LEAVING CERTIFICATE

BIOLOGY

REVISION BOOKLET

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CONTENTS

UNIT 1: BIOLOGY – THE STUDY OF LIFE

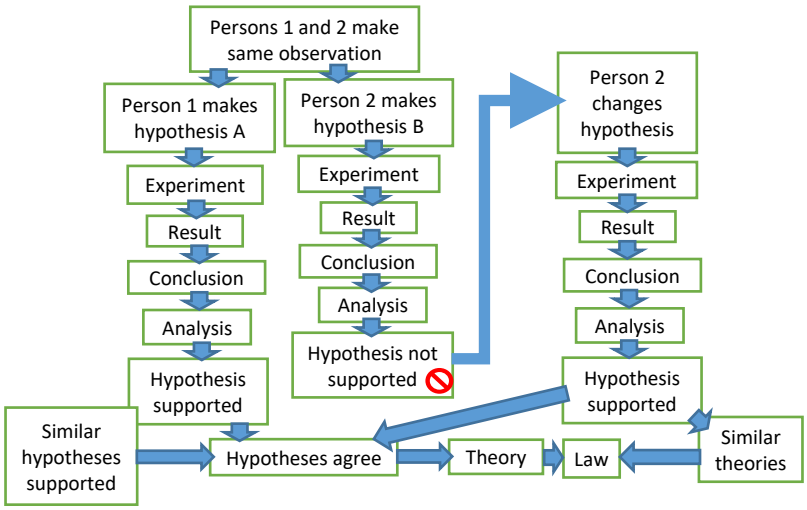
CHAPTER 1: SCIENTIFIC METHOD

Biology is the study of living organisms

Three areas of study in biology:

1. Ecology
2. Physiology
3. Anatomy

Steps in the scientific method:



1. **Observation**: taking in of information received about the natural world
2. **Hypothesis**: an educated guess/idea based on an observation
3. **Experimentation**: an experiment is a test designed to prove/disprove a hypothesis
4. **Collection of data**: data are results obtained after carrying out an experiment
5. **Conclusion**: explanation of the results
6. **Analysis**: explaining new knowledge in relation to existing knowledge
7. **Reporting & publishing results**: writing up & publishing results in a scientific journal.
8. **Development of theory and principle**: a **theory** is a hypothesis supported by many experiments; a **law/principle** is a factual explanation of an important aspect of nature

Principles of Experimentation:

- Careful planning and design
- Safety e.g. wearing gloves and lab coat
- Experimental control: a control is a factor in an experiment that provides a standard upon which results may be compared
- Sample size: larger sample size gives a better representation in the results
- Random selection: e.g. clinical trials must include younger people as well as older
- Replicates: a replicate is a repeat of an experiment
- Double-blind testing: neither doctor nor patient knows whether an active drug has been given

Limitations of the Scientific Method:

- **Extent of our basic knowledge**: lack of knowledge leads to inadequate hypotheses
- **Basis of investigation**: lack of technology/materials/equipment
- **Interpretation of results**: scientists may interpret results differently
- **Application to a changing natural world**: information obtained from organisms in the past may not be valid today – they may have to be repeated
- **Accidental discovery**: experiments may have gone completely "wrong" – i.e. "we did not get the desired result" or "we made an error in preparation and an unexpected result is obtained"; e.g. discovery of penicillin

CHAPTER 2: CHARACTERISTICS OF LIFE

Definitions:

- **Life**: describes an organic-based object that shows the characteristics of metabolism and continuity of life
- **Diversity of living organisms**: refers to the large variety of organisms on Earth
- **Metabolism**: the sum of all the chemical reactions in a living organism
- **Continuity of life**: how living organisms arise from living organisms of the same type

The five characteristics of life:

1. Biological Organisation
2. Nutrition
3. Homeostasis/Excretion
4. Response
5. Reproduction

1. Biological Organisation:

Biological organisation: different levels of complexity in living organisms

Cell → tissue → organ → organ system → organism → population

- The cell is the building block of life
- Molecules (proteins, fats, carbohydrates) organised into organelles, organised into cells, organised into tissues, organised into organs, organised into systems, organised into an organism

Nutrition:

Nutrition: the way in which living organisms obtain and use food

- All our energy ultimately comes from the Sun
- Plants create glucose from carbon dioxide and water using the energy in sunlight – photosynthesis
- Herbivores eat the plants and the flow of energy begins – the food chain
- Carnivores eat the herbivores
- The chemical energy in the bonds of glucose is converted by a cell's machinery to other forms of energy so the organism can do work

Excretion:

Excretion: the getting rid of waste products of metabolism from the body

- An organism's body has ways to maintain its internal environment (homeostasis)
- Excretion is one way in which an organism maintains its internal environment
- Excretion in animals occurs via lungs, kidneys and skin
- Excretion in plants occurs via stomata (leaves) and lenticels (stem)
- Excretion in single-celled organisms (e.g. bacteria) occurs via diffusion

Response:

Response: the way in which living organisms react to their environment

- A living organism responds to environmental changes thereby maintaining a favourable metabolic environment
- In animals the stimulus is detected by sense organs that respond to light, sound, temperature, chemical equilibrium, touch, movement and direct mainly muscles to produce movement
- In plants responses are usually very slow – they respond to light and water by altering the direction of growth – tropisms (e.g. phototropism and geotropism)

Reproduction:

Reproduction: the way in which an organism or organisms create a new individuals

- Every living organism has the inherent ability and need to reproduce, and occurs by usually by one of two methods:
  1. Asexual reproduction: formation of offspring by one individual organism (all offspring are genetically identical to the parent)
  2. Sexual reproduction: formation of offspring from two parents (male and female)

CHAPTER 3: NUTRITION

- **Nutrition:** the way in which living organisms obtain and use food.
- **Metabolism:** sum of all chemical reactions in an organism.
- **Continuity of life:** the way organisms arise from organisms of the same type.

Function of Food

- Food is a complex of chemicals required by a living organism to help with growth and repair and for the production of energy.

Six Common Elements in Food

1. Carbon (C)
2. Hydrogen (H)
3. Oxygen (O)
4. Nitrogen (N)
5. Phosphorus (P)
6. Sulphur (S)

Five Elements in Food as Dissolved Salts

1. Sodium (Na)
2. Magnesium (Mg)
3. Calcium (Ca)
4. Potassium (K)
5. Chlorine (Cl)

Three Trace minerals

1. Iron (Fe)
2. Copper (Cu)
3. Zinc (Zn)

Biomolecules

- Biomolecules are chemicals found in and produced by living organisms
- There are 4 major types of biomolecules:
    1. Carbohydrates
    2. Lipids
    3. Proteins
    4. Vitamins

Carbohydrates

- The general formula for all carbohydrates is: $C_x(H_2O)_y$
- Three categories of carbohydrates:
    1. Monosaccharides ($C_6H_{12}O_6$)
    2. Disaccharides ($C_{12}H_{22}O_{11}$)
    3. Polysaccharides ($(C_6H_{10}O_5)_n$

Monosaccharides

- Glucose [$C_6H_{12}O_6$] – a reducing sugar and formed by breakdown of glycogen
- Fructose [$C_6H_{12}O_6$] – a reducing sugar and found in many fruits
- Galactose [$C_6H_{12}O_6$] – a reducing sugar formed by breakdown of lactose (in milk)

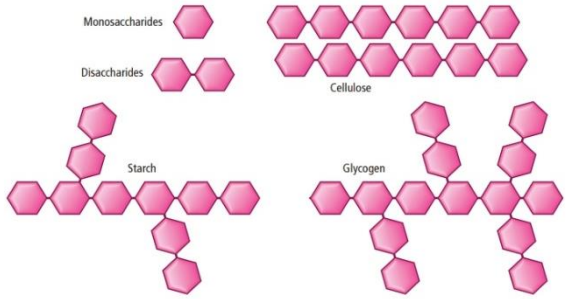
Disaccharides

1. Maltose (a reducing sugar)
    - Found in germinating seeds (e.g. barley)
    - Glucose + Glucose → Maltose [$C_{12}H_{22}O_{11}$] + H_2O
2. Sucrose (**NOT** a reducing sugar)
    - Commonly known as table sugar
    - Glucose + Fructose → Sucrose [$C_{12}H_{22}O_{11}$] + H_2O
3. Lactose (a reducing sugar)
    - Found in milk – some people have lactose-intolerance
    - Glucose + Galactose → Lactose [$C_{12}H_{22}O_{11}$] + H_2O

Polysaccharides

1. Starch (also known as amylose)
    - Plants store glucose as starch, e.g. potatoes, bananas
    - Long chains and some branching of glucose molecules - easy to digest
2. Cellulose (also known as fibre/roughage)
    - Found in cell walls and stems of plants such as celery
    - Composed of many glucose molecules in long chains - difficult to digest

3. Glycogen
    - Animals store glucose as glycogen in liver and muscles
    - Glycogen is more branched than starch



Structural and Metabolic roles of Carbohydrates

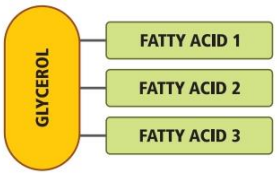
- *Structural role:* Cellulose: component of cell walls; keeps plant upright
- *Metabolic role:* Energy: Mono-, Di-, and Polysaccharides are metabolised to release energy

Lipids

- Lipids: consist of the elements C, H, and O (have fewer O atoms than carbs)
- Two main categories:
    1. Triglycerides
    2. Phospholipids
- Food sources of lipids: Butter, oils, margarines, cream, olives, animal fat

Triglycerides

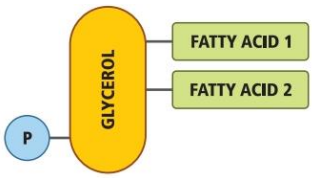
- Triglycerides: one molecule of glycerol and 3 fatty acid molecules
- Fats: solid at room temperature
- Oils: liquids at RT – contain different types of fatty acids than fats



Structure of a triglyceride

Phospholipids

- Phospholipids: contain one molecule of glycerol, 2 fatty acids and one phosphate molecule
- They make up the structure of all cell membranes



Structure of a phospholipid

Structural & metabolic roles of Lipids

Structural role:

- Phospholipids: component of cell membranes of all living cells
- Triglycerides: form adipose tissue that surrounds important internal organs and acts as a shock absorber

Metabolic role:

- Energy: triglycerides are stored by organisms as a source of energy

Proteins

- Proteins consist of elements: C, H, O, N – no particular ratios
- Sulphur and phosphorus are also present in some proteins
- There are 20 common amino acids found in proteins
- Two main categories of protein:
    1. *Fibrous proteins*: little or no folding (e.g. proteins found in hair, skin & nails)
    2. *Globular proteins*: lots of folding (e.g. protein hormones, enzymes and antibodies)

Structural and Metabolic roles of Proteins

Structural role:

- Skin, nails and hair contain keratin
- Muscle composed of actin and myosin
- Bone, ligaments and tendons contain collagen

Metabolic role: Make up enzymes, antibodies and some hormones (e.g. insulin)

Vitamins

- Complex organic substances needed only in tiny amounts
- Share no common chemical characteristics – all chemically unique
- Identified by letters based on their chemical structure
- A, D, E, and K are fat-soluble vitamins
- B-group and C are water-soluble vitamins

Structural and Metabolic roles of Vitamins

Structural role: Vitamins do not have any structural role in living organisms
Metabolic role: Homeostasis and normal metabolism (see tables below for specific metabolic roles of the vitamins)

Note: for the Leaving Certificate you need to know one fat-soluble and one water-soluble vitamin, their functions, and deficiency symptoms

Water-soluble vitamins	**Deficiency disorders**	**Metabolic role**	**Sources**
Vitamin B_1 (thiamine)	Beri beri (neurological disorder)	Carbohydrate metabolism	Pork, bread
Vitamin B_2 (riboflavin)	Swollen mouth	Carbohydrate metabolism	Eggs, meat, milk
Vitamin B_3 (niacin)	Skin lesions (pellagra)	Carbohydrate metabolism	Chicken, beef, tomatoes
Vitamin B_5 (panthenic acid)	Fatigue and low glucose levels	Carbohydrate metabolism	Bread, eggs, meat
Vitamin B_6 (pyridoxine)	Anaemia	Formation of red blood cells	Bread, nuts, seeds
Vitamin B_7 (biotin)	Dermatitis and hair loss	Fat metabolism	Nuts, seeds, liver
Vitamin B_9 (folic acid)	Spina bifida; anaemia in adults; nervous system development	Formation of red blood cells	Spinach, egg yolk, sunflower seeds
Vitamin B_{12} (cobalamin)	Anaemia	Formation of red blood cells	Eggs, milk, fish
Vitamin C (ascorbic acid)	Scurvy	Formation of collagen	Citrus fruits
Fat-soluble vitamins	**Deficiency disorders**	**Metabolic role**	**Sources**
Vitamin A (retinol)	Night-blindness	Formation of rhodopsin (pigment in eye)	Cod liver oil, butter, margarine
Vitamin D (calciferol)	Rickets in children; osteomalacia in adults	Absorption of calcium in the digestive system	Sunlight, eggs, milk
Vitamin E (tocopherol)	Poor nerve impulse conduction	Growth in children; antioxidant in adults	Eggs, milk, nuts and seeds
Vitamin K (quinone)	Inability to clot blood	Blood clotting	Intestinal bacteria, spinach

Minerals

Minerals are elements required by organisms every day to maintain health. They all have varying functions:

Animal mineral	**Good source**	**Function**	**Deficiency symptom**
Iron (Fe)	Red meat	Component of haemoglobin	Anaemia
Calcium	Dairy products	Component of bone	Osteomalacia

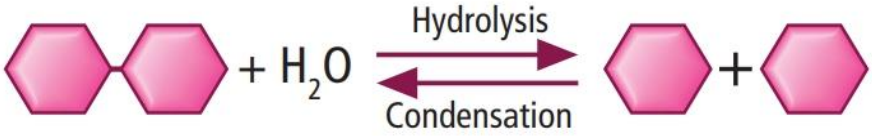
Plant mineral	**Source**	**Function**	**Deficiency in plant**
Calcium	Soil	Component of middle lamella	No growth
Magnesium	Soil	Component of chlorophyll	No growth

Water

Water is vital to life as we know it…

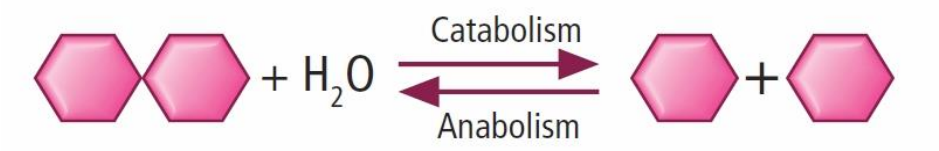
- It makes up 70 – 95% of cell mass
- It is an excellent solvent in which all biochemical reactions occur
- It participates in chemical reactions – e.g. photosynthesis, respiration and digestion

- Transports substances around the body of animals and plants
- Carries substances into and out of cells
- Good absorber of heat energy



Anabolism and Catabolism

- Anabolism is the building up of large biomolecules from smaller molecules using energy, e.g. photosynthesis and protein synthesis
- Catabolism is the breaking down of large biomolecules into smaller molecules with the release of energy, e.g. respiration and digestion



Mandatory activities: to conduct qualitative tests for:

A: Test for starch

Equipment:

- Starch powder
- Bread
- Potato
- Banana

Method:

- Prepare a starch solution and add three drops of iodine
- Add three drops of iodine to each of the bread, potato and banana
- Observe any changes

Testing a potato for starch

Result:

- A colour change occurs: yellow-red to blue-black

Conclusion:

- Bread, potato and banana are foods containing starch

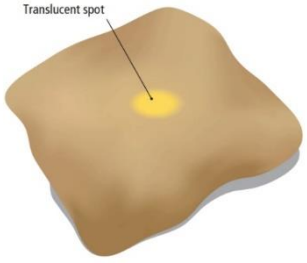
B: Test for fat

Equipment:

- Sunflower oil
- Butter
- Milk (full-fat)
- Orange juice

Method:

- Rub the foods into brown paper
- Add a few drops of water to a piece of brown paper (control)
- Allow the papers to dry on a radiator
- Observe any changes



Result:

- The pieces of brown paper containing oil, butter and milk each have a translucent spot
- The brown paper with the orange juice and water did not have a translucent spot

Conclusion:

- Sunflower oil, butter and milk contain fat
- Orange juice and water do not contain fat

C: Test for a reducing sugar

Equipment:

- Benedict's solution
- Bunsen/hotplate
- Glucose powder
- Orange juice
- Cranberry juice

Method:

- Prepare a glucose solution
- Add 1 ml of the glucose solution and 1 ml of each of orange juice, cranberry juice, and water (control) to test tubes
- Add 1 ml Benedict's solution to each test tube
- Heat all test tubes in a beaker of hot water
- Observe any changes

Result:

- A colour change occurs: blue to orange/brick-red

Conclusion:

- Orange juice and cranberry juice contain a reducing sugar

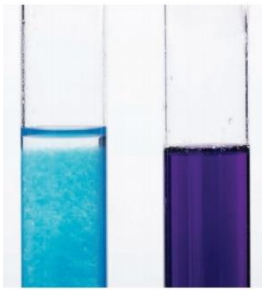
D: Test for a protein

Equipment:

- Sodium hydroxide solution
- Copper sulphate solution
- Egg white/albumin powder
- Milk

Method:

- Prepare diluted solutions of egg white and milk
- Add a few drops of sodium hydroxide to each test tube followed by a few drops of copper sulphate solution
- Observe any changes



Colour change associated with Biuret test

Result:

- A colour change occurs: blue to violet

Conclusion:

- Milk and egg white contain protein

CHAPTER 4: ECOLOGY

Definitions:

- **Ecology is the study of the interactions between organisms and between organisms and their environment**
- **An ecosystem is a group of clearly distinguished organisms that interact with their environment as a unit**
- **The biosphere is that part of the planet in which living organisms can be found**
- **A habitat is the place where a plant or animal lives**
- **A population is all the members of the same species living in the habitat**
- **A community is all the different populations of species living in the habitat**

Environmental Factors (Terrestrial)

- Abiotic factors: non-living factors, e.g. aspect: north-facing slopes are cooler and darker than south facing slopes (in Northern hemisphere only)
- Biotic factors: living factors, e.g. available food: more food will enable more organisms to survive
- Climatic factors: effects of weather, e.g. rain: more rain means more water, which supports more life
- Edaphic factors: effects of soil, e.g. soil pH: pH affects growth of particular plants as pH affects enzyme action (see Chapter 9: Enzymes)

Environmental Factors (Aquatic)

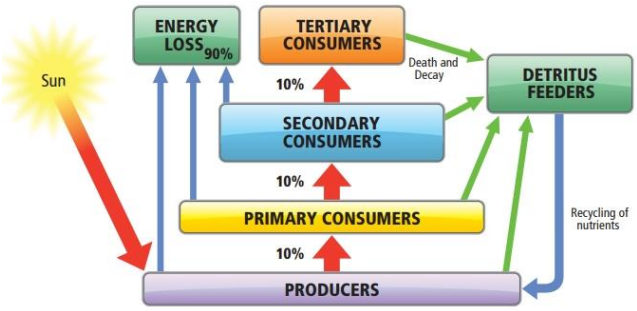
- Light
- Currents
- Wave action
- Salt content
- Oxygen concentration

Energy Flow

- Sun: ultimate source of energy
- Feeding allows 'energy flow' from organism(s) to organism(s)
- Producers: photosynthetic organisms that make their own food
- Consumers: organisms that obtain their food from other organisms
    1. **Primary consumers**: feed on producers (herbivores; decomposers; detritus feeders; omnivores)
        - Herbivore: animals that feeds on plant material only
    2. **Secondary consumers**: feed on primary consumers (carnivores; scavengers; omnivores)
        - Omnivore: animals that feed on both plants and animals
        - Carnivore: animal that feeds on other animals only
    3. **Tertiary consumers**: feed on secondary consumers (carnivores; scavengers; omnivores)

Energy is passed from one trophic level to another.

- Food chains tend to be limited to four or five organisms due to a **large** amount of energy being lost as it is transferred up the food chain.
- Only a small amount is transferred from one organism to the next due to a large amount being lost as heat and energy being used up in respiration.

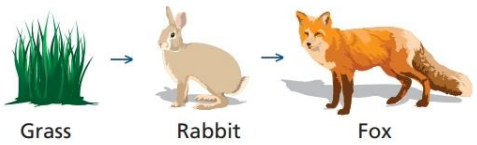


Food Chain:

A **grazing food chain** is a sequence of organisms in which each one is eaten by the next member in the chain

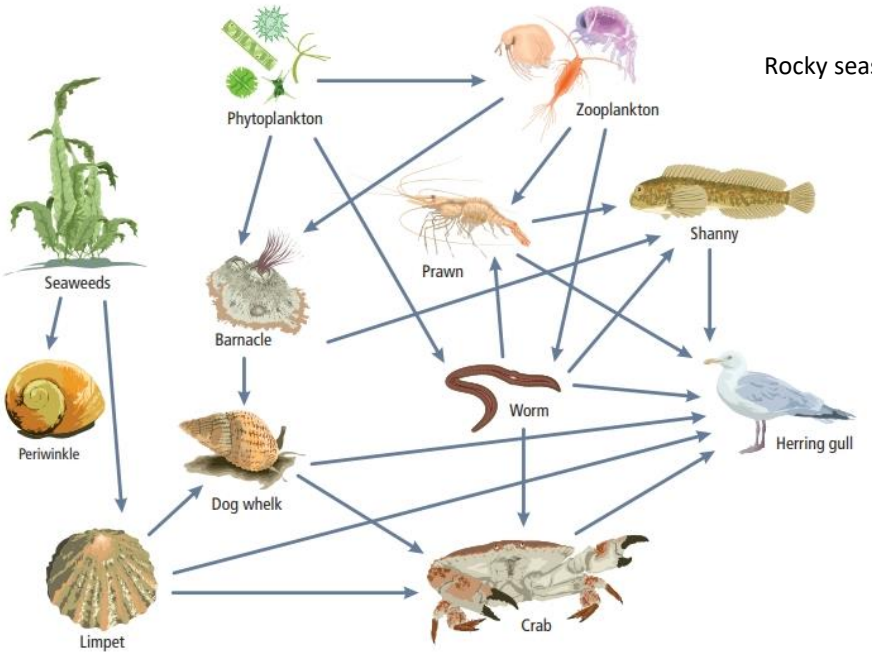
Examples of food chains:

- Leaf → Caterpillar → Thrush → Falcon
- Grass → Rabbit → Fox
- Algae → Limpet → Starfish→ Gull
- Plankton → Barnacle → Whelk → Crab

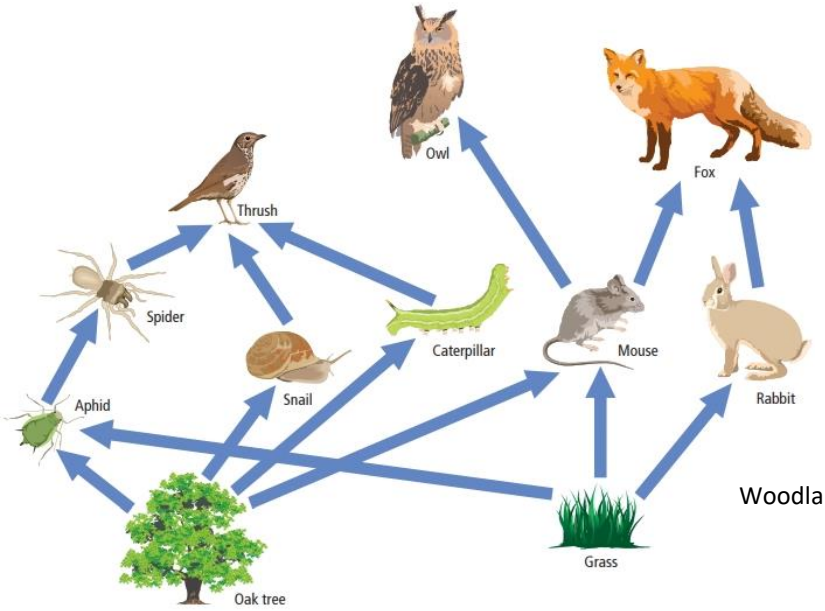


Food web:

A **food web** consists of two or more interlinked food chains.



Rocky seashore food web



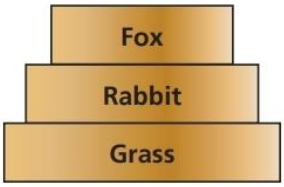
Woodland food web

Pyramids of numbers:

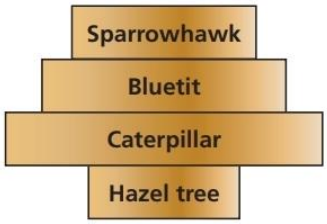
A **pyramid of numbers** shows the no. of organisms at each stage in a food chain

Ecological pyramids are ways of comparing different communities of the ecosystem in order of different trophic levels. There are three general types:

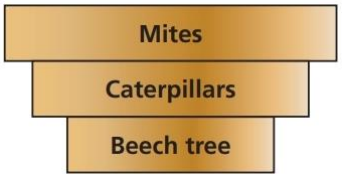
- Upright pyramids of numbers: the numbers of organisms at each trophic level decreases. (Organism's body size usually (but not always) increases as you go up the pyramid)
- Partially upright pyramids of numbers: the number of organisms at the beginning of the chain (producers) is very small when compared to the trophic levels that follow.
- Inverted pyramids of numbers: the numbers of organisms at each trophic level increase



Upright pyramid of numbers



Partially upright pyramid of numbers



Inverted pyramid of numbers

Limitations of the use of pyramids of numbers:

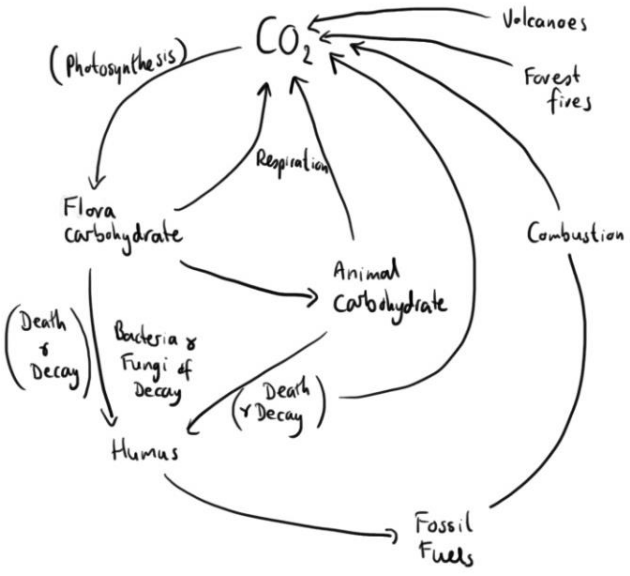
- Pyramid of numbers does not take into account the actual numbers of organisms involved
- Pyramid of numbers cannot be drawn to scale
- Some are not technically pyramids – they are inverted

Niche:

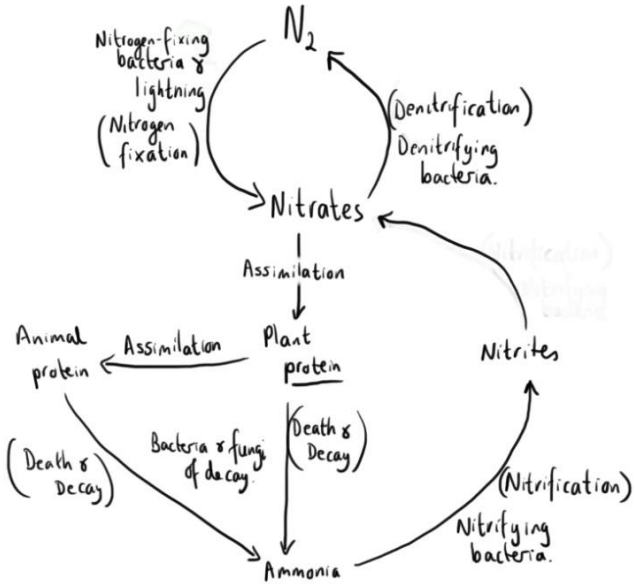
A **niche** is the functional role an organism plays in a particular habitat, e.g fox's role is to keep numbers of rabbits and hares down.

Nutrient recycling: the way in which elements (such as carbon and nitrogen) are exchanged between living and non-living components of an ecosystem

The Carbon Cycle:



The Nitrogen Cycle:



Human Impact on Ecosystem:

Pollution: is any harmful addition to the environment

1. *Domestic pollution*: e.g. carbon dioxide
   Harmful effect: can cause global warming
   Control measure: change to renewable forms of energy; e.g. solar panels
2. *Agricultural pollution*: e.g. fertilisers
   Harmful effect: can cause eutrophication (algal blooms) of rivers/lakes
   Control measure: only spread fertiliser during dry weather
3. *Industrial pollution*: e.g. sulphur dioxide
   Harmful effect: can contribute to acidic rain
   Control measure: use sulphur-free fuels OR change to renewable forms of energy; e.g. use electric vehicles

Conservation: is the management of the environment

1. **Agriculture**:
   - Storing slurry in leak-proof pits
   - Only spread slurry on land in summer
   - Do not spread fertilisers or spray insecticides in wet conditions
   - Growing of organic crops and livestock
2. **Fisheries**:
   - Analysing water samples
   - Fishing quotas
   - Monitoring of fish stocks
   - Mesh sizes of nets are large to allow younger fish to escape
3. **Forestry**:
   - Tops of trees and branches are not wasted – they are converted to sawdust and then to MDF
   - Felled trees are replaced with young trees for the future
   - Effective and rapid action plans for forest fires

Waste Management:

Problems associated with waste disposal:

- Disease-causing micro-organisms are present and can be harmful
- Toxic/harmful chemicals are present and can be harmful
- Nutrient elements: P and N can cause eutrophication of rivers and lakes
- Landfill sites are unsightly and attract vermin/scavengers
- Dumping waste at sea leads to pollution and harms sea life.
- Incineration can release toxic chemicals which are harmful to the breathing system.

In general, wastes can be minimised by employing the three R's:

- **Reduce**: do not buy foods that use excess packaging
- **Reuse**: household objects can be reused – for example ice cream tubs, glass bottles, etc.
- **Recycle**: many materials used can be recycled, such as glass bottles, paper, plastics, metals, and organic waste

Waste Minimisation:

- **Agriculture**: Slurry (eutrophication) is stored in leak-proof pits and only spread on land when it is dry
- **Fisheries**: Waste parts of fish are pulped, dried, and recycled as fertiliser and/or pig feed on farms
- **Forestry**: Waste pieces of trees are processed into chip board, MDF board, etc.

Role of Micro-organisms in Waste Management and Pollution Control:

- Landfill sites: Bacteria break down the organic waste
- Sewage: Small amounts of sewage are treated naturally by bacteria in water; large amounts of sewage have to be treated by sewage-treatment plants (also involves bacteria)

Sewage Treatment:

Sewage can cause eutrophication of lakes and rivers if released directly into them – this causes fish kills. Therefore sewage must be treated. Sewage generally goes through three stages of treatment:

1. Primary
2. Secondary
3. Tertiary

1. Primary Sewage Treatment

- Physical method: Screening objects by flowing sewage through metals grills
- Sedimentation of sewage where it is stored in tanks and smaller particles such as grit settle out at the bottom producing sludge which is removed.

2. Secondary Sewage Treatment

- Biological method: Bacteria and fungi are added to the water and sludge: organic matter in sludge and waste water is broken down with the production of methane gas, carbon dioxide and water
- Chlorination: at the end of the biological process the waste water is usually treated with chlorine to destroy any remaining micro-organisms

3. Tertiary Sewage Treatment

- Chemical method: Removal of minerals by addition of chemicals that cause the minerals to precipitate out of the waste water

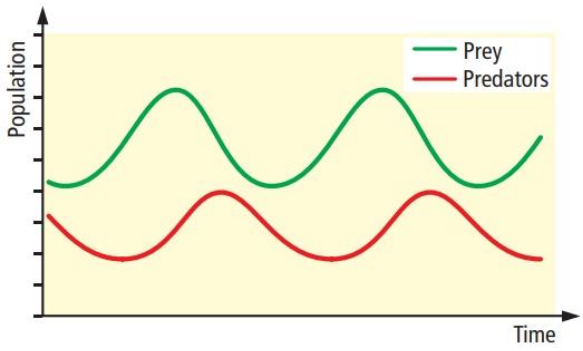
Ecological Relationships

a) Competition
b) Predation
c) Parasitism
d) Symbiosis

a) **Competition** struggle for a resource that is in short supply
   - *Contest competition*: physical struggle between two organisms with one organism obtaining all of the resource
   - *Scramble competition*: struggle between a number of organisms with all the organisms obtaining a small amount of the resource
   - Competition limits the size of a population of organisms.
   - Adaptation occurs to reduce competition; e.g. caterpillar eats cabbage; butterfly eats nectar

b) **Predation**: catching, killing, and eating of another organism, e.g. snake is predator and a mouse is its prey.

Predator-prey relationship over time:



Factors that affect predator-prey relationships

- Availability of food
- Concealment/ camouflage
- Movement (speed)

c) **Parasitism:** one organism (the parasite lives in or on another organism (called the host) and the host is harmed; e.g. Athlete's foot; Ringworm

d) **Symbiosis** occurs when two organisms of different species live in close association and at least one of them benefits, e.g. bacteria in human digestive system produce vitamin K and get food and a safe environment in return

Population Dynamics:

Factors that affect the human population:

- Disease – reduces numbers
- Famine – reduces numbers
- War – reduces numbers
- Contraception – reduces numbers
- Access to good healthcare – maintains and can increase numbers
- Access to a good education – maintains/increases numbers

CHAPTER 5: STUDY OF AN ECOSYSTEM

Broad Overview of a Selected Ecosystem

Suitable ecosystems include:

- Hedgerow
- Stream
- Rock pool
- Rocky seashore
- Old wall
- Small woodland
- Small meadow
- Freshwater pond
- Waste land
- An overgrown garden
- Soil
- Peatland
- Grassland

Practical Activity: Select and visit one ecosystem, e.g. woodland

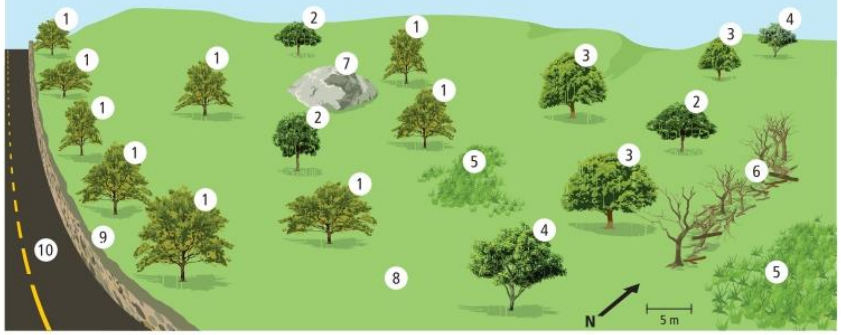
Physical properties:

- Presence of large mature trees with some areas of grassland and the presence of a large rock
- It is close to a main road
- Provides a home to main species of animals
- There is a large gradient in the ecosystem

General presence of life:

- Flora: many trees and shrubs, plants, and grasses
- Fauna: herbivores, birds and predators

Map of a woodland with a key rocky seashore food web



Legend:

1. Ash
2. Horse chestnut
3. Oak
4. Sycamore
5. Nettles
6. Deadwood
7. Large rock
8. Grass
9. Stone wall
10. Road

Practical Activity: Observation and Scientific Study of a Selected Ecosystem

Identify any five fauna and any five flora using simple keys:

Flora:

- Hawthorn
- Blackthorn
- Gorse
- Blackberry bramble
- Fuschia
- Holly
- Rowan (Mountain ash)
- Ash saplings
- Hazel
- Willow

Fauna:

- Beetles
- Butterflies
- Hoverflies
- Snails
- Ladybirds
- Hare
- Foxes
- Badgers
- Hedgehog
- Mice

Identify a variety of habitats within the selected ecosystem

There are a number of habitats in the selected ecosystem of the woodland and different organisms are found in each of the habitats.:

- Soil
- Leaf litter
- Shrub level
- Canopy level

Ecology Apparatus

Identify & use various apparatus for collection methods in an ecological study

- Mammal trap
- Pitfall trap
- Cryptozoic trap
- Beating tray
- Pooter
- Nets (sweep/insect net, plankton net or fish net)
- Direct search
- Tullgren funnel

Traps:

Mammal trap

- Bait attracts small mammals into box
- Once they enter the trap door prevents exit
- Bedding provides comfort

Pitfall trap

- Involves simple metal can or plastic cup embedded in the ground and covered to prevent water entering
- Bait is sometimes used

Cryptozoic trap

- Shelter trap involving a piece of old wood, a log, or a large stone
- Small animals like slugs and woodlice hide under a cryptozoic trap during periods of inactivity

Beating tray

- A large sheet/plastic tray held under a tree or bush
- The tree or bush is shaken gently
- Insects fall onto tray and can be identified

Pooter

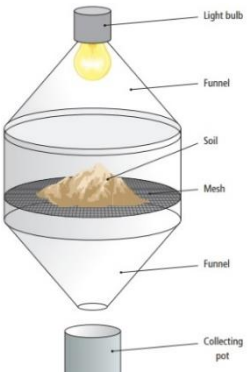
- Device ecologists use to pick up small organisms, like insects
- Suck in the tube with the gauze on the end and place the other tube over the insect to be captured.

Sweep nets, insect nets, plankton nets

- Sweep nets are used to capture small insects and other small animals
- Plankton nets are used in aquatic environments and collect plankton by being dragged through the water.

Tullgren funnel

- Used to extract organisms from soil samples.
- A soil sample is placed in the removable upper part of the funnel.
- Heat and light from the lamp creates a temperature gradient of approximately 14°C in the soil sample.
- This causes the downward movement of soil arthropods through the gauze to a receiver attached to the base of the funnel



Organism Distribution

Two ways in which organism distribution is determined:

1. Qualitative survey – record the presence or absence of a species in a habitat.
2. Quantitative survey – record the number of organisms of a species in a habitat.

Quantitative Surveys

- Count the number of organisms of a species in a habitat
- Ecological apparatus used depends on the species; e.g. mammal traps for fast moving animals such as mammals; sweep nets for insects; pitfall traps for beetles; cryptozoic traps for worms and woodlice; quadrats for small plants.

Quantitative survey of plants/flora:

- Plants and flora can be quantified using quadrats, belt transects or line transects

Quadrats:

- Quadrats can be used to quantify plants/flora and slow-moving animals (e.g. shellfish on the rocky seashore).
- Quadrats can be plastic, wooden or metal square frames of various sizes e.g. 1, 0.5, or 0.25 metres squared.
- Quadrats can be graduated (sub-divided into smaller squares) or a basic quadrat.
- Disadvantages of using quadrats is that they cannot be used to quantify trees or large bushes or fast-moving animals.
- Quadrats are always placed randomly in habitat by throwing a pencil over your shoulder and placing the quadrat where the pencil landed.
- Two possible types of measurement can be taken with a quadrat:
    1. Percentage frequency
    2. Percentage cover

Percentage frequency:

Percentage frequency: chance of finding a named species with any one throw of the quadrat.

- A basic quadrat is placed randomly within the habitat (as described previously).
- The presence or absence of a named species is noted.
- This is repeated at least 5 times for each species.
- A table of results is drawn up as shown.

Plant species	1	2	3	4	5	% Frequency
Grass	✓	✓	✓	✓	✓	100
Dock leaf		✓				20
Lesser celandine			✓		✓	40
Thistle	✓		✓			40
Dandelion		✓	✓	✓		60

% frequency table

Percentage cover:

Percentage cover: area of the ground covered by the aerial parts of the plant.

- A graduated quadrat is randomly placed within the habitat.
- If the graduated quadrat has 25 squares, each individual square represents 4% of the entire quadrat.
- The area of each square a species covers is estimated. In this way, it is subjective (individual's own opinion) and can be a very inaccurate method.
- The totals from each square is totalled to come up with a percentage cover value for each species.

Plant species	1	2	3	4	5	% Cover
Grass	80	75	90	69	92	81.2
Dock leaf	14	21	18	20	16	17.8
Lesser celandine	0	0	4	2	0	1.2
Thistle	0	2	11	0	0	2.6
Dandelion	6	0	2	9	4	4.2

% cover table

Transects:

- There are two types: belt transects and line transects.
- Transects are useful for studying numbers of plants/flora or slow-moving animals that vary due to the slope of the land, e.g. rocky seashore.

Belt transects:

- Set up using two long ropes marked off at regular intervals (e.g. 1m/ 2m/ 5m etc) or one long rope and a graduated quadrat.
- If using the two ropes the number of each species is counted at each interval and recorded.
- If using the rope and the quadrat, the number of organisms of each species is counted in the usual way (see "quadrats" above).

Belt transect using a rope and a graduated quadrat

Line transects:

- Set up using a long rope/string marked off at regular intervals (e.g. 1m)
- Useful for quantifying species along a gradient.
- Carried out by recording the presence/absence of a particular species at each interval.
- Repeated at different locations.
- They have the advantage that they can include and quantify trees (unlike quadrat studies).

A line transect

Quantitative survey of animals/fauna:

- Slow-moving animals such as barnacles/limpets can be quantified using quadrats in the same way plants are quantified.
- Most animals are fast-moving and are quantified by the **capture-recapture technique**.

Capture-recapture technique:

- Animals are caught using one of the methods listed earlier – e.g. mammal traps.
- It is easiest to use the recapture-technique on easily-caught animals, e.g. snails.
- Snails live in long grass, bushes/shrubs and in trees.
- Search for snails in the habitat and mark each one with a small inconspicuous tippex mark (so as to not make visible to predators) on the side of their shell.
- Record the total number found and marked.
- Place the snails back in the same position.
- Approximately one week later, return and search for snails again, taking note of the total number found and the total number of these snails that had the mark.
- Use the formula below to estimate the number of snails in the habitat:

Sources of error in studying an ecosystem:

- Miscalculation – e.g. when estimating percentage frequency
- Misidentification – e.g. species not identified correctly
- Sample size too small

$$\text{Number of snails} = \frac{(Caught\ 1st) x (Caught\ 2nd)}{(Marked\ 2nd)}$$

NOTE

'Caught 1st' refers to the number of snails caught on the first visit.

'Caught 2nd' is the number of snails caught on the second visit.

'Marked 2nd' is the number of marked snails found on the second visit.

Study the effects of abiotic factors on the suitability of an organism to its habitat

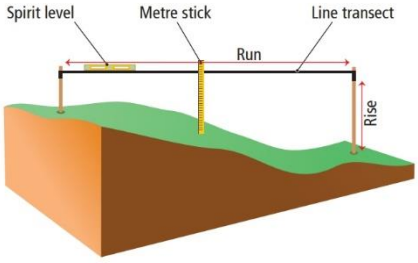
An **abiotic factor** is a non-living, environmental condition that affects living organisms in a habitat.

Example of abiotic factors:

- Soil/water pH level
- Soil/water/air temperature
- Light intensity
- Water current speed/direction
- Wind speed/direction
- Soil/water/air oxygen levels
- Soil/water mineral content
- Percentage humus content
- Water salinity
- Degree of exposure
- Aspect
- Slope

Examples of instruments used to measure abiotic factors:

- pH levels are measured using a pH meter
- Air temperature is measured using a thermometer
- Light intensity is measured using a light meter
- Water current speed/direction is measured using a water flow meter
- Wind speed/direction is measured using an anemometer
- Aspect is measured using a compass
- Slope is measured using a tape measure and a spirit level



Measuring slope

An anemometer

A light meter

Then describe how each of the three factors you chose affects living organisms in your choice of habitat; e.g. Ferns only grow under the shade of large trees; moss requires a large moisture content to live/survive; broad-leaved trees cannot survive at high altitude or on ground with a very steep slope.

Identifying Organism Adaptations

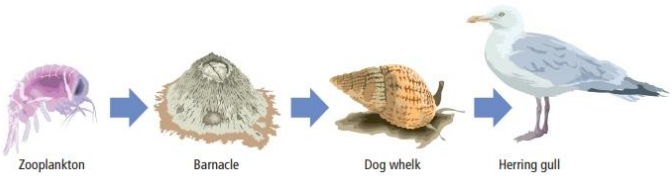
- Adaptations are necessary for an organism to survive new conditions
- Adaptations may be structural, competitive, or behavioural
- Describe **ONE** adaptation of an organism you studied in your habitat
  - Snail has a protective shell
  - Ladybird has a red covering to warn birds that it is poisonous to eat
  - Blackthorn has thorns to protect its fruits
  - Bladder wrack seaweed has vesicles full of air so that the fronds of the seaweed float in the water increasing levels of photosynthesis.

Identifying Organisms' Role in Energy Transfer

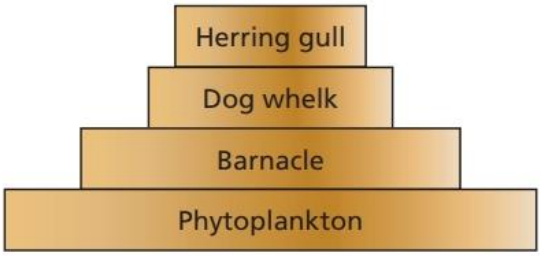
- Identify where each organism in your habitat is located in the food chain/web
- From the data collected on your field trip construct a food chain, food web, and pyramid of numbers

Analysis

- Learn to analyse, assess, and discuss your results and conclusions
- Is there any relationship between the results and conclusions of your study and local ecological issues
- Prepare a portfolio/report/project (no less than 1,000 words, no more than 2,500 words)

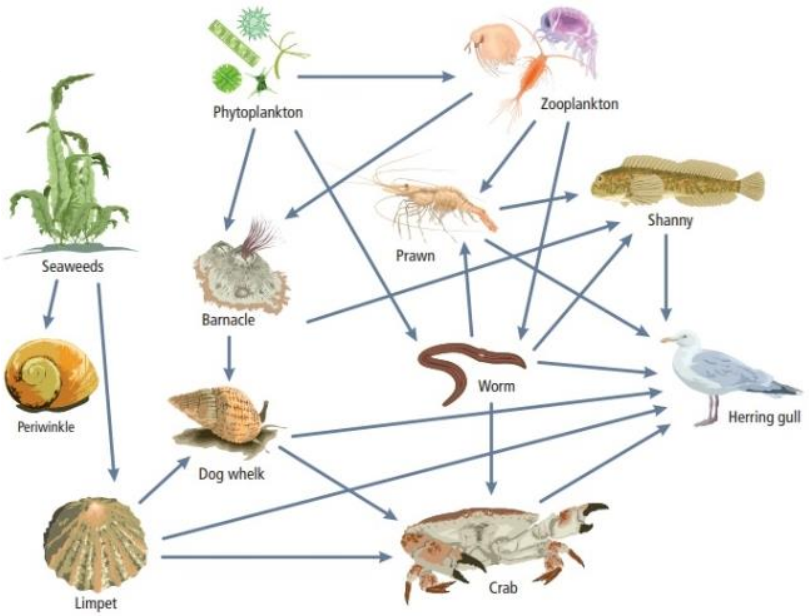


A rocky seashore food chain

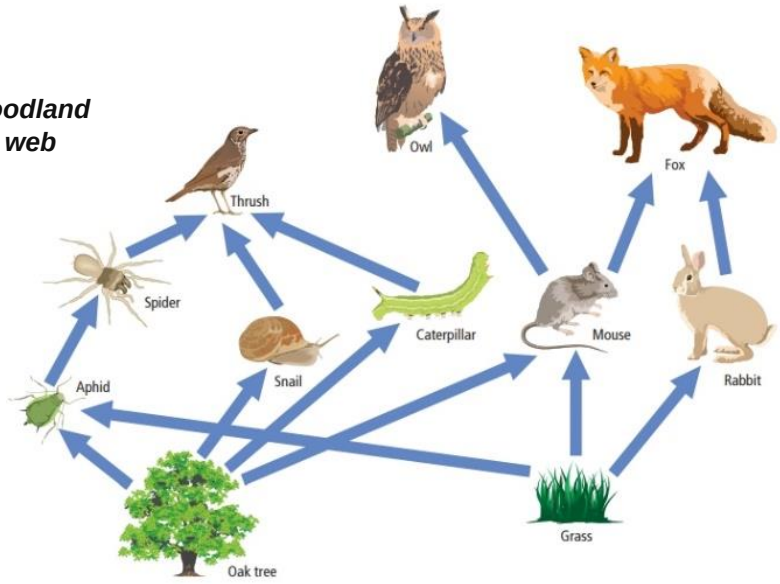


A rocky seashore pyramid of numbers

A rocky seashore food web



A woodland food web



UNIT 2: THE CELL

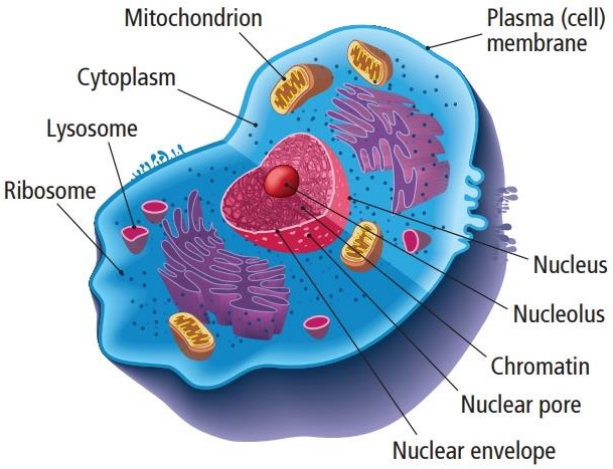
CHAPTER 6: THE CELL

Cells are the basic functional unit of all life.

Ultrastructure of cells:

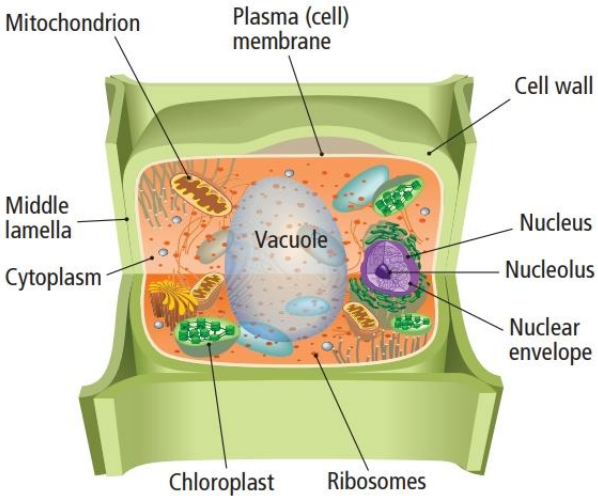
Animal cell:
The typical animal cell is shown in the diagram below.
Important structures inside the typical animal cell include:

- Cell membrane – controls what substances enter and leave the cell
- Cytosol – medium in which all metabolic reactions occur
- Nucleus – controls all activities of the cell
- Nucleolus – makes RNA
- Mitochondrion – carries out the reactions of respiration
- Lysosome – destroys old, worn out cell organelles
- Ribosome – makes proteins



Plant cell:
The typical plant cell is shown in the diagram below.
Important structures inside the typical plant cell include:

- Cell membrane – controls what substances enter and leave the cell
- Cell wall – gives shape and support to the plant cell
- Cytosol – medium in which all metabolic reactions occur
- Nucleus – controls all activities of the cell
- Nucleolus – makes RNA
- Mitochondrion – carries out the reactions of respiration
- Chloroplast – carries out the reactions of photosynthesis
- Large central vacuole – stores food, water, minerals, vitamins, and wastes
- Lysosome – destroys old, worn out cell organelles
- Ribosome – makes protein

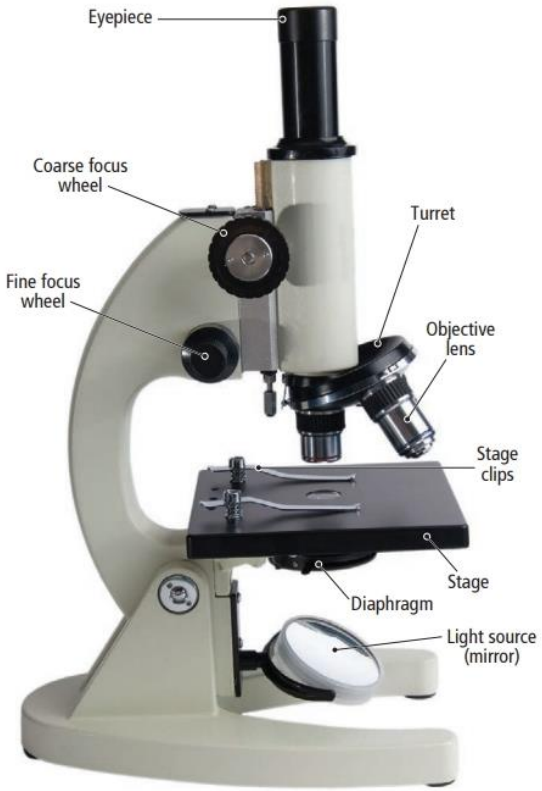


The Microscope

- A microscope is used to view very small living organisms and cells
- You must be familiar with and know how to use a light microscope

Two types of microscope you need to know:

- *Light (compound) microscope*: uses visible light, two or more lenses, and a specimen – usually stained to make structures more visible
- *Electron microscope*: uses a beam of electrons (e^-), a number of electromagnetic lenses (that focus and diverge the beam of e^-), a piece of photographic film (like X-ray film), and a specimen



Parts of the light microscope and their functions:

- Eyepiece lens: magnifies the image; closest to the observer's eye
- Objective lens: magnifies the image; closest to the specimen
- Stage: holds the specimen (slide)
- Diaphragm: controls the amount of light shining through specimen
- Light source/mirror: sends light up through the stage and specimen
- Fine/coarse focus wheels: make fine/large adjustments to the clarity of the image

Using a Light Microscope

1. Ensure low-power lens (4X) is in position before placing specimen on stage
2. Separate stage and objective as much as possible using coarse wheel before placing specimen on stage

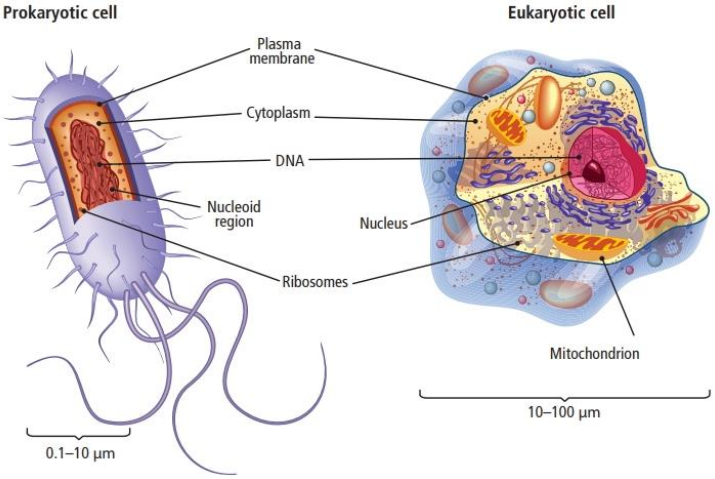
3. Adjust mirror or turn on light underneath stage
4. Ensure diaphragm is fully open to allow light pass through
5. Place specimen slide on stage so that specimen is directly above hole in stage
6. Bring 4X close to specimen – it is easier and safer to do initial focusing using low-power and coarse focus
7. Looking through eyepiece bring image into focus by turning the coarse and fine focus wheels towards you slowly
8. Adjust diaphragm if necessary during focusing as image may be too bright to view specimen
9. Once in focus, move slide around gently on stage to see different fields of view
10. Change the objective to the 10X lens
11. Draw a sketch of the field of view
12. Change the objective to the 40X lens carefully as this lens may hit the slide and cause damage
13. Refocus using fine focus wheel
14. Draw a sketch of the field of view
15. Once finished move the 4X lens back to the main position – only then remove slide

The Electron Microscope

- Uses a beam of electrons to view specimens.
- Produces magnifications of up to 1,000,000X.

