# B I O L O G Y Sl

**( Chapter 1 —> 6 )**

# Chapter 1 —> Cell biology

## 1.1 introduction to cells

Magnification: Magnification = ruler measurement / real life measure

Cell theory:

1) all living things are composed of cells
2) The cell is the smallest unit of life
3) Cells only arise from pre-existing cells

Challenges to the cell theory:

Striated muscle —> are very long —> 300 mm
—> multi-nucleated with continuous plasma membrane
—> not conform to standard view of the cell as autonomous unit
Aseptate fungal hyphae —> very large
—> cytoplasm is continuous so challenges idea of discrete cells
—> multi-nucleated
Giant algae (Acetabularia) —> single-celled organism
—> Gigantic in size (5-100 mm)
—> Complex in form
—> Single nucleus (challenges idea large organism->many cells

Functions of life:

- **M**etabolism —> All the enzyme-catalysed reaction in a cell / organism
- **R**esponse —> Responding to and interacting with the environment
- **H**omeostasis —> The maintenance and regulation of internal cell condition
- **G**rowth —> Growing and changing size / shape
- **E**xcretion —> The removal of metabolic waste
- **R**eproduction —> Producing offsprings either sexually or asexually
- **N**utrition —> Feeding by either synthesis of organic molecules or absorption

Unicellular organisms are the smallest organisms capable of independent life
—> paramecium and scenedesmus are two examples

Surface are to volume ratio:

- Larger SA:V ratio —> cell more efficient
—> diffusion pathways are shorter so faster metabolism
—> concentration gradient easier to generate
—> heat lost more quickly
- To maximise SA:V ratio —> cells divide
—> cells compartmentalise
—> cells create inner membranes
- Villi in intestinal tissue and alveoli in the lungs (microvilli) have a large SA:V ratio

Emergent properties:

- Arise from the interaction of component parts
- Atoms —> molecules —> cells —> tissues —> organ —> organ system —> organism

## Gene expression and differentiation:

- Each cell contains the entire set of genetic instructions of the organism and have the same identical genome
- In embryonic stem cells the entire genome is active
- Totipotent , pluripotent , multipotent , unipotent
- Newly formed cells receive signals which deactivate genes
- Active genes —> euchromatin / inactive genes —> heterochromatin (condensed)
- The fewer the active genes, the more specialised the cell is
- 220 distinct highly specialised cell types in humans
- Stem cells —> are self-renewable —> can continuously divide and replicate
  —> Potency —> have the capacity to differentiate into specialised cell types
  —> can be used as a viable therapeutic option to replace non-stem cells

## Stargardt's macular dystrophy:

- Causes progressive vision loss to the point of blindness
- recessive genetic condition (photoreceptor cells degenerate)
- Retinal stem cells are injected into the retina and become functional replacing dead cells

## Parkinson's disease

- Degenerative disorder of the central nervous system caused by death of dopamine-secreting cells in the midbrain (dopamine is a neurotransmitter, for smooth movements)
- Typically exhibit tremors, rigidity, slowness of movement and postural instability
- Treated by replacing dead nerve cells with living, dopamine-producing one

## Leukemia:

- Cancer of blood or bone marrow —> high levels of poorly-functioning white blood cells
- Hematopoetic stem cells harvested and then chemotherapy
- HSCs transplanted back and differentiate into white blood cells

## Stem cell sources:

Embryo —> almost unlimited growth potential and totipotent
—> high risk of tutor development
—> kills an embryo
—> less chance of genetic damage
—> not genetically identical to the patient
Cord blood —> easily obtained but in limited quantity
—> reduced potential
—> low risk of tumour
—> limited capacity to differentiate
—> low chance of genetic damage
—> fully compatible
Adult —> Difficult to obtain and with reduced potential
—> low risk of tumour
—> limited capacity to differentiate
—> may be genetic damage
—> fully compatible

## Artificial stem cell techniques

- Somatic cell nuclear transfer —> Involves the creation of embryonic clones by fusing a diploid nucleus with an enucleated egg cell —> more embryos are created by this process then needed
- Nuclear reprogramming —> Inducing a change in the gene expression profile of a cell in order to transform it into a different cell type —> as it uses oncogenic retroviruses and transgenes and this increases the risk of health consequences (ex. cancer)

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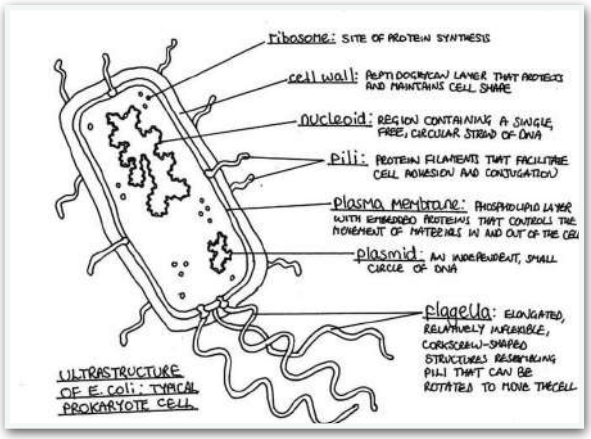
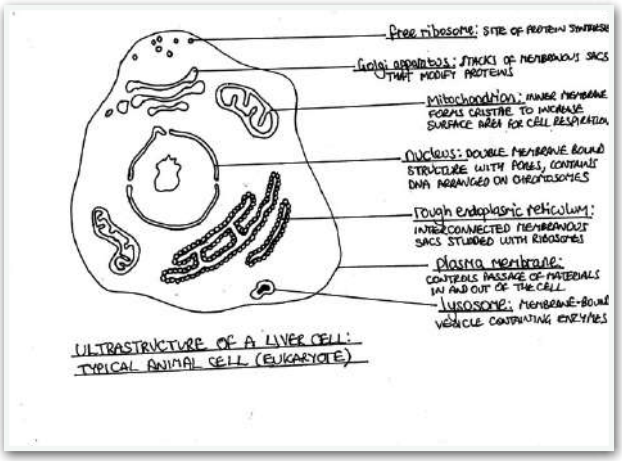
## 1.2 Ultrastructure of cells

- Resolution —> the shortest distance between two point that can be distinguished
- Ultrastructure —> a structure specimen that are at least 0.1nm in their smallest dimension




### Ultrastructure of a prokaryote ( E. Coli )

- Prokaryotes —> organisms with no nucleus
- Archaebacteria —> found in extreme environments (ex. Extremophiles)
- Eubacteria —> traditional bacteria including most known pathogenic forms
- Binary fission —> a form of asexual reproduction used by prokaryotic cells




### Ultrastructure of an eukaryote (Liver cell)

-eukaryotes are organisms whose cells contain a nucleus

-Are compartmentalised by membrane-bound structures (organelles)

- Divided into four distinct kingdoms:

—> Protista —> unicellular organisms

—> Fungi —> have a cell wall made of chitin and have an heterotrophic nutrition

—> Plantae —> have a cellulose cell wall and obtain nutrition autographically

—> Animalia —> no cell wall and obtain nutrition via heterotrophic ingestion

### Organelles:

- Ribosomes —> site of polypeptide synthesis
- Cytoskeleton —> provides internal structure and mediates intracellular transport
- Plasma membrane —> semi permeable and selective barrier surrounding the cell
- Nucleus —> Stores genetic material as chromatin; nucleolus is site of ribosome assembly
- ER —> transports materials between organelles (smooth for lipids and rough fo proteins)
- Golgi apparatus —> sorting, storing and modification and export of secretory products
- Mitochondrion —> site of aerobic respiration
- Peroxisome —> catalyses breakdown of toxic substances and other metabolites

- Centrosome —> radiating microtubules form spindle fibres and contribute to cell division
- Chloroplast —> site of photosynthesis
- Vacuole —> maintains hydrostatic pressure
- Cell wall —> provides support and mechanical strength; prevents excess water uptake
- Lysosome —> breakdown / hydrolysis of macromolecules

### Electron microscopy:

- Use beams focused by electromagnets to magnify and resolve microscopic specimens
- TEM —> Transmission…—> high resolution cross-sections of objects
- SEM —> Scanning… —> display enhanced depth to map the surface of objects in 3D
- Much higher range of magnification and resolution in respect to light microscope, but cannot display living specimens in natural colours

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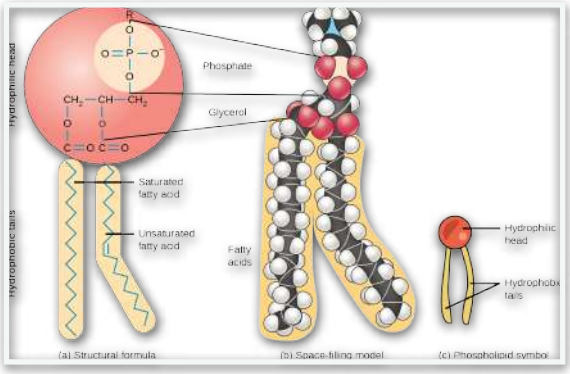
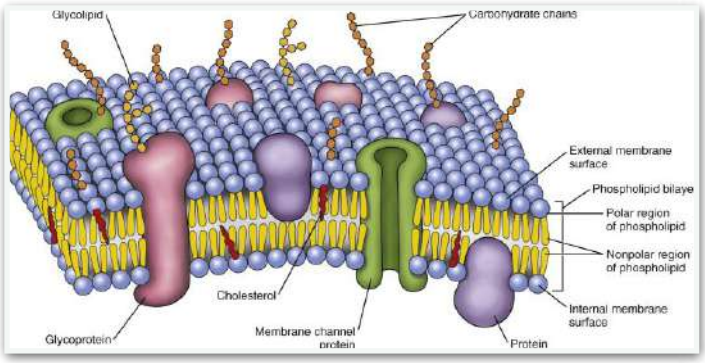
## 1.3 Membrane structure

### Phospholipids:




### Phospholipid bilayer:




- Phospholipids arrange spontaneously into a bilayer with the hydrophobic tail regions facing inwards, so shielding from the surrounding polar fluids (are amphipathic)
- The bilayer is held together by weak hydrophobic interactions between the tails
- Individual phospholipids can move within the bilayer —> creates fluidity and flexibility, so allowing spontaneous breaking and reforming of the membrane for endo/exocytosis

### T.R.A.C.I.E.

- **T**ransport —> Protein channels and pumps
- **R**eceptors —> Peptide-based hormones
- **A**nchorage —> Cytoskeleton attachments and extracellular matrix
- **C**ell recognition —> MHC proteins and antigens
- **I**ntercellular joinings —> Tight junctions and plasmodesmata
- **E**nzymatic activity —> Metabolic pathways

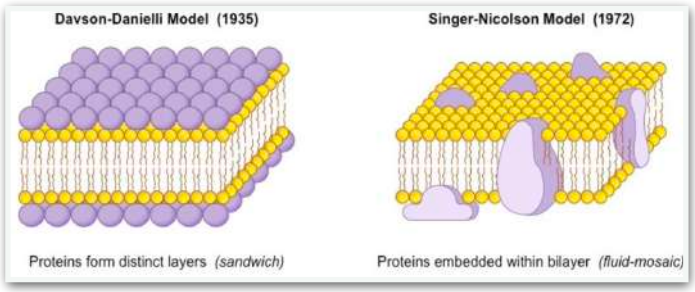
- Integral proteins —> permanently attached to the memb. and typically transmembrane
- Peripheral proteins —> temporarily attache by non-covalent interactions and on one side

## Cholesterol:

- It makes phospholipids pack more tightly and regulates the fluidity and flexibility
- Absent in plant cells as they are already supported by a rigid cell wall made of cellulose
- Is a steroid and is amphipathic (has both hydrophilic and hydrophobic regions)
- Restricts the movements of phospholipids (fluidity) and avoids crystallisation of the tails

## Singer - Nicholson fluid mosaic:

- According to this model, proteins were embedded within the lipid bilayer
- From 1972 —> most preferred model




## Davson - Danielli:

- a protein lipid sandwich (trilaminar —> 3 layers)
- Membrane proteins were discovered to be insoluble in water —> proteins would not be able to form a uniform and continuous layer around the outer membrane surface
- Fluorescent antibody tagging —> showed membrane proteins were mobile and not fixed —> membranes from two different cells tagged with red and green and colours mixed
- Freeze fracturing caused rough surfaces, so proteins had to be also trans-membrane

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# 1.4 Membrane transport

- The phospholipid bilayer is selectively permeable and there are many ways to go through
- Movement across may occur actively or passively

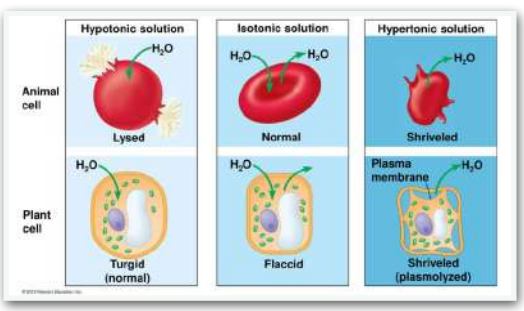
## Passive transports:

**Diffusion:**

- The passive net movement of particles from areas of high concentration to areas of low conc.
- Small and non-polar molecules will be able to freely diffuse across cell membranes
- Affected by —> concentration gradient
  - —> surface area
  - —> length of diffusion pathways
  - —> temperature
  - —> molecular size

**Osmosis:**

- Diffusion but in water
- Water is considered the universal solvent
- Aquaporins —> integral proteins that speed up water diffusion
- Osmotic control —> fluid introduction (rehydration)
  - —> eye drops / wash
  - —> organs for transport
  - —> keeping areas of damaged skin moist



**Facilitated diffusion:**

- The passive use of carrier and channel proteins to move large and polar molecules in the direction dependent on the concentration gradient
- Carrier proteins —> Integral glycoproteins which bind a solute and undergo a conformational change to translocate the solute across the membrane
  —> can bind to only correct solutes such as with enzymes and substrates
  —> much slower rate of transport than channel protein —> 1000 molecule x ‘’
- Channel proteins —> integral lipoproteins which contain a pre via which ions may cross
  —> are ion-selective and may be gated to regulate certain passages of ions
  —> only move molecules along a concentration gradient
- Potassium channels —> integral proteins with hydrophilic inner pore —> potassium ions move
  —> are typically voltage-gated and cycle between an opened and closed conformation depending on the transmembrane voltage

Primary + Secondary transport:

- Primary active transport requires ATP and uses energy from the hydrolysis of ATP to move molecules across the membrane against their concentration gradient
- Secondary active transport uses energy in the form of concentration differences of a second solute

**Active transport:**

- Uses energy to move molecules against a concentration gradient —> the energy may come from ATP or indirectly coupling transport with another molecule that is moving along its gradient
- Involves the use of carrier proteins —> a specific solute will bind to the protein pump on one side of the membrane —> hydrolysis of ATP causes a conformational change in the protein pump —> the molecule is translocated across the membrane and released

**Sodium-Potassium pumps:**

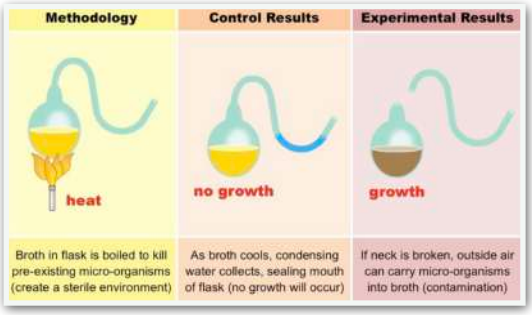
- An integral protein that exchanges 3 sodium ions with two potassium ions
- Three sodium ions bind to intracellular sites on the protein —> a phosphate from hydrolysis of ATP is transferred to the pump —> the pump undergoes a conformational change translocating sodium across the membrane —> the phosphate group is released causing the protein to go back to the original conformation

Vesicles

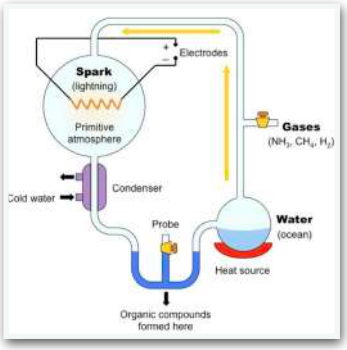
- Move materials within cells (usually ER —> Golgi apparatus —> Lysosome or cell membrane)
- Endocytosis —> taking in of large external substances by forming a vesicle
  —> Phagocytosis —> solid
  —> Pinocytosis —> liquid
- Exocytosis —> release of large substances in a vesicle
  —> constitutive secretion —> occurs continuously
  —> regulated secretion —> response to a trigger

## 1.5 Origin of cells

### Biogenesis:




1) Cells are highly complex structures and no mechanism has been found for producing cells from a simpler subunit
2) All known examples of growth are a result of cell division
3) Viruses do not consist of cells and can't survive outside
4) The genetic code is universal
5) Pasteur's Experiment




### Abiogenesis:

1)Non-living synthesis of simple organic molecules
2)Assembly into more complex polymers —> deep-sea thermal vents gave the conditions
3)Certain polymers formed capacity to self-replicate —> RNA instead of DNA
4)Formation of membranes —> phospholipids naturally assembled
5)Miller-Urey experiment

### Endosymbiotic theory:

1) Eukaryotic cells are believed to have evolved from early prokaryotes that were engulfed by phagocytosis —> the prokaryotic cell remained undigested and contributed to the cell
2) Plasma membrane enfolded —> nucleus created
3) Mitochondria, chloroplasts —> endosymbionts

### Evidence for endosymbiotic theory:

- Own DNA
- 70s ribosomes as prokaryotes
- Double membrane
- Susceptible to antibiotics
- Transcribe and translate DNA
- Same size as bacteria
- Arise only from pre-existing

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## 1.6 Cell division

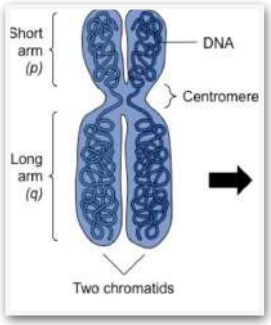
### Why replication (mitosis):

- Growth —> organisms increase their size by increasing number of cells
- Asexual reproduction —> just for certain eukaryotic organisms
- Tissue repair —> new cells created to replace dead or damaged cells
- Embryonic development —> zygote uses mitosis to become an embryo

### Interphase:

- G1 —> increase the volume of cytoplasm, centrosomes move to opposites, nuclear membrane dissolves, organelles duplicate and nutrients are obtained
- S —> DNA is replicated
- G2 —> equal to G1 —> cell finishes growing and prepares for cell division

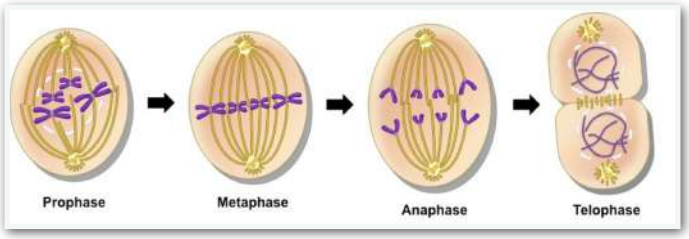
## Chromosomes:




- DNA is temporarily packaged into a tightly wound and condensed chromosome prior to division (supercoiling)
- In this way it is easy to be segregated, however is inaccessible to transcriptional machinery

## PMAT:

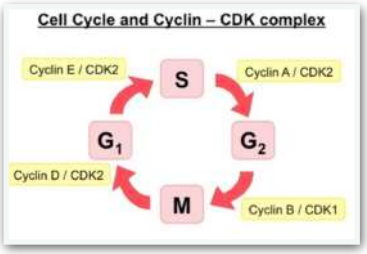
- Prophase —> DNA supercoils
  —> centrosome move to opposites
  —> nuclear membrane dissolves
- Metaphase —> sister chromatids line up as spindle fibres contract (equator)
- Anaphase —> separation sister chromatids
  —> chromatids now chromosomes
- Telophase —> spindle fibres disappear
  —> chromosomes decondense
  —> nuclear membranes reform




## Cytokinesis:

- The division of the cytoplasm
- Animal cells —> A ring of contractile proteins at the equator pulls the plasma membrane inward —> cleavage furrow —> when reaches the center —> pinches off and two cells are formed —> centripetal as from outside to inside
- Plant cells —> vesicles migrate to the centre of the cell
  —> vesicles form tubular structures
  —> cell plate continues forming until full existing cell wall
  —> centrifugal as from inside to outside

## Cyclins:




- Are needed to tell cells to progress to the next stage (cell cycle)
- Bind to enzymes called cyclin-dependent kinases (CDK)

## Tumours and Cancer:

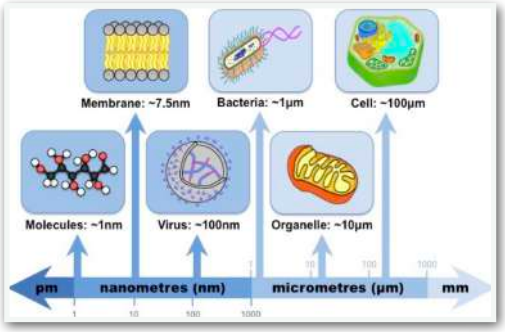
- Tumour —> abnormal growth of tissue resulting from uncontrolled cell division
- Cancer —> a malignant tumour
- Mutagens —> agents that cause gene mutation
  —> chemicals —> carcinogens
  —> biological —> viruses
  —> short-wave ultraviolet light and high energy radiation
- Oncogenes —> control cell cycle and cell division
- Proto-oncogenes —> code for proteins that stimulate the cell cycle and promote cell growth
- Tumour suppressor genes —> code for proteins that repress the cell cycle progression
- Metastasis —> tumour expands from primary tumour and creates secondary tumours

# 1. Extra

## Microscopes:

- Are scientific instruments that are used to visualise objects that are too small to see naked eye
- Light microscopes —> uses lenses to bend light and magnify images
  —> Can be used to view living specimens in natural colour
  —> chemical dyes and fluorescent labelling used to see specific structures
- Electron microscopes —> uses electromagnets to focus electrons —> greater magn. and resol.
  —> can be used to view dead specimens in monochrome
  —> TEM —> generates a cross-section
  —> SEM —> maps in 3D

## Cell scale:




## Classification of kingdoms:

| Property | Monera | Protista | Fungi | Plantae | Animalia |
|---|---|---|---|---|---|
| Nucleus | No | Yes | Yes | Yes | Yes |
| Cell organisation | Unicellular (mostly) | Unicellular (mostly) | Unicellular and multicellular | Multicellular (mostly) | Multicellular (mostly) |
| Cell wall | Yes (peptidoglycan) | Sometimes | Yes (chitin) | Yes (cellulose) | No |
| Nutritional class | Autotrophic; heterotrophic | Autotrophic; heterotrophic | Heterotrophic | Autotrophic | Heterotrophic |
| Mode of nutrition | Absorption | Absorption; Ingestion | Absorption | Absorption (mostly) | Ingestion (mostly) |
| Example | Archaea; Eubacteria | Protozoa; Algae | Yeasts; Moulds; Mushrooms | Mosses; Ferns; Flowers | Insects; birds; fish |

## Phospholipids:

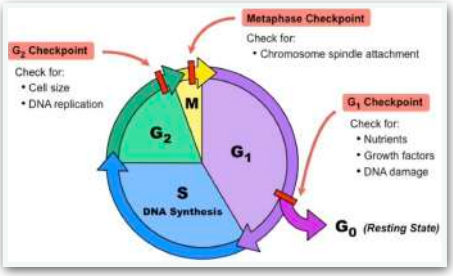
- May vary in the length and relative saturation of the fatty acid tails
- Shorter fatty acid tails will increase fluidity as they are less viscous

## Transport:

- Co-transport —> coupled transport of two distinct molecules
  —> symport —> molecules transported in the same direction
  —> antiport —> molecules in opposite directions

## Checkpoints:

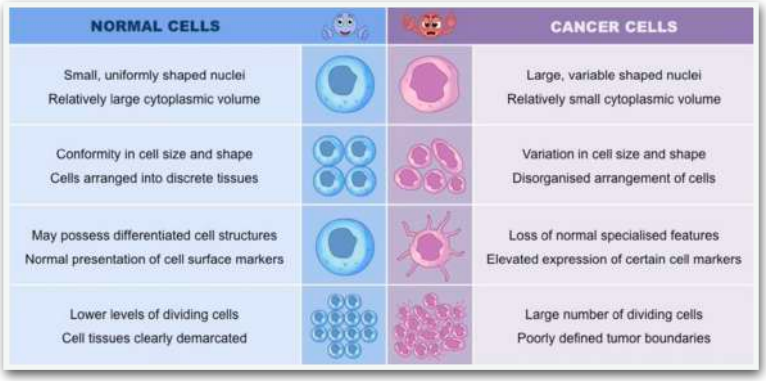
- Cell cycle checkpoints are mechanisms that ensure the fidelity and continued viability of mitotic division in cells




## Cell death:

| | Necrosis (uncontrolled cell death) | Apoptosis (programmed cell suicide) |
|---|---|---|
| Size | Cellular swelling | Cellular shrinkage |
| | Many cells affected | One cell affected |
| Uptake | Cell contents ingested by macrophages | Cell contents ingested by neighbouring cells |
| | Significant inflammation | No inflammatory response |
| Membrane | Loss of membrane integrity | Membrane blebbing, but integrity maintained |
| | Cell lysis occurs | Apoptotic bodies form |
| Organelles | Organelle swelling and lysosomal leakage | Mitochondria release pro-apoptotic proteins |
| | Random degradation of DNA | Chromatin condensation and non-random DNA degradation |

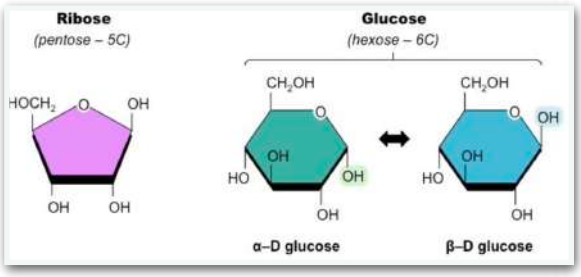
## Normal vs Cancer cells:



# Chapter 2 —> Molecular Biology

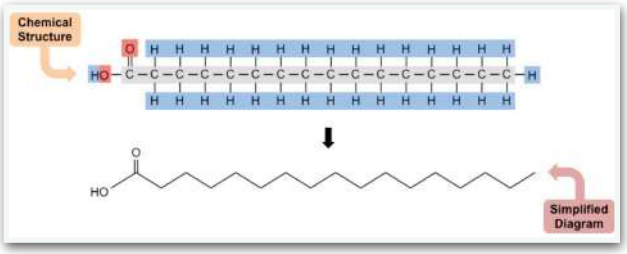
## 2.1 Molecules to Metabolism

### Carbohydrates:



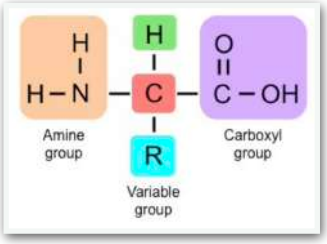

- Contain carbon, hydrogen, oxygen —> $CH_2O$
- Organic compounds consisting of one or more simple sugars
- Principally function as a source of energy and a recognition molecule

### Lipids:



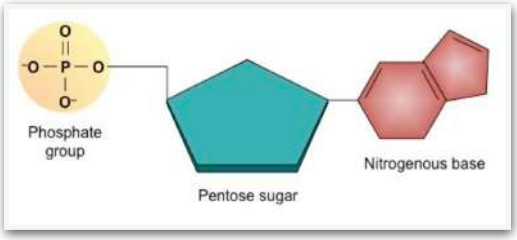

- Contain C,H,O
- Insoluble in water and soluble in non-polar solvents
- Triglycerides, phospholipids, steroids
- May be utilised as a long-term energy storage molecule or signalling molecule

### Proteins:




- Contain C,H,O,N and sometimes sulphur
- Large organic compounds made by amino acids
- Hormones, enzymes, gas transport
- Major regulatory molecules involved in catalysis

### Nucleic acids:




- Contain C, H, O, N and phosphorus
- Made by nucleotides —> base, sugar and phosphate
- Genetic material of all cells and determines the inherited features of an organism

### Metabolic reactions:

- Metabolism —> the web of all enzyme-catalysed reactions that occur within a cell or organism —> provide a source of energy for cellular processes and enables synthesis of new materials
- Condensation makes bonds —> water in —> anabolic reactions
- Hydrolysis breaks bonds —> water out —> catabolic reactions —> Dehydration reaction —> catabolic reaction
- Both require enzymes

### Falsifying vitalism —> Synthesis of Urea:

- Vitalism thought that organic molecules could only be synthesised by living systems
- Frederick Wöhler —> 1828 —> synthesised Urea with ammonium cyanite
- This demonstrated that organic molecules are not fundamentally different to inorganic ones

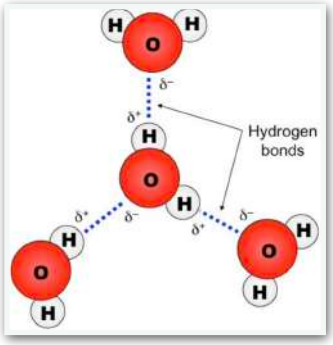
## 2.2 Water

### Bonds:

- $H_2O$ —> having more protons, the oxygen attracts the electrons more strongly
- The oxygen end is slightly negative and the hydrogen end is slightly positive
- This make $H_2O$ molecules become polar
- $H_2O$ molecules can associate via weak hydrogen bonds

### Properties:

**Cohesion:**
- Due to the polarity of water
- Although hydrogen bonds are weak, the being many gives a large force
- Water molecules are strongly cohesive




**Adhesion:**
- Due to the polarity of water
- $H_2O$ molecules tend to stick to other charged or polar molecules
- Capillary action is caused by the combination of adhesive forces

**Thermal:**
- It takes a lot of energy to change temperature in water
- Used as a coolant in organisms
- 4200 J to raise temperature of 1g by 1°C —> specific heat capacity
- High heat of vaporisation
- High heat of fusion

**Solvent:**
- The polar attraction of large quantities of water molecules can interrupt intra-molecular forces and so dissociating the atoms —> is able to dissolve polar and ionic substances

**Hydrophilic:**
- All substances that dissolve in water
- Substances chemically attracted to water

**Hydrophobic:**
- If do not have charges and are non-polar
- Lipids are hydrophobic

**Transport in the blood:**
- Glucose —> polar hence soluble —> carried by blood plasma
- Amino acids —> amine group (polar) —> carried by blood plasma
- Oxygen —> carried by haemoglobin as non-polar
- Lipids —> large and non-polar —> carried in lipoprotein complexes

### Methane VS water:
- Non-polar (low specific heat capacity) —> methane
- Polar (high specific heat capacity) —> water

## 2.3 Carbohydrate and lipids

### Carbohydrates:

**Monosaccharides:**

- Glucose —> $C_6H_{12}O_6$ —> sugar that fuels respiration
- Galactose —> $C_6H_{12}O_6$ —> less sweet —> common in milk and some times in cereals
- Fructose —> $C_6H_{12}O_6$ —> sweets carbohydrate —> common in milk and honey
- Ribose —> $C_6H_{12}O_6$ —>backbone of RNA/DNA when deoxyribose

**Disaccharides (1 glycosidic bond):**

- Maltose —> $C_{12}H_{22}O_{12}$ —> glucose + glucose —> honey …
- Lactose —> $C_{12}H_{22}O_{12}$ —> glucose + galactose —> milk …
- Sucrose —> $C_{12}H_{22}O_{12}$ —> glucose + fructose —> table sugar …

**Polysaccharides (Oligosaccharide 3 to 20 monosaccharides):**

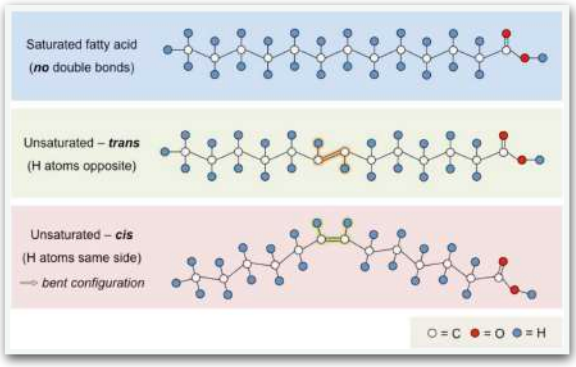
- Cellulose —> beta-glucose —> straight chain —> 1 - 4 —> indigestible for most animals
  —> structural polysaccharide that is found in the cell wall of plants
  —> very high tensile strength
- Starch —> alpha-glucose —> curved chain —> 1 - 6
  —> an energy storage polysaccharide found in plants
  —> size of molecule not fixed
  —> amylose —> forms a helix —> 300 - 3000 glucose units
  —> amylopectin —> globular shape —> 2000 - 200000 units
- Glycogen —> $(C_6H_{12}O_6)_n$ —> usually 30000 units —> alpha-glucose —> compact
  —> stored in the liver and in some muscles in human
  —> useful as energy and storage

### Fatty acids:

**Types of fatty acids:**

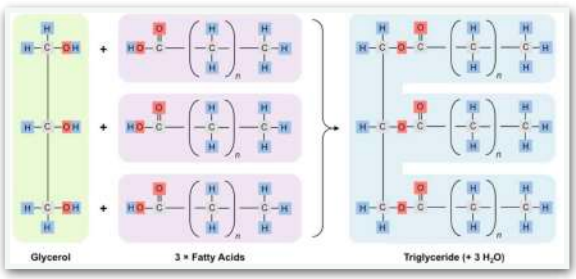
| Type of Fatty Acid | Double Bonds | Diagram |
|---|---|---|
| Saturated | None | |
| Monounsaturated | One | |
| Polyunsaturated | Multiple (>1) | |

**Cis / trans isomer:**




### Tryglicerids:

- The largest class of lipids and function primarily as long-term energy storage molecules
- Animals store them as fats; plants store them as oils
- Can be either saturated or unsaturated depending on the composition of the fatty acid chains



## Energy storage:

| Carbohydrate (Glycogen) | | Lipid (Triglyceride) |
|---|---|---|
| Short-term energy storage | **Storage** | Long-term energy storage |
| More effect on osmotic pressure | **Osmolality** | Less effect on osmotic pressure |
| More readily digested – used for aerobic or anaerobic respiration | **Digestion** | Less easily digested – can only be used for aerobic respiration |
| Stores half as much ATP per gram (~1760kJ per 100g) | **ATP Yield** | Stores twice as much ATP per gram (~4000kJ per 100g) |
| Water soluble as monomers / dimers – easier to transport | **Solubility** | Not water soluble (hydrophobic) – more difficult to transport |

- 1 gram of lipid is 6 times more energetic than glycogen

## Blood cholesterol levels:

- Low density lipoproteins —> carry cholesterol from the liver to the rest of the body —> increased by saturated fats and trans fats
- High density lipoproteins —> scavenge excess cholesterol and carry it back to liver for disposal —> decreased by trans fats and increased by cis fats
- High cholesterol levels in the blood —> hardening and narrowing of arteries (atherosclerosis)
- Accumulation of fat within the arterial walls lead to the development of plaques and restricted blood flow —> coronary heart disease

## BMI; Body Mass Index:

- Not a diagnostic tool
- Used as a screening tool to identify possible weight problems
- BMI = mass in kg / (height in m)$^2$

---

# 2.4 Proteins

## Condensation:

- Proteins are comprised of long chains of recurring monomers called amino acids
- A ribosome condenses two amino acids into a dipeptide
- Peptide bonds —> types of covalent bonds
- Ribosomes —> where polypeptides are synthesised
- 20 types of amino acids which are universal to all living organisms
- DNA —> mRNA —> polypeptide
- From DNA to mRNA —> transcription
- From mRNA to polypeptide —> translation

## Protein structure:

- Primary —> the order of the amino acids of which the protein is made
  —> controls all subsequent levels of structure due to the chemical properties
- Secondary —> alpha helix —> folds into a spiral / beta-pleated sheet —> directionally-oriented strand conformation / Random coil —> when no secondary structure exists
- Tertiary —> the overall three-dimensional configuration of the protein
- Quaternary —> interaction between multiple polypeptides
  —> haemoglobin is composed of four polypeptide chains (two alpha and two beta)

## Fibrous and Globular proteins:

| | Fibrous | Globular |
|---|---|---|
| **Shape** | Long and narrow | Round / spherical |
| **Purpose** | Structural | Functional |
| **Acid Sequence** | Repetitive amino acid sequence | Irregular amino acid sequence |
| **Durability** | Less sensitive to changes in pH, temperature, etc. | More sensitive to changes in pH, temperature, etc. |
| **Examples** | Collagen, myosin, fibrin, actin, keratin, elastin | Enzymes, haemoglobin, insulin, immunoglobulin |
| **Solubility** | (Generally) insoluble in water | (Generally) soluble in water |

## Gene —> Polypeptide:

- A gene sequence is converted into a polypeptide sequence via two processes:
- 1 —> Transcription —> making mRNA transcript based on a DNA template
- 2 —> Translation —> using the instructions of the mRNA transcript to link amino acids

## Functions:

- Collagen —> gives tensile strength to cells
- Insulin —> pancreas —> triggers a reduction in blood glucose
- Glucagon —> pancreas —> triggers an increase in blood glucose
- Immunoglobulin —> antibodies
- Haemoglobin —> responsible for transport of oxygen
- Rhodopsin —> pigment responsible for the detection of light
- Actin and myosin —> muscle contraction
- Rubisco —> enzyme involved in the light independent stage of photosyntheses

## Proteome:

- The totality of proteins expressed within a cell, tissue or organism at a certain time
- Influenced by the genome (genes) and environment
- Unique to every individual

## Denaturation:

- Irreversible process which causes a structural change in a protein
- Caused usually by heat or pH changes
- Bonds and interactions are disrupted or broken

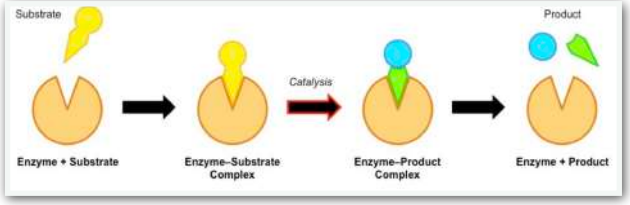
---

## 2.5 Enzymes

- A globular protein that increases the rate of biochemical reaction by lowering the activation energy threshold
- Reactions typically occur in aqueous solutions —> substances moving randomly

## Components:

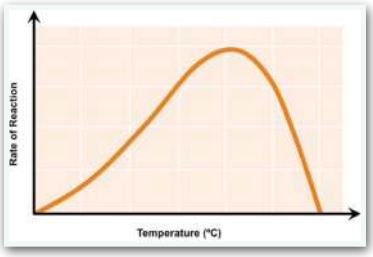
- Substrate —> reactant in biochemical reaction
- Enzyme —> catalyst
- Active site —> region where substrate bind; specific to substrate



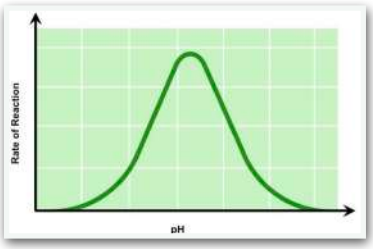
## Lock-and-Key + Induced fit models:

- Lock and key —> Active site matches —> structurally —> 3d structure specific
  —> chemically —> attraction needed
- Induced fit model —> the enzyme's active site is not a completely rigid fit for the substrate
  —> active site will undergo a conformational change (broad specificity)

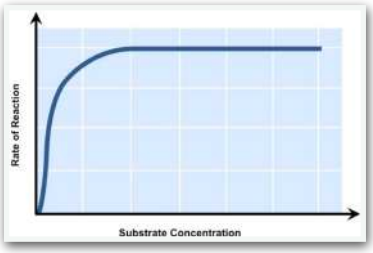
## Enzymatic activity:




**Temperature:**
- Higher $E_K$ —> more collisions
- Higher temperature —> higher activity
- Lower temperature —> insufficient thermal energy
- To high temperature —> denaturation




**PH:**
- Altering pH —> could change shape of molecule
- Different enzymes —> different pH




**Substrate concentration:**
- Increasing substrate concentration —> more reactions
- Increased chance for substrate to collide with enzymes
- Optimum concentration —> maximum efficiency
- Plateau reached after a certain point

## Enzyme immobilisation:

- Concentration can be increased as enzyme not dissolved
- Enzymes can be recycles as easy to separate from mixture
- Enzymes can be removed at precise times
- Enzymes are more stable —> denature less quickly

---

# 2.6 Structure of DNA and RNA

## Nucleic acids:

- Are the genetic material of the cell and are composed of recurring monomeric units called nucleotides
- Three principal components: —> 5-carbon pentose sugar , phosphate group , nitrogenous bases
- Two types of nucleic acids present in cells —> DNA and RNA
- DNA is more stable and is a double stranded form that stores the genetic blueprint for cells
- RNA is a more versatile single stranded form that transfers the genetic information for decoding

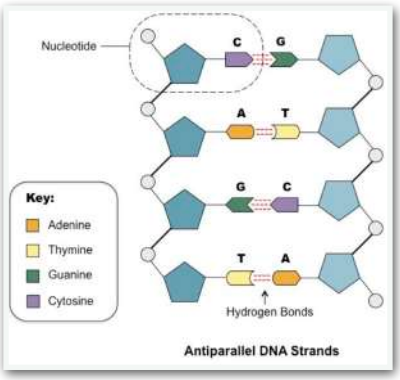
## Structure:

- DNA is a double-helix (two strands) —> antiparallel
- Each strand is made of single units called nucleotides
- Bases join strands by hydrogen bonds
- C pairs with G —> 3 hydrogen bonds

| | DNA | RNA |
|---|---|---|
| Pentose sugar | Deoxyribose | Ribose |
| Base Composition | Adenine (A)<br>Guanine (G)<br>Cytosine (C)<br>**Thymine (T)** | Adenine (A)<br>Guanine (G)<br>Cytosine (C)<br>**Uracil (U)** |
| Number of strands | Double stranded<br>(forms a double helix) | Single stranded |

- T pairs with A —> 2 hydrogen bonds
- Uracil replaces thymine in RNA
- Phosphodiester bonds
- The sequence of bases make ups the genetic code
- DNA strands pair via complementary base pairing

### Watson and crick:




- building models allowed them to visualise the molecule
- Triple-helix rejected —> so double-helix
- Nitrogenous bases were not initially configure correctly and hence did not demonstrate complementarity
- To allow base pairing strands must be anti-parallel
- Their model also suggested possible mechanisms for replication and that information was encoded in triplets of bases
- Rosalind Franklin —> X-ray crystallography data confirmed the arrangement in a double-helix

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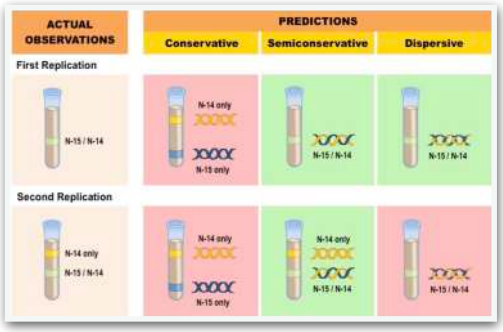
## 2.7 DNA replication, transcription and translation




### DNA replication:

-Is a semi-conservative process —> one strand will be from the original template molecule, one strand will be newly synthesised

-Each new strand formed will be identical to the original strand separated from the template

-Meselson-Stahl experiment —> used radioactive isotopes of nitrogen to validate the process

### DNA helicase:

- Used to unwind and unzip the DNA (is an enzyme)
- Separates the two strands by breaking the hydrogen bonds
- ATP used helicase
- Two separated strands become parent strands for replication

### DNA polymerase:

- Creates complementary strands from the parent strands
- Catalyses the covalent phosphodiester bonds
- Moves in opposite directions on each strand

### DNA replication:

- Adenine, Guanine —> Purines
- Thymine, Cytosine —> Pyrimidines
- DNA replication —> semi-conservative process

## Polymerase Chain Reaction:

- Used to amplify large quantities of a specific sequence of DNA —> over 1 billion copies
- Used to copy a segment of DNA, not whole genome
- For DNA profiling, recombination, species identification, …
- 3 steps —> denaturation —> DNA heated to separate in two strands (90°C)
  —> Annealing —> DNA primers attach to opposite end of strands in cooler temp. (55°C)
  —> Elongation —> sample heated to optimal temp for Taq DNA polymerase (75°C)
- Taq DNA polymerase —> enzyme isolated form the thermophilic bacterium Thermus aquaticus

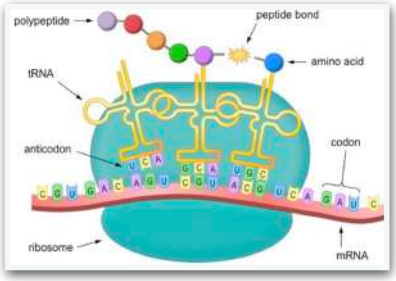
## Transcription and translation:

**Transcription:**

- Occurs in the nucleus and is the process by which an RNA sequence is produced from a DNA template —> copies gene sequence into mRNA
- RNA polymerase separates the DNA strands and synthesises a complementary RNA copy
- Once the RNA sequence has been synthesised, RNA polymerase detaches from the DNA molecule and the double helix reforms
- Antisense —> the strand that is transcribed (it is complementary to the RNA sequence)
- Sense —> the strand that is not transcribed (is identical to the RNA sequence)

**Translation:**

- The process of protein synthesis in which the genetic information in the mRNA is translated into a sequence of amino acids on a polypeptide chain

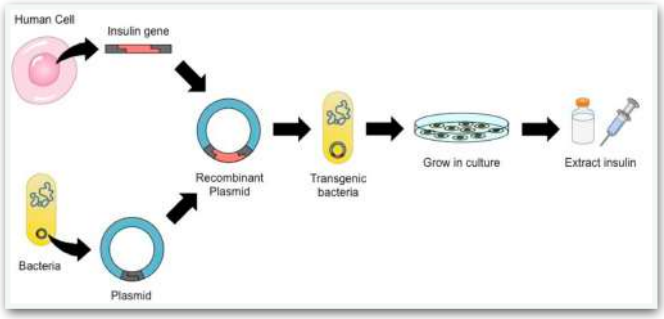



-tRNA —> carries a specific amino acid
-Ribosome —> catalyse the formation of peptide bonds in adjacent amino acids (condensation)
—> small subunit binds to the mRNA
—> large subunit binds to the tRNA
—> protein-making machinery (ribose) —> reads mRNA to translate it in amino acid

## The genetic Code:

- The set of rules by which information in the mRNA is converted into proteins by living cells
- Every living organism uses the same code so genetic information is transferable between species
- 1 amino acid per codon (triplet of bases)
- The order of the codons in the mRNA sequence determines the order of amino acids in the chain
- 64 different codon combinations ($4^3$)
- 20 possible amino acids
- Different codons can translate for the same amino acid —> degenerate
- All amino acids start with AUG and terminate with a stop codon
- Stop codon causes the release of the polypeptide
- tRNA carries the amino acid

## Insulin production via Recombinant Gene transfer:



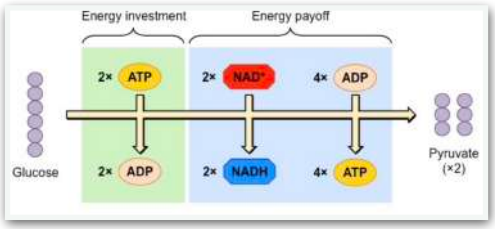
## 2.8 Cell respiration

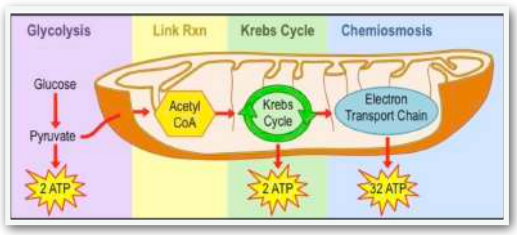
### Cell respiration:

- The controlled release of energy from organic compounds to produce ATP
- Anaerobic respiration —> the partial breakdown of glucose in the cytosol for small yield of ATP
- Aerobic respiration —> utilises oxygen to completely break down glucose in the mitochondria for a larger ATP Yield
- ATP —> one molecule of ATP contains three covalently linked phosphate groups

### Anaerobic respiration:

- Proceeds in the absence of oxygen and does not result in the production of any further ATP mol.
- Pyruvate —> in animals —> converted into lactic acid
  —> in plants converted in ethanol or $CO_2$
- Muscle contraction requires the expenditure of high amounts of energy and thus requires high levels of ATP, so the body will break down glucose anaerobically



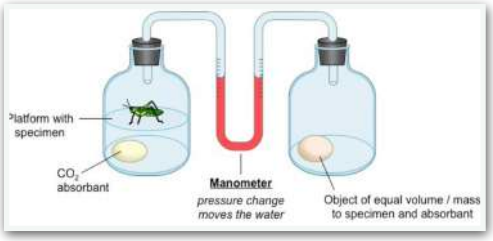




### Aerobic respiration:

-Requires the presence of oxygen and takes place in the mitochondrion
-Pyruvate is broken down into carbon dioxide and water —> large amount of ATP (34 / 36 mole.)
-Link reaction, citric acid cycle and electron transport chain

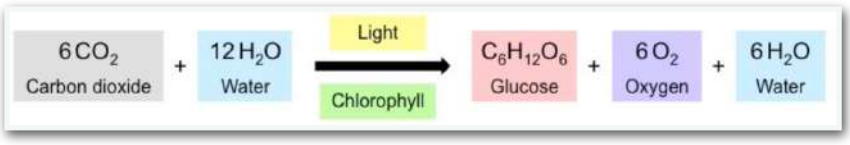
### Respirometer:

- Device that determines an organism's respiration rate measuring the exchange of $O_2$ and $CO_2$
- Factors which may affect reparation rates are temperature, hydration, light, age and activity level




## 2.9 Photosynthesis

### Equation:

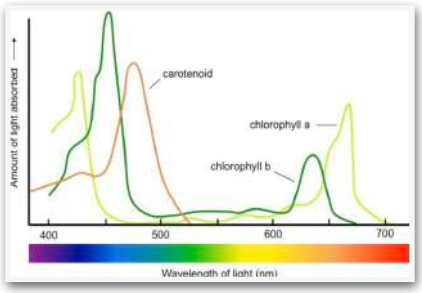



- The reverse of cell respiration
- The process by which cells synthesise organic compounds from inorganic molecules with light
- Photosynthetic organisms use light energy to create ATP —> used by the organism or to synthesise organic compounds such as starch and cellulose
- Photolysis —> the splitting of water molecules

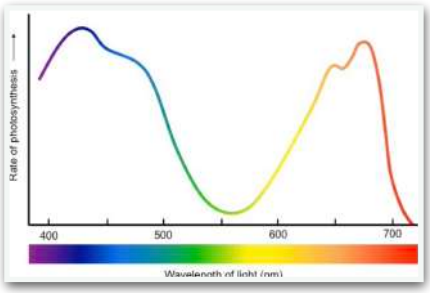
## Chlorophyll:

- A green pigment found in photosynthetic organisms that is responsible for light absorption
- Absorbs light most strongly in the blue portion and then in the red portion, while reflect green

- Absorption spectrum —> indicates the wavelengths of light absorbed by each pigment




- Action spectrum —> the overall rate of photosynthesis x wavelength of light




## Photosynthetic reactions:

- Light dependent reactions —> convert light energy from the sun into chemical energy (ATP)
- Light independent reactions —> use the chemical energy to synthesise organic compounds

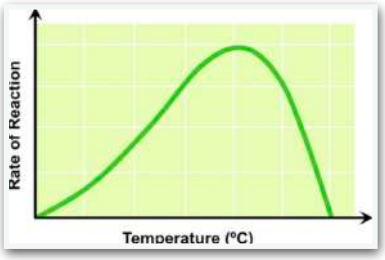
## Chromatographs:

- An experimental technique by which mixtures can be separated
- Paper chromatography —> uses paper (cellulose) as the stationary bed
- Thin layer chromatography —> thin layer of adsorbent which runs faster and separates better

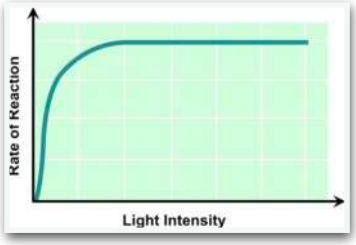
## Limiting Factors:

**Temperature:**

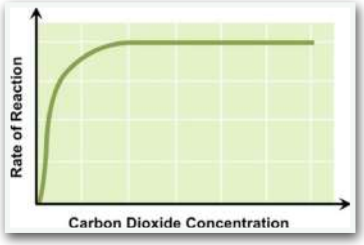
- Photosynthesis is controlled by enzymes which are sensitive to temperature fluctuations
- Above a certain temperature the rate of photosynthesis decreases as enzymes begin to denature




**Light intensity:**




**$CO_2$ concentration:**



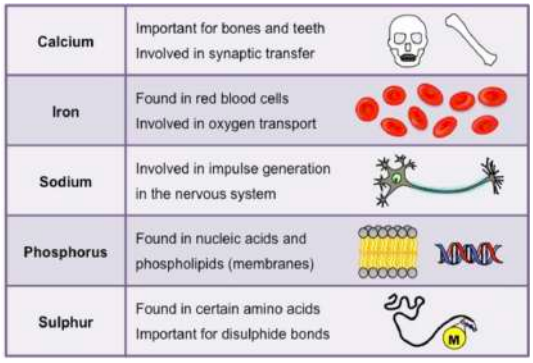

## Measuring:

- $CO_2$ uptake —> measured as an increase in surrounding pH
- Oxygen production —> submerging the plant and counting bubbles
- Glucose production —> change in plant's dry biomass
- Starch —> staining with iodine solution and using a colorimeter

# Extra:

## Types of bonding:

- Intramolecular bonds —> Atoms may join together by gaining and losing electrons
  —> Ionic bonds —> occur between metals and non-metals
  —> creates a strong electrostatic attraction between the two
  —> Covalent bonds —> occurs between two non-metals
  —> carbon can form four covalent bonds as 4 missing electrons
  —> weaker bonds compared to ionic bonds
- Intermolecular bonds —> Atoms from one molecule may attract atoms from another molecule
  —> these bonds are much weaker than intramolecular bonds
  —> hydrogen bonds are a very common type



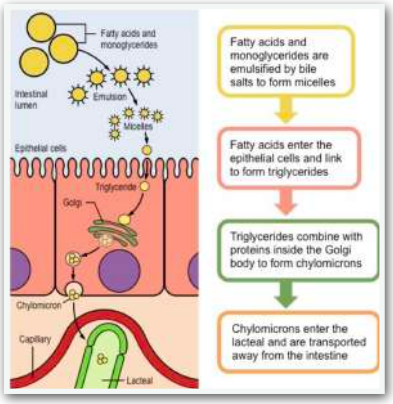

## Trace elements:

-Chemical elements required by living things other than carbon, hydrogen, oxygen and nitrogen

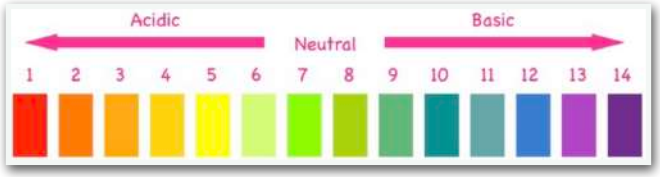
## Functions of lipids:

- Storage of energy
- Hormonal roles
- Insulation
- Protection
- Structural components of cells

## Lipid absorp. and transport:



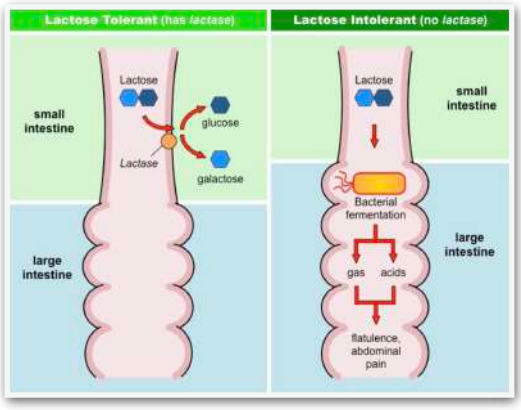

## pH scale (power of Hydrogen):




## Types of enzymes:

| Enzyme Class | Reaction Catalyzed | Example |
|---|---|---|
| Hydrolase | Hydrolysis (catabolic) | Lipase, protease |
| Isomerase | Rearrangement of atoms within a molecule | Phosphohexoisomerase |
| Lyase | Splitting chemicals into smaller parts without using water (catabolic) | Decarboxylases, aldolases |
| Oxidoreductase | Transfers electrons or hydrogen atoms from one molecule to another | Dehydrogenases, oxidases |
| Synthetases | Joining of two molecules by the formation of new bonds (anabolic) | DNA ligase, DNA polymerase |
| Transferase | Moving a functional group from one molecule to another | Kinases, transaminase |

## Lactose intolerance:




## Central Dogma:

-Explains the flow of genetic information within a cell —> DNA codes for RNA via the process of transcription (occurs within the nucleus) —> RNA codes for protein via the process of translation (occurs at the ribosomes)
-This flow was considered uni-directional until 1970 when it was discovered that retroviruses could copy DNA from an

RNA sequence —> possess an enzyme (*reverse transcriptase*) that allows for reverse transcription to occur
- Reverse transcription is now used in scientific studies to establish gene expression profiles

## Degeneracy:

- More than one codon may code for a single amino acid
- Possible because the genetic code has 20 amino acids but has 64 different codon combinations

## Point mutations:

- Point mutations are changes to one base in the DNA code and may involve either:

- The substitution of a base (e.g. A**T**G becomes A**C**G)
- The insertion of a base (e.g. ATG becomes AT**C**G)
- The deletion of a base (e.g. A**T**G becomes AG)
- The inversion of bases (e.g. A**TG** becomes A**GT**)

- Base substitutions may create either silent, missense or nonsense mutations, while insertions and deletions cause frameshift mutations

## Uses of ATP:

- **B**iosynthesis of macromolecules (e.g. polymer assembly)
- **A**ctive transport (e.g. endocytosis / exocytosis)
- **N**erve transmission
- **G**rowth and repair (e.g. mitotic division)
- **M**ovement (e.g. muscle contraction)
- **E**mission of light (e.g. bioluminescence)

## Aerobic vs Anaerobic:

| | Anaerobic | Aerobic |
|---|---|---|
| *Reactants* | Glucose | Glucose **and** oxygen |
| *Combustion* | Incomplete | Complete |
| *Energy Yield* | Low (2 ATP) | High (36 – 38 ATP) |
| *Products* | **Animals:** Lactic acid<br>**Yeast:** Ethanol + $CO_2$ | $CO_2$ and $H_2O$ |
| *Location* | Cytoplasm | Cytoplasm **and** mitochondrion |
| *Stages* | Glycolysis<br>Fermentation | Glycolysis<br>Link reaction<br>Krebs cycle<br>Electron transport chain |

# Chapter 3 —> Genetics

## 3.1 Genes

### Genes and loci:

- DNA is the genetic blueprint which codes for, and determines, the characteristics of an organism
- Influences physical, behavioural and physiological features of the organism
- Chromosomes —> structures in which DNA is packaged and organised
- Gene —> a sequence of DNA that encodes for a specific trait
- Locus —> the position of a gene on a particular chromosome

### Alleles:

- Are alternative form of a gene that code for the different variations of a specific trait
- Differ from each other by one or a few bases

### Mutations:

- A change in the nucleotide sequence of a section of DNA coding for a specific trait
- Beneficial mutations —> (missense mutations) —> create new variations of a trait
- Detrimental mutations —> (nonsense mutations) —> truncate the gene sequence (stop)
- Neutral mutations —> (silent mutations) —> have no effect on the functioning of the feature
- Frameshift mutations —> addition or removal of a base alters the reading frame of the gene
  —> affect every codon beyond the point of mutation

### Sickle cell Anaemia:

- Results from a change to the 6th codon in the beta chain of haemoglobin
- DNA —> changes from GAG to GTG (glutamic acid to valine produce)
- mRNA —> changes from GAG to GUG on the 6th codon position
- Insoluble fibrous strands form —> insoluble haemoglobin cannot carry oxygen as effectively
  —> individual constantly tired
  —> sickle shape forms —> creates clots within the capillaries
  —> sickle cells destroy more rapidly, so low red blood (anaemia)

### Genome:

- The totality of genetic information of a cell, organism or organelle
- Human genome —> 46 chromosomes, 21000 genes, 3 billion base pairs
- Human Genome Project —> an international cooperative to sequence the human genome
  —> mapping —> number, location, size and sequence of human genes
  —> screening —> allowed to detect sufferers and carriers of diseases
  —> medicine —> new protein discovery lead to improved treatments
  —> ancestry —> lead to insight into origins, evolution a patterns of man

### Gene comparisons:

| Species | *Escherichia coli* | *Gallus gallus* | *Homo sapiens* | *Daphnia pulex* | *Oryza sativa* |
|---|---|---|---|---|---|
| Number of Genes | ~4,200 | ~17,000 | ~21,000 | ~31,000 | ~38,000 |
| Common Name |  Bacteria |  Chicken |  Human |  Water flea |  Rice |

-Number of genes is not a valid indicator of biological complexity

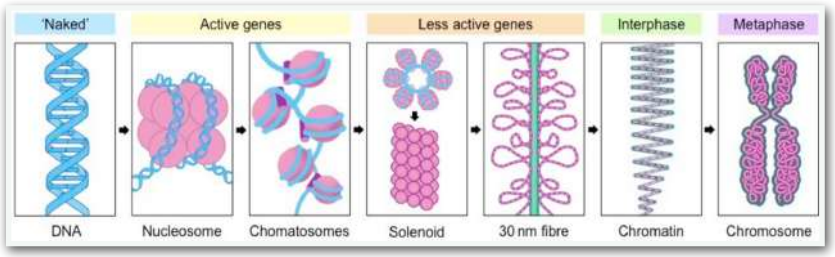
## 3.2 Chromosomes

### Prokaryotic genetics:

- Prokaryotes do not possess a nucleus
- DNA is instead naked and in the cytoplasm (nucleoid)
- Plasmids —> small, circular DNA molecules that contain a few genes and can self-replicate
  —> bacterial cells may exchange plasmids via their sex pili
- Genophore —> naked strand of DNA

### Eukaryote Genetics:

- The packaging of DNA with histone proteins results in a greatly compacted structure




### Identifying Genes (ex. 7q31) :

- p arm —> longer section
- q arm —> shorter section
- First number —> chromosome number
- Third letter —> position of the arm

### Homologous pairs:

- Sexually reproducing organisms inherit their genetic sequences from both parents (2 x chrom.)
- Homologous chromosomes —> maternal and paternal chromosome pairs
  —> share the same structural features
  —> share the same genes at the same loci position, alleles may differ

### Diploid vs Haploid:

- Diploid (2n) —> two sets of chromosomes
  —> will possess two gene copies (alleles) for each trait
  —> all somatic body cells are diploid, new ones created via mitosis
- Haploid (n) —> sex cells (gametes) with half the number of chromosomes
  —> will possess a single gene copy (allele) for each trait
  —> all sex cells are derived from diploid cells via meiosis

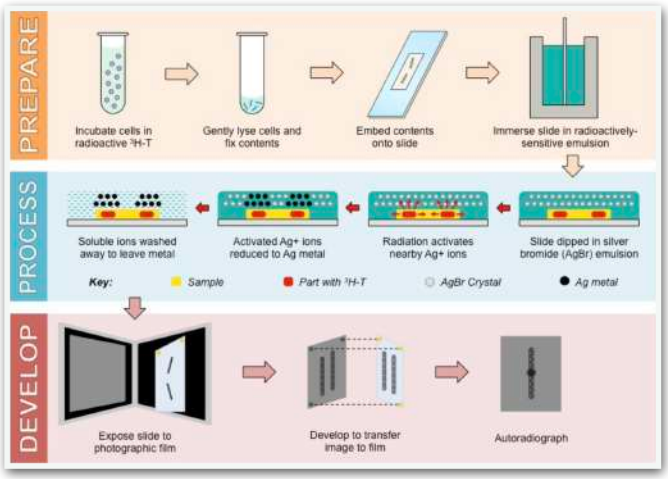
### Autosome vs Heterosome:

- Sex chromosomes —> determine the sex of individual (xx female) (xy male non-homologous)
- The Y chromosome contains the genes for developing male sex characteristics
- The Y chromosome is contained in the male sperm
- Autosomes —> the remaining chromosome in the organism

### Karyograms:

- Karyotypes —> the number and types of chromosomes in a eukaryotic cell —> harvesting cells and chemically inducing cell division and arresting mitosis while chromosomes are condensed
- Karyograms —> the visual profile generated

## Autoradiography:




## Chromosome length:

-John Cairns —> invented a technique for measuring the length of DNA molecules
-Previously chromosomes only measured while condensed
-DNA replication involves formation of a replication bubble
-DNA replication is bi-directional

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# 3.3 Meiosis

## Meiotic division:

- Meiosis —> the process by which sex cells are made in the reproductive organs
- Reduction division of a diploid germline cell into four genetically distinct haploid nuclei
- Consists of two cellular divisions —> first meiotic division separates pairs of homologous chromosomes to halve the chromosome number (diploid —> haploid)
  —> second meiotic division separates sister chromatids
- Sister chromatids —> separated during meiosis II

## Stages of meiosis:

- Interphase —> DNA is replicated to produce chromosomes consisting of two sis chromatids
- Interkinesis —> may occur between meiosis I and II, but no DNA replication occurs

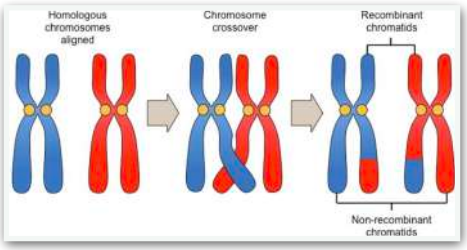
**Meiosis I:**

- P I —> chromosomes condense, nuclear membrane dissolves, hom. chromosomes form bivalents and crossing over occurs
- M I —> spindle fibres from opposing centrosomes connect to bivalents and align at the equator
- A I —> spindle fibres contract and split the bivalent, hom. Chromosomes move to opposites
- T I —> chromosomes decondense, nuclear membrane reform, cytokinesis (two haploid cells)

**Meiosis II:**

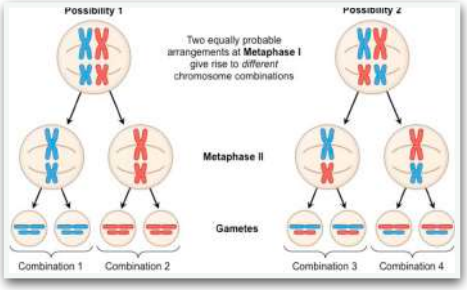
- P II —> chromosomes condense, nuclear membrane dissolves, centrosomes move to opposites
- M II —> spindle fibres from opposing centrosomes attach to chrom. and align at the equator
- A II —> spindle fibres contract and separate the sis chromatids bringing them to opposites
- T II —> chromosomes decondense, nuclear membrane reforms, cytokinesis (four haploid cells)

## Crossing over:




- May occur in prophase I —> hom. chromosomes undergo synapsis, in which they pair up in bivalents
- Chiasmata —> were hom. chromosomes are held together
- Recombination —> new gene combinations are formed on chromatids
- If crossing over occurs the haploid cells will be genetically distinct (sister chromatids are no longer identical)

## Random/independent Assortment:




- During metaphase I —> hom. chromosomes line up at the equator as bivalents in 2 possibilities
- Random —> the orientation of pairs of hom. chromosomes is random
- Gamete combinations —> $2^n$ (23 haploid number for humans)

## Sexual life cycle:

- In order to reproduce, organisms need to make gametes that are haploid
- Fertilisation of two haploid gametes (egg + sperm) results in the formation of a diploid zygote
- If chromosome number was not halved in gametes, chromosomes would double each generation

## Genetic variation:

- Meiotic division and sexual reproduction promote genetic variation in offsprings

- Crossing over —> Offspring with recombinant chromosomes will have unique gene combinations which are not present in either parent
- Random orientation —> if crossing over also occurs, the number of different gamete combinations becomes immeasurable
- Random fertilisation —> will always generate different zygotes

## Non-disjunction:

- Refers to the chromosomes failing to separate correctly, resulting in gametes with one extra or missing chromosome (aneuploidy)
- May occur via —> failure of homologues to separate in anaphase I
  —> failure of sister chromatids to separate in anaphase II
- Chromosomal abnormalities —> if a zygote is formed from a gamete that has experience non-disjunction, the resulting offspring will have extra or missing chromosomes in every body cell
- Monosomy —> one chromosome less ; Trisomy —> one chromosome more

**Down syndrome:**

- Have three copies of chromosome 21 (trisomy 21) as a result of non-disjunction
- Studies show that the chances of non-disjunction increase as the age of parents increase

## Karyotyping:

- Typically used to determine the gender of an unborn child and see chromosomal abnormalities

### Chorionic Villi sampling:

- The removal of a sample of the chorionic villus (placental tissue) via a tube inserted via cervix
- It can be done at around 11 weeks of pregnancy with a slight risk of inducing miscarriage +-1%

### Amniocentesis:

- Involves the extraction of a small amount of amniotic fluid (contains fetal cells) with a needle
- Usually done around 16 weeks of pregnancy with a low risk of miscarriage +- 0.5%

### Nuclear translucency scan:

- Non-invasive test —> done in the 11 / 13 week of pregnancy with an ultra-sound scan
- Large amount of nuchal fluid is strongly correlated with down syndrome

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## 3.4 Inheritance

### Mendel's law:

- An Austrian monk who developed the principles of inheritance from experiments on pea plants
- Organisms have discrete factors that determine its features
- Organisms possess two versions of each factor and each gamete has one version of each factor
- Parents contribute equally to the inheritance of offspring
- For each factor, one version is dominant over another and will be expressed

1) Law of segregation —> when gametes form, alleles separate so that each gamete carries only one allele for each gene
2) Law of independent assortment —> the segregation of alleles for one gene occurs independently to that of any other gene
3) Principle of dominance —> recessive alleles will be masked by dominant alleles

### Haploid gametes and zygosity:

- Gametes —> haploid sex cells formed by meiosis (males produce sperm; women produce ova)
- As gametes contain only one copy of each chromosome, they can only carry one allele per gene
- During fertilisation, two alleles are present for each gene apart for the male sex chromosome Y

- Homozygous —> the maternal and paternal alleles are the same
- Heterozygous —> the maternal and paternal alleles are different
- Hemizygous —> only one allele present (XY combination)

### Modes of Inheritance:

- Genotype —> the gene composition for a specific trait
- Phenotype —> the observable characteristic of a specific trait (determined by genotype and env.)

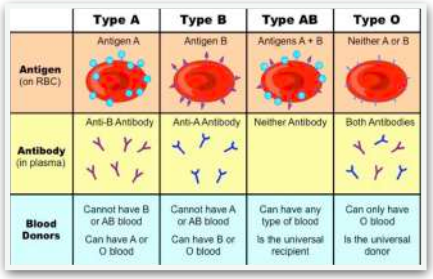
**Complete dominance:**
- The dominant (A) allele will mask the recessive (a) allele when in a heterozygous state
- Homozygous dominant and heterozygous forms will be phenotypically indistinguishable
- The recessive allele will only be expressed in the phenotype when in a homozygous state

**Co-dominance:**

- Occurs when pairs of alleles are both expressed equally in the phenotype of a heterozygous
- Have an altered phenotype as the alleles are having a joint effect

## ABO human red blood:

- A and B alleles are co-dominant and each modify the structure of the antigen to produce variants
- O allele is recessive and does not modify the basic antigenic structure
- $I^A$ $I^B$ $i^O$
- Blood transfusions are not compatible between certain blood groups




## Punnet grids:

- A monohybrid cross determines the allele combinations for potential offspring for one gene only
- The genotypic and phenotypic ratios calculated via Punnet grids are probabilities

## Genetic diseases:

- Are caused when mutations to a gene abrogate normal cellular function, leading to the development of a disease phenotype
- Can be caused by recessive, dominant or co-dominant alleles
- Autosomal recessive genetic diseases need both alleles to be faulty (remain carriers)
- Autosomal dominant genetic diseases only require one copy of a faulty allele to occur
- Co-dominant genetic diseases require one copy of a faulty allele to occur (milder symptoms)

## Cystic fibrosis:

- An autosomal recessive disorder caused by a mutation in the CFTR gene on chromosome 7
- Individuals produce mucus which is unusually thick and sticky
- The mucus clogs the airways and secretory ducts of the digestive system —> respiratory failure and pancreatic cysts
- Malaria cannot infect sickle cell as red blood cells are too small $Hb^A$ $Hb^S$ s = sickle / a= normal

## Huntington's disease:

- An autosomal dominant disorder caused by a mutation to the HTT gene on chromosome 4
- HTT gene —> possesses a repeating CAG that is usually present in low amounts (10-25 repeats)
- More than 28 CAG repeats are unstable and cause the sequence to amplify
- When repeats exceed 40, the protein will misfiled and cause neurodegeneration
- Usually occurs in late adulthood around 40 years
- Symptoms —> uncontrollable spasmodic movements and dementia

## Sex linked genes:

- When a gene controlling a characteristic is located on a sex chromosome
- Y chromosome —> much shorter than the X chromosome and contains only a few genes
- X chromosome —> longer and contains many genes not present in the Y chromosome
- Sex-linked conditions are usually X-linked as very few genes exist on the Y chromosome
- X-linked dominant traits are more common in females
- X-linked recessive traits are more common in males as disease cannot be masked by other allele

**Haemophilia:**
- A recessive genetic disorder in which the body's ability to control blood clotting is impaired
- Coagulation factors are located on the X chromosome
- Fibrin formation is prevented (responsible to stop blood)
- Different forms can occur depending on which coagulation factor is mutated
- Can be treated by using injections of clotting factors produced industrially via gene transfer

**Red-Green colour blindness:**
- A recessive genetic disorder in which an individual fails to discriminate between red and green
- Caused by a mutation to the red or green retinal photoreceptors (located on the X chromosome)
- Can be diagnosed using the Ishihara colour test

### Gene mutation rates:

- A change to the base sequence of a gene that can affect the structure and function of the protein
- Mutations can be spontaneous or induced by exposure to external elements
- Radiation, chemical and biological elements can cause mutations
- Mutagens —> agents which increase the rate of genetic mutations and can lead to mutations

- Hiroshima —> elevated rate of leukemia
  —> elevated rates of other cancers
- Chernobyl —> at least 6000 thyroid cancers
  —> horses and cattle died
  —> contained meat banned for year

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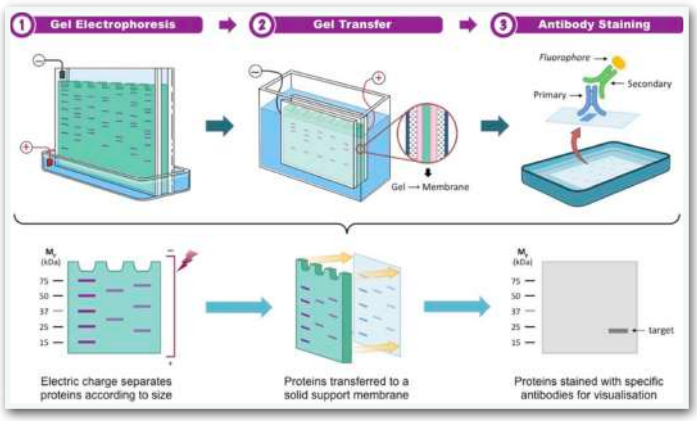
## 3.5 Genetic modification and biotechnology

### Gel electrophoresis and DNA profiling:

- Laboratory technique used to separate and isolate proteins or DNA fragments based on size
- DNA profiling —> a technique by which individuals can be identified and compared via their respective profiles
- Short tandem repeats —> DNA made up of repeating elements
- Commonly used in criminal investigations and to settle paternity disputes —> the more DNA fragments combine higher the match

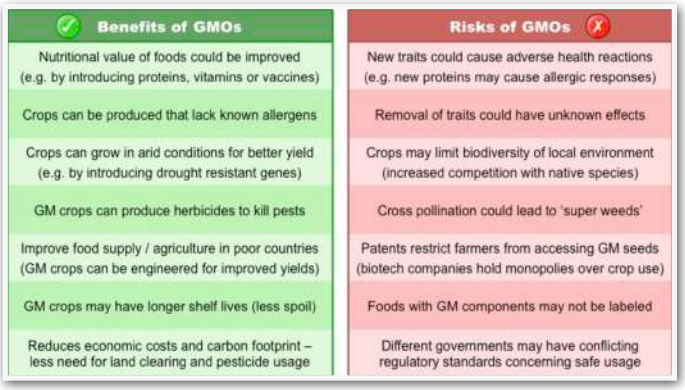



### Gene transfer:

1) isolation of gene and vector by PCR
   —> bacterial plasmids are commonly used as vectors as they can self-replicate and express
2) Digestion of gene and vector by restriction endonuclease
   —> restriction enzymes cleave the sugar-phosphate generating sticky ends
3) Ligation of gene and vector by DNA ligase

—> the gene of interest is inserted into the plasmid vector, and this is possible only because the sticky ends of the gene and vector overlap via complementary base pairing

4) Selection and expression of transgenic construct
the recombinant construct is introduced into an appropriate host cell or organism



| Benefits of GMOs | Risks of GMOs |
|---|---|
| Nutritional value of foods could be improved (e.g. by introducing proteins, vitamins or vaccines) | New traits could cause adverse health reactions (e.g. new proteins may cause allergic responses) |
| Crops can be produced that lack known allergens | Removal of traits could have unknown effects |
| Crops can grow in arid conditions for better yield (e.g. by introducing drought resistant genes) | Crops may limit biodiversity of local environment (increased competition with native species) |
| GM crops can produce herbicides to kill pests | Cross pollination could lead to 'super weeds' |
| Improve food supply / agriculture in poor countries (GM crops can be engineered for improved yields) | Patents restrict farmers from accessing GM seeds (biotech companies hold monopolies over crop use) |
| GM crops may have longer shelf lives (less spoil) | Foods with GM components may not be labeled |
| Reduces economic costs and carbon footprint – less need for land clearing and pesticide usage | Different governments may have conflicting regulatory standards concerning safe usage |

GMO debate:

-GMO organisms are used in agriculture to improve crop yields and reduce farming costs
-GM crops can be used to improve human nutritional standards

**Bt corn:**
- A genetically modified maize lethal to certain types of larvae
- The caterpillar stage of the monarch feeds on milkweed which commonly grows on the edge of corn fields
- Studies show that monarchs fed with milkweed leaves covered with Bt corn pollen tend to have a high rate of mortality

Clones:

- A group of genetically identical organisms or cells derived form a single original parent cell
- Mechanisms exist whereby sexually reproducing organisms can produce clones
- Stem cells can be artificially generated from adult tissue using SCNT

**Somatic Cell Nuclear Transfer:**
- A method by which cloned embryos can be produced using differentiated adult cells
- The advantage is that it is known what traits the clones will develop
- Reproductive (offspring) or therapeutic cloning (new tissues or organs)

1) Somatic cells are removed form the adult donor and are culture
2) An unfertilised egg is removed from a female adult and its haploid nucleus is removed
3) The enucleated egg cell fuses with the nucleus from the adult donor to make a diploid egg cell
4) An electric current is used to stimulate the egg to divide and develop into an embryo
5) The embryo is the implanted into the uterus of a surrogate and will develop into a genetic clone

**Natural cloning:**
- Binary fission —> the parent organism divides equally in two to produce two genetically identical daughter organisms
- Budding —> cells split off the parent organism generating a smaller daughter organism which eventually separates from the parent
- Fragmentation —> new organisms grow from a separated fragment of the parent organism
- Parthenogenesis —> embryos are formed from unfertilised ova
- Vegetative propagation —> small pieces can be induced to grow independently thanks to the totipotent meristematic tissue possessed by the adult plants
- Monozygotic twins —> created when a fertilised egg splits into two identical cells, two embryos
- Dizygotic twins —> an unfertilised egg splits into two cells, then fertilised by two diff. sperms

**Embryonic cells:**

- Are pluripotent and can be separated artificially in the laboratory or naturally
- The separation of embryonic cells has to happen early in the development cycle (8th stage)
- The separated groups of cells are then implanted into the uterus of a surrogate
- The embryo used is formed randomly via sexual reproduction, so the genetic features can vary

### Stem cutting:

- A separated portion of plant stem that can regrow into an independent clone via vegetative prop.
- Nodes —> points from which a leaf, branch or aerial root may grow
- Internode —> points between nodes
- Stem cutting is a common method employed to rapidly propagate plant species
- Variables are —> cutting position and length, growth medium, concentration of growth hormones, temperature conditions, availability of water and other environmental conditions

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## Extra:

### Sickle cell versus malaria:

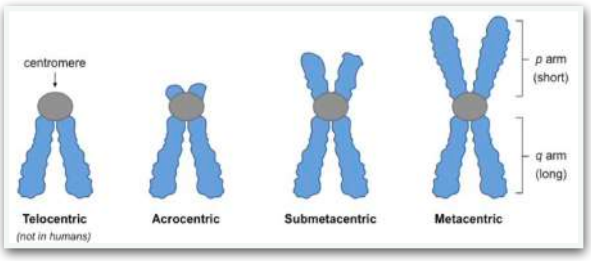
- Sickle cell anaemia is controlled by a single gene mutation
- Individuals who only possess the sickle cell allele will have abnormally shaped red blood cells that are destroyed by the spleen —> reduction in red blood cells
- Individuals who only possess the normal blood cell allele do not suffer from sickle cell anaemia but are more susceptible to malaria
- Incidence of malaria —> in areas where malaria is common there is a higher incidence who carry both alleles —> produce enough normal blood to avoid severe effects, but also produce enough sickle cells to give an increased resistance to the malarial parasite (heterozygous advantage)

### Genome structure:

- Comprises of roughly 3.2 billion base pairs across 46 chromosomes —> only a small fraction of 1.5 % of these, sequences code for functional genes
- The remainder is made up of repeating elements, pseudogenes, microsatellites and transposons
- Transposons —> a segment of DNA that inserts itself into another section within the genome
- Pseudogenes —> a non functional sequence of DNA that is homologous to an active gene
  —> Processed pseudogenes —> portion of DNA raised from reversed transcription
  —> Non-processed pseu. —> arise from gene duplication and inactivation mutation

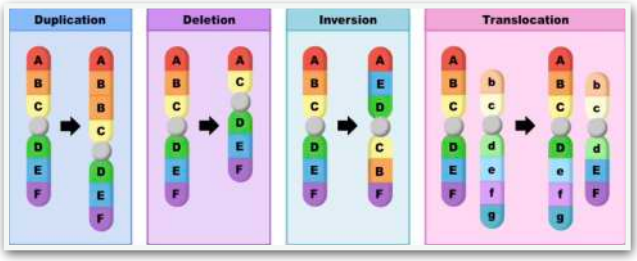
### Chromosome types:

- Metacentric —> centromere in the middle
- Submetacentric —> centromere off-centre vs top
- Acrocentric —> centromere off-set severely
- Telocentric —> centromere at end of chromosome



## Block mutations:

- Are caused by transposons, which by changing positions within the genome alter the sequence




## Mitosis versus Meiosis:

| | Mitosis | Meiosis |
|---|---|---|
| Divisions | One | Two |
| Independent Assortment | No | Yes (metaphase I) |
| Synapsis | No | Yes – form bivalents |
| Crossing Over | No | Yes (prophase I) |
| Outcome | Two cells | Four cells |
| Ploidy | Diploid | Haploid |
| Use | Body cells | Sex cells (gametes) |
| Genetics | Identical cells | Variation |

## Somatic vs Germline mutations:

-Somatic mutations —> occur in a single body cell and cannot be inherited
-Germline mutations —> occur in gametes and can be passed onto offspring

## Polyploidy:

- A condition whereby an organism has more than two complete sets of chromosomes in all cells
- Far more common in plant species which lack separate sexes and are capable of self-pollination
- Very rare in animal species due to the consequences of having extra allele copies of every gene

## Lethal alleles:

- Alleles that cause an organism to die only when present in a homozygous condition —> the gene involved is considered an essential gene and the lethal allele may be either dominant or recessive
- Achondroplasia —> a genetic condition which causes dwarfism —> when dominant and present in the homozygous state it causes death, heterozygous will be dwarf, and homozygous recessive people will be in normal size

## Epistasis:

- Describes a condition whereby one gene controls the expression of another gene
- Example —> Black fur is dominant to brown fur, but in absence of hair pigment mice will appear albino

## Pleiotropy:

- Occurs when a single gene affects multiple traits —> mutations will tend to be severe and affect multiple systems
- Sickle cell anaemia —> the rapid breakdown of red blood cells causes anaemia —> leads to increased lethargy and higher risks of infection
  —> clotting of sickle cells in vessels can cause heart attacks + brain damage
  —> accumulation of blood cells in specific organs can lead to loss function

## Mosaicism:

- Describes presence of two populations of cells with distinct genotypes within a single organism
- More pronounced when errors occur in early embryo development (affects more cells)

## Vector delivery:

- A vehicle that is used to deliver genetic material to a target cell via horizontal gene transfer
- Non-viral delivery —> commonly via plasmids which can be introduced in cells by:
  —> electroporation —> electric current applied (makes holes in membrane)
  —> heat shocking —> heat destabilises the cell membrane
  —> particle bombardment —> DNA-coated particles are shot into the cells
  —> microinjection —> a glass micropipette injects vector directly in the cell
  —> lipofection —> vector is transferred within a liposome in the cell
- Viral delivery —> transduction —> insertion of a viral vector into a cell
  —> viruses integrate their DNA into the host genome (beneficial or detrimental)
  —> advantage —> protein synthesis will be driven by endogenous expressions
  —> disadvantage —>random insertion into the genome may abrogate key host genes
- Viruses can have either a DNA genome (adenovirus) or an RNA genome (retrovirus)

## Examples of GMOs:

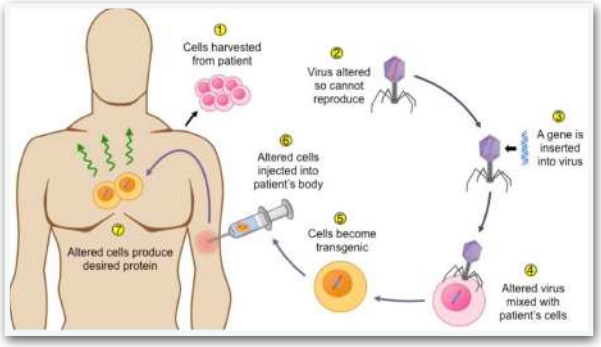
| GMO | Description | Picture |
|---|---|---|
| Golden Rice | Rice modified with daffodil genes to have more beta-carotene, which the body converts to Vitamin A |  |
| Flavr Savr Tomatoes | Tomatoes modified by the removal of genes responsible for the softening of fruit, meaning the tomatoes spoil more slowly |  |
| Bt Corn | Corn modified with a bacterial insecticide gene so that it produces insect toxins within its cells, protecting it from pest species |  |
| Aqua Advantage Salmon | Salmon modified with growth hormone regulating genes in order to grow to market sizes in significantly less time |  |
| Glow in the Dark Animals | Animals modified with genes for fluorescent proteins will glow in the dark – this novel feature serves no practical purpose |  |

## cDNA and Microarrays:

-Individuals can be screened for genetic diseases and cancers by using cDNA and microarrays
-cDNA —> a molecule synthesised from an mRNA template via reverse transcription —> represent gene sequences that are actively transcribed by cells
-Microarray —> a collection of microscopic DNA sequences attached to a solid surface —> represent fractions of a large library of genes present in a cell
—> If a gene is active within a cell, then the cDNA (produced from the mRNA transcript) will bind to its complementary oligo

## Gene therapy:

- Inserting genes into an individual's cells to treat hereditary diseases (replaces defective alleles)
- Example —> in humans, in the treatment of adenosine deaminase (ADA) deficiency (autosomal recessive disease causing severe combined immunodeficiency (SCID) in sufferers) —> Individuals who have done gene therapy show an increase in the levels of ADA




## Gene silencing:

- The ability of a cell to prevent the expression of a particular gene
- Gene knockout —> genetic technique in which a specific gene is made inoperative in a organism
- The Cre-LoxP system uses the enzyme Cre recombinase to remove genetic sequences located between two Lox sites —> Using recombinant DNA technology, LoxP sequences are inserted on either side of a gene of interest in a test animal —> The Cre gene is inserted next to a tissue-specific promoter in another test animal —> When the two animals are bred, the resulting offspring will possess LoxP sequences and a tissue-specific Cre recombinase —> The Cre recombinase removes the gene located between the Lox sites (creates a conditional knockout)

# Chapter 4 —> Ecology

## 4.1 Species and Ecosystem

### Species:

- A group of organisms that can potentially interbreed to produce fertile, viable offsprings
- Members of a single species cannot produce fertile offsprings with members from another specie
- When two different species do produce offspring by cross-breeding, this hybrids are sterile
- Population —> a group of organisms of the same species that live in the same area at same time
- Community —> a group of populations living together and interacting with each other in an area
- Habitat —> the environment or location in which a specie normally lives
- Ecosystem —> a community and its abiotic environment
- Ecology —> the study of the relationship between living organisms and their environment

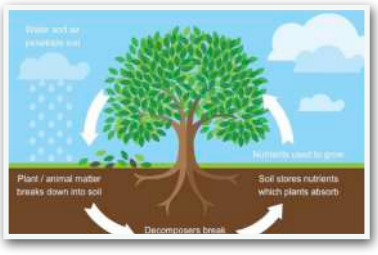
### Modes of nutrition:

- Autotrophs —> synthesises its own organic molecules from simple inorganic substances
  —> energy for this process is from sunlight or via oxidation of inorganic molecules
  —> obtain simple inorganic substances needed from the abiotic env. (air, water, soil)
  —> usually producers in the food chain
- Heterotrophs —> obtains organic molecules from other organisms
  —> consumers, they cannot produce own organic molecules from other sources
- Mixotrophs —> unicellular organisms which may use both forms of nutrition based on available
  —> Euglena gracilis —> chlorophyll for photosynthesis and may feed on detritus

### Heterotrophs:

- Herbivores —> consumers that feed principally on plant matter
- Carnivores —> consumers that feed principally on animal matter
- Omnivores —> consumers that have a principle diet composed of both plant and animal matter
- Scavengers —> type of consumer that principally feed on dead and decaying carcasses
- Detritivores —> ingest organic molecules found in the non-living remnants of organisms
- Saprotrophs —> release digestive enzymes and then absorb the external products of digestion
  —> decomposers as facilitate the breakdown of dead organic material

### Nutrient cycling:




- Nutrients —> material required by an organism, are limited
- Chemical elements are constantly recycled after they are used

### Mesocosms:

- Biotic components —> communities …
- Abiotic components —> habitat …
- Sustainability —> energy availability —> light from the sun provides the initial energy source
  —> nutrient availability —> saprotrophic decomposers ensure constant recycling of inorganic nutrients within an environment
  —> recycling of wastes —> bacteria can detoxify harmful waste byproducts
- Mesocosms —> enclosed environments that allows a small part of a natural environment to be observed under controlled conditions (terrarium —> small transparent container)

1) Building a verdant foundation
2) Selecting the right plants
3) Maintaining appropriate conditions

### Quadrat sampling:

- A rectangular frame of known dimensions that can be used to establish population densities
- Not effective as a method for counting motile organisms (only plants and sessile animals)

### Types of metabolism:

- Carbon source —> organisms can obtain carbon for synthesising organic molecules
- Energy source —> organisms can derive the energy they need for living and growing
  —> phototrophic from light and chemotropic from chemical compounds
- Reducing equivalents —> are chemical species that can transfer electrons needed for energy conversions and biosynthesis

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## 4.2 Energy flow

### Energy source:

- Light is the initial energy for most types of communities
- Photoautotrophic —> use sunlight as source of energy
- Light is absorbed and converted into chemical energy through photosynthesis
- The light energy is used to make organic compound from inorganic sources

### Trophic levels and food chains:

- Trophic level —> the position an organisms occupies within a feeding sequence
- Food chain —> the linear feeding relationships between species in a community

| | |
|---|---|
| Trophic Level 1 | Producer |
| Trophic Level 2 | Primary Consumer |
| Trophic Level 3 | Secondary Consumer |
| Trophic Level 4 | Tertiary Consumer |

### Energy loss:

- Not all energy stored in organic molecules is transferred via heterotrophic feeding
- Some energy loss from —> being excreted as part of the organism's faeces
  —> remaining unconsumed as the uneaten portions of the food
  —> respiration …
- Organisms release heat, which does not pass to the next trophic level of the food chain
- A continuous influx of energy is required (ex. sun) because of heat

### Energy transformations:

- Energy transfer is never 100% efficient
- Transformations are ~10% efficient, with 90% of available energy lost between trophic levels
- Higher trophic levels receive less energy / biomass from feeding and so need to eat larger quantities to obtain sufficient amounts

### Pyramids of energy:

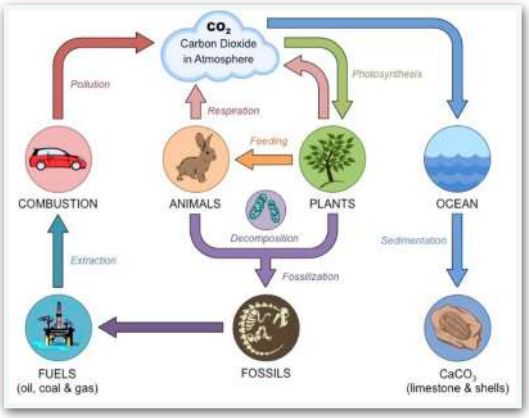
- Graphical representation of the amount of energy at each trophic level of a food chain
- kJ $m^{-2}$ $year^{-1}$
- Each level should be roughly one tenth of the size of the preceding level
- As the trophic level increases, the biomass and energy available decreases

---

## 4.3 Carbon cycling

### Carbon cycling:

- A biogeochemical cycle whereby carbon is exchanged between the different spheres of the Earth
- Atmosphere (air), lithosphere (ground), hydrosphere (water) and biosphere (living things)
- Atmospheric gases —> $CO_2$ / $CH_4$
- Oceanic carbonates —> dissolved in $H_2O$, corals and shells
- Organic materials —> carbohydrates, lipids, proteins …
- Non-living remains —> fossil fuels and detritus
- Compensation point —> the uptake of $CO_2$ by plants is balanced by the production of $CO_2$ by respiration



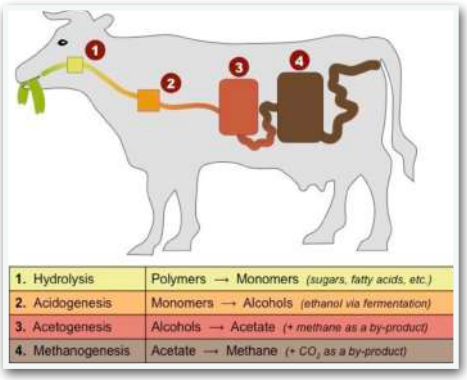

### Aquatic conversion:

| Oceanic Carbon Conversions |
|---|
| **Step 1:** $CO_2$ (atmospheric) ⇌ $CO_2$ (dissolved) |
| **Step 2:** $CO_2$ (dissolved) + $H_2O$ ⇌ $H_2CO_3$ (carbonic acid) |
| **Step 3:** $H_2CO_3$ ⇌ $HCO_3^-$ (bicarbonate ion) + $H^+$ |
| **Step 4:** $HCO_3^-$ ⇌ $CO_3^{2-}$ (carbonate ion) + $H^+$ |
| **Step 5:** $CO_3^{2-}$ + $Ca^{2+}$ ⇌ $CaCO_3$ (calcium carbonate) |

-Limestone creation —> When the hydrogen carbonate ions come into contact with the rocks and sediments on the ocean floor and acquire metal ions creating calcium carbonate
-When the organism dies and settles to the sea floor, the hard components may become fossilised in the limestone

### Methane:

- Methanogens —> archaean microorganisms that produce methane ($CH_4$) as a metabolic by-product in anaerobic conditions
- Found in —> Wetlands
  —> Marine sediments
  —> Digestive tract of ruminant animals
- Acetic acid → Methane and Carbon Dioxide
- Carbon Dioxide and Hydrogen → Methane and Water




- When organic matter is buried in anoxic conditions (e.g. sea beds), deposits of methane (natural gas) form underground
- Rising global numbers of domesticated cattle —> increasing the levels of methane
- When methane is released into the atmosphere as a result of anaerobic reactions, it only persists for ~12 years —> will be naturally oxidised to form carbon dioxide and water

### Fossil fuels:

**Partial decomposition:**

- Saprotrophic bacteria and fungi will decompose dead organisms and return nutrients to the soil for cycling —> requires oxygen
- Waterlogged regions may lack oxygenated air spaces within the soil (so anaerobic conditions)
- Anaerobic respiration by organisms in these regions produces organic acids (acidic conditions)
- Saprotrophic bacteria and fungi cannot function in these conditions —> no decomposition

**Coal formation:**
- Carbon-rich molecules remain in the soil and form peat from non-decomposed organisms
- The heat and pressure force out impurities and remove moisture from peat
- Remaining material has a high carbon concentration and chemical transformation produces coal

**Oil/natural gas formation:**
- Form as the result of the decay of marine organisms on the ocean floor
- Sediments deposit on top of the organic matter, creating anoxic conditions
- Burial and compaction —> the organic material becomes heated and hydrocarbons are formed
- Hydrocarbons form oils and gases —>forced out of source rock and accumulate in porous rocks
- Takes place over millions of years, making them a non-renewable energy source

## Combustion:

- When organic compounds rich in hydrocarbons are heated in the presence of oxygen
- Exergonic —> produces energy + releases $CO_2$ and $H_2O$ as by-products
- Two main sources are fossil fuels and biomasses

**Fossil fuels:**
- Organic compounds become rich in hydrocarbons if compacted underground millions of years
- Coal / Oil / Natural gases

**Biomass:**
- manufacture fuels from biological processes
- Living organisms produce hydrocarbons as part of their total biomass —> hydrocarbons can be extracted and purified to produce an alternative fuel source
- New raw materials are provided and waste products are removed
- Renewable

## Carbon fluxes:

- The rate of exchange of carbon between the various carbon sinks / reservoirs (4 spheres of earth)
- Factors influencing the rate of carbon exchange are:
    —> Photosynthesis
    —> Respiration
    —> Decomposition
    —> Gaseous dissolution —> exchange of carbon gases between the ocean and atmosphere
    —> Lithification —> compaction of carbon sediments into fossils and rocks in the crust
    —> Combustion
- Estimates can be made to directly measure the size of the carbon sinks or the fluxes (gigattones)
- Main causes of change in carbon flux —> climate, human activity, natural events

**Climate:**
- Rates of photosynthesis —> higher in summer (more light)
- Oceanic temperatures —> determine how much carbon is dissolved $CO_2$
- Melting of polar caps —> frozen detritus will decompose and start uncovering

**Natural events:**
- Forest fires —> release high levels of carbon dioxide when plants burn
- Volcanic eruptions —> release carbon compounds from the Earth's crust into the atmosphere

**Human activity:**
- Deforestation —> will reduce removal of atmospheric $CO_2$ via photosynthesis
- Increased number of ruminant livestock —> higher levels of methane
- Combustion —> release of $CO_2$ in the atmosphere

**$CO_2$ levels:**
- Fluctuate annually
- $CO_2$ levels are steadily increasing year on year since the industrial revolution
- Atmospheric $CO_2$ levels are currently at the highest levels recorded since measurements began
- Efforts to reduce fossil fuel combustion by using alternative energy sources (e.g. solar power)

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## 4.4 Climate change

### Greenhouse gases:

- Absorb and emit long-wave (infrared) radiation —> traps and holds heat within the atmosphere
- Collectively make up less than 1% of the Earth's atmosphere
- Water vapour and carbon dioxide are the largest warming gases
- Water vapour —> created through evaporation of water bodies and is removed by precipitation
- Carbon dioxide —> made by cell respiration and combustion —> photosynthesis and absorption
- Methane and nitrogen oxides

### Factors affecting impact of greenhouse effect:

- Ability to absorb long-wave radiation —> greater capacity to absorb long-wave radiation —> greater warming impact
- Concentration within the atmosphere —> the greater the concentration the greater the impact
  —> rate of release and persistence in the atmosphere

| | Water | Carbon Dioxide | Methane | Nitrous Oxide |
|---|---|---|---|---|
| |  |  |  |  |
| Atmospheric Concentration | 0.01–4%* | 385 ppm | 1797 ppb | 322 ppb |
| Rate of Increase | n/a | 1.5 ppm/yr | 7.0 ppb/yr | 0.8 ppb/yr |
| Atmospheric Lifetime | Very short 1–5 days | Variable 5–200 yr | 12 yr | 120 yr |
| Global Warming Potential (GWP) | n/a† | 1 | 21 | 310 |

### Greenhouse effect:

- A natural process whereby the atmosphere behaves like a greenhouse to trap and retain heat —> the Earth has moderate temperatures for organisms to maintain life processes (homeostasis)
- Without, Earth's temperatures would drop significantly at night in the absence of direct sunlight

1) Sun radiates short wave radiation
2) Earth absorbs short wave radiation and re-emits it in a long wave radiation
3) Green-house gases absorb and re-radiate this longer wave radiation keeping the heat trapped

### Climate changes:

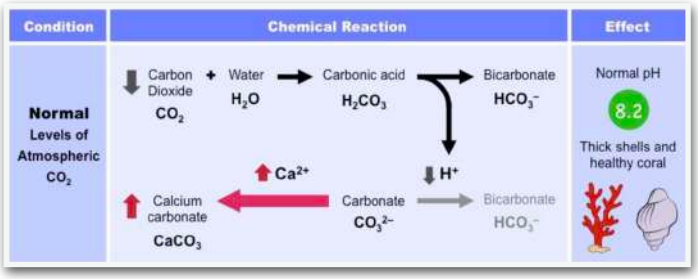
- Greenhouse gases play a pivotal role in determining global temperatures and climate patterns
- Increases in greenhouse gas concentrations will lead to an enhanced greenhouse effect —> More extreme weather conditions, more droughts and rainfalls, changes to circulating ocean currents

## Vostok station, Antartica:

- Link between global temperatures and carbon dioxide concentrations was established by analysing data over a long time period
- Ice cores taken from the Vostok station in Antarctica provide evidence of the environmental conditions at the time of freezing —> 420,000 years and covers the past four glacial cycles
- By analysing the gas bubbles trapped in ice, historical $CO_2$ levels and air temperatures (via oxygen isotopes) can be deduced

## Ocean acidification:

- $CO_2$ solubility is temperature dependent (more soluble when cooler), so less $CO_2$ will be absorbed as temperatures rise —> 1/3 of total $CO_2$ absorbed by oceans
- Rising levels of atmospheric carbon dioxide are causing a decrease in the pH of ocean water
- The decrease in ocean pH is predicted to threaten the survival of marine organisms that require calcium carbonate




- The disappearance of coral reefs could result in a loss of shoreline protection and habitat, altering coastal ecosystems —> 1 trillion $ in loss by 2100
- Increasing the dissolved $CO_2$ levels in oceans would cause invasive species of algae to flourish

## Greenhouse debate:

- **Claim 1:** Climate has changed in the past and current trends merely reflect the Earth's natural climatic cycle

  Climate changes do occur naturally, but usually not as abruptly as what is seen currently

- **Claim 2:** Climate change is being caused by solar activity and the effect of greenhouse gas emissions is negligible

  Over the last 35 years the sun has shown a slight cooling trend, however average global temperatures have increased

- **Claim 3:** Certain changes in climate conditions cannot be linked to greenhouse gas emissions

  Global sea levels began to increase after greenhouse gas emissions significantly increased following the industrial revolution

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# Extra:

## Species interaction:

- Positive association —> two species interact directly within a shared environment
- Negative association —> interactions with environment are mutually detrimental to both species

## Niche:

- Describes the functional position and role of an organism within its environment
- Ecological niches —> includes habitat, activity patterns, resources and interactions
- Fundamental niche —> entire set of conditions under which an organism can survive+reproduce
- Realised niche —> is the set of conditions actually used by a given organism after interactions with other species are taken into account
- Competitive exclusion —> one species will use the resources more efficiently and drive the other species to local extinction
- Resource partitioning —> two species will alter their use of the niche to avoid direct competition, allowing for co-existence

## Ecological productivity:

- Refers to the rate of generation of biomass in an ecosystem
- Primary production —> the production of chemical energy in organic compounds by producers
  —> Gross primary production (GPP) is the amount of chemical energy as biomass that a producer creates in a given length of time
  —> Net primary production (NPP) is the amount of chemical energy that is not consumed by respiration (NPP = GPP – respiration)
- Secondary production —> describes the generation of biomass by heterotrophic organisms
  —> can be categorised according to gross (total) and net (usable) amounts of biomass

## Biomagnification:

- Biomagnification —> the increase in the concentration of a substance at a particular trophic level
  —> pesticide DDT and mercury
- Bioaccumulation —> the increase of a substance (such as a pollutant) in a particular organism

## Biogeochemical cycles:

- Pathway by which a chemical substance moves through the biotic and abiotic spheres of Earth
- Nitrogen cycle —> 79 % of earths atmosphere is composed by nitrogen but it is inert in this form
  —> chemically processed by nitrogen-fixing bacteria to be used by plants
  —> $N_2$ in the soil converted back into inert nitrogen gas by denitrifying bacteria
- Phosphorus cycle —> primary component of DNA and energy-storing molecules (ATP)
  —> not found as a gas in the atmosphere
  —> is fixed to soil particles but may be released by the weathering of rocks
- Sulphur cycle —> essential component of living organisms (proteins and enzyme cofactors)
  —> sulphur in the air and soil may be oxidised to form sulphates
  —> sulphates are reduced by plants and bacteria
  —> can also be mineralised into inorganic forms and incorporated with metals
  —> burning of fossil fuels releases sulphur dioxide causing acid rain

## Precautionary principle:

- States that when a human-induced activity raises a significant threat of harm to the environment or human health, then precautionary measures should be taken even if there is no scientific consensus regarding cause and effect

## Carbon footprint:

- The total amount of greenhouse gases produced to directly and indirectly support human activity
- Expressed in equivalent tonnes of carbon dioxide
- Reducing, reusing and recycling are efforts to reduce a carbon footprint

## Greenhouse impacts:

- Disease spread
- Ice caps melting —> releasing detritus trapped in ice and rising sea levels
- Extreme weather conditions
- Extinction events
- Temperature increases
- Habitat destruction

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# Chapter 5 —> Evolution

## 5.1 Evolution evidence

### Evolution:

- Describes a change over time —> change refers to the heritable characteristics of a species
- Heritable characteristics —> encoded by genes and transferred between generations as alleles
- Biological evolution —> change in the allele frequency of population gene pool over generations
  —> cumulative changes that occur within a population between generations

### Fossils:

- Fossil records provide evidence by revealing features of ancestors for comparison against living descendants —> represents the totality of fossils (both discovered and undiscovered)
- Fossil —> the preserved remains or traces of any organism from the remote past
  —> Body fossils —> provide direct evidence of ancestral form (bones, teeth, leaves, …)
  —> Traces —> provide indirect evidence of ancestral forms (footprints, tooth marks, …)

**Law of fossil succession:**

- Fossils can be dated by determining the age of the rock layer (strata) in which the fossil is found
- Sedimentary rock layers —> develop in a chronological order —> each strata represents a variable length of time that is classified according to a geological time scale
- The ordered succession of fossils suggests that newer species likely evolved as a result of changes to ancestral species —> prokaryotes appeared in fossil record before eukaryotes
  —> ferms appear in fossil record before flowering plants
  —> Invertebrates appear in fossil record before vertebrate species

**Transitional fossils:**

- Demonstrate the intermediary forms that occurred over the evolutionary pathway from one gene —> create links between species by exhibiting traits common to both an ancestor and descendant
- Archaeopteryx —> links the evolution of dinosaurs to birds
- The fossil record is incomplete —> because fossilisation requires a set of circumstances in order to occur —> very few organisms become fossils
- Only the hard parts of an organisms are typically preserved —> only fragments are discovered
- With limited fossil data it can be difficult to discern the evolutionary patterns

**Fossil evidence:**

- Australopithecus —> an early hominid ancestor that first appears in the fossil record 4 million year ago —> demonstrates key evolutionary changes from homo sapiens

| Structural Change | Evolutionary Advantage |
|---|---|
| More downward-facing foramen magnum | Facilitated transition to bipedalism (walking upright without use of hands)<br><br>– needs to maintain an erect posture<br>– increases weight-bearing on lower limbs<br>– hands available for tool manipulation<br>– head no longer most anterior part of body |
| S-shaped curvature of spine | |
| Longer leg : arm length ratio | |
| Larger heel bone and alignment of big toe | |
| Shift in position of gluteal muscles | |
| Reduced brow ridge and jaw protrusion | |
| Larger cranial capacity | Increased intellectual prowess |
| Smaller teeth and narrower jaw | Changed dietary requirements (more meat) |
| Lower and broader pelvis | Altered birthing patterns (for larger infants) |
| Marked reduction in body hair | Reflects use of fur clothing from hunting |
| Increased average height | Consequence of improved diet |

## Selective breeding:

- A form of artificial selection in which man intervenes in the breeding of species to produce desired traits in offspring —> the trait's frequency becomes more common in new generations
- It provides evidence of evolution as targeted breeds can show significant variation in a short period
- Selective breeding of plant crops has allowed for the creation of new types of foods
  —> plants of genus Brassica have been bred to produce different foods by artificial selection
  —> broccoli, cabbage, and kale
- Selective breeding of domesticated animals has resulted in new breeds of offspring
  —> Horses —> have been selectively bred across many generations to produce variation according to a targeted function (race horses speed and draft horses power)
  —> Cows —> have been selectively bred across many generations to produce offspring with improved milk production (increase in muscle)
  —> Dogs —> show an enormous amount of variety due to the targeted selection of traits
  —> Toy dogs were bread to be small while racing dogs were bred to be fast

## Comparative anatomy:

- Illustrate adaptive radiation, whereby several new species rapidly diversify from ancestor
- Organisms may show certain structural features that are similar, implying common ancestry
- Homologous structures —> anatomical features similar in basic structure —> the more similar the structures are, the more related the two organisms are
  —> mammals, birds, amphibians and reptiles all share arrangement of bones in their appendages based on a five-digit limb

## Speciation:

- The evolutionary process by which two related populations diverge into separate species
- Within a population of any given species there will be genetic variation —> this variation will be continuous and follow a normal distribution curve as the change rate is gradual and cumulative
- If two populations of a species become geographically separated, the will experience different ecological conditions —> they will adapt to different environments and gradually diverge
- Divergence levels depend on the extent of geographical separation and amount of time passed
  —> as the genetic divergence increases, the genetic compatibility decreases
  —> at a certain moment divergence will be such that the two populations cannot interbreed
  —> when they can no longer interbreed and produce fertile, viable offsprings they are considered separate species

## Peppered moths (Biston betularia):

- Exist in two distinct polymorphic forms —> light colouration and a darker melanic variant
- Unpolluted environment —> trees are covered by a pale-coloured lichen (camouflage for lighter)
- Polluted environment —> sulphur dioxide kills the lichen while soot blackens the bark (for dark)
- Before industrial revolution environment unpolluted and lighter moth had a survival advantage
- Following industrial rev. the environment became heavily polluted so dark moth advantaged
- Environmental policies nowadays are reducing pollution levels so altering the frequencies again

## 5.2 Natural selection

### Charles Darwin:

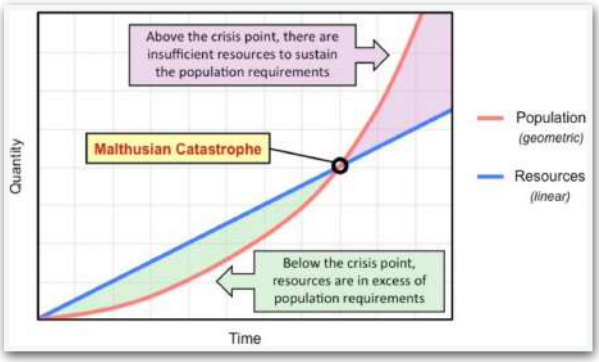
- Theory of natural selection —> it is not necessarily the strongest or most intelligent that survives, but the ones most responsive to change
- Natural selection occurs in response to:
  —> Inherited variation —> genetic variation within a population that can be inherited
  —> Competition —> There is struggle for survival (more offsprings than what supported)
  —> Selection —> Environmental pressures lead to differential reproduction within pop.
  —> Adaptations —> individuals with beneficial traits are more likely to survive + pass trait
  —> Evolution —> over time, change in allele frequency within the population gene pool

### Variation:

- Natural selection requires variation among members of a species in order to differentiate survival
  —> can manifest as either discontinuous (distinct class) or continuous (just a characteristic)
- There are three main mechanisms by which genetic variation may occur:
  —> Mutations —> changing the genetic composition of gametes changes characteristics
  —> Meiosis —> via either crossing over (prophase I) or independent assortment (meta I)
  —> Sexual reproduction —> combination of genetic material creates new gene combination

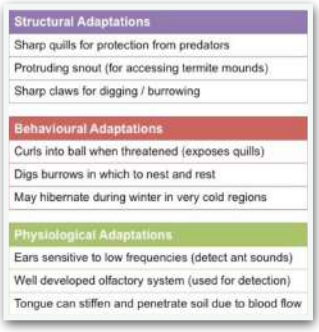
### Competition:

- Species tend to produce more offspring than the environment can sustainably support
- Malthusian dilemma (Thomas Malthus) —> populations multiply geometrically while food resources only increase arithmetically
- If left to course, a stable population will inevitably outgrow its resource base —> competition




### Adaptations:

- Features of organisms that aid their survival by allowing them to be better suited to environment
- May be classified in different ways:
  —> Structural —> physical differences in biological structure (neck in the giraffe)
  —> Behavioural —> differences in patterns activity
  —> Physiological —> variations in detection and response by vital organs
  —> Biochemical —> differences in molecular composition of cells and enzyme functions
  —> Developmental —> variable changes that occur across the life span of an organism
- Organisms with beneficial adaptations will be more likely to survive enough to reproduce and pass on these genes
- Adaptations of Echidna are shown on the left



### Allele frequency:

- The variation that exists within a population is heritable and is determined by presence of alleles
  —> alleles may be passed from parent to offspring via sexual reproduction
- Alleles encode for the phenotypic polymorphisms of a particular trait and may be:
  —> Beneficial —> alleles will better equip the organisms to survive (more offsprings)
  —> become more frequent during time
  —> Neutral —> alleles will not affect the organisms survival prospects
  —> Detrimental —> alleles harm the survival prospects of an organism (fewer offsprings)
  —> become less frequent during time
- Due to natural selection the proportion of different alleles will change across generations

### Adaptive radiation:

- Describes the rapid evolutionary diversification of a single ancestral line
- It occurs when members of a single species occupy a variety of distinct niches with different environmental conditions —> members evolve different morphological features in response to the different selection pressures
- Daphne major —> adaptive radiation can be seen in the variety of beak types seen in the finches
  —> is a volcanic island that forms part of the archipelago of Galapagos islands
  —> finches show marked variation in beak size and shape according to diet

### Antibiotic resistance:

- Antibiotics —> chemicals produced by microbes that either kill or inhibit the growth of bacteria
  —> commonly used by man as a treatment for bacterial infections
- Antibiotic resistance via gene mutation may occur over many generations because:
  1) when treated with antibiotics, resistant bacteria will survive and reproduce
  2) it will flourish in the absence of competition from strains of bacteria killed by antibiotic
  3) resistance may be transferred to susceptible strains (transferring plasmid via conjugation)
  4) the introduction of the antibiotic has caused the resistant gene to become more frequent

- Straphyloccoccus aureus —> has antibiotic resistance due to evolution
  —> can cause infections to the skin (lesions) or more serious infections (meningitis)
  —> historically these infections were cured by using the antibiotic methicillin
  —> bacterial strains resistant to methicillin developed —> these strains proliferated
  —> MRSA infections are especially present in hospitals where use of methicillin
  —> medical practitioners now prescribe alternate antibiotic agents to treat infections

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## 5.3 Classification

### Binomial system:

- The formal system by which all living species are classified (taxonomy)
- Periodically assessed and updated internationally every 4 years
- It provides value because:
  —> it allows for identification and comparison of organisms based on characteristics
  —> it allows all organisms to be named according to a globally recognised scheme

—> it can show how closely related organisms are, allowing for prediction of evolution
—> it makes it easier to collect, sort and group information about organisms

- Every organisms is designated a scientific name with two parts
  1) The genus —> written first and is capitalised
  2) The species —> follows the genus and is written in lower case

## Domains of life:

1) Eukarya —> eukaryotic organisms that contain a membrane-bound nucleus (protist, plants, fungi and Animalia)
2) Archaea —> prokaryotic cells lacking a nucleus and consist of the extremophiles (methanogens, thermophiles, …)
3) Eubacteria —> prokaryotic cells lacking a nucleus and consist of the common pathogenic forms (E. coli, S. aureus, …)

## Hierarchy of Taxa:

- Taxonomy —> the science involved with classifying groups of organisms on the basis of shared characteristics
- Organisms are grouped according to a series of hierarchical taxa (the more taxa the more related)

| Animal Example | Taxonomic Rank | Plant Example |
|---|---|---|
| Animalia | **Kingdom** | Plantae |
| Chordata | **Phylum** | Angiospermophyta |
| Mammalia | **Class** | Eudicotidae |
| Primate | **Order** | Ranunculales |
| Hominidae | **Family** | Ranunculacae |
| *Homo* | **Genus** | *Ranunculus* |
| *sapiens* | **Species** | *acris* |
| Human | Common Name | Buttercup |

## Classification:

**Artificial classification:**
- Involves arbitrarily selecting unifying characteristics first to then group organisms accordingly
- Advantage —> such schemes are easy to develop and relatively stable
- Disadvantage —> do not generally show evolutionary relationships so are not commonly used

**Natural classification:**
- Involves grouping organisms based on similarities first to then identify shared characteristics
- All members of a particular group would have shared a common ancestor —> so can be used to predict characteristic shared by species within a group
- All members that share a lower taxa must share all higher taxes
- Advantage —> it identifies traits based on groupings rather than assigning groups based on traits
- Disadvantage —> the schemes are highly mutable and tend to change when info. is discovered

**Phylogenetic classification:**
- Now being used to differentiate organisms based on genetics
- Organisms who share a greater level of homology in their DNA or amino acid sequences are expected to be more closely related

## Plant phyla:

| | Structures | Vascularisation | Reproduction | Other Features | Examples |
|---|---|---|---|---|---|
| *Bryophyta* | No 'true' leaves, roots or stems | None | Spores | Anchored by rhizoids | Mosses |
| *Filicinophyta* | Have leaves, roots and stems | Present | Spores | Leaves are pinnate | Ferns |
| *Coniferophyta* | Have leaves, roots and stems | Present | Seeds (in cones) | Woody stems | Conifers |
| *Angiospermophyta* | Have leaves, roots and stems | Present | Seeds (in fruits) | Have flowers & fruits | Flowers |

- The plantae kingdom has 12 phyla

## Animal phyla:

- The Animalia kingdom can be sub-divided into two main groups (invertebrates and vertebrates)
- Chordata —> have bilateral symmetry, have a separate mount and anus, and have a notochord and a hollow, dorsal nerve tube for at least some period of their life cycle

| | Symmetry | Body Cavity | Segmentation | Other Features | Examples |
|---|---|---|---|---|---|
| *Porifera* | Asymmetrical | None (have pores) | None | Spicules for support | Sea sponge |
| *Cnidaria* | Radial | Mouth but no anus | None | Stinging cells (cnidocytes) | Jellyfish, coral, sea anemone |
| *Platyhelmintha* | Bilateral | Mouth but no anus | None | Flattened body (↑ SA:Vol ratio) | Tapeworm, planaria |
| *Annelida* | Bilateral | Mouth and anus | Segmented | Move via peristalsis | Earthworm, leech |
| *Mollusca* | Bilateral | Mouth and anus | Non-visible (mantle & foot) | May have a shell (made by mantle) | Snail, octopus, squid, bivalves |
| *Arthropoda* | Bilateral | Mouth and anus | Segmented | Exoskeleton (chitin) | Insects, spiders, crustaceans |

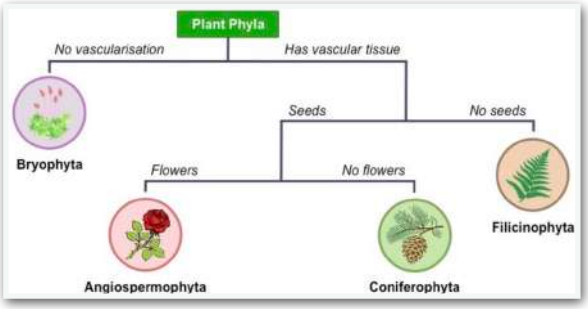
## Vertebrates:

- Some chordates, develop the nerve tube into a spine and the notochord will form a protective backbone —> grouped in the sub-phylum vertebrata

| | Body covering | Reproduction | Breathing | Temperature | Other Features |
|---|---|---|---|---|---|
| *Fish* | Scales made out of bony plates | External | Gills | Ectothermic | Have a swim bladder |
| *Amphibian* | Moist skin | External | Simple lungs (and via skin) | Ectothermic | Larval state in water, adult state on land |
| *Reptile* | Scales made out of keratin | Internal (lays soft eggs) | Lungs with extensive folding | Ectothermic | Simple teeth with no living tissue |
| *Bird* | Feathers | Internal (lays hard eggs) | Lungs with bronchial tubes | Endothermic | Have wings and beaks with no teeth |
| *Mammal* | Hair | Internal – live births (except monotremes) | Lungs with alveoli | Endothermic | Feed young with milk from mammary gland |

## Dichotomous keys:

- Method of identification whereby groups of organisms are divided into two categories repeatedly
- With each sequential division more info is known about the specific features of the organism
- When the organism no longer shares characteristics with any organism it has been identified
- Better to use immutable features to identify specimens

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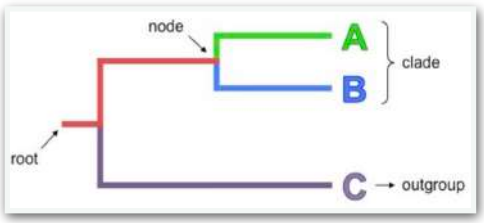
## 5.4 Cladistics

### Clades:

- Cladistics —> a method of classifying organisms into groups of species called clades
- Each clade consists of an ancestral organisms and all of its evolutionary descendants
- Members of a clade will possess common characteristics as a result of their share lineage
- Cladograms —> tree diagrams where each branch point represents the splitting of two new groups from a common ancestor —> distinct species are formed via divergent evolution
- Show the likely evolutionary history (phylogeny) of a clade

Cladograms:




Molecular evidence:

- Organisms use DNA+RNA as genetic material + genetic code for protein synthesis is universal
- This means that base and amino acid sequences can be compared to ascertain relatedness
- The more similar the base sequences of two species are, the more related the species are
- When comparing molecular sequences, scientist may use:
  —> Non-coding DNA provides best comparison as mutations will occur more readily
  —> Gene sequences mutate at a slower rate as may affect protein structure and function
  —> Amino acid sequences have the slowest rate of change due to codon degeneracy
- Molecular clock —> some genes or protein sequences may accumulate mutations at constant rate
  —> different genes or proteins may change at different rates
  —> rate of change for a particular gene may differ between different organisms
  —> Over long periods, earlier changes may be reversed by later changes

Structural evidence:

- Historically classification was based primarily on morphological differences
- Closely related species were expected to show similar structural features
- Two key limitations in morphological differences:
  —> closely related organisms can exhibit very different structural differences due to adaptive radiation
  —> distantly related organisms can display very similar structural features due to convergent evolution
- Convergent ev. —> independent evolution of similar features in species with distinct lineages
  —> may occur when different species in the same habitat (same selection pressures)
- Homologous structures —> traits similar because they are derived from common ancestry
- Analogous structure —> traits superficially similar, but derived by separate evolutionary patterns

Figwort plant family:

- Were the 8th largest family of flowering plants (275 different genera)
- Taxonomists examined the chloroplast gene in figworts and decide to split the figwort species into five different clades —> now 36th largest group among angiosperms

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Extra:

Evidence of evolution:

- Fossil record, selective breeding and comparative anatomy are three of the most widely recognised pieces of evidence
- Biogeography, vestigial structures and comparative embryology provide evidence for evolution
- Molecular evidence is now being used to demonstrate evolutionary relationships

- Vestigial structures —> some species show the presence of functionless and reduced remnants of organs that were once present in their ancestors —> not needed anymore
  —> demonstrate the evolutionary divergence of a species from a past activity
  —> pelvic bone in whales —> suggests they were terrestrial mammals
- Biogeography —> describes the distribution of lifeforms over geographical areas
  —> related species are usually found in close physical proximity
  —> fossils found in a region tend to closely resemble the modern organisms
  —> it suggests that closely distributed species share a common lineage
  —> most modern marsupials are found almost exclusively in Australia
  —> continental drift —> over 250 million years ago there was only one continent
- Comparative embryology —> studies show that growing embryos in animals or plants show that closely related species have similar stages of development —> common evolutionary pattern
  —> all terrestrial animals have non-functioning gill slits (aquatic)
  —> many vertebrates demonstrate a primitive tail at early stages

## Fossilisation:

- Rare process as the vast majority of deceased organisms disappear without leaving a trace
- In order to occur —> hard body parts needed
  —> preservation of remains
  —> high pressure to promote mineralisation of remains
  —> anoxic conditions to protect against oxygen damage and prevent decomp.

1) Death and decay —> only hard body parts remain
2) Deposition —> hard remains are covered with slit and sand
3) Permineralisation —> pressure causes the hard organic material to be replaced by minerals
4) Erosion / exposure —> movement of land return the fossil to the surface

## Geological time scale:

- Earth formed 4.6 billion years ago and the earliest forms of life appeared 3.5 billion years ago
- The geological time scale measures time on a scale involving four units:
  —> epoch —> the smallest unit of time on the scale
  —> periods —> epochs are grouped together into larger units calle periods
  —> era —> periods are combined to make a subdivision called era
  —> eon —> the largest division of geological time

## Radioactive dating:

- Common method to determine the age of fossils
- Radioisotopes are alternative forms of an element (same protons but different neutrons) —> these isotopes are unstable and decay at a constant rate (three types of radioactive decay)
  —> Alpha decay —> atom releases two protons and two neutrons to form a new element
  —> Beta decay —> a neutron decays to produce a proton, electron and anti-neutrino
  —> Gamma decay —> involves the release of electromagnetic radiation (no mass change)
- $^{14}C$ has an half-life of only 5730 years —> can only data samples less than 60000 years old
- $^{40}K$ is released in lava and has an half life of 1.3 billion years —> long range dating

## Theories of evolution:

- Evolutionary theories began emerging in the 1800's as new geological and biological discoveries reformed existing knowledge —> before "fixity" (man was always man)
- Jean-Baptiste Lamarck —> proposed that species changed as result of habitual use of features
  —> modified features could be passed to successive generations
  —> was essentially flawed —> cutting a tail does not produce tail-less
- Charles Darwin —> based on a combination of Lamarckian ideas and recent fossil discoveries
  —> species living today changed over time form a single ancestral organism
  —> limiting natural factors will restrict growth
  —> organisms with useful traits have an adaptive advantage (reproduce more)
- Neo Darwinism —> the synthesis of Darwinian theory and modern genetics
  —> Gregor Mendel describes how traits are inherited
  —> Watson and Crick elucidated the genetic basis of inheritance

## Selection pressures:

- External agents which affect an organism's ability to survive in a given environment
- Can be negative (trait presence diminishes) or positive (increases presence of trait)
- Include resource availability, environmental conditions and biological factors

| Density Dependent Factors |
|---|
| **P**redators |
| **A**vailability of resources (e.g. shelter, water) |
| **N**utrient supply (i.e. food source) |
| **D**isease / pathogenic spread |
| **A**ccumulation of wastes |
| **Density Independent Factors** |
| **P**henomena (e.g. natural disasters) |
| **A**biotic factors (e.g. temperature, $CO_2$ levels) |
| **W**eather conditions (e.g. floods, storms, etc.) |

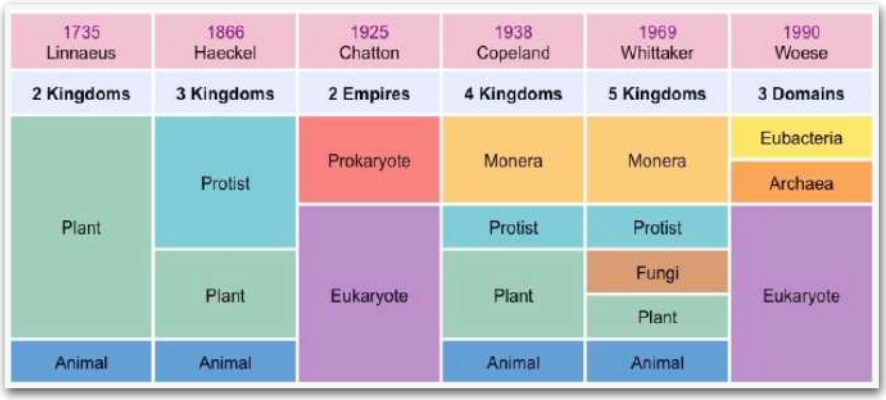
## Species diversification:

- Evolution —> all cumulative changes that occur in the heritable characteristics of a population
- Microevolution —> describes evolutionary changes that occur within a short period of time
  —> gene mutations, sexual reproduction and gene flow
  —> genetic drift —> change in the gene pool as a result of an event
  —> natural selection
- Macroevolution —> describes evolutionary changes that occur over relatively long geological periods (results in speciation)
  —> changes in large populations (mostly due to significant env. changes)

## Artificial gene transfer:

- Vertical gene transfer is due to reproduction by organisms across generations
- Horizontal gene transfer occurs instead within a single generation (plasmids in bacteria)
- Humans can extract plasmids and use them as a vector to deliver genes of interest

## Past nomenclatures:



## Archaea, Eubacteria and Eukarya:

| Characteristic | Archaea | Bacteria | Eukarya |
|---|---|---|---|
| Membrane lipids with branched hydrocarbons | ✔ | | |
| Chromosomes are circular | ✔ | ✔ | |
| Lacks nuclear envelopes | ✔ | ✔ | |
| Lacks membrane bound organelles | ✔ | ✔ | |
| Methionine is the initiator amino acid for protein synthesis | ✔ | | ✔ |
| Lack peptidoglycan in the cell wall | ✔ | | ✔ |
| Growth not inhibited by streptomycin and chloramphenicol | ✔ | | ✔ |
| Histones are associated with DNA | ✔ | | ✔ |
| Contains several types of RNA polymerase | ✔ | | ✔ |

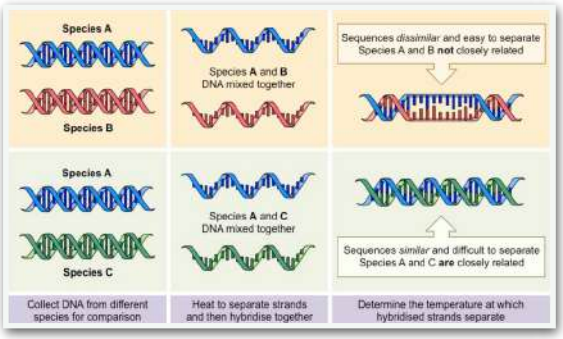
## Animal complexity:

- Body symmetry —> describes the alignment of body parts around a central axis
  —> Porifera —> the most primitive as lack any body symmetry
  —> Cnidaria —> sedentary and have radial symmetry
  —> all other animals have bilateral symmetry (allows directional movement)
- Body openings —> Porifera —> the most basic invertebrate and have no body openings
  —> Cnidaria and platyhelminths —> have a singular body opening
  —> all other phyla have two body openings (result in tubular digestive system)
- Body segmentation —> allows for the specialisation of function in these different areas
  —> Porifera and Cnidaria lack distinctive body segmentation
  —> may not be clearly visible but still present
- Chordates —> all have notochord, hollow dorsal nerve tube, pharyngeal slits and postanal tail

## Viruses:

- Do not share the same classification system as organisms because they are not considered alive
- Are classified mainly according to phenotypic characteristics:
  —> morphology
  —> nucleic acid type (DNA or RNA)
  —> method of viral replication
  —> host organisms
  —> types of disease caused

## In situ Hybridisation:




## Mitochondrial DNA (mtDNA):

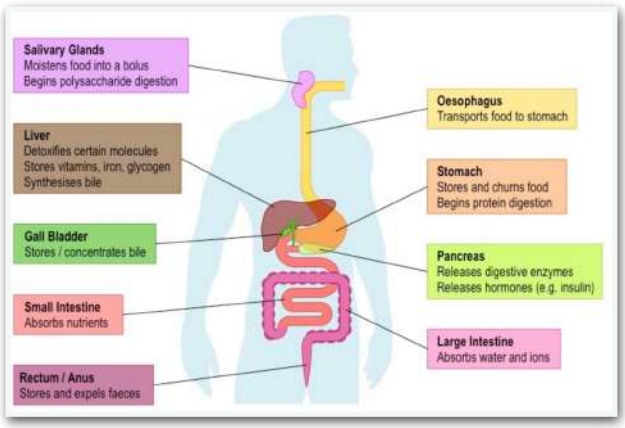
-Is an important tool for tracing evolutionary relationships within a specie
-Is better than nuclear DNA when determining phylogenetic pathways as:
—> Maternal inheritance —> mtDNA is inherited only by the mother (more direct lineage)
—> No recombination —> as passed only by mother
—> Higher mutation rate
—> High copy number —> as many mitochondria

# Chapter 6 —> Human Physiology

## 6.1 Digestion

### Digestive system:

- Two major groups of organs which comprise the human digestive system:
  —> Alimentary canal —> organs through which food actually passes (oesophagus, stomach, small & large intestine)
  —> Accessory organs —> aid in digestion but do not actually transfer food (salivary glands, pancreas, liver, gall bladder)




### Mechanical digestion:

**Chewing:**
- Occurs in the mouth —> food is broken down in the mouth by the grinding action of teeth
- The tongue pushes food towards the back of the throat than down the oesophagus as a bolus
- The epiglottis prevents the bolus from entering the trachea
- The uvula prevents the bolus from entering the nasal cavity

**Churning:**
- Occurs in the stomach —> the stomach lining contains muscles which physically squeeze and mix the food with strong digestive juices
- Food is digested within the stomach for several hours and is turned into chyme (creamy)
- The chyme enters the small intestine (duodenum) where absorption occurs

### Chemical digestion:

**Stomach acids:**
- The stomach contains gastric glands which release digestive acids to create low pH ( 2 )
- The acidic environment denatures proteins and other macromolecules
- The stomach epithelium contains a mucous membrane which prevents acids from damaging the gastric lining
- The pancreas releases alkaline compounds —> neutralise the acids when entering the intestine

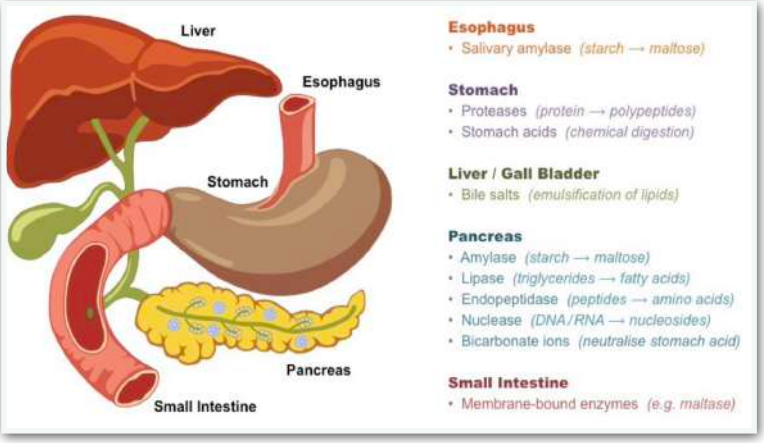
**Bile:**
- Produced by the liver and stored and concentrated within the gall bladder before being released into the intestine
- Bile salts interact with fat globules to divide them into smaller droplets (emulsification)
- Emulsification of fats increases the total surface area available for enzyme activity

**Enzymes:**
- Allow digestive processes to occur at body temperatures and at sufficient speeds for survival
- Are specific for a substrate —> allow digestion of certain molecules to occur in distinct places

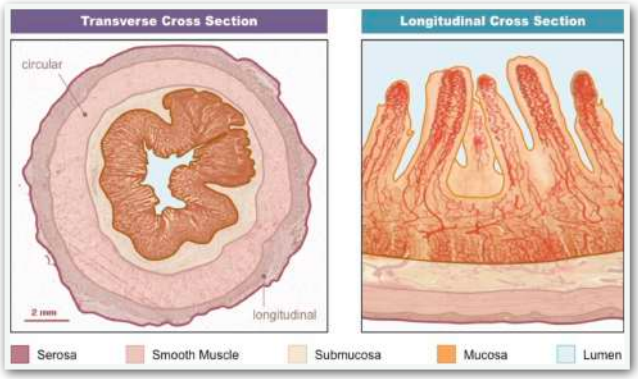
## Movement of food:

**Peristalsis:**
- Continuous segments of longitudinal smooth muscle which rhythmically contract and relax
- The principal mechanism of movement in the oesophagus (occurs also in the stomach and gut)
- Food is moved unidirectionally along the alimentary canal in a caudal direction (mouth - anus)

**Segmentation:**
- Involves the contraction and relaxation of non-adjacent segments of circular smooth muscle in the intestines
- Move chime in both directions —> allows for a greater mixing of food with digestive juices
- Bidirectional propulsion of chyme can slow overall movement




## Small intestine:

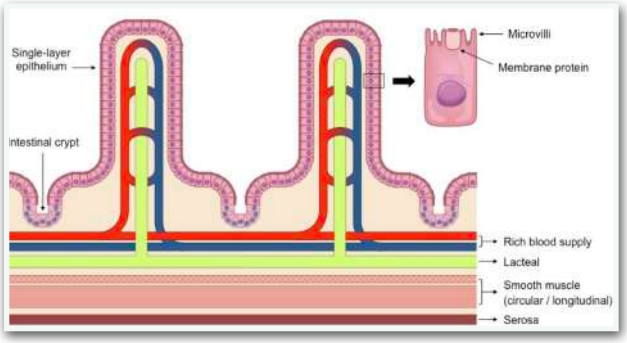



- Absorbs usable food substances (nutrients)
- Is composed by four main tissue layers

**Structure:**
- Serosa —> protective outer covering composed of a layer of cells —> reinforced by fibrous connective tissue
- Muscle layer —> outer layer of longitudinal muscle and inner layer of circular muscle
- Submucosa —> connective tissue separating the muscle layer from the innermost mucosa
- Mucosa —> highly folded inner layer —> absorbs material through its surface epithelium from the intestinal lumen
- Ileum —> final section of the small intestine (image on the right)

**Villi:**
- Intestinal villi contain several key features which facilitate the absorption of digestive products
- Microvilli —> ruffling of epithelial membrane further increases surface area
- Rich blood supply —> dense capillary network rapidly transports absorbed products
- Single layer epithelium —> minimises diffusion distance between lumen and blood
- Lacteals —> absorbs lipids from the intestine into the lymphatic system
- Intestinal glands —> Exocrine pits (scripts of Lieberkuhn) release digestive juices
- Membrane proteins —> facilitate transport of digested materials into epithelial cells

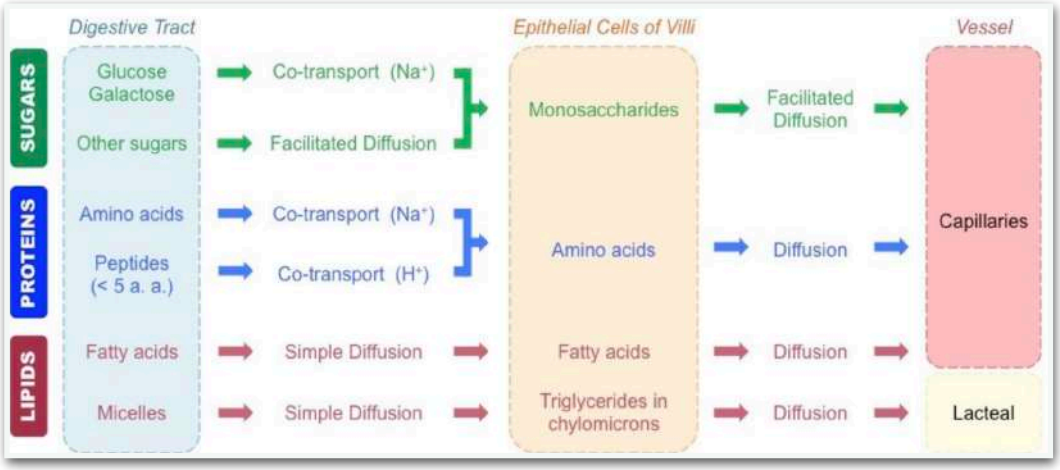
**Structure of Villus epithelium:**



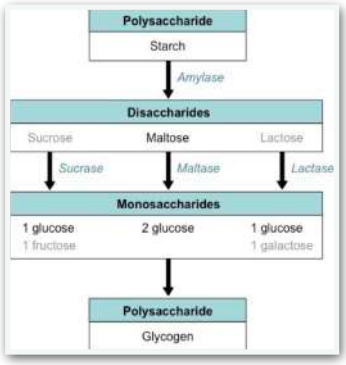

- Tight junctions —> occluding associations between the plasma membrane of two adjacent cells —> creates an impermeable membrane —> keep digestive fluids separated from tissues and maintain a concentration gradient by ensuring one-way movement
- Microvilli —> increase SA of the plasma membrane by >100x —> membrane has immobilised digestive enzymes and channel proteins for material uptake
- Mitochondria —> epithelial cells of intestinal villi will possess large numbers of mitochondria to provide ATP for active transport mechanisms (primary, secondary or pinocytosis)
- Pinocytotic vesicles —> the non-specific uptake of fluids and dissolved solutes

## Absorption (membrane transport mechanisms):

- During absorption, digested food monomers must pass from the lumen into the epithelial lining
- Secondary Active Transport —> glucose and amino acids are co-transported across the epithelial membrane by the active translocation of sodium ions ($Na^+$)
- Facilitated diffusion —> channel proteins help hydrophilic food molecules pass through the hydrophobic portion of the plasma membrane and are often situated near specific membrane-bound enzymes —> used for certain monosaccharides, vitamins and some minerals
- Osmosis —> water will diffuse across the membrane in response to the movement of ions and solutes —> occurs in both small and large intestine
- Simple diffusion —> hydrophobic materials may freely pass through the hydrophobic portion of the plasma membrane —> will often pass through the lacteal before going into blood vessels
- Bulk transport —> via endocytosis —> precisely pinocytosis




## Starch digestion:




- Starch is a polysaccharide which accounts for 60% of the carbohydrates consumed by humans
- Exists in form of linear chains (amylose), and branched chains (amylopectin)
- The digestion of starch is initiated by salivary amylase in the mouth and continued by pancreatic amylase in the intestine —> not in stomach as optimal pH for amylase activity is 7

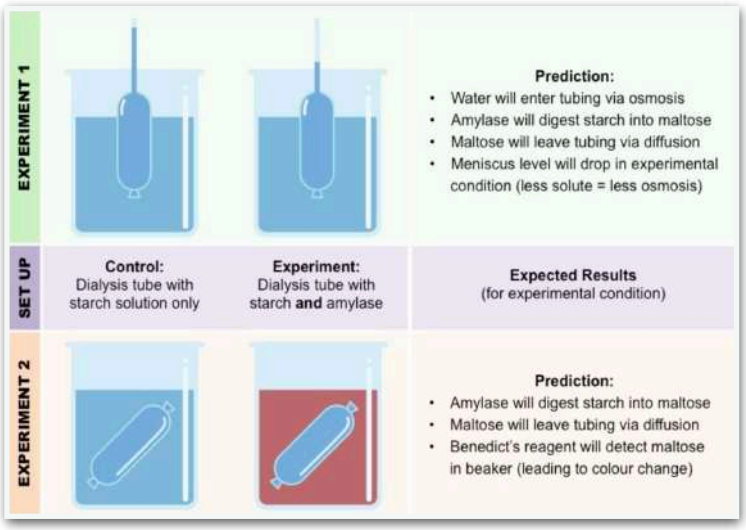
- Amylose becomes maltose and amylopectin becomes branched chains called dextrins
- Maltose and dextrin are digested by enzymes (maltase) which are fixed to the epithelial lining in the small intestine —> this hydrolysis results in the formation of glucose monomers
- Glucose can be hydrolysed to produce ATP or can be stored as glycogen

**Pancreas role:**

- Produces enzyme amylase —> released from exocrine glans (acing cells) into the intestinal tract
- Produces hormones insulin and glucagon —> released from endocrine glands (islets of Langerhans) into the blood —> controls concentration of glucose in the bloodstream
- Insulin lowers blood glucose levels by increasing glycogen synthesis and storage in the liver and adipose tissues
- Glucagon increases blood glucose levels by limiting the synthesis and storage of glycogen

**Modelling digestion:**

- The digestive system serves mostly to break down large molecules into smaller subunits as cell membranes are impermeable to large molecules
- Dialysis tubing (Visking tubing) —> contains pores typically ranging from 1-10 nm in diameter and is semi-permeable according to molecular size
  —> large molecules such as starch cannot pass through the tubing, but maltose can
  —> is not selectively permeable based on charge unlike membranes of living cells
- Measuring Meniscus levels (experiment 1) and measuring Maltose diffusion (experiment 2)

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## 6.2 The blood system

### William Harvey:

- Modern understanding of the circulatory system is based upon his discoveries in the 17th century
- Harvey proposed that —> arteries and veins were part of a single connected blood network (did not predict the existence of capillaries)
  —> arteries pumped blood from the heart
  —> veins returned blood to the heart

## Overview of Pulmonary and systemic circulation:

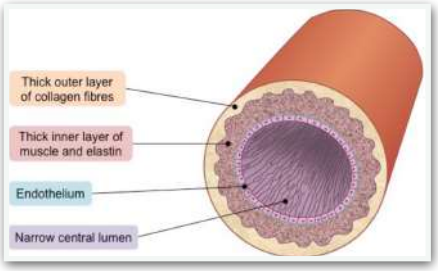
- The human heart is a four chambered organ —> two atria and two ventricles
- The atria act as reservoirs —> blood returning to the heart is collected via veins and passed to ventricles
- The ventricles act as pumps —> expel the blood from the heart at high pressure via arteries

- The left side of the heart pumps oxygenated blood around the body (systemic circulation) —> will have a much thicker muscular wall (myocardium) as it must pump blood much further
- The right side of the heart pumps deoxygenated blood to the lungs (pulmonary circulation)

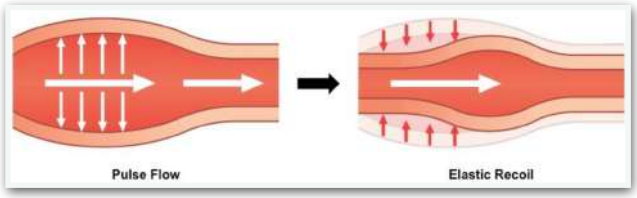
## Arteries:

- Convey blood at high pressure from the heart ventricles to the tissues of the body and lungs
- Specialised structure —> narrow lumen to maintain a high blood pressure (80 - 120 mmHg)
  —> have a thick wall containing an outer layer of collagen to prevent the artery from rupturing under the high pressure
  —> the arterial wall also contains an inner layer of muscle and elastic fibres to help maintain pulse flow (it can contract and stretch)

## Flow of blood:

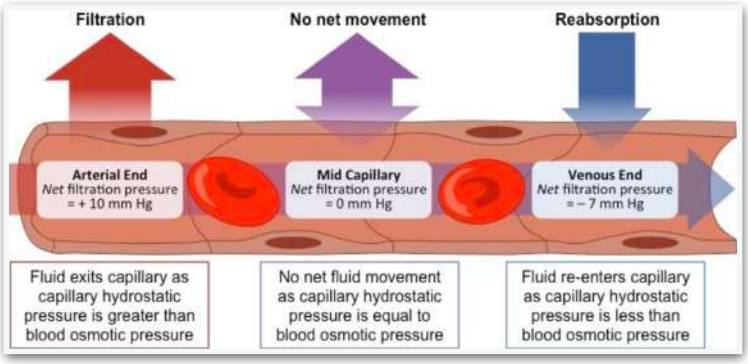


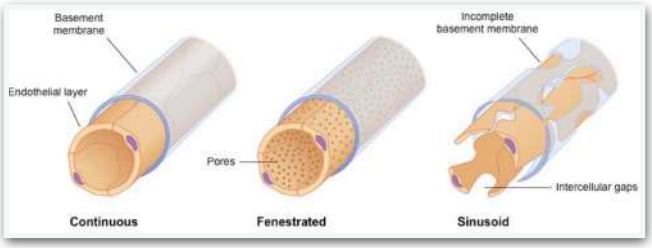

- Blood is expelled from the heart upon ventricular contraction and flow through the arteries in repeated pulses
- Muscle fibres —> help to form a rigid arterial wall that is capable of withstanding the high blood pressure without rupturing —> can also contract to narrow the lumen to help maintain blood pressure throughout the cardiac cycle
- Elastic fibres —> allow arterial wall to stretch and expand upon the flow of a pulse through the lumen —> the pressure exerted on the arterial wall is retired to the blood as an elastic recoil



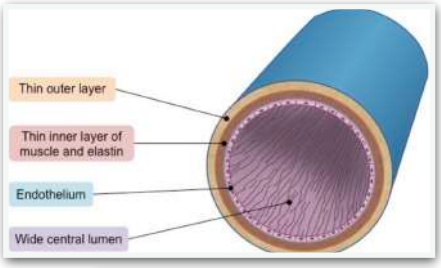

## Capillaries:

- Exchange materials between the cells in tissues and blood travelling at low pressure (<10mmHg)
- Arteries split into arteriole which in turn split into capillaries —> decreases arterial pressure as total vessel volume increases —> branching ensures blood is moving slowly and everywhere
- After material exchange, capillaries will pool into venues which will turn into larger veins
- Specialised structure —> very small diameter (5µm) —> one single red blood cell at a time
  —> capillary wall is made of a single layer to minimise diffusion distance
  —> are surrounded by a basement membrane which is permeable to necessary materials
  —> pores to aid in the transport of materials between tissue fluid and blood
- Capillaries structure may vary depending on its location in the body and specific role:
  —> capillary wall may be continuous with endothelial cells held together by tight junctions to limit permeability of large molecules
  —> in tissues specialised for absorption the capillary wall may be fenestrated
  —> sinusoidal capillaries have open spaces between cells (permeable to large molecules)

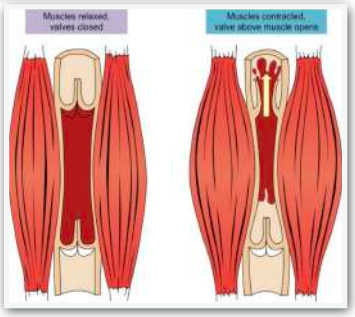



## Veins:




- Collect the blood from the tissues and covey it at low pressure to the atria of the heart
- Specialised structure —> have a very wide lumen —> maximise blood flow
  —> have a thin wall containing less muscle and elastic fibres as blood is flowing at a very low pressure (5-10 mmHg)
  —> valves to prevent backflow as low pressure
- Veins typically pass between skeletal muscle groups —> facilitate venous blood flow via periodic contractions
- Typically run parallel to arteries —> similar effect can be caused by the rhythmic arterial blue created by a pulse



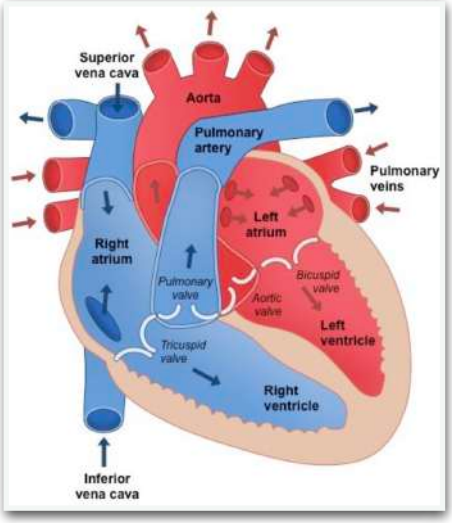
## Vessel comparison:

| | Arteries | Veins | Capillaries |
|---|---|---|---|
| *Function* | Send blood **from** heart | Send blood **to** heart | Material exchange with tissues |
| *Pressure* | High | Low | Low |
| *Lumen Diameter* | Narrow | Wide | Extremely narrow (one cell wide) |
| *Wall Thickness* | Thick | Thin | Extremely thin (single cell thick) |
| *Wall Layers* | Three<br>• Tunica adventitia<br>• Tunica media<br>• Tunica intima | Three<br>• Tunica adventitia<br>• Tunica media<br>• Tunica intima | One<br>• Tunica intima |
| *Muscle & Elastic Fibres* | Large amounts | Small amounts | None |
| *Valves* | No | Yes | No |

## Heart structure:

- Chambers —> two atria —> smaller chambers near top of the heart —> collect blood from body and lungs
  —> two ventricles —> larger chambers near bottom of heart that pump blood to body and lungs
- Heart valves —> atrioventricular valves (between atria and ventricles)
  —> bicuspid valve on left side; tricuspid valve on right side
  —> semilunar valves (between ventricles and arteries) —> aortic valve on left side; pulmonary valve on right

- Blood vessels —> the vena cava (inferior and superior) feeds into the right atrium and returns deoxygenated blood from the body
  —> pulmonary artery connects to the right ventricle and sends deoxygenated blood to the lungs
  —> pulmonary vein feeds into the left atrium and returns oxygenated blood from the lungs
  —> aorta extends from the left ventricle and sends oxygenated blood around the body




## Heart beat:

- The contraction of the heart is myogenic —> the signal for cardiac compression arises within the heart tissue itself
- Cardiomyocytes give signal for a heart beat —> not brain signals
- Sinoatrial node (SA) —> cluster of cells within the wall of the right atrium —> cardiomyocytes —> primary pacemaker —> 60 - 100 cardiac contraction per minute (normal sinus rhythm)
- If sinoatrial node fails a secondary pacemaker (AV node) maintains cardiac contractions (40-60)
- If both fail —> tertiary pacemaker (bundle of His) coordinates contraction (30-40)
- Interference of the pacemakers will lead to irregular and uncoordinated contractions (fibrillation)
- Normal sinus rhythm may be re-established with a controlled electrical current (defibrillation)

1) Sinoatrial node sends out an electrical impulse that stimulates contraction of the myocardium
2) The impulse directly causes the atria to contract and stimulates the atrioventricular node at the junction between the atrium and ventricle
3) The AV node sends signals down the septum via a nerve bundle (Bundle of His)
4) The bundle of His innervates nerve fibres (Purkinje fibres) in the ventricular wall —> causes ventricular contraction

- There is a delay between atrial and ventricular contractions —> results in two heart sounds —> this delay allows time for the ventricles to fill with blood (maximise blood flow)

## Heart rate:

- Nerve signals from the brain can trigger rapid changes in heart beat rate, while endocrine signals can trigger more sustained changes
- Also changes to blood pressure levels or $CO_2$ concentrations will trigger changes in heart rate

**Nerve signalling:**
- Pacemakers are under automatic control from the brain (by medulla oblongata —> brain stem)
- Two nerves connected to the medulla regulate heart rate by either increasing or decreasing it
  —> sympathetic nerve releases neurotransmitter noradrenaline (norepinephrine) increase bpm
  —> parasympathetic nerve (vagus nerve) releases neurotransm. acetylcholine decrease bpm

**Hormonal signalling:**
- Hormones are chemical messengers released into the bloodstream —> act specifically on distant target sites (like the heart
- The hormone adrenaline (epinephrine) is released from the adrenal glands (above the kidneys)

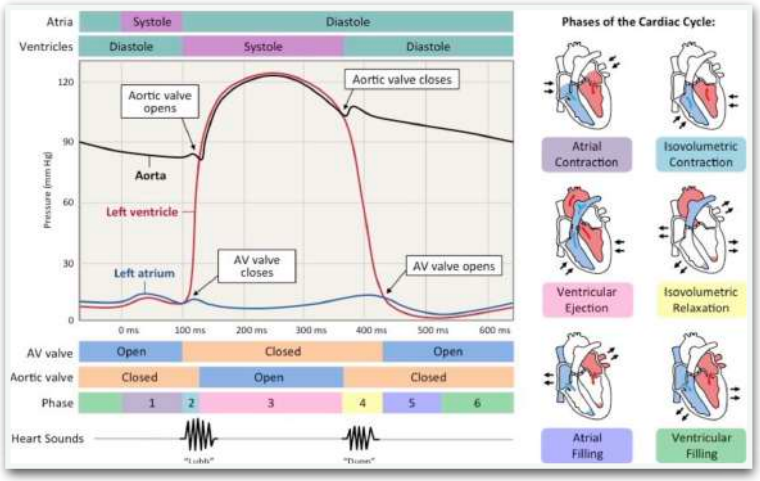
—> increases heart rate by activating same chemical pathways as neurotransmitter noradrenaline

## Cardiac cycle:

- Describes the series of events that take place in the heart over the duration of a single heart beat
- It is comprised of a period of contraction (systole) and relaxation (diastole)

**Systole:**
- Blood returning to the heart will flow into the atria and ventricles as the pressure in them is lower
- When ventricles are 70% full, atria will contract —> more pressure so blood goes into ventricles
- As ventricles contract, ventricular pressure exceeds atrial pressure and AV valves close to prevent back flow (first heart sound)
- With both sets of heart valves closed, pressure rapidly builds in the contracting ventricles (isovolumetric contraction)
- When ventricular pressure exceeds blood pressure in the aorta, the aortic valve opens and blood is released into the aorta

**Diastole:**
- As blood exists the ventricle and travels down the aorta, ventricular pressure falls
- When ventricular pressure drops below aortic pressure, the aortic valve closes to prevent backflow (second heart sound)
- When the ventricular pressure drops below the atrial pressure, the AV valve opens and blood can flow from atria to ventricle



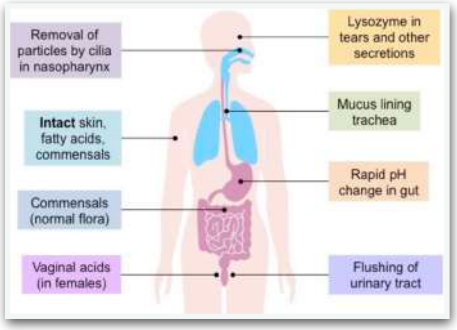

## Heart diseases:

- Coronary arteries —> blood vessels that surround the heart and nourish the cardiac tissue to keep the heart working —> if they become occluded, the region of the blocked artery will die and cease to function

**Atherosclerosis:**
- The hardening and narrowing of the arteries due to the deposition of cholesterol
- Atheromas (fatty deposits) develop in the arteries and significantly reduce the lumen (stenosis)
- Pressure increases —> causes damage to the arterial wall from shear stress
- Lesions called atherosclerotic plaques form as the smooth lining of the artery is degraded
- Thrombus —> restricts blood flow and happens if the plaque ruptures
  —> becomes an embolus if dislodged and can cause a blockage in a smaller arteriole

- Can lead to blood clots which cause coronary heart diseases when they occur in coronary arteries
- Myocardial tissue needs oxygen and nutrients brought via the coronary arteries to function
- If a coronary artery becomes blocked, an acute myocardial infarction (heart attack) will result
- Blockages are treated by by-pass surgery or creating a stent (balloon angioplasty)
- Risk factors are —> age, genetics, obesity, diseases, diet, exercise, sex, smoking

## 6.3 Disease defences




### Surface barriers:

- First line of defence against infectious diseases —> prevent entry of pathogens in the bod
- Skin —> protects external structures when intact
  —> dry, thick, tough region of dead surface cells (epidermis)
  —> dermis —> contains biochemical defence agents —> sebaceous glands secrete chemicals + enzymes which inhibit microbial growth on skin
  —> Also secretes lactic acid and fatty acids to lower the pH (5.6 - 6.4)
- Mucous membranes —> protects internal structures (externally accessible cavities and tubes)
  —> thin living surface cells that release fluids to wash away pathogens (mucus, saliva, tear)
  —> contains biochemical defence agents —> can destroy cell walls and cause cell lysis
  —> mucous membranes may be ciliated to aid in the removal of pathogens

### Clotting (haemostasis):

- Is the mechanism by which broken blood vessels are repaired when damaged
- Functions to prevent blood (erythrocytes) loss from the body and limit pathogenic access to the bloodstream when the skin is broken
- Platelets —> undergo a structural change when activated to form a sticky plug at damaged region
- Fibrin strands —> form an insoluble mesh of fibres that trap blood cells at the site of damage

**Coagulation cascade:**

- Process by which blood clots are formed —> involves a complex set of reactions

1) Clotting factors cause platelets to be sticky and adhere to damaged region to form a solid plug
2) These factors also initiate localised vasoconstriction to reduce blood flow to damaged region
3) The factors trigger the activation of zymogen prothrombin into the activated enzyme thrombin
4) Thrombin catalyses the conversion of the soluble plasma protein fibrinogen into insoluble fibrin
5) The fibrin strands form a mesh of fibres around the platelet plug —> temporary blood clot
6) When the damaged region is repaired, plasmin enzyme is activated and dissolves the clot

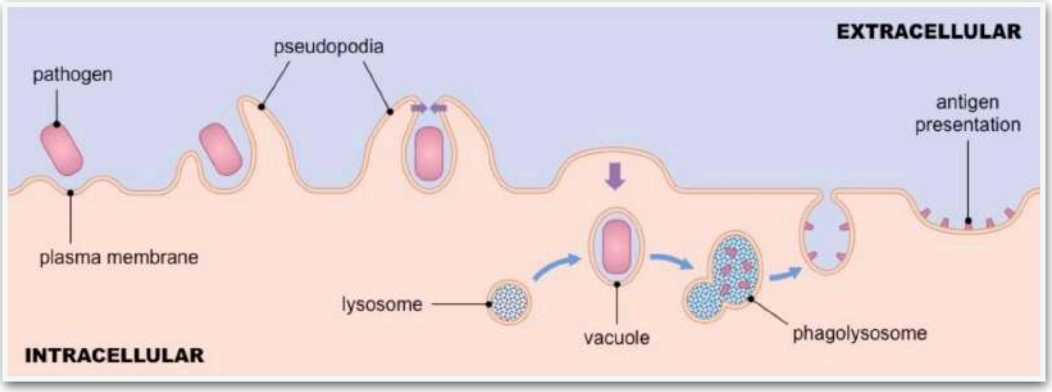
**Coronary Thrombosis:**

- The formation of a clot within the blood vessels that supply and sustain the heart tissue
- May lead to an acute myocardial infarction (heart attack)
- Vessels get damaged due to atherosclerosis

### Phagocytes:

- Are the second line of defence against infectious disease
- Innate immune system —> is non-specific in its response
- Phagocytic white blood cells —> principle component which engulfs and digests foreign bodies
- Other components include inflammation, fever and antimicrobial chemicals
- Two key properties —> does not differentiate between different types of pathogen (non-specific)
  —> responds to an infection the same way every time (non-adaptive)
- Phagocytic leukocytes circulate in the blood and move into the body tissue (extravasation) in response to infection

- Damaged tissues release chemicals (e.g histamine) —> draw white blood cells to site of infection (via chemotaxis)
- Pathogens are engulfed when cellular extensions (pseudopodia) surround the pathogen by macrophages
- The vesicle is then fused to a lysosome —> phagolysosome —> pathogen is digested
- Pathogen fragments (antigens) may be on surface of phagocyte —> stimulate 3rd line of defence



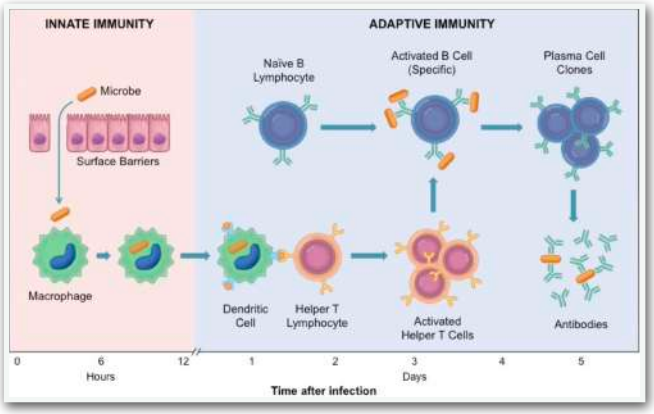

## Lymphocytes:

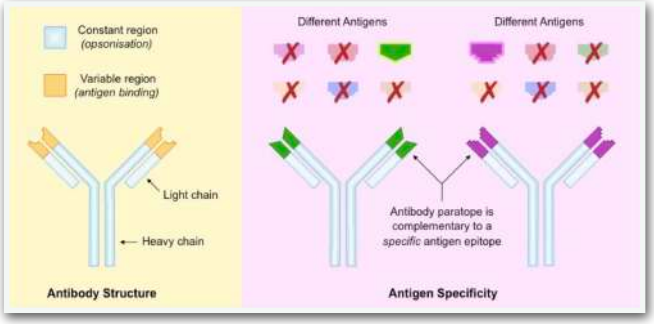
- Third line of defence against infectious diseases
- Adaptive immune system —> is specific in its response —> results in production of antibodies
- It can differentiate between particular pathogens and target a response specific to a pathogen
- Can respond rapidly upon re-exposure to a specific pathogen —> prevents symptoms from developing (immunological memory)

- B lymphocytes are antibody-producing cells that recognise and target a particular antigen
- Helper T lymphocytes (regulator cells) —> release chemicals (cytokines) to activate specific B cells

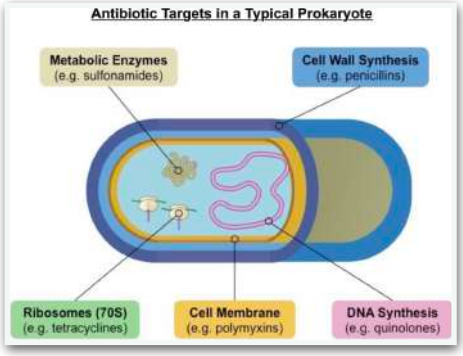
## Antibodies:

- A protein produced by B lymphocytes and plasma cells that is specific to a given antigen
- Antigen —> a substance that the body recognises as foreign and that will elicit an immune response
- Antibodies are made of 4 polypeptide chains —> joined together by disulphide bonds (Y shaped)
- Variable regions —> differ between antibodies and are at the end of the arms where the antigen binds
- The rest of the molecule is constant for all antibodies —> serves as recognition for the immune system (opsonisation)
- Exists an antigen-antibody specific interaction



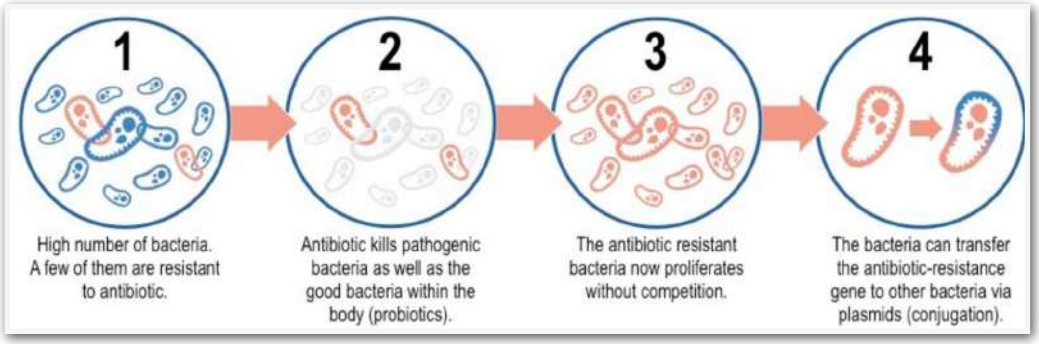
## Antibiotics:




-Compounds that kill or inhibit the growth of microbes by targeting prokaryotic metabolism
-Targets may be —> key enzymes, 70s ribosomes and components of the cell wall as they are not possessed by eukaryotic cells but only by pathogenic bacteria
-Kill the invading bacteria (bactericidal), or suppress its potential to reproduce (bacteriostatic)

- Viruses do not possess a metabolism and do instead take over the cellular machinery of the host
- Viruses must be treated with specific antiviral agents —> targets features specific to viruses

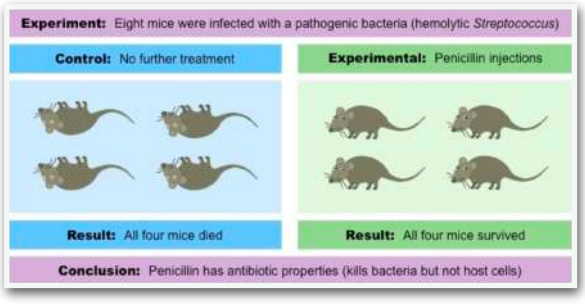
- Antibiotics can be narrow spectrum (effective against specific bacteria), or broad spectrum (effective against many bacteria)
- Resistant bacterial strains are increasing due to:
  —> overprescription of antibiotics and misuse —> many don't need a prescription or are used in livestock feed
  —> multi-drug resistant bacteria are very common in hospitals where antibiotic use is high




## Penicillin:

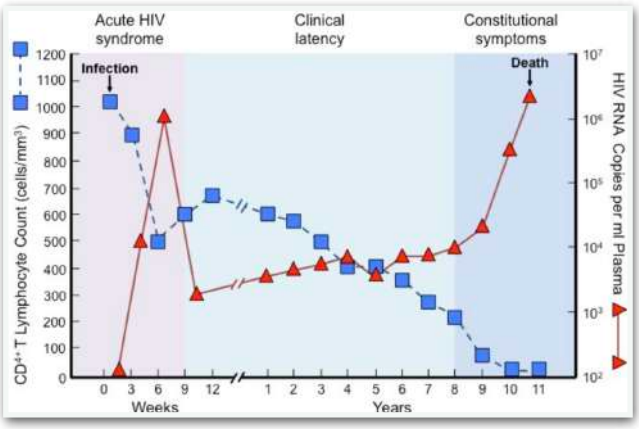
- The first chemical compound found to have antibiotic properties —> identified by Alexander Fleming in 1928
- Discovery was an accident —> from unintended contamination of a dish containing S. Aureus
- The mould was releasing a substance (penicillin) that was killing the nearby bacteria

**Florey and Chain experiment:**
- Medical application were demonstrated in 1940
- All three were awarded the Nobel price for medicine
- Several synthetic derivatives have been created, including methicillin —> offer many benefits including a broader spectrum, more stability and greater tolerance



## HIV infection:

- Human Immunodeficiency Virus —> a retrovirus that infects helper T cells —> disables the body's adaptive immune system
- It causes a variety of symptoms and infections know as Acquired Immune-Deficiency Syndrome
- Effects —> following infection the virus undergoes a period of inactivity (clinical latency) during which infected helper T cells reproduce
  —> the virus becomes active again and begins to spread —> destroys the T lymphocytes in the process (lysogenic cycle)
  —> lower immunity as with low helper T cells antibodies are unable to be produced
  —> the body becomes susceptible to opportunistic infections —> death mainly




- HIV is transmitted through the exchange of body fluids
- The risk of exposure to HIV through sexual contact is minimised by using latex protection
- A small minority of people are immune to HIV infection (lack CD4+ receptor required on T cells)
- Global issue but prevalent in poorer nations with poor education and health systems
- Transmits via sexual contact, pregnancy, childbirth, breast feeding, injection drug use, blood transfusion, organ transplant and occupational exposure

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# 6.4 Gas exchange

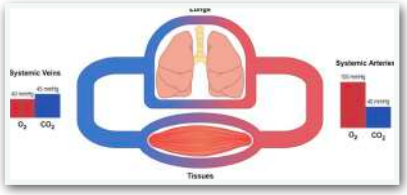
## Ventilation:

- Physiological respiration involves the transport of oxygen to cells within the tissues
- It is comprised of three distinct processes and is not to be confuse with cellular respiration

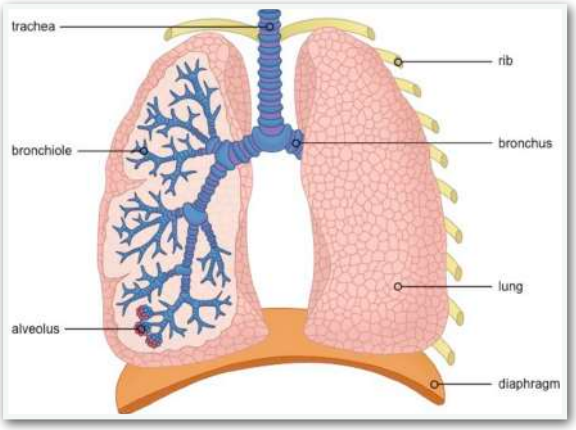
1) Ventilation —> exchange of air between the atmosphere and the lungs —> achieved by the physical act of breathing
2) Gas exchange —> exchange of oxygen and $CO_2$ between the alveoli and bloodstream (passive)
3) Cell respiration —> release of ATP from organic molecules —> oxygen needed for aerobic

**Purpose of ventilation:**

- Gas exchange is a passive process —> ventilation system is needed to maintain a concentration gradient in the alveoli
- $O_2$ is constantly being removed from the alveoli into the bloodstream + $CO_2$ is being released
- Lungs function as a ventilation system by continually cycling fresh air into the alveoli —> have a very large surface area to increase the overall rate of gas exchange —> $O_2$ levels high, while $CO_2$ levels low

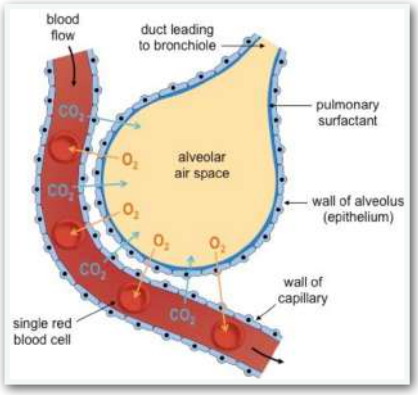


## Lung structure:




**The respiratory system:**

- Air enters the respiratory system through the nose/mouth and passes through the pharynx to the trachea
- From the trachea, air goes down until two bronchi
- The right lung has three lobes, while left only two due to heart position
- In each lung the bronchi divide into many smaller airways (bronchioles) —> increases surface area
- Each bronchiole terminates with a cluster of air sacs (alveoli) —> gas exchange with bloodstream occurs here




**Structure of an alveolus:**

- Have specialised structural features
- Thin epithelial layer (one cell) to minimise diffusion distance
- Are surrounded by a rich capillary network
- Are roughly spherical in shape —> maximise SA
- Internal surface is covered with a layer of fluid —> dissolved gases are better able to diffuse into the bloodstream

## Pneumocytes:

- Are the cells that line the alveoli and comprise of the majority of the inner surface of the lungs
- Alveolar cells —> two types —> type 1 and type 2 pneumocytes

**Type 1 pneumocytes:**

- Are involved in the process of gas exchange between the alveoli and the capillaries
- Are squamous (flattened) in shape and thin (0.15µm) —> minimise diffusion distance
- Are connected by occluding junctions —> prevent leakage of tissue fluid into the alveolar space
- Are amitotic and unable to replicate —> type 2 cells can differentiate in type 1 cells if required

**Type 2 pneumocytes:**

- Are responsible for the secretion of pulmonary surfactant —> less surface tension in the alveoli
- Are cuboidal in shape and possess many granules (store surfactant components)
- 5% of alveolar surface but 60% of total cells

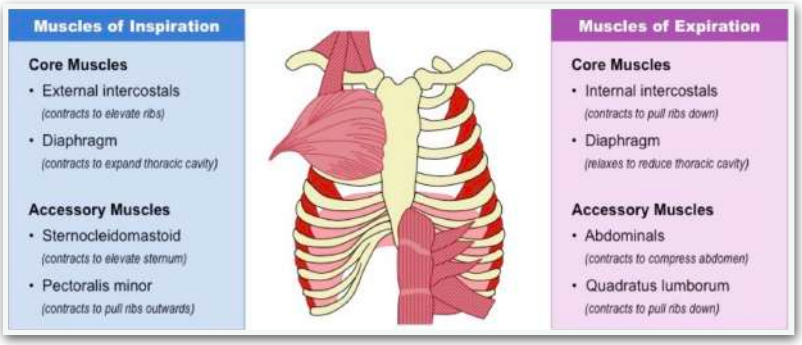
- Alveoli are lined by a layer of liquid in order to create a moist surface conducive to gas exchange with the capillaries —> easier for oxygen to diffuse across the alveolar and capillary membranes when dissolved in liquid
- Moist lining also creates a tendency for the alveoli to collapse and resist inflation other than assisting with gas exchange as there is a high surface tension
- As an alveoli expands with gas intake, the surfactant becomes more spread out across the moist alveolar lining —> this increases surface tension and slows the rate of expansion —> ensures all alveoli inflate at same rate

## Breathing:

- The active movement of respiratory muscles that enables the passage of air into and out of lungs
- The contraction of respiratory muscles changes the volume of the thoracic cavity
- According to Boyle's law —> volume of cavity increases —> pressure in the thorax decreases
  —> volume of cavity decreases —> pressure in the thorax increases
- Gases will move from a region of high pressure to a region of lower pressure
  —> pressure in the chest is less than atm. —> air will move into the lungs (inspiration)
  —> pressure in the chest is greater than atm. —> air will move into the lungs (expiration)
- Changing chest volume creates a pressure differential between the chest and atmosphere —> air moves to equalise
- Atmospheric pressure is lower at high altitudes —> greater increase in chest volume is required before a pressure differential is formed —> harder to breathe

## Respiratory muscles:

- Inspiration and expiration are controlled by two sets of antagonistic muscle groups
- This means that when inspiratory muscles contract, expiratory muscles relax




**Inspiration:**

- Diaphragm muscles contract —> cause diaphragm to flatten and increase the volume of the thoracic cavity
- External intercostals contract —> pull ribs upwards and outwards (expanding chest)
- Accessory muscles —> Additional muscle groups may help pull the ribs up and out (sternocleidomastoid and pectoralis minor)

**Expiration:**

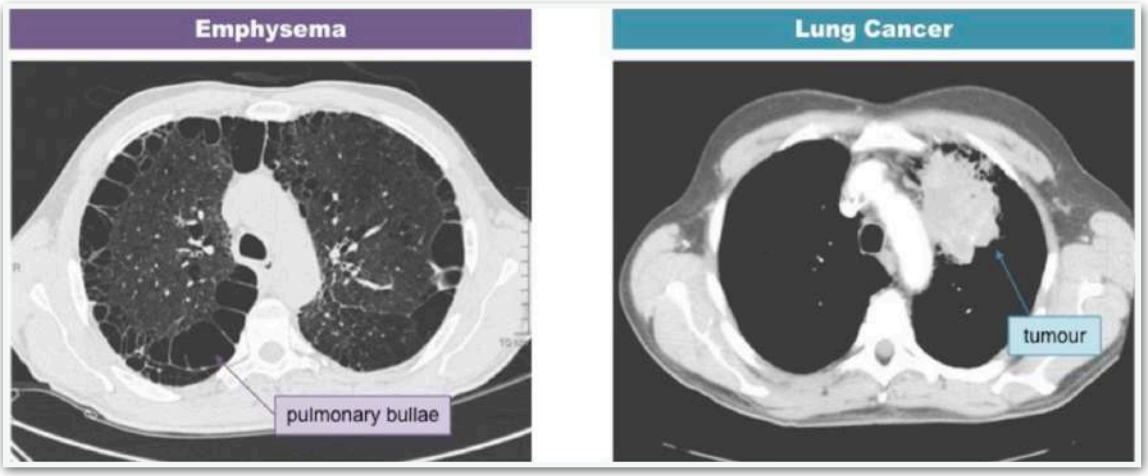
- Diaphragm muscles relax —> cause diaphragm to curve upwards and reduce volume of cavity
- Internal intercostal muscles contract —> pull ribs inwards and downwards
- Abdominal muscles contract and push the diaphragm upwards during forced exhalation
- Accessory muscles —> additional muscle groups may help pull the ribs downwards (quadratas lumborum)

## Lung disorders:

- Lung cancer describes the uncontrolled proliferation of lung cells —> leads to abnormal growth of lung tissue (tumour) —> can impact on normal tissue function
- Lung cancers are the most common cause of cancer-related death worldwide
  —> lungs are vital to normal body function
  —> lungs possess a very rich blood supply —> increases metastasis chances to happen
- Common symptoms of lung cancers include —> coughing up blood, wheezing, respiratory distress and weight loss + if the cancer mass compresses adjacent organs it can cause chest pain, difficulty swallowing and heart complications
- Causes of lung cancer include —> Radiation, ageing, pollution, environment, diseases, genetics, occupation, asbestos, tobacco and smoke (second hand)

**Emphysema:**

- Lung condition where the walls of the alveoli lose elasticity due to damage to the alveolar walls —> results in the abnormal enlargement of the alveoli —> lead to lower SA for gas exchange
- Degradation of the alveolar walls can cause holes to develop and alveoli to merge into huge air spaces (pulmonary bullae)
- Majorly cause by smoking —> chemical irritants in cigarette smoke damage the alveolar walls
- The damage to lung tissue leads to the recruitment of phagocytes to the region —> produce an enzyme called elastase
- Elastase is released as part of an inflammatory response and breaks down the elastic fibres in the alveolar wall —> can be blocked by an enzyme inhibitor (α-1-antitrypsin) if low concentrations
- Emphysema cases are rarely due to a hereditary deficiency in this enzyme inhibitor due to a gene mutation
- Common symptoms include —> shortness of breath, phlegm production, expansion of the ribcage, cyanosis and an increased susceptibility to chest infections




Spirometry:

- Ventilation in humans changes in response to levels of physical activity
  —> ATP production produces $CO_2$ as a waste product can consumes oxygen
  —> changes in blood $CO_2$ levels are detected by chemosensory in the walls of the arteries which send signals to the brainstem
  —> as exercise intensity increase, so does demand for gas exchange —> more ventilation
- Exercise will increase ventilation rate and increase tidal volume (volume of air per breath)

**Measuring respiration:**

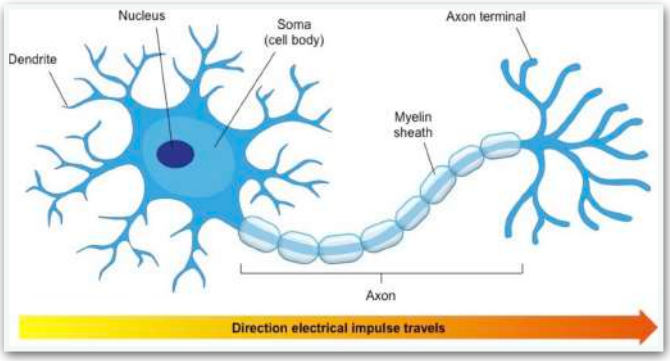
- Methods to measure respiration —> simple observations, chest belt + pressure meter and spirometer

- Spirometry involves measuring the amount and flow at which air can be inhaled and exhaled
- Spirometer —> device that detects the changes in ventilation and presents the data on a digital display
- Breathing into a balloon and measuring the volume of air in a single breath (more simplistic method) —> volume can be determined by submerging the balloon in water

## 6.5 Neurons and synapses

### Neurons:

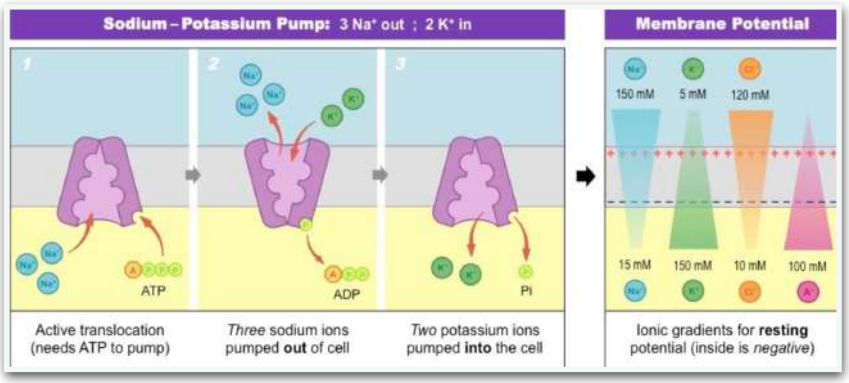
- Specialised cells that function to transmit electrical impulses within the nervous system —> the nervous system converts sensory information into electrical impulses in order to rapidly detect and respond to stimuli
- Can be sensory, relay or motor
- Have three basic components —> dendrites —> short branched fibres that convert chemical information from neurons or receptor cells into electrical signals
  —> axon —> elongated fibre that transmits electrical signals to terminal regions for communication with other neurons or effectors
  —> soma —> cell body containing the nucleus and organelles (basic metabolic processes)




-Myelin sheath —> improves the conduction speed of electrical impulses along the axon
—> requires additional space and energy
—> surrounds the axon with an insulating layer

### Resting potential:

- Neurons generate and conduct electrical signals by pumping positive ions ($Na^+$ and $K^+$) across their membrane —> unequal distribution creates charge difference —> membrane potential
- A resting potential is the difference in charge across the membrane when a neutron is not firing



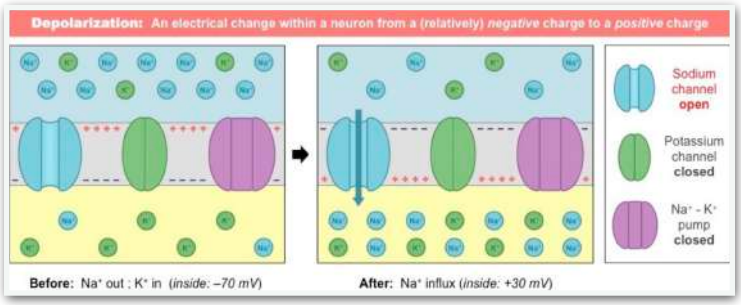

-Typically in a resting potential, the inside of the neutron is more negative relative to the outside (approximately 70mV)
-Resting potential is done thanks to an active process controlled by sodium-potassium pumps

### Action potential:

- The rapid changes in charge across the membrane that occur when a neutron is firing
- Occur in three main stages —> depolarization, repolarization, and a refractory period

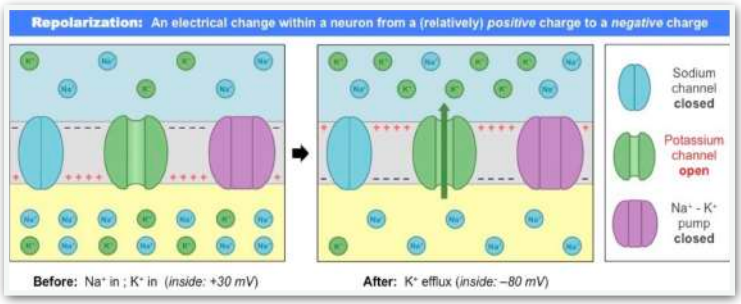
**Depolarization:**

- Refers to a sudden change in membrane potential —> from negative to positive internal charge
- It is in response to a signal initiated at a dendrite which make sodium channels open within the membrane of the axon
- As $Na^+$ ions are more concentrated outside of the neuron, the opening of sodium channels causes a passive influx of sodium —> membrane potential becomes more positive (depolarization)



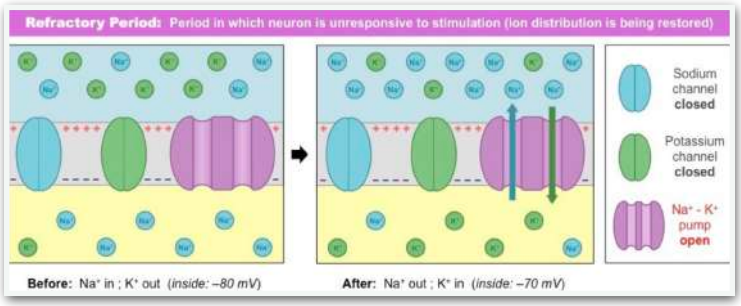

**Repolarization:**

- Refers to the restoration of a membrane potential following depolarisation
- Following the sodium influx, potassium channels open within the membrane of the axon
- As $K^+$ ions are more concentrated inside the neuron, the opening of potassium channels causes a passive efflux of potassium —> membrane potential returns to a more negative internal differential (repolarization)




**Refractory period:**

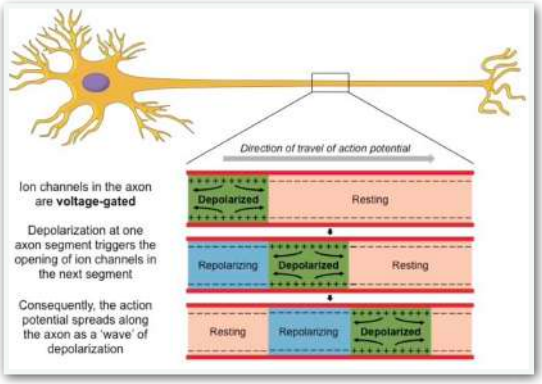
- Refers to the period of time following a nerve impulse before the neuron is able to fire again
- In a normal resting state —> sodiums ions mainly outside neuron, while potassium ions mainly inside (resting potential)
- Following depo and repolarisation —> ionic distribution is largely reversed
- The resting potential must be restored via the anti port action of the sodium-potassium pump before the neuron can fire again

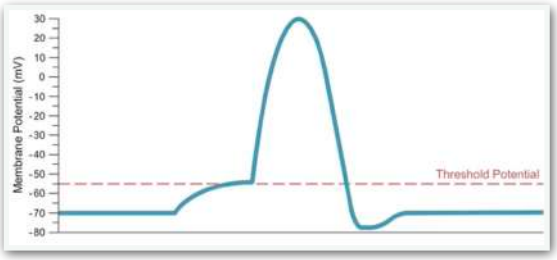



Nerve impulses:

- Are action potentials that move along the length of an axon as a wave of depolarization
- Depolarization occurs when ion channels open and cause a change in membrane potential
- The ion channels that occupy the length of the axon are voltage-gated —> so depolarization triggers the opening of ion channels in the next segment of the axon —> causes depolarization to spread along the length of the axon as a unidirectional wave

- Action potentials are generated within the axon according to the all-or-none principle
- An action potential of the same magnitude will always occur provided a minimum electrical stimulus is generated
- 55 mV is the minimum stimulus to open voltage-gated ions channels —> if not neuron will not fire
- Threshold potentials are triggered when the combined stimulation from the dendrites exceeds a minimum level of depolarisation



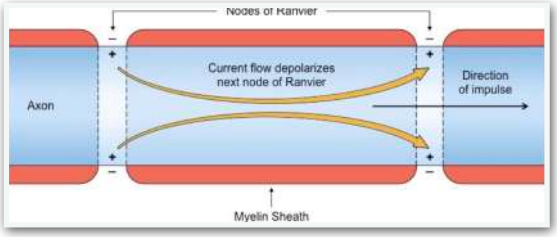

## Oscilloscope traces:

- Oscilloscopes are scientific instruments that are used to measure the membrane potential across a neuronal surface
- A typical action potential will last for 3-5 milliseconds and has 4 key stages

1) Resting potential —> the neuron is in a state of rest (-70 millivolts)
2) Depolarization —> corresponds to the rising spike in the graph (+30 millivolts)
3) Repolarization —> corresponds to the falling spike (via potassium efflux) (-80 millivolts)
4) Refractory period —> levels return to resting potential due to the action of the $Na^+/K^+$ pumps

## Myelination:

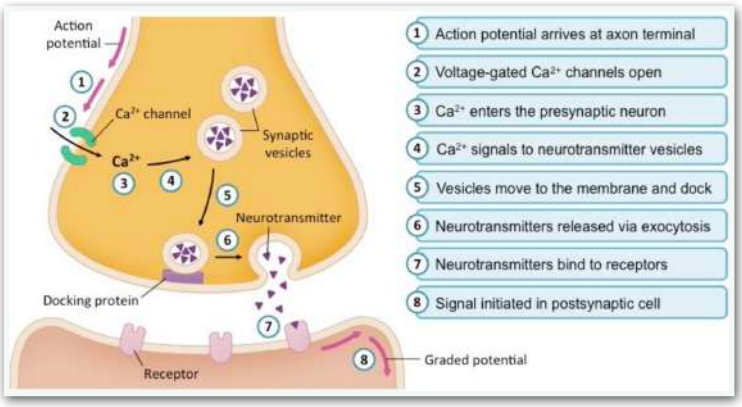
- Fatty white substance which functions as an insulating layer —> all other areas will appear grey matter which consists of neuronal cell bodies, dendrites, support cells (glial cells) and synapses
- Is a mixture of protein and phospholipids that is produced by glial cells
- Main purpose is to increase the speed of electrical transmissions via saltatory conduction




- Along unmyelinated neurons, action potentials propagate sequentially along the axon in a continuous wave of depolar.
- In myelinated neurons, action potentials hop between the gaps in the myelin sheath (nodes of Ranvier)
- This results in an increase in speed by a factor of up to 100
- The disadvantage of myelination is that it takes up significant space within an enclosed environment

## Synaptic transfer:

- Electrical signals are not able to be conducted when a semi-permeable membrane is absent
- Synapses are the physical gaps that separate neurons from other cells —> neurons transmit information across synapses by converting the electrical signal into a chemical signal



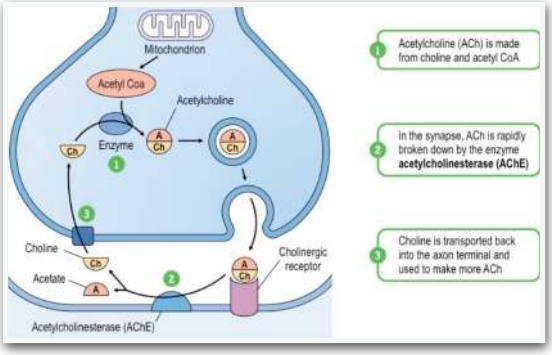
## Neurotransmitters:

- Are chemical messengers released from neurons and function to transmit signals across the synaptic cleft
- Are released in response to the depolarisation of the axon terminal of a presynaptic neuron
- They bind to receptors on post-synaptic cells and can trigger (excitatory) or prevent (inhibitory) a response

| Target Cell | Response |
|---|---|
| Neuron | Stimulation or inhibition of an electrical signal (nerve impulse) |
| Glandular Cell | Stimulation or inhibition of secretion (exocrine or endocrine) |
| Muscle Fibre | Stimulation or inhibition of muscular contraction / relaxation |

**Acetylcholine:**

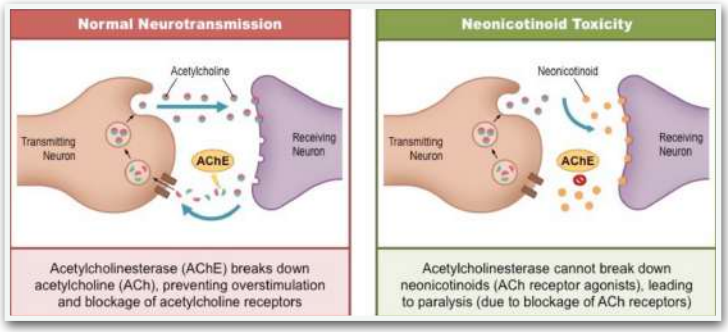
- Is a neurotransmitter used by both the central nervous system and peripheral nervous system
- Released at neuromuscular junctions and binds to receptors on muscle fibres to trigger muscle contraction —> it is even though also released within the autonomic nervous system to promote parasympathetic responses (rest and digest)




- Is created in the axon terminal by combining choline with an acetyl CoA group —> gets stored in vesicles until released via exocytosis in response to a nerve impulse
- Acetylcholine activates a post-synaptic cell by binding to one of two classes of specific receptor (nicotine or muscarinic)
- It must be continually removed from the synapse as overstimulation can lead to fatal convulsions and paralysis, while low activation promotes nerve signalling

- Is broken down into its two component parts by the synaptic enzyme acetylcholinesterase (AChE) —> enzyme is either released into the synapse from the presynaptic neuron or is embedded on the membrane of the post-synaptic cell
- The liberated choline is returned to the presynaptic neuron where it is coupled with another acetate to reform acetylcholine

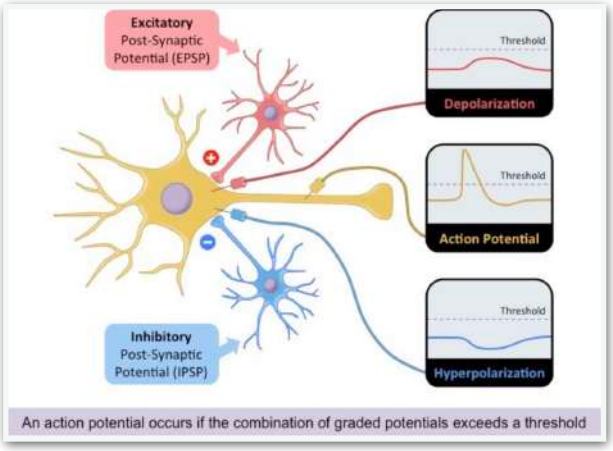
**Neonicotinoid pesticides:**




- Are able to irreversibly bind to nicotinic acetylcholine receptors and trigger a sustained response —> neonicotinoid pesticides cannot be broken down by acetylcholinesterase —> results in permanent overstimulation of target cells
- Insects have a different composition of acetylcholine receptors which bind to neonicotinoids much more strongly —> for this reason are significantly more toxic to insects than mammals (for this reason they are highly effective pesticides)
- Neonicotinoid pesticides have certain disadvantages:
  - —> have been linked to a reduction in honey bee populations (bees are important pollinator)
  - —> have been linked to a reduction in bird populations (loss of insects as food source)
  - —> certain countries have restricted the use of neonicotinoid pesticides (including EU)

## Graded potential:

- Neurotransmitters bind to neuroreceptors on the post-synaptic membrane of target cells and open ligand-gated ion channels —> the opening of these channels cause small changes in membrane potential known as graded potentials
- A nerve impulse is only initiated if a threshold potential is reached, so as to open the voltage-gated ion channels within the axon
- Excitatory neurotransmitters (noradrenaline) cause depolarisation by opening ligand-gated sodium or calcium channels
- Inhibitory neurotransmitter (GABA) cause hyperpolarisation by opening ligand-gated potassium or chlorine channels
- The combined action of all neurotransmitters acting on a target neuron determines whether a threshold potential is reached
- If depolarization > hyperpolarization and a threshold is reached —> neuron will fire
- If hyperpolarization < depolarization and a threshold is not reached —> neuron will not fire

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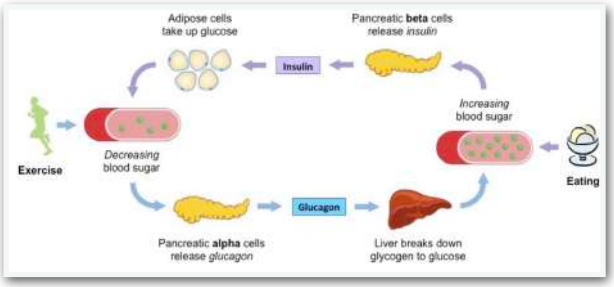
# 6.6 Homeostasis

## Insulin and Glucagon:




-The body needs glucose to make ATP (via cell respiration) —> amount fluctuates according to demand

-High levels of glucose in the blood can damage cells —> creates hypertonicity —> levels must be therefore regulated

-Are two antagonistic hormones are responsible for regulating blood glucose concentrations

- Are released from pancreatic pits (islets of Langerhans) and act principally on the liver
- High levels of blood glucose —> Insulin is released from beta cells of the pancreas and cause a decrease in blood glucose concentration
  - —> by stimulating glycogen synthesis in the liver (glycogenesis)
  - —> by promoting glucose uptake by the liver and adipose tissue
  - —> by increasing the rate of glucose breakdown (cell respiration)
- Low levels of blood glucose —> Glucagon is released from alpha cells of the pancreas and cause an increase in blood glucose concentration
  - —> by stimulating glycogen breakdown in liver (glycogenolysis)
  - —> promoting glucose release by the liver and adipose tissue
  - —> decreasing the rate of glucose breakdown (cell respiration)

## Diabetes mellitus:

- Metabolic disorder that results from a high blood glucose concentration over a prolonged period
- Type I —> caused by the body not producing insulin —> treated with insulin injections
- Type II —> caused by the body failing to respond to insulin production —> rated by carefully monitoring and controlling dietary intake

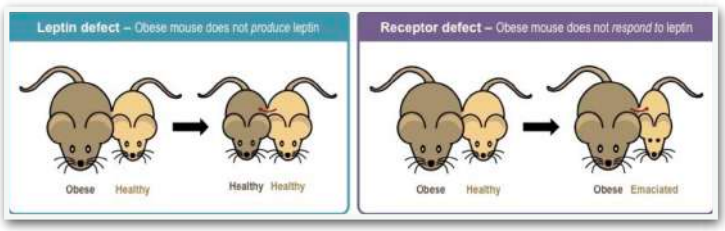
| Type I<br>Insulin-Dependent Diabetes Mellitus (IDDM) | Type II<br>Non Insulin Dependent Diabetes Mellitus (NIDDM) |
|---|---|
| Usually occurs during childhood (early onset) | Usually occurs during adulthood (late onset) |
| Body does not *produce* sufficient insulin | Body does not *respond* to insulin production |
| Caused by the destruction of β-cells (autoimmune) | Caused by the down-regulation of insulin receptors |
| Requires insulin injections to regulate blood glucose | Controlled by managing diet and lifestyle |

## Thyroxin:

- Hormone secreted by the thyroid gland in response to signals initially derived from the hypothalamus
- Acts on nearly every tissue in the body and is essential to the proper development and differentiation of cells
- Primary role —> increase the basal metabolic rate —> by stimulating carbohydrate and lipid metabolism via the oxidation of glucose and fatty acids
- Heat is a consequence of increasing metabolic activity —> thyroxin helps to control body temp. —> can be released in response to a decrease in body temperature to stimulate heat production
- Is partially composed of iodine —> deficiency of iodine in the diet will lead to decreased production of thyroxin
- Iodine deficiency —> causes the thyroid gland to become enlarged —> disease known as goitre

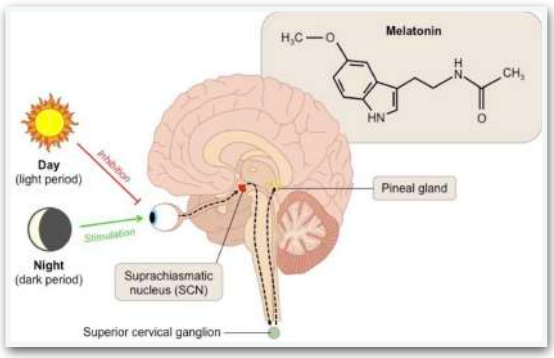
## Leptin:

- Hormone produced by adipose cells —> regulates fat stores in the body by suppressing appetite
- Binds to receptors located within the hypothalamus to inhibit appetite
- Overeating causes more adipose cells to be formed —> more leptin is produced and viceversa
- Obese people are constantly producing higher levels of leptin —> become desensitised to leptin
  —> more likely to feel hungry and less likely to recognise when they are full
  —> leptin resistance develops with age —> potential for weight gain later in life
- Was considered as a treatment for obese people
- Mice experiments —> conducted by surgically fusing the blood circulation of obese and healthy mice (parabiosis)




- Human experiments —> humans have naturally high levels of leptin in the bloodstream
  —> obesity usually caused by unresponsiveness to leptin not a deficiency
  —> very few participants experienced significant weight loss
  —> many patients experienced adverse side effects including skin irritations
  —> leptin treatments are so not considered to be effective in treating obesity

## Melatonin:

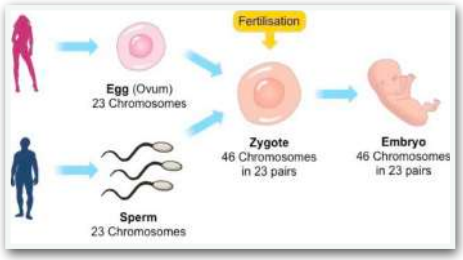



- Hormone produced by the pineal gland within the brain in response to changes in light
- Suprachiasmatic nucleus (hypothalamus) —> relays light exposure to retina and inhibits melatonin secretion
- Is secreted in response to periods of darkness (higher concentration at night)

**Circadian rhythms:**
- Are the body's physiological responses to the 24 hour day-night cycle
- Are driven by an internal (endogenous) circadian clock —> can be modulated by external factors
- Melatonin secretion plays a pivotal role in the control of circadian rhythms —> synchronises circadian rhythms and regulates the body's sleep schedule
    —> melatonin secretion is suppressed by bright light (principally blue wavelengths)
    —> over a prolonged period melatonin secretion becomes entrained to anticipate the onset of darkness and the approach of the day
    —> melatonin promotes activity in nocturnal animals and promotes sleep in diurnal animals
    —> during sleep necessary physiological changes occur in body temperature, brain wave activity and hormonal production
    —> melatonin levels naturally decrease with age —> leads to changes in sleeping patterns

**Jet Lag:**
- Physiological condition resulting from a change to the body's normal circadian rhythm
- Alteration is cause by the body's inability to rapidly adjust to a new time zone —> pineal gland keeps recreating melatonin according to old time zone
- Symptoms include headaches, lethargy, increased irritability and reduced cognitive functions
    —> should only last a few days
- Melatonin can be taken artificially in order to make the body respond quicker to the new rhythm

## Sexual reproduction:




**Modern theory:**
- Based on evidence discovered using light microscopes
- Viable microscopes not invented until 17 years after Harvey's death
- Fetus forms from a combination of both male and females gametes

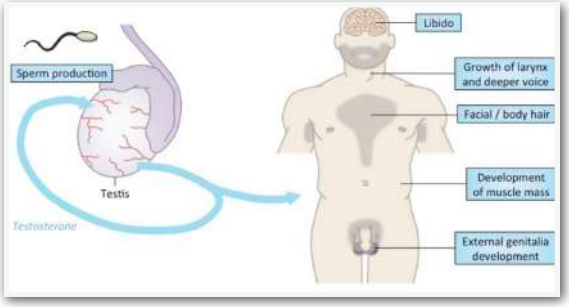
**"Soil and seed theory":**
- One of the earliest theories as to how animals reproduce sexually —> proposed by Aristotle
- The male produces a "seed" which forms an "egg" when mixed with menstrual blood "soil"
- The "egg" then develops into a foetus inside the mother according to the information contained within the male "seed" alone
- Theory debunked by William Harvey
    —> studied the sexual organs of female deer after mating ito identify the developing embryo
    —> was unable to detect a growing embryo until approximately 6-7 weeks after the mating
    —> concluded that Aristotle's theory was incorrect + that menstrual blood did not contribute
    —> Harvey was unable to identify the correct mechanism of sexual reproduction
    —> Harvey said that the fetus did not develop from a mixture of male and female "seeds"

## Sex development:

- Humans have 46 chromosomes in all diploid somatic cells —> 22 pairs are autosomes and the 23rd pair are the sex chromosomes —> females XX and males XY
- Y chromosome includes a gene called the SRY gene (Sex Determining Region Y) —> leads to male development
- The SRY gene codes for a testis-determining factor (TDF) that causes embryonic glands to form into testes (male gonads)
- In absence of the TDF protein —> embryonic gonads will develop into ovaries (female gonads)
- The male and female gametes produce different hormones to promote further development of sex characteristics —> testes produce testosterone to promote further dev. of male sex characteristics
  —> ovaries produce estrogen and progesterone to promote dev. of female sex…

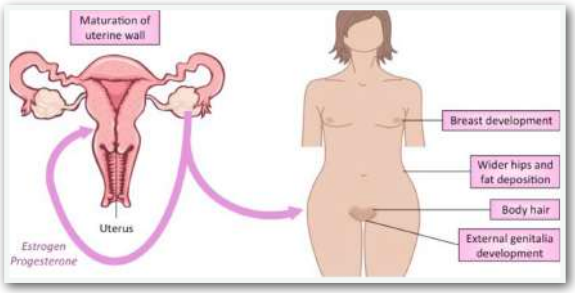
**Testosterone:**

- Responsible for pre-natal development of male genitalia
- Is involved in sperm production following the onset of puberty
- It aids in the development of secondary sex characteristics —> body hair, muscle mass, voice…
- It helps to maintain the male sex drive (libido) —> desire

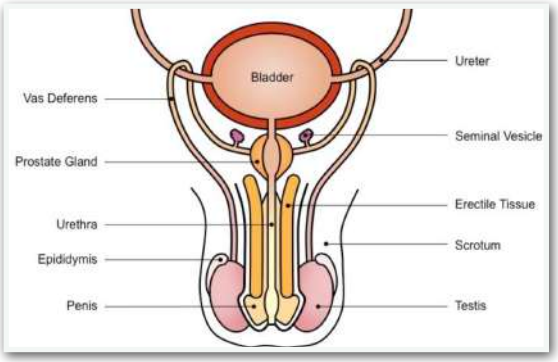



**Estrogen and progesterone:**

- Promote pre-natal development of the female reproductive organs
- Are responsible for the development of secondary sex characteristics —> body hair, breast dev. …
- Are involved in monthly preparation of egg release following puberty
- Initially are secreted by the mother's ovaries and then the placenta until formed

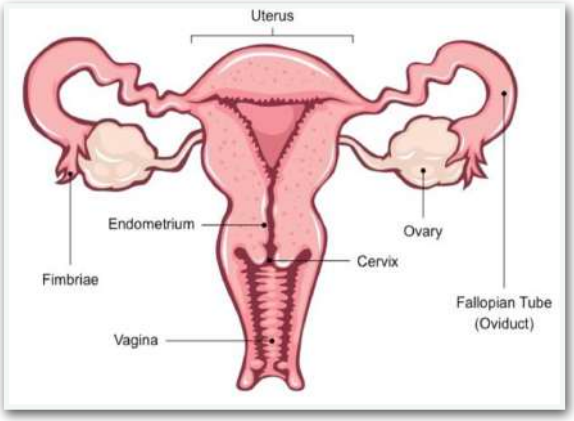



## Male reproductive system:




- Includes all the organs responsible for the production of sperm (male gamete) + organs that are involved in synthesising the semen in which the sperm is transported during copulation

1) Testis —> responsible for the production of sperm and testosterone
2) Epididymis —> site where sperm matures and develops the ability to be motile —> stored here until ejaculation
3) Vas Deferens —> long tube which conducts sperm from the testes to the prostate gland during ejaculation
4) Seminal Vesicle —> secretes fluid containing fructose (to feed sperm), mucus (to protect sperm) and prostaglandins (triggers uterine contractions)
5) Prostate Gland —> secretes an alkaline fluid to neutralise vaginal acids (necessary to maintain sperm viability)
6) Urethra —> conducts sperm/semen from the prostate gland to the outside of the body via penis




## Female reproductive system:

- Includes all the organs responsible for the production of an oocyte (female gamete) + organs involved in initially developing and maintaining an embryo during the early stage of pregnancy

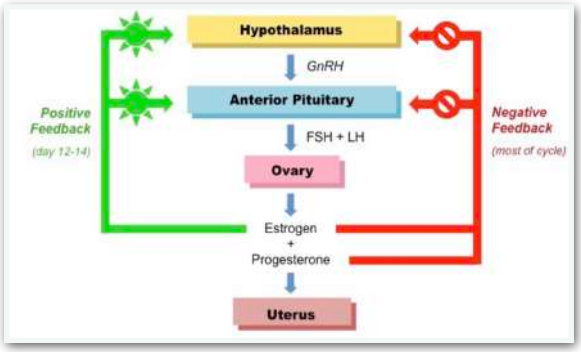
1) Ovary —> where the oocytes mature prior to release (ovulation) + responsible for estrogen and progesterone secretion
2) Fimbria —> fringe of tissue adjacent to an ovary that sweep an oocyte into the oviduct
3) Oviduct —> transports the oocyte to the uterus —> also where fertilisation typically occurs
4) Uterus —> the organ where a fertilised egg will implant and develop to become an embryo
5) Endometrium —> mucous membrane lining of the uterus —> thickens in preparation for implantation or is otherwise lost via menstruation
6) Vagina —> passage leading to the uterus by which the penis can enter —> uterus protected by a muscular opening called the cervix

## Menstrual cycle:

- Describes recurring changes that occur within the female reproductive system to make pregnancy possible —>cycle lasts 28 days and begins at puberty (menarche) and end with menopause

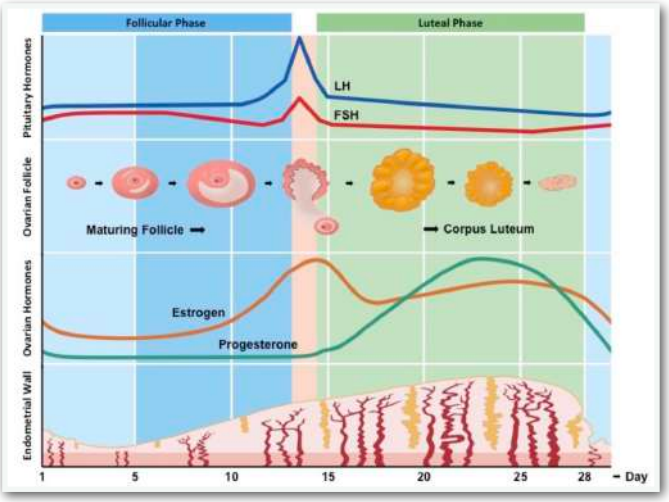
| Endocrine Gland | Hormone | Function |
|---|---|---|
| Anterior Pituitary  | FSH | • Stimulates follicular growth in ovaries<br>• Stimulates estrogen secretion (from developing follicles) |
| | LH | • Surge causes ovulation<br>• Results in the formation of a corpus luteum |
| Ovaries  | Estrogen | • Thickens uterine lining (endometrium)<br>• Inhibits FSH and LH for most of cycle<br>• Stimulates FSH and LH release pre-ovulation |
| | Progesterone | • Thickens uterine lining (endometrium)<br>• Inhibits FSH and LH |

-Two key groups of hormones control and coordinate the menstrual cycle:
—> Pituitary hormones (FSH and LH) are released from the anterior pituitary gland and act on the ovaries to develop facilities
—> Ovarian hormones (estrogen and progesterone) are released from the ovaries and act on the uterus to prepare for pregnancy




Key events:

1) Follicular Phase —> Follicle stimulating hormone (FSH) is secreted from the anterior pituitary and stimulates growth of ovarian follicles —> the dominant follicle produces estrogen which inhibits FSH secretion to prevent other follicles creating and estrogen acts on the uterus to stimulate the thickening of the endometrial layer
2) Ovulation —> midway through the cycle (12 days) estrogen stimulates the anterior pituitary to secrete hormones —> results in a large surge of luteinising hormone (LH) and a lesser surge of FSH —> LH cases the dominant follicle to rupture and release an egg (secondary oocyte)
3) Luteal phase —> rupture follicle develops into a slowly degenerating corpus luteum which secretes high levels of progesterone and lowers levels of estrogen




4)Menstruation —> if fertilisation occurs, the developing embryo will implant in the endometrium and release hormones to sustain the corpus luteum

—> if fertilisation doesn't occur, the corpus luteum eventually degenerates (forms a corpus albicano after 2 weeks) —> when this happens estrogen and progesterone levels drop and the endometrium can no longer be maintained —> is sloughed away and eliminated from the body as menstrual blood —> after this cycle begins again

## In vitro fertilisation:

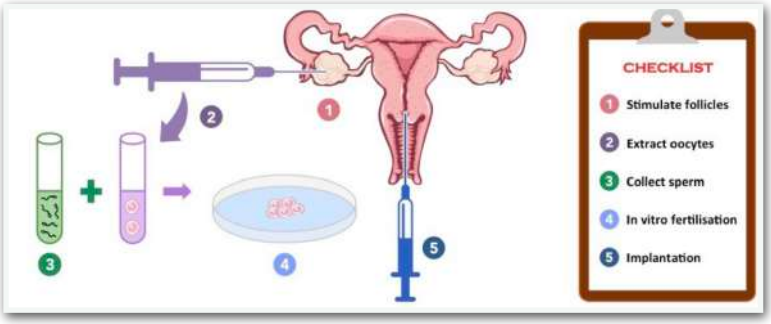
- Refers to fertilisation that occurs outside of the body (in glass)
- It involves using drugs to suspend normal ovulation (down regulation), before using hormone treatments to collect multiple eggs (superovulation)

**Down regulation:**
- Drugs are used to halt the regular secretion of FSH and LH —> in turn stops secretion of estrogen and progesterone
- By arresting the hormonal cycle, doctors can take control of the timing and quantity of egg production by the ovaries
- Usually takes about two weeks and is typically delivered in the form of a nasal spray

**Superovulation:**
- Involves using artificial doses of hormones to develop and collect multiple eggs from the woman
- Patient is firstly injected with large amounts of FSH to stimulate development of many follicles
- Follicles are then treated with human chorionic gonadotrophin (hCG —> hormone usually produced by a developing embryo) —> stimulates the follicles to mature and the egg is then collected (via aspiration with a needle) prior to the follicles rupturing

**Fertilisation:**
- The extracted eggs are then incubated in the presence of a sperm sample from the male donor
- The eggs are then analysed under a microscope for successful fertilisation

**Implantation:**
- Approximately two weeks prior to implantation the woman begins to take progesterone treatments to develop the endometrium
- Healthy embryos selected and transferred into the female uterus —> multiple in order to improve chances of successful implantation (possibly multiple births)
- Roughly two weeks after the procedure, a pregnancy test taken to see if successful



## Extra:

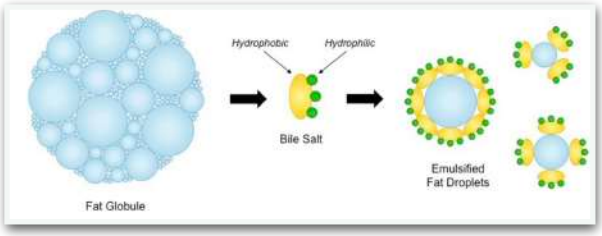
### Stages of digestion:

- Ingestion —> food is taken into the body via the act of eating
- Digestion —> food is broken down physically and chemically
- Absorption —> digested food products are absorbed into the bloodstream and transported to cells
- Assimilation —> digested food products are converted into the fluid/ solid parts of a cell/ tissue
- Elimination —> undigested food residues are digested from the body as semi-solid faeces

### Lipid digestion:

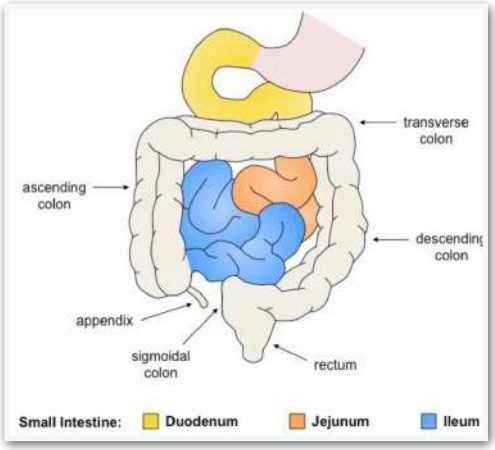
- Being hydrophobic, lipids will group together (coalesce) to form large globules of fats
- Lipase —> enzyme responsible for lipid digestion —> generally soluble in water and only hydrophobic at the active site
- Lipase will only bind to the lipid-water interface (external part of the globule) —> so interior of fat globule is inaccessible to lipase —> digestion of lipids in this form is very slow

- Bile —> watery fluid that contains bile salts and pigments (bilirubin) —> it is made by the liver and is released from the gall bladder
- Bile salt molecules have both a hydrophobic surface (interacts with the lipid) and a hydrophilic surface (faces out and prevents lipids from coalescing)
- This divides the fat globule into smaller droplets (emulsification) —> increases the total SA available for enzyme activity




### Lipid absorption:

- When fatty acids are absorbed into epithelial cells of the intestinal lining they form triglycerides
- Triglycerides are combined with proteins inside the golgi apparatus —> form chylomicrons
- Chylomicrons —> released from the epithelial cells and are transported via the lacteals to the liver —> while in the liver they may be modified to form a variety of lipoproteins
- Low density and high density lipoproteins




### Sections of the gut:

- Small intestine (nutrient absorption) / large intestine (water abso.)
- Duodenum —> first segment of SI —> fed by digestive fluids from the pancreas and gall bladder —> sodium bicarbonate is released from the pancreas to neutralise stomach acids so that pH= 7
- Jejunum —> second segment of SI —> where digestive process is largely completed —> pancreatic enzymes and enzymes released by intestinal glands complete break down of sugars, proteins and lipids
- Ileum —> final segment of SI —> for nutrient absorption —> highly folded (villi and microvilli) —> maximise SA and optimise material absorption (also bile is absorbed and returned to the liver)

- Large intestine —> principal function is to absorb any remaining water and mineral ions
  —> made by (ascending, transverse, descending, sigmoidal) * colon and rectum
  —> the appendix is also considered a part although it is a vestigial remnant without an important function

Blood composition:

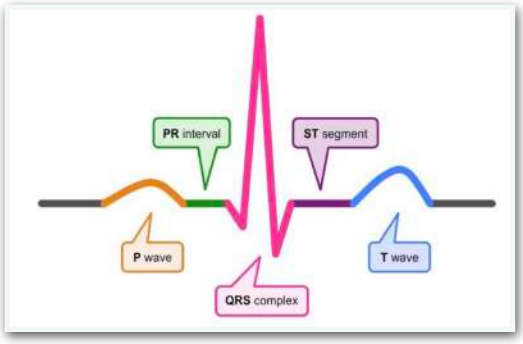
- Fluid medium in which materials are transported around the body via blood vessels
- Average human adult contains 5 / 6 liters of blood (77 ml per kilogram)
- Three main components:

—> Plasma —> 55% of blood —> consists mainly of water as solvent
—> contains electrolytes (minerals with charge) to keep fluid balance and pH
—> Proteins in the blood plasma maintain osmotic potential (albumin), transport lipids (globulin) and help clot (fibrinogen)
—> used to transport various materials needed by body and wastes produced by body cells —> nutrients, antibodies, carbon dioxide, hormones, oxygen, urea and heat
—> Red blood cells —> 45% of blood —> also called erythrocytes —> responsible for transporting oxygen around the body
—> oxygen is bound to haemoglobin at the lungs and released from the RBC at respiring body tissues
—> Buffy coat —> 1% —> fraction of a blood sample that contains white blood cells and platelets
—> Withe blood cells (leukocytes) are involved in the body's immune defence
—> platelets (thrombocytes) are involved in blood clotting

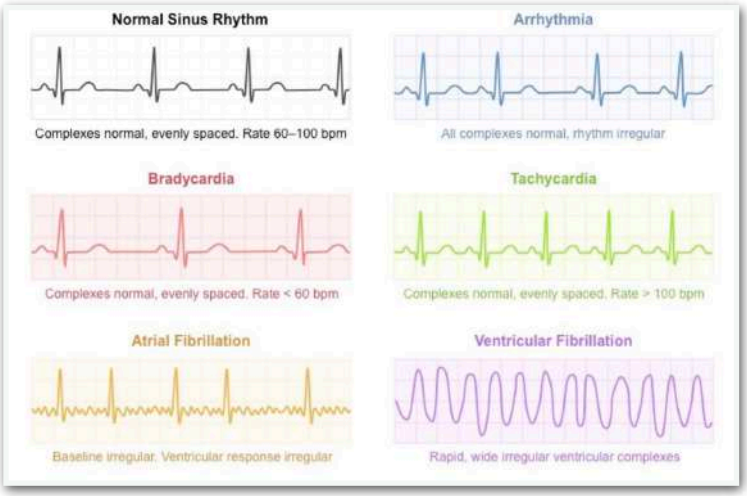
Blood pressure:

- Two types —> systolic pressure and diastolic pressure
- Systolic —> higher value that represents the pressure in the vessel when the heart is contracting
- Diastolic —> lower value that represents the pressure in the vessel when the heart is relaxing
- Measured in arteries using a sphygmomanometer as veins do not have sufficient pressure
- Sphygmomanometer —> cuff that cuts off circulation to a region (usually brachial artery in arm)
  —> pressure of the cuff is slowly released until a pulse can be audibly detected with a stethoscope (systolic pressure - normally 120 mmHg)
  —> pressure continues to be released from the cuff until pulse disappears (diastolic pressure - normally 80 mmHg)

Electrocardiography:

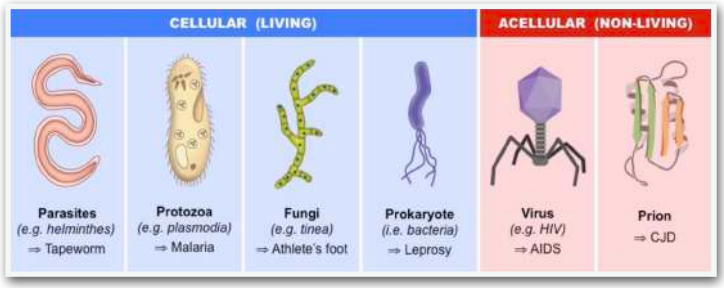



- Heart function can be diagnostically assessed by measuring the electrical activity of the heart with each condition
- Electrocardiograph —> machine to measure activity
- Electrocardiogram —> generates data
- P wave —> represents depolarisation of the atria in response to signalling from the sinoatrial node (atrial contraction)
- QRS complex —> represents depolarisation of the ventricles —> triggered by signals from the AV node
- T wave —> represents repolarisation of the ventricles + the completion of a standard heart beat
- PR and ST —> between periods of electrical activity —> intervals which allow for blood flow




## Pathogens:

-Disease causing agent that disrupts the normal physiology of the infected organism
- Can be cellular or acellular




- Viruses —> metabolically inert and incapable of reproducing independently of a host cell (dead)
  —> typically have an inner core of nucleic acid surrounded by a protein coat (capsid)
  —> simpler viruses may lack a capsid (viroids), while more complex have lipid envelope
  —> can be either DNA-based (adenoviruses) or RNA-based (retroviruses)
- Prions —> infectious protein that has folded abnormally into structure capable of causing disease
  —> can cause normally folded proteins to refold into the abnormal from —> propagate
  —> prion proteins aggregate together to form amyloid fibres that cause holes to form in the brain —> spongiform encephalopathy
  —> infectious prion proteins have a higher beta-sheet content —> more resistant to denaturation and difficult to treat
- Bacteria —> unicellular prokaryotes —> can reproduce quickly and compete for space+ nutrition
  —> most are relatively harmless and may even form mutualistic relationships with host
  —> may cause disease by producing toxic compounds (exotoxins) or releasing the substances when destroyed (endotoxins)
  —> toxins retain their destructive capacity beyond bacterial death —> food poisoning
- Fungi —> disease-causing fungi usually attack the body surfaces (skin, mucous membranes, …)
  —> can be categorised according to whether unicellular (yeasts) or multicellular (moulds)
  —> moulds consist of branching filaments called hyphae —> may form a mass of invading threads calle mycelium
- Parasites —> organism that grows and feeds on an organism to detriment of the host's survival
  —> can be ectoparasites (live on surface of the host) or endoparasites (live within host)
  —> endoparasites can include micro parasites or macroparasites

| NON-SPECIFIC DEFENCES (INNATE IMMUNITY) | | SPECIFIC DEFENCES (ADAPTIVE IMMUNITY) |
|---|---|---|
| First line of defense | Second line of defense | Third line of defense |
| • Skin<br>• Mucous membranes<br>• Secretions of skin and mucous membranes | • Phagocytic leukocytes<br>• Antimicrobial proteins<br>• Inflammatory response<br>• Fever | • Lymphocytes<br>• Antibodies<br>• Memory cells |

## Lines of defence:

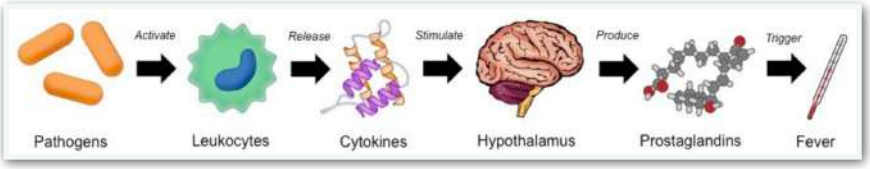
- First line —> surface barriers that prevent pathogens from entering the body
- Second line —> non-specific cellular and molecular responses of the innate immune system
  —> defences do not differentiate between different types of pathogen
  —> phagocytic leukocytes, inflammations, antimicrobial proteins and fever
- Third line —> lymphocytes that produce antibodies to specific antigenic fragments
  —> each B cell produces a specific antibody (body has millions) capable of detecting distinct antigens
  —> helper T cells regulate B cell activation —> ensures antibodies are mass-produced at the appropriate times
  —> both B and T cells will differentiate to form memory cells after activation —> long term immunity to a particular pathogen

## Inflammation:

- Non-specific way in which the body responds when a pathogen damages body tissue
- If tissue damage occurs —> mast cells (localised) and basophils (circulating) release histamine —> causes local vasodilation and increase capillary permeability to improve the recruitment of leukocytes to the region
- Damaged cells also release chemotactic factors which attract leukocytes to the site of infection
- Side effects of inflammation —> redness, heat, swelling, tenderness and pain
- Can be either short-term (acute) or long-term (chronic)

## Fever:

- Abnormally high temp. associated with infection and is triggered by the release of prostaglandins
- May help to combat infection by reducing the growth rate of microbes (microbial enzymes)
- May also increase metabolic activity in body cells and activate heat shock proteins to strengthen immune response
- Up to a certain point a fever may be beneficial, but beyond a tolerable limit it can cause damage to the body's own enzymes




## Types of leukocytes:

- Neutrophils —> 60-70% of all white blood cells —> first responder to microbial infection
  —> are unable to renew their lysosomes and die after having phagocytoses a few pathogens —> forms the majority of pus
- Eosinophils —> 1-3% —> prominent at sites of allergic reaction and parasitic infection
  —> release chemical products which perforate cell membrane —> function as the primary response to large multicellular parasites (helminth infections, …)
- Basophil —> less than 1% —> responsible for initiating inflammatory responses
  —> circulate in the bloodstream and release chemicals histamine and heparin
  —> common contributors to allergic responses as they promote inflammation
- Monocyte —> 1-6% —> largest type of leukocyte —> share phagocytosis duties with neutrophil
  —> slower to respond than neutrophils but are longer lasting as can renew lysosomes

—> will differentiate into two types of cells in response to pathogenic infection —> macrophages (will remain in the tissue and phagocytose) and dendritic cells which present antigen fragments to lymphocytes

- Lymphocyte —> 20-30% —> responsible for the production of antibodies which target specific antigens present on pathogens
  —> more common in the lymphatic system than blood and are slower to respond
  —> B cells (antibody-secreting plasma cells) and T cells (mediate B cell activity)
  —> involved in the destruction of virus-infected body cells (via cytotoxic T cells)

## Haemophilia:

- X-linked recessive condition that impairs the body's ability to control blood clotting
- People with haemophilia have lower levels of functional clotting factors in their blood plasma —> normal coagulation cascade is impaired and fibrin formation does not occur
- Haemophilia A (clotting factor XIII deficiency) is more common than B (clotting factor IX def.)

## Lung capacity:

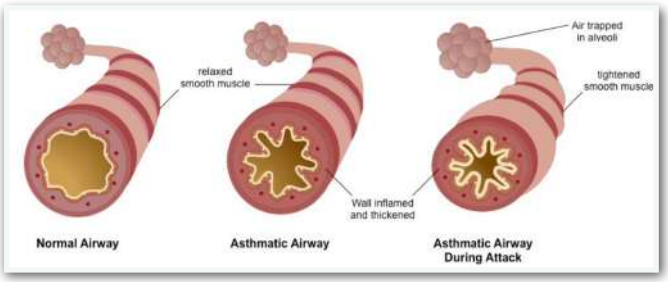
- Refers to the volumes of air associated with the different phases of the respiratory cycle
- Total lung capacity —> volume of air in the lungs after a maximal inhalation (6 liters in male)
- Vital capacity —> V of air that can be exchanged by lungs via max. inhalation and exhalation
- Residual volume —> volume of air always present in the lungs —> 20%
- Tidal volume —> volume of air that is exchanged via normal breathing —> 500ml per breath
- Height, location and lifestyle affect an individual's total lung capacity

- Ventilation rate at rest for a typical adult is 12 - 16 breaths per minute

## Effects of exercise:

- $VO_2$ —> volume of oxygen absorbed by the body per minute and supplied to the tissues
- $VO_2$ max —> max. rate at which oxygen can be absorbed and supplied to body tissues
- If energy demands exceed oxygen intake, ATP may be produced via anaerobic respiration —> produces lactic acid —> is transferred to the liver and requires oxygen to covert to pyruvate
- Oxygen debt —> extra oxygen required to restore normal body functioning after exercise
- The body requires more oxygen to generate a set amount of energy when metabolising fats as compared to carbohydrates —> during high intensity exercise lower fat metabolism

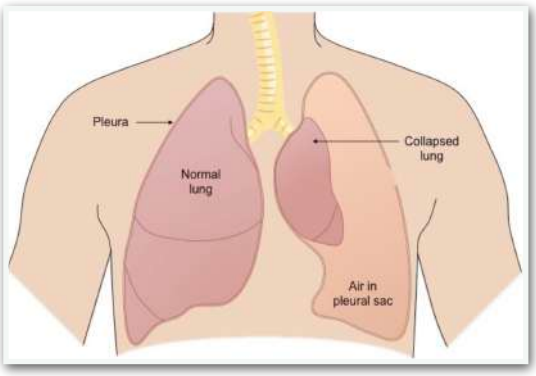
Lung disorders:




**Asthma:**

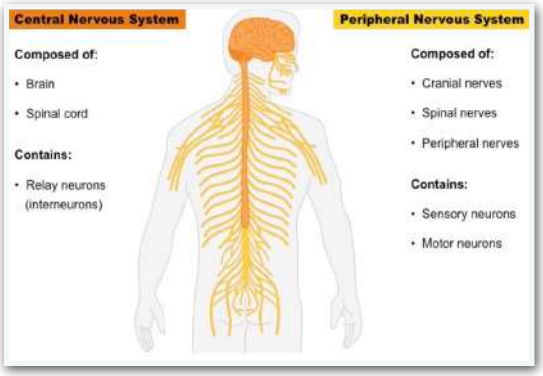
- Common chronic inflammation of the airways to the lungs —> leads to swelling and mucus production —> reduced airflow and bronchospasm
- During an acute asthma attack, constriction of the bronchi smooth muscle may cause significant airflow obstruction —> shortness of breath, chest tightness, wheezing and coughing
- Severe cases of asthma may be life threatening if left untreated —> may be caused by recurring environmental triggers (allergen, smoke, cold air, certain medications and arthropods)

**Pneumothorax:**



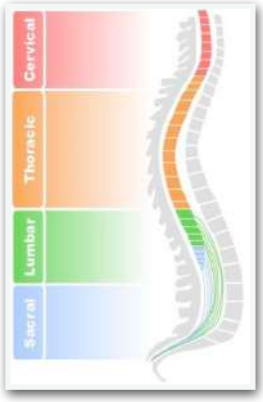

-Abnormal collection of gas in the pleural space —> causes uncoupling of lung from chest wall
- Pleural cavity (fluid-filled space between lung and chest wall)
- Surface tension of the pleural fluid causes the lung to adhere closely to the chest wall and thus inflate upon chest expansion
- If cavity becomes filled with air (pneumothorax) or blood (haemothorax) —> lungs will collapse until pressure is relieved
- Build up of fluid or gas will compress other local organs (including heart) —> life threatening complications
-Usually treated by inserting a syringe into the pleural cavity and draining the excess liquid or gas

Nervous system:




- Coordinates the actions of complex organisms via transmission of electrochemical signals —> transmitted by neurons (specialised network cells)
- —> CNS —> central nervous system —> made up by the brain and spinal cord

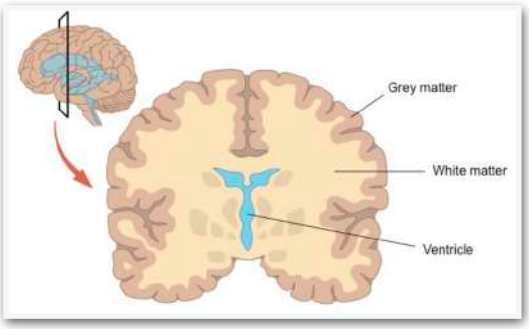
—> PNS —> peripheral nervous system —> made up of peripheral nerves which link the CNS to the body's receptors and effectors




- CNS —> integrates information received from peripheral nerves and coordinates bodily responses —> majority of this occurs in the brain, but spinal cord for reflex actions
- PNS —> sends information to the CNS via sensory neurons and activates effectors via motor neurons

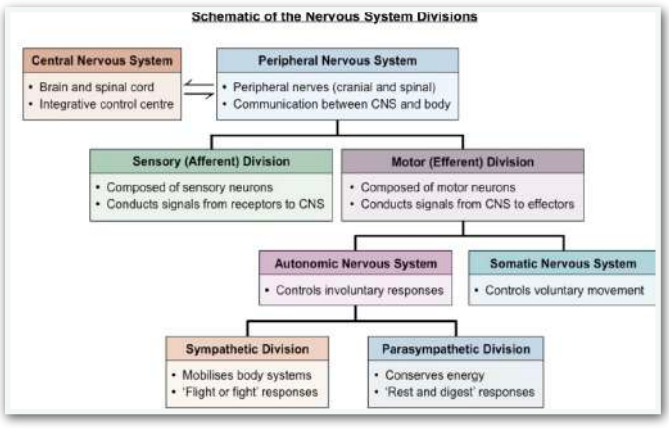
—> some peripheral nerves feed into the spinal cord at anatomical dermatome —> damage to a particular region of the spine will affect the body parts innervated by nerves ventral to that region —> injuries to the cervical region are most severe as more of the body is affected (C1 and C4 injuries impair normal breathing)

**White and Grey matter:**




- White matter —> composed of bundles of myelinated axons which connect the various grey matter regions together
- Grey matter —> composed of the neuronal cell bodies and dendrites + unmyelinated nerve fibres

—> regions of the brain where info. is processed

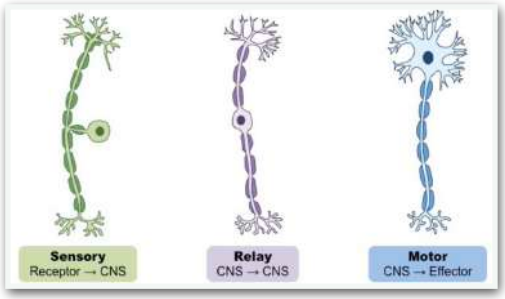


## Stimulus-Response:

1) Stimulus —> change in the environment (external or internal) that is detected by a receptor
2) Receptors —> transform environmental stimuli into electrical nerve impulses
3) Impulses are transmitted via neurons to the CNS for decision-making
4) Response is selected —> (consciously or unconsciously) —> signal is transmitted to effectors
5) Effectors —> organs (muscles or glands) that produce a response to stimulus
6) Response —> change in the organisms resulting from the detection of a stimulus

**Types of neurons:**

- Sensory —> transmit info from sensory receptors to the CNS
- Relay —> (interneurons) transmit info within the CNS as part of decision-making process
- Motor —> transmit info from CNS to effectors for response



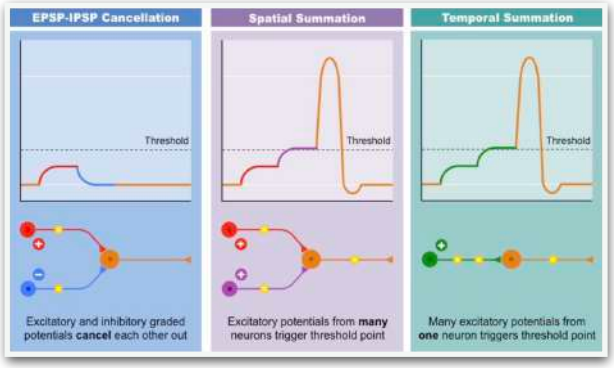

- Their basic structure differs in length, cell body (soma) position and the comparative distribution of dendrites and axon terminals

**Reflex actions:**

- Rapid and involuntary response to a stimulus —> from simple signalling pathway —> reflex arc
- Do not involve the brain —> sensory information is directly relayed to motor neurons within the spine —> results in a faster response (does not involve conscious though or deliberation)
- Are particularly beneficial in survival situations when quick reactions are necessary to avoid permanent