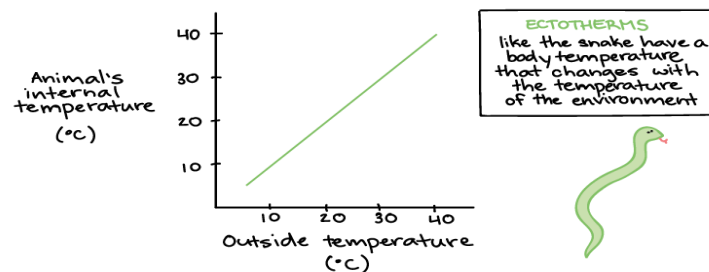
- ♥ It is the temperature deep inside the body, known as the internal or core body temperature, which must be kept stable.
- ♥ We can get a good measure of our human core body temperature by taking the temperature in the **mouth**, in the **anus** or on the **surface of the eardrum**.
- ♥ Living organisms are continually gaining heat from cellular respiration and by **conduction, convection** and **radiation** from their surroundings.
 - ≈ **Conduction:** is the transfer of heat by physical contact. Eg. If you pick up an ice cube you'll lose heat to the ice, if you walk barefoot on stone on sunny day, you will absorb heat from the stone.
 - ≈ **Convection:** wind helps move air away from your body by convection, bringing along new cooler air and thus increasing the transfer of heat from skin to air
 - ≈ **Radiation:** the transfer of heat from a warmer object to a cooler one by infrared radiation, that is, without direct contact. Eg you've been warmed by heat from the sun, a fire or a radiator in a building.
 - ≈ **Evaporation:** vaporization of water from a surface leads to loss of heat. Eg. When sweat evaporates from your skin.
- ♥ They are also constantly **losing heat** by the evaporation of water from the body surfaces and by **conduction, convection** and **radiation** to their surroundings.



- ♥ It is the balance of these gains and losses that gives the **core temperature**.
- ♥ With regard to temperature regulation animals can be divided into two groups.
- ♥ These are:
 - ☞ Poikilotherms
 - ☞ Homeotherms

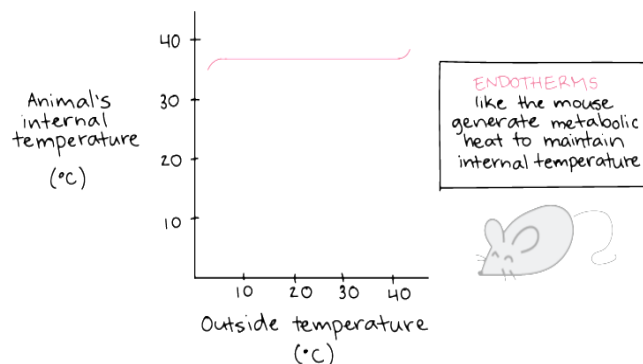
a) Poikilotherms (Exothermic animals)

- These animals produce little internal heat and have little insulation.
- Animals whose body temperature is governed by the external temperature.
- Ectothermic body temperature rises and falls along with the temperature of the surrounding environment
- They rely largely on the environment for their body heat.
- Their body temperature can vary according to the environment. E.g., fish, amphibian and reptiles.



b) Homoiotherms (Endothermic animals)

- Animals whose body temperature within certain limits is independent of the temperature of their external environment
- They rely on a high metabolic rate to generate heat and they have mechanisms to regulate their body temperature at a fairly constant level.
- They have to burn large quantities of fuel-food- to maintain their internal body temperature.
- Keep their body temperature in as narrow range.
- More or less independent of the temperature of the environment.
- Animals with a relatively constant internal body temperature which is usually higher than the external temperature. E.g., birds and mammals.



Temperature control in Poikilotherms

- ♠ Most ectotherms do regulate their body temperature to some degree. They just don't do it by producing heat
- ♠ Rely on **changes to their behavior** and **their body structures** to use the heat in their environment to maintain a reasonably steady and useful body temperature.
- ♠ When they are cold, they may:
 - bask in the sun
 - press their bodies close to a warm surface
 - erect special sails or areas of skin to absorb more heat from the sun
- ♠ When they are getting too hot, they may:
 - move into the shade
 - move into water or mud

Temperature control in Homoiotherms

A. Physiological (biological) methods of temperature regulation in Homoiotherms

1) Sweating

- ▶ Sweat is mainly made up of water, salt & a small amount of nitrogenous waste.
- ▶ When you are hot sweat oozes out of the sweat glands
- ▶ As the water evaporates it cools the skin, taking heat from the body.
- ▶ When sweat a lot can affect water & ion balance b/c water & salt are lost in the sweat so need to take more water & ions in through drink or food to replace the water & ions.
- ▶ Sweat itself is not cool, and it can only cool you down if it evaporates.
- ▶ In hot, humid conditions you may sweat a lot but it won't cool down b/c the water can't evaporate!
- ▶ In cold weather, little or no sweat is formed so little heat is lost by evaporation.

2) Vasodilation

- @ If the body temperature starts to go up, the blood vessels supplying the capillaries in your skin **dilate**, so that more blood flows through the capillaries.
- @ The skin flushes & more heat is lost through radiation from the surface called vasodilation and it is particularly obvious in pale-skinned people.
- @ Less blood flows through the slightly deeper vessels in your skin as a result.

3) Panting and licking

- ✚ many mammals have thick, furry coats and so cannot evaporate sweat easily from the skin surface even when they are getting hot.
- ✚ Some animals, such as dogs and cats, only have sweat glands in small areas of the skin such as the feet.
- ✚ to increase the amount of heat lost through evaporation, animals may lick themselves, coating parts of their bodies with saliva which evaporates and cools them down.
- ✚ They also pant which allows water to evaporate from the moist surfaces of the mouth & cools them down.

4) Vasoconstriction

- ⇒ if your core temperature begins to fall the blood vessels which supply your skin capillaries **constrict** (close up) to reduce the flow of blood through the capillaries.
- ⇒ This reduces the heat lost through the surface of the skin, and makes you look paler.
- ⇒ This is known as **vasoconstriction** and it works to keep you as warm as possible.
- ⇒ More blood flows through the deeper blood vessels of your skin as a result.

5) Piloerection (pulling the hairs upright)

- ~ The hair erector muscles contract. In furry animals this pulls the hairs upright, trapping an insulating layer of air which is very effective at conserving heat.
- ~ Our hairs are also pulled upright, but we have so little body hair that it has little or no effect on heat conservation.
- ~ The most obvious effect is that we get goose bumps on our skin – each bump is the contracted muscle pulling on a hair.
- ~ When the core temperature starts to climb, the hair erector muscles which move our body hair all relax and our hair lies very flat against our skin.
- ~ Again, in humans this has very little effect, but in hairy animals this reflex action is important because it reduces the layer of insulating air trapped in the fur and so makes it easier to lose heat by convection.

6) Shivering and metabolic responses

- ⊖ If your core body temperature drops your metabolic rate speeds up, producing more heat energy so your body temperature starts to go up.

- ⊖ Your liver in particular is involved in this because it is a very large organ which carries out many different metabolic reactions.
- ⊖ As part of this response, you may start to shiver.
- ⊖ When you shiver your muscles contract rapidly, w/c involves lots of cellular respiration
- ⊖ This releases some energy as heat which is used to raise the body temperature.
- ⊖ As you warm up, shivering stops.
- ⊖ But if your core body temperature starts to rise, the metabolic rate drops so less heat is produced.

7) Fat layer under the skin (subcutaneous fat)

- ✓ it is important that homoiotherms only loss or gain heat when they really need to. So under the surface of the skin is an insulating layer of fat.
- ✓ This prevents unwanted heat loss. It is particularly noticeable in animals which live in very cold conditions, for example, seals and whales.
- ✓ The very thick layer of fat under their skin is known as blubber.
- ✓ Like poikilotherms, homoiotherms use behavioural methods to control their internal body temperature.

B. Behavioural methods of temperature regulation in homoiotherms

1) Clothing

- ┌ People choose suitable clothes for the weather as we do not have fur or feathers to keep us warm.
- ┌ We wear warm clothes when the weather is cold and fewer, cooler clothes when the external temperature is hot.

2) Seeking shade or shelter

- ┌ Like many other animals, people look for shade to keep them cool when it is hot and sunny, and look for shelter from cold, wet or windy conditions to help prevent excess heat loss and keep them warm, for example, native male rats live underground in burrows all the time in arid deserts.

3) Taking high-calorie food in cold conditions

- ☞ We need to use more metabolic energy to keep warm so we eat high-calorie food in cold conditions. Birds and other mammals do the same.

4) Hibernation

- ® In cold winters, some homoiothermic animals will hibernate.
- ® They cannot eat enough to keep their body temperature stable through the cold winter, so they sleep through the bad conditions.
- ® These animals eat a lot and gain a lot of fat before hiding away in a warm nest or burrow and going into a very deep sleep.
- ® Their metabolic rate falls and so does their body temperature.
- ® They do not wake up until the warmer weather of spring arrives with more food for them to eat, for example, dormice and hedgehogs in the UK.

5) Aestivation

- In hot countries, some animals ‘hibernate’ through the hottest weather as they cannot keep their bodies cool enough.
- These animals usually hide themselves underground or under a layer of mud and go into a deep sleep until conditions cool down again, for example, East African land snails can aestivate for up to three years in times of extreme drought.

¶ In both hibernation and aestivation, the animals:

- ☞ Heart beat slowly
- ☞ Blood circulates sluggishly
- ☞ Body temperature drops
- ☞ Breathing intervals become very long
- ☞ Live on very food or depend on their stored food (fat)

6) Wallowing or bathing

- # By wallowing in mud or bathing in water, the animals cover themselves in water & the water evaporates from the surface of their skin, cooling them down, for example, elephants and pigs.
- # Some animals cannot lose enough heat through sweating alone to keep their bodies cool enough in hot weather. This is a particular problem for some larger animals.

7) Burning fires, central heating, air conditioning, etc.

- ✚ By burning a fire or turning on the heating we can warm things up and reduce the heat we lose, keeping us warmer.
- ✚ Air conditioning is used in some buildings and vehicles to cool the air down if it gets too hot, so the people inside can lose more heat and keep themselves cool

UNIT 4: Food making and growth in plants

4.1 The leaf

- There are four main organs of a flowering plant.
 - The **flowers_** contain the reproductive organs.
 - The **leaves_** use light energy, carbon dioxide and water to make food by photosynthesis.
 - The **stem_** provides support and a transport system for water and minerals to the leaves and flowers. It also transports food from the leaves to the roots and flowers.
 - The **roots_** anchor the plant to the ground and absorb water and minerals.

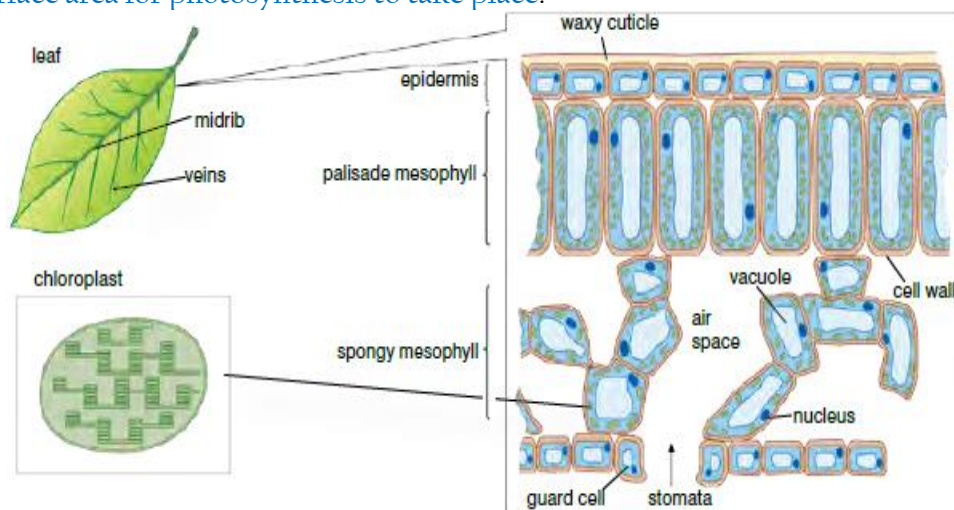
A photosynthesizing machine

- Photosynthesis is amazing process which is the basis of all life on earth.
- In this process plants:
 - Take the inorganic molecules CO_2 and water and use them to produce the organic molecule glucose along with inorganic oxygen in the presence of energy from light.
 - Provides the food we eat and the oxygen we breathe.
- It all takes place in the leaves of plants.
 - Whenever there is light available leaves are perfectly adapted to allow the maximum possible amount of photosynthesis to take place.

Adaptations of a leaf for photosynthesis

- **The leaf is flat and wide, giving**
 - a large surface area to collect light
 - Short distances for gases to diffuse.
 - The veins bring water from the soil to the cells.
- **The waxy cuticle**
 - a waterproof layer found on the surface of many leaves to help prevent water loss.
- **The palisade mesophyll**
 - The **main photosynthetic tissue** of the plant.
 - There are many cells, closely packed together near the surface of the leaf to get as much light as possible.
 - Each cell has many chloroplasts – hundreds of them
 - **Spread out through the cytoplasm of the cell when light levels are high**
 - **Cluster at the top of the cell when light levels are low.**
- **The spongy mesophyll**
 - Has **fewer cells with fewer chloroplasts.**
 - However, there are **lots of air spaces** and a **big surface** area for gas exchange.
 - Some photosynthesis takes place here
 - More importantly it is where the carbon dioxide **needed for photosynthesis moves into the cells, and the oxygen moves out.**
 - Water lost in transpiration evaporates from the cells here as well.

- The **lower epidermis** has openings known as **stomata**
 - Allow CO₂ to diffuse into the leaf and oxygen and water vapour to diffuse out.
 - **Guard cells** open and close the stomata hole to control the entry of CO₂ and loss of water by transpiration.
- The **vascular bundles** contain the **xylem** and **phloem**
 - **vascular bundles** part of the transport system in vascular plants, containing xylem and phloem
 - **xylem** dead tissue which brings water from the soil to the cells of the leaves
 - **Phloem**, living tissue which carries the products of photosynthesis away from the leaves to all of the cells of the plant.
- Each **chloroplast** contains **stacks of membranes** and **chlorophyll** give an **increased surface area for photosynthesis to take place**.



4.2 Photosynthesis

- Like all living organisms plants need food to provide them with the energy for respiration, growth and reproduction.

Heterotrophs (feeding on others)

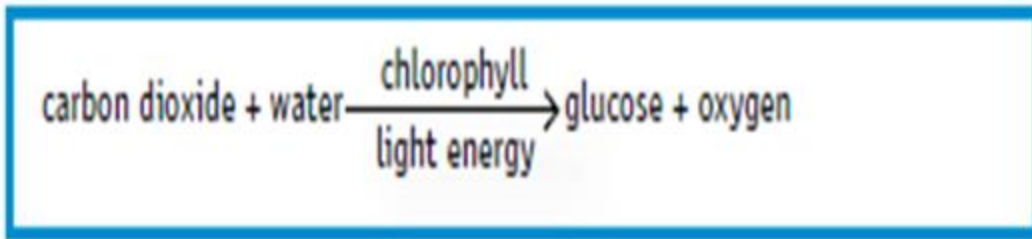
- Many organisms, including all animals, eat food to get the energy they need to live.

Autotrophs (feeding themselves)

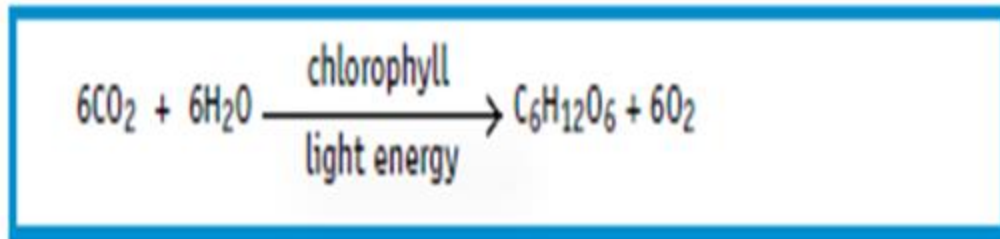
- plants produce their own food in a process known as **photosynthesis**.
- photosynthesis takes place in the green parts of plants, especially the leaves, in the presence of light.

What is photosynthesis?

- Photosynthesis can be summed up in the following equation:



The chemical equation for the same process is:



During photosynthesis

- Light energy from the sun is absorbed by a green substance called chlorophyll.
- The energy is used to convert CO_2 from the air and water from the soil into a simple sugar, glucose, with oxygen as a by-product.

Glucose produced during photosynthesis:

- Some used immediately by the cells of the plant for [respiration](#) to provide energy for cell functions, growth and reproduction.
- The energy released in respiration is used to build up smaller molecules into bigger molecules:
 - Glucose is built into:
 - **Starch** for storage.
 - Glucose is soluble_ it affect the water balance.
 - Starch is insoluble_ so it has no effect on the concentration of solutions.
 - Starch is also a very compact molecule, so it takes up relatively little room.
 - Starch is easily broken down again into glucose molecules when it is needed.
 - Molecules like **fructose** (fruit sugar) and **sucrose** (a double sugar unit) to be transported around the plant.
 - More complex carbohydrates like **cellulose** to make new plant cell walls.
 - Sugars, along with nitrates and other nutrients used to make **amino acids**.
 - These amino acids are then built up into proteins to act as enzymes and make up much of the cytoplasm of the cells.
 - **Fats and oils** (lipids) for storage in seeds and to make up part of the cell membranes.
 - **Chlorophyll**, using minerals such as magnesium taken up from the soil.

What is needed for photosynthesis?

- For photosynthesis to occur successfully CO₂, Water, supply of light energy and green pigment Chlorophyll is needed.

The need for light

The light - dependent reaction

- Light energy is absorbed by chlorophyll molecules through activation of their electrons and used to split water molecules into hydrogen and oxygen.
- Adenosine triphosphate (ATP) is produced as well.
- The hydrogen is used in the rest of the process, and the oxygen is given off as a gas.
 - Oxygen waste product of the light reactions of photosynthesis.

Light independent reaction

- In light independent reaction phase ATP produced and hydrogen generated (during light dependent phase) are used in a series of reduction reactions that convert carbon dioxide into glucose.
 - This stage does not need light to take place. However, without the products of the light dependent reaction the light-independent reactions can't take place at all!
 - If plants are deprived of light for any substantial amount of time they will die, because once the stores of starch have been used up they are not replaced and so there is no energy available for the metabolic reactions of the cells
- The simplest way of demonstrating the need of a plant for light is to deprive it of light and see what happens__ this is called **destarching** the plant – and then compare the leaves with those from a plant kept in the light.
 - Destarching is the process of eliminating starch reserves from a plant by depriving it of light.
 - Alternatively you can cover either a whole leaf or part of a leaf of a destarched plant with black paper or foil. This prevents light from reaching the covered area.
Leaf A is from a destarched plant which has been kept in the dark; leaf B is from a plant kept in the light.



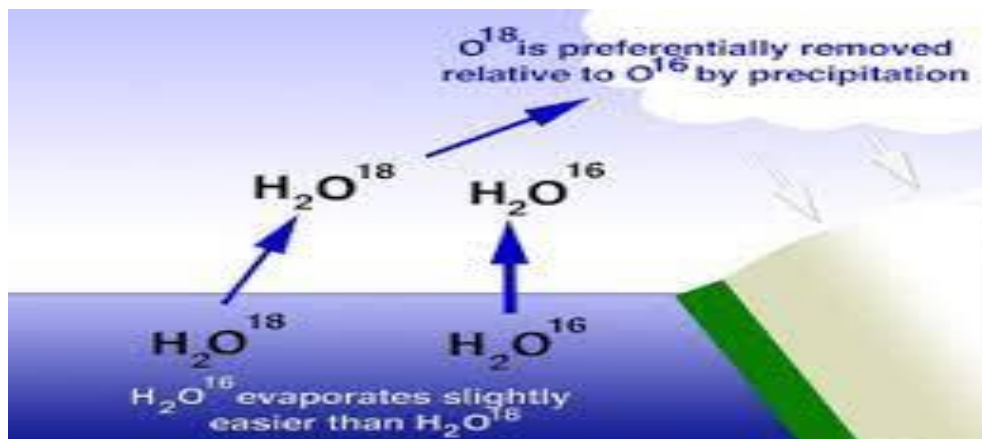
The need for carbon dioxide

- A source of carbon is needed for the plants to synthesize **sugars**.
- CO₂ from the air or in solution in water is the only form that plants can use in photosynthesis.
- As the CO₂ level increases, the rate of photosynthesis goes up.
- You can easily remove the CO₂ from the air surrounding a leaf or a plant using potassium hydroxide, which absorbs CO₂.

- However, the individual plant cells still produce carbon dioxide as they respire and so it is almost impossible to entirely deprive a plant of the gas.
- A more valid approach is to change the levels of carbon dioxide in the air surrounding a plant in high-intensity light and measure the changes in the rate of photosynthesis.

The need for water

- Carbon dioxide alone is not sufficient to produce carbohydrates.
- Water is the only source of hydrogen needed to produce carbohydrates.
- All the cells of a plant have a constant supply of water both as:
 - a waste product of respiration and
 - from the transpiration stream
- You cannot demonstrate that water is required for photosynthesis just by depriving the plant of it – the plant would die long before the effect of lack of water on photosynthesis would show.
- The only way to show that water is needed for the process of photosynthesis is to supply the plant with 'heavy' water containing the ^{18}O isotope of oxygen.
- These atoms are radioactive, and the radiation they produce can be detected as it is taken up and used by the plant.
 - Substances like this are known as radioactive tracers.
- Oxygen gas produced during photosynthesis comes from the splitting of the water molecules using light energy. This is known as photolysis (splitting using light).



The need for chlorophyll

- The simplest way to demonstrate that chlorophyll is needed for photosynthesis to take place is to consider the leaves of a variegated plant.
- Variegated leaves have areas that contain chlorophyll and areas that do not. (having patches of different colors)
- The chlorophyll-free regions are usually yellow or creamy-white in colour.
- If a destarched variegated plant is then exposed to light for several hours and you test one of the leaves for the presence of starch, the iodine solution changes colour only in those regions of the leaf that were green.

This shows that without chlorophyll photosynthesis did not take place.

The importance of photosynthesis

- Photosynthesis is very important as:
 - The source of energy for almost all living organisms.
 - Provide oxygen for respiration process.
 - Maintain atmospheric and water oxygen levels.
 - Remove carbon dioxide from the atmosphere all the time
 - It maintains the balance of oxygen and carbon dioxide in the atmosphere.

4.3 Transport in plants

The transport systems in plants rely heavily on osmosis, diffusion, and active transport.

Osmosis

- Vital for keeping the plant cells **turgid**.
- It is also very important **for moving water around** within the plant itself.
- Water moves into the plant root cells across the cell membrane along a concentration gradient by osmosis.
- The roots are covered with special cells, which have tiny hair-like extensions called the **root hairs**.
 - Root hairs increase the surface area for osmosis to take place.
- Once water has moved into the root hair cells, the cytoplasm of the root hair cells is more dilute than cytoplasm of the surrounding cells.
- Water moves into the neighboring cells by osmosis
- These cells now have more dilute cytoplasm than the cells next to them, and the water moves on by osmosis until it reaches the xylem and transpiration stream.

Active Transport in Plants

- Mineral ions in the soil are usually found in very dilute solutions – more dilute than the solution within the plant cells.
- By using active transport (use ATP) plants can absorb these mineral ions, needed for making proteins, and other important chemicals from the soil, even though it is against a concentration gradient.

A double Transport System

- There are two separate transport systems in plants. Transport through
 - **Phloem and**
 - **Xylem**

Phloem

- Made up of living tissue
- Transport organic material made by photosynthesis
- Use energy to move substance (active transport)
- Food substance move both up and down of the plant
- Thin walled and contain liquid rich food

Xylem

- ✓ It is dead and here is no active transport taking place
- ✓ Carries water and mineral ions from the soil around the plant.
- ✓ Water is absorbed from the soil into the plant by roots.
- ✓ The movement of the water in the xylem is due to transpiration and it is passive.
- ✓ Water only moves up from the roots to the leaves.
- ✓ As water evaporates from the surface of the leaves, water is pulled up through the xylem to take its place.
- ✓ This constant moving of water molecules through the xylem from the roots to the leaves is known as the **transpiration stream**.

What affects the opening and closing of the stomata?

- Guard cells contain chloroplasts so they can photosynthesize, unlike the other cells in the epidermis layer.
- So when there is sunlight, the concentration of sugar in the guard cells goes up as a result of photosynthesis.
- Water then moves into the guard cells by osmosis from the epidermal cells around them.
- The sausage-shaped guard cells become very turgid, and as they swell up they bend, opening a gap – the stoma – between them.
- The pore closes by the reverse process – water moves out of the guard cells by osmosis into the surrounding cells and as the level of turgor in the guard cells falls, the stoma closes.

The need of transport

1. To transport sugar made in leaves around the plant.
 - Plant store glucose in the form of starch which is osmotically inert.
 - Plant deposited starch in root tubers, stem, fruit and leaves.
2. To transport waters and mineral from root to leaves.
 - Mineral is needed to make protein and other molecule.
 - Plant need water is for two reasons:
 - i. Maintain turgor pressure
 - ii. Raw material for photosynthesis

Moving Water through the Plant

- ✓ The constant moving of water molecules through the xylem from the roots to the leaves is known as the **transpiration stream**.
- ✓ The process of evaporation of water from the leaf is called **transpiration**
- ✓ Once water has reached the xylem vessels, it moves up to the stem by the help of the following processes;
 - ❖ Root pressure
 - ❖ Capillarity
 - ❖ Transpiration pull
 - ❖ Adhesive forces and Cohesive forces

Root pressure

- Water is continuously absorbed in the xylem vessels of the root.
- It builds up a hydrostatic pressure that pushes the water up in the stem.
 - ✓ This pressure is referred to as **root pressure**.

Capillarity

- This is the tendency of water to rise up through very narrow tubes.
- Xylem vessels have very small diameters which enables water to rise up in vessels of the plant.
- The processes of cohesion and adhesion constitute the capillarity force
- Water molecules attract one another by cohesive forces.
- The attraction between water molecules and xylem walls is known as adhesion.

Transpiration pull

- Is a biological process which the force of pulling is produced inside the xylem tissue.
- This force helps in the upward movement of water into the xylem vessels
- Transpiration pull is believed to be a result of an interplay of several forces e.g. cohesion and adhesion.

In the xylem, two physical forces help the water to move up. Adhesive and cohesive forces

Adhesive forces

- ✓ Between the water and the walls of the xylem which support the whole column of water, no matter how tall it is.

Cohesive forces

- ✓ The attraction of molecules for the other molecules of the same kinds
- ✓ The water molecules tend to stick together and get pulled upwards like a string of beads.
- ✓ When water reaches the xylem in the leaves, there is a reversal of the situation in the roots.

Factors affecting the rate of transpiration

There are several factors affecting the rate of transpiration. The most known factors are :

Temperature:

- ✓ A change in temperature affects both the kinetic movement of water molecules and the relative humidity of air.
- ✓ An increase in temperature increases the rate of transpiration if other factors are kept constant.
- ✓ The higher the temperature, the more evaporation takes place.

Wind:

- ✓ On a windy day, the saturated vapour is continuously swept away from the stomata hence exposing the stomata to less humid air.

- ✓ This increases on the rate of transpiration.
- ✓ If the air is moving – it is windy – then water-vapor-rich air is always being removed from around the leaf.

Intensity:

- ✓ Sunlight leads to opening of stomata by the plants to allow in carbon dioxide for photosynthesis.
- ✓ Increasing the light intensity, leads to an increase in the size of the stomatal pore hence more water is lost from the leaves.

Humidity

- ✓ Humidity is the amount of water vapour in the atmosphere.
- ✓ If water molecules outside the leaf increase i.e. the humidity rises, the rate of transpiration will decrease.
- ✓ Humidity may increase due to transpiration or rainfall.
- ✓ **Water evaporates more rapidly into dry air than into humid air.**

Adaptation of plants to reduce water loss in difficult environments

- They may have
 - ✓ **Very thick, waxy cuticles** to reduce any water loss.
 - ✓ **Developed very hairy leaves**, which trap a micro-atmosphere around the stoma.
 - ✓ Other plants have **reduced their leaves to very narrow spikes** to reduce the surface area over which water may be lost.
 - ✓ On some plants the **stomata are sunk** into pits.
 - ✓ Often in grasses the **leaves are rolled**, trapping a microenvironment of moist air inside.
 - ✓ **Closing of the stomata** – some plants open their stomata during the night and close them during the day.

Ring experiment

- ✓ To find out whether, **xylem or phloem tissue** are involved in transport of food material removing a ring from a woody branch will result in the removal of the Phloem tissue.
- ✓ The swelling above the ring where the phloem is removed will be caused by an accumulation of sugars in the region above the ring.

Transpiration and agriculture

- Transpiration has many implications for the way we grow our crops – and the crops we choose to grow.
- So, whenever possible we need to **irrigate our fields** and **water the plants** so that they can transpire fully, which allows them to photosynthesize and grow as much as possible.
- It is not only the **level of sunlight** and the **temperature** which affects transpiration rate in our plants.
- **Wind** also increases the rate of transpiration. If we can grow our crops in relatively sheltered places, the rate of water loss will be slower and so our crops are more likely to grow well.
- The final way in which transpiration affects agriculture is in our **choice of crop plants**.

- Some plants are more resistant to water loss by transpiration than others.
- By choosing crops which are suited to the conditions where we are growing them, we can improve our yields and make sure that transpiration works for us and does not cause our plants to wilt and fail.

4.4. Response in plants

- Plants need to respond to factors such as light, water and gravity to make sure that they:
 - Grow the right way up and
 - Make as much food by photosynthesis as possible.
- Plants achieve their co-ordination and responsiveness through a system of **hormones**.
 - **Hormones** are chemical messengers which are produced in one part of an organism and have an effect elsewhere.
- Plant hormones (phytohormones) have several effects on plants. For example, they co-ordinate:
 - Flowering
 - Cell division and
 - Cell elongation.
- These are essentially growth processes and **plant responses of this type are called growth responses**.
- Since growth is a slow process, most plant responses are slow.

The germination of seeds

- In most flowering plants, growth starts when **the seed begins to germinate**.
- Seeds come in many different **sizes** and **shapes**.

Basic structure of seeds

1. Endosperm

- It is food storage tissue.

2. Embryo

- Has three main parts –

- **Plumule** (embryonic shoot),
- **Radicle** (embryonic root) and
- **Cotyledons** (embryonic leaves)_ the number of cotyledon that are present which gives us the main division of the angiosperms into:

Monocotyledons (one seed leaf) _

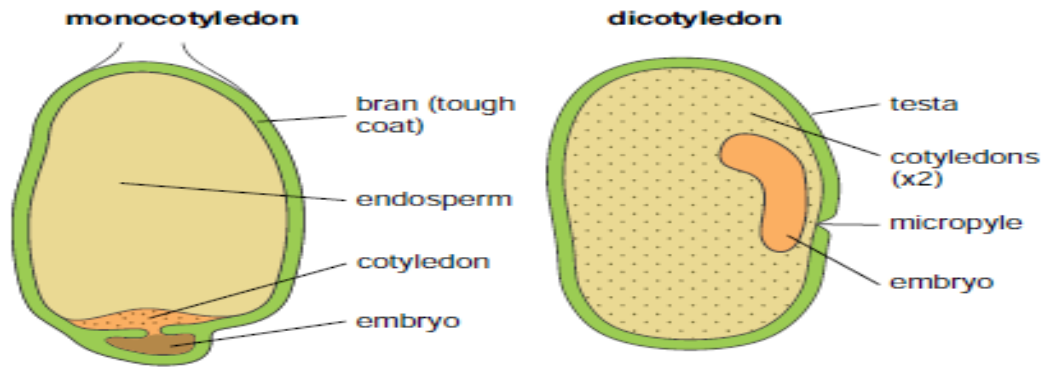
- Endosperm is the main food store
- Embryo remains a very small part of the seed

Dicotyledons (two seed leaves)

- Endosperm moves food into the cotyledons which become the main food store

3. The testa

- The seed coat, which may be **thin** and **papery** like the covering on a groundnut or very **strong** and **hard** like the shell of a nut.



What needed for seed to germinate?

- ✓ water, warmth and oxygen

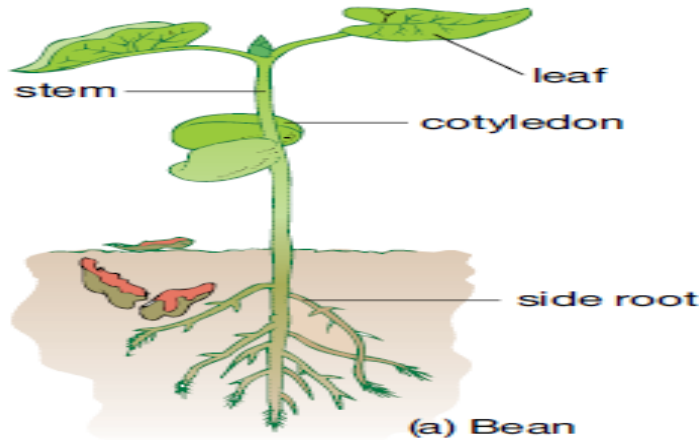
During germination,

- A lot of energy is needed_ it comes from the **stored food** materials.
 - **Starch** is the main food storage material.
 - It is stored either in the **cotyledons** or in the **endosperm**.
 - **Starch** $\xrightarrow[\text{hydrolysis}]{\text{Diastase}}$ **Sugars**
 - In some seeds **fats** and **oils** are stored.
 - **Fats** $\xrightarrow[\text{hydrolysis}]{\text{Lipase}}$ **fatty acids and glycerol**.
 - In others seed proteins stored.
 - **Proteins** $\xrightarrow{\text{Proteolytic}}$ **amino acids**.
- Changes which occur during the germination of a bean seed – a dicot seed.
 1. The seed absorbs water through the **micropyle** (**small hole**) and swells.
 2. The **testa** (seed coat) bursts and the **radicle** emerges.
 3. As the **radicle** elongates it pushes the seed out of the ground.
 - The curved part of the radicle which protrudes is called the **epicotyl**.
 - The seed coat is discarded and the two cotyledons (seed leaves) open out and begin to photosynthesize.
 4. The **Plumule** emerges from in between the cotyledons and produces the first true leaves. At this stage, the young plant is called a **seedling**.

Epigeal (dicot) and hypogeal (monocot) germination

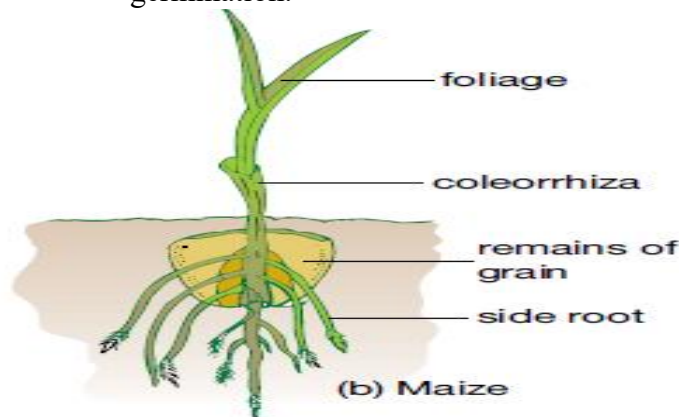
Epigeal germination

- Cotyledon is carried above the soil.
- Most dicotyledonous plants have seeds which exhibit Epigeal germination.
 - Example__ Castor oil seeds, groundnuts, Cotton and Bambara nuts.
- Epigeal germination also occurs in a few monocotyledonous.
 - Example__ Onions and lilies.



Hypogeal germination

- A type of germination in which the **cotyledons remain underground**.
- Monocotyledon exhibit hypogeal germination
 - Examples_ **wheat, sorghum and millet**.
- A few dicotyledonous seeds such as **kidney beans** and **broad beans** exhibit hypogeal germination.



- Germination of any type can occur only in a seed which is viable /alive.
- The length of time a seed can remain viable varies in different species.
 - Many seeds can remain viable for up to 50 years if properly stored.

Three things will determine whether your seeds are still viable:

- **Age of the seeds.**
 - All seeds will be viable for one to two years. After two or three years, germination rates will drop.
- **The type of seed.**
 - Some seeds like onions and sweet corn have a short lifespan

- **How you've stored the seeds.**

- Seeds stay viable much longer when you store them in a cool, dry, dark place. Reducing humidity is key.

Plant hormones and growth

- Growth in plants is influenced by chemical messengers called hormones.

Examples:

- Auxins (including indole-acetic acid, IAA),
- Gibberellic acid,
- Cytokinin,
- Ethylene and
- Absciscic acid.
- Some of these hormones promote growth, others inhibit it.

Auxins (IAA)

- Involved in general plant growth.
- It stimulates the elongation of the new plant cells.
- It is also involved in **apical dominance**.
- **apical dominance** growth concentrated in the terminal bud, allowing it to grow taller, thereby increasing its exposure to sunlight
- IAA is made at the tip of the main shoot and as it moves down the stem it slows down the growth of side shoots. So the main shoot dominates the whole plant.
- Auxin also stimulates the growth of roots.
- If auxin is applied to a cut stem it will stimulate new roots to grow.
- The best-known function of auxins is in the responses of plants to the world around them.
- The responses of plants towards things such as light and gravity are called **tropisms**

Gibberellins

- Stimulate the growth of plant stems.
- If you take a dwarf plant and give it gibberellins the stems will grow until the plant is a normal size.
- Also help seeds to break their dormant period and start to grow.

Cytokinin

- Stimulate cell division in plants.
- The balance between auxins and cytokinin in a tissue culture of plant cells decides whether roots or shoots will grow.

Ethylene

- It is a gas at room temperature and it causes fruit to ripen.
- It also causes fruit and leaves to fall from the plant in some species.

Absciscic acid (ABA)

- It inhibits growth and plays a major role in leaf fall.
- It is also involved in seed dormancy.
- There is some evidence that it may be involved in geotropisms, but it plays a small part compared to IAA.

Tropic responses

- Responses to stimuli that come from one direction are known as tropisms.

Phototropism

- Tendency of plants to move or grow towards light
- Shoots grow towards the light, it is termed as positive **phototropism**.

Geotropism

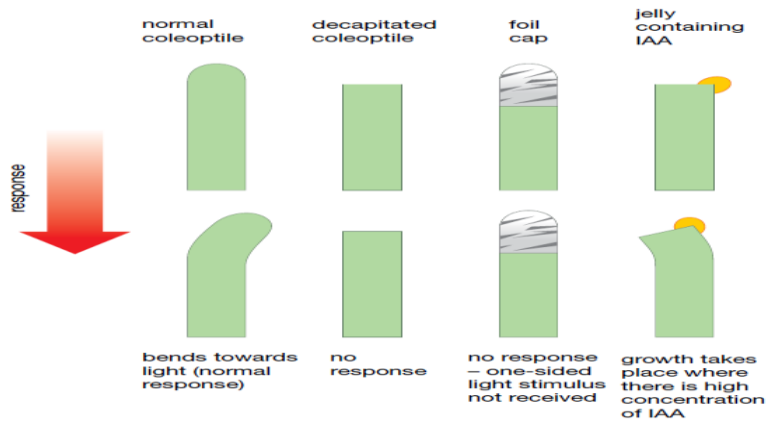
- It is movement in response to the stimulus of gravity.
- Roots are **positively geotropic** (they grow towards gravity) while shoots are **negatively geotropic** (they grow away from gravity).
- The response of seedlings to gravity can also be investigated using a piece of apparatus known as a clinostat.

Hydrotropism

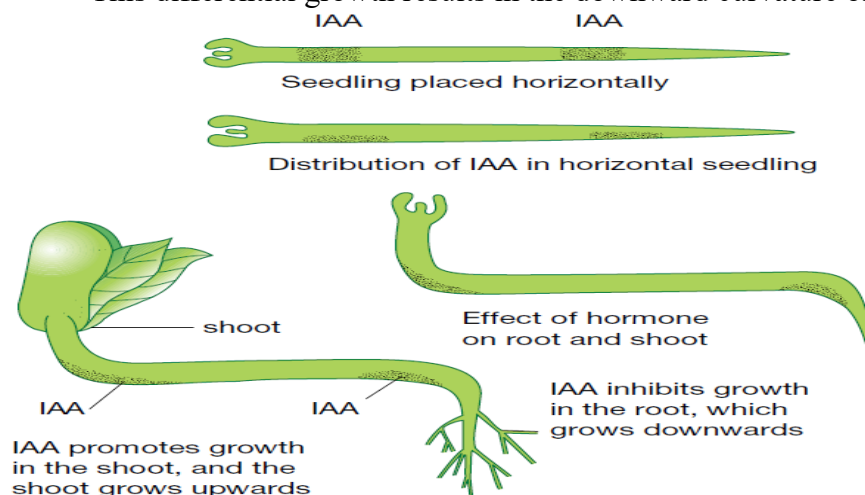
- The type of response by which roots grow towards water is termed hydrotropism.
- ❖ These responses are described as directional responses, tropic responses or tropisms.

How are tropic responses brought about?

- Maize grains germinate to produce a straight shoot called a coleoptiles.
- Coleoptiles are widely used in experiments to investigate the role of hormones in shoot growth.
- It is known that the growth region of a shoot is some distance below the tip.
- This fact suggests that removal of the tip would not affect the growth of the shoot.
- However, when the tips of the coleoptiles are removed (they are decapitated), they don't grow.
- It has been found out that the growth hormone, auxin, produced in the tip is **indole-3-acetic acid (IAA)**.
- IAA diffuses from the tip to the growth region to initiate growth.
- In the decapitated seedlings,
 - the source of IAA production was removed,
 - the seedling grew for a while and then stopped.
 - This is b/c some IAA had already diffused away from the tip before decapitation.
- Experiments have shown that IAA diffuses away from light.
- When a shoot is illuminated on one side, IAA in that side diffuses towards the dark side of the shoot. This causes a build-up of the hormone in the dark side of the shoot.
- Since growth is directly proportional to the amount of IAA, the dark side will grow faster than the illuminated side.



- The upward growth of the shoot and the downward growth of the root, when the bean seedlings were placed horizontally, involve plant hormones.
- **In the shoot,**
 - The force of gravity causes an accumulation of IAA on the underside of the plumule.
 - This promoted more growth in that region than the upper portion.
- **In the root**
 - The downward growth of the root is also influenced by IAA, but in the root tip the hormone inhibits growth, rather than stimulating it.
 - The force of gravity causes an accumulation of IAA on the underside of the root, resulting in reduced growth in that region.
 - The corresponding upper side of the root, which had very little or no IAA, grows faster than the underside.
 - This differential growth results in the downward curvature of the root.



Importance of tropic and nastic responses

In tropisms,

- Some stimuli to which plants respond positively are the basic requirements for the plant's life.

For example

- When positive hydrotropism occurs, roots come into close contact with water. This makes it possible for them to absorb as much water and mineral salts as possible for the plant.
- When a plant responds positively to light its leaves become well exposed to it. This maximises the amount of light available for photosynthesis.