Prokaryotic and Eukaryotic Cells

- Prokaryotic cells have a tough outer cell wall and have no membrane-bound nucleus nor membrane-bound organelles
- Eukaryotic cells have a membrane-bound nucleus and organelles



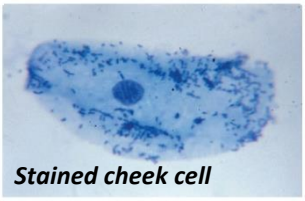
Mandatory Experiment: to view animal and plant cells, stained and unstained, using the light microscope at 100X and 400X

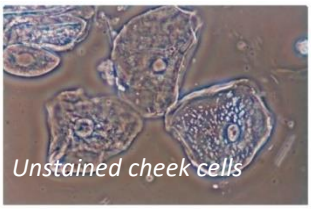
Equipment:

- Cotton wool buds (to obtain human cheek cells)
- Onion
- Microscope slides
- Coverslips
- Methylene blue (for animal cells)
- Iodine (for plant cells)
- Mounted needle
- Tissue
- Water
- Light microscope

Method for viewing animal cells (human cheek cells):

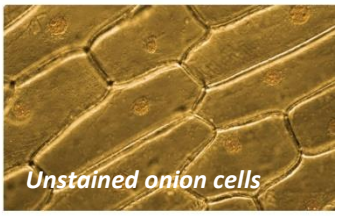
1. Using a cotton wool bud, rub the inside of mouth and smear onto a glass slide.
2. Place a drop of methylene blue on the smear and allow to soak in for 5 min.
3. Blot off excess stain from the edge and add a drop of water to smear.
4. Lower coverslip slowly from a 45º angle to avoid trapping air bubbles.
5. View slide under the microscope at 40X, focus using the coarse focus wheel.
6. View the cells under higher powers by focusing using the fine focus wheel
7. Sketch the visible fields of views at 100X and 400X.

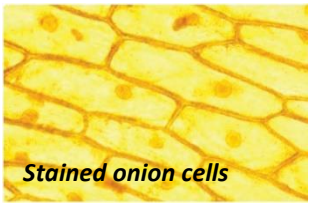




Method for viewing plant cells (onion):

1. Cut onion and remove a single layer of cells and place on glass slide.
2. Add a few drops of iodine onto the onion tissue and allow to soak in for 5 min.
3. Blot off excess stain from the edge and add a drop of water to onion tissue.
4. Lower coverslip slowly from a 45º angle to avoid trapping air bubbles.
5. View under the microscope at 40X, focus using the coarse focus wheel.
6. View the cells under higher powers by focusing using the fine focus wheel.
7. Sketch the visible fields of views at 100X and 400X.





CHAPTER 7: DIVERSITY OF CELLS

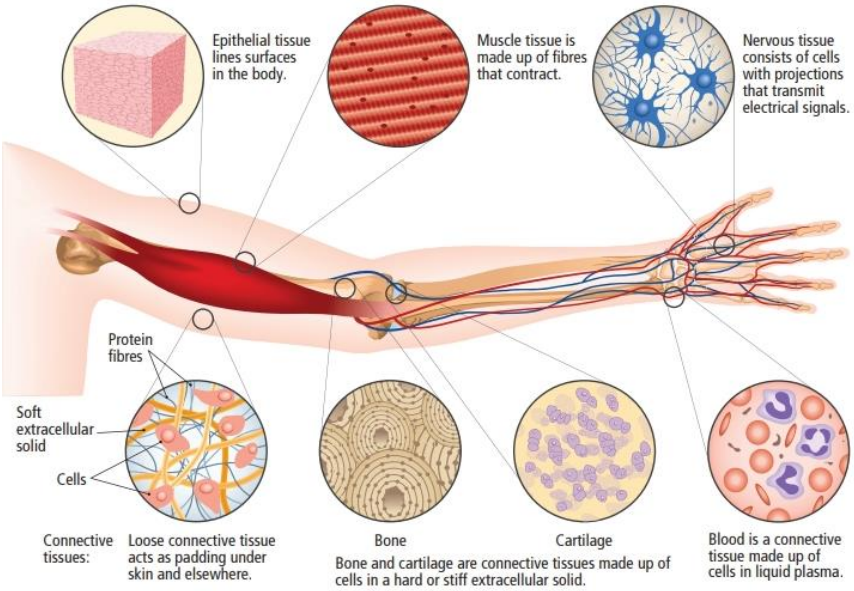
Tissue:

Tissue: a group of similar cells with a shared function

Animal tissues

There are four main categories of animal tissue:

- **Epithelial tissue**: adapted by being closely packed layer of cells covering the outside of the body and on internal organs and cavities within body – functions in protection, absorbing, and/or secretion depending on location, e.g. skin, kidney and gland tubules, blood vessels (capillaries, arteries, veins) and mucous membranes.
- **Connective tissue**: sparsely located cells adapted to secrete a flexible matrix (e.g. collagen fibres) and functions in binding together and supporting other tissues, e.g. blood, cartilage, adipose, bone, tendons and ligaments.
- **Muscular tissue**: adapted by being contractile cells (muscle fibre) capable of generating movement – e.g. movement of limbs (striated muscle); food in the digestive system (smooth muscle) and moving blood (cardiac muscle).
- **Nervous tissue**: excitable cells adapted by being able to generate their own electrical impulses. Nervous tissue is composed of neurons consisting of a cell body, dendrites and axons. They function in sensing stimuli and transmitting signals from one part of the body to the other.



Plant tissues

There are four main categories of plant tissue:

- **Meristematic tissue**: rapidly divides by mitosis to give rise to growth.
- **Dermal tissue**: covering layer of tissue – functions in protection.
- **Vascular tissue**: functions in transport of substances around the plant. There are two types of vascular tissue:
  1. Xylem (transports water & minerals)
  2. Phloem (transports glucose and amino acids)
- **Ground tissue**: makes up the bulk of plants – functions in photosynthesis, storage and support.

Organs:

Organ: group of tissues that carry out a particular function

- Examples of animal organs: heart; lungs; kidneys
- Examples of plant organs: leaf; flower; stem

Organ systems:

Organ system: group of organs that carry out a number of linked functions

- Examples of animal organ systems: circulatory system
- Examples of plant organ system: root system

Tissue culture:

Tissue culture: the growth of cells in a nutrient medium outside a living organism

Applications of tissue culture:

It is possible to grow individual cells or groups of living cells (tissues) in artificial (in vitro), sterile growth medium, such as growing skin grafts. The growth medium contains a large mixture of many nutrients – including glucose, amino acids, hormones, minerals, vitamins, and antibiotics to prevent micro-organisms taking hold. Tissue culture is also used in cancer research and vaccine production and is artificial vegetative propagation of plants.

CHAPTER 8: MOVEMENT THROUGH CELL MEMBRANES

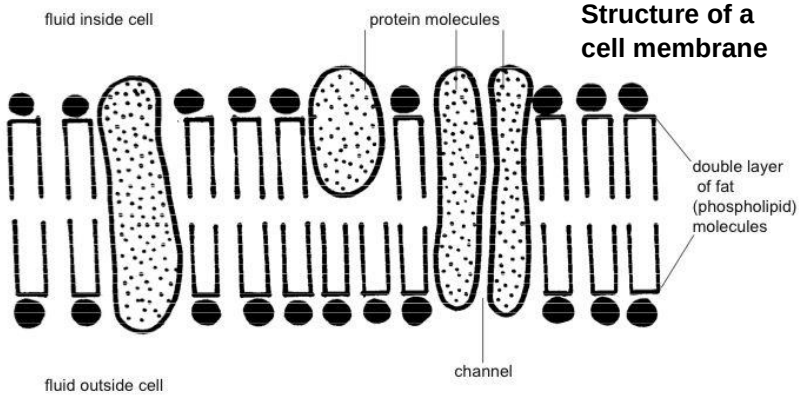
Selective Permeability

- Selectively permeability refers to the cell membrane controlling what substances enter and leave the cell. Selective permeability is controlled by proteins embedded in the cell membrane.

Diffusion

- Diffusion is the movement of particles from a region of high concentration to a region of low concentration (i.e. down a concentration gradient)

An example of diffusion is in the movement of oxygen and carbon dioxide across the alveolar membranes from regions of relatively high concentration to regions of relatively low concentration. See Chapter 35.



Structure of a cell membrane

Osmosis

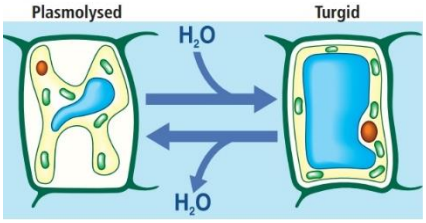
- Osmosis is the movement of water molecules from a region of high water concentration to a region of low water concentration across a semi-permeable membrane

An example of osmosis is in *Amoeba* where water is continuously moving into the cell by osmosis from the freshwater (high water concentration) to the interior of the cell (lower water concentration). See Chapter 22.

Application of Osmosis

Osmosis is used by food industry for preservation of food. Any microorganisms present will die due to water leaving the cells.

- Tinned fruits are placed in a concentrated sugar (syrup) solution
- Meats can be salted



Turgor, Plasmolysis and Crenation

- **Turgor** is the pressure exerted by the cells contents on the cell wall of a plant cell. The cell wall prevent it from bursting.
- **Plasmolysis** is the loss of water from a plant cell such that the cell membrane detaches from the cell wall.
- **Crenation** is the loss of water from an animal cell. It shrivels up.

A normal red blood cell (red) and a crenated blood cell (above)

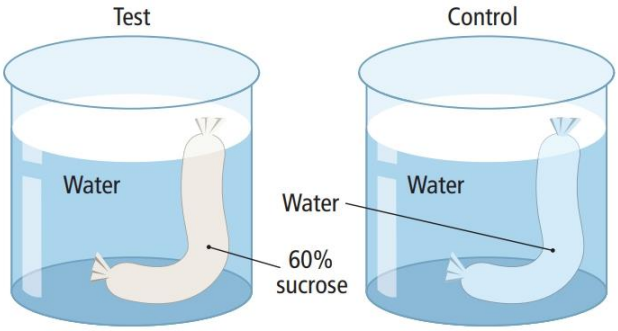
Mandatory Practical Activity: to demonstrate osmosis

Equipment:

- Visking tubing
- Water
- Syringe
- Sucrose
- Beaker

Method:

- Set up the equipment as shown in the diagram.
- Weigh each tubing and record.
- Leave the tubes sitting in water for at least 30 minutes or overnight.



Result:

- The mass of the control tubing remained the same.
- The mass of the test tubing increased.

Conclusion:

- The mass of the test tubing increased due to osmosis – movement of water across the Visking tubing membrane.
- Sucrose is a molecule that cannot pass through the Visking tubing membrane.

CHAPTER 9: ENZYMES

- **Metabolism** is the sum of all the chemical reactions in an organism

All energy in living organisms all came from the Sun.

- **Enzymes** are folded, globular-shaped protein catalysts that speed up reactions without being used up.

Examples of catabolic enzymes:
- Pepsin – digests proteins into peptides
- Amylase – digests starch into maltose
- Lipase – digests fats into fatty acids and glycerol

Examples of anabolic enzymes:
- Potato phosphorylase – makes starch from glucose
- DNA polymerase – makes DNA from its building blocks (nucleotides)

Active site theory of enzyme action

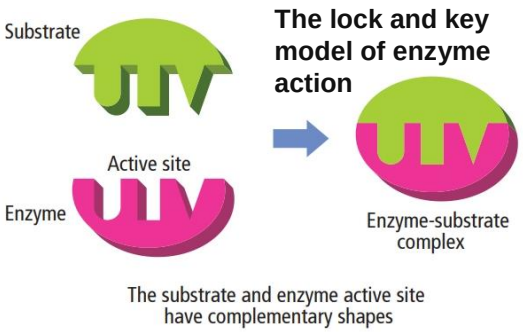
All enzymes have an **active site** where the enzyme combines with its **specific substrate.**

Definitions:
- **Active site:** area of the enzyme where substrate enters and is changed into product(s).
- **Specificity**: refers to the enzyme's ability to react with only one substrate.
- **Substrate**: substance upon which the enzyme acts.
- **Product**: substance that results from the action of an enzyme.

Active site theory involves two models of enzyme action:
1. *Lock and key model*
2. *Induced fit model*

Lock and Key Model

1. **Enzyme** has a rigid shape
2. The **substrate** enters the active site of the enzyme and fits snugly, much like a key fits in a lock
3. An **enzyme-substrate complex** is formed
4. Substrate is changed into product(s)
5. Product(s) exit the active site

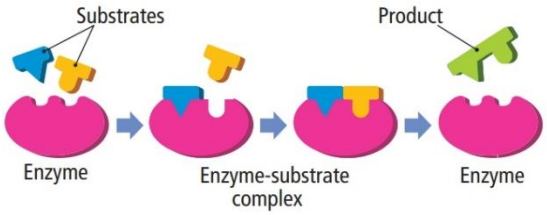


The lock and key model of enzyme action

The substrate and enzyme active site have complementary shapes

Induced Fit Model

1. **Substrate** enters active site
2. The enzyme changes its shape slightly to accept substrate
3. An **enzyme-substrate complex** is formed
4. Substrate is changed into product(s)
5. Product(s) exit the active site and the enzyme returns to its original shape



The induced fit model of enzyme action

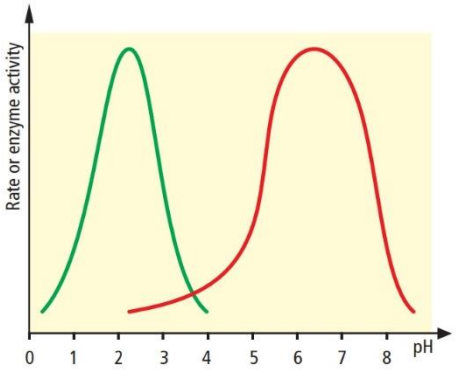
Factors affecting enzyme function

pH and temperature are two important environmental conditions that affect the rate at which enzymes act. All enzymes have an optimum pH and optimum temperature at which their activity is a maximum.

Optimum Activity of an Enzyme

- Optimum activity refers to the conditions under which an enzyme works best.

pH
- pH refers to the level of acidity or basicity of a liquid/solution.
- Enzymes are affected by pH because acids and bases can affect the shape of an enzyme.
- Most enzymes have a pH at which they work best, called the optimum pH.
- The optimum pH for most enzymes present in animals is pH 7.4.
- Some animal enzymes have an optimum pH of 2 (e.g. pepsin in the stomach).



Effect of pH on enzyme activity

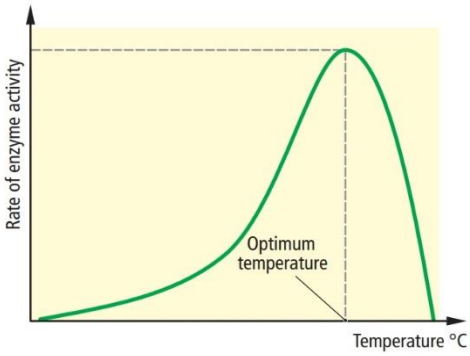
Temperature

- Environmental temperatures affect enzymes because very warm or hot temperatures can cause the enzyme to change shape.
- Cooler temperatures tend not to change the shape of enzymes – they just slow their activity.
- All enzymes have an optimum temperature – at which they work best.
- Most human enzymes work best at a temperature of 37 ºC.
- Plant enzymes work best between the temperatures of 10 – 30 ºC, depending on their natural habitat.

Heat Denaturation of Enzymes

- **Denaturation** involves a permanent change in the shape of an enzyme so that it does not act on its substrate

Enzymes can become denatured at high temperatures. For example, human enzymes will begin to denature at around 40 ºC. During infections the temperature of the human body can reach 42 ºC [the body's cells produce heat shock proteins which protect the folded shape of important enzymes].



Effect of temperature on enzyme activity

Bioprocessing

- **Bioprocessing** is the use of micro-organisms, or their components, such as enzymes to make useful products.

Bioprocessing occurs in bioreactors.

- A **bioreactor** is a vessel in which a product is formed by a cell or cell component, such as an enzyme.

Enzyme and substrate are placed in the bioreactor and the bioreactor is kept very carefully at the correct temperature and pH in order to achieve the maximum amount of product.
Examples of bioprocessing:

- Production of beer using yeast
- Production of insulin using genetically-modified E coli bacteria
- Production of cheese using the enzyme rennin
- Production of fructose from glucose using glucose isomerase

Bioprocessing with Immobilised Enzymes

- **Immobilised enzymes** are enzymes that are attached to or trapped in an inert insoluble material

Bioprocessing is carried out in bioreactors

- A **bioreactor** is a vessel in which a product is formed by a cell or cell component, such as an enzyme.

Immobilised enzyme and substrate are placed in the bioreactor and the bioreactor is kept very carefully at the correct temperature and pH in order to achieve the maximum amount of product
Three ways in which enzymes are immobilised:

1. Carrier-binding method: when the enzyme is attached to water-insoluble substances such as cellulose or agarose
2. Cross-linking method: when enzymes are attached together covalently using glutaraldehyde
3. Entrapment method: when the enzyme is trapped in a gel such as alginate

Uses of Immobilised Enzymes

- Immobilised lactase breaks down lactose in milk for lactose-intolerant people
- Immobilised rennin is used in the cheese-making process
- Immobilised glucose isomerase is used in sweet manufacture as fructose is sweeter than glucose

Advantages of Immobilised Enzymes
Immobilised enzymes have advantages over free enzyme (enzyme in solution):

- Easy recovery of product and enzyme at end of reaction
- Immobilised enzymes can be reused many times reducing costs to manufacturers

Bioprocessing is carried out using one of two general procedures:

1. Batch culture
2. Continuous-flow culture

Batch Culture

- A fixed amount of substrate is placed in bioreactor

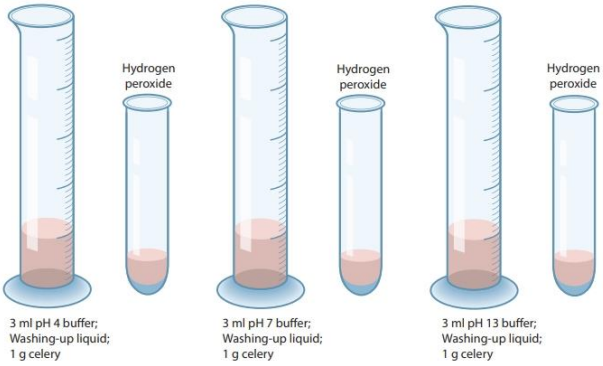
- Reaction and microorganisms are allowed to proceed through some or all of the stages of the microorganism growth curve (lag, log, stationary, decline phases)
- Product is collected at end of the reaction/process
- Bioreactor is then cleaned out for the next batch

Continuous-flow Culture
- Substrate is continually put into the bioreactor
- Reaction and microorganisms are maintained in the log phase of growth
- Product is continually collected

Mandatory Activity: to investigate effect of pH on enzyme action.

Equipment:
- Lab coat & safety goggles
- Graduated cylinders
- Celery
- Knife
- Hydrogen peroxide
- pH buffers 4, 7 and 13
- Washing up liquid
- Stopwatch
- Droppers
- Waterbath

Method:
- Three graduated cylinders with celery (catalase enzyme), pH buffer (4, 7, 13) and 1 drop washing-up liquid set up in 25˚C water bath.
- Hydrogen peroxide added to all three cylinders at the same time.
- Volumes in graduated cylinders noted at 0, 1, 2 and 3 min, if needed.
- Rate of enzyme action calculated by a simple subtraction of the difference in volume during one of the selected minutes.



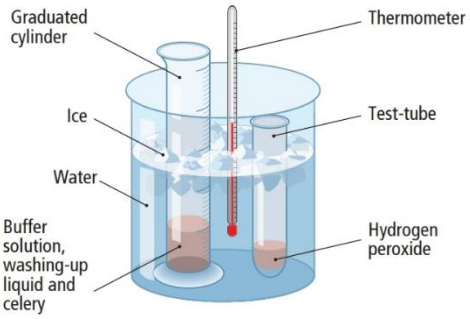
Result:
- pH 7 graduated cylinder showed the most enzyme action (greatest amount of bubbles/foam produced).

Conclusion:
- pH 7 is the optimum pH for catalase.

Mandatory Activity: to investigate effect of temperature on enzyme action.

Equipment:
- Lab coat & safety goggles
- Graduated cylinders
- Celery
- Knife
- Hydrogen peroxide
- pH buffer 7
- Washing up liquid
- Stopwatch
- Droppers
- Waterbaths (0 ˚C, 25 ˚C and 80 ˚C)

Method:
- Three graduated cylinders with celery (catalase enzyme), pH buffer 7 and 1 drop washing-up liquid set up in three separate water baths of 0˚C (sitting in ice), 25˚C, and 80˚C.
- Hydrogen peroxide added to all three cylinders at the same time.
- Volumes in graduated cylinders noted at 0, 1, 2 and 3 min.
- Rate of enzyme action calculated by a simple subtraction of the difference in volume during one of the selected minutes.



Result:
- 25 ˚C graduated cylinder showed the most enzyme action (greatest amount of bubbles/foam produced).

Conclusion:
- 25 ˚C is the optimum temperature for catalase.

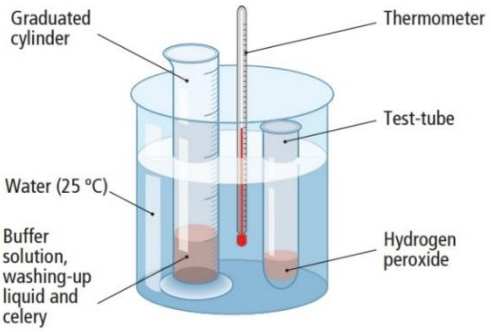
Mandatory Activity: to investigate effect of heat denaturation on enzyme action.

Equipment:
- Lab coat & safety goggles
- Graduated cylinders
- Celery
- Knife

- Hydrogen peroxide
- pH buffer 7
- Washing up liquid
- Stopwatch
- Droppers
- Waterbaths (0 ˚C and 100 ˚C)

Method:

- Two graduated cylinders with celery (catalase enzyme), pH buffer 7 and 1 drop washing-up liquid set up in two separate water baths of 25 ˚C and 100 ˚C
- Contents of each graduated cylinder were allowed to reach required temperature (approximately 15 minutes).
- Hydrogen peroxide added to both cylinders at the same time.
- Volumes in graduated cylinders noted at 0, 1, 2 and 3 min.
- Rate of enzyme action calculated by a simple subtraction of the difference in volume during one of the selected minutes.



Result:

- 25 ˚C graduated cylinder showed enzyme action (formation of bubbles)
- 100 ˚C graduated cylinder showed no enzyme action (no bubbles produced).

Conclusion:

- The enzyme in the 100 ˚C graduated cylinder had been denatured by the hot temperature.

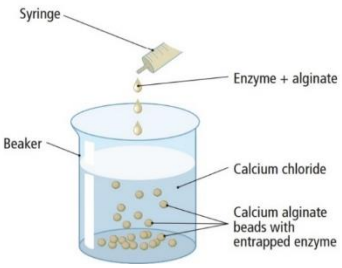
Mandatory Activity: to immobilise an enzyme and examine its application.

Equipment:

- Lab coat
- Safety goggles
- Dried Yeast
- Sodium alginate
- Calcium chloride
- Beakers
- Dropping funnel
- Syringe
- Tea strainer
- Sucrose
- Clinistix strips/ Benedict's solution

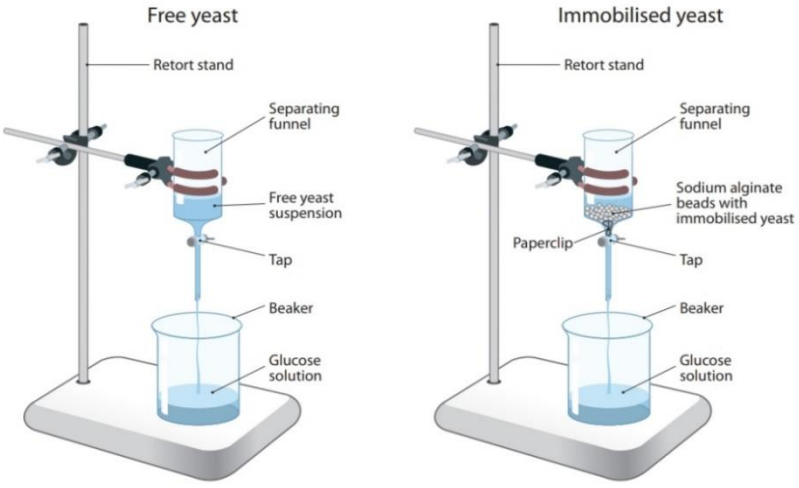
Method:

- Yeast cells and sodium alginate are dissolved in water separately and mixed.
- The mixture is dropped slowly (drop by drop) using syringe into $CaCl_2$ solution.
- Beads of Yeast-alginate solidify and washed three times using water and a tea strainer and placed in a dropping funnel.
- A sucrose solution is placed into funnel and the immobilised yeast beads added.
- Product is produced in the funnel and released by opening tap of funnel.
- Product is tested for reducing sugar (glucose and fructose) – e.g. Benedict's test



Result: The product was clear – no yeast was present in the product. The product tested positive for reducing sugar.

Conclusion: Immobilised yeast converted sucrose to glucose + fructose without contaminating the product



CHAPTER 10: ENERGY CARRIERS (HL ONLY)

Oxidation – Reduction

- Oxidation is the loss of electrons
- Reduction is the gain of electrons

Use the mnemonic, “OILRIG”, to remember.

Oxidation – reduction (redox) reactions are very important for living organisms as energy can be transferred very efficiently from one form to another – i.e. chemical energy to heat, kinetic, sound energy

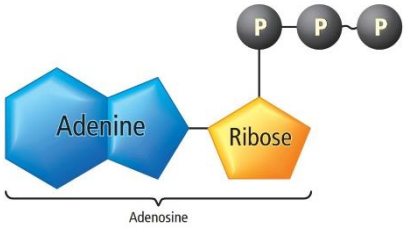
Energy carriers take part directly in metabolic reactions by:

- Gaining high energy electrons (reduction)
- Losing electrons that have given up their energy (oxidation)

ATP (adenosine triphosphate)

ATP Is the ‘energy currency’ of the cell.
It is composed of:

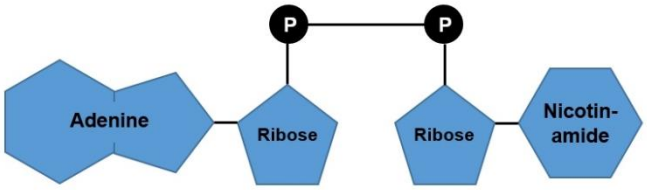
- Adenine
- Ribose
- Three phosphates



ATP – Adenosine triphosphate (NOTE: you **DO** have to be able to draw and label this diagram for LC Biology)

NAD (nicotinamide adenine dinucleotide)

- Electron carrier used in *aerobic respiration*
- Picks up energised electrons (reduction) after a bond is broken and carries them to the electron transport chain where they release their energy in an enzyme-controlled environment to produce ATP

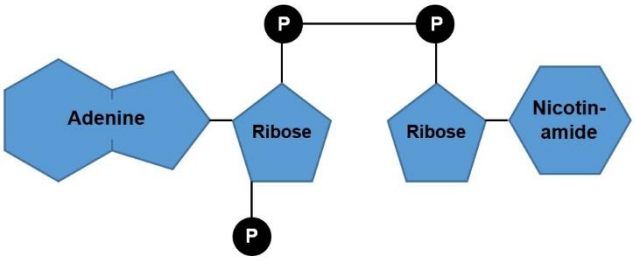


NADH – Nicotinamide adenine dinucleotide (NOTE: you **DO NOT** have to be able to draw the structure of NADH for LC Biology)

$$NAD^+ + 2e^- + H^+ \rightarrow NADH$$

NADP (nicotinamide adenine dinucleotide phosphate)

- Electron carrier used in *photosynthesis*
- Picks up energised electrons (reduction) that came from chlorophyll and carries them (as well as protons) to the dark stage where CO_2 is reduced to form glucose.



NADPH – Nicotinamide adenine dinucleotide phosphate (NOTE: you **DO NOT** have to be able to draw the structure of NADH for LC Biology)

$$NADP^+ + 2e^- \rightarrow NADP^- + H^+ \rightarrow NADPH$$

CHAPTER 11: PHOTOSYNTHESIS

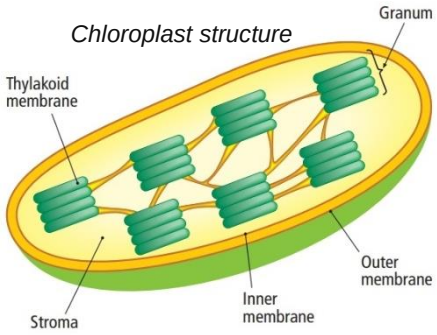
Introduction

- **Photosynthesis** is the process of using sunlight energy and chlorophyll to produce glucose from carbon dioxide and water.

Balanced equation: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

- Photosynthesis occurs in the **chloroplast** and requires the green pigment chlorophyll.

General Process of Photosynthesis



- Sunlight is absorbed by chlorophyll (found in **thylakoid membranes**).
- Chlorophyll molecules are found in **photosystems** which gather light energy.
- This absorbed energy is used to split water into three different components:
  1. **Hydrogen ions** (also called **protons**) are stored in the chloroplast – an area called the proton pool.
  2. **Oxygen** passes out of plant cell and leaf into the atmosphere.
  3. **Electrons** are given to chlorophyll.
- Chlorophyll that has energy because of sunlight transfers that energy to its electrons, creating **high-energy electrons**.
- High-energy electrons, protons and carbon dioxide are combined to make **glucose**.

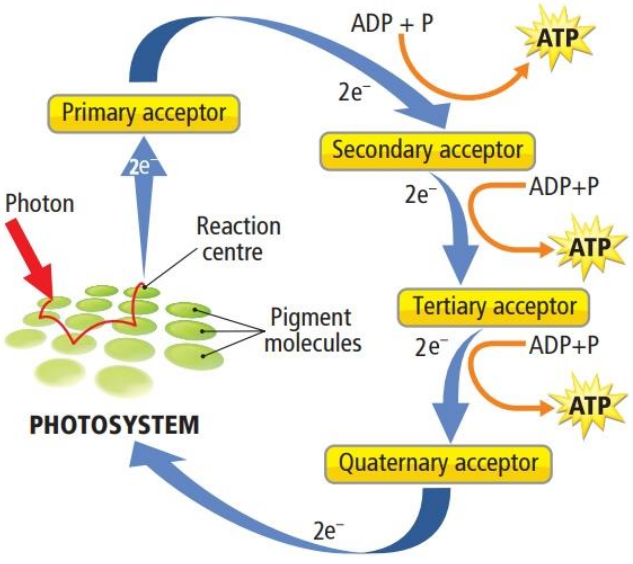
Detailed Process of Photosynthesis

Photosynthesis occurs in the chloroplast in two stages:

- **Light stage** – requires the direct input of light and occurs in the **thylakoid membranes**.
- **Dark stage** (light-independent stage OR Calvin Cycle) – **does not** require the direct input of light and occurs in the **stroma**.

Light Stage

- Sunlight photon strikes a cluster of chlorophyll molecules called a **photosystem**.
- The chlorophyll molecules transfer the energy to a **reaction centre chlorophyll** (RCC).
- The energy is absorbed by an electron which becomes a '**high-energy electron**'.
- The energised electron is released from the RCC and takes one of two paths:
  1. Cyclic pathway (pathway 1)
  2. Non-cyclic pathway (pathway 2)



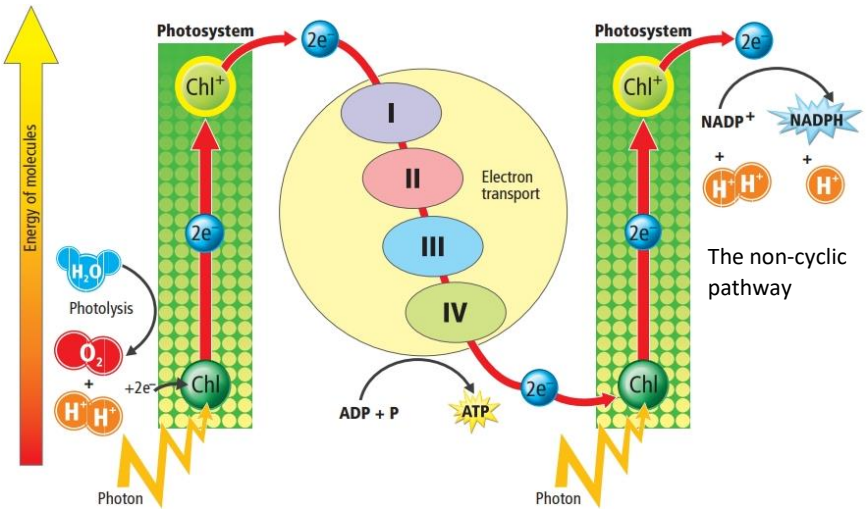
1. Cyclic pathway

- The energised electron is picked up by an electron acceptor.
- It is passed along electron acceptors **losing energy** along the way.
- This energy is used to power the **production of ATP** from ADP and a P.
- Once the electron has been passed through it is **taken back up by the RCC**.
- The ATP is passed onto the next stage of photosynthesis – the dark stage.

***2. Non-cyclic pathway* (pathway 2)**

- The energised electron is picked up by an electron acceptor.
- It is passed along electron acceptors **losing energy** along the way.
- This energy is used to power the **production of ATP** from ADP and a P.
- The **photosystem is deficient in electrons and splits water** into electrons, protons and oxygen gas (**photolysis**).
- The **electrons are taken up by the photosystem**, the **protons are stored in a proton pool** within the chloroplast and the **oxygen gas is either released** into the atmosphere **or used in respiration**.

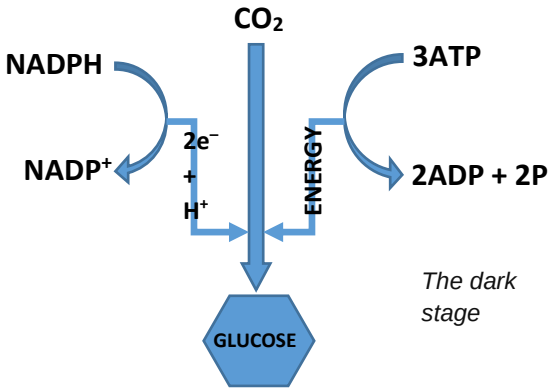
- The electrons that passed through the electron acceptors are now low-energy electrons and are now passed onto another photosystem.
- Light strikes this second photosystem and the **electrons are re-energised**.
- The electrons are released and **captured by NADP⁺ to become NADP⁻**.
- Protons are attracted towards and taken up by NADP⁻ to become NADPH.
- NADPH and ATP are passed onto the next stage of photosynthesis – the dark stage.



The non-cyclic pathway

Dark Stage (Calvin cycle)

- Occurs in the stroma of the chloroplast.
- NADPH and ATP from the light stage are used **to reduce** (addition of protons and electrons) **carbon dioxide**.
- **Glucose is formed** in this reaction.
- As a result, **NADPH is converted back to NADP⁺ and ATP is converted back to ADP and a phosphate**.

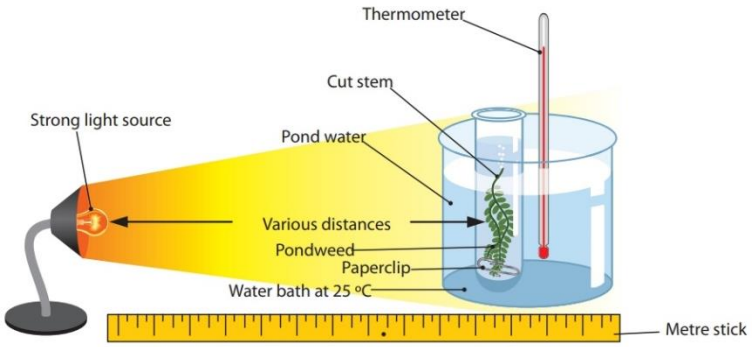


The dark stage

Mandatory Experiment: to investigate the effect of light intensity OR carbon dioxide concentration on the rate of photosynthesis

Equipment:

- Pondweed (*Elodea*)
- Metre stick
- Pond water
- Thermometer
- Paperclip
- Sodium hydrogen carbonate
- Stopwatch
- Backed blade
- Strong light source



Method:

- Obtain fresh pondweed.
- Cut a small section using the backed blade and crush the cut end slightly between your fingers.
- Place pondweed in a test tube with pond water.
- Ensure the cut end is facing upwards and weigh the pondweed down by attaching a paperclip.
- Shine the strong light source on the pondweed for 5 minutes to allow the pondweed to adjust.
- Move the light source various distances from the pondweed.
- Allow the pondweed to adjust to each new light intensity for 5 min before counting the number of bubbles per min at each distance.
- Calculate the light intensity at each distance by using the formula, $^1/_{d^2}$ (where d is the distance from the light source)
- Fill in the table shown:

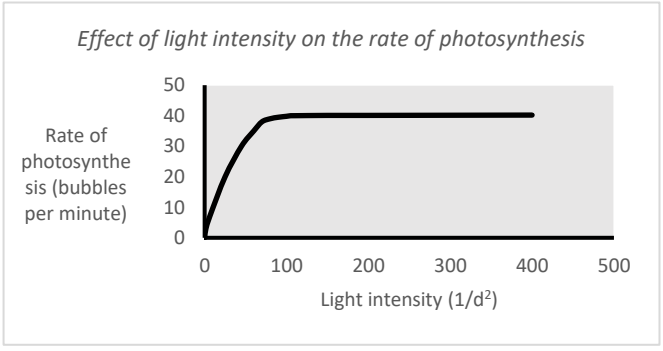
Distance from light source (m)	0.05	0.1	0.2	0.4	0.8
Bubbles/min (trial 1)					
Bubbles/min (trial 2)					
Bubbles/min (trial 3)					
Average bubbles/min					
Light intensity ($\frac{1}{d^2}$)	400	100	25	6.25	1.56

Result:

- As the light source is moved further away from the pondweed, the rate of bubbles per minute decreases.

Conclusion:

- The rate of photosynthesis increases with light intensity.
- The rate of photosynthesis stops increasing, levelling off when the plant has become light saturated.



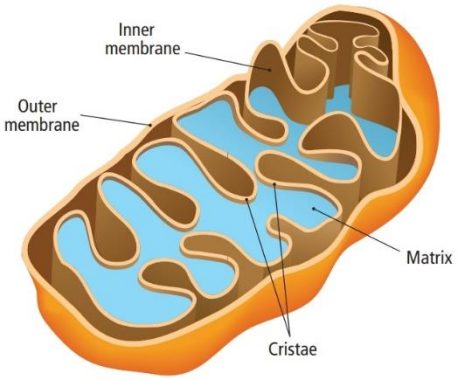
CHAPTER 12: RESPIRATION

Internal versus external respiration

- Internal (cellular) respiration is the enzyme-controlled release of energy from food.
- External respiration (breathing) is the exchange of gases with environment.

Aerobic versus anaerobic respiration

- Aerobic respiration is the enzyme-controlled release of energy from food **using** oxygen
- Anaerobic respiration is the enzyme-controlled release of energy from food **without the use** of oxygen



Aerobic respiration occurs in the **mitochondrion**.

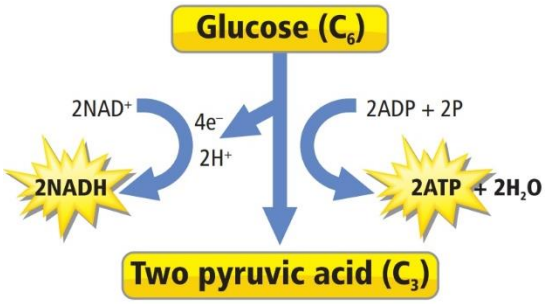
Structure of the mitochondrion

Mitochondria have a double membrane with a highly folded internal membrane to give greater surface area for the reactions of respiration.

Aerobic respiration

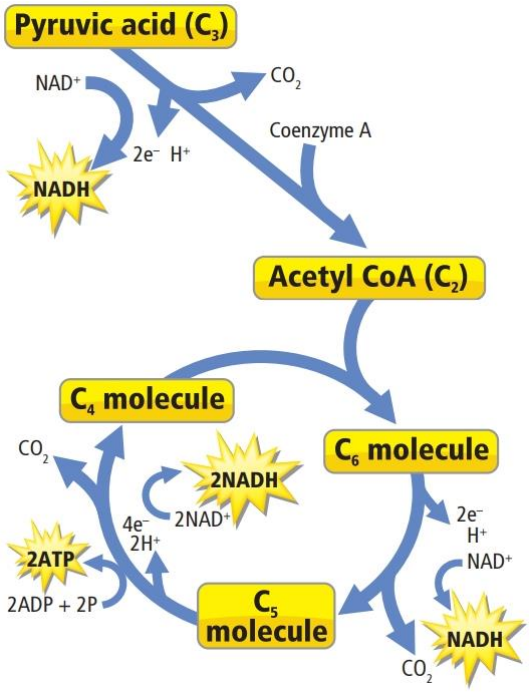
Aerobic respiration consists of **two** stages:

1. Stage 1 (Glycolysis)
2. Stage 2 (Krebs cycle & Electron Transport Chain)



Stage 1: Glycolysis

- Oxygen-independent (can occur in presence or absence of oxygen)
- Occurs in cytosol
- Glucose (a 6-carbon molecule) is changed into 2 three-carbon molecules (pyruvate)
- This breaking down of glucose releases high energy electrons and protons – they are captured by NAD^+ to become NADH
- Glycolysis also produces two molecules of ATP directly

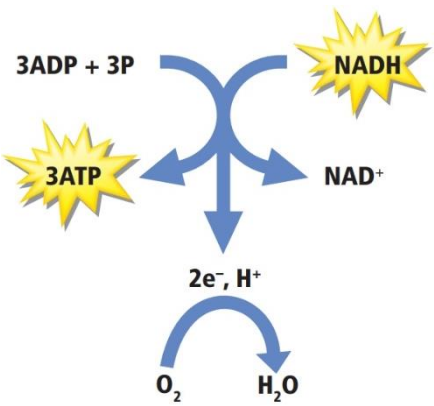


Stage 2: Krebs cycle

- Oxygen-dependent (can only occur in the presence of oxygen).
- Occurs in the lumen of the mitochondrion (matrix).
- Pyruvate enters the mitochondrion and is converted to two-carbon molecule (acetyl-coA) with release of NADH and carbon dioxide.
- The acetyl-coA then joins with four-carbon molecule from the previous Krebs cycle to form six-carbon molecule.
- The six-carbon molecule is then broken down into five-carbon molecule with release of carbon dioxide and NADH.
- The five-carbon molecule is then broken down into four-carbon molecule with release of ATP, carbon dioxide, and 2NADH.
- The four-carbon molecule goes into the next Krebs cycle.
- The ATP goes to power metabolism (chemical reaction in cells).

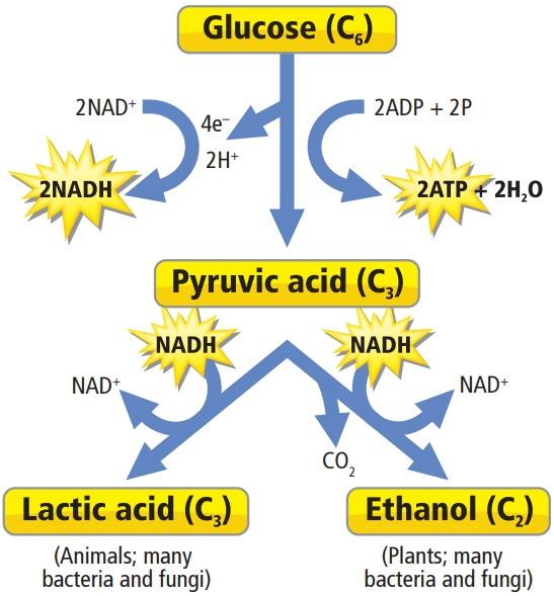
Stage 2 (continued): Electron Transport Chain

- Oxygen dependent (can only occur in the presence of oxygen).



- Occurs in the inner membranes of the mitochondria (cristae).
- The NADH is an energy carrier that travels the short distance to the cristae and releases its high energy electrons and protons.
- The energy carried by the high energy electrons is used to power the production of three ATP molecules from ADP molecules and phosphates.
- The resultant low energy electrons, along with the proton, are combined with oxygen gas to form water.
- The three ATP molecules are then used within the cell for other reactions (e.g. anabolic reactions such as protein synthesis).
- NAD^+ returns to the lumen of the mitochondrion to take part in another reaction.

Anaerobic respiration
Anaerobic respiration occurs when no oxygen or limited oxygen is present.
Two stages:
1. Glycolysis
2. Lactic acid fermentation/Alcohol fermentation



Lactic acid fermentation:
- Pyruvic acid is reduced by NADH (in other words, NADH gives its electron and proton to pyruvic acid) and forms lactic acid. NADH is oxidised (loses its electrons and proton).
- Both pyruvic acid and lactic acid have three carbon atoms, so **NO** carbon dioxide is produced.
- Lactic acid fermentation occurs in all animals (when there is a lack of oxygen) and in some bacteria and fungi.

Ethanol fermentation:
- Pyruvic acid is reduced by NADH (in other words, NADH gives its electron and proton to pyruvic acid) and forms ethanol. NADH is oxidised (loses its electrons and proton).
- Ethanol has two carbon atoms and pyruvic acid has three carbon atoms, so one carbon atom is lost, in the form of carbon dioxide (which is then released/excreted).
- Ethanol fermentation occurs in all plants (when there is a lack of oxygen) and in some bacteria and fungi.

Role of microorganisms in industrial fermentation:

Industrial fermentation is a type of **bioprocessing**.

Bioprocessing:

Bioprocessing: use of living cell, or their components (such as enzymes) to make useful products or carry out useful procedures.

Bioprocessing is carried out in bioreactors.

Bioreactor:

A **bioreactor** is a vessel in which a product is formed by a cell or cell component (such as an enzyme).

Examples of bioprocessing:

- Brewing alcohol
- Producing dairy products
- Making vinegar

Bioprocessing is carried out in **two** ways:
1. Batch culture
2. Continuous flow culture

1. Batch culture:
- Nutrient medium, microorganisms/enzymes and substrate are added at the start.
- The microorganisms are allowed to proceed through the lag, log and stationary phases and then product is removed at the end of the process.
- Sometimes microorganisms are allowed to proceed through all of the stages of the microorganism growth curve and the product is removed at the end of the process.

2. Continuous flow culture:
- Nutrient medium, microorganisms/enzymes and substrate are added all the time (continuously).
- The microorganisms are kept in the log phase of the microorganism growth curve.
- Product is removed all the time (continuously).

Bioprocessing with immobilised cells/enzymes:

Microorganisms and enzymes can be immobilised (trapped in a gel) and then used in bioprocessing.

Advantages:
- Produces a pure, uncontaminated product
- Immobilised enzymes/cells can be reused many times

Uses of immobilised cells/enzymes:
- Immobilised yeast cells are used in the industrial fermentation of beers, wines and spirits.
- Pencillin G is produced using immobilised Penicillium fungal cells
- Immobilised E. coli is used in water treatment plants

Mandatory Experiment: to prepare alcohol using yeast

Equipment:

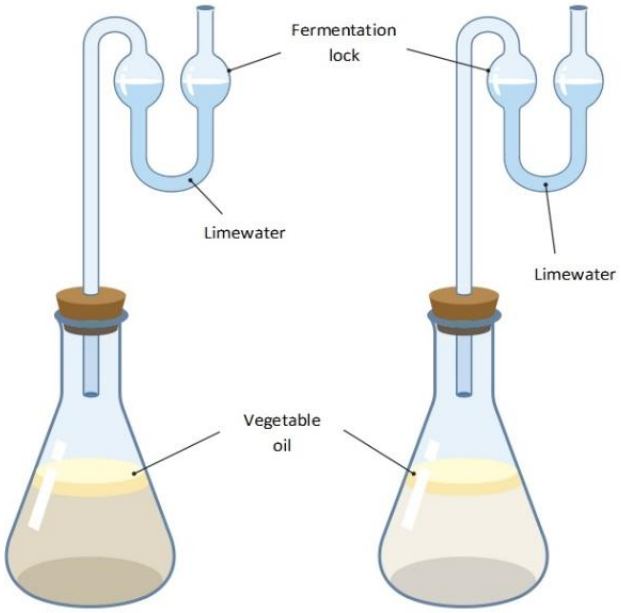
- Yeast
- Glucose
- Deionised water
- Beakers
- Conical flasks
- Vegetable oil
- Fermentation lock
- Limewater
- Incubator
- Filter paper
- Funnel
- Potassium iodide
- Sodium hypochlorite
- Water bath

Method:

- Dissolve 50 g glucose in 500 ml deionised water and bring to the boil (to exclude oxygen).
- Separate into two conical flasks (250 ml glucose solution in each).
- Once cooled add 5 g yeast to one of the conical flasks and label this “TEST’ – the other flask remains as the control (without yeast).
- Slowly pour a layer of vegetable oil on top of each glucose solution (keeps the oxygen out).
- Place a stopper in each and attach fermentation locks each containing limewater.
- Leave in a 25˚C incubator for approximately 3-4 days.

Test for alcohol (Iodoform test):

- Filter the solutions obtained from each conical flask.
- Place 3 ml of each in two separate test tubes.
- Add 3 ml of a **potassium iodide** solution and 5 ml of a **sodium hypochlorite** solution to each test tube.
- Warm the test tubes gently in a hot water bath and observe any changes.



Results:

- Appearance of pale yellow crystals in the ‘TEST’.
- No appearance of pale yellow crystals in the control.

Conclusion:

- Yeast produced alcohol by anaerobic respiration in the ‘TEST’.
- Oxygen must be lacking or limited in order for alcohol to be produced.

CHAPTER 13: CELL CYCLE

Cell Continuity:

Cell continuity is where cells arise from cells of the same type OR organisms arise from organisms of the same type.

- Living organisms maintain cell continuity by **mitosis** and/or **meiosis** and **cell division**.

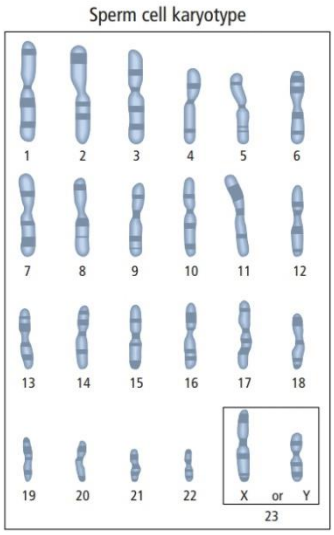
Chromatin and Chromosomes

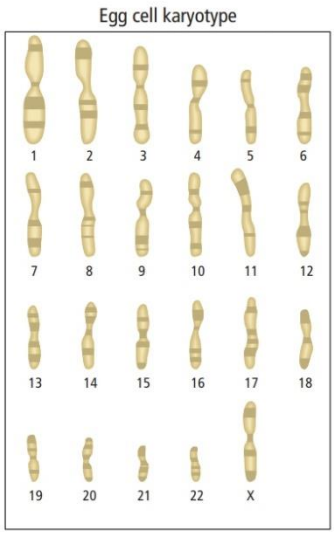
- Chromatin is elongated DNA
- Chromosomes are composed of DNA and protein
- Chromosomes are arranged into homologous pairs – pairs of chromosomes that contain genes that control the same characteristics

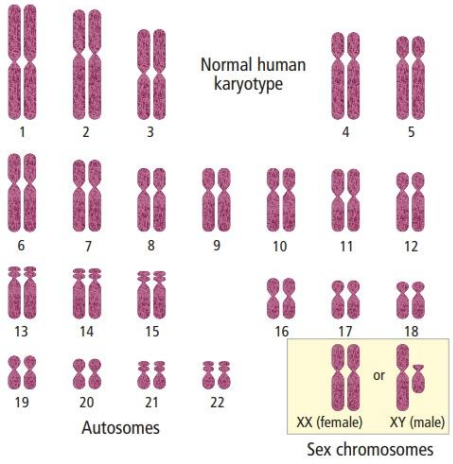

Human sex chromosomes

Haploid and diploid

- **Haploid means <u>one</u> set of chromosomes**
- **Diploid means <u>two</u> sets of chromosomes**
  - In humans the haploid number is 23
  - The diploid number is 46 – arranged into 23 pairs

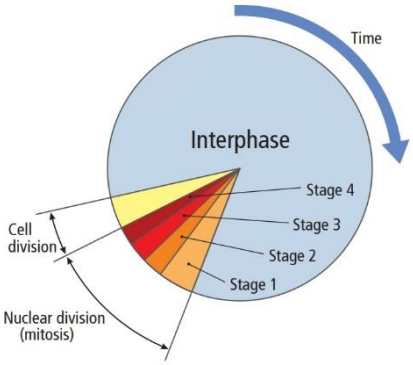






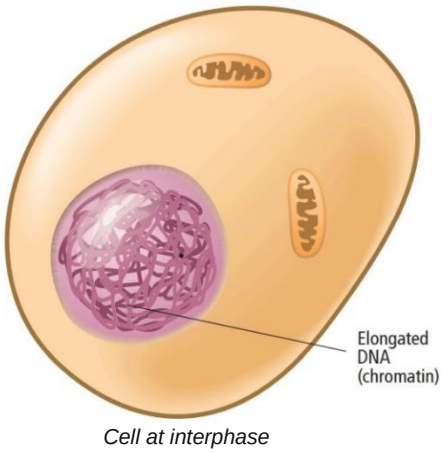
The Cell Cycle

- The cell cycle occurs under three distinct stages (see pie chart):
  - Interphase
  - Mitosis
  - Cell division



Interphase

- Interphase is the stage where a cell is not dividing and a cell spends the vast majority of its time in this stage.
- Chromosomes are elongated and the cell goes about its daily functions
- Towards the end of interphase the cell organelles and all the DNA are replicated.
- Towards the end of interphase, the DNA is replicated and condenses into duplicated chromosomes which are held together by centromeres – see diagram



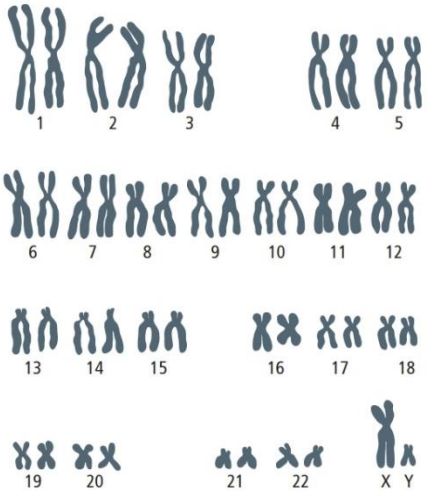
Cell at interphase

Mitosis

- Mitosis is nuclear division that leads to the formation of two identical daughter cells

Stages of mitosis:

- Stage 1: Prophase
- Stage 2: Metaphase
- Stage 3: Anaphase
- Stage 4: Telophase



Stage 1: Prophase (diagram A)

- The nuclear membrane begins to disappear and spindle fibres begin to appear from the centrioles

Stage 2: Metaphase (diagram B)

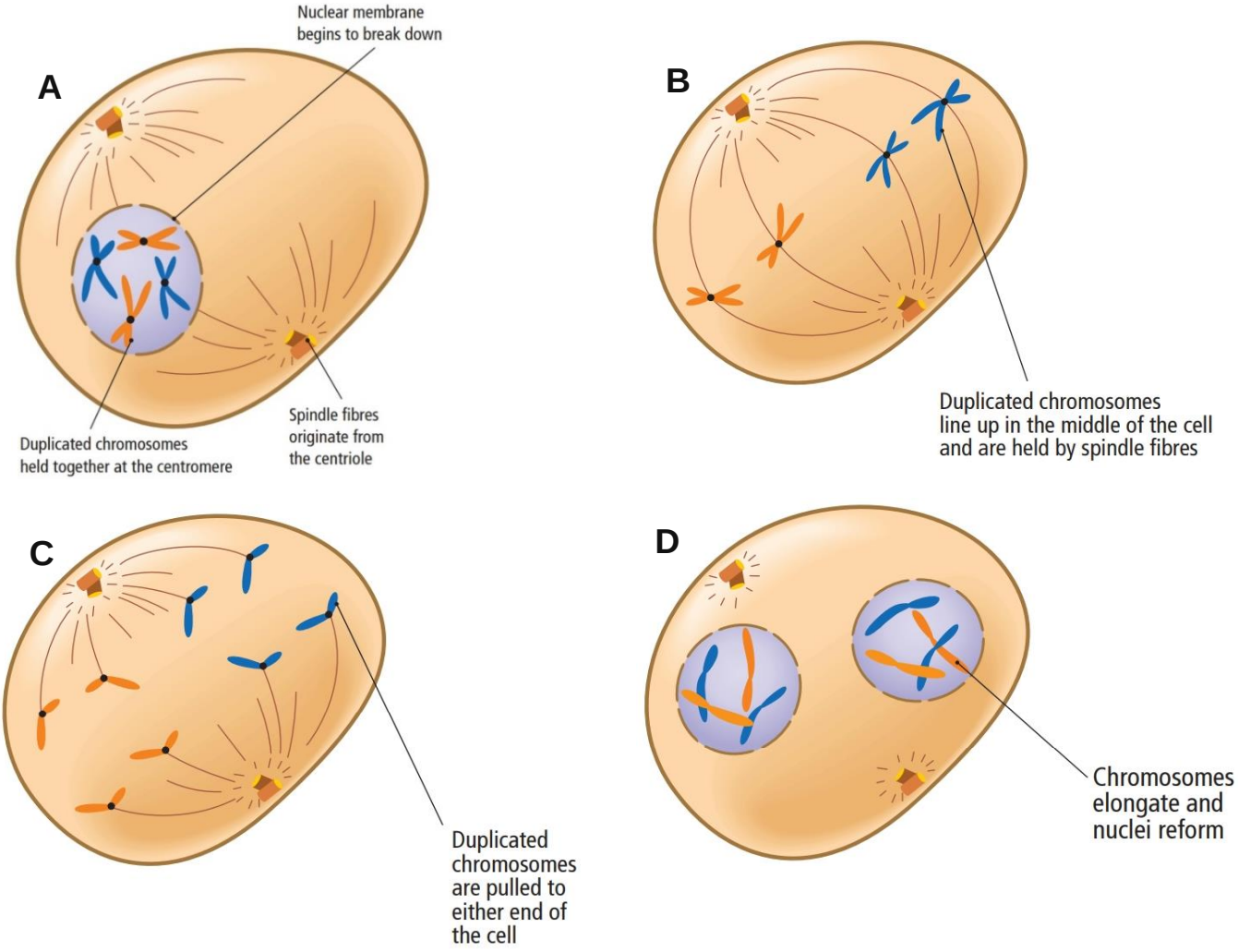
- The replicated chromosomes line up along the equator of the cell held in place by spindle fibres

Stage 3: Anaphase (diagram C)

- The spindle fibres begin to contract pulling one chromosome from each pair to each pole

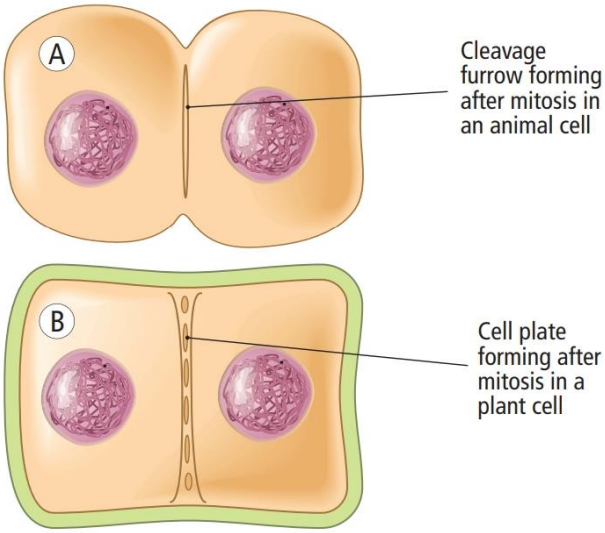
Stage 4: Telophase (diagram D)

- The chromosomes at each pole begin to unravel and lengthen; spindle fibres disappear; and the nuclear membranes reform at each pole



Cell Division (Cytokinesis)

- Cell division occurs immediately after mitosis and is different depending on whether in animal cells or in plant cells.
- In animal cells, the membrane pinches inwards forming a cleavage furrow, with two cells eventually being formed.
- In plant cells, vesicles form down the middle of the dividing cell, forming a cell plate which eventually becomes the cell wall, forming two individual cells.



Cell division – Meiosis:

- Meiosis is nuclear division whereby four new daughter cells are produced each with half the number of chromosomes as the parent cell

Cancer

- **Cancer is a disease whereby a cell loses its ability to control both the rate of mitosis and cell division**
- Mitosis is normally carefully controlled but when it is out of control it can result in cancer
- Cancer can be either benign or malignant
  - Benign cancer involves cells that divide out of control for a limited period of time and do not spread
  - Malignant cancers involve cells that divide rapidly uncontrollably and spread and invade other tissues – destroying that tissue in the process
- Anything that has the potential to cause cancer is called a carcinogen – which damage DNA
- Examples of two carcinogens:
  - UV light – damages DNA of skin cells
  - Cigarette smoke – damages the DNA of cells lining the mouth, airways and lungs

CHAPTER 14: DNA AND RNA

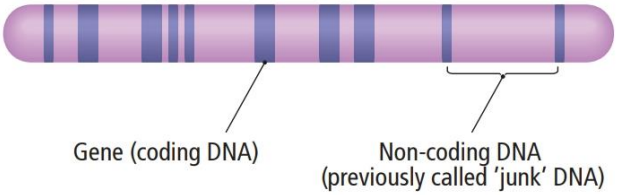
Definitions:

- Heredity is the passing on of characteristics from one generation to the next
- A gene is a short region of a chromosome that contains a code for the production of a protein
- Gene expression is the process where the DNA code is used to make a protein

Genetic Code

- The code for a particular protein can be thousands of bases long
- Only approx 3% of DNA is thought to actually code for proteins (coding DNA)
- The rest (97%) is called non-coding DNA – does not code for any proteins

Chromosome Structure

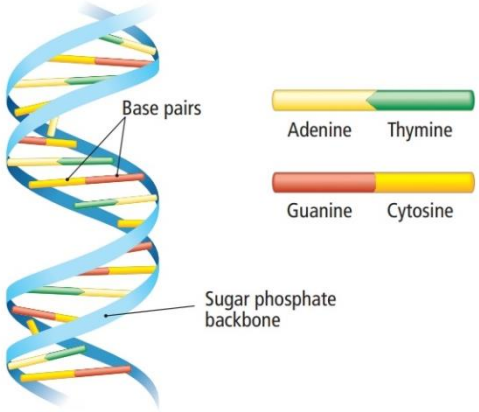


- The genes are contained within a much longer piece of DNA called a chromosome (see diagram above).
- The genes are spread out along the length of the chromosome.
- There is coding DNA (DNA that codes for a specific protein) and non-coding DNA (DNA whose function is generally unknown).
- The non-coding regions of the chromosomes used to be called 'junk DNA'
- Chromosomes are composed of 40% DNA: 60% protein.
- The protein (histones) makes the DNA very stable and enable it to be supercoiled into a very small space (i.e. the nucleus) •DNA wraps around proteins called histones, which then supercoil into a chromosome.
- NOTE: chromosome only exist during mitosis.
- At all other times the DNA is in the form of chromatin.

DNA

- DNA stands for **d**eoxyribo**n**ucleic **a**cid.
- It is a polymer and has a helical shape.
- DNA consists of two strands (double-stranded) – made up of alternating sugar (deoxyribose) and phosphate molecules
- The two strands are attached to each other by nitrogenous bases
- DNA contains 4 bases:
  1. Adenine (A)
  2. Guanine (G)
  3. Thymine (T)
  4. Cytosine (C)

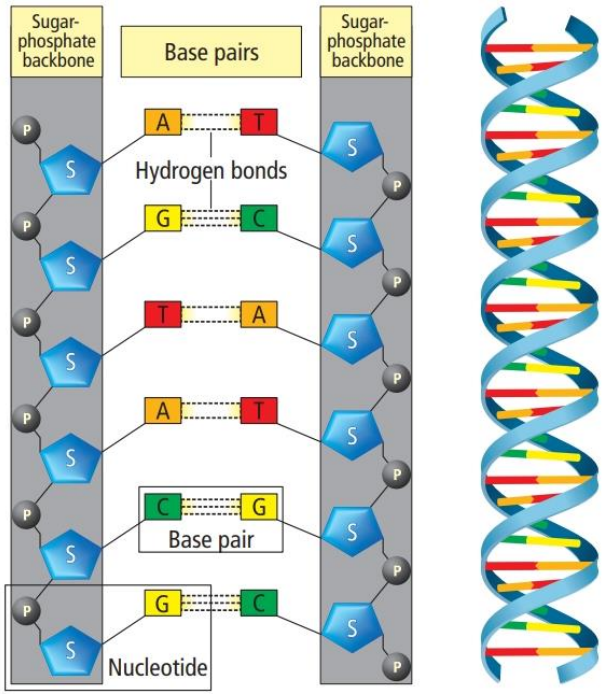
Adenine and guanine are **purines**
Thymine and cytosine are **pyrimidines**



- The strands are twisted creating a spiral ladder
- The spiral ladder shape is called a double helix
- The bases attach the two strands together in pairs (complementary base pairing)
- The bases always attach to the sugar molecules

Complementary base pairing

- Complementary base pairing occurs between the bases in DNA:
- Adenine can only pair with thymine (A = T)
- Cytosine can only pair with guanine (C ≡ G)
- A = T: double hydrogen bond
- C ≡ G: triple hydrogen bond
- Individual hydrogen bonds are very weak but as there are so many hydrogen bonds they are collectively very strong – holding the two strands of DNA together and making DNA very stable

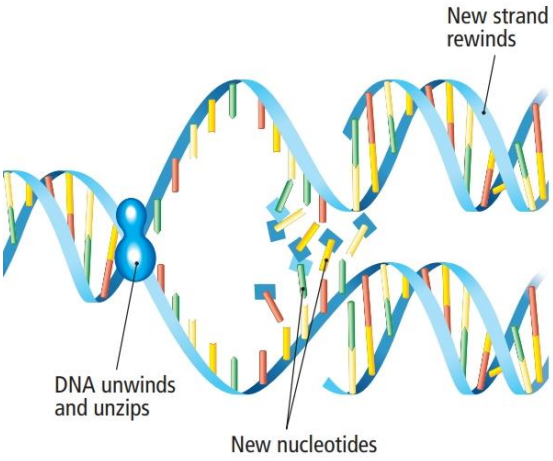


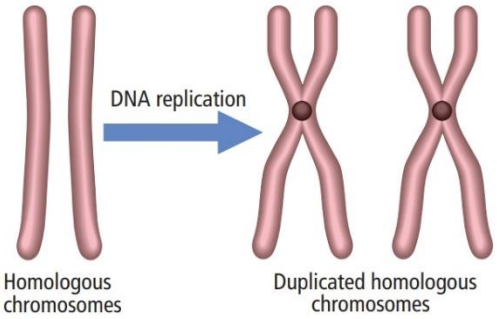
Nucleotide

- A nucleotide is a 3 molecule unit composed of a phosphate, sugar (deoxyribose), and base (A, T, C or G)
- It is the basic unit of the structure of DNA (see diagram)

DNA replication

- DNA replication occurs towards the end of interphase
- An enzyme unwinds and unzips the DNA
- Free nucleotides diffuse in from the cytosol and are placed into their complementary position by the enzyme DNA polymerase
- Once the DNA has been replicated the DNA coils and supercoils into chromosomes in preparation for mitosis/meiosis





DNA Profiling

- DNA profiling is a method of making a unique pattern of bands from a sample of DNA for identification purposes.

DNA Profiling Method

1. **DNA isolation:**

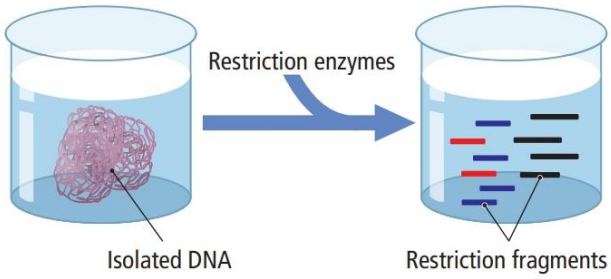
   DNA isolation: extraction/release of DNA from cells.

   - DNA is released from cells using detergent that dissolves cell membranes.
   - Even small samples (e.g. hair follicle/blood smear) the amount of DNA can be increased (by DNA replication) several million-fold in a few hours.

2. **Cutting:**

   Cutting: DNA is cut into fragments

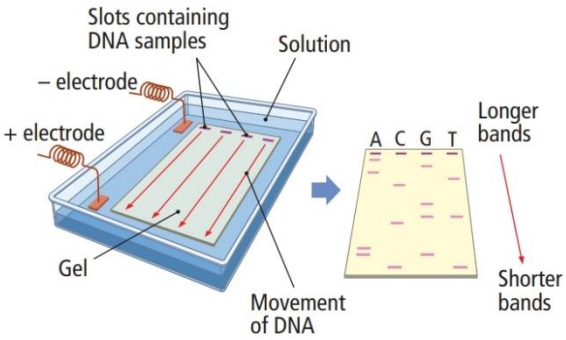
   - Restriction enzymes cut DNA at specific base sequences producing DNA fragments (restriction fragments) that are different sizes.
   - Everyone's DNA is different which means that restriction enzymes will cut everyone's DNA in slightly different places.



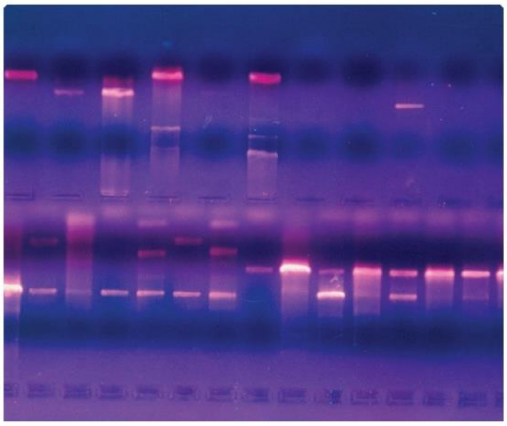
3. **Separation:**

   Separation: DNA fragments are separated based on size.

   - Because almost everyone has unique DNA they also have their own unique set of restriction fragments after the cutting stage.
   - The mixture of restriction fragments can be separated out into a unique pattern of bands by gel electrophoresis.
   - Agarose gel is poured into specialised shallow tray and allowed to set.
   - The mixture of DNA is loaded into 'wells' at the top end (negative end) of the gel and an electric current is passed through the gel.
   - DNA is a negatively charged molecule and is attracted to the positive end.
   - The large restriction fragments will move more slowly than the short fragments – this creates a unique pattern of bands of fragments.



4. Pattern analysis:



Pattern analysis: bands of DNA become visible and are compared.

- An invisible pattern has been produced by the gel electrophoresis.
- To make the pattern visible the whole gel is stained (e.g. ethidium bromide) and then viewed under UV light.
- The patterns produced are compared and analysed for identification purposes.

Applications of DNA Profiling

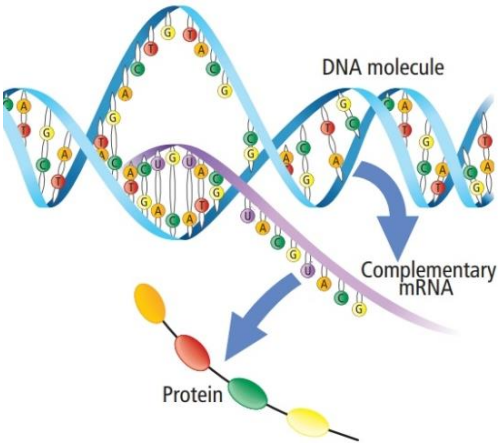
- Species identification
- Criminology: placing suspect at a crime scene
- Medical: used often in paternity testing

RNA

- RNA – ribonucleic acid
- RNA is single stranded
- RNA contains nitrogenous bases:

1. Adenine (A)
2. Uracil (U)
3. Cytosine (C)
4. Guanine (G)

- RNA contains the sugar ribose.
- Nucleotides in RNA are composed of a phosphate, sugar (ribose) and a base (A, U, C, or G)
- RNA is made by the enzyme RNA polymerase using one DNA strand as a template.



DNA versus RNA

DNA		**RNA**	
Double-stranded		Single-stranded	
Sugar: deoxyribose		Sugar: ribose	
Nucleotides:	Adenine	Nucleotides:	Adenine
	Thymine		Uracil
	Guanine		Guanine
	Cytosine		Cytosine

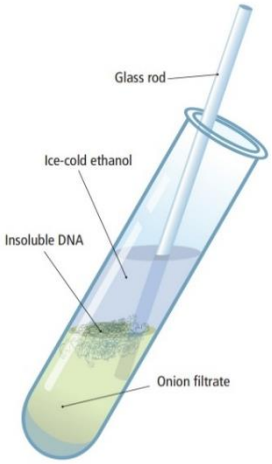
Experiment: to isolate DNA from onion tissue

Equipment:

- Onion
- Beakers
- Stirring rod
- Hotplate/waterbath
- Icebath
- Droppers
- Ice-cold ethanol
- Protease
- Coffee filter paper
- Salt
- Washing-up liquid
- Distilled water
- Blender
- Knife

Method:

- Finely chop a small onion.
- Add onion to 3 g salt and 100 ml distilled water in a beaker.
- Heat (to a maximum of 60˚C) and stir mixture gently for 15 minutes (heat denatures enzymes that breaks DNA down).
- Cool in ice bath for 5 minutes (to prevent the DNA itself being broken down).
- Blend mixture for 3 seconds (this step breaks the cell walls).
- Filter blended mixture through coffee filter paper (not lab filter paper as coffee filter paper allows the DNA through).
- Take 3 ml of filtrate in test tube and add 3 drops of **protease** (freshly squeezed kiwi fruit juice) – slowly swirl the test tube to mix (proteases digest the histones)
- Slowly add 10 ml **ice-cold ethanol** down the side of the test tube (DNA is insoluble in ice cold ethanol)



Result:

- DNA becomes visible at the junction between the filtrate and ice-cold ethanol.

Conclusion:

- DNA is a white cloudy solid.
- DNA is insoluble in ice-cold ethanol.
- DNA can be isolated from cells using everyday household substances.

CHAPTER 15: PROTEIN SYNTHESIS

Protein synthesis is the making of a protein.

It is carried out by a **ribosome**.

Protein synthesis involves three stages: transcription; translation; and protein folding

1. Transcription

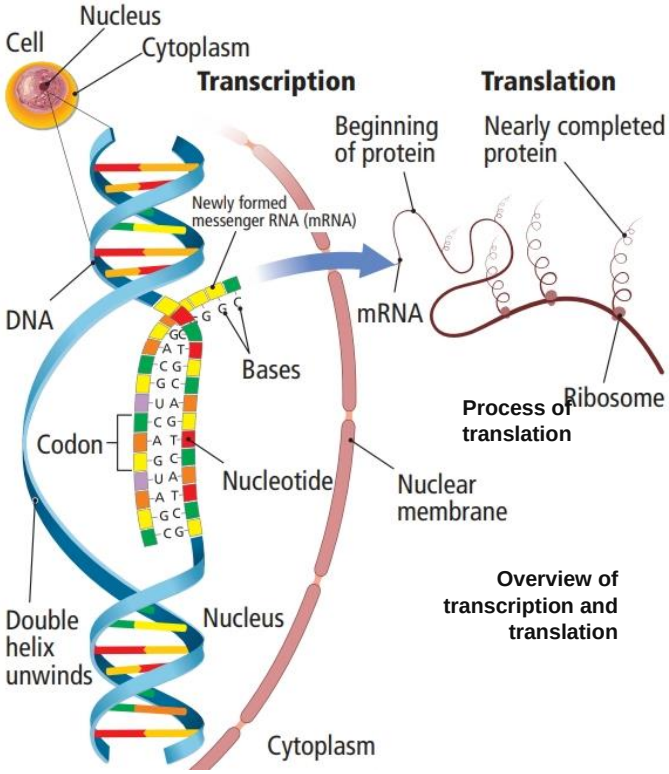
Transcription is the making of messenger RNA using a DNA template.

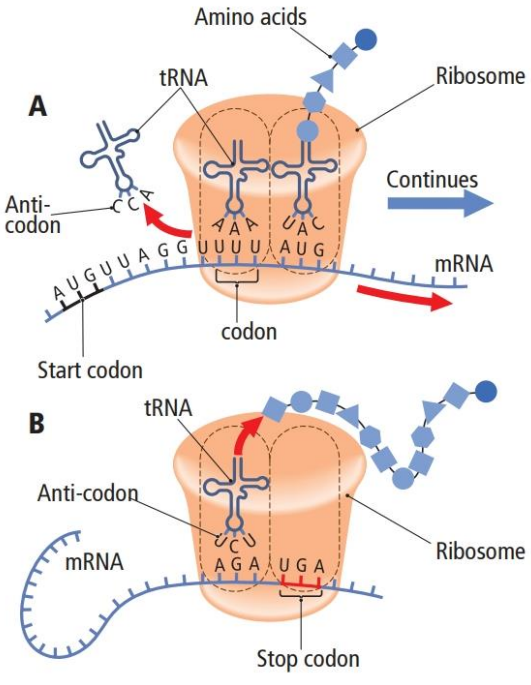
- Enzymes unwind the double helix and separate the two strands by breaking the hydrogen bonds between the bases where the gene is located
- RNA polymerase synthesises messenger RNA (mRNA) using one of the strands of DNA as a template

2. Translation

Translation is the making of a protein using the code in mRNA.

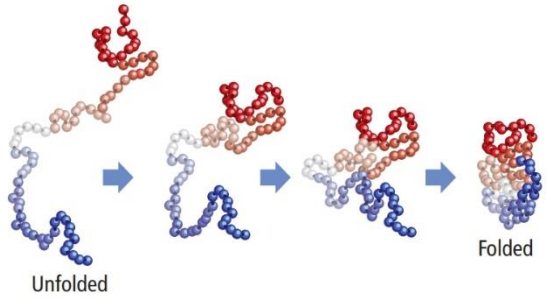
- mRNA moves to cytoplasm (figure 3) and combines with a ribosome made up of two ribosomal RNA (rRNA) subunits
- **A codon (or a 'triplet') is a sequence of three bases present on mRNA or DNA.**
- Each codon 'tells' the ribosome to do one of three things:
  - Start making a protein (start codon)
  - Add on an amino acid to a growing chain of amino acids
  - Stop making the protein and release the chain of amino acids (stop codon)
- Transfer RNA (tRNA) is another type of RNA – it is found free-floating in the cytoplasm and is responsible for carrying one amino acid. (Remember amino acids are the building blocks of proteins)
- tRNA has a 3-base (triplet) sequence called the anti-codon that is complementary to a particular codon on the mRNA.
- **An anti-codon is a sequence of three bases present on tRNA.**
- Each tRNA in turn (with its own amino acid) lines up with the mRNA (figure 4A and B) in the ribosome and an amino acids are joined together by peptide bonds in a long polypeptide line which will form the protein
- This process continues until the stop codon on the mRNA is reached at which point all the translation machinery separates and the protein is released.





3. Protein Folding

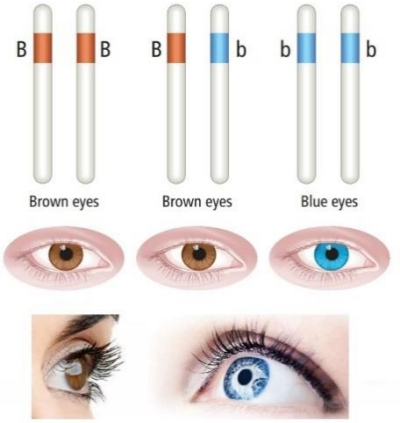
- The chain of amino acids leaves the ribosome and is sent to specific areas of the cell where it is packaged and folded into its functional shape (figure 5)
- It goes and carries out its specific function (e.g. enzyme action)



CHAPTER 16: INHERITANCE & GENETIC CROSSES

Definitions:

- **Genetics**: study of inheritance.
- **Inheritance**: passing on of traits from one generation to the next.
- **Traits**: physical/chemical characteristics that a living organism possesses.
- **Gamete**: haploid sex cell.
- **Fertilisation**: fusion of two haploid gametes to produce a diploid zygote.
- **Allele**: alternative form of the same gene.
- **Locus**: position of an allele or gene on a chromosome.
- **Homozygous**: two alleles are the same.
- **Heterozygous**: two alleles are different.
- **Dominance**: one allele masks the effects of another allele.
- **Recessive**: allele's effect is only expressed in the homozygous condition.
- **Genotype**: genetic make-up of an individual.
- **Phenotype**: physical make-up of an individual.



Alleles/ Homozygous/ Heterozygous/ Dominance/ Recessive:

There can be a number of different **alleles** controlling the same characteristics; e.g. eye colour in humans: blue and brown are two common colours. Each organism has a maximum of two alleles for each characteristic. Alleles are usually assigned letters with a capital letter signifying a **dominant** allele and a lower-case letter signifying a **recessive** allele. B (brown eyes); b (blue eyes), etc.

- BB is described as homozygous dominant.
- Bb is described as heterozygous.
- bb is described as homozygous recessive.

Genetic crosses:

Genetic cross: diagram or table showing how characteristics are inherited.

Monohydrid crosses:

Monohybrid cross: genetic mating between two organisms where one gene is studied.

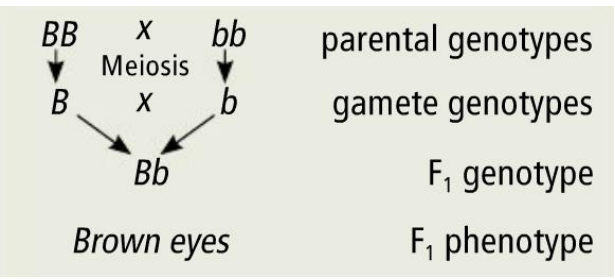
Examples of characteristics that can be studied using monohybrid crosses:

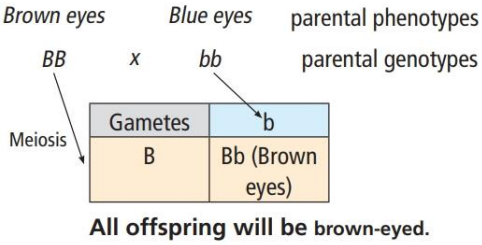
- Ability to tongue roll (dominant) versus inability to tongue roll (recessive).
- Cleft chin (dominant) versus non-cleft chin (recessive).
- Free ear lobes (dominant) versus attached ear lobes (recessive).

There are various possible combinations of monohybrid crosses that are possible:

Study of the inheritance of single traits to the first filial generation involving homozygous parents:

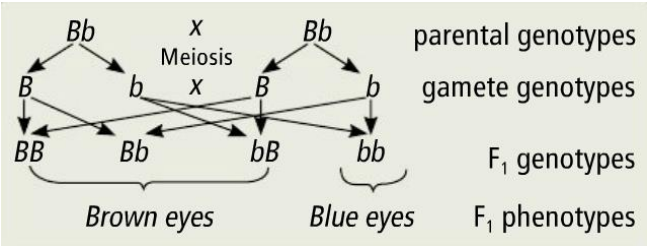
Brown eyed parent and a blue eyed parent (both homozygous):

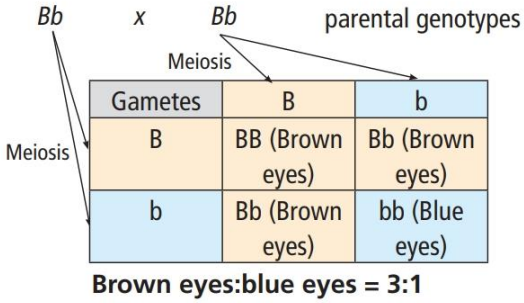




Study of the inheritance of single traits to the first filial generation involving heterozygous parents:

Brown eyed parent and a blue-eyed parent (both heterozygous):





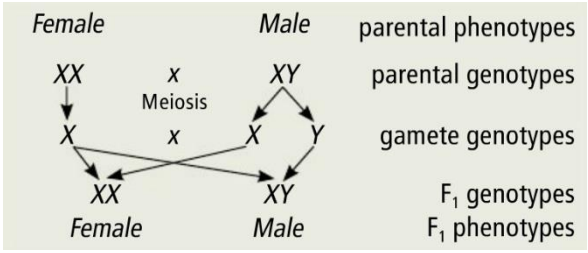
Brown eyes:blue eyes = 3:1

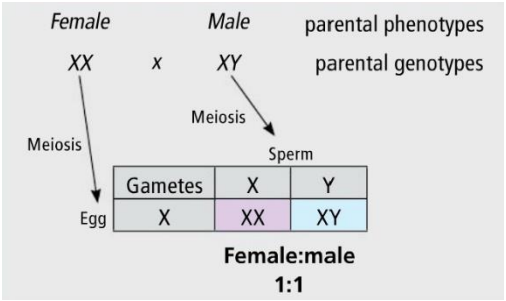
Genetics of sex determination:

The sex chromosomes determine the sex (male or female) of an organism. Homologous chromosomes are arranged in pairs. Normally, there are two possible combinations of sex chromosomes in humans: XX (female) or XY (male). The diagram below shows how the sex chromosomes are inherited.

Sex determination in other species:

In some species XX are male and XY are female! Examples include: some birds, some reptiles, moths and butterflies.



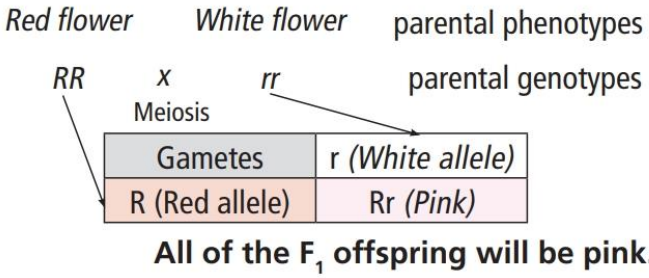


Female:male 1:1

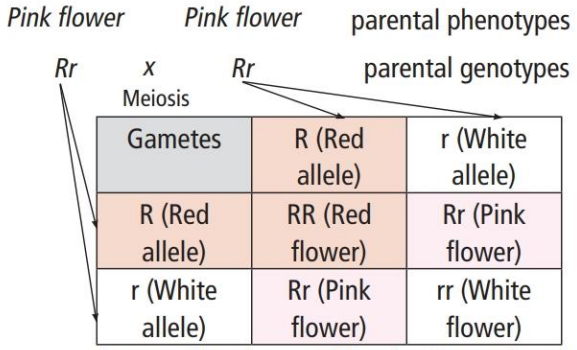
Incomplete dominance:

Incomplete dominance: neither allele of an allelic pair is dominant or recessive with respect to each other – they are equally expressed and the resulting phenotype is a mixture, or bl end, of the two.

An example of incomplete dominance is flower colour in the snapdragon plant.
A red-flowered snapdragon plant (RR) crossed with a white-flowered snapdragon plant (rr) produces pink-flowered offspring (see below).
If the offspring are crossed the following second filial generation phenotypes are possible:



All of the F_1 offspring will be pink.



The F_1 offspring will be in the ratio of:

1 red flower:2 pink flowers: 1 white flower.

Another example of incomplete dominance is in cattle coat colour.
A red-coated bull (RR) crossed with a white-coated cow (rr) produces road-coated offspring (see below).
If the offspring are crossed the following second filial generation phenotypes are possible:

Red coat White coat parental phenotypes

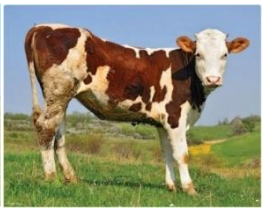
RR x rr parental genotypes

Meiosis

Gametes	r *(White allele)*
R (Red allele)	Rr *(Roan coat)*

All of the F_1 offspring will be roan.





Roan coat Roan coat parental phenotypes

Rr x Rr parental genotypes

Meiosis

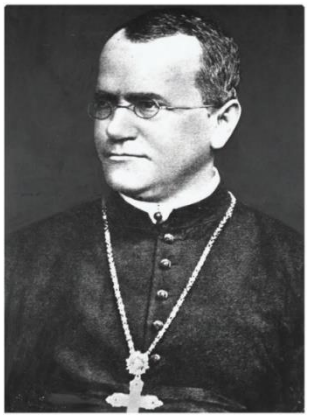
Gametes	R (Red allele)	r (White allele)
R (Red allele)	RR (Red coat)	Rr (Roan coat)
r (White allele)	Rr (Roan coat)	rr (White coat)

The F_1 offspring will be in the ratio of:

1 red coat:2 roan coats:1 white coat.

Origin of Genetics

Work of Gregor Mendel



Mendel was an Augustinian monk, known as the father of modern genetics.
Gregor Mendel (1822 – 1884)
Mendel carried out genetic studies on pea plants. He studied seven characteristics:

1. Flower colour (purple versus white)
2. Flower position (axial versus terminal)
3. Pea colour (yellow versus green)
4. Pea shape (round versus wrinkled)
5. Pod colour (green versus yellow)
6. Pod shape (inflated versus constricted)
7. Height (tall versus short)

	Flower colour	Flower position	Pea colour	Pea shape	Pod colour	Pod shape	Height
Dominant	purple	axial	yellow	round	green	inflated	tall
Recessive	white	terminal	green	wrinkled	yellow	constricted	short

As a result of his work, Mendel came up with his two Laws of Genetics:

First Law of Segregation:

Each cell contains two factors for each trait. These factors separate at gamete formation, so that each gamete contains only one factor from each pair of factors. At fertilisation, the new organism will have two factors for each trait, one from each parent.

Second Law of Independent Assortment:

Members of one pair of factors separate independently of another pair of factors during gamete formation.

Explanation of Mendel's First Law of Segregation:

Chromosomes are arranged into homologous pairs. During meiosis, half of the gametes receive one of the homologous chromosomes with the other half of gametes receiving the other homologous chromosome.

Explanation of Mendel's Second Law of Independent Assortment:

Mendel's second law applies to crosses involving more than one gene, that is, two pairs of alleles. Each allele of a pair can combine completely randomly with either member of another pair (see below).

Dihybrid crosses:

Dihybrid cross: genetic mating between two organisms where two separate genes are studied.

Study of the inheritance to the second filial generation of two traits using the Punnett square technique:

In Mendel's genetic experiments on pea plants, he studied two traits at the same time. He also studied how these traits were inherited through two generations. He found the ratios of the resulting offspring. One pair of traits that he studied at the same time in pea plants was height and flower colour. He took pure-breeding (homozygous for both traits) pea plants and crossed them. This was a cross between homozygous plants. One plant was tall and had purple flowers. The other plant was short and had white flowers.

He found that the offspring of a cross between these parents always produced plants that were tall and purple-flowered. This was called the F1 generation.

Mendel then self-crossed these offspring and found that the F2 generation and discovered that a complicated ratio of phenotypes resulted.
The ratio of phenotypes from this dihybrid cross is 9:3:3:1.

- 9 tall and purple-flowered pea plants
- 3 tall and white-flowered pea plants
- 3 short and purple-flowered pea plants
- 1 short and white-flowered pea plant

Another cross Mendel studied was a mating between a tall, purple-flowered pea plant (heterozygous for both traits) and a short, white-flowered pea plant. He discovered that the offspring from this cross had phenotypes that appeared in a 1:1:1:1 ratio.

Tall, Purple *Short, white* parental phenotypes
TTPP x *ttpp* parental genotypes
Meiosis

Meiosis	Gametes	tp
	TP	TtPp (Tall, purple flowers)

All the offspring are tall and have purple flowers.

Tall, Purple *Tall, Purple* parental phenotypes
TtPp x *TtPp* parental genotypes
Meiosis

	TP	Tp	tP	tp
TP	TTPP	TTPp	TtPP	TtPp
Tp	TTPp	TTpp	TtPp	Ttpp
tP	TtPP	TtPp	ttPP	ttPp
tp	TtPp	Ttpp	ttPp	ttpp

Tall, Purple *Short, white* parental phenotypes
TtPp x *ttpp* parental genotypes
Meiosis

	tp
TP	TtPp (Tall, purple flowers)
Tp	Ttpp (Tall, white flowers)
tP	ttPp (Short, purple flowers)
tp	ttpp (Short, white flowers)

Linkage:

Linkage: genes are present on the same chromosome.

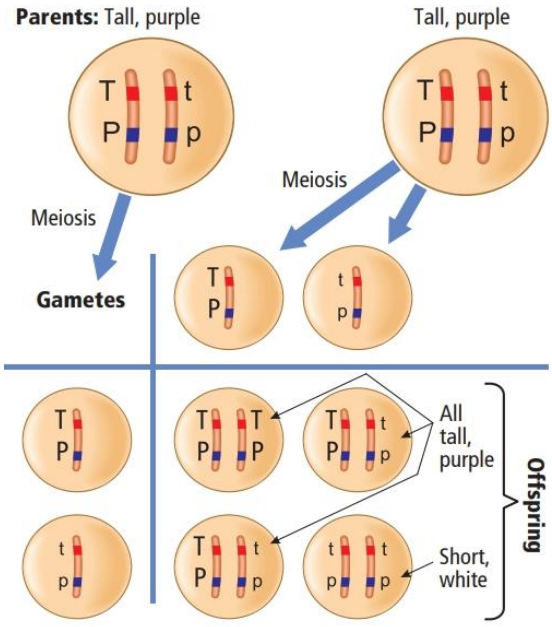
Below is the cross Mendel performed on pea plants where the genes are linked. The ratio of the offspring phenotypes changes when genes are linked because linked genes tend to stay together during gamete formation (meiosis). When genes are on the same chromosome (linked) there are fewer unique gametes.

Similarly, in a cross between heterozygous parents (for both traits) where the genes are linked, the ratio of the phenotypes becomes 3:1.

Tall, Purple *Short, white* parental phenotypes
TtPp x *ttpp* parental genotypes
Meiosis

	tp
TP	TtPp (Tall, purple flowers)
tp	ttpp (Short, white flowers)

The ratio of the offspring is 1:1.



Chromosome diagrams:

TtPp x *TtPp* parental genotypes
Meiosis

	TP	tp
TP	TTPP	TtPp
tp	TtPp	ttpp

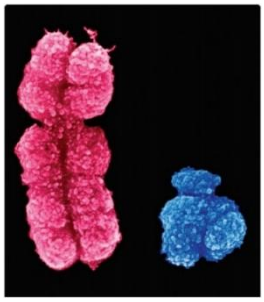
Tall, purple-flowered plant: short, white-flowered plant = 3:1.

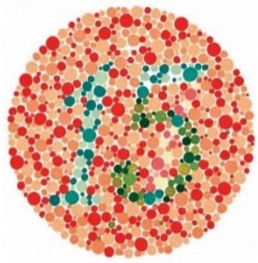
You could be asked to draw a chromosome diagram given a particular genotype or a particular genetic cross. On the left is an example of the genetic cross described above in the form of a chromosome diagram.

Notice the genes are present on the same chromosome, meaning that there will be less variation amongst these traits in the offspring – linked genes tend to stay together at gamete formation.

In the cross involving heterozygous parents where the genes are not linked the ratio of the phenotypes present in the offspring is 9:3:3:1. However, in a cross involving heterozygous parent where the genes are linked, the ratio of the phenotypes in the offspring becomes 3:1.

Sex linkage



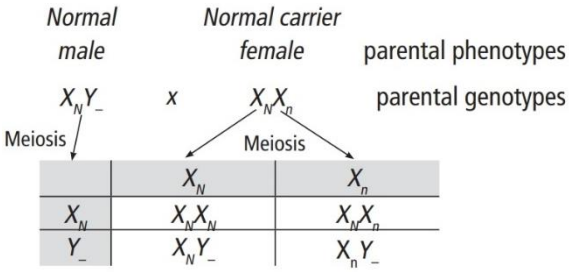


Sex linkage: genes are located on the X chromosome.

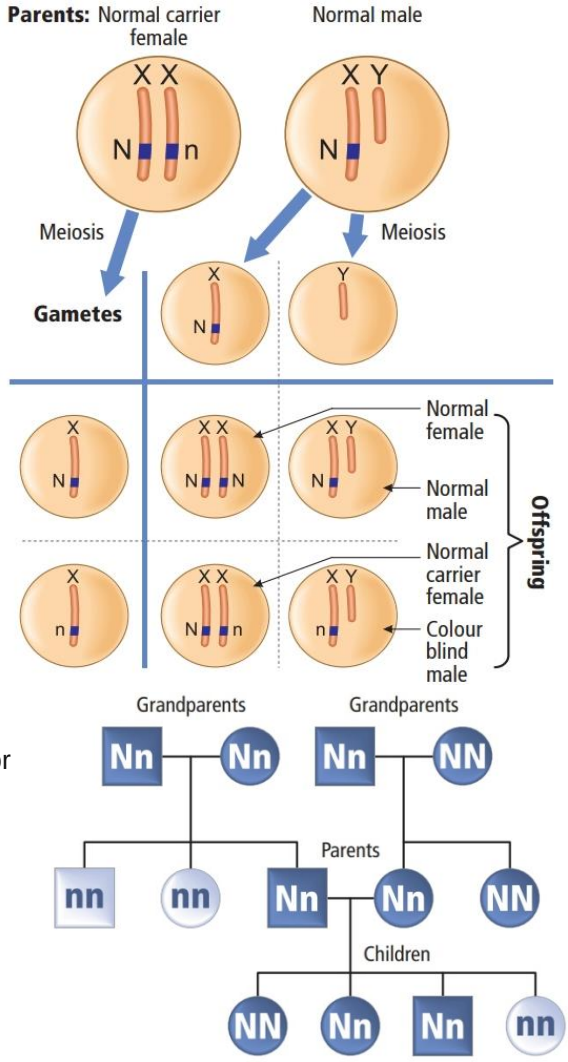
In humans, female are 'XX' whereas males possess a 'Y' chromosome and are therefore 'XY'. The 'X' chromosome is longer than the 'Y' chromosome. This means that many genes that are present on the 'X' chromosome are not present on the 'Y'chromosome.
Males only have **one** copy of many sex-linked genes rather than two. Two examples of sex-linked characteristics in humans that you must learn about are:

- Red-green colour vision
- Blood-clotting

Both of these characteristics are controlled by genes present only on the 'X' chromosome. There is no corresponding gene for these characteristics on the 'Y' chromosome. This is represented in genetic crosses as 'Y_'.



As a result of males are more likely to suffer from haemophilia and red-green colour-blindness than females because they inherit an 'X' chromosome with a mutated gene from their mother.
If they inherit a normal gene from their mother, this is represented by 'X_N'. If they receive a mutated gene from their mother, this is represented as 'X_n'.



Pedigree studies

Pedigree studies are used by geneticists and genetic counsellors for determining and explaining inheritance of certain characteristics. Squares always represent males with circles representing females. Inheritance of cystic fibrosis is often explained using pedigree studies.

Non-nuclear inheritance

Non-nuclear inheritance refers to inheritance of DNA via the mitochondria and chloroplasts. It does not follow Mendel's Laws of Genetics as mitochondria and chloroplasts are inherited independently of the nucleus and always inherited maternally (i.e. via the egg cell because it is the egg cells that carry the cell organelles).

CHAPTER 17: VARIATION & EVOLUTION

Variation

Variation: differences amongst members of the same species.

Variation amongst species occurs by two mechanisms:

- Sexual reproduction: produces variation due to meiosis
- Mutation: produces variation due to changes in the DNA

Mutation: changes in the structure or amount of DNA in a cell.

Mutations can occur spontaneously or by means of an agent, called a mutagen.

Mutagen: agent that increases the rate of mutations.

Examples of mutagens:

- Cigarette smoke
- UV light
- Asbestos
- Radon gas
- X-rays

Mutations can be of two types:

1. Gene mutations
2. Chromosome mutations

Gene mutation: changes in the structure of a single gene; e.g. sickle cell anaemia.

Chromosome mutation: changes in the structure or number of chromosomes; e.g. Down's syndrome.

Evolution

- **Evolution**: genetic changes in species, over a long period of time, to produce new species in response to environmental stresses.
- **Species**: group of similar organisms that can interbreed to produce fertile offspring.
- **Speciation**: formation of a new species following many changes in the structure of an organism until the new species cannot interbreed to produce fertile offspring with the original species.

Theory of Natural Selection

Natural selection: process by which particular traits become more common in a population due to that trait being advantageous to the species.

Examples of natural selection:

Sickle cell anaemia (SCA):
SCA is a **recessive** genetic condition (must have two recessive alleles to suffer from SCA) where the haemoglobin in red blood cells does not form properly due to a mutation in a single gene and causes the cells to take up a sickle shape. They cannot carry as much oxygen as normal red blood cells. However, people who are **carriers** of the defective gene (heterozygous) show increased resistance to malaria. This gives them an advantage over homozygous dominant and homozygous recessive people. This is an example of natural selection in humans where people who are heterozygous for the SCA gene have an advantage.

MRSA – methicillin-resistant Staphylococcus aureus
MRSA stands for methicillin-resistant Staphylococcus aureus. It is a species of bacterium that is resistant to many antibiotics. Overuse of antibiotics has given a chance to certain strains of bacteria to become resistant to antibiotics. Strains that develop mutations that give them the ability to survive in the presence of antibiotics are naturally selected. They will reproduce and pass on this trait to their offspring.

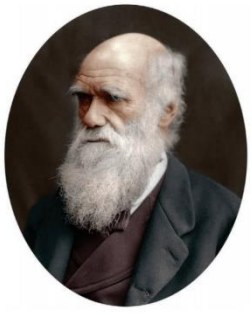
Charles Darwin and Alfred Russell-Wallace
Darwin and Russell-Wallace were two English naturalists who both independently came up with the Theory of Natural Selection.

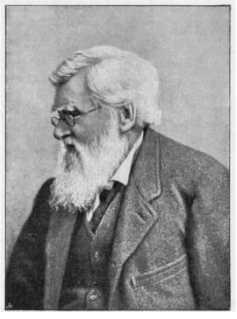
- Charles Darwin (1809 – 1882)
- Alfred Russell-Wallace (1823 – 1913)

Darwin's theory of natural selection made a number of observations and conclusions:

Observations:

1. Species produce many more offspring than is necessary (overbreeding).


Charles Darwin


Alfred Russell-Wallace

2. There is a limited supply of resources to allow survival of the species.
3. Numbers of species remain relatively constant over long periods of time.
4. All species show inherited variations among their members.

Conclusions:

1. There is a 'struggle for existence' (competition) between species and between members of the same species for food, space, shelter and mates.
2. Organisms most suited to their environment, due to favourable characteristics, will survive and reproduce at a faster rate than those less well suited.
3. The characteristics that make an organism most suited to its environment will accumulate among the population.

Evidence for evolution:

Remember you need to know just one source of evidence for evolution.

Paleontology: study of fossils

Paleontology is a source of evidence for evolution as fossils show increasing complexity over time.

- **Fossil**: preserved remains of an organism, part of an organism or an imprint left by that organism.

Comparative anatomy: study of the similarities and differences in the structure of living organisms

Comparative anatomy is a source of evidence for evolution as certain structures of organisms from different species show similarities; e.g. the pentadactyl limb.

Comparative embryology: study if the similarities and differences in the structure of the embryo from different species

Comparative embryology is a source of evidence for evolution as the structure of the early embryo from many different species is very similar.

Comparative biochemistry: study of the similarities and differences in the chemistry of living organisms

Comparative biochemistry is a source of evidence for evolution as all living organisms possess DNA and/or RNA and its molecular structure is essentially the same for all living organisms.

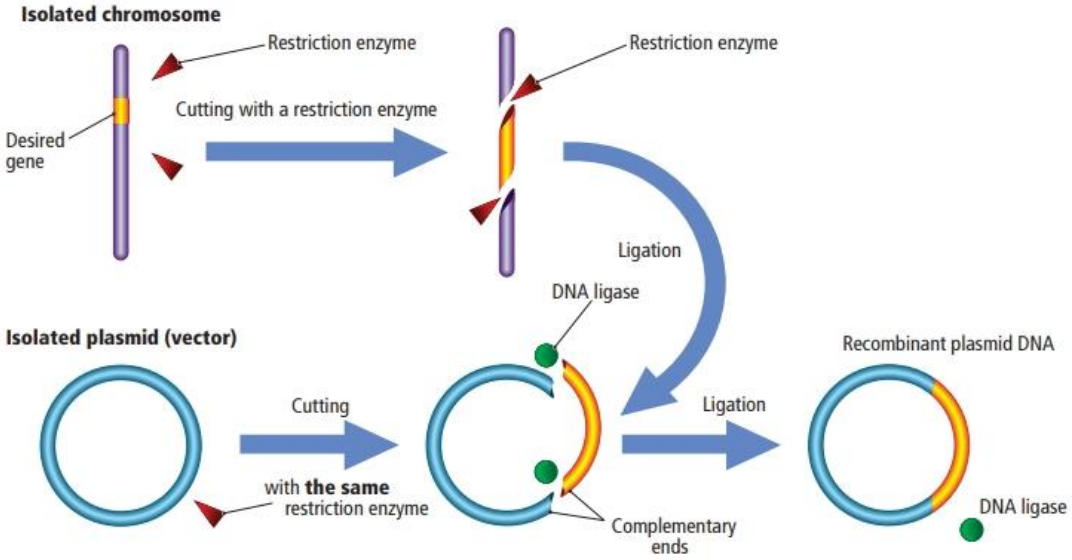
CHAPTER 18: GENETIC ENGINEERING

Genetic engineering: artificial manipulation and alteration of genes.

Process of Genetic Engineering:

1. **Isolation:** process of removing DNA from cells.

Isolation involves using detergents to break open the cell membranes and nuclear membranes to release the DNA.



2. **Cutting and ligation**

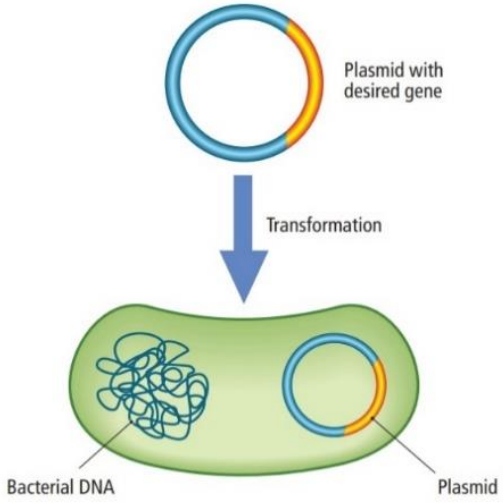
Cutting: removal of a gene from a piece of DNA using a **restriction enzyme**.

Enzymes called **restriction enzymes** are added to the DNA to cut out the desired gene. The same restriction enzyme is used to cut open a **vector** – into which the gene will be inserted (see diagram on the next page).
It is important to use the same restriction enzyme because then the gene will attach to the vector due to the presence of complementary ends – as both pieces of DNA were cut using the same enzyme. The gene is inserted into the **vector** (e.g. a plasmid or a virus) by the enzyme, **DNA ligase**.

Vector: piece of DNA (such as a bacterial plasmid or a virus) that will carry a gene of interest into a host cell.

Ligation: joining of a gene to a vector using DNA ligase.

Once the gene has been inserted into the vector, the new piece of DNA is called '**recombinant DNA**' because it contains DNA from two species. **Recombinant DNA**: piece of genetically modified DNA that contains DNA from two or more different species.

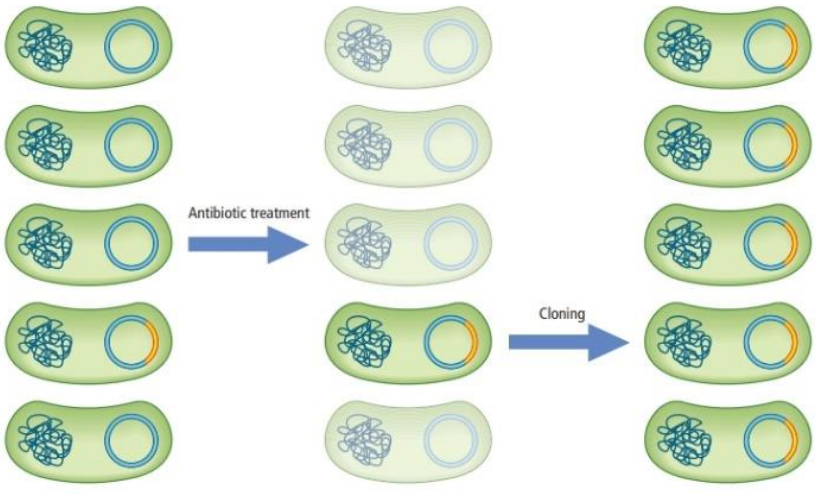


3. **Introduction of base sequence changes/ Transformation**

Transformation is the term used to generally describe the uptake of recombinant DNA into a host cell (e.g. bacterial cell)

4. **Selection and cloning**

Not all cells take up the recombinant DNA. Geneticists want only cells that have been 'transformed' with the recombinant DNA. This is achieved by selecting for cells that have taken up the DNA by killing cells that have not. Recombinant DNA usually contains an antibiotic-resistant gene that gives any cells that take up recombinant DNA the ability to survive in the presence of a strong antibiotic. Any cells that do not take up the recombinant DNA are killed by the antibiotic.



Selection: process of killing any cells that did not take up the recombinant DNA.

The 'transformed' cells are allowed to reproduce by mitosis. This is called 'cloning'.

Cloning: process of producing identical copies of a cell.

5. Expression

Once a workable number of transformed cells have been produced, they are stimulated to produce their product.

Expression: stimulation of a cell to produce the product of a particular gene.

Applications of genetic engineering:

Plant application:

Corn in Spain has been genetically modified to be resistant to herbicide and insects.

Animal application:

Mice have been genetically modified to glow green when exposed to UV light. A green fluorescent protein (GFP), originally discovered in jellyfish, is made by all the cells of the mouse.

Microorganism application:

E. coli bacteria have been genetically modified with human genes, such as the human insulin gene. The bacteria produce human insulin, which is then purified and used to treat type I diabetes.

UNIT 3: THE ORGANISM

CHAPTER 19: DIVERSITY OF LIFE

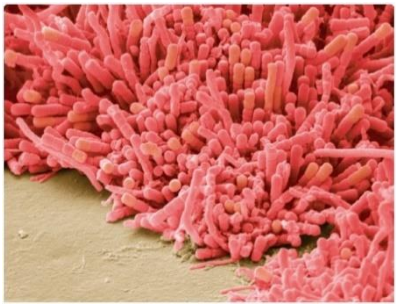
Introduction:

In order to make it simpler to study and describe life, scientists classify living organisms. All living organisms can be classified into one of five groups, called kingdoms.

- **Taxonomy**: study of the classification of living organisms.

The five kingdoms of life

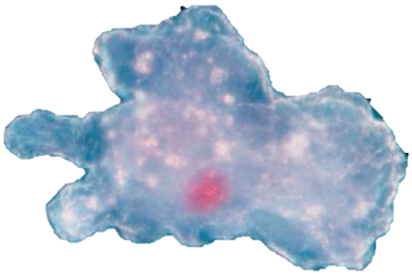
Monera:



Monera: includes all bacteria – the most numerous organisms on Earth.
Common characteristics of bacteria include:

- Very small
- Prokaryotic
- No membrane-bound organelles
- No nucleus
- Proteoglycan cells wall
- Possess circular chromosomes

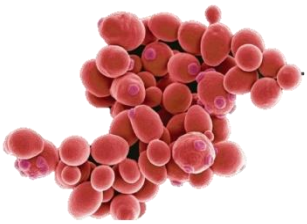
Protista:



Protista: small single-celled organisms such as Amoeba, Cryptosporidium and algae (such as seaweeds).
Common characteristics of protistans:

- They are all aquatic-based
- Some are autotrophic (e.g. algae); some are heterotrophic (e.g. Amoeba)
- Some are multicellular (e.g. seaweeds); some are single celled (e.g. Amoeba)
- Some reproduce asexually (e.g. Amoeba); some reproduce sexually (e.g. seaweeds)

Fungi:



Fungi: single-celled or multicellular heterotrophic organisms such as yeasts, moulds and mushrooms.
Common characteristics:

- They all possess chitin in their cell walls
- They are all heterotrophic
- They all reproduce by means of spores – by producing the spores either by asexual or sexual reproduction

Plantae:

Plantae: Multi-cellular photosynthetic organisms.
Common characteristics:

- All are multicellular
- All are photosynthetic
- All have cellulose in their cell walls
- All have vacuoles for storage in their cells
- They can reproduce asexually or sexually

Animalia:

Animalia: Multi-cellular heterotrophic organisms.

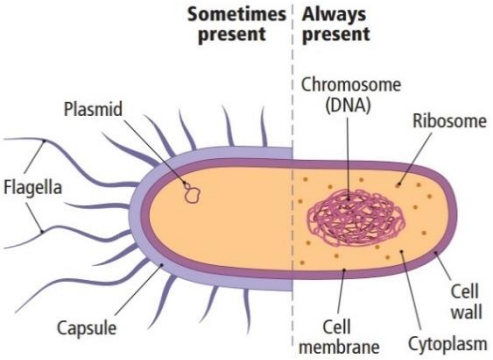
- They are all multicellular
- They are all heterotrophic
- They all reproduce sexually

CHAPTER 20: KINGDOM MONERA

Introduction:

- Kingdom Monera refers to all species of bacteria and they are ubiquitous.
- They are the most numerous living organisms on Earth and biggest biomass.
- Bacteria are prokaryotes – meaning they do not have a membrane-bound nucleus nor membrane-bound organelles (see Chapter 6: Cell Structure).

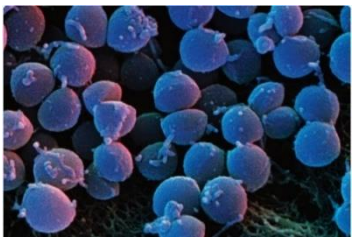
Structure of Bacteria:



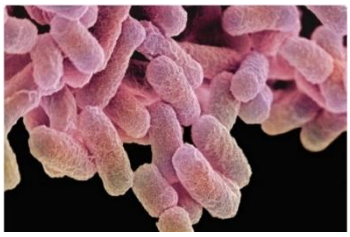
All bacteria have a cell wall and cell membrane, but no organelles (they are prokaryotic). Many bacteria have an additional layer of protection called the capsule and flagella (for movement).

- **Capsule**: slime layer for protection.
- **Cell wall**: structure and protection.
- **Cell membran**e: selectively permeable controlling what enters and leaves.
- **Flagellum**: movement.
- **Chromosome**: DNA and protein carrying genes.
- **Ribosome**: protein synthesis.
- **Cytoplasm**: liquid portion of the cell in which all metabolic reactions occur.
- **Plasmid**: circular piece of DNA that gives the bacterium special traits such as antibiotic resistance.

Types of bacteria:



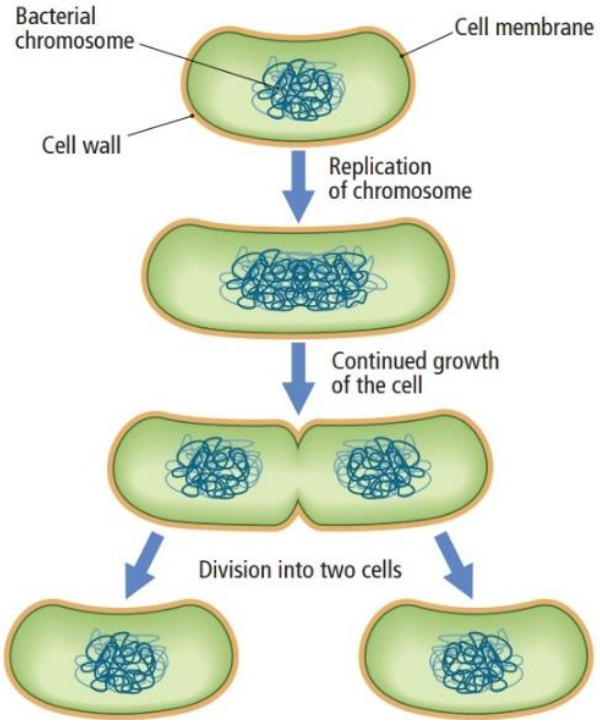
1. **Spherical (*coccus*/*cocci*)**
   These bacteria are round and spherical in shape; e.g. *Staphylococcus aureus* (bacterium normally present on human skin).
2. **Spiral (*spirillum*/*spirilla*)**
   These bacteria are a spiral or helical shape; e.g. *Helicobacter pylori* (bacterium that often causes stomach ulcers).
3. **Rod (*bacillus*/*bacilli*)**
   These bacteria are rod-shaped; e.g. *Lactobacillus casei* (bacterium found in milk – also known lactic acid bacteria).



Bacterial Reproduction:

Bacteria reproduce by **binary fission** which is asexual reproduction in bacteria.

- DNA is replicated.
- Cell elongates.
- Cell membrane and cell wall pinch inwards.
- Cell divides in two.

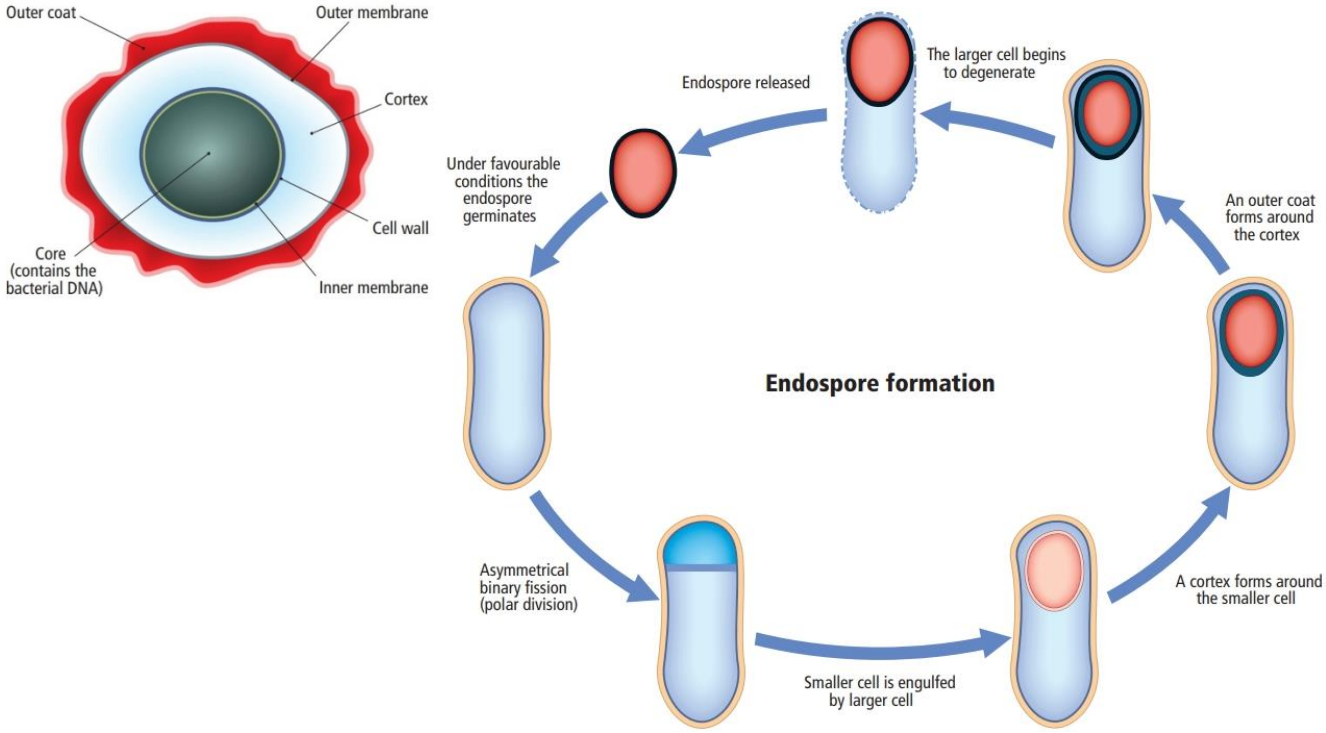


Endospore formation

Endospore: thick, tough-walled, dormant and dehydrated bacterial cell formed during unsuitable conditions.

Process:

- Conditions become unfavourable.
- Cell undergoes asymmetrical binary fission with the smaller cell being engulfed by the larger cell.
- A thick wall, called the **cortex** forms.
- Outer coat forms around the cortex.



Nutrition in bacteria:

- **Nutrition**: way in which organisms obtain and use food.

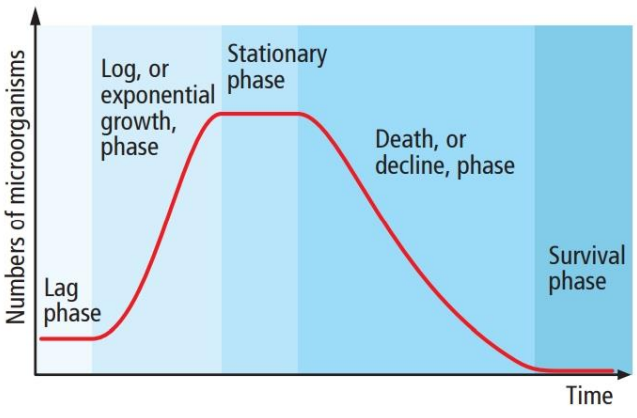
There are two types of nutrition: **autotrophic** and **heterotrophic** nutrition.

Autotrophic nutrition Bacteria make their own food		**Heterotrophic nutrition** Bacteria obtain their food from other organisms	
Photosynthesis Bacteria make their own food using the energy in sunlight	**Chemosynthesis** Bacteria make their own food from chemicals in the air, soil or water	**Saprophytism** Bacteria feed off dead organisms, breaking them down	**Parasitism** Bacteria feed off a living host causing harm
e.g. Purple sulphur bacteria	e.g. nitrogen fixing bacteria	e.g. bacteria of decay	e.g. E. coli

Factors affecting bacterial growth

- **Temperature**: lower temperatures mean lower enzyme activity and a much slower rate of bacterial binary fission.
- **pH**: changes in pH affect enzyme function (see Chapter 9: Enzymes) meaning pH values outside of optimum mean that certain bacteria cannot survive.
- **External solute concentrations**: the concentration of the solution surrounding the cell affects the rate of osmosis. If osmosis occurs too quickly in either direction (in or out of the cell) then the cell may die.

Growth curve of microorganisms



1. **Lag phase**: microorganisms are adjusting to a newly colonised environment. Bacterial reproduction is low.
2. **Log phase**: microorganisms start to reproduce rapidly. There is plenty of space and nutrients present.
3. **Stationary phase**: nutrients begin to run out and bacterial reproduction rate equals bacterial death rate.
4. **Decline phase**: death of microorganisms is at a higher rate than reproduction due to food having been almost used up and the build-up of wastes.
5. **Survival phase**: some microorganisms produce endospores and can survive the harsh conditions (e.g. lack of food)

Economic importance of bacteria

For leaving cert biology you must be able to give two examples of beneficial bacteria and two examples of harmful bacteria.

***Beneficial bacteria*:**

1. *E. coli* – bacteria of the large intestine are responsible for producing vitamins.
2. Lactic acid bacteria (*Lactobacillus casei*) – found in milk and help in the production of dairy products. They also colonise our digestive systems producing lactic acid and inhibiting the growth of harmful bacteria.

***Harmful bacteria*:**

1. Strep throat bacteria (*Streptococcus pyogenes*) – causes sore throat.
2. Tuberculosis bacteria (*Mycobacterium tuberculosis*) – cause of tuberculosis.

Antibiotics

Antibiotics: chemicals produced by microorganisms that kill other microorganisms.

***Overuse of antibiotics*:**

Overuse of antibiotics has led to the emergence of antibiotic resistance among bacterial strains such as MRSA (methicillin-resistant *Staphylococcus aureus*).

Food processing

Food processing: making useful products for consumption using microorganisms.
There are two types of food processing:

1. Batch food processing
2. Continuous flow food processing

***Batch food processing*:**

- Fixed amount of nutrients is added to a bioreactor.
- Microorganisms added to bioreactor.
- Microorganisms act on the substrate going through the lag, log and stationary phases of the growth curve.
- Product is removed at the end of the process.
- An example of a food produced by batch food processing is **yoghurt**.

***Continuous flow food processing*:**

- Nutrients are added to the bioreactor all the time.
- Microorganisms are maintained in the log phase of growth.
- Product is removed from the bioreactor all the time.
- An example of a food produced by continuous flow food processing is **single-celled protein** used in animal feed.

CHAPTER 21: KINGDOM FUNGI

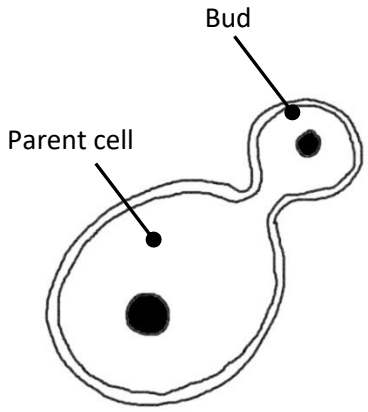
Introduction

- All fungi reproduce by means of spores.
- All fungi are **heterotrophic.**
- They can be single-celled (e.g. Yeasts) or multicellular (e.g. mushrooms).
- All fungi are **eukaryotic** – meaning they have a membrane-bound nucleus and membrane-bound organelles.
- All fungi have cell walls made of **chitin**.

Nutrition: way in which organisms obtains and uses food.

- There are two types of heterotrophic nutrition in fungi:
    1. **Saprophytic**
    2. **Parasitic**.
- *Saprophytic fungi*: obtain their food from dead organisms; e.g. fungi of decay.
- *Parasitic fungi*: obtain their food from living organisms; e.g. Athlete's foot

Yeast (*Saccharomyces cerevisiae*)



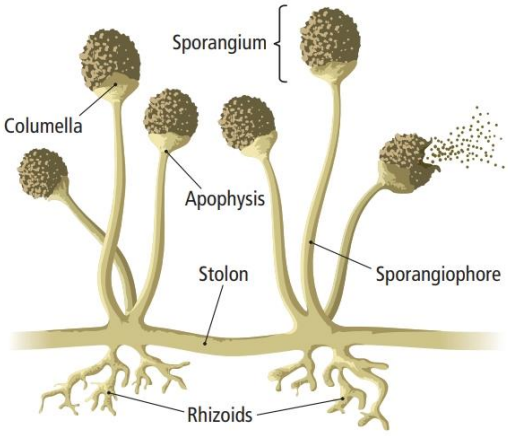
Structure

- Single-celled
- Cell wall made of chitin
- Granular cytoplasm

Reproduction

- Asexual by mitosis in a process known as 'budding' – a small swelling forms on the cell; it fills with cytoplasm and the nucleus divides by mitosis with one of the resulting nuclei moving into the 'bud'.

Rhizopus (Common bread mould)

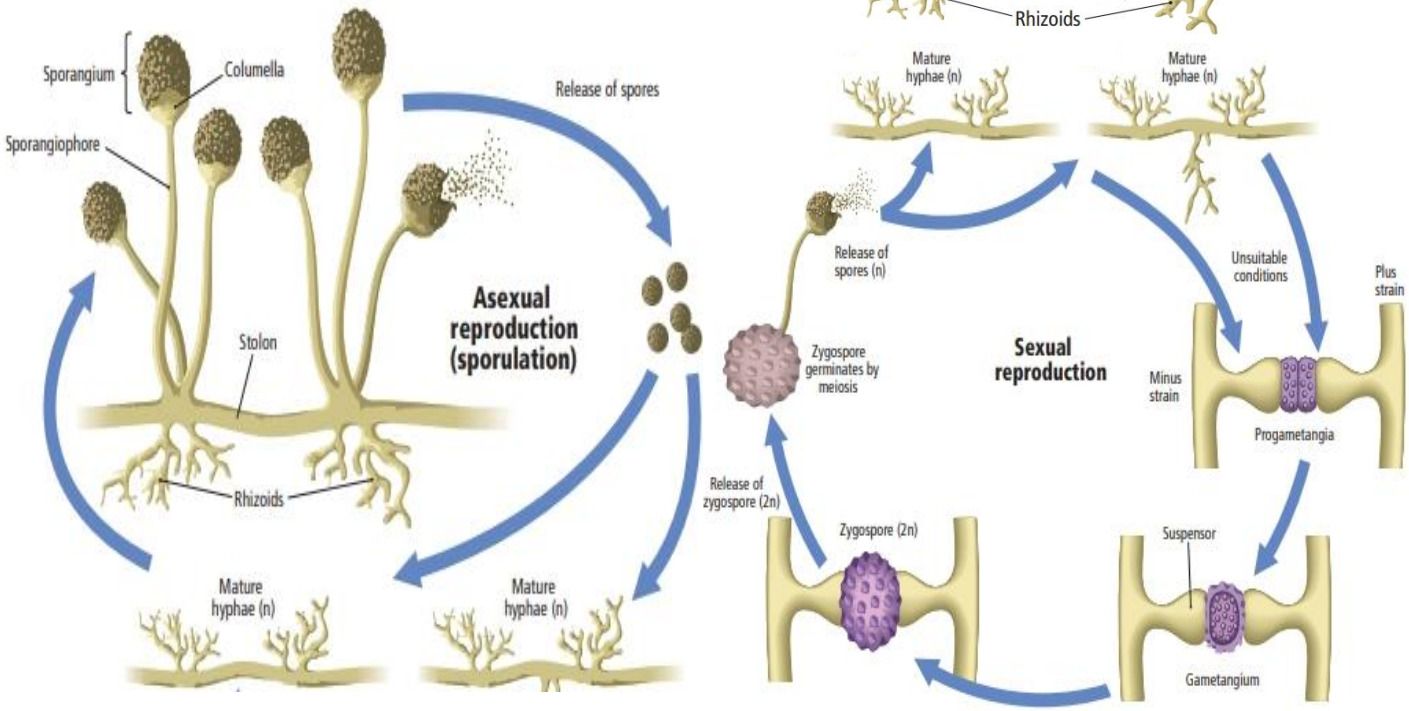


Structure

- Multicellular
- Cell wall made of chitin
- Hyphae – thin, microscopic, thread-like tubules.
- Sporangia – structures that hold spores.

Reproduction

- Asexual – by means of formation of spores, a process known as sporulation.
- Sexual – by means of formation of a diploid zygospore.



Lab procedures when handling microorganisms:

- Use aseptic technique: procedure where contact with, or contamination by, microorganisms is avoided.

Aseptic technique: procedures taken to avoid contamination with pathogens

Sterile: no organisms are present

- Always wear a lab coat.
- Wash your hands before and after the experiment.
- Wear protective gloves where appropriate.
- Wear safety glasses where appropriate.
- Keep your hands away from your face at all times in the laboratory.
- Clean the bench thoroughly before and after use and swab with disinfectant, such as 70% ethanol or Milton.
- Clean and sterilise all glassware involved in the experiment before and after use by placing in an autoclave or a pressure cooker for 15 minutes.
- When using Petri dishes and containers to grow microorganisms, only open very slightly and for the shortest possible time to avoid contamination.
- If using forceps or an inoculating loop, use a Bunsen flame to sterilise before and after use.

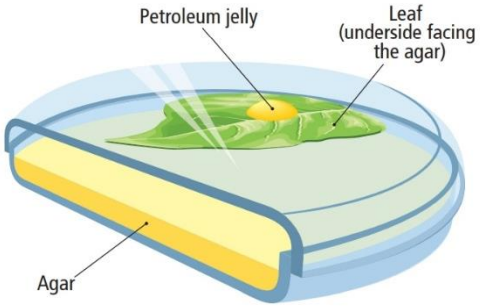
Practical activity: to investigate the growth of leaf yeast using agar plates and controls.

Apparatus/equipment:

- Malt
- Agar powder
- Beakers
- Hotplate/ heating equipment
- Disinfectant
- Petri dishes
- Ash leaves
- Ethanol
- Petroleum jelly
- Incubator
- Lab coat and safety goggles and gloves

Method:

- Follow aseptic technique as described above.
- Make up a 1.5% solution of **malt** agar (1.5 g agar in 100 ml distilled water along with a teaspoon of malt and sterilise by boiling the solution.
- Pour the malt agar into three Petri dishes and allow to set solid (~10 minutes)
- Obtain old Ash leaves from your local park. [NOTE: September/October is the best time of year to do this activity, as the leaf yeast have had the spring and summer months to reproduce on the leaves).
- Disinfect one of the leaves by rubbing with alcohol/Milton.
- Attach this leaf to the inside of the lid of one Petri dish using some petroleum jelly and ensuring the underside of the leaf is facing the agar.
- Attach the other leaf (not sterilised) to the inside of the lid of the other Petri dish.
- Ensure neither leaf is touching the agar.
- Leave a third Petri dish closed.
- Seal the dishes shut and store the dishes **upside down in the incubator set at 25˚C for 24 hours** and then turn them right side up for the remaining few days (4-6 days).

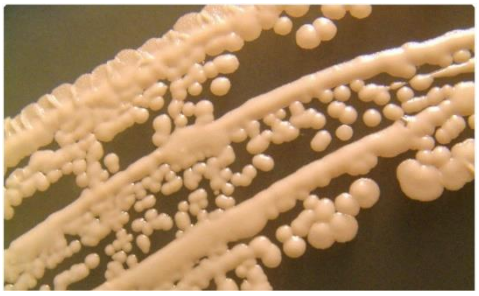


Result:

- Pink colonies form on the agar of the test.
- The controls showed no growth of leaf yeast.

Conclusion:

- Leaf yeast grow best on the underside of a leaf – as they are not washed off by rain or damaged by UV light.
- Leaf yeast live in larger numbers on older leaves as they have had the spring and summer months to grow and multiply.

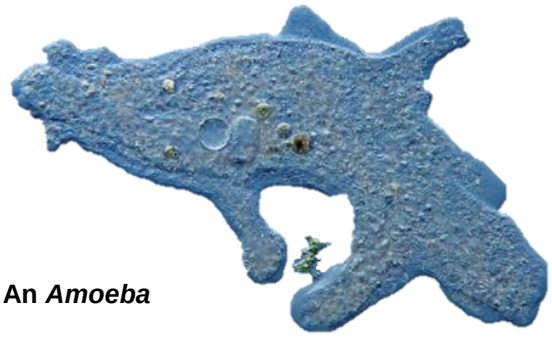


Pink leaf yeast growing on malt agar

CHAPTER 22: PROTISTA

Introduction

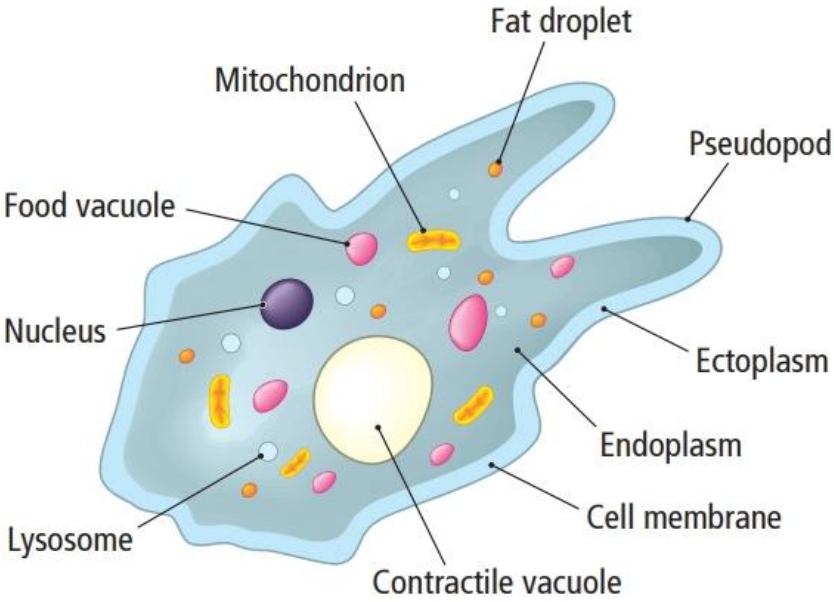
Kingdom Protista includes organisms such as algae, seaweeds and *Amoeba*.
All organisms of Kingdom Protista are **eukaryotic** in nature.
Amoeba



An *Amoeba*

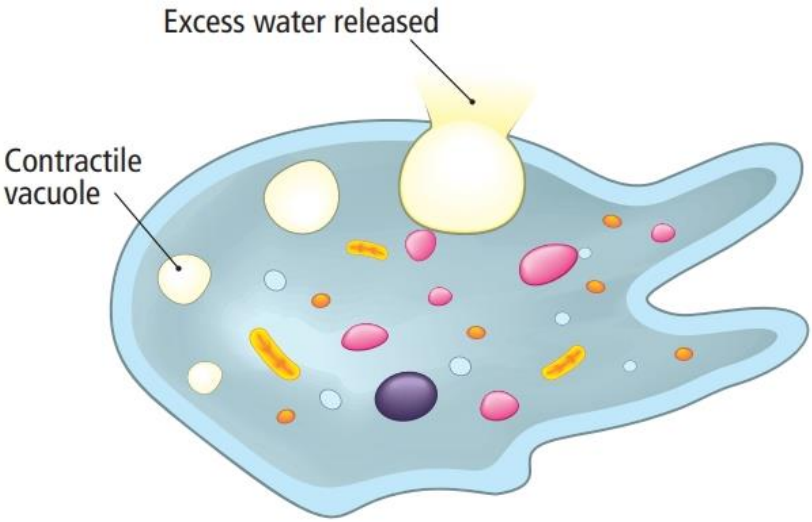
Structure

- Single celled
- No definite shape
- Cytoplasm is composed of a thin viscous outer layer called the **ectoplasm** and a fluid internal **endoplasm**.
- Possesses **pseudopods** for movement and feeding.
- Contains fat droplets and food vacuoles giving the cell a granular appearance.
- Possesses **contractile vacuoles** that carry out osmoregulation.



Osmoregulation in *Amoeba*

- Water is always moving into fresh water *Amoeba* due to osmosis.
- If this water is not removed from the cell, the *Amoeba* would burst.
- *Amoeba* removes this water by actively pumping (using ATP) water into a contractile vacuole.
- When the contractile vacuole reaches a certain size, it fuses with the cell membrane and releases the water outside the cell.



Osmoregulation in *Amoeba*

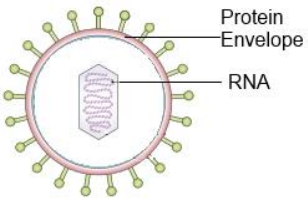
CHAPTER 23: VIRUSES

Introduction:

The study of viruses is called **virology**.

Living versus non-living?

- Virologists consider viruses to be simply infectious agents and not living. This is because:
    - They are not cells
    - They require living host cells in order to replicate themselves
    - They possess either DNA or RNA (never both)



Basic structure

All viruses are composed of an outer protein coat surrounding a piece of DNA or RNA. Some viruses possess an outer lipid membrane.

Shapes of viruses

1. Rod-shaped

- Viruses that are rod-shaped have proteins packaged tightly into a helix; e.g. tobacco mosaic virus.

2. Round

- Viruses that are round are composed of 20 identical proteins arranged into a spherical protein coat; e.g. rhinovirus, which causes colds and flu.

3. Complex

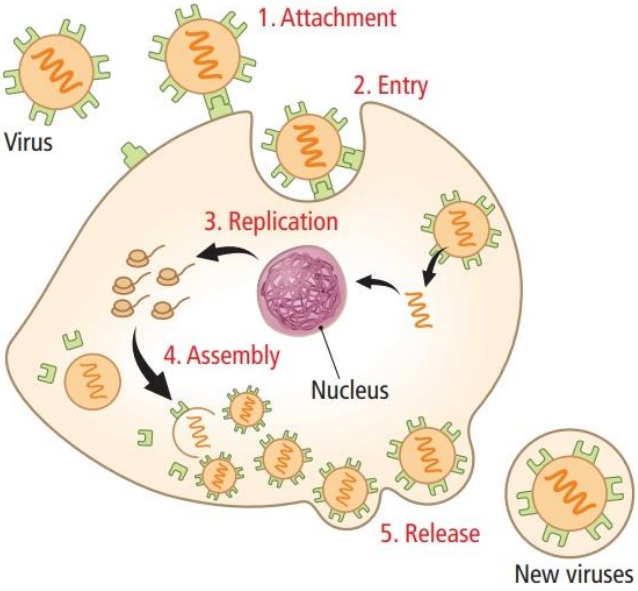
- Complex viruses can have various shapes. The most common is the bacteriophage – they infect bacteria.

Replication of viruses

Viruses are **obligate parasites** meaning they can only replicate using a living host cell.

Process of viral replication:

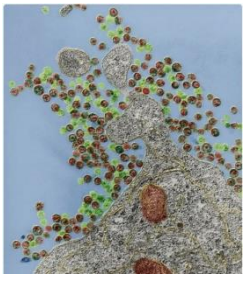
1. **Attachment**: the virus uses its external proteins to latch onto a target cell by joining to membrane proteins on the surface of the host cell.
2. **Entry**: either the entire virus moves inside the cell or it injects its nucleic acid into the cell.
3. **Replication**: the virus or the viral nucleic acid takes over the cell's nucleus and protein synthesis system (ribosomes). New viral proteins and new copies of viral DNA/RNA are made.
4. **Assembly**: The new DNA/RNA and viral proteins are put together in their correct positions to make new viruses.
5. **Release**: the newly formed viral particles are released from the cell either by budding out through the cell membrane or by causing the cell to burst.

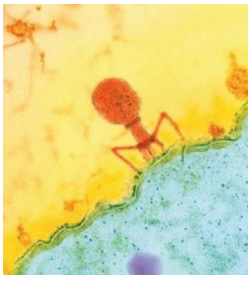


Economic importance of viruses

Beneficial effects: Viruses are regularly used in genetic engineering of various types of cells. They are used as vectors.

Harmful effects: Viruses can cause illnesses and disease, e.g. colds and influenza (rhinovirus), AIDS (HIV), hepatitis (hepatovirus), poliomyelitis (polio virus), measles (paramyxovirus), and chicken pox (varicella zoster virus); and in other organisms, conditions such as foot and mouth disease in sheep and mosaic diseases in plants (e.g. tobacco mosaic virus in the tobacco plant).





CHAPTER 24: KINGDOM PLANTAE

Introduction:

All flowering plants are called **angiosperms**. All plants are **multicellular** and **photosynthetic**
Plants are divided into two groups:

1. Monocotyledonous
2. Dicotyledonous

A cotyledon is an embryonic seed leaf.

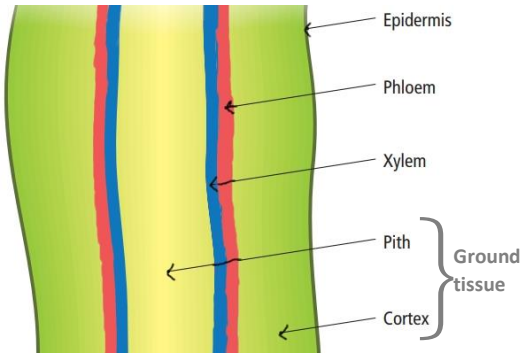
During early development of the plant, cotyledons are used as a food source or for photosynthesis (depending on the type of plant).

- **Monocotyledonous plants have one embryonic seed leaf.**
- **Dicotyledonous plants have two embryonic seed leaves.**

Tissue types in flowering plants:

1. **Dermal**: outer covering – functions in protection, gas exchange or absorption of water and minerals (depending on its location).
2. **Ground**: makes up the bulk of the plant – functions in photosynthesis, storage or support (depending on its location).
3. **Vascular**: composed of xylem and phloem tissue – functions in water and mineral transport (xylem) and food transport (phloem).
4. **Meristematic**: develops into the above three types of tissue.

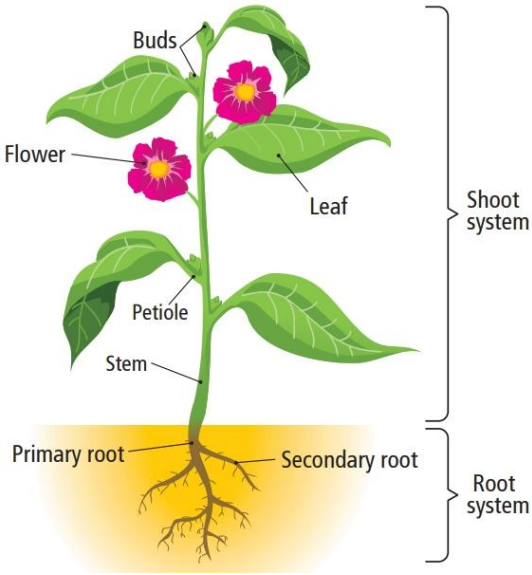
Longitudinal section of stem in dicots



Meristem: plant tissue composed of rapidly dividing unspecialised cells. These cells are dividing by mitosis.

Structure of the flowering plant

The diagram shows the structure of a typical flowering plant.
All plants are composed of a root system and shoot system.



Shoot system:

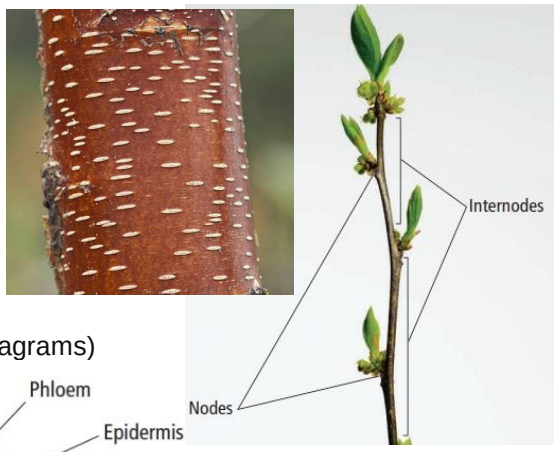
The shoot system consists of the following organs: stem, branches, petioles, buds, leaves, flowers, seeds and fruits.
Functions of the shoot system include:

- Photosynthesis
- Support
- Transport
- Sexual reproduction
- Food storage
- Gas exchange

Stem:
Stem functions mainly in support and transport – but can function in photosynthesis (herbaceous). The stem also functions in growth.

The stem is divided into **nodes** and **internodes**.

- Nodes are regions where branching occurs.
- Internodes are where no branching occurs.



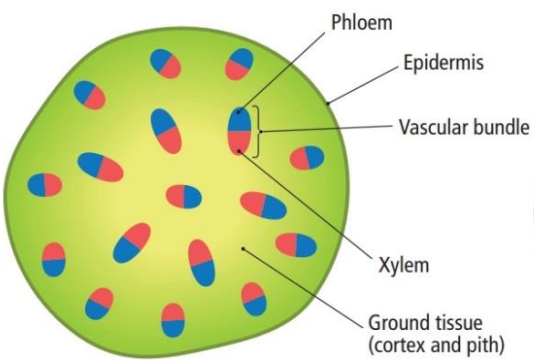
Stems also have **lenticels**.

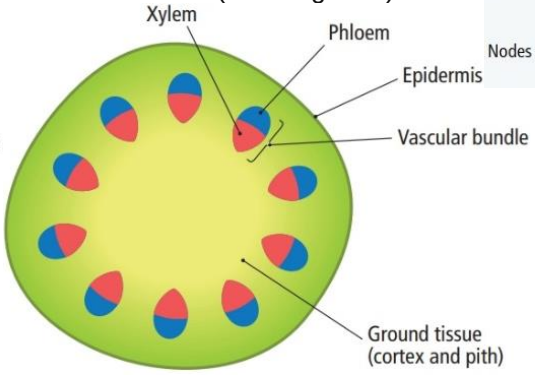
Lenticels:

- Lenticels are small pores on a stem that function in gas exchange.

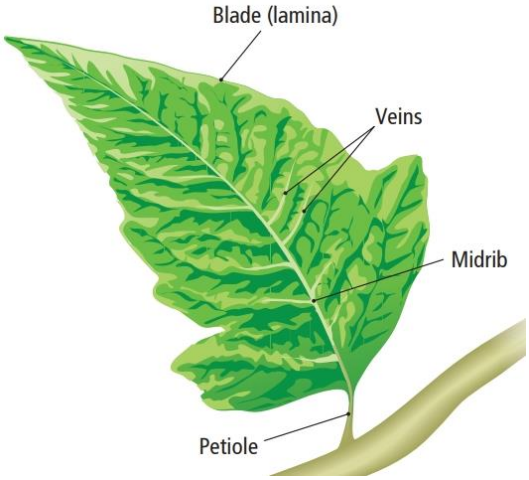
Internal structure of the stem:

The structure of the stem differs between monocots and dicots (see diagrams)





Leaf:



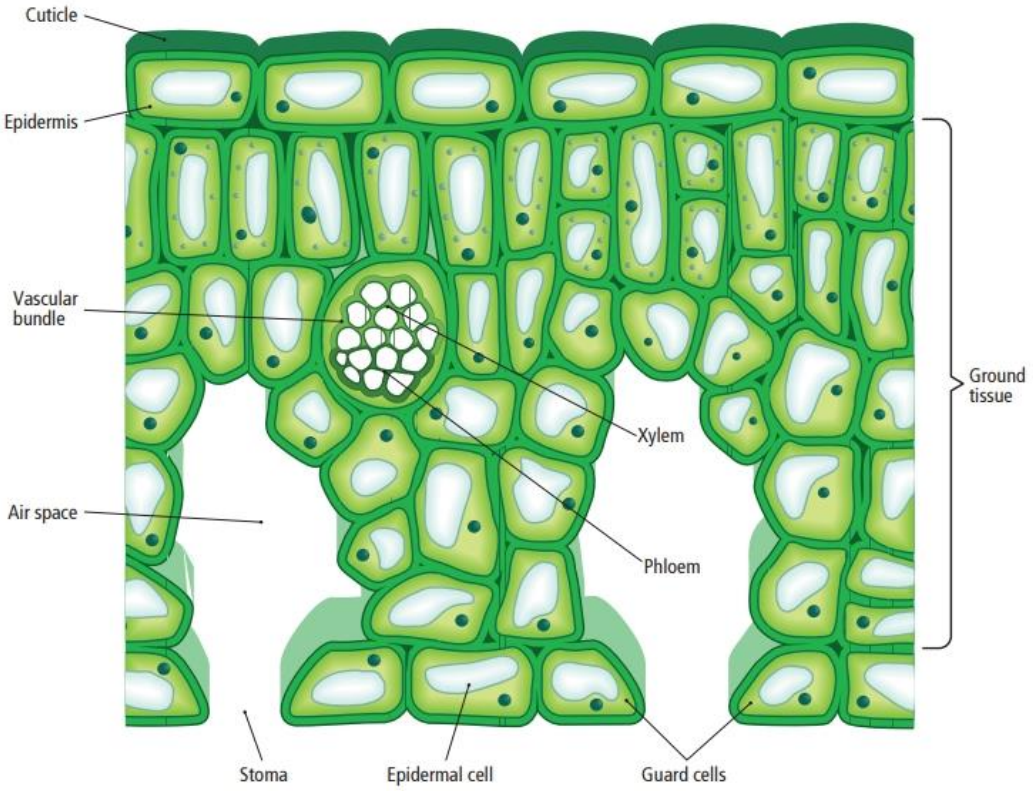
- Thin organ with a large external surface area.
- Organ that makes food for the plant and functions in transpiration.
- Contains the green pigment, chlorophyll.
- The outer dermal layer secretes a waxy cuticle to prevent excess water loss.
- Contains many air spaces that gives greater surface area for gas exchange.
- The cells that make up the upper layer of ground tissue within the leaf contain many chloroplasts that carry out photosynthesis.
- The lower epidermal layer has many pores, called stomata.
- Stomatal opening and closing is controlled by guard cells.

Leaf venation:
The veins on leaves are of two types:

Parallel:
- The veins run parallel, the entire length of the leaf; e.g. grass, tulip, daffodil.
- Most monocot plants have parallel venation.

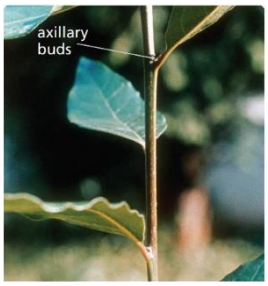
Net/Reticulate:
- The veins spread out from a central vein called the midrib (see above).
- Most dicot plants have net or reticulate venation.

Internal structure of leaf:
Functions of parts of the leaf:
- Cuticle: prevent excess water loss from the leaf.
- Epidermis: protection, outer covering of the leaf.
- Vascular bundle: transport of substances around the plant
- Air space: efficient gas exchange.
- Stoma: transpiration.
- Guard cell: control the opening and closing of the stoma.
- Ground tissue: photosynthesis in the leaf.



Bud:
There are three types of bud:
1. *Axillary bud*: present at the axil of leaf (between the stem and the petiole).
2. *Apical bud*: present at the tip of the plant or the tip of a branch.
3. *Adventitious bud*: present almost anywhere on plant - stem, branch, root, leaf.

A bud is an undeveloped shoot



Flower arrangement between monocots and dicots
- Monocots have flower parts arranged in multiples of three.
- Dicots have flower parts arranged in multiples of four or five.
- Monocot flower

Root system:

A network of underground branches that have various functions:

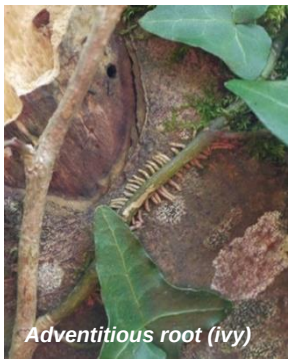
- Anchorage
- Absorbing water and minerals
- Transport of absorbed water and minerals to the shoot system
- Storage of food
- Support

Types of root system:

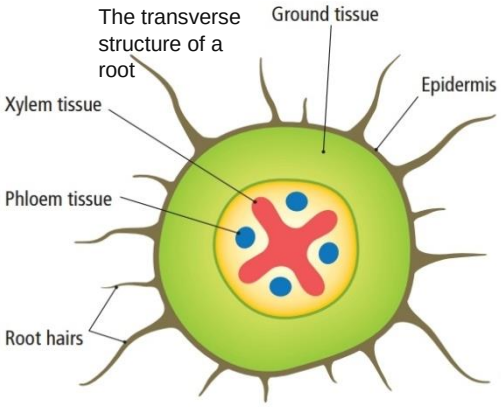
1. Tap root system: one main root growing downwards with small secondary roots; e.g. carrot, dandelion.
2. Fibrous root system: main roots of equal size; e.g. grass.
3. Adventitious root system: roots that grow in unusual places such as the stem or branches; e.g. bayan tree, ivy.

Tap root (dandelion)

Fibrous root (marigold)



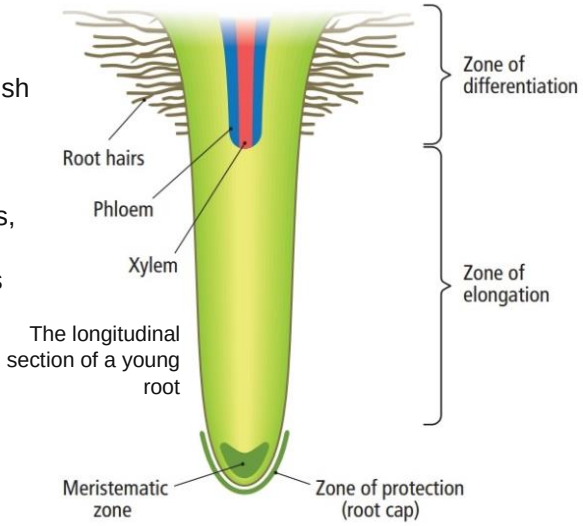
Adventitious root (ivy)



Root structure:

There are four zones of a young root.

1. Zone of protection: consists of a root cap, enabling the root to push its way through the ground.
2. Meristematic zone: consists of meristematic tissue that divides rapidly by mitosis, creating new root tissue.
3. Zone of elongation: area of the root affected by growth regulators, where the cells increase in size.
4. Zone of differentiation: area of the root where unspecialised cells start to become specialised, becoming ground, dermal and vascular tissues.

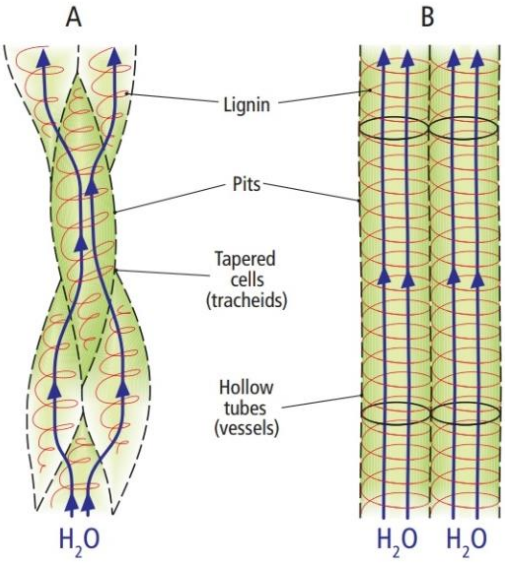


Vascular system

The vascular system in a plant is composed of two types of tissue: xylem and phloem.

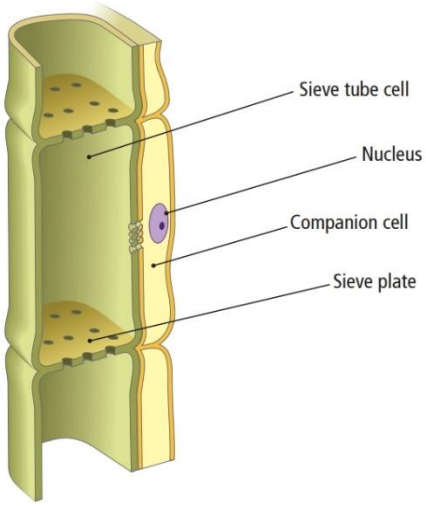
Xylem:

- A dead tissue – there is no cytoplasm and no nuclei in xylem tissue.
- Contains lignin that gives the tissue high strength.
- Transports water and dissolved minerals upwards.
- Composed of two types of cell: **tracheids** (structure A in the diagram) and **vessels** (structure B in the diagram).



Phloem:

- A living tissue.
- Transports food (in the form of sucrose) upwards and downwards, depending on where food is needed.
- Composed of **companion cells** and **sieve tube cells**.



Mandatory Activity: to prepare and examine microscopically a transverse section of a dicot stem at 100x and 400x.

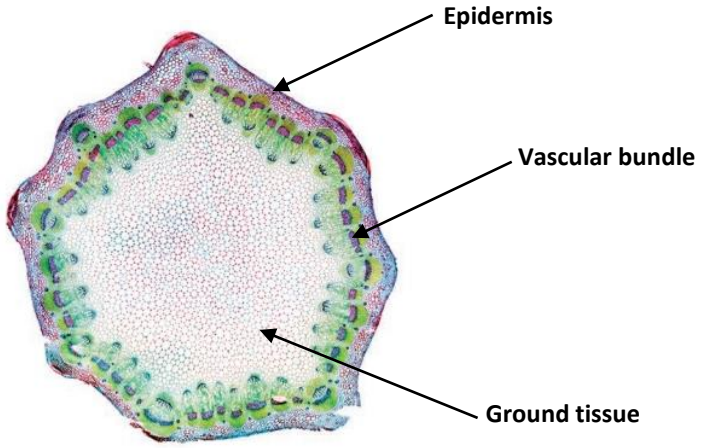
Equipment/apparatus:

- Geranium stem
- Backed blade
- Carrot
- Clock glass
- Paint brush
- Water
- Glass slide and coverslip
- Light microscope

Method:

- Cut a thin section of stem from an herbaceous stem such as a geranium.
- Cut a triangular shaped slit along the length of a carrot and place the internode stem into the slit.
- Wet a backed blade and carefully cut (cutting away from fingers) a few sections through the stem and carrot (avoid wedge-shaped sections).
- Transfer the sections to a clock glass of water using a paint brush.
- Place section on a glass slide with water (to prevent the section drying out).
- Carefully lower a glass coverslip from a 45º angle (this prevents the formation of air bubbles).
- View the section firstly under low and then under high magnification.
- Make a sketch of each and label.

Result:



Conclusion:

- Vascular bundles are arranged in a circle with the stem of dicot plants.

CHAPTER 25: NUTRITION IN THE FLOWERING PLANT

Introduction:

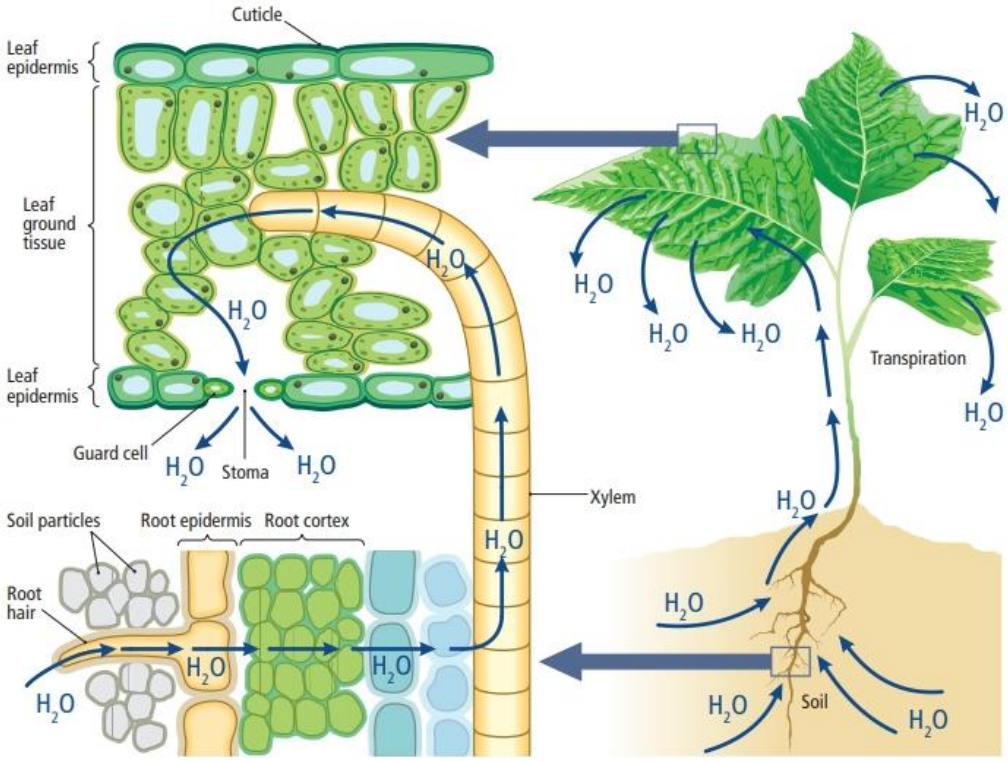
- **Nutrition is the way in which organisms obtain and use food.**

Water is a very important substance obtained and transported throughout plants.

- **Transpiration stream is the movement of water through a plant.**

Transpiration stream is maintained by:

1. Osmosis: is the movement of water from high water concentration to low water concentration across a semi-permeable membrane.
2. Root pressure: is the force exerted by water within the xylem tissue of the roots.
3. Transpiration: is the loss of water from the aerial parts of a plant.

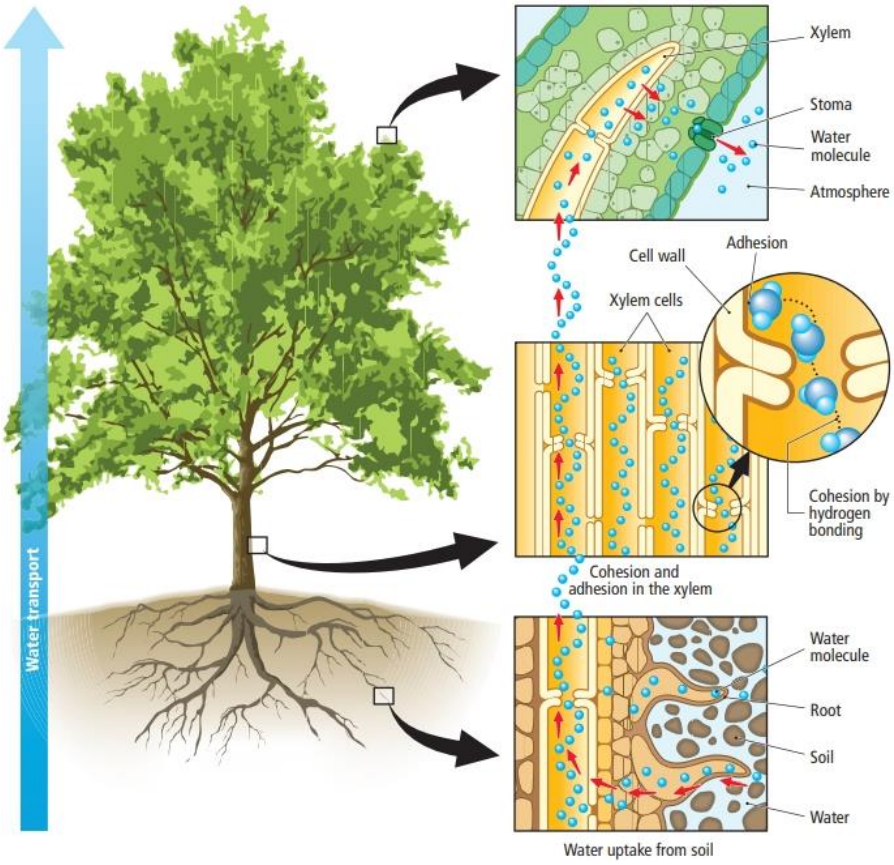


Water and mineral uptake:

- Water enters the root hairs by osmosis, moving from high water concentration to low water concentration.
- Minerals dissolve easily in water and move into the root by diffusion – either by passive transport or by active transport (requires ATP).
- Water moves across the ground tissue and into xylem tissue.
- Water is then transported up the plant.

Cohesion-tension model of water transport

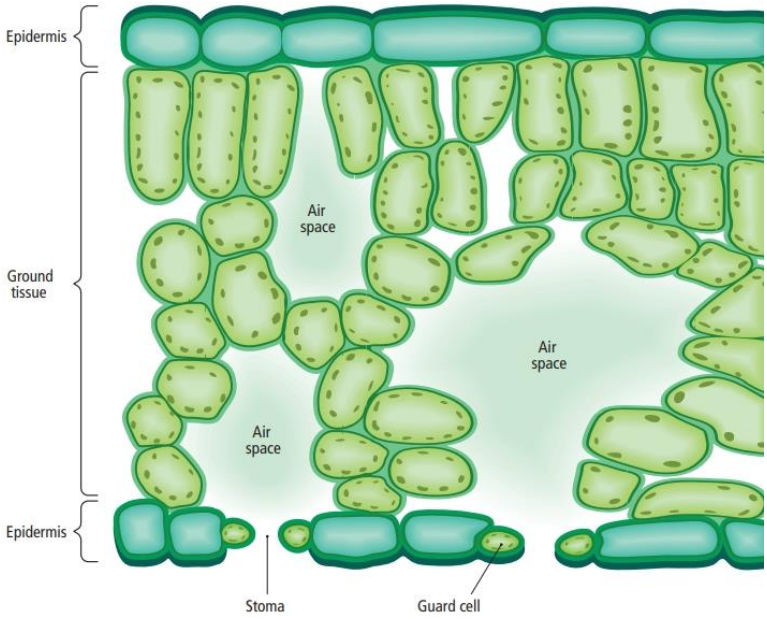
- **John Joly** and **Henry Dixon** were two Irish scientists who first proposed the cohesion-tension model of water transport.
- Water moving into the xylem tissue of the root causes a pressure build up – this is called **root pressure**.
- **Root pressure** contributes to the upward movement of water molecules.
- Water molecules have hydrogen bonds between them maintaining them in the liquid form – this is **cohesion** of the water molecules.
- Water molecules also tend to stick easily to the sides of the xylem vessels – this is called **adhesion** of the water molecules.
- **Transpiration** of the water molecules occurs mainly from the leaves – this pulls the column of water molecules upwards through the xylem, creating a **tension** in the water molecules.



Control of transpiration

Transpiration is controlled by:

- Waxy cuticle – prevents direct water loss from the surface of leaves.
- Stomata – controls the rate of transpiration by opening and closing.
- Lenticels – allows a small amount of transpiration but also allows oxygen in (for respiration) and carbon dioxide out (excretion).

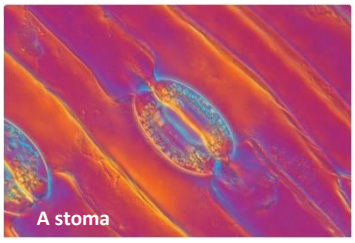


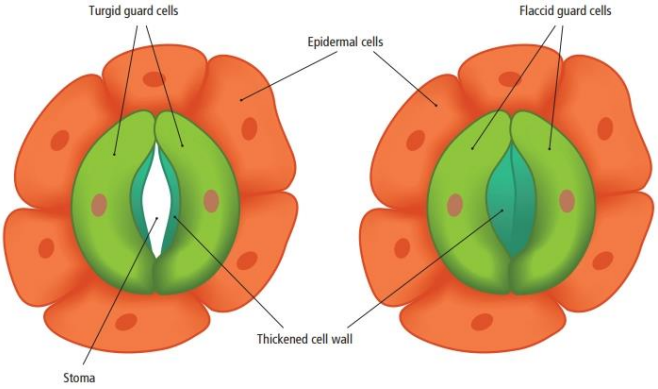
Carbon dioxide uptake

Carbon dioxide is mostly taken in from the atmosphere through **stomata** (see picture below), but can be taken from the mitochondria (that carry out respiration, producing CO_2) within the leaf cells (respiration).

Stomatal opening and closing

- Stomata open during the day and close during the night, in general
- High levels of water can cause the stomata to open – the plant tries to get rid of excess water
- Low water levels causes stomata to close – plant tries to conserve water
- Windy conditions can cause stomata to close – plant tries to conserve water
- Guard cells are the structures that control the opening – when they become turgid they curve away from each other – opening the stoma; when they lose water (become flaccid) they remain together and the stoma closes.
- Carbon dioxide levels are the main controlling factor in whether stomata open or close – high CO_2 levels cause the stomata to close and low levels of CO_2 cause them to open.





An open stoma (left) and a closed stoma (right)

Transport of the products of photosynthesis

- **Oxygen** – it is a by-product of photosynthesis and is either released into the atmosphere or is used by the leaf cells in respiration
- **Glucose** – the main product of photosynthesis, can be used immediately in respiration, stored in the cell as starch or converted to sucrose and transported to another area of the plant.

Modified plant food storage organs

Plants store food in mainly in the form of starch and can store it in different areas, depending on the species.

Root storage organ:
Tap roots, such as the carrot and parsnip are root storage organs where a lot of starch is stored.

Modified root (carrot)

Stem storage organ:
Potatoes and asparagus are examples of plants that can store starch in their stems.

Modified stem (potato tuber)

Leaf storage organ:
Onions and garlic store food in modified leaves – in the form of a tightly packed 'bulb'.

Modified leaf (onion)

Petiole storage organ:
Celery and rhubarb are examples of plants that store food in their petioles

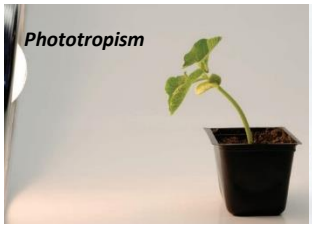
Modified petiole (celery)

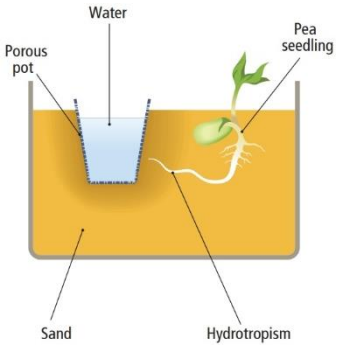
CHAPTER 26: RESPONSE IN THE FLOWERING PLANT

Introduction:

Plants have the ability to respond to their environment.

- **Stimulus: anything that causes a response in an organism.**
- **Response: reaction of an organism to a stimulus.**
- **Growth regulator: chemical that controls the growth of a plant.**
- **Tropism: growth response of a plant to a stimulus.**
- **Phototropism: growth of a plant in response to light.**
- **Geotropism: growth response of a plant to gravity.**
- **Thigmotropism: growth response of a plant to touch.**
- **Hydrotropism: growth response of a plant to water.**
- **Chemotropism: growth response of a plant to chemicals.**





Auxin

Auxin is a growth promoter. An example of an auxin is indole acetic acid (IAA).

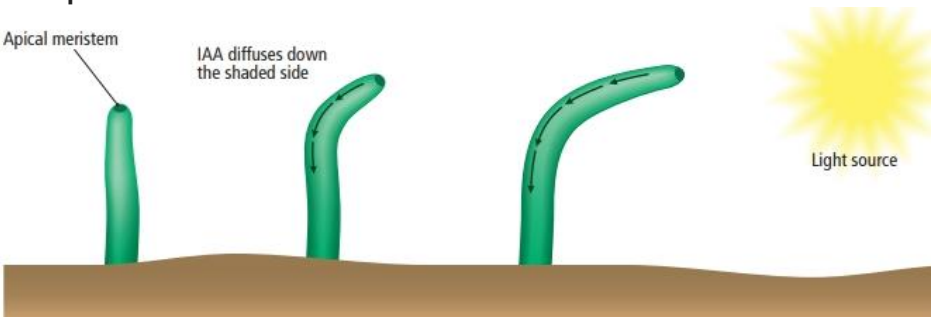
Production sites: Auxins are produced in the meristematic tissue of shoot tips and root tips.

Functions:

- Stimulates cell elongation
- Stimulates cell division
- Differentiation of cells into xylem and phloem
- Apical dominance
- Delaying of fruit ripening
- Phototropism and geotropism

Mechanism of a plant tropism – phototropism

- IAA (auxin) is produced in the apical meristem of the shoot.
- This diffuses down the shaded side of the stem.
- This causes cell elongation on the shaded side.
- The shaded side of the stem grows more quickly than the exposed side.
- This causes the shoot to bend towards the source of light.



Uses of plant growth regulators

- Naphthalene acetic acid (NAA) is used as a commercial rooting powder.
- Ethene is used as a ripening agent for fruit.

Plant adaptations for protection:

Anatomical adaptations:

- Epidermis – protects against pathogens entering the plant.
- Guard cells – protect against excess water loss.
- Some plants have bark – to protect against herbivores.
- Cacti have evolved to have no leaves (to protect against water loss) and spikes (to protect against herbivores).

Chemical adaptations:

- Corn lily produces a toxin called cyclopamine to protect itself against herbivores
- Many plants produce alkaloids that protect against insects and herbivores.
- Poison ivy produces a chemical called urushiol that protects against herbivores.
- Conifers produce monoterpenes that protect against many insect herbivores.

Practical activity: to investigate the effect of IAA on the growth of plant tissue.

Apparatus/chemicals:

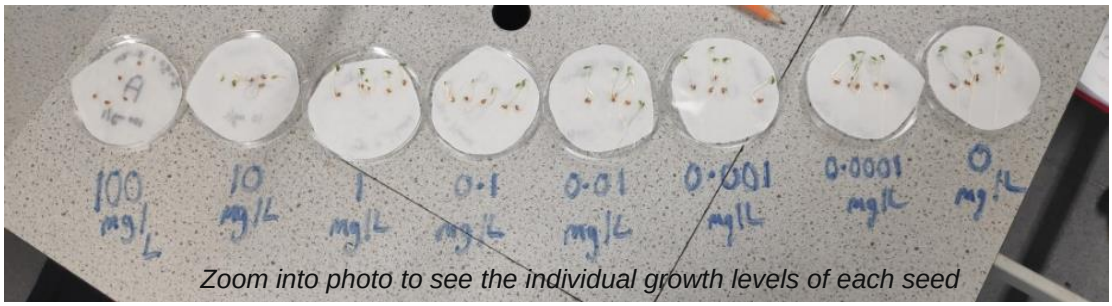
- Cress seeds
- Petri dishes
- Cotton wool
- Filter paper
- Acetates with printed grid
- IAA stock solution (100 mg/L)
- Ethanol
- Water
- Droppers
- Tissue paper
- Tape
- Lab coat, gloves & safety goggles

Method:

- Set up 8 Petri dishes labelled A-H.
- Make up a stock IAA solution (100mg/L) by dissolving IAA in 2 ml of ethanol. Then make up to 1L using water.
- Add 10 ml of the stock IAA to dish A.

Serial dilution:

- Take 1 ml from A and place in dish B, then add 9 ml water to dish B and mix.
- Using a new pipette take 1 ml from dish B and place in dish C.
- Add 9 ml distilled water to dish C and mix and keep repeating this procedure for dishes D to G.
- Place 9 ml distilled water dish H (control).
- In the lids of each dish place 5 radish seeds in a straight line.
- Place a filler paper on top of each set of seeds in the lid of each dish.
- Place cotton wool on top of each filter paper.
- Pour the contents of each dish into the cotton wool in the lid of each dish.
- Close each dish, tape them together (ensure the seeds are all lined up in the same orientation) and leave the dishes on their sides (so that shoots and roots have room to grow) in a 25 °C incubator for approx 2 weeks
- At the end of 2 weeks, observe results (see photo below) and carefully remove each seedling and measure the lengths of each root and shoot from each seed.



Zoom into photo to see the individual growth levels of each seed

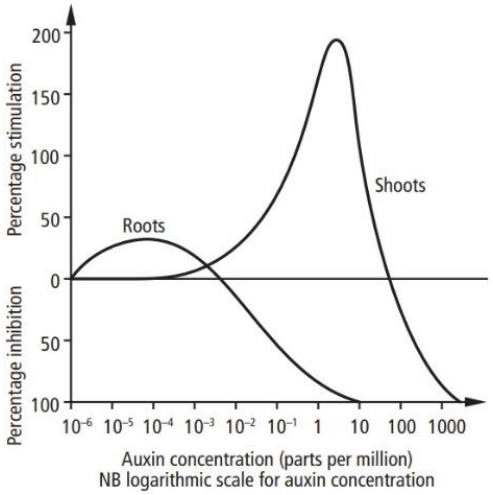
Results:
The following results tables (below) should be filled in: (NOTE: The first row in each table is Dish H (**control**), the second row is Dish G and so on

Note, in the dishes with high concentrations of IAA, there should be little to no growth. Therefore, there will probably be zeros in the last row of each table (dish A)

To calculate percentage stimulation or inhibition, use the following formula:

$$\text{\% stimulation or inhibition} = \frac{\text{Avg length} - \text{Avg length of control}}{\text{Avg length of control}} \times 100$$

Plot and draw a graph of **% stimulation & inhibition** (vertical axis) against **IAA (auxin) concentration** (horizontal axis) – your graph should look something like the one below (taken from LC Higher Level Biology Examination Q14 (b), 2005).



Concentration of IAA		Length of roots (mm)					Average length (mm)	Percentage stimulation or inhibition
ppm	mg/L	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5		
0 (control)	0 (control)							
10^{-4}	0.0001							
10^{-3}	0.001							
10^{-2}	0.01							
10^{-1}	0.1							
$10^{0} = 1$	1							
10^{1}	10							
10^{2}	100							

Concentration of IAA		Length of roots (mm)					Average length (mm)	Percentage stimulation or inhibition
ppm	mg/L	Seed 1	Seed 2	Seed 3	Seed 4	Seed 5		
0 (control)	0 (control)							
10^{-4}	0.0001							
10^{-3}	0.001							
10^{-2}	0.01							
10^{-1}	0.1							
$10^{0} = 1$	1							
10^{1}	10							
10^{2}	100							

CHAPTER 27: VEGETATIVE PROPAGATION

Introduction:

- **Vegetative propagation** is a type of asexual reproduction in plants.
- **Asexual reproduction** is the production of a new individual from one parent.

There are **two** main types of vegetative propagation:

1. Natural vegetative propagation
2. Artificial vegetative propagation

1. Natural Vegetative Propagation

There are four types of natural vegetative propagation.

(i) ***Stem propagation*****:**

New plants can arise from stems of certain species of plants, e.g. the strawberry plant. Long branches grow from its stem that 'run' along the surface of the soil – they are called "**runners**". When they are far enough away from the parent plant they grow a shoot and root and a new strawberry plant is produced.

(ii) ***Root propagation*****:**

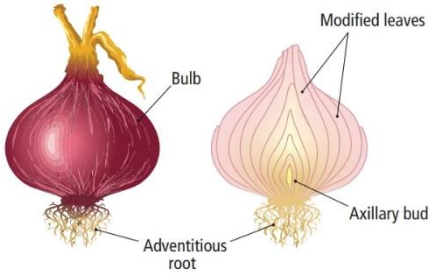
New plants can arise from the roots of certain plants, e.g. the raspberry plant. Shoots grow from the roots under the ground. These are called **root sprouts** or "**suckers**". They eventually develop into a new plant.

(iii) ***Leaf propagation*****:**

This type of propagation is rare. It occurs in the Devil's backbone plant (native to Madagascar). Tiny leaflets develop along the edge of a main leaf and then fall off and develop into a new plant.

(iv) ***Bud propagation*****:**

Buds are new growth points found on all plants. Some buds are capable of producing a new plant, e.g. onion plant.



2 Artificial vegetative propagation

There are four sub-types of artificial vegetative propagation. These are used by farmers and horticulturists to propagate plants rapidly.

(i) ***Cutting propagation*****:**

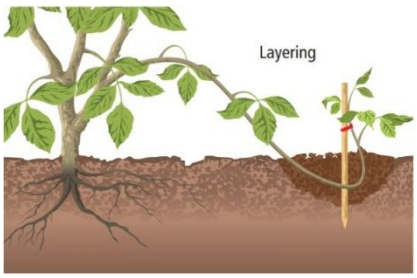
Cutting involves removing a small piece of a parent plant and growing it with the use of various growth regulators, e.g. rooting powders such as IBA or NAA (see Chapter 26).

(ii) ***Layering propagation*****:**

The stem is bent down into the soil nearby and growth regulators added; used on climbing plants such as *Clematis*.

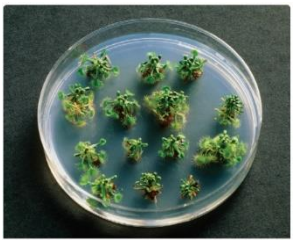
(iii) ***Grafting propagation*****:**

Shoot system (**scion**) of one plant is attached to the root system (**stock**) of another plant; used for producing large brightly coloured roses or eating apples, both of whose own natural stocks are weak. A strong grafted stock helps to produce a better crop.



(iv) ***Tissue culture propagation (micropropagation)*****:**

Growing a large number of **plantlets** in nutrient medium from small tissue samples. It is very expensive and labour intensive.

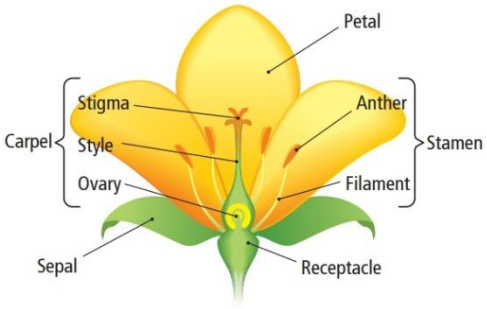


CHAPTER 28: SEXUAL REPRODUCTION IN THE FLOWERING PLANT

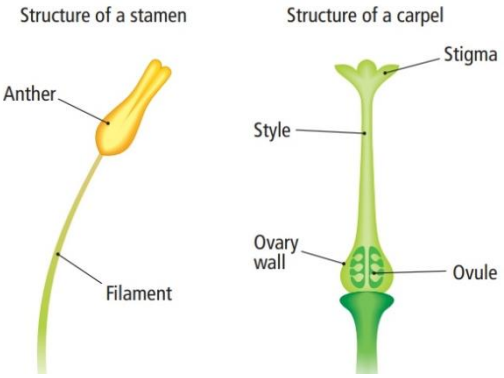
Introduction:

Sexual reproduction: forming a new organism from two parents.

Structure of the flower



- *Receptacle*: supports the flower.
- *Sepal*: thick, green, leaf-like structures that protect the developing flower when it is in bud form.
- *Petals*: large and brightly coloured in animal-pollinated plants; small and green in wind-pollinated plants.
- *Stamen*: male organ consisting of two parts:
  1. *Anther*: pollen formation
  2. *Filament*: supports the anther in a position where pollen will be easily transferred
- Carpel: female organ consisting of three parts:
  1. *Stigma*: pollen is trapped by the stigma
  2. *Style*: supports the stigma in a position where pollen will be trapped
  3. *Ovary*: where the eggs and the ovules develop

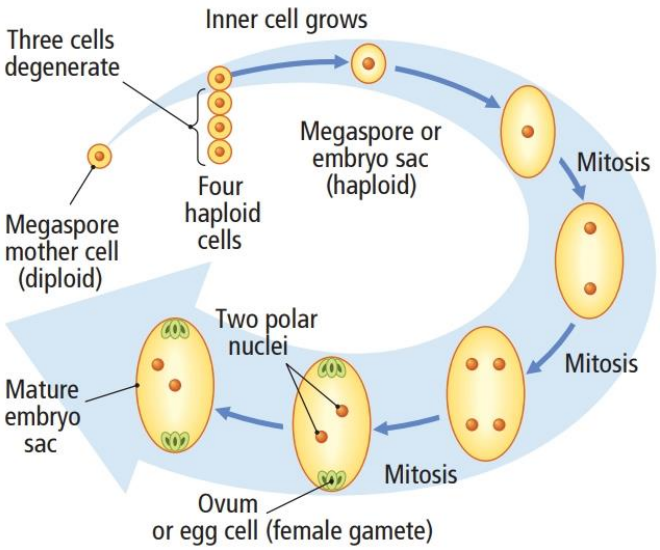


Gamete Formation

- *Gamete*: haploid sex cell
- The male gamete is **one of the sperm nuclei that develops from the generative nucleus** (see below). The generative nucleus is carried by the pollen grain. There are two nuclei within each pollen grain:
  1. Tube nucleus
  2. Generative nucleus
- The female gamete is the egg cell that is present in the embryo sac of the ovule

Embryo Sac Development

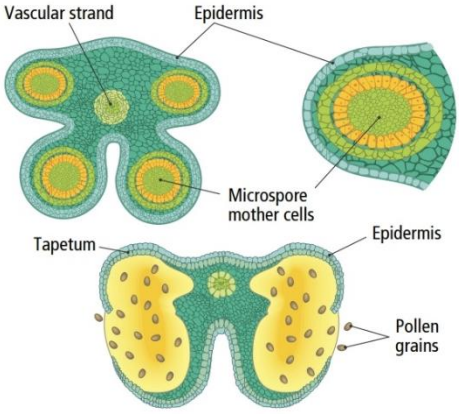
- Within the ovary are a number of **ovules**.
- Each ovule is composed of two outer wall called **integuments**.
- The **micropyle** is a small opening in the integuments allowing the pollen tube to enter.
- The inner layer of each ovule has a layer called the **nucellus** – which nourishes the developing embryo sac.
- Within each ovule are a number of diploid cells – one of which develops further to become the **megaspore mother cell.**
- The megaspore mother cell divides by **meiosis** to produce 4 haploid cells.
- Three of these haploid cell die and **one survives** to become the **embryo sac.**
- The embryo sac (megaspore) grows and the haploid nucleus divides by **mitosis** to form 2 haploid nuclei.
- The two haploid nuclei undergo **mitosis** a second time forming 4 haploid nuclei.
- A **third** and final round of **mitosis** occurs to produce **8 haploid nuclei**.
- The 8 haploid nuclei take up the positions as shown.
- Cell membranes and a thin cell wall form around 6 of the haploid nuclei.

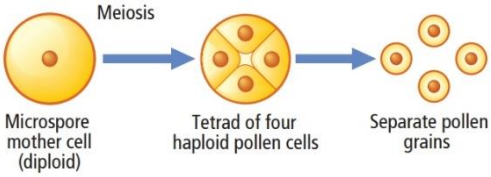


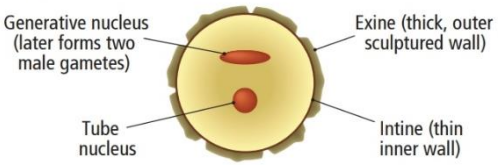
- The two remaining haploid nuclei remain free and are called **polar nuclei.**
- The **egg cell** is present at the bottom of the embryo sac.

Pollen Grain Development

- The anther has 4 chambers called **pollen sacs**, where the millions of pollen grains develop and mature.
- Each pollen sac has an outer fibrous layer (dermal tissue) that protects the pollen sacs.
- Inside the protective layer is the **tapetum** – which nourishes the developing pollen grains.
- On the innermost layer of the pollen sac is diploid cells (containing two sets of chromosomes) called **microspore mother cells**.
- Microspore mother cells divide by **meiosis** (process of halving the number of chromosomes present in a cell) to produce four immature, haploid (single set of chromosomes) cells, called a **tetrad**.
- The immature, haploid pollen grains (**microspores**) then mature over time and develop a tough outer wall called an **exine** and a softer inner wall called the **intine**.
- **Mitosis** of the haploid nucleus in each microspore occurs, producing a pollen grain with two haploid nuclei:
  - **Tube nucleus**
  - **Generative nucleus**





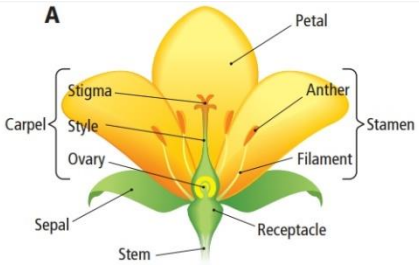


Pollination

- **Pollination is the transfer of pollen from anther to stigma of a flower of the same species**

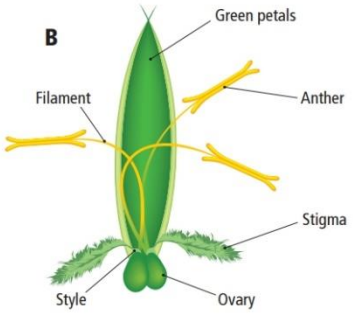
There are two types:

1. **Self-pollination**: where a flower allows pollen to fertilise the egg cell within the ovary of the same plant – disadvantageous to species as resulting seeds less likely to form healthy plant
2. **Cross-pollination**: where a flower transfers pollen from anther to stigma of different plant of same species – more advantageous as greater variation is shown



Pollination Methods

- *Wind*: pollen is produced in large amounts by the flower and is usually small, light and smooth to allow easy transfer by wind, e.g., grasses
- *Animal*: pollen is produced in relatively small amounts grains are larger and stickier and they are usually transferred by insects (examples include dandelions, daisies, tulips, roses)



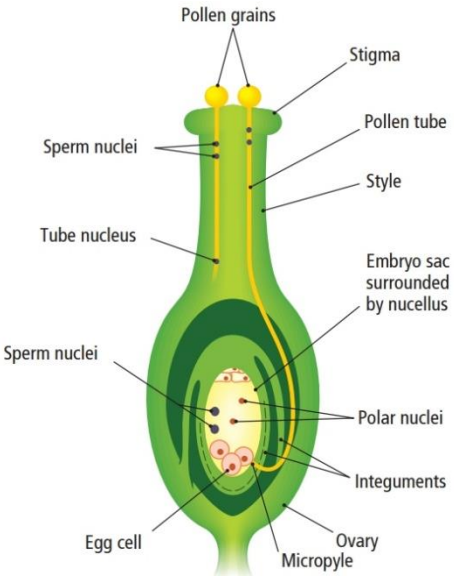
Fertilisation

- **Fertilisation: union of the male and female gametes to form a diploid zygote**

Once the pollen grain is trapped by the stigma, the **pollen tube** forms by action of the tube nucleus. The generative nucleus enters the pollen tube and divides by mitosis to form two haploid nuclei called **sperm nuclei.**
The sperm nuclei enter the embryo sac and '**double fertilisation'** occurs:

1. One fertilises the **egg** – **diploid** (2n) **zygote** results.
2. Other fuses with the two **polar nuclei** to form **triploid** (3n) **endosperm** cell which goes on to divide by mitosis and absorbs nutrients and functions as a food store.

An adaptation of angiosperms to life on dry land is pollen tube formation as no external water is required for fertilisation to occur



Seed Formation

- The ovule develops into the seed
- Integuments become the testa (seed coat)
- The diploid zygote becomes the plant embryo
- The embryo develops further into the radicle, plumule, and cotyledon(s)
- Triploid endosperm nucleus divides repeatedly by mitosis to produce many cells that swell with food

Endospermic Seeds v Non-Endospermic Seeds

- *Endospermic seed*: the plant embryo increases in size and only absorbs some of the endosperm, e.g. Corn
- *Non-Endospermic seed*: the plant embryo increases in size absorbing all of the endosperm in the process e.g. Broad bean

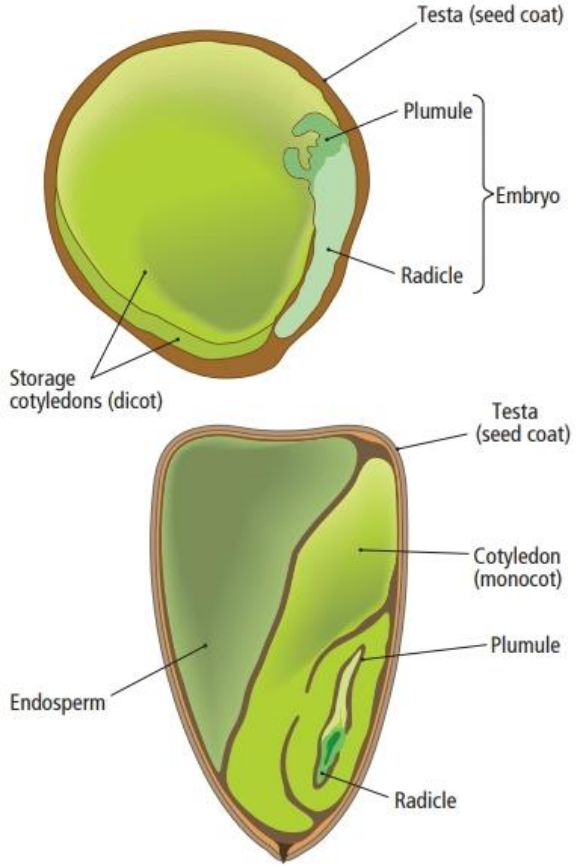
Monocot versus Dicot Seeds

Monocot seeds:

- Tend to be endospermic (e.g. corn)
- One cotyledon
- When germinating, the food is obtained mainly from the endosperm
- Tend to have parallel venation in their leaves (e.g. grasses)

Dicot seeds:

- Tend to be non-endospermic (e.g. broad bean)
- Two cotyledons
- When germinating the food is obtained mainly from the cotyledons
- Tend to have net venation in their leaves (e.g. broad bean)



Fruit Formation

Fruits are formed from the ovary under the influence of auxins
Fruits can be classified into two groupings:

1. True fruits – those that form from the ovary (e.g. oranges)
2. False fruits – those that form from the receptacle (e.g. apples)

Advantages of fruit formation for flowering plants

- Fruits protect seeds
- Fruits attract animals to eat them
- Fruits help in the dispersal of seeds away from the parent plant

Seed Dispersal

Dispersal is the transfer of the seeds away from the parent plant

Advantages of dispersal are:

- Avoid competition
- Increases chances of surviving winter
- Colonise new habitats
- Increase the number of the species

Seeds can be dispersed in one of four ways:

1. Wind
2. Water
3. Animal
4. Self-dispersal

1. **Wind dispersal:**
   Seeds are generally very light and usually have some anatomical adaptation (hairs, wings) that enables them to be transported a long distance from parent plant, e.g. dandelions, sycamore.
2. **Water dispersal:**
   Seeds are usually enclosed within an air-filled fruit that is capable of floating, e.g. water lillies, coconuts.
3. **Animal dispersal:**
   Seeds may be enclosed within a sticky fruit, e.g. burdock, goosegrass
   Seeds may be enclosed by a fleshy fruit, e.g. strawberries, blackberries
4. **Self-dispersal:**
   Seeds are enclosed within a pod that explodes open when it becomes dry, e.g. pea pods

Dormancy

Dormancy is a resting period in which the seed undergoes no growth and has a very low metabolism

Advantages of dormancy include:

- Allows plant to avoid harsh conditions of winter
- Gives embryo time to fully develop
- Provides extra time for dispersal

Biotechnological Issues

- Seedless fruits
- Larger fruits
- Vegetable production
- Ethene as a ripening agent
- Dormancy of seeds in agriculture and horticulture

Seedless Fruits & Larger Fruits

Parthenocarpy is the process of growing fruit that do not have seeds

Parthenocarpy is carried out in two ways:

1. Breeding of plants in such a way as to produce seedless fruit (pollination occurs but no fertilisation)
2. Use of auxins – auxins are sprayed onto plant and stimulate fruit formation

Parthenocarpy is linked to production of larger fruits as auxins causes fruits to become much bigger than normal during development
Genetic engineering has also been used in producing larger fruit, e.g. tomatoes

Ethene as a Ripening Agent
Ethene (C_2H_4) is gas that causes fruit to ripen (turn from green to characteristic colour)

Germination

Germination is the regrowth of the embryo, following a period of dormancy, when the environmental conditions are suitable.

Factors necessary for germination:

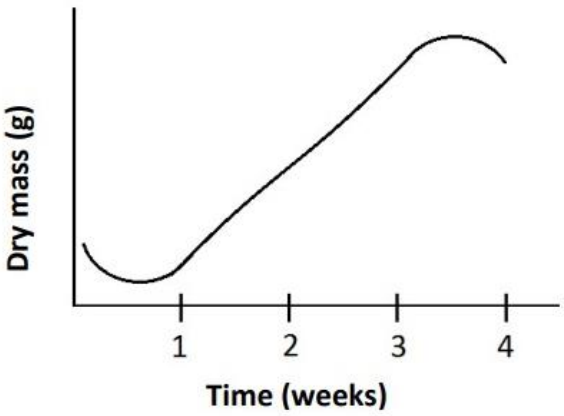
1. Water
2. Oxygen
3. Suitable temperature

Digestion and Respiration in Germination

Digestion of food substrates is required during germination as food stores in the form of oils and starch need to be mobilised and converted to usable forms – like fatty acids and glycerol and glucose.

Respiration is required to produce ATP as the embryo is growing and so anabolic reactions are occurring all the time (anabolic reactions require large amounts of ATP).

Dry mass refers to the mass of the germinating seed/seedling. It decreases in the first part of germination (due to nutrients being used up in respiration), but then increases after the seedling begins to photosynthesise.



Stages of Seedling Growth

There are two ways in which a seedling grows after germination:

1. Cotyledons remain below the soil (**hypogeal germination**), e.g. broad bean
    - The epicotyl (part of the embryo just above the cotyledons but below the plumule) grows rapidly leaving the cotyledons behind in the soil and pushing the plumule above the soil to photosynthesise.
2. Cotyledons move above the soil (**epigeal germination**), e.g. sunflower
    - The hypocotyl (part of the embryo just below the cotyledons but above the radicle) grows rapidly pushing the plumule and the cotyledons above the soil to photosynthesise.

Mandatory Experiment: Investigate Factors Affecting Germination

Equipment and Method:

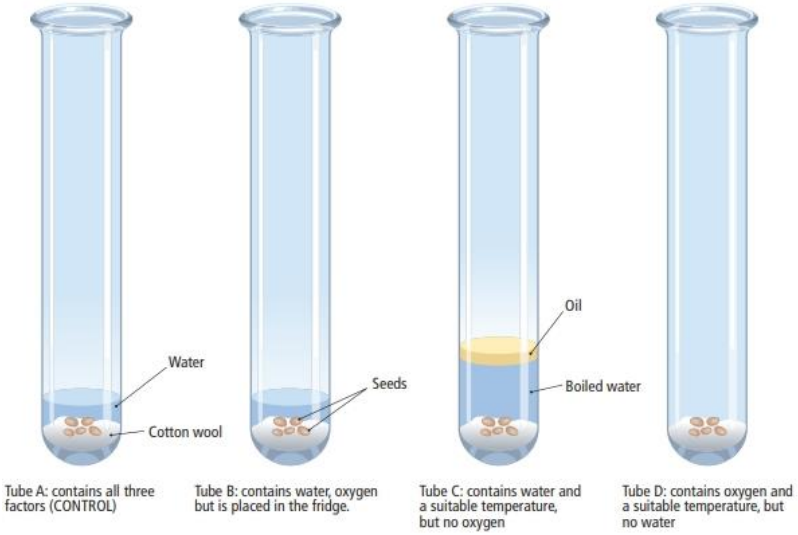
- Set up 4 test tubes and treat them as described in the diagram below.

Results:

- There should be no growth in tubes B, C and D.
- There should be growth in tube A (control)

Conclusion:

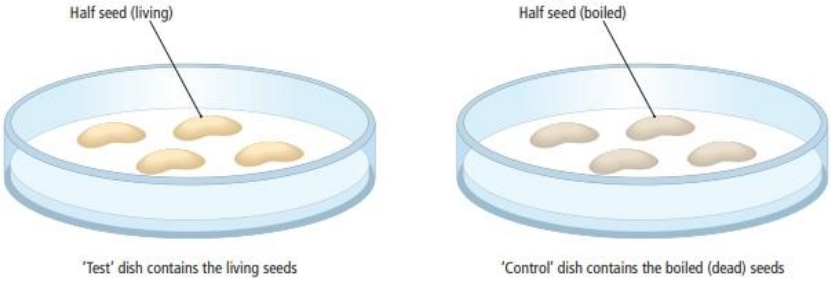
- Water, oxygen and a suitable temperature are required for germination and growth.



Mandatory Experiment: To Show Digestive Activity of a Germinating Seed

Equipment and Method:

- Set up apparatus as shown in the diagram below.
- Leave both dishes in an incubator at a suitable temperature for a few days.
- After a few days incubation, flood each dish with iodine.
- Allow iodine to sit for a couple of minutes and then pour off the excess.



Results:

- The area under the seeds in the control dish should turn blue black
- The area under the seeds in the test dish should remain red-yellow colour

Conclusion:

- Germinating seeds digest starch.
- Boiled seeds do not digest starch due to the digestive enzymes having been denatured.

CHAPTER 29: HOMEOSTASIS

Introduction:

- **Homeostasis is the maintenance of a constant internal environment.**

Temperature regulation in plants

If a plant is too hot (e.g. during the summer), then it will increase transpiration in an effort to cool down.

Temperature regulation in animals

1. **Endotherms**: animals whose internal temperature remains constant despite environmental temperature changes; e.g. mammals and birds.
2. **Ectotherms**: animals whose internal temperature changes with environmental temperature; e.g. insects, lizards, amphibians, fish.

Endotherms

When they are cold:

- *Shivering* – rapid contraction & relaxation of skeletal muscles generates heat.
- *Vasoconstriction* – narrowing of the capillaries in the skin directs blood to core areas helping to conserve heat.
- *Piloerection* – piloerector muscle contracts causing hair to stand up away from the skin, trapping a layer of air.
- *Thyroxine secretion* – the hormone thyroxine increases metabolism thereby generating heat.

When they are too hot:

- *Sweating* – release of sweat onto the surface of the skin via sweat glands cools the body down by evaporation.
- *Vasodilation* – widening of the capillaries close to the surface of the body thereby releasing heat.
- *Rapid breathing* – exchanges more air with the lungs helping to release heat from the body.

Ectotherms

Ectotherm activity levels depend directly on the temperature of their environment. If they need to warm themselves up, they will often sit in direct sunlight (e.g. lizards bathing in the sun).

pH regulation

pH levels must be tightly regulated in all living organisms. This enables enzymes to function at their optimum level (see Chapter 9).
In animals blood pH must be kept at 7.4. The acidity of the blood is controlled by the lungs and the kidneys of animals. See Chapter 35 and 37.
Plants rely on the soil being the correct pH to enable full growth and reproduction.

Glucose level regulation

Glucose levels in animals must be kept at a concentration of approximately 1 g/L. If it drops too low, coma and death can result. If glucose levels rise too high it can cause damage to blood vessels and nerves. Glucose levels are controlled by two hormones: insulin (lowers blood glucose) and glucagon (raises blood glucose).

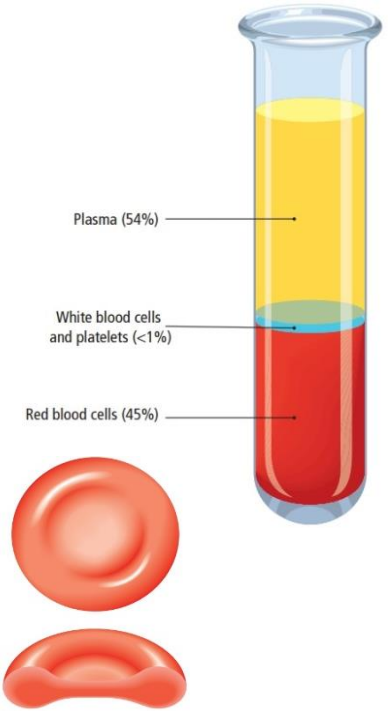
Osmoregulation

Osmoregulation is the maintenance of the correct amount of water in the body. The kidneys will excrete excess water and conserve water if the body is lacking water.

CHAPTER 30: BLOOD

Blood components and their functions

Blood is a tissue composed of a mixture of components:
1. Plasma
2. Red blood cells
3. White blood cells
4. Platelets



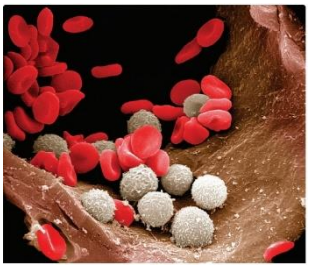
Plasma

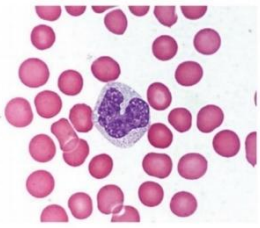
Plasma is the liquid portion of the blood composed mostly of water. It makes up approximately 54% of blood volume. It functions in transporting cells and substances all around the body.

Red blood cells

Red blood cells are also called erythrocytes. They are made in the bone marrow of long bones. They function in transporting oxygen around the body. They have a red pigment called **haemoglobin**. Haemoglobin is a protein with an iron atom at its centre. Red blood cells have a biconcave shape (see diagram). This enables them to transfer oxygen more efficiently as it gives a greater surface area for diffusion. Red bloods cells do not have a nucleus. This enables them to carry more haemoglobin and hence oxygen and enables them to be smaller cells capable of squeezing through very narrow capillaries.

White blood cells

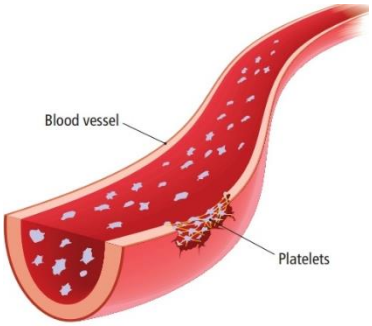




There are many types and sub-types of white blood cells. They are also produced in the bone marrow and mature in various organs and tissues throughout the body. They function in keeping the body free of pathogens (disease-causing organisms).
For this chapter you only have to know about two types:
Monocytes – develop into more specific white blood cells called macrophages and phagocytes.
Lymphocytes – develop into a variety of sub-types of lymphocytes, some of which are responsible for producing antibodies.

Platelets

Platelets are also known as thrombocytes (yellow cells in the picture below). They are also produced in the bone marrow and function in blood clotting. Deep vein thrombosis can result if blood clots form in a vein – usually in a large vein in the leg.



Blood groups

The ABO blood group system is the most important blood grouping system used.

There are four blood groups:
- A
- B
- AB
- o

The ABO blood system

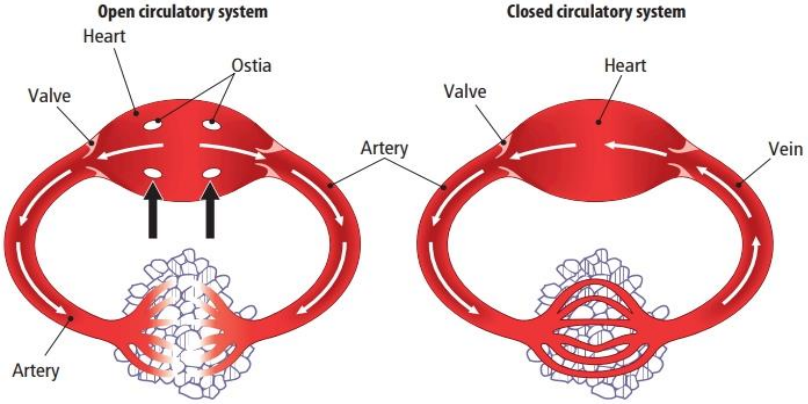
Blood type (genotype)	Type A (AA, AO)	Type B (BB, BO)	Type AB (AB)	Type O (OO)
Red blood cell surface proteins (phenotype)				

Another blood grouping system used is called the Rhesus system. Everyone is either Rhesus positive (Rh+) or Rhesus negative (Rh–). If a person is Rhesus positive, then they possess the Rhesus factor on the surface of their red blood cells; if a person is Rhesus negative, then they do not possess the Rhesus factor on their red blood cells.
It is possible for a foetus to have a different blood type to its mother. It is important that the blood of the foetus does not mix with the blood of the mother. The placenta ensure this (see Chapter 41). If they do mix, then a haemolytic reaction can occur where antibodies are produced against either the mother's red blood cells and/or the baby's red blood cells.

CHAPTER 31: HUMAN CIRCULATORY SYSTEM

Introduction

The human circulatory system demonstrates the organisational complexity of the human. It is made up of a number of different tissues organised into organs such as the heart, arteries, arterioles, capillaries, venules and veins that are present in almost every area of the body.



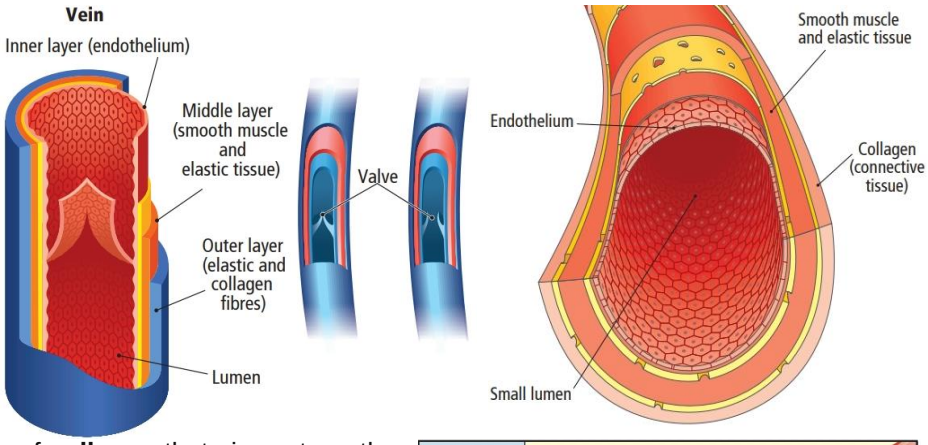
Open versus closed circulatory systems:

- *Open Circulatory System*: blood is pumped from a simple heart and flows out of blood vessels and around tissue cells of the organism, e.g. invertebrates, such as insects. The blood is then returned to the heart via small pores called ostia.
- *Closed Circulatory System*: blood flows around the body enclosed in blood vessels and does not leaves the blood vessels, e.g. human.

Structure of the human circulatory system

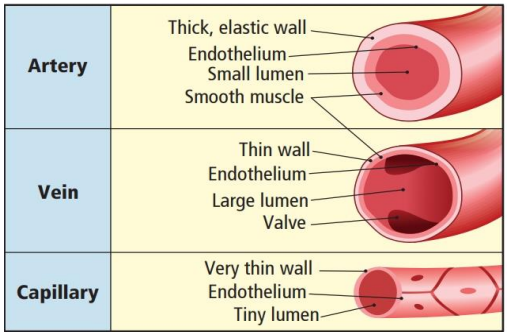
The human circulatory system consists of:

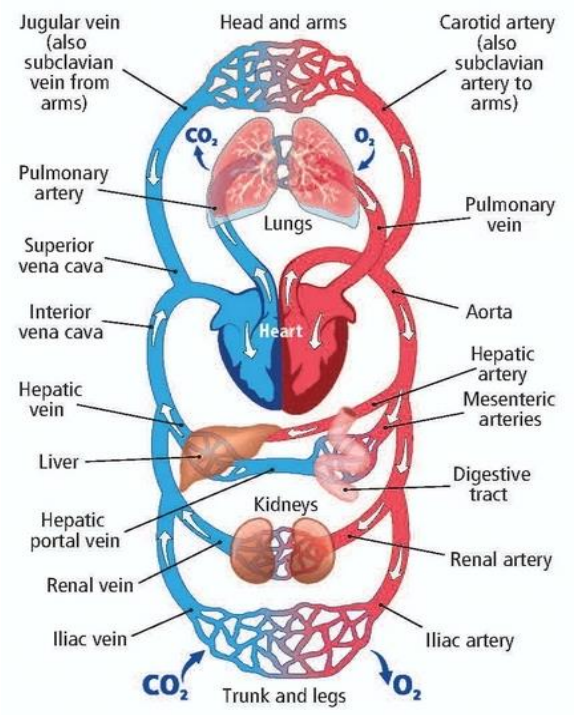
- Blood vessels
- Heart
- Blood



Blood vessels:

- **Arteries**: blood vessels that carry blood away from the heart in pulses. It has a thick wall and small lumen. The thick wall of arteries contains a tough outer layer of **collagen** that gives strength to the artery that supports the pressure the blood is under from the heart. It also contains a layer of **smooth** (involuntary) **muscle** that contracts pushing blood along. The internal layer of the artery is composed of a layer of cells called the **endothelium**.
- **Veins**: blood vessels that carry blood towards the heart in an even flow. They have thin walls, a large lumen and valves. Blood pressure in veins is much lower than arteries, hence the thinner wall. They also have smooth muscle to push blood along in one direction and have valves to prevent back flow of blood.





- **Capillaries**: blood vessels with walls one cell thick that carries blood from arterioles to venules through tissues, releasing nutrients and taking away wastes.

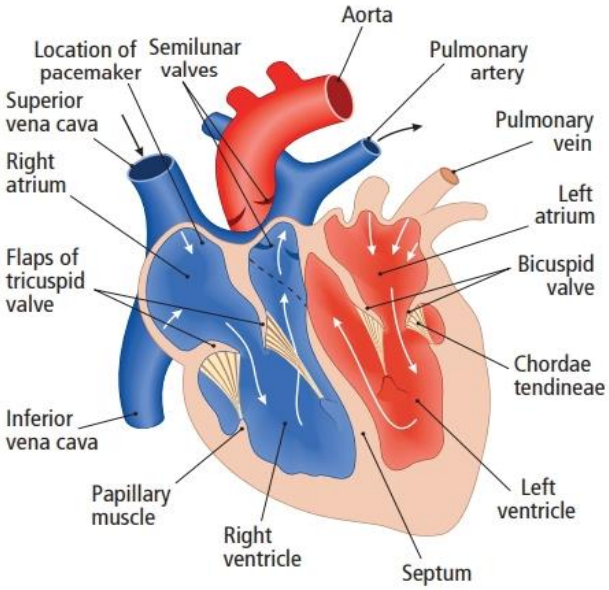
Systemic and pulmonary circuits

The human circulatory system consists of two blood circuits: the systemic circuit and the pulmonary circuit. This is why the human circulatory system is described as a **double circulatory system**. The **systemic circuit** carries blood to all the major organs of the body, except the lungs.
The lungs have their own blood circuit, called the **pulmonary circuit**.
The diagram shows all the arteries and veins emanating from, and returning to, the heart and internal organs.

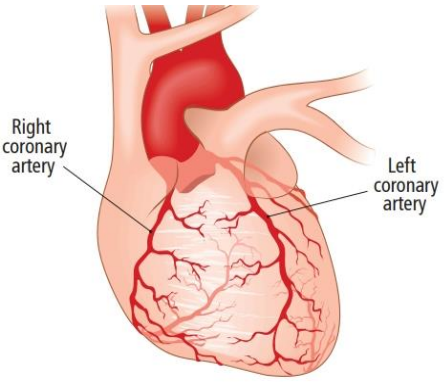
Portal system

A portal system is a network of blood capillaries that connect two organs or tissues, e.g. hepatic portal system connects the small intestines to the liver via the hepatic portal vein.

Structure of the heart



- **Aorta**: largest artery in the body carrying oxygenated blood *away* from the left side of the heart to all the major organs of the body (except the lungs).
- **Coronary artery**: (figures below) is a small branch of the aorta and provides the heart muscle with blood – delivering nutrients and oxygen and removing wastes, such as CO_2.
- **Pulmonary artery**: carries deoxygenated blood *away* from the right side of the heart to the lungs to excrete carbon dioxide and absorb more oxygen.
- **Pulmonary vein**: carries oxygenated blood *towards* the right-hand side of the heart from the lungs.
- **Left atrium**: upper left chamber of the heart that receives blood from the lungs and contracts pumping blood into the left ventricle.
- **Bicuspid valve**: allows one-way flow of blood from the left atrium into the left ventricle – prevents back-flow of blood.
- **Chordae tendineae**: connective tissue holding the heart valves in position.
- **Left ventricle**: strongest of the four heart chambers and pumps blood into the aorta. It has a thick wall because it pumps blood all around the systemic circuit.
- **Septum**: divides the heart into two separate pumps.
- **Right ventricle**: Pumps deoxygenated blood to the lungs via the pulmonary artery.
- **Papillary muscle**: contracts preventing the heart valves prolapsing backwards.
- **Inferior vena cava**: carries deoxygenated blood from the lower half of the body back to the heart.
- **Tricuspid valve**: allows one-way flow of blood from the right atrium to the right ventricle – preventing back-flow.



- **Right atrium**: upper right chamber of the heart that receives blood from the vena cavae and contracts pumping blood into the right ventricle.
- **Superior vena cava**: carries deoxygenated blood from the upper half of the body back to the heart.
- **Semilunar valves**: allow one-way flow of blood out of the heart – prevent back-flow of blood into the heart.

The cardiac cycle

The cardiac cycle is controlled by the **pacemaker** – which is located in the wall of the right atrium. The pacemaker is a type of **nervous tissue**.

Atrial contraction:

- Pacemaker sends an electrical signal to the cardiac muscle of the atria.
- The atria contract
- Blood moves into the ventricles through the heart valves

Ventricular contraction:

- The electrical signal that came from the pacemaker then travels onto the cardiac muscle of the ventricles.
- The ventricles contract.
- Blood is pushed out of the heart via the semilunar valves

The cardiac cycle (detailed)

The cardiac cycle is controlled by two pacemakers in the heart:

- The sino-atrial node (SA node) located in the wall of the right atrium
- The atrio-ventricular node (AV node) located in the septum between the right atrium and ventricle.

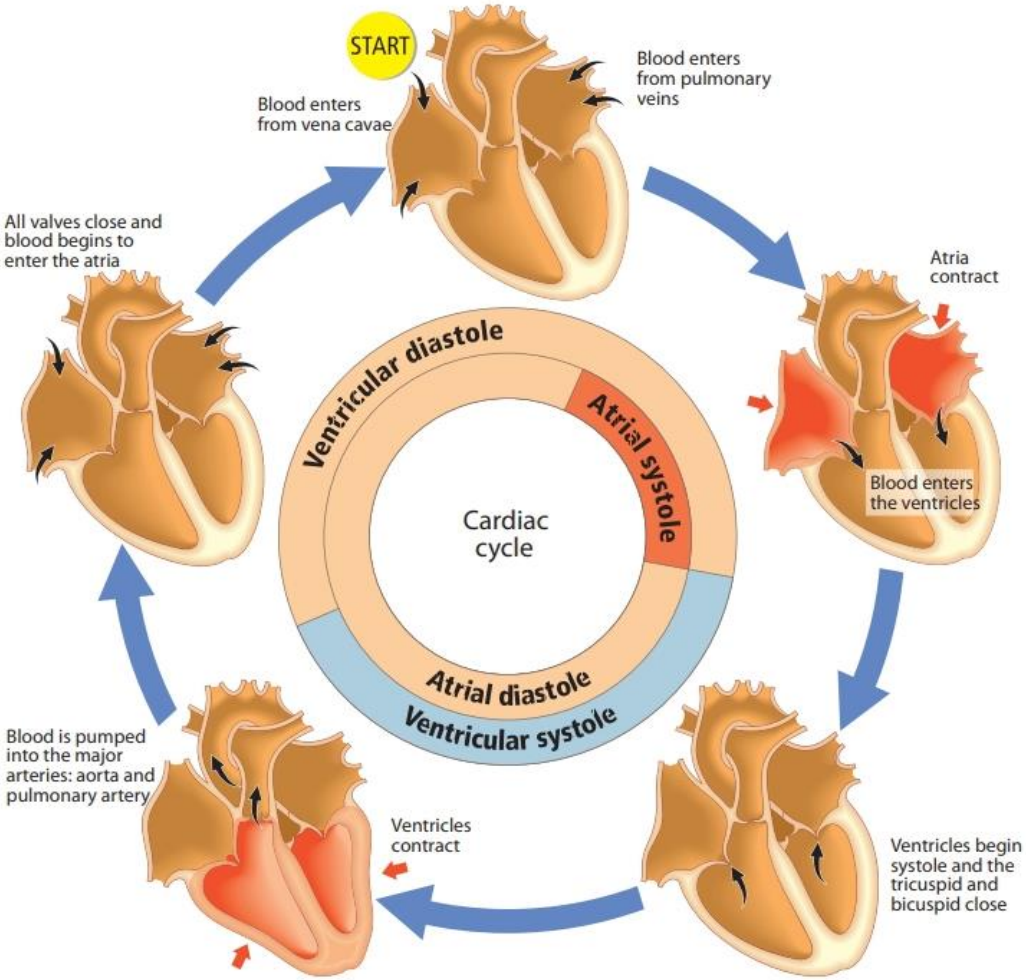
Both pacemakers are types of **nervous tissue**.

Atrial systole and ventricular diastole:

- Atria receive blood from the major veins (vena cavae and pulmonary veins).
- The SA node sends an electrical signal to the cardiac muscle of the atria.
- The atria contract (**systole**).
- The bicuspid and tricuspid valves open.
- Blood flows into the ventricles, which are not contracting (**diastole**).

Ventricular systole and atrial diastole:

- Electrical signal reaches the AV node, which relays the signal onto the cardiac muscle of the ventricles.
- The ventricles contract (systole).
- The bicuspid and tricuspid valves close and the semilunar valves open.
- Blood flows out of the heart via the aorta and pulmonary artery.



Heart sounds

- The heart sounds are described as a 'lub-dub'.
- The 'lub' is the sound of the bicuspid and tricuspid valves closing.
- The 'dub' is the sound of the semi-lunar valves closing.

Pulse and blood pressure

- **Pulse: expansion of an artery as blood passes through.**

The pulse is caused by the heart contracting and pushing blood along in spurts.

- **Blood pressure: force blood exerts on the walls of blood vessels.**

Blood pressure is measured as two values: systolic pressure and diastolic pressure. Normal blood pressure is 120/80 mmHg, where mmHg stands for millimetres of mercury. Blood pressure is measured using a **sphygmomanometer**.

Effects of smoking, diet and exercise on the circulatory system

Smoking:

- Cigarettes contain many addictive chemicals, of which the most important is nicotine.
- Nicotine raises heart rate and blood pressure putting a strain on the circulatory system.

Diet:

- A diet high in saturated fats increases blood pressure and the risk of atherosclerosis (or hardening of the arteries).
- Salt in the diet also raises blood pressure by increasing thirst and water intake.

Exercise:

- Exercise stimulates a temporary increase in heart rate and blood pressure.
- It strengthens the heart and promotes healthy blood vessels.

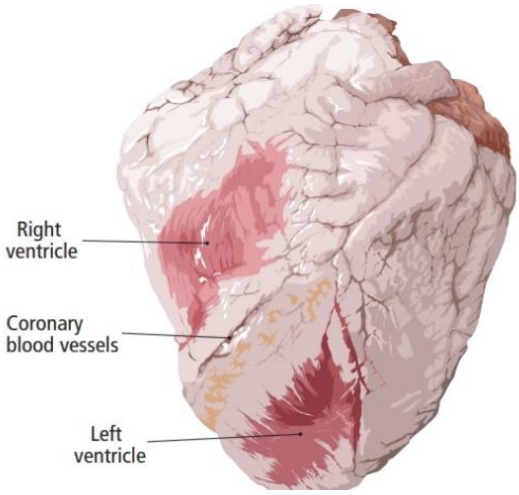
Practical activity: to dissect, display and identify an ox's or a sheep's heart.

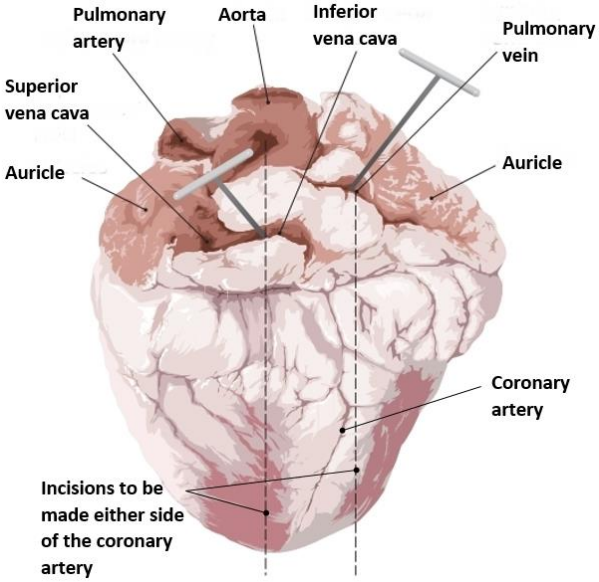
Equipment:

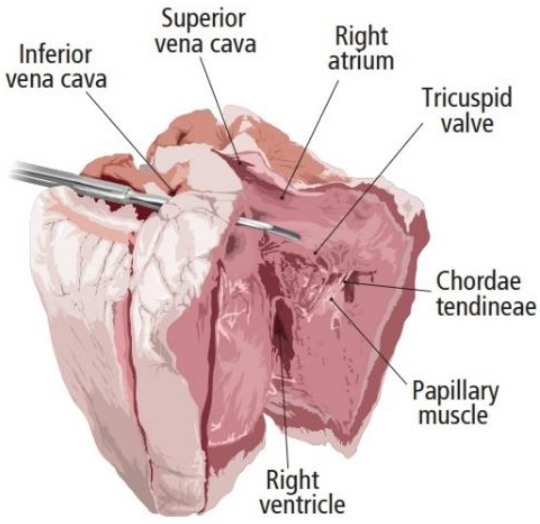
- Dissection board/tray
- Seeker
- Scissors
- Scalpel
- Tweezers/forceps
- Gloves
- Lab coat
- Safety goggles
- Sheep's heart
- Pins and labels

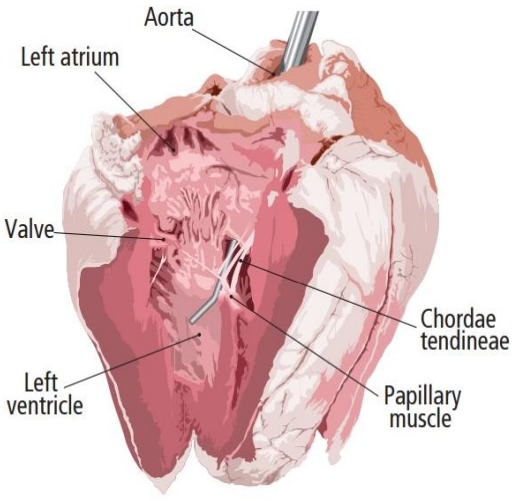
Method:

- Wash the heart (to get rid of any blood).
- Place the heart on a dissection tray.
- Distinguish between the left and right sides.
- The left side is firmer than the right.
- Distinguish between the front and back sides.
- The back side of the heart is flatter.
- Identify the coronary artery on the front.
- Identify the four major blood vessels at the top of the heart.
- Examine the flaps of tissue on top of the heart (auricles).
- Sketch a labelled diagram of the external structure of the heart.
- Make two incisions either side if the coronary artery into the atria and ventricles.
- Open up the incisions and identify the four chambers of the heart, tricuspid and bicuspid valves, papillary muscles and chordae tendineae.
- Insert a probe down through the pulmonary artery (should come through into the right ventricle).
- Cut down through the pulmonary artery and identify the semilunar valve.
- Insert another probe down through the aorta (should come through into the left ventricle).
- Cut through the wall of the aorta and identify the other semilunar valve.
- Label as many internal structures as you can find using pins and labels.









Practical activity: to investigate the effect of exercise on pulse rate.

Equipment:

- Stopwatch
- Heart rate monitor (optional)
- Exercise equipment (optional)

Method:

- Pulse rate is the number of times the artery expands per minute and because it is caused by the heart beating, it is a direct measure of heart rate.
- Find your pulse by placing your second & third fingers on your wrist/neck.
- Measure your pulse rate three times by counting the number of beats in one minute while at rest.
- Calculate your average resting pulse rate.
- Walk slowly for 5 min and measure your pulse rate again. Repeat twice.
- Walk briskly for 5 min and measure your pulse rate once again. Repeat twice.
- Finally, run for 5 min and measure your new pulse rate. Repeat twice.
- You can also see the effect of vigorous exercise on pulse rate by running as fast as you can for 3 – 5 min.
- The result of the investigation is that exercise causes heart/pulse rate to increase – this is due to the increased need for oxygen and the increased need to get rid of the carbon dioxide produced as a result of exercise.
- NOTE: a quicker way of measuring pulse rate is by counting the number of beats in 10 seconds and multiplying by six (this is actually a more accurate way of measuring pulse rate immediately after exercising).
- Fill in the results table below.

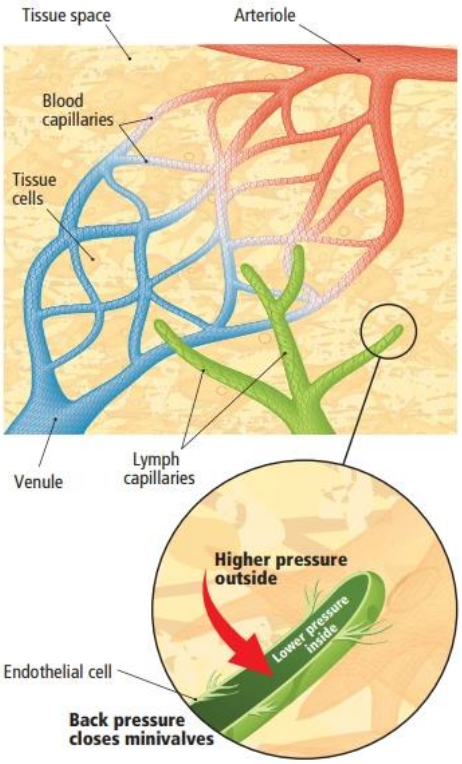
Results table:

	Trial 1	Trial 2	Trial 3	Average rate
Resting (sitting down)				
Gentle exercise (e.g. walking)				
Moderate exercise (e.g. jogging)				
Intense exercise (e.g. running)				
Vigorous exercise (e.g. sprinting)				

CHAPTER 32: HUMAN LYMPHATIC SYSTEM

Introduction:

The lymphatic system is closely associated with both the immune system and the circulatory system.



Structure of the lymphatic system:

- Lymph
- Lymph vessels
- Lymph nodes
- Spleen
- Tonsils
- Adenoids
- Lacteals
- Thymus gland

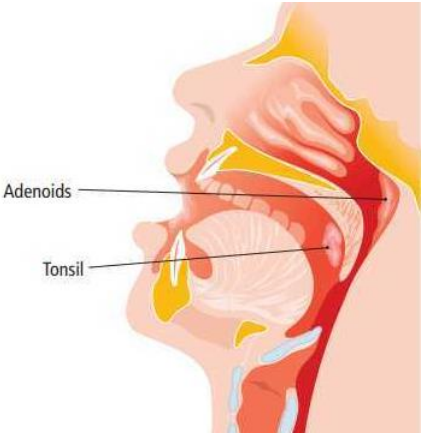
Lymph: clear liquid that is collected from around cells and is transported by the lymphatic system back to the bloodstream.

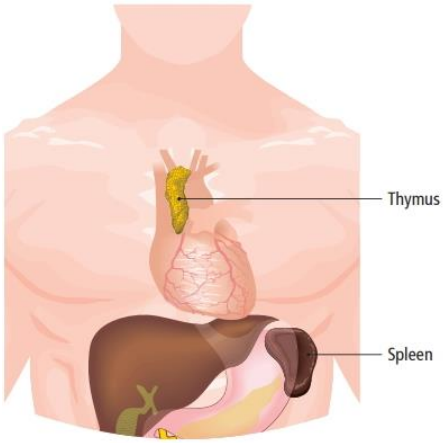
Lymph vessels: narrow, dead-ending tubes that transport lymph and are present in every tissue and organ throughout the body.

Lymph nodes: small, spherical-shaped organs of the lymphatic system that contain many white blood cells.

Spleen: lymphatic organ located just underneath and to the left of the stomach that functions in the maturation of lymphocytes. It also filters out bacteria, viruses and abnormal cells.

Thymus: specialised lymphatic organ located just in front of the heart and behind the sternum. It functions in the maturation of lymphocytes. It also produces the hormone thymosin (see Chapter 38)





Adenoids and tonsils: the adenoids are located at the back of the nasal cavity while the tonsils are located at the back of the mouth on either side. They function in killing pathogens during an infection. For example, the tonsils can become sore and swollen during colds, flu and throat infections; the adenoids also become swollen during an infection (such as a cold) and give the feeling of a 'blocked nose'.

Functions of the Lymphatic System

- Collects extracellular fluid and returns it to the blood stream at the subclavian veins.
- The lymph nodes filter lymph removing bacteria, viruses, abnormal cells and cell debris.
- Absorbs fat from the small intestine.
- Maturation of lymphocytes.

CHAPTER 33: HUMAN DIGESTIVE SYSTEM

Introduction:

The human digestive system functions in **nutrition**. It is a long tube stretching the entire length of the body. This tube, as a whole, is called the **alimentary canal**.

Definitions:

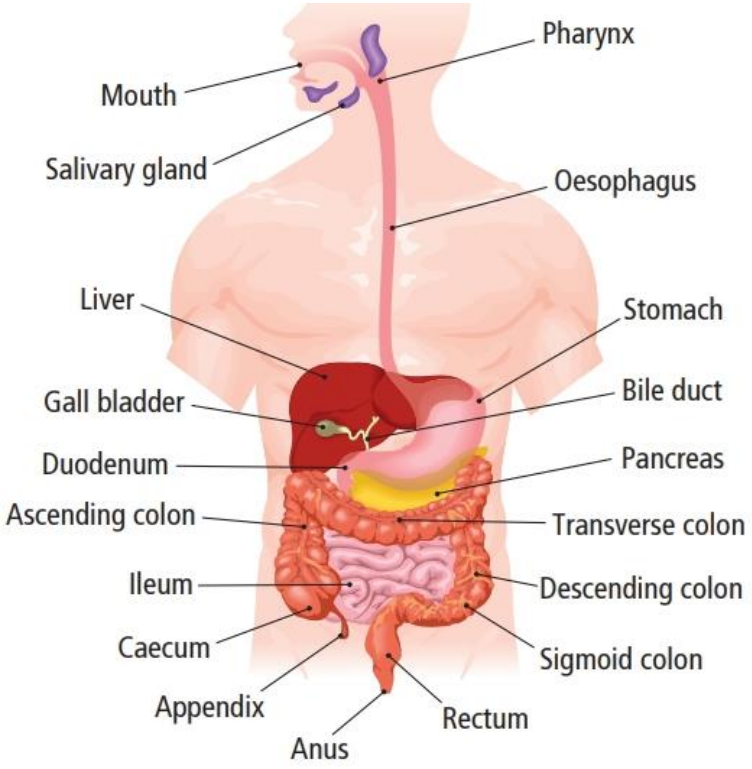
- **Nutrition**: the way in which organisms obtain and use food
- **Herbivore**: an animal that eats only plant material; e.g. deer.
- **Carnivore**: an animal that eats only animal material; e.g. lion.
- **Omnivore**: an animal that eats both animal and plant material; e.g. pig.

Nutrition in the human:

There are **four** stages of nutrition:

1. **Ingestion**: the taking in of food into the mouth.
2. **Digestion**: the breakdown of food.
   - There are two types: mechanical and chemical digestion.
     - i **Mechanical digestion**: the physical breakdown of large food particles into smaller ones.
     - ii **Chemical digestion**: the breakdown of food using enzymes.
3. **Absorption**: the passage of single biomolecules from the gut into the cells lining the gut.
4. **Egestion**: the getting rid of undigested material.

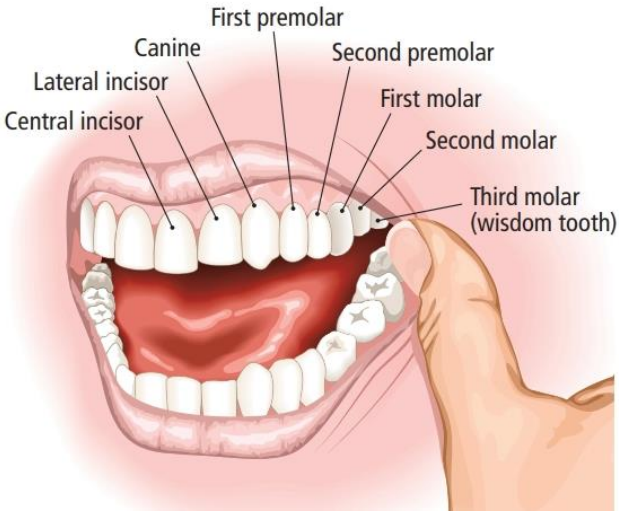
Structure & function of the digestive system:



Mouth: also known as the buccal or oral cavity and has a number of functions. It contains teeth and tongue that both function in mechanical digestion. Saliva also acts in the mouth.

Teeth: the teeth are located in the mouth. There are 32 teeth is a fully formed healthy adult mouth: 8 *incisors*; 4 *canines*; 8 *premolars*; and 12 *molars*.
The human dental formula is: 2(I $^{2}/_{2}$; C $^{1}/_{1}$; PM $^{2}/_{2}$; M $^{3}/_{3}$)

- I stands for incisor. There are four on the top (2 on each side) and four on the bottom (2 on each side). Incisors function in cutting food.
- C stands for canine. There are a total of four canines (2 on the top, one on each side and 2 on the bottom, one on each side). Canines function in tearing and ripping food.
- PM stands for pre-molars. There are a total of eight (4 on the top, two on each side and four on the bottom, two on each side). Premolars have cusps that function in grinding and crushing food.
- M stands for molar. There are a total of 12 (6 on the top, three on each side and 6 on the bottom, three on each side. The back four molars are also known as wisdom teeth. Molars also have cusps that grind and crush food.



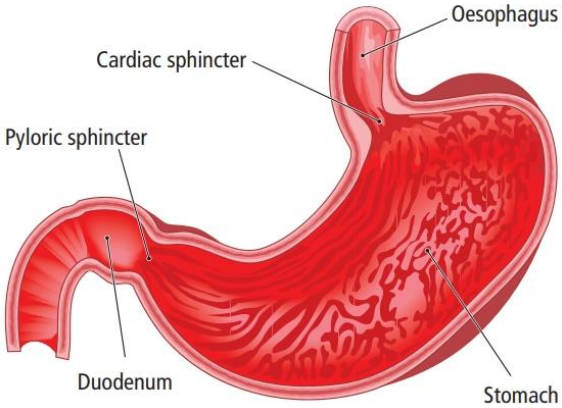
Salivary glands: produce saliva which is a mixture of water, mucous, and the enzyme amylase which digests starch into maltose.

Pharynx: the pharynx (or throat) is involved in swallowing.

Oesophagus: tube that is approximately 30 cm long and carries food from the pharynx to the stomach by contraction of smooth muscle in its wall. This is called *peristalsis*.

- **Peristalsis**: rhythmical waves of smooth muscle contraction pushing food along the alimentary canal in one direction.

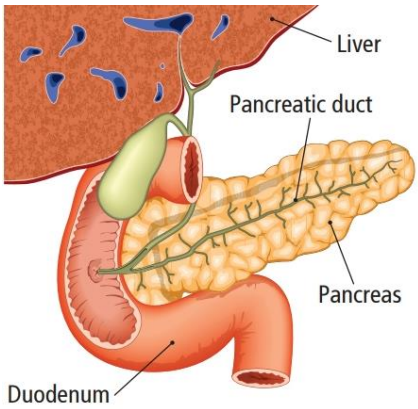
Stomach: muscular bag, located in the upper left abdomen, that receives food from the oesophagus. It stores food for approximately 2 hours and mixes it with gastric juice. This mixture is called chyme (see below).



Gastric juice: gastric juice is produced by the gastric glands of the stomach wall (mucosa). It is composed of:

1. *Water*: moistens the food and acts as the medium in which chemical digestion occurs. It also takes part in the hydrolysis reactions that are important in chemical digestion.
2. *Mucous*: protects the internal wall of the stomach from digesting itself.
3. *Hydrochloric acid*: creates an acidic environment within the stomach (with a pH as low as 1). The acid helps to digest proteins by denaturing them and kills pathogens.
4. *Pepsin*: released from the cells of the gastric glands in an inactive form called pepsinogen. This is so that the enzyme does not digest the cell before being released. Once pepsinogen comes into contact with the acidic conditions of the stomach it is converted to the active pepsin which digests proteins into peptides.

Duodenum: 30 cm long tube that receives chyme from the stomach. It is also the main location for chemical digestion.

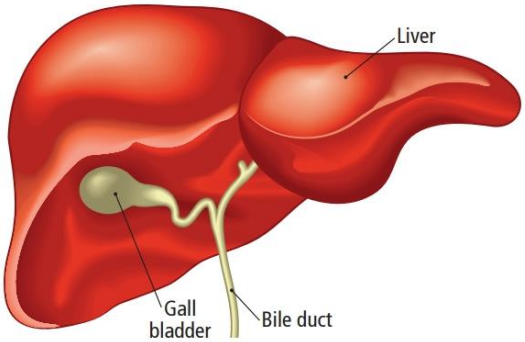


Pancreas: is an organ located just underneath the liver and stomach. It secretes pancreatic juice for digestion of food. Pancreatic juice contains:

1. *Water*: acts as the medium in which enzyme reactions occur and takes part in hydrolysis reactions.
2. *Mucous*: protects the internal surface (mucosa) of the duodenum and ileum.
3. *Sodium bicarbonate*: neutralises acidic chyme entering from the stomach.
4. *Lipase*: digests lipids into fatty acids and glycerol.
5. *Amylase*: digests starch into maltose.

Liver: largest internal organ of the human body. It is located in the upper right abdomen. The liver has many functions:

- Breaks down old, worn out red blood cells and the haemoglobin.
- Breaks down excess amino acids, in a process called **deamination**, into urea (which is then excreted by the kidneys).
- Produces bile: bile contains water, mucous, salts (for emulsifying lipids), cholesterol and bile pigments (bilirubin and biliverdin). Note: emulsification is a type of physical digestion – breaking large fat droplets into smaller ones.
- Stores fat-soluble vitamins A, D, E and K.
- Stores minerals, such as iron.
- Produces plasma proteins (such as complement)
- Stores glycogen – which is the storage form of carbohydrates in animals.
- Detoxifies alcohol and other toxins present in the body.

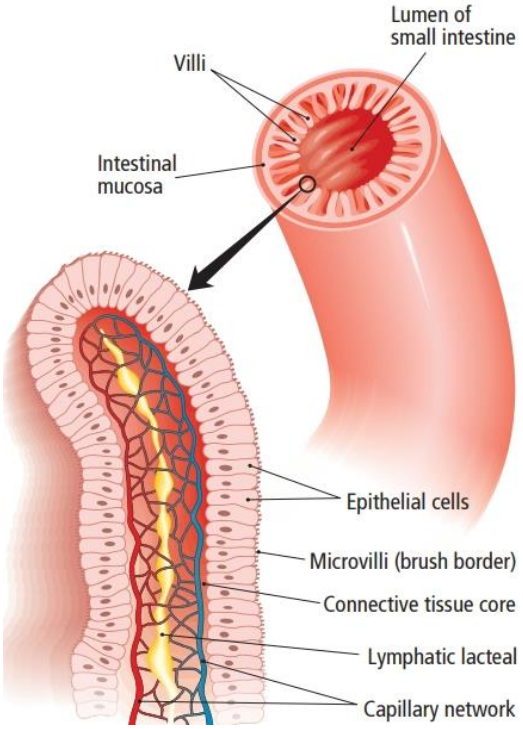


Gall bladder: small bag-like organ located underneath the liver. It stores bile produced by the liver before releasing it into the duodenum.

Bile duct: carries bile and pancreatic juice to the duodenum.

Ileum: 6m long tube functioning in absorption of the products of digestion. The mucosa of the ileum has special adaptations that enable it to carry out absorption very efficiently. The ileum has:

- Villi and microvilli – increase the surface area of the ileum available for absorption.
- A good blood capillary network – enables the products of digestion to be transported away quickly to where they are needed.
- A lymph supply (each villus has a lacteal) – responsible for the absorption of lipids.



Appendix: small blind-ending tube attached to the caecum that is thought to function as part of the defence system.

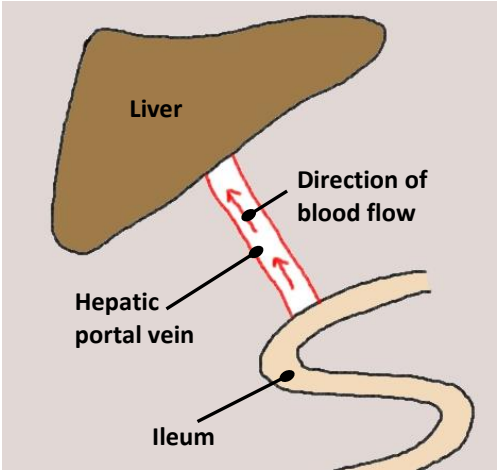
Caecum: first part of the large intestine. Functions in absorption of water. It contains a large number of bacteria that function in producing vitamins and preventing growth of pathogenic bacteria.

Colon: part of the large intestine. Functions in absorption of water, vitamins and minerals. There are bacteria present in the colon that produce vitamins that can then be absorbed and prevent growth of pathogenic bacteria.

Rectum: any undigested and unabsorbed material left at the end of the process is stored in the rectum as faeces before being released.

Anus: opening of the rectum. It is a sphincter that is consciously controlled.

Hepatic portal system: network of blood vessels in the intestines connected to another network of blood vessels in the liver by the **hepatic portal vein**. Nutrients are absorbed by the small intestine and transported to the liver before being released to the rest of the body through the hepatic vein.



Balanced Diet:

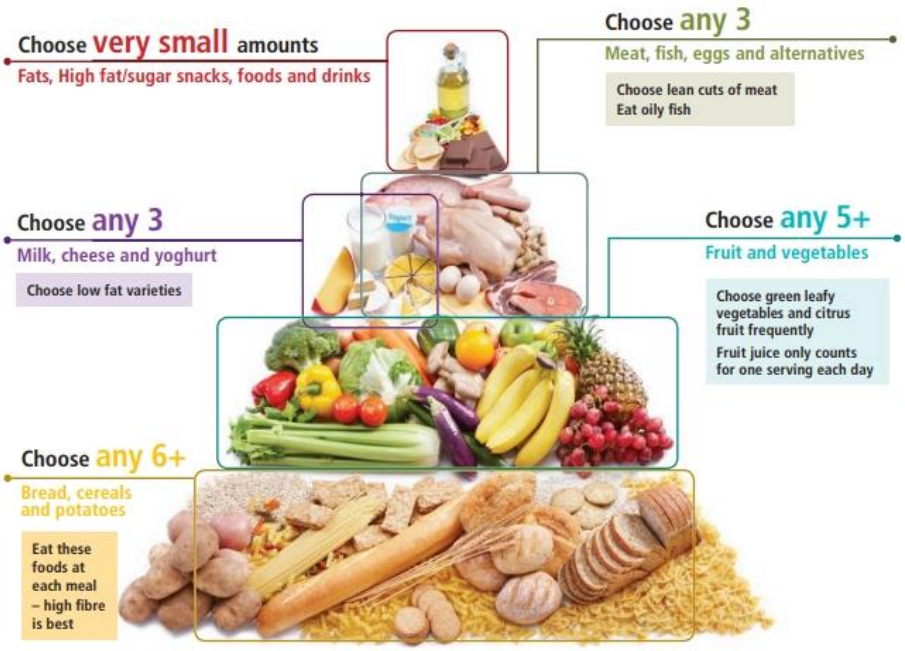
A balanced diet is one that contains all seven nutrients in the correct proportions.

The seven nutrients are:

1. Carbohydrates
2. Lipids:
3. Proteins
4. Fibre
5. Vitamins
6. Minerals
7. Water

Food pyramid

There are recommended daily amounts of different food types to have in the diet. An imbalance in any one of the nutrients or food types can lead to malnutrition.

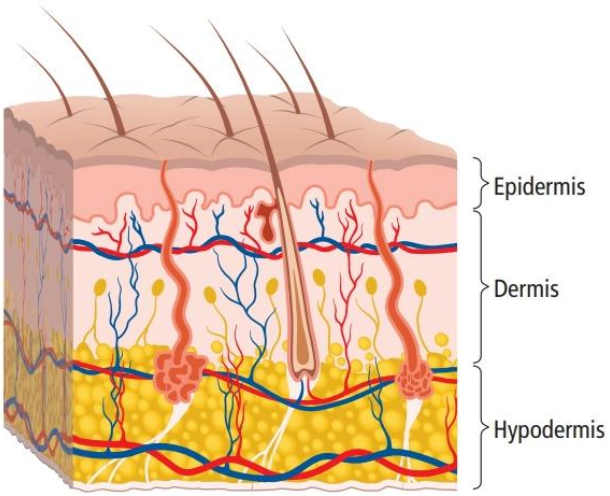


CHAPTER 34: HUMAN DEFENCE SYSTEM

Introduction:

General Defence System

- *Skin*
- *Mucous membranes*
- *Phagocytosis*
- *Fever*
- *Defence chemicals*

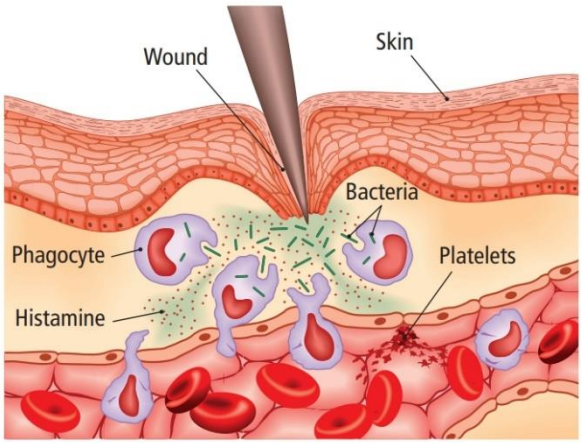


Skin

- Sweat and sebum secretions contain chemicals that kill bacteria and fungi.
- Blood clotting prevents entry of microorganisms if the skin is damaged.

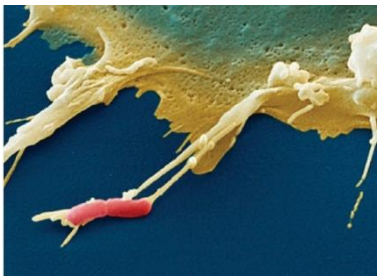
Mucous membranes

- Traps foreign particles.
- Lining of respiratory tracts - mucous traps debris and microorganisms and cilia move it up to the pharynx where it is swallowed.
- Lining of digestive tract – HCl in stomach kills all microorganisms.
- Lining of reproductive tracts – low pH in vagina kills microorganisms.



Phagocytosis

- Phagocytes are a type of white blood cell – they move and feed like *Amoeba*.
- Recognise foreign material and engulf it.
- Only takes one-hundredth of one second to engulf one bacterium.
- Each phagocyte can engulf over 100 bacteria.
- Attracted to and accumulate in extremely large numbers at an infection site.



Fever

- Chemicals released by defence cells cause the hypothalamus to raise the body's temperature
- Increased body temperature interferes with enzymes in bacteria and viruses which prevents the reproduction of these microorganisms

Defence chemicals

- Virus-infected cells release interferon that acts as a warning chemical to other cells making them more resistant to proteins entering cells.
- Liver secretes complement proteins that help the immune system in ridding the body of the foreign invader.
- Irritation (e.g. infection or foreign material) causes cells to release histamine which causes blood vessels to dilate (redness) and attracts white blood cells.
- Lysozyme (which kills bacteria) is present in tears.

Specific Defence System

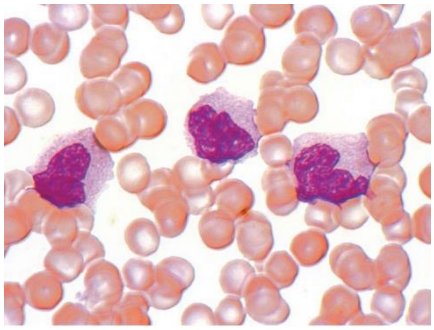
Specific Defence System refers to the immune system (it reacts to individual pathogens). Organs that are part of the immune system include:

- Spleen
- Thymus
- Lymph nodes

Blood and lymph contain white blood cells called monocytes and lymphocytes (produced in bone marrow).
All microorganisms have antigens on their surfaces that make it 'foreign' to the body.

- Antigens are foreign molecules capable of eliciting an antibody response.
- An antibody is a protein produced by lymphocytes in response to an antigen.

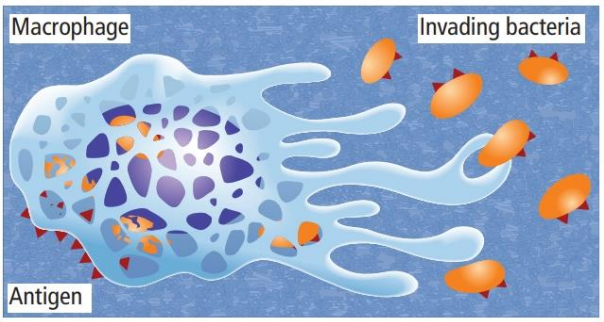
Antigens are found in bacterial cell walls, viral coats, foreign cells, and on cancerous cells. Immunity to specific antigens usually lasts for a long time (10 to 20 years).



Monocytes:

- Develop into macrophages which engulf tagged (antibody attached to antigen) invaders and untagged invaders.
- Macrophages that have engulfed tagged pathogens display the antigen belonging to the pathogen on their surface stimulating other cells to respond to the antigen and kill the invader.

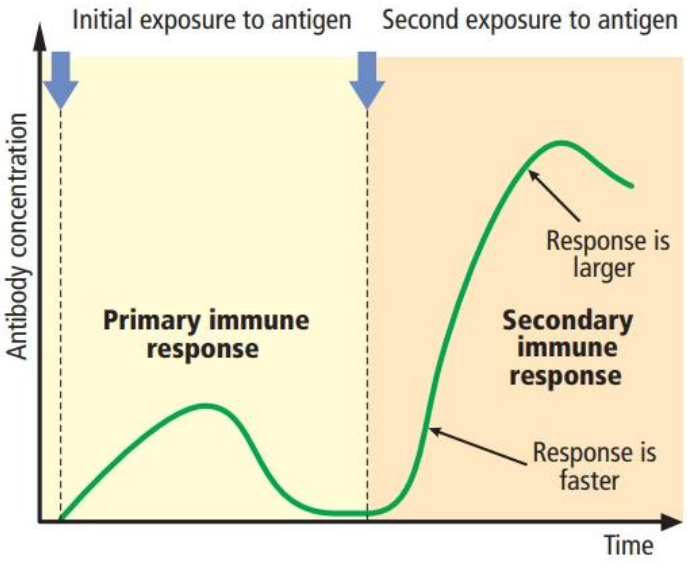
Lymphocytes:



- Involved in induced immunity: (acquired immunity) **production of antibodies in response to the presence of specific antigens on pathogens**
- Antigens may be displayed on cells that have been infected with a virus
- Lymphocytes specifically recognise foreign bodies and set up an immune reaction where a response to the invader is carried out
- Antibodies are produced by lymphocytes which attach to invader. Other lymphocytes recognise the antibody that is attached to invader (i.e. the invader has been tagged for destruction) and phagocytose (engulf and digest) it.

Two basic types of induced (acquired) immunity:
1. Active immunity
2. Passive immunity

Active Immunity



There are **two** types of active immunity:
1. **Natural active immunity**: is where an individual suffers from infection, develops symptoms and produces antibodies against the pathogen (**primary immune response**). Natural active immunity is usually long-lasting because after infection has been eliminated, the immune system produces memory lymphocytes (see below) that are capable of responding to the same antigen many years after initial infection (see graph). If the individual is infected again with the same pathogen/antigen, then there is a **secondary immune response** which is faster and larger (more antibodies are produced and more quickly) than the primary response.
2. **Artificial active immunity**: is where an individual receives a **vaccination** (see below). The individual receives a weakened dose of a pathogen and the immune system reacts against it producing antibodies and memory lymphocytes. The individual does not (generally) suffer symptoms.

Passive Immunity

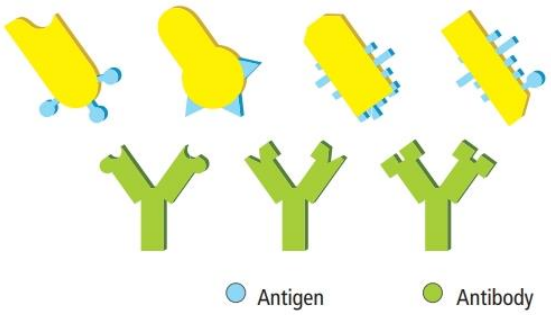
There are two types of passive immunity:
1. **Natural passive immunity**: is where an individual receives antibodies from an external source – e.g. breast milk supplies antibodies to infant and in serious life-threatening disease antibodies can be injected into patient to fight disease such as rabies or tetanus
2. **Artificial passive immunity**: is where an individual receives antibodies (made in a different organism) by injection (immunisation – see below) to fight off a potentially life-threatening disease (e.g. tetanus or rabies).

Neither natural nor artificial passive immunity involves the production of memory lymphocytes and is therefore only effective for short time.

Immunisation and Vaccination

- Immunisation is protection against pathogens or toxins by vaccination or by injection of antibodies or antidotes
- Vaccination is the administration usually by injection of a non-disease-causing dose of a pathogen or part of a pathogen (e.g. the antigen of the pathogen or its toxin) which elicits the production of antibodies and importantly memory lymphocytes

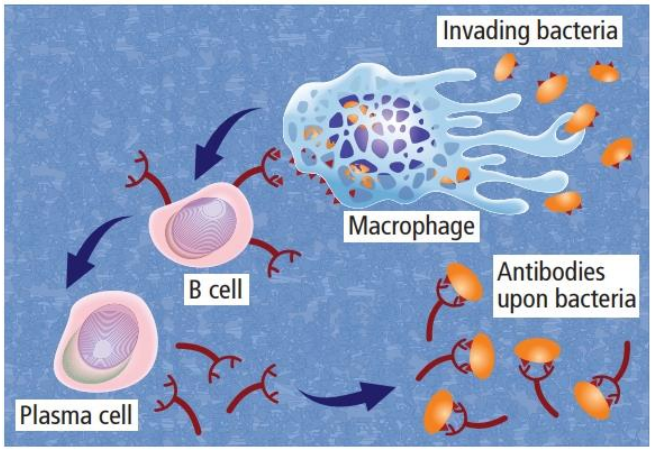
Advanced Study of Lymphocytes



Lymphocytes (leucocytes/white blood cells):

These are specialised cells that recognise particular types of antigen and respond to them in a variety of ways. There are two main groupings of lymphocytes:

1. B lymphocytes: produced and mature in bone marrow and then migrate to lymphoid tissue – such as lymph nodes, tonsils and spleen. They produce antibodies.
2. T lymphocytes: produced in bone marrow but mature in thymus gland and then migrate to lymphoid tissue in same way as B lymphocytes. They have a variety of functions (see below).



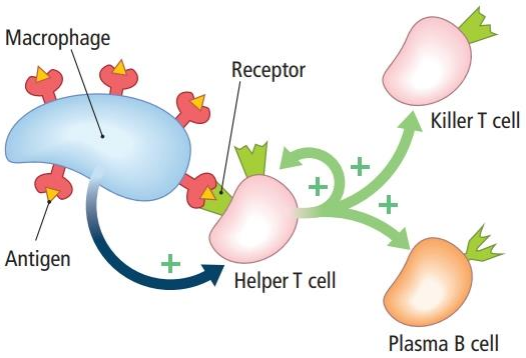
B lymphocytes (B cells):

- Each B lymphocyte carries receptors for **only one specific antigen**.
- Each B lymphocyte **produces only one type of antibody** in response to that specific antigen.
- Once a B lymphocyte has been activated by presence of antigen it multiplies itself to produce a clonal population, called **plasma B cells**. Some plasma B cells become memory B cells that remain in lymph nodes for a long time and can respond to the same antigen in the future (long-term immunity).
- Once a B lymphocyte has been activated by presence of antigen it multiplies itself to produce a clonal population, called **plasma B cells**. Some plasma B cells become memory B cells that remain in lymph nodes for a long time and can respond to the same antigen in the future (long-term immunity).

T lymphocytes (or also called T cells):

T cells multiply rapidly when activated by a specific antigen – the daughter cells differentiate (change) into four major types of immune cell:

1. Helper T-cells
2. Killer T-cells
3. Suppressor T-cells
4. Memory T-cells

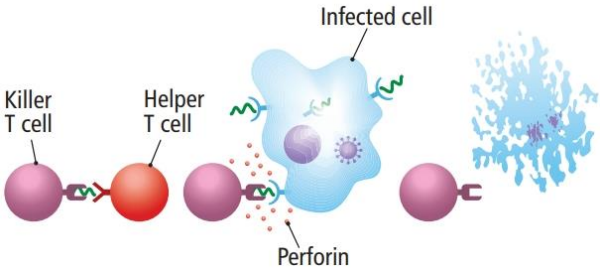


1. *Helper T-cells*

Helper T-cells enlarge during an immune response and secrete chemicals, such as interferon that stimulate B-cells to increase production of antibodies.
Helper T-cells also stimulate killer T-cells and accelerate the action of phagocytes (monocytes)

2. *Killer T-cells*

Recognise cancer cells and cells that have been infected with virus and act by placing proteins called perforins in their membranes – perforins cause the infected cell to die by a process called apoptosis (programmed cell death).



3. Suppressor T-cells

Responsible for maintaining the immune response at a manageable level, prevent it getting out of control (type of negative feedback mechanism) and/or stopping an immune reaction. Suppressor T-cells cause the killer T-cells and excess B-cells to die at the end of the immune reaction.

4. *Memory T-cells*

Memory T-cells they survive a long time in the lymph nodes and can respond to a specific pathogen in the future. Memory T-cells stimulate memory B-cells to start producing antibodies when they encounter the same pathogen again and they stimulate killer T-cells to multiply and become active.

CHAPTER 35: HUMAN BREATHING SYSTEM

Structure and functions:

Nasal and buccal cavities:
- Mouth and internal areas of the nose
- Function in warming and moistening air entering lungs
- Mucus and small hairs filter the air and then transport the dirt-loaded mucus to the pharynx where it is swallowed

Pharynx (throat):
- Area between oesophagus and windpipe (trachea)
- Pharynx has a sphincter (epiglottis) that closes over the opening to the trachea (glottis) that prevents food travelling into the trachea

Glottis:
- Opening to the trachea

Epiglottis:
- Sphincter that closes over the glottis to prevent food getting into the trachea during swallowing
- Swallowing causes the vocal cords to pull on the glottis and the larynx to be pulled upwards thereby closing the epiglottis over the glottis

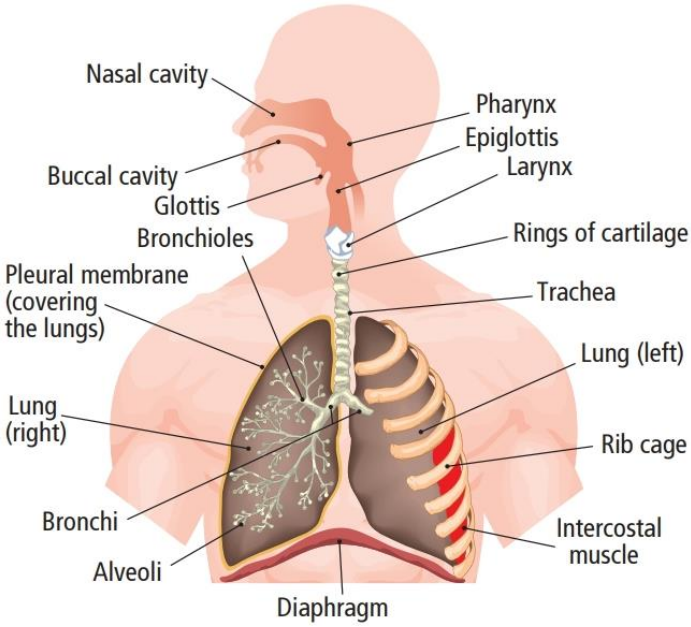
Larynx (voice box):
- Made of cartilage and sits on top of the trachea
- Three functions:
  1. Produces sound
  2. Controls air flowing into and out of the trachea
  3. Directs food into the oesophagus

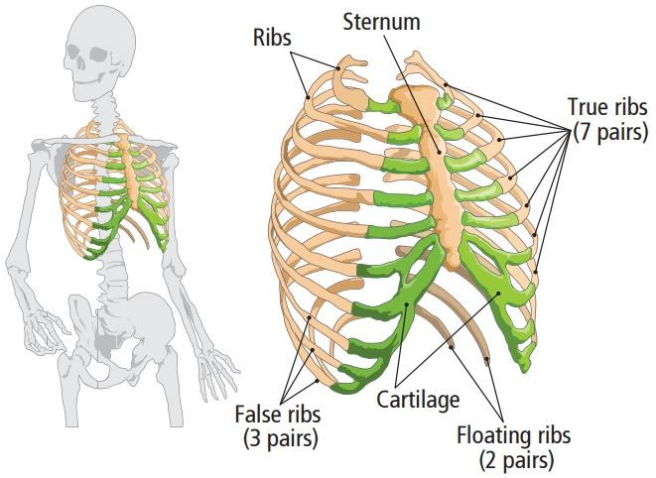
Trachea (windpipe):
- Directs inhaled air into the lungs
- Contains c-shaped rings of cartilage that keeps the trachea open
- Cilia of trachea carry dirt-laden mucus up the pharynx

Bronchi:
- Two divisions of the trachea
- Directs air into each lung
- Supported by cartilage

Bronchioles:
- Tiny divisions of the bronchi
- Air passages that are less then 1 mm in diameter
- Not supported by cartilage

Lungs:
- Composed of spongy, elastic tissue that expands easily during inhalation and recoils rapidly as exhalation occurs



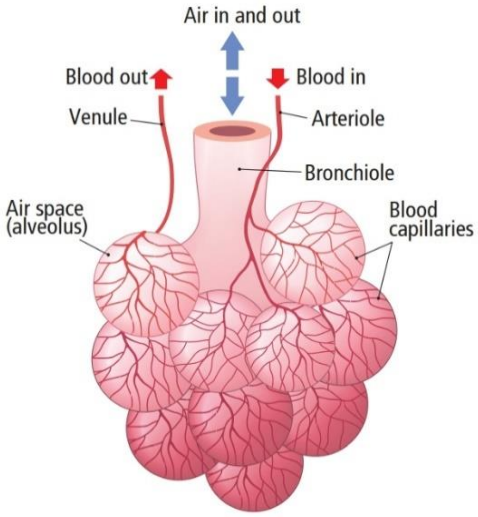


Pleural membranes:
- Thin pair of membranes covering and separating the lungs from other organs, such as the heart
- The lungs are stuck to the rib cage and diaphragm by the pleural fluid (think of a layer of water between a table and a piece of glass and how difficult it is to lift it off the table)

Rib cage:
- Composed of 12 thoracic vertebrae, 12 ribs, and the sternum
  - First 7 pairs are called ‘true’ ribs (because they attach directly to the sternum)
  - Next 3 pairs are called ‘false’ ribs (because they attach to the sternum by cartilage)
  - Last 2 pairs are called ‘floating’ ribs (because they do not attach to the sternum)
- Muscles are located between each rib – called intercostal muscles that contract causing the rib cage to move upwards and outwards, drawing air into the lungs

Alveoli:

- Tiny air sacs at the end of the bronchioles where gas exchange occurs.
- Walls of alveoli are only 1 cell thick to maximise diffusion.
- Each alveolus has rich blood capillary network surrounding it.
- There are ~700 million alveoli with a total surface are of 90 m^2.

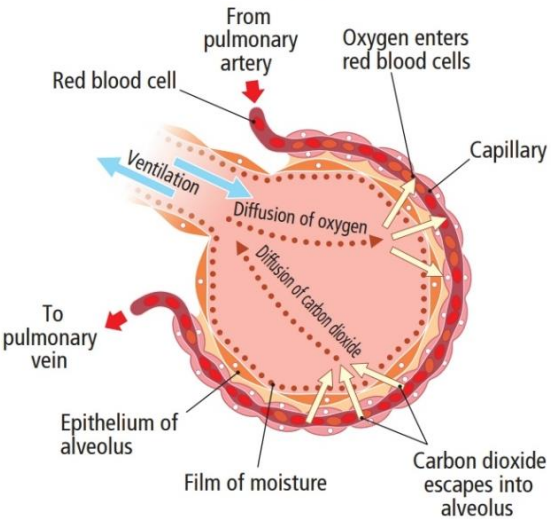


Essential Features of Alveoli and Capillaries

- Alveoli are numerous
- Alveoli have rich blood capillary network nearby
- Alveoli have walls only one-cell thick
- Alveoli surface is moist
- Alveoli walls are elastic
- Capillaries that surround each alveolus have walls that are only one-cell thick

Gas exchange:

Occurs by diffusion. Water and carbon dioxide move outwards (from the blood to the alveolar space). Oxygen moves inwards (from the alveolar space into the blood) – see diagram below:



Transport of Gases

- Inhaled O_2: 21% (atmospheric oxygen)
- Exhaled O_2: 16%
- Inhaled CO_2: 0.04%
- Exhaled CO_2: 4%
- Inhaled $H_2O(g)$: variable
- Exhaled $H_2O(g)$: 100% humidity
- Oxygen is transported mostly (97%) by haemoglobin as oxyhaemoglobin
- Remaining oxygen (3%) is carried dissolved in solution by the plasma
- Carbon dioxide is transported mostly (80%) by the plasma as either hydrogen carbonate ions, HCO_3^-(70%) or as dissolved carbon dioxide (10%)
- Remaining carbon dioxide (20%) is carried by the haemoglobin in red blood cells

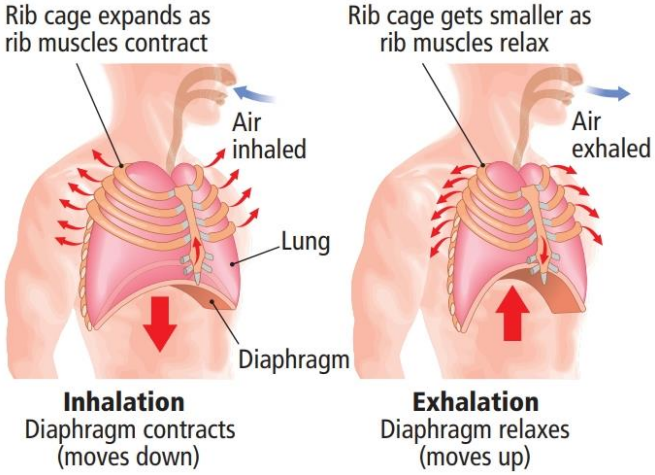
Mechanism of breathing:

Inhalation:

- Active process where the brain sends signal to the inspiratory muscles (intercostals and diaphragm) to contract
- Rib cage expands upwards and outwards and the diaphragm moves downwards
- The pressure within the thoracic cavity decreases and air rushes in
- Inhalation can be consciously and sub-consciously (during sleeping) controlled

Exhalation:

- Passive process where normally no signal is sent to the inspiratory muscles
- Can be an active process during strenuous activity (e.g. intense exercise, coughing, sneezing, etc.) when the brain send signal to the abdominals to contract forcibly expelling air from the thoracic cavity
- During exhalation intercostals and diaphragm relax
- Rib cage moves down and inwards and the diaphragm moves upwards
- The pressure within the thoracic cavity increases and air rushes out



Carbon Dioxide and Breathing Control

- Carbon dioxide dissolved in the blood is the most powerful stimulant for an increase in the rate of breathing
- Receptors in the brain sense the levels of carbon dioxide in the blood and respond by increasing or decreasing the rate and depth of breathing

Effect of Exercise on Breathing Rate

- Exercise stimulates increased respiration which produces more carbon dioxide which diffuses into the bloodstream
- The brain is extremely sensitive to changes in the carbon dioxide concentration within the bloodstream and acts on this by increasing breathing rate and heart rate to excrete the excess carbon dioxide via the lungs

Breathing Disorders

Asthma:

- *Possible cause*: immune reaction to an external allergen (e.g. pollen)
- *Symptom*: difficulty breathing due to constriction of the airways
- *Possible preventative measure*: avoid the allergen (e.g. pollen)
- *Possible treatment*: use of an inhaler that has drugs in it that stimulate the airways (bronchi and bronchioles) to widen and dilate

Bronchitis:

- *Possible cause*: smoking, air pollution, dust, viral infection, bacterial infection
- *Symptoms*: laboured breathing, episodes of constant coughing, excessive production of mucus and inflamed airways
- *Possible preventative measure*: do not smoke, avoid second-hand smoke, pollutants and dust
- *Possible treatment*: stop smoking, avoid polluted air, use of bronchodilating drugs or antibiotics (if cause is pathogenic bacteria)

Practical activity: to investigate the effect of exercise on breathing rate.

Equipment and method:

- Breathing rate is measured by counting the number of breaths in one minute. One breath is counted as a combination of one inhalation **and** one exhalation.
- Measure breathing rate at rest three times and average. Average breathing rate at rest is between 12 – 20 breaths per minute.
- Walk slowly or exercise very gently for three minutes and count the number of breaths per minute either during the exercise or at the end.
- Walk briskly/jog slowly/exercise moderately for three minutes and count the number of breaths per minute.
- Run/exercise vigorously for a three minutes and once again measure the number of breaths per minute.
- Record results in a table.

Results:

	Breathing rate (breaths per minute)
Resting	
Walking/exercising gently	
Walking/exercising moderately	
Running/exercising vigorously	

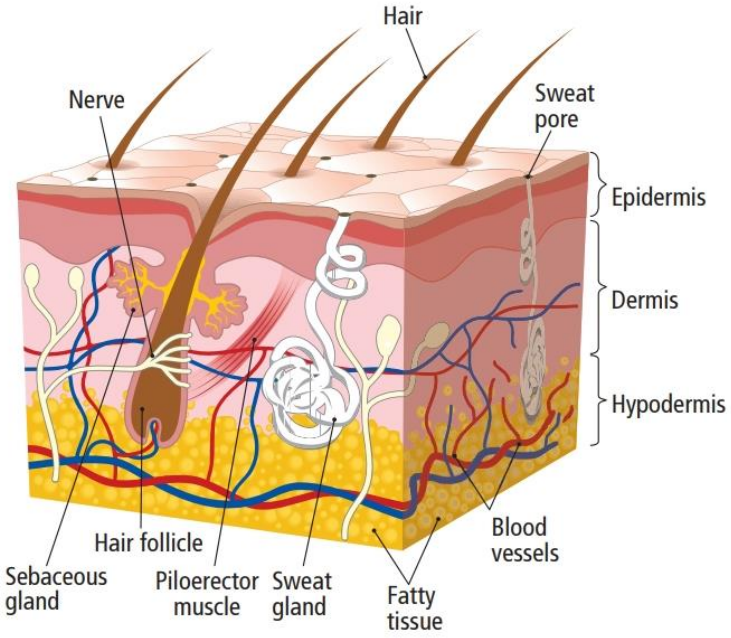
Conclusion:

- Exercise increases breathing rate.

CHAPTER 36: HUMAN INTEGUMENTARY SYSTEM

Introduction:

The skin is composed of two main layers: the epidermis and the dermis. The subcutaneous layer is often included in describing the structure of the skin, but is technically not part of the skin.



- **Epidermis**: this is the uppermost layer of the skin and is composed mostly of dead cells. It consists of three sub-layers called the cornified layer, granular layer and Malpighian layer.
    1. **Cornified layer**: consists entirely of dead cells that are brushed off continuously. Acts as the primary barrier to the outside world.
    2. **Granular layer**: consists of cells filled with the strong protein keratin.
    3. **Malpighian layer**: consists of a layer of cells called melanocytes – which produce melanin (brown pigment in skin). They also produce the rest of the cells that make up the granular and cornified layers.
- **Dermis**: this layer is just below the epidermis and contains all of the organs of the skin, such as capillaries and blood vessels, nerve endings, various sense organs, sebaceous glands and hair follicles. It is also rich in collagen and elastin. This helps to give skin its strength and elasticity.
- **Subcutaneous layer** (**hypodermis**): is located below the dermis and is composed of cells filled with fat. This layer contains the adipose tissue. Sunlight action on this layer is responsible for producing vitamin D that the body can use in the digestive system to absorb calcium from food.

Functions of the skin

- Protection – acts as a physical barrier preventing entry of pathogens
- Excretion – excretes water, salts and a very small amount of urea
- Temperature regulation:
    1. Goose bumps (see picture below) are visible and hairs stand on end (due to contraction of the piloerector muscle) and vasoconstriction occurs when the body is cold.
    2. Sweat is produced, vasodilation occurs, and hairs lie flat when the body is too warm.
- Fat storage – adipose tissue just below the skin stores fat and acts as an insulator
- Sense organ – sense organs such as temperature and pain receptors send signals to the brain when stimulated
- Production of vitamin D – sunlight action on the fatty tissue within the skin causes the production of vitamin D, which is needed to absorb calcium from the digestive system

CHAPTER 37: HUMAN URINARY SYSTEM

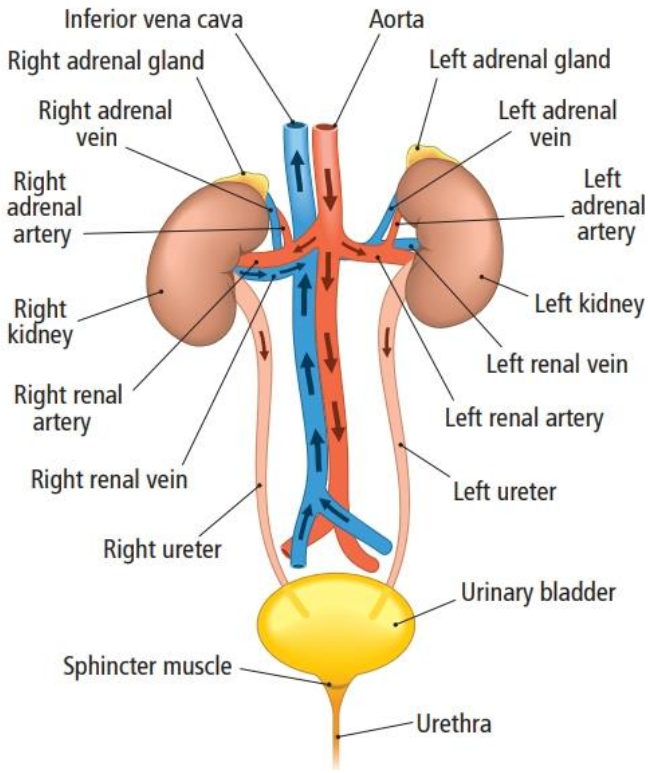
Introduction:

The human urinary system is an excretory system. It helps to maintain homeostasis.

- **Excretion**: the getting rid of the waste products of metabolism.
- **Homeostasis**: the maintenance of a constant internal environment.
- **Urination (micturition)**: the passing of urine from the body.

Structure of the human urinary system

- **Kidneys**: filter the blood taking out the waste products of metabolism, e.g. urea.
- **Ureters:** carry urine from the kidney to the urinary bladder.
- **Urinary bladder**: stores urine.
- **Urethra**: carries urine outside of the body.

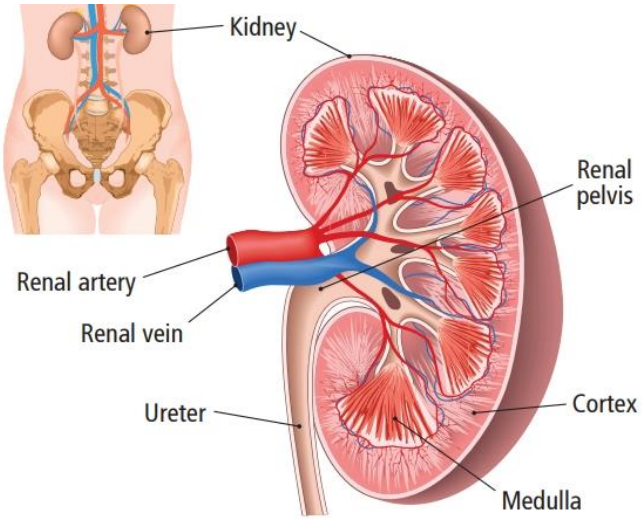


Kidney structure and functions:

- **Excretion**: the main function of the kidney is to filter the blood taking out metabolic waste products producing urine.
- **Osmoregulation**: the kidneys control the amount of water in the body. If there is too much water in the body, the kidneys will excrete the excess water and if there is not enough water in the body, the kidneys will excrete much less water in an effort to conserve the remaining water in the body.
- **pH control**: the kidneys can control the acidity and alkalinity of the blood by excreting hydrogen ions or conserving hydrogen ions.
- **Hormone production**: the kidneys produce the hormone erythropoietin (EPO). EPO stimulates the bone marrow to produce red blood cells (erythrocytes).

Urine production

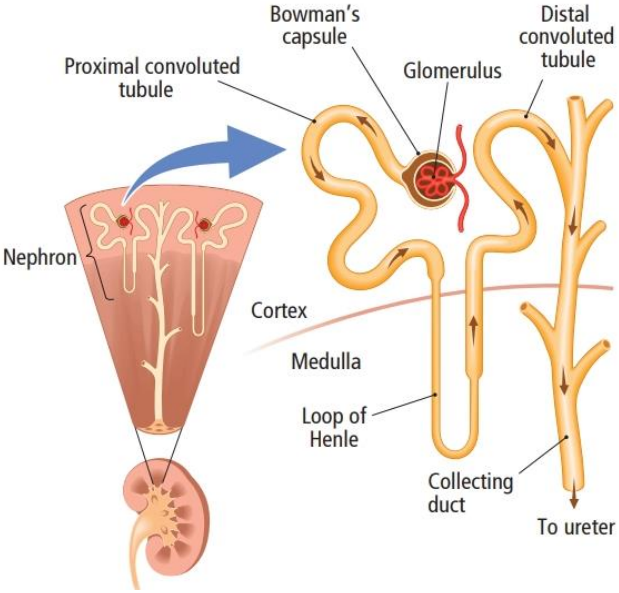
1. ***Filtration***:
   - Filtration occurs in the cortex of the kidney.
   - Blood flows through capillaries of the kidneys and water, salts, urea, glucose and amino acids are filtered out of the blood.
   - Red blood cells, white blood cells, platelets and large plasma proteins (such as antibodies) are not filtered through as they are too big.
   - The liquid that results after filtration is called the filtrate – it contains wastes as well as useful substances that need to be reabsorbed.
2. ***Reabsorption***:
   - Reabsorption occurs in both the cortex and medulla.
   - Substances in the filtrate that are useful to the body (such as glucose and amino acids) are taken out of the filtrate back into the bloodstream.
3. ***Secretion***:
   - The kidney also transports substances such as drugs and hydrogen ions out of the bloodstream into the tubules of the kidney to contribute to the urine.



The nephron – the functional unit of the kidney

There are approximately 1 million nephrons in each kidney. They are composed of four main parts:

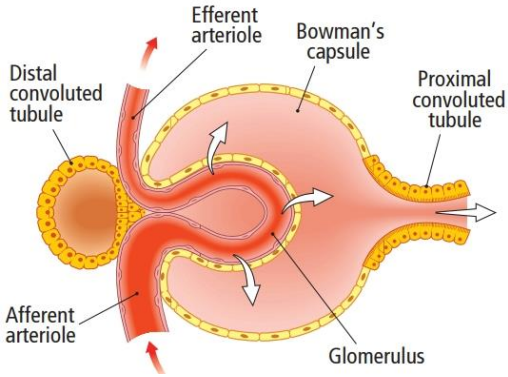
1. **Bowman's capsule** – where filtration occurs.
2. **Proximal convoluted tubule** – where most reabsorption occurs.
3. **Loop of Henle** – where more reabsorption occurs.
4. **Distal convoluted tubule** – where reabsorption of water and secretion of drugs and hydrogen ions occurs.



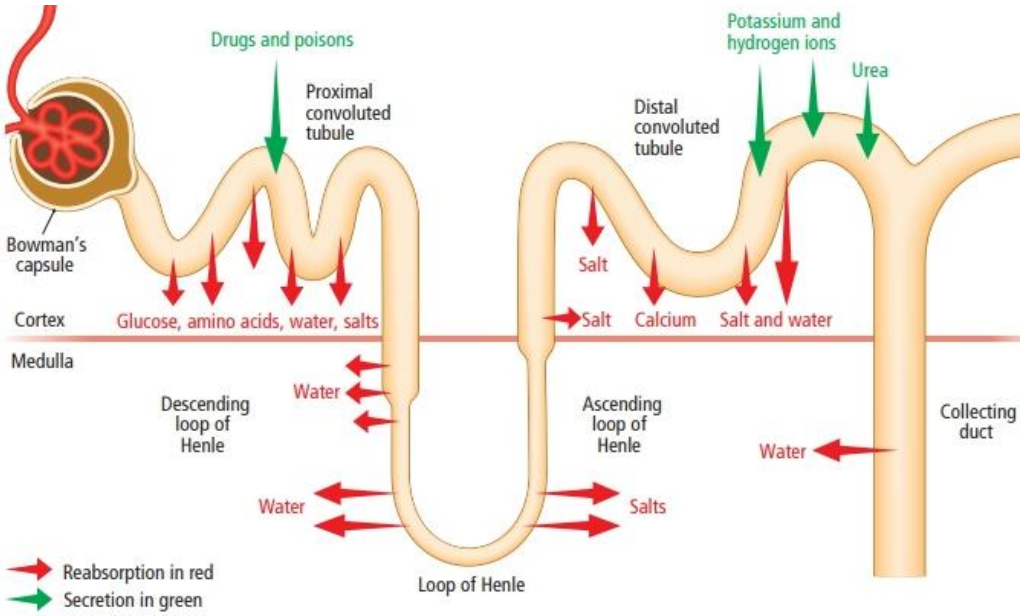
Blood supply

- The nephron receives blood from the renal arterioles.
- The renal arterioles carry blood to **afferent arterioles**.
- Each afferent arteriole enter the Bowman's capsule.
- The 'ball' of blood vessels within in the Bowman's capsule is called the **glomerulus**.
- The blood is then carried away from the Bowman's capsule via the **efferent arteriole**.
- This blood is then circulated around the nephron for reabsorption of useful substances.
- The afferent arteriole is slightly wider than the efferent arteriole – which causes an increased blood pressure within the glomerulus. This increased blood pressure helps with the process of filtration in the Bowman's capsule.

Urine production – detailed process



1. ***Filtration*:**
   - Filtration occurs from the glomerulus into Bowman's capsule.
   - Blood enters the glomerulus from the afferent arteriole.
   - Blood is under high pressure in the glomerulus and substances such as water, salts, urea, glucose and amino acids pass through.
   - The liquid that passes through is called the **glomerular filtrate**.
   - The Bowman's capsule is cup-shaped providing maximum area for filtration.
   - The endothelium of the Bowman's capsule is only one cell thick.
   - The capillary walls of the glomerulus are one cell thick and more leaky than normal capillaries
2. ***Reabsorption*:**
   - Useful substances (such as glucose and amino acids) in the glomerular filtrate pass back into the bloodstream.
   - Water is reabsorbed in the proximal convoluted tubule, descending loop of Henle, the distal convoluted tubule and the collecting duct.
   - All the glucose and amino acids are reabsorbed in the proximal convoluted tubule.
   - Salts are reabsorbed in the proximal convoluted tubule, the ascending loop of Henle and the distal convoluted tubule.



3. ***Secretion*:**
   - Certain substances pass into the tubules of the nephron from the bloodstream by active transport.
   - Drugs and poisons are actively transported out of the bloodstream into the proximal and distal convoluted tubules.

Kidney failure

- Occasionally the nephrons of the kidney might not work properly and kidney failure may result.
- Patients with total kidney failure have to undergo dialysis.
- Dialysis is where a machine takes blood from the body and removes wastes and excess water from the blood before returning it to the body.
- In the long term, kidney failure patients usually receive a kidney transplant.

Osmoregulation – detailed process:

The kidneys control the amount of water and salts that are excreted.

Too much water in the body:

The brain detects the amount of water in the body. If it is too high, the pituitary stops secreting a hormone called anti-diuretic hormone (ADH). This travels in the bloodstream to the distal convoluted tubules and collecting ducts of the kidney and causes them to become less permeable and therefore, more water is excreted.

Too little water in the body:

The brain detects a reduced amount of water in the body and causes the pituitary to release ADH that travels in the bloodstream to the distal convoluted tubules and collecting ducts and causes them to become more permeable. Water is then reabsorbed into the blood and less is excreted in the urine.

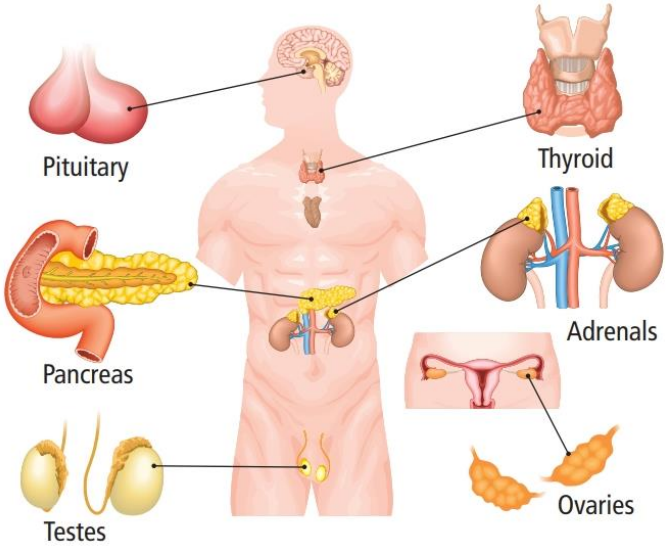
CHAPTER 38: HUMAN ENDOCRINE SYSTEM

Introduction:

The human endocrine system is composed of endocrine glands.

- **An endocrine gland is an organ that secretes a hormone directly into the bloodstream.**
- **A hormone is a chemical messenger secreted by an endocrine gland directly into the bloodstream where it travels to a target organ/tissue where it exerts a specific effect.**

The locations of the various endocrine glands are shown below:



Exocrine versus endocrine glands:

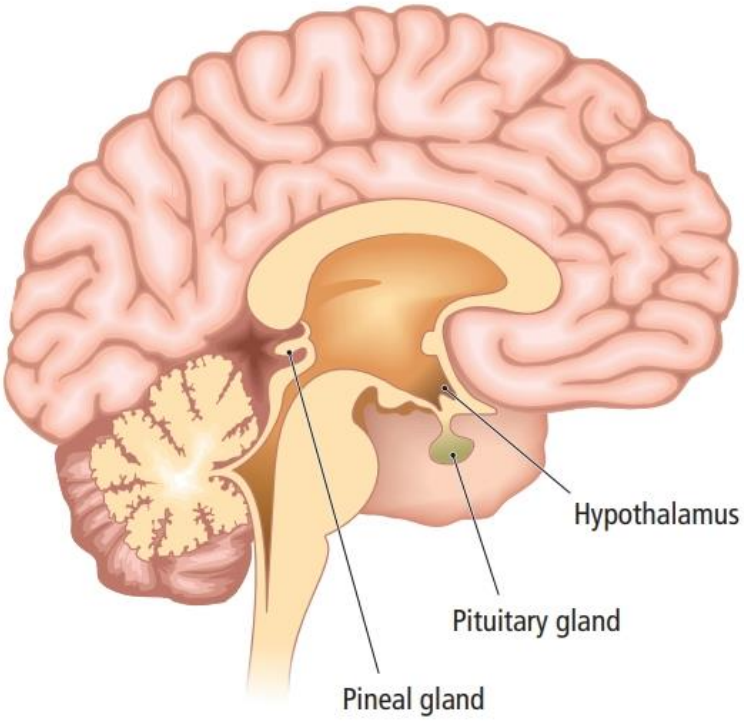
- Exocrine gland is an organ that secretes its product into a duct.
- Endocrine gland secretes its product directly into the bloodstream.

Endocrine action versus nerve action:

- Endocrine action is slow, prolonged, and chemical in nature.
- Nerve action is fast, short-lived, and electrical in nature.

Endocrine glands

The locations of the three main endocrine glands in the human brain



Hypothalamus:

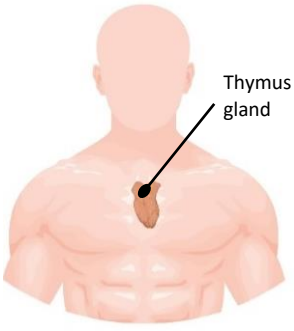
- The hypothalamus is located towards the base of the brain just above the pituitary gland.
- It secretes hormones directly into the bloodstream that travel the short distance to the pituitary gland and therefore can regulate the secretions of the pituitary, e.g. growth hormone releasing hormone – which causes the release of growth hormone from the pituitary.

Pineal gland:

- The pineal gland is located deep within the centre of the brain.
- It secretes melatonin which regulates biorhythms such as sleep and the menstrual cycle.

Pituitary gland:

- The pituitary (master endocrine gland) is located at the base of the brain and controls all other endocrine glands (outside of the central nervous system).
- It secretes many hormones; e.g. growth hormone (GH) stimulates protein synthesis and bone elongation.
- Gigantism is a symptom of excess secretion of growth hormone and is usually caused by a pituitary tumour which can be treated by surgery.
- Dwarfism is a symptom of growth hormone deficiency. It is treated by injections of growth hormone during childhood.

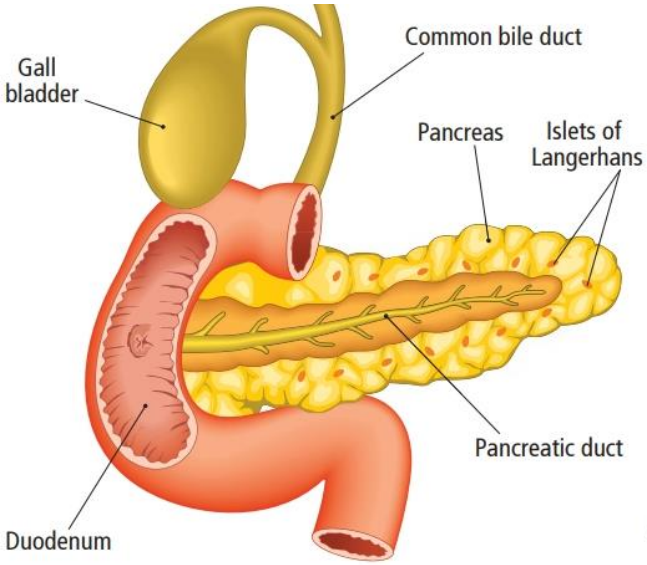


Thymus gland:

- The thymus gland is located just in front of the heart and behind the sternum.
- It secretes thymosin which helps white blood cells (that are made in the bone marrow) to mature into active immune cells.

Pancreas endocrine gland:

- The pancreas is located underneath the stomach on the left-hand side of the abdomen.
- It is both an endocrine gland and an exocrine gland.
- The endocrine part is composed of islets of Langerhans which secrete *insulin*.
- Insulin stimulates all cells in the body to absorb glucose.

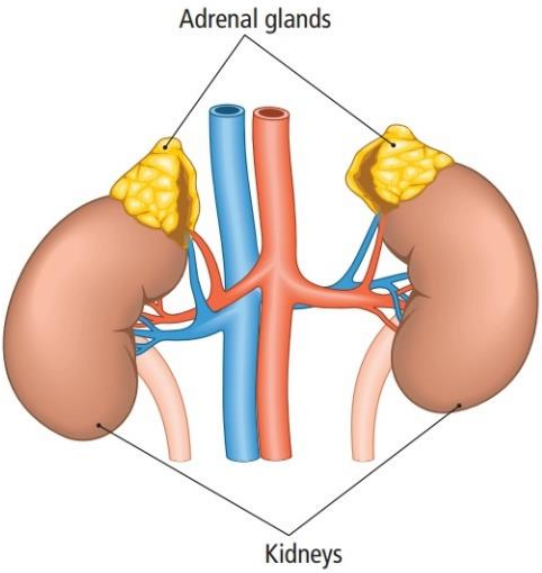


Symptoms of insulin deficiency and its treatment:

- Diabetes results if there is no insulin or lack of insulin in the body
- Insulin is used as a hormone supplement to treat type I diabetes

Adrenal glands:

- The adrenal glands are located on top of each kidney in the back of the abdomen.
- They secrete adrenaline ('fight or flight' hormone) which is secreted in times of stress or danger.



Functions of adrenaline:

- Increases blood flow to the brain and muscles
- Decreases blood flow to the skin and internal organs such as the intestines
- Dilates the bronchioles allowing more air in
- Increases blood glucose levels and increases heart and breathing rates

Ovaries and testes:

- Ovaries: secrete oestrogen and progesterone which are both involved in the menstrual cycle and in preparing the female body for a possible conception.
- Testes: secrete testosterone which stimulates the changes that occur in the male at puberty and also help to maintain these changes (called secondary sexual characteristics)

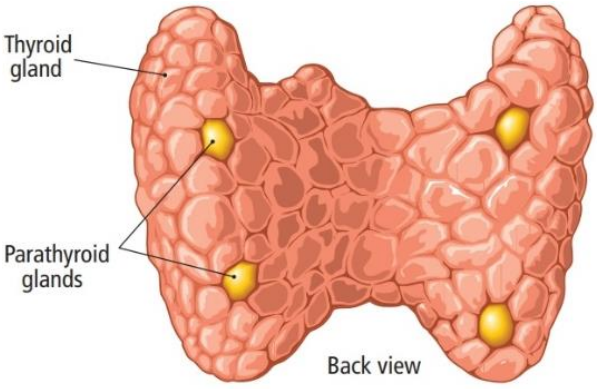
Anabolic steroids act in the same way in which testosterone acts – builds up muscle – therefore, anabolic steroids are used by body-builders.

Parathyroid glands:

- The parathyroids are present in each lobe of the thyroid gland in the neck.
- They secrete parathormone which stimulates increased blood calcium levels by releasing of calcium from bone.

Thyroid gland:

- The thyroid gland is located in the neck.
- The thyroid secretes thyroxine which increases metabolism

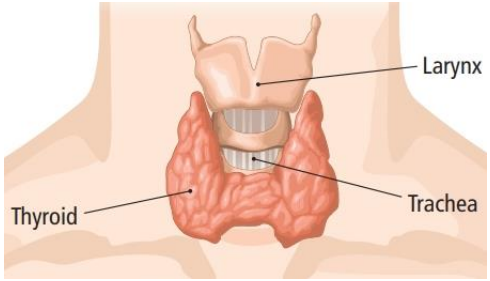


Symptoms of thyroxine deficiency:

- Goitre (thyroid gland swells)
- Low metabolic rate and mental retardation (cretinism in children)
- Tiredness, fatigue and weight gain (fluid build-up – oedema)

Treatment of thyroxine deficiency:

- Thyroxine is administered (tablets)
- Iodine is administered (tablets)



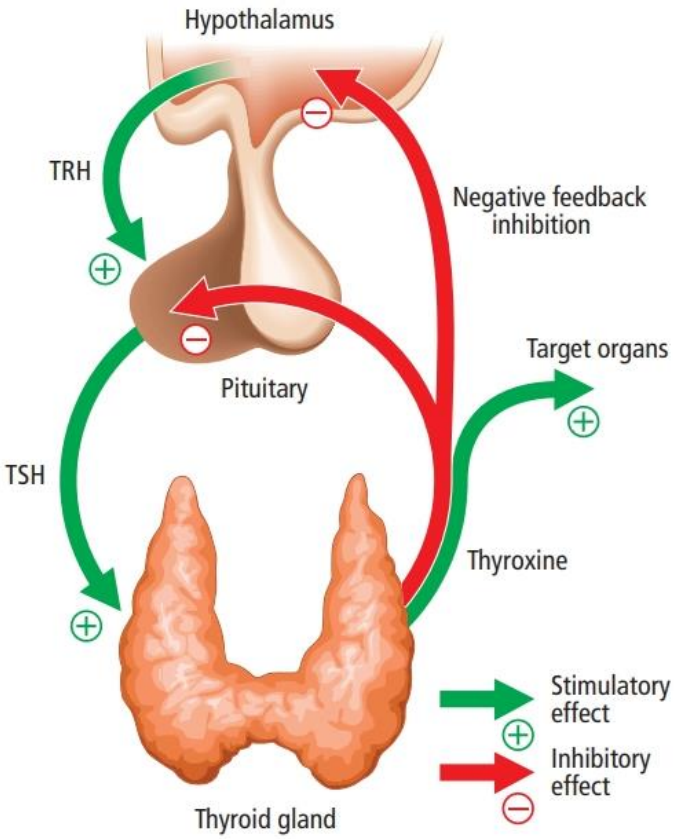
Symptoms of excess of thyroxine secretion:

- Bulging eyeballs (exophthalmia)
- Goitre (thyroid gland swells)
- Increased appetite

- Irritability
- Heat intolerance

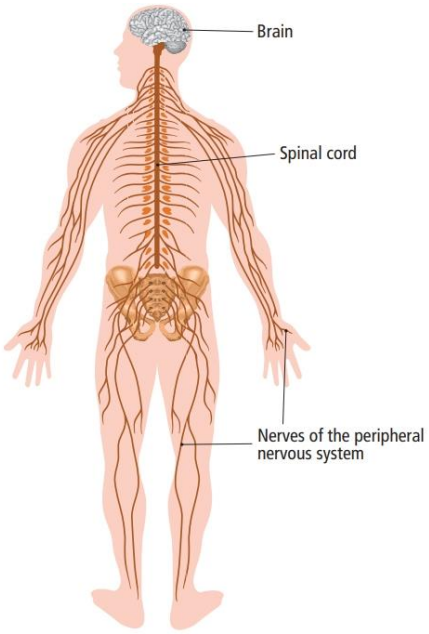
Treatment:
- Surgical removal of part of the thyroid
- Anti-thyroid drugs
- Administration of radioactive iodine

Negative Feedback Mechanism of Thyroxine
- When thyroxine levels rise above normal:
- Pituitary stops secreting thyroid-stimulating hormone (TSH) thereby causing the thyroid to reduce secretion of thyroxine
- When thyroxine levels fall below normal:
- Pituitary starts secreting TSH causing the thyroid gland to secrete more thyroxine
- When iodine is completely absent from diet thyroxine cannot be made – therefore, pituitary keeps secreting TSH which builds up to extreme levels in the thyroid causing goitre.



CHAPTER 39: HUMAN NERVOUS SYSTEM

Introduction:



The nervous system is a type of response system.
The human nervous system consists of two main parts:

- Central nervous system
- Peripheral nervous system

The **central nervous system** is composed of the brain and spinal cord

The **peripheral nervous system** is composed of all the nerves not found within the boundaries of the central nervous system as well as the collections of nerve cells called ganglia.

Structure of the human nervous system

The functional unit of the human nervous system is the **neuron**.

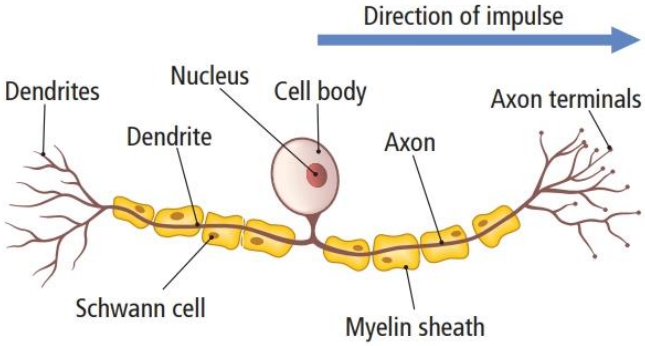
- **Neuron: nerve cell specialised to carry electrochemical impulses.**

There are three types of neuron:

1. Sensory neurons: carry impulses towards the central nervous system.
2. Interneurons: carry impulses from one neuron to another completely within the central nervous system.
3. Motor neurons: carry impulses from an interneuron to an effector.

An **effector** is an organ or tissue that carries out an action in response to a signal from the nervous system.

Sensory neuron:



Characteristics of sensory neurons:

- The dendrite ends are part of sensory organs (e.g. eye, ear, taste buds etc.)
- They have a very long dendrite that extends from the cell body
- The cell body is found **OUTSIDE** the central nervous system in the dorsal root ganglia
- They have shorter axons than motor neurons

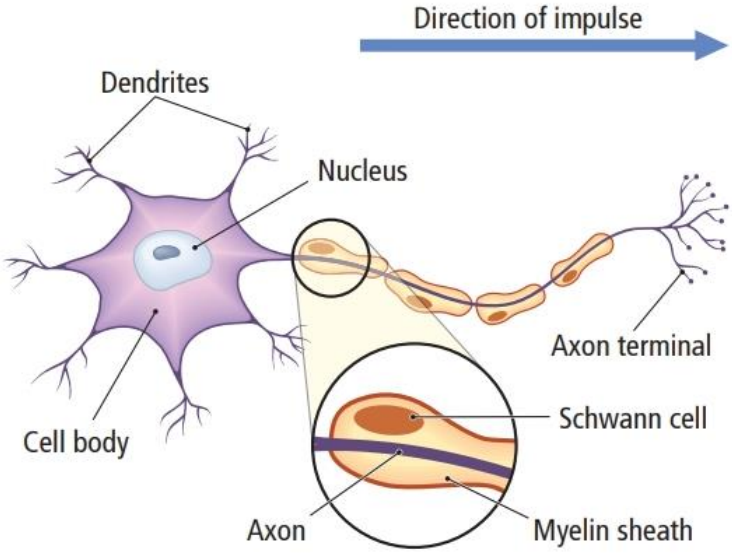
Function of sensory neurons:

- Carry impulses from a sense organ to the central nervous system

Interneuron:

- Found completely within the central nervous system
- Transfer message/impulse from sensory neurons to motor neurons
- Have very short dendrites and very short axons

Motor neuron:



Characteristics of motor neurons:

- Have very short dendrites
- Have a very long axon
- The cell body is WITHIN the central nervous system

Function of motor neurons:

- Carry impulses from the central nervous system to an effector (e.g. skeletal muscle or gland)

Neuron cell components

- Dendrites: receive impulses from other neurons and carry them to the cell body
- Cell body: located between the dendrites and axon. It is responsible for the upkeep of the cell and for producing neurotransmitter substances.
- Neurotransmitter: chemical substance released by a neuron to transmit a nerve impulse to another neuron or effector.
- Axon: carries impulses away from the cell body towards axon terminals.

- Myelin sheath: layers of lipids formed from a Schwann cell that wrap around the axon and dendrites of neurons. It insulates the axon/dendrite maintaining and speeding up the electrochemical impulse.
- Schwann cell: produces myelin sheath.
- Axon terminals: present at the end of the axon and contain synaptic vesicles which contain neurotransmitters.
- Synaptic vesicles: contain neurotransmitter chemicals which are released when the vesicles fuse with the cell membrane.

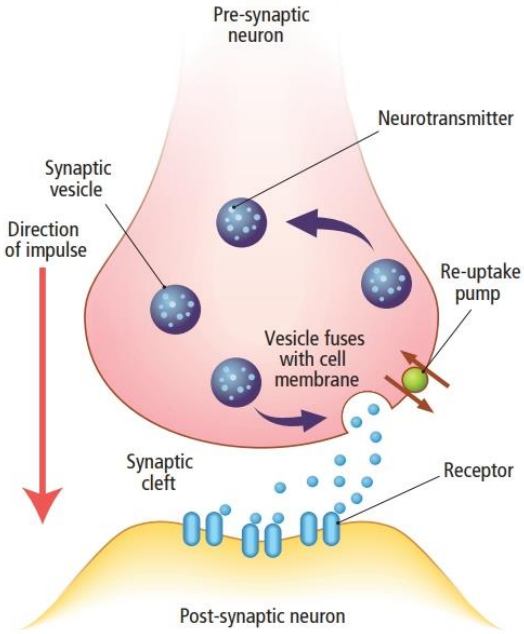
Nerve impulse:

The nerve impulse is a short-lived electrochemical signal that travels along neurons via movement of chemical ions into and out of the neuron.

Transmission of the nerve impulse to another neuron:

Occurs at synapses.

- **Synapse**: structure where two neurons come into close contact so that a nerve impulse can be transmitted between the two neurons.



Transmission process:

- Nerve impulse arrives at an axon terminal (presynaptic neuron)
- Synaptic vesicles are stimulated to fuse with the cell membrane
- Neurotransmitter chemicals are released from the vesicle into the gap between the two neurons, called the synaptic cleft; examples of neurotransmitter substances include: acetylcholine, noradrenaline and dopamine.
- Once the neurotransmitter is in the synaptic cleft it travels the short distance to the dendrite of the postsynaptic neuron where it stimulates the cell membrane to allow ions to flow inwards, setting up a new electrochemical impulse.
- The neurotransmitter is then either broken down by enzymes or reabsorbed into the presynaptic neuron.

Functions of the synapse:

- Allow transmission of the impulse from one neuron to another.
- Control the direction of the impulse – the impulse cannot travel backwards.
- Act as junctions allowing the impulse to be split up and travel along many different neurons or join many impulse together into one impulse.

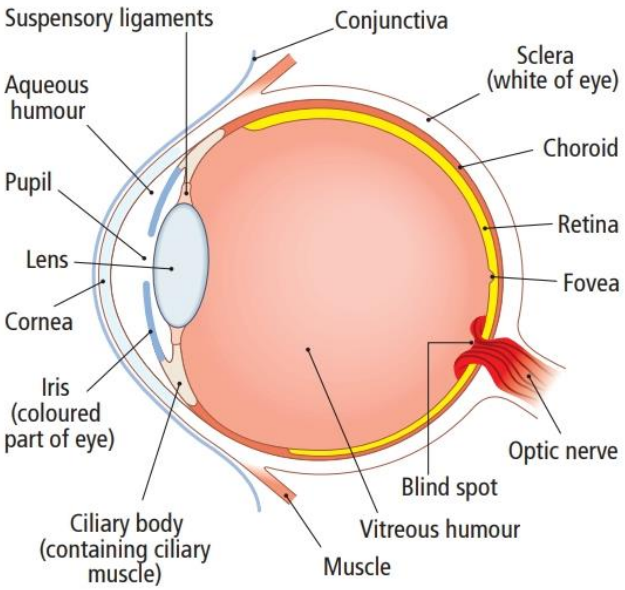
The Peripheral Nervous System:

The senses:

1. Sight:

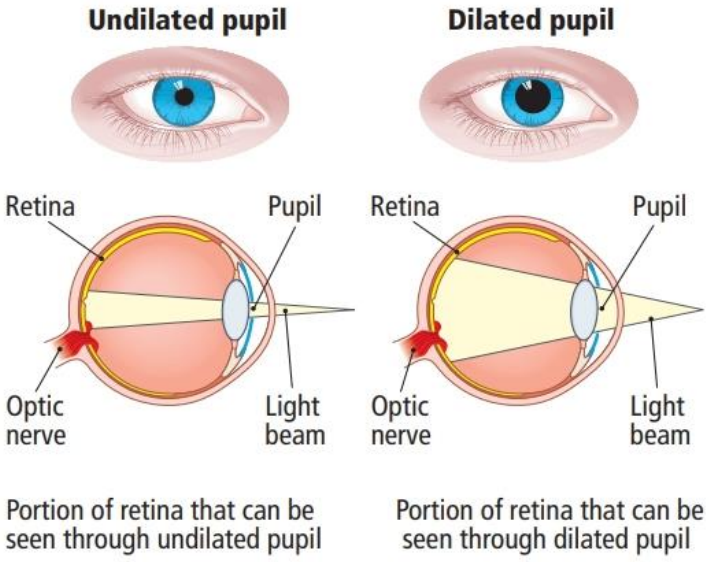
The eyes are the sense organs for sight.

Functions of the parts of the human eye:

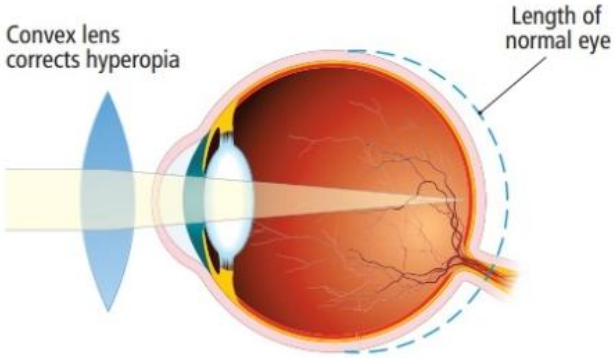


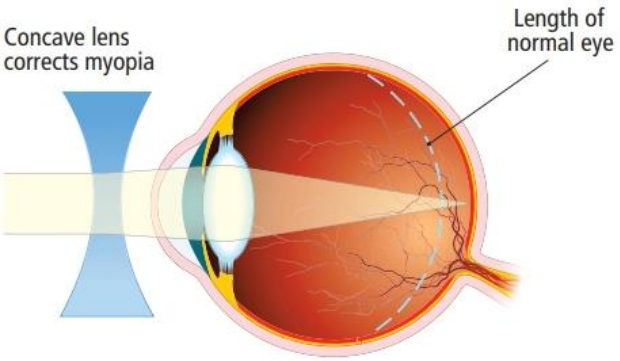
- **Conjunctiva**: produces mucous protecting the front of the eye.
- **Cornea**: transparent part of the sclera that protects the front of the eye; it also allows light to enter the eye and refracts the light rays slightly as part of focusing light onto the retina.
- **Iris**: coloured part of the eye; type of smooth muscle that can contract and relax in response to the amount of light entering the eye; when light is bright the iris contracts limiting the amount of light getting in; when light is dim, the iris relaxes allowing more light into the eye.
- **Pupil**: hole in the internal part of the eye just behind the iris; it allows light into the eye and its size is controlled by the iris; it appears black due to light entering and not leaving the eye as it is all absorbed by the eye.
- **Aqueous humour**: watery liquid present inside the cornea - gives shape to the front of the eye.
- **Vitreous humour**: viscous liquid present inside the eye ball that maintains the shape of the eye by maintaining outward pressure on the sclera.

- **Ciliary body**: type of smooth muscle surrounding the lens that can contract and relax changing the shape of the lens (called **accommodation**).
- **Suspensory ligament**: attaches to and surrounds the ciliary body providing a lever for the contraction of the ciliary muscle.
- **Lens**: transparent structure held in place by the ciliary body and suspensory ligament; changes shape in response to contraction and relaxation of the ciliary body; responsible for focusing light onto the retina.
- **Sclera**: white of the eye covering the entire eye ball except the front part; protects the eye and acts as the attachment surface for external muscles that move the eye in different directions.
- **Choroid**: heavily pigmented layer lying between the retina and sclera; absorbs all of the light entering the eye and helps to prevent reflection within the eye.



- **Retina**: light-sensitive structure of the eye; contains rods and cones; rods are sensitive to black and white; cones are sensitive to red, green and blue light.
- **Fovea**: region of the retina where all the light rays converge when you look directly at an object; mostly composed of cones.
- **Blind spot**: region of the retina where all the nerve fibres from the retina converge and exit the eye and travel to the brain; there are no light-sensitive cells in this regions; there is one in each eye.
- **Optic nerve**: collection of sensory neurons that carry messages to the brain.





Disorders of the eye:

Long-sightedness (Hyperopia):

Symptom: Near objects appear blurred.
Cause: Eyeball is either too short or the focusing elements are too weak.
Treatment: Convex lens placed in front of the eye.

Short-sightedness (Myopia):

Symptom: Distant objects appear blurred.
Cause: Eyeball is either too long or the focusing elements are too strong.
Treatment: Concave lens in front of the eye.

2. Hearing:

- Detection of sound.
- The ear is responsible for detection of sound.
- The ear is composed of three parts:
    1. Outer ear
    2. Middle ear
    3. Inner ear

Outer ear:

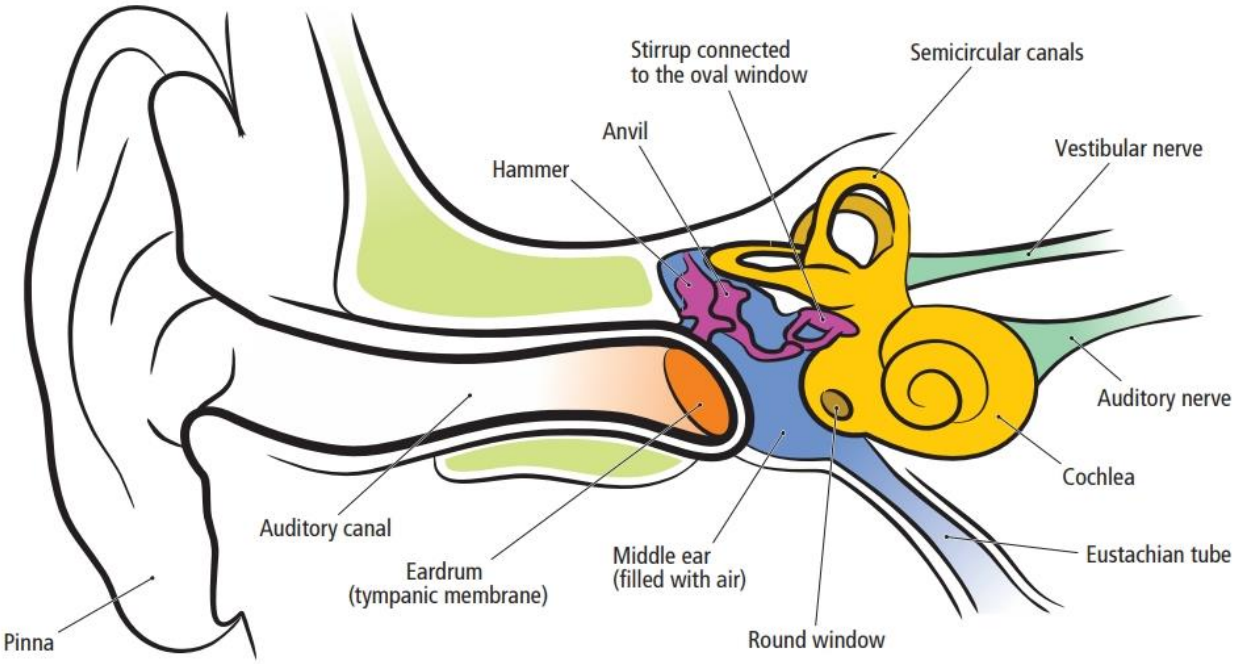
- Composed of the pinna and auditory canal. These pick up sound waves and channel them to the eardrum.

Middle ear:

- The sound waves arrive at the eardrum and are transferred onto the three small bones of the ear – the ossicles. They are called the hammer, anvil and stirrup. They transfer sound waves onto the inner ear. They can amplify soft sounds and dampen loud sounds.
- The Eustachian tube is also part of the middle ear. It is connected to the throat so that pressure differences can be equalised during swallowing preventing damage to the eardrum.

Inner ear:

- Functions in both hearing and balance.
- Composed of two main structures: the cochlea and the semi-circular canals.



1. Cochlea:

- Receives sound vibrations from the ossicles via the oval window – which is the opening to the cochlea covered by a thin membrane. This thin membrane vibrates with the same frequency with which the ossicles vibrate.
- It is filled with lymph through which the sound waves pass.
- There are hair cells within the inner wall of the cochlea that sense the vibrations of the lymph within the cochlea and convert these vibrations into electrical impulses that are then sent onto the brain via the auditory nerve.
- Finally, there is a round window below the oval window that vibrates with an opposite phase to the round window allowing vibrations to be transferred within the lymph more efficiently.

2. Vestibular apparatus:

- Consists of three semi-circular canals filled with lymph.
- Each canal has hair cells lining its internal walls.
- As the head moves the lymph moves within the canals stimulating the hair cells.
- The movement of the lymph is converted into electrical impulses by the hair cells and these impulses are transferred to the brain via the vestibular nerve.

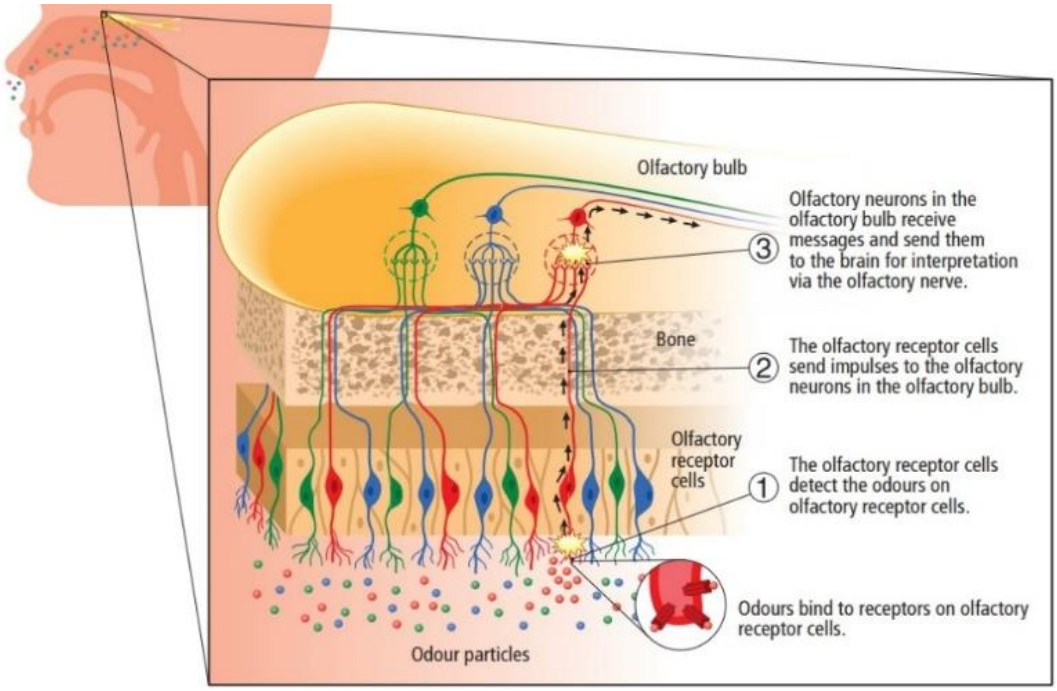
Disorder of the ear:

Glue ear:

Symptom: Inflammation of the middle ear, muffled hearing and pus formation.
Cause: Infections by viruses and/or bacteria.
Treatment: Ear drops or a grommet for severe infections.

3. Smell:

- The sense of smell is also called olfaction.
- It occurs in the nasal cavity.
- There are specialised cells called olfactory receptor cells.
- This group of cells senses the odours and sends signals to the brain via the olfactory bulb and the olfactory nerve.

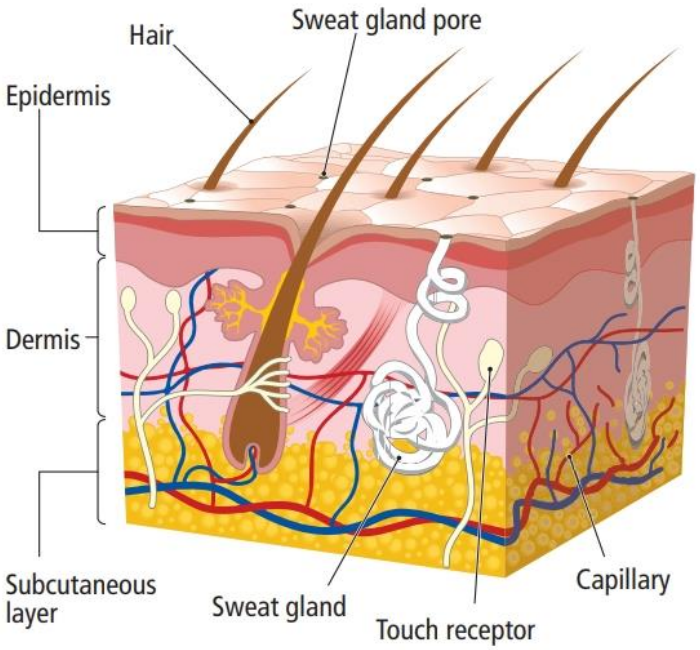


4. Taste:

- Taste is the sense of detecting flavours.
- Taste buds in the tongue are the organs associated with taste.
- There are five basic tastes: sweet, sour, salt, bitter and umami.
- Taste buds are evenly distributed over the upper surface of the tongue.

5. Touch:

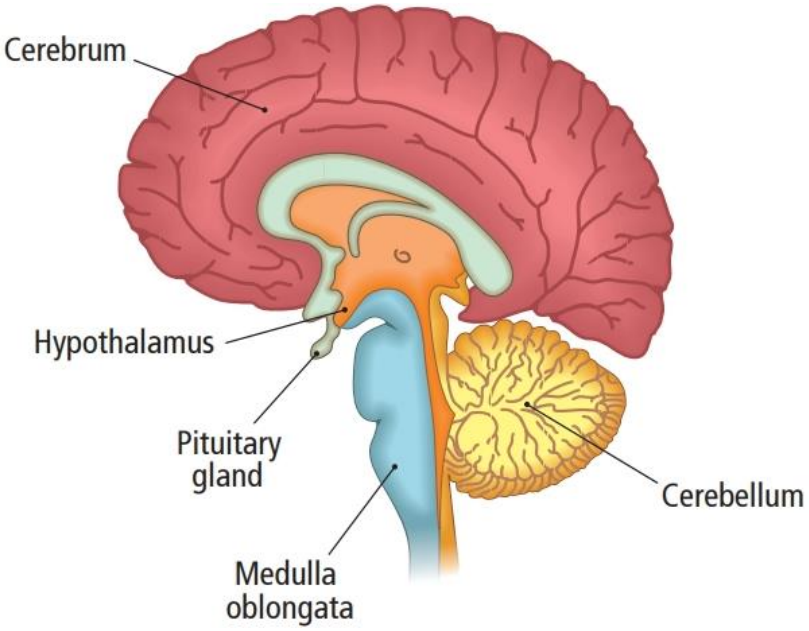
- The skin is the main organ system associated with touch.
- There are touch receptors all over the skin, but their concentration varies.
- The fingertips have high concentrations of touch receptors.



The Central Nervous System

The Brain

The brain is the most complex organ of the human body. It is composed of a number of different parts: **cerebrum**; **cerebellum**; **medulla oblongata**; **hypothalamus**; **pituitary gland**.



Cerebrum:

- Largest part of the brain.
- Composed of two symmetrical hemispheres (left and right).
- High folded surface giving extra area for neurons.
- Divided into different lobes: frontal lobe; temporal lobe; parietal lobe; occipital lobe, with each lobe having specific functions.
  1. Frontal lobe: functions in reasoning, short-term memory, intelligence, personality, problem solving, emotion, language and movement.
  2. Temporal lobe: function in long-term memory, speech, hearing.
  3. Parietal lobe: functions in sensations, touch and their relationship to movement.
  4. Occipital lobe: functions in vision.

Cerebellum:

- Located at the back of the brain.
- Functions in control and coordination of movement.

Medulla oblongata:

- Belongs to part of the brain called the brainstem (on top of the spinal cord).
- Functions in breathing, heart rate, blood pressure, vomiting, coughing, sneezing and swallowing.

Hypothalamus:

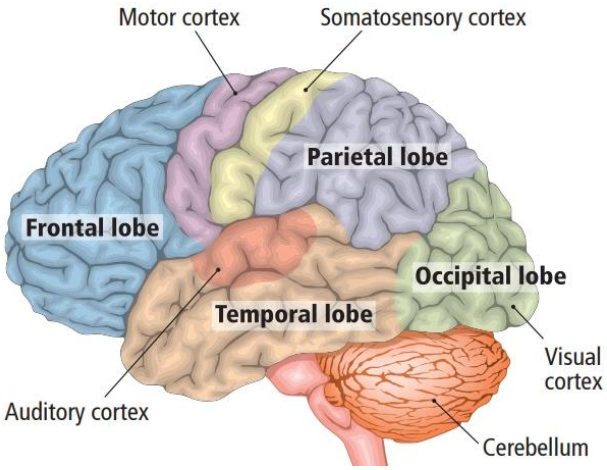
- Small region of the brain located just above the brain stem and pituitary.
- Functions in controlling the endocrine system via secretion of neurohormones such as growth hormone-releasing hormone (GHRH) and thyrotropin-releasing hormone (TRH).
- It also functions in controlling body temperature, hunger and thirst.

Pituitary gland:

- The pituitary gland is the link between the nervous and endocrine systems.
- It releases many hormones including: growth hormone (GH) and thyroid-stimulating hormone (TSH).

Nervous System Disorder: Parkinson's Disease)

Cause: Death of specific neurons deep within the brain. The reasons for the death of these neurons is unknown but thought to be caused by exposure to pesticides.
Symptoms: Shaking and trembling of the hands, arms and legs during movement, a stiff and rigid body and fixed stare.
Treatment: Physiotherapy, exercise and a drug called levodopa.

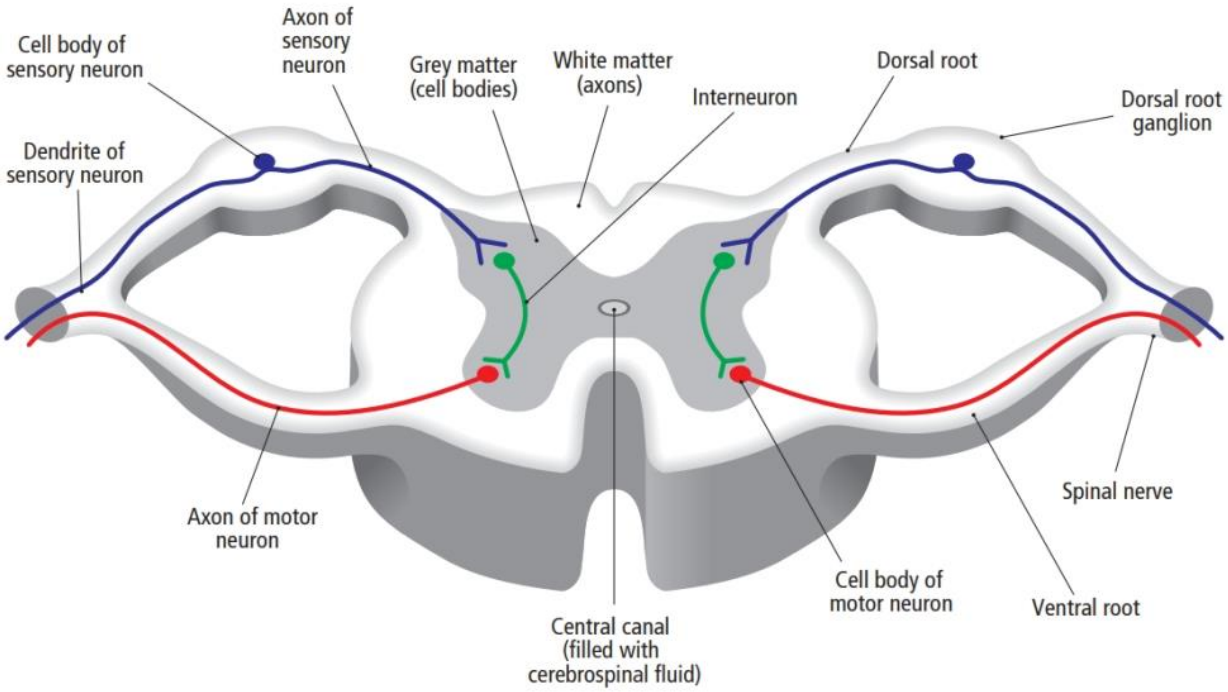


The spinal cord:

- The spinal cord is a bundle of nerve fibres enclosed within the spine, covered in three layers of specialised membranes called the meninges and surrounded in cerebrospinal fluid.
- It carries messages to and from the brain.
- It has 31 pairs of spinal nerves.
- There are structures called a dorsal root, dorsal root ganglion and a ventral root associated with each spinal nerve.
- The dorsal root carries sensory neurons.
- The dorsal root ganglion contains the cell bodies of those sensory neurons.
- The ventral root carries the motor neurons.
- The spinal cord is composed of white matter and grey matter with the outer region of the spinal cord white matter and the inner region grey.
- There is a central canal that is filled with cerebrospinal fluid.

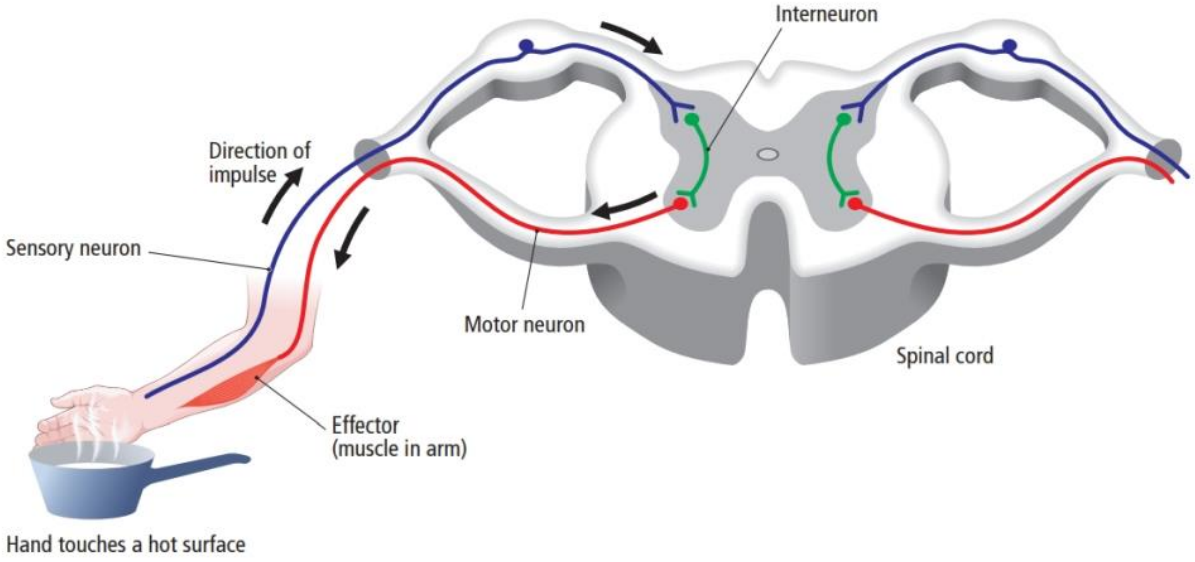
Reflex action:

Reflex actions are involuntary responses to a stimulus.



- Reflex actions enable an animal to protect itself from dangerous situations.
- Reflex actions are carried out by reflex arcs, consisting of a sensory neuron, an interneuron and a motor neuron.
- A common reflex action is the withdrawal reflex – where if you touch something hot you will pull your hand away very quickly.
- The sensory neuron (PNS) detects that something hot has been touched and sends a message to the spinal cord via the dorsal root.
- The sensory neuron passes the message on to an interneuron (CNS)
- The interneuron passes the message on to the motor neuron, whose cell body is just inside the grey matter of the spinal cord.
- The motor neuron sends a message out through the ventral root to the skeletal muscles of the arm to pull the hand away from the hot object.

Comparison of the nervous system with the endocrine system:



	Nervous system:	**Endocrine system:**
Speed of response:	Fast	Slow
Messages carried by:	Electrochemical (ion movement)	Chemical hormones
Speed of transmission:	Fast	Slow
Length of response:	Short-lived	Long-lived
Areas affected:	Specific areas	Wide areas

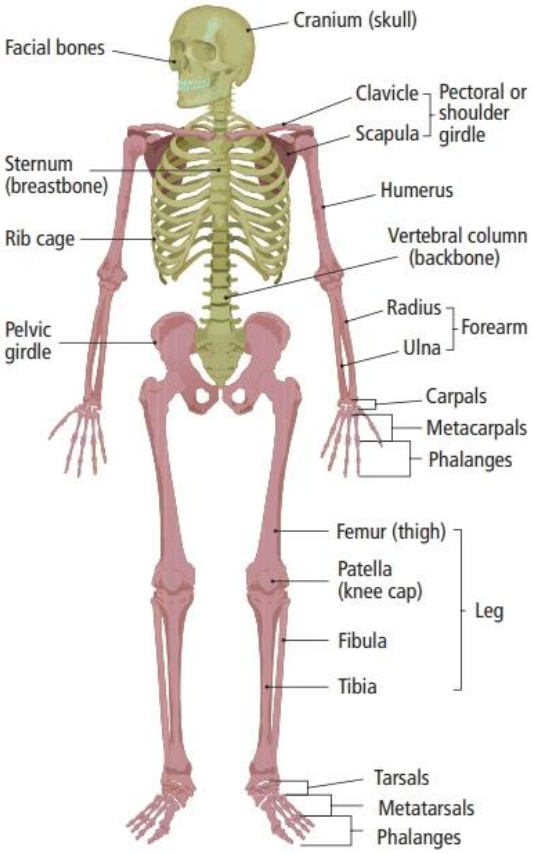
CHAPTER 40: HUMAN MUSCULOSKELETAL SYSTEM

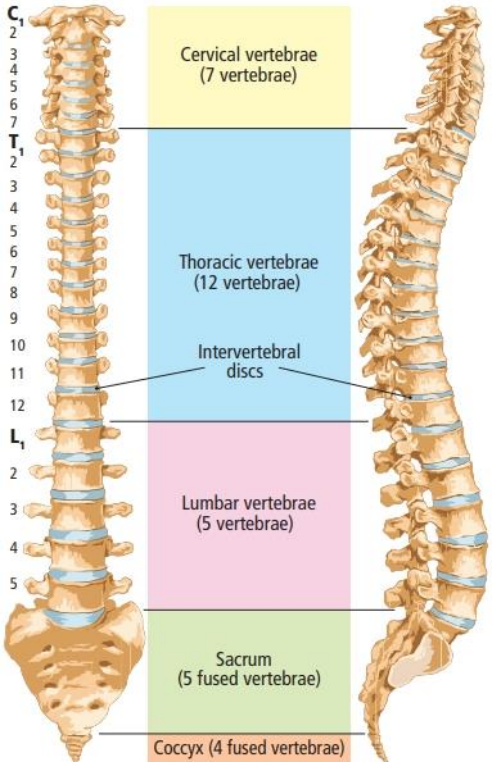
Structure & function of the human skeleton

- Shape and support
- Protection: of internal organs
- Movement: muscles use skeleton as levers
- Production of red and white blood cells
- Hearing: ossicles vibrate and amplify vibrations
- Ingestion and digestion: physical digestion in the mouth
- Storage: of minerals (calcium and phosphorus) that can be taken by the body when needed

The human skeleton is divided into two main areas:

1. Axial skeleton
2. Appendicular skeleton





1. Axial Skeleton

There are 80 bones in the axial skeleton, including: skull, ossicles, spine, ribs and sternum.

Skull:
Also known as the cranium, consisting of 8 fused bones and facial bones.

Vertebral column:
Consists of 33 small bones divided into 5 regions: cervical (7) thoracic (12), lumbar (5), sacrum (5) and coccyx (4).

Vertebrae:

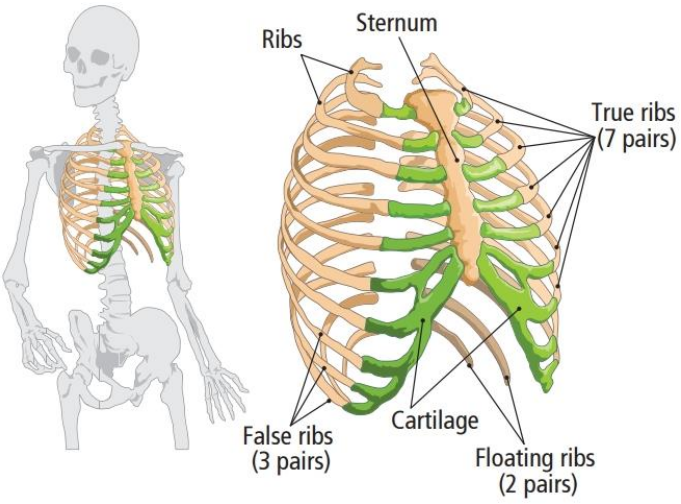
- Protect spinal cord.
- Give support to thoracic cavity and abdomen.

Invertebral discs:

- Located between each vertebra – held in place by ligaments.
- Elastic and compressible.
- Provide flexibility and act as shock absorbers.
- Can "slip" – where soft centre of disc bulges out. It is called **prolapsed** invertebral disc. Can push against nerve often causing pain.

Ossicles:
Consist of three small bones – the smallest in the human body

- Hammer (malleus)
- Anvil (incus)
- Stirrup (stapes)



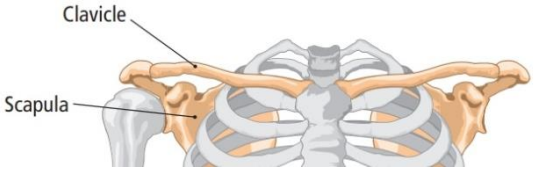
Ribs:

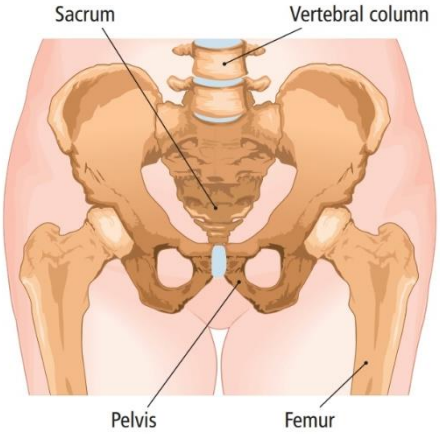
- 12 pairs originate from the vertebral column
- 7 pairs are "true ribs" (attached directly to sternum)
- 3 pairs are "false ribs" (attached indirectly to the sternum by only cartilage)
- 2 pairs are "floating ribs" (attached to spine only)

2. Appendicular Skeleton:

Consists of 126 bones:

- Pelvic girdle (hips)
- Pectoral girdle (shoulders):
  - Scapula (shoulder blade)
  - Clavicle (collar bone)
- Limbs:
  - Arms: humerus, radius, ulna, carpals, metacarpals, and phalanges
  - Legs: femur, tibia, fibula, tarsals, metatarsals, and phalanges





Macroscopic Anatomy of a Long Bone

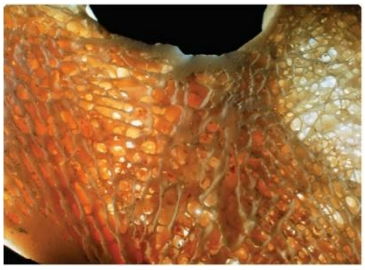
Bone is mixture of organic (35%) and inorganic (65%) material.

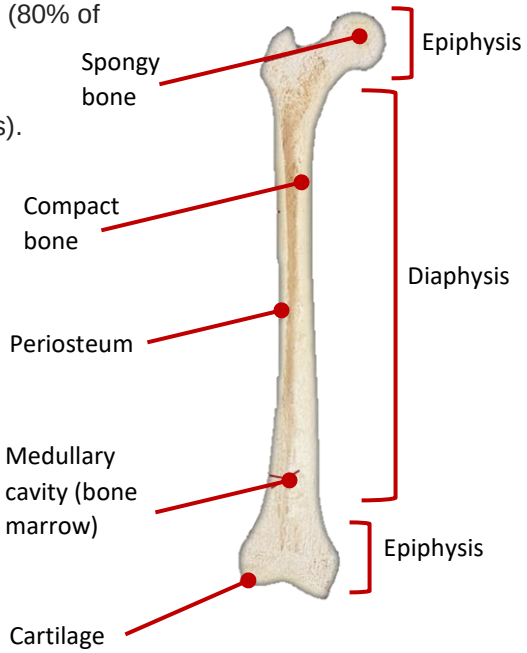
Periosteum: thin layer of connective tissue that covers the outer surface of bone in all places except at joints.

Compact bone: dense and hard and forms the outer parts of a bone (80% of the weight of human skeleton). Function: support and protection.

Medullary cavity: central cavity of the bone where red and yellow marrow are stored. Located mainly in the shaft of the bone (diaphysis). Function: storage of fat and formation of red blood cells.

Spongy bone: found in the heads of long bones and is found throughout the inner cavity of long bones. It is where arteries and veins are found. It is low density (has lots of 'spaces') but still strong due to the 'lattice' structure. Functions: gives strength and production of red blood cells (when red marrow is present).

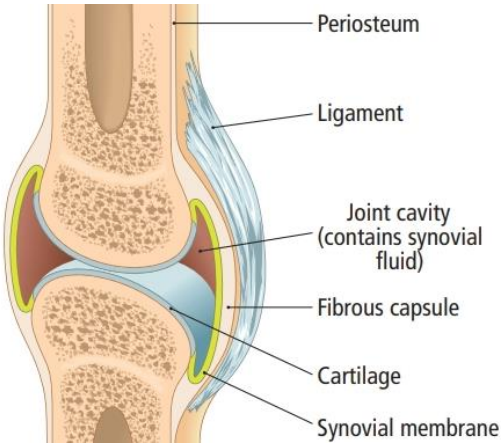




Cartilage: type of dense, gel-like connective tissue made of collagen. Cartilage is found at the ends of long bones at joints, between the ribs and sternum, the ear, the nose, the trachea and bronchi (rings of cartilage) and between intervertebral discs Functions: shock absorption and allows friction-free movement

Joints:

- Immovable – fused joints of the skull
- Slightly movable – vertebral joints
- Free-moving/Synovial:
  - Ball-and-socket joints of the shoulder and hip
  - Hinge joints such as the elbow and knee.



Ligaments and Tendons:

- Ligaments connect bone to bone and are composed of collagen.
- Tendons attach muscles to bone and are composed of collagen.

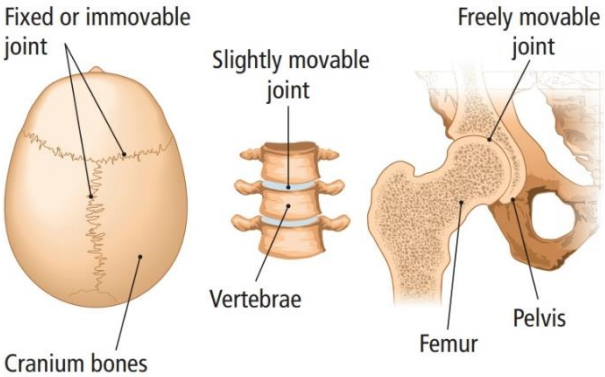
Skeletal muscle:

- Contractile tissue – has ability to shorten and generate a pulling force.
- Voluntary muscles – we can consciously control contractions of skeletal muscle.
- Function: movement.

Antagonistic muscle pairs:

Antagonistic muscle are pairs of muscles where when one contracts the other relaxes (have opposite effects).

- e.g. biceps and triceps of the upper arm.

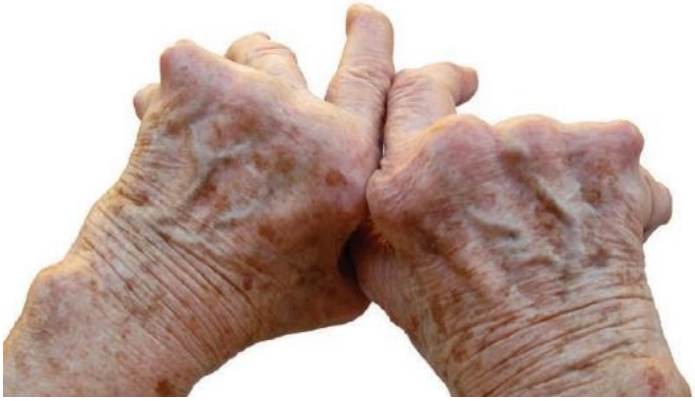


Musculoskeletal disorder – osteoporosis:

- Brittle-bone disease – bones are porous/less dense and break more easily.
- Possible cause: Bone replacement has slowed down.
- Prevention: Physical exercise.
- Treatment: physiotherapy, physical exercise, dietary calcium, and vitamin D supplements.

Musculoskeletal disorder – Rheumatoid Arthritis:

- Joint (fingers, wrists, ankle most common) become stiff and sore (inflammation occurs).
- Articular cartilage has been destroyed and bones fuse.
- Possible cause: Immune reaction against the body's own cartilage.
- Prevention: No known preventative measure yet.
- Treatment: Pain-killers and anti-inflammatory drugs are administered.
- Badly affected areas, such as hip or knee can be replaced with artificial joints.

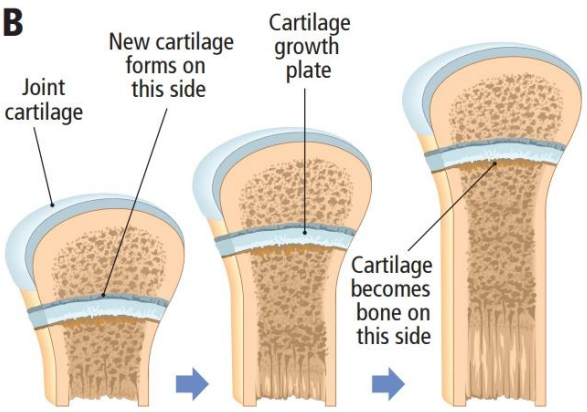


Growth and Development in Bones:

- Skeleton of early embryo is mostly cartilage.
- Bone formation begins just before week 8.
- Specialised cells called osteoblasts secrete a thick layer of bone around the cartilage of the diaphysis – a tube of bone now encircles the diaphysis.
- Cartilage continues to grow at ends – epiphyses – bone elongates.
- After birth the epiphyses start to calcify.
- Cartilage remains at the junctions between the diaphyses and epiphyses – this area is called the growth plate.
- The growth plates enable the bones to elongate during childhood and eventually calcify and are replaced by bone at the end of puberty then fully grown – 18 in females and 21 in males.

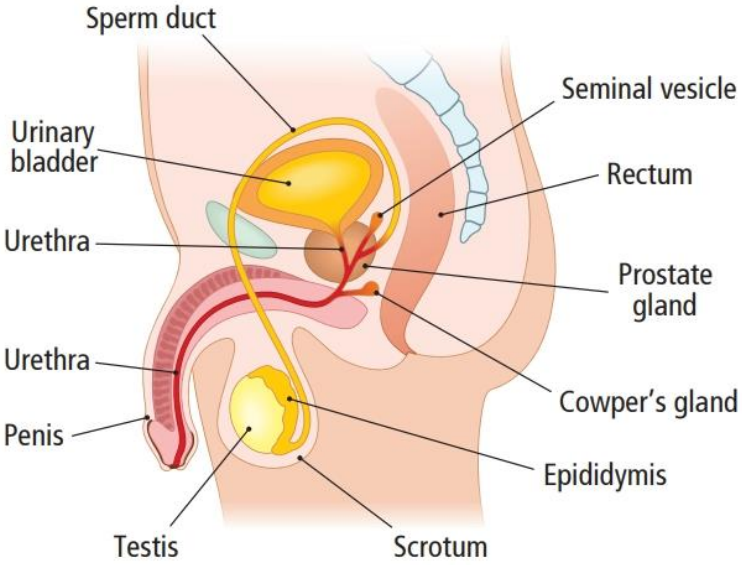
Bone Renewal:

- Bone is a living organ and is capable of self-renewal.
- Bone is constantly broken down (by osteoclasts) and replaced (by osteoblasts).
- Skeleton is completely replaced every 7 years and complete replacement slows down with age.
- Osteoclasts remove calcium and osteoblasts lay calcium down.
- Renewal of bones is affected by the hormone parathormone, which causes an increase in the breakdown of bone. Parathormone is secreted by the parathyroids (see chapter 38). Bone renewal is also affected by exercise levels and dietary calcium.



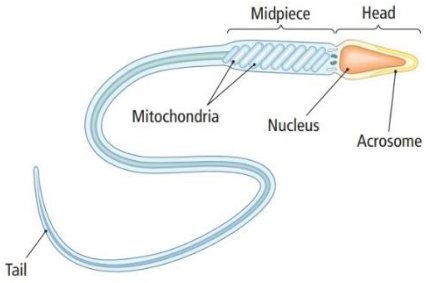
CHAPTER 41: HUMAN REPRODUCTIVE SYSTEM

The male reproductive system



- **Penis**: muscular organ through which urine and semen travel. It can also fill with blood, becoming erect. This occurs during sexual arousal, enabling the penis to be inserted into the vagina.
- **Sperm ducts**: there are two sperm ducts that carry sperm from the testes to the urethra.
- **Prostate gland**: exocrine gland located just underneath the bladder. It secretes fluid contributing to semen.
- **Cowper's glands**: pair of exocrine glands that also secrete fluid contributing to semen.
- **Seminal vesicles**: pair of exocrine glands that also secrete fluid contributing to semen.
- **Epididymis**: sperm storage organs that are located on top of each testis. Sperm mature in the epididymis before being released during sexual intercourse. If sperm is not released, it is broken down and absorbed by the cells of the epididymis.
- **Testes**: pair of exocrine and endocrine glands located outside the body in a sac called the scrotum. They are responsible for producing **sperm** (exocrine secretion) and the hormone **testosterone** (endocrine secretion). Testosterone is produced by the testes in response to **luteinising hormone** (**LH**, which is secreted by the pituitary).
- **Scrotum**: pouch in which each testis are located. They hold the testes outside the body as sperm production requires a temperature of 35 ºC.

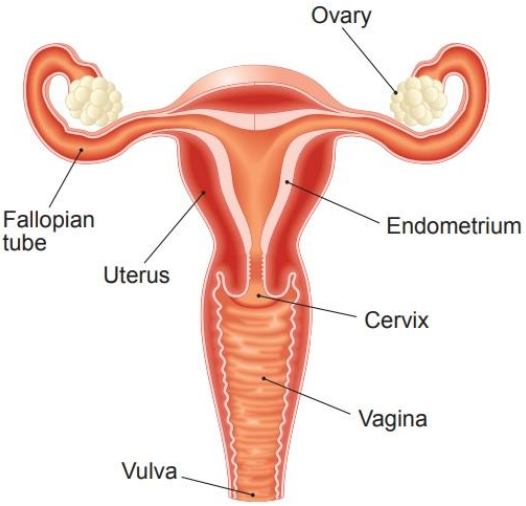
Sperm production



The testes produce sperm in response to the hormone **follicle-stimulating hormone** (**FSH**, which is secreted by the pituitary).
Sperm are produced by **meiosis** (see Chapter 13: The Cell Cycle).
Sperm are highly specialised cells containing three parts: head, midpiece and tail.

- **Head**: contains the **nucleus** with 23 chromosomes (human haploid number) and an **acrosome** – needed to penetrate the egg cell at fertilisation.
- **Midpiece**: contains many **mitochondria** that produce energy needed for movement of the sperm cell towards the egg cell.
- **Tail**: responsible for propelling the sperm cell.

The female reproductive system



- **Vulva**: consists of a number of external genital organs, forming the entrance to the vagina and function in sexual arousal.
- **Vagina**: muscular organ approximately 7 cm long. It is also known as the birth canal and receives the penis during sexual intercourse.
- **Cervix**: located at the top of the vagina – between the vagina and uterus.
- **Uterus** (womb): muscular organ that holds the developing embryo and foetus during pregnancy. The internal lining of the uterus is called the **endometrium** and undergoes a series of changes throughout the female's 28 day cycle.
- **Fallopian tubes**: also known as the oviducts, they form the tubes that carry the egg/fertilised egg from the ovaries to the uterus.
- **Ovaries**: two exocrine and endocrine organs located within the abdomen at the end of the fallopian tubes. They release one **egg** (exocrine secretion) per menstrual cycle and the hormones **progesterone** and **oestrogen** (endocrine secretion) directly into the bloodstream.

Egg cell development

- Eggs are present in the female ovaries from birth.
- Eggs begin to be ovulated (released from the ovary) at puberty in the female (age 13 approx).
- Usually only one egg is released (ovulated) per 28 days (length of the female menstrual cycle).

Role of meiosis in gamete formation

Meiosis is a nuclear division leading to four daughter cells each with half the chromosomes as the parent cell.

Meiosis is required for gamete formation so that following fertilisation, the new individual will have the correct number of chromosomes in all cells. Meiosis also creates variation in the gametes, so that all gametes are genetically unique. Therefore, no two offspring are the same (unless they came from the same zygote).

Secondary Sexual Characteristics

Secondary sexual characteristics are those features that distinguish males from females, but are not part of the reproductive system.

Secondary sexual characteristics in males include:

- Facial hair
- Pubic hair
- Enlarged larynx
- Broad shoulders and chest
- Large musculature

Secondary sexual characteristics in females include:

- Pubic hair
- Breasts
- Wide hips

Roles of the sex hormones

- **Testosterone**: produced by the testes in response to the pituitary hormone luteinising hormone (LH). It functions in maintaining male secondary sexual characteristics and plays a role in the production of sperm.
- **Oestrogen**: produced by the ovaries in response to follicle stimulating hormone (FSH). It functions in the formation and maintenance of female secondary sexual characteristics and the repair of the endometrium during the menstrual cycle.
- **Progesterone**: produced by the ovaries following ovulation. It functions in maintaining the endometrium during the menstrual cycle and during pregnancy.

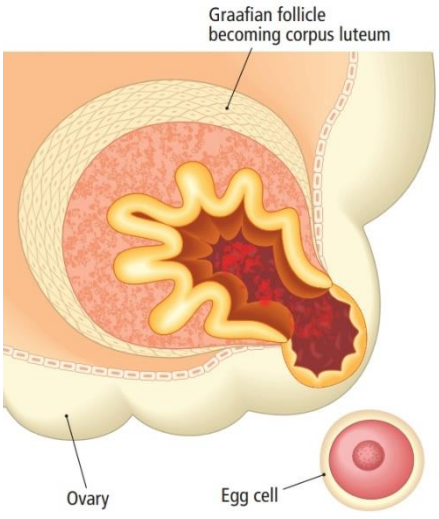
Menstrual Cycle – detailed study and hormonal control

- The female menstrual cycle is a series of changes that occur in the female reproductive tract over the period of 28 days.
- It begins in the female at puberty and continues every 28 days until menopause (approximately age 45), when the female stops ovulating eggs.
- It can be divided into three separate phases:

1. Follicular phase and menses
2. Ovulation
3. Luteal phase

1. Follicular phase and menses (days 1-13):

- This phase begins with menses – which is the shedding of the lining of the uterus (endometrium) and occurs during days 1-5 of the cycle.
- It is caused by low levels of oestrogen and progesterone.
- Low levels of the female sex hormones removes the inhibition of these hormones on the pituitary. Follicle-stimulating hormone (FSH) levels begin to increase once again.
- FSH causes new follicles to form in the ovaries and they secrete oestrogen.
- One of these follicles becomes dominant and is called the Graafian follicle.
- The Graafian follicle continues to grow from days 6-13, increasing in size and secreting increasing amounts of oestrogen.
- Increasing amounts of oestrogen helps to repair the lining of the uterus.
- Increasing amounts of oestrogen also inhibit FSH secretion from the pituitary, ensuring no further follicles develop during the cycle.



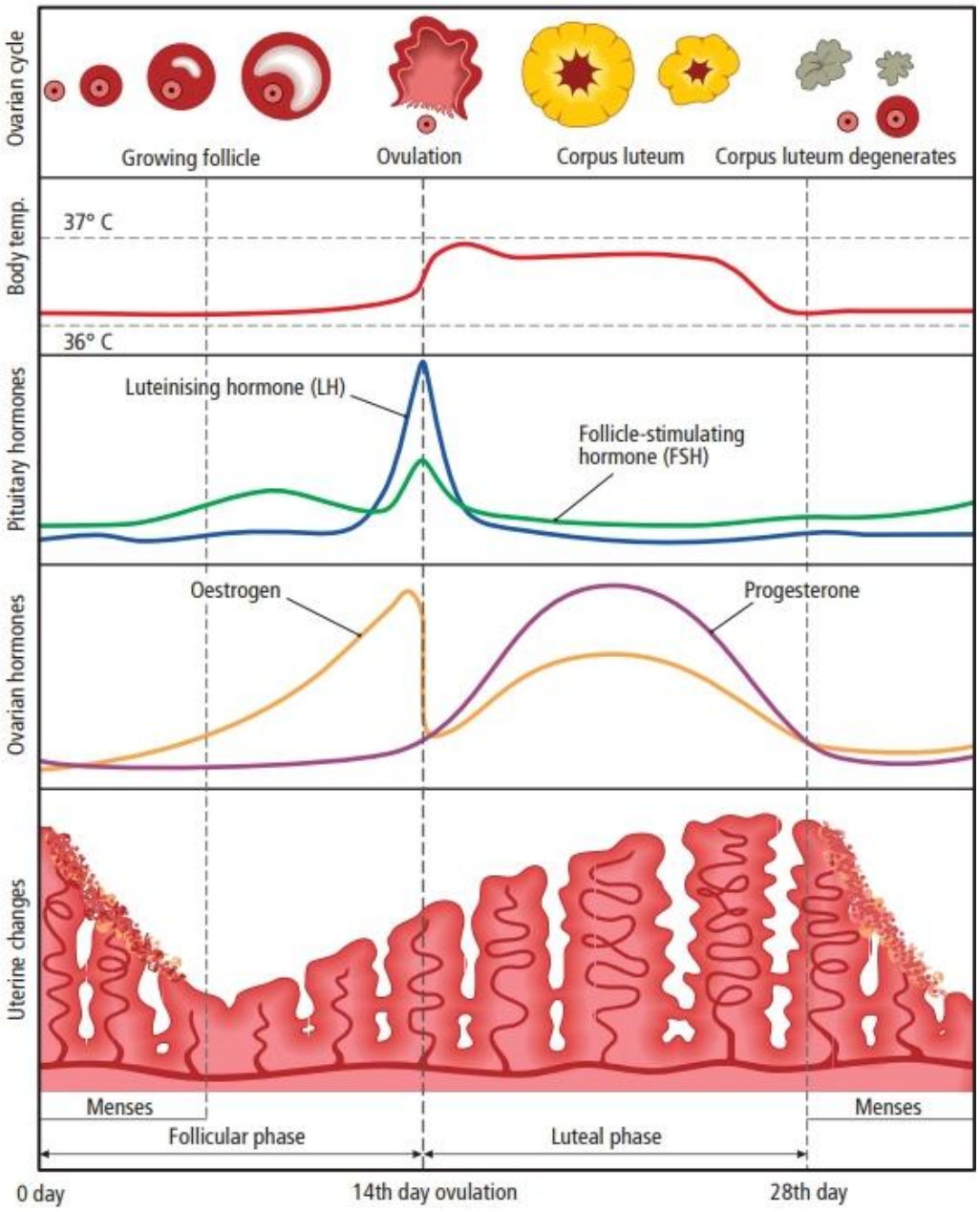
2. Ovulation (day 14):

- Oestrogen levels reach a critical level in the blood stream just before ovulation (approx. day 14).

- This critical level of oestrogen stimulates the pituitary to secrete a burst or surge of luteinising hormone (LH).
- The surge in LH levels causes ovulation – release of an egg cell from the ovary into the oviduct.

3. Luteal phase (days 15-28):

- Once the Graafian follicle has released its egg, it becomes the corpus luteum or yellow body and oestrogen levels drop.
- The corpus luteum secretes increasing amounts of progesterone.
- Progesterone maintains the endometrium and thickens it further.
- Towards the end of the luteal phase, progesterone and oestrogen levels drop.



Menstrual disorders:

Endometriosis:

Endometriosis is where the cells lining the uterus (endometrium) move and grow outside the uterus.

Symptoms: Pain in the pelvic area and infertility.
Treatment: Pain medication, hormonal drugs to treat any hormonal imbalance, or surgery in severe cases.

Fibroids:

Fibroids are benign tumours that grow in the muscular wall of the uterus.

Symptoms: Pain and heavy menstrual bleeding.
Treatment: Pain medication, ultrasound, or surgery in severe cases.

Stages of sexual intercourse:

Sexual arousal:

- In males: blood flows into the penis, which becomes erect so that it can be inserted into the vagina.
- In females: secretions from the vagina and blood flowing into the vagina causing it to elongate.
- Increases in heart rate and breathing rate occur in both sexes.

Copulation: is the insertion of the erect penis into the vagina.

Orgasm: occurs when sexual arousal reaches a maximum (climax).

Ejaculation: is the release of semen from the penis during sexual intercourse.

Fertilisation:

Fertilisation is the fusion of a sperm cell with an egg cell to form a diploid zygote.

Survival time of sperm and egg cells:

- Sperm survive anywhere from 0 to 7 days in the female reproductive tract.
- Egg cells Egg cells survive up to 48 hours after ovulation.

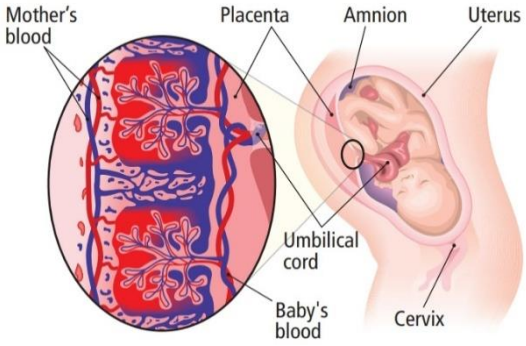
Location of fertilisation: always occurs in the fallopian tubes.

Fertile period: part of the menstrual cycle where the female is most likely to become pregnant.

Implantation and placenta formation:

Implantation is the embedding of the embryo into the lining of the uterus.

Placenta:



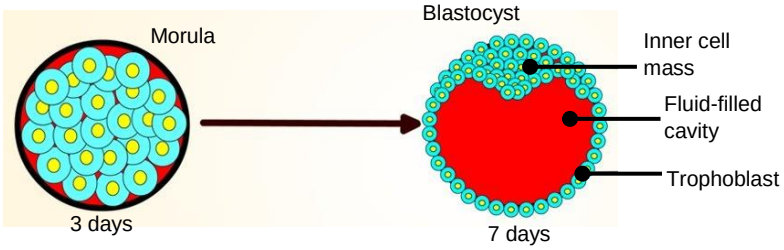
- Composed of uterine and embryonic tissue.
- Fully formed and functional after 3 months.
- Attached to the foetus via the umbilical cord.

Functions of the placenta:

- Secretes progesterone, taking over from the corpus luteum.
- Allows nutrients, water, oxygen antibodies, drugs and hormones to pass from the mother's bloodstream to the baby's bloodstream.
- Allows wastes produced by the baby, such as carbon dioxide and urea, to pass to the mother's bloodstream for excretion.
- Keeps mother's blood separate from baby's blood (as they could be two different blood groups).

Development of the embryo

- At fertilisation, the zygote starts to divide by mitosis
- A ball of cells called the **morula** is formed.
- The morula moves down the fallopian tube towards the uterus.



The morula is a ball of undifferentiated cells that forms as a result of mitosis.

- Mitosis continues in the morula which then becomes a **blastocyst** around day 7.

A blastocyst is a fluid-filled sac containing an inner cell mass that gives rise to the embryo.

- Mitosis continues in the blastocyst producing an inner cell mass with three layers:
  1. Ectoderm
  2. Mesoderm
  3. Endoderm
- The ectoderm gives rise to the skin and nervous system.
- The mesoderm gives rise to the musculoskeletal system, kidneys, lungs, heart.
- The endoderm gives rise to the liver, pancreas and the inner linings of the breathing, digestive and excretory systems.
- A protective sac, called the amnion, forms around the developing embryo.
- Amniotic fluid fills the sac and acts as a shock absorber.
- At the end of the eighth week of pregnancy all the major internal organs have formed and the embryo is known called a foetus.
- At the 12th week the placenta is fully formed and functional.
- As pregnancy progresses, the foetus increases in size and the internal organs mature in readiness for life outside the uterus.

Childbirth

Childbirth is divided into three stages:

1. Labour
2. Parturition
3. Afterbirth

1. Labour

- Ranges from 1 hour to 72 h.
- Walls of the uterus begin to contract caused by secretion of the hormone oxytocin from the pituitary.
- The amniotic sac breaks ('breaking of the waters').

2. Parturition

- Parturition is the process of the baby being born.
- The baby is usually delivered through the birth canal head first.
- The umbilical cord is clamped, cut and sealed to prevent excess blood loss.

3. Afterbirth

- The afterbirth involves the passing of the placenta from the uterus.

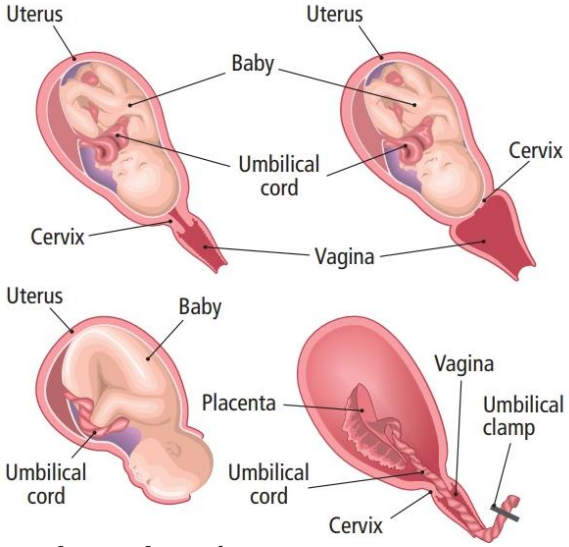
Lactation:

Lactation is the production and secretion of milk by the breasts of the female.

- The production of milk by the breasts is controlled by a pituitary hormone, prolactin.
- In the days after childbirth, the breasts secrete a thick yellow substance called colostrum – a nutritious and concentrated form of milk that contains antibodies that protects the baby in the first few weeks and months of life.

Advantages of breast-feeding:

- Contains all the correct nutrients in the correct proportions.
- Contains antibodies.
- Correct temperature.
- Sterile – contain no bacteria or viruses.
- Promotes a strong bond between mother and baby.
- Helps the mother's body recover more quickly after pregnancy.
- Thought to reduce the chances of developing breast cancer later in life.



Birth control:

Birth control is procedures taken to limit the number of offspring produced.

Abortion: is the chemical or physical removal of an embryo or foetus from the uterus.

Contraception: is the intentional prevention of pregnancy by stopping fertilisation or implantation from occurring.

There are four methods of contraception:

1. **Natural contraception**: the couple avoid sexual intercourse during the female's fertile period (rhythm method).
2. **Mechanical contraception**: a barrier is used to prevent the sperm from reaching and fertilising the egg cell (e.g. the use of a condom and diaphragms)
3. **Chemical contraception**: using spermicides or hormones. Condoms, domes and diaphragms are often coated in a spermicide that kills the sperm as soon as they come into contact with it. Hormones are used as contraceptives in the form of the 'contraceptive pill' – which prevents ovulation.
4. **Surgical contraception**: involves the ligation (tying and cutting) of the fallopian tubes in females (tubal ligation) and of the sperm ducts in males (vasectomy).

Infertility:

Infertility is the inability to contribute to conception.

Male infertility can be due to:

- Low sperm count
- Low sperm mobility
- Endocrine gland failure

Female infertility may be due to:

- Fallopian tube blockage
- Endocrine gland failure

Corrective measures for both male and female infertility include:

- Hormonal treatment
- Surgery
- IVF (*in vitro* fertilisation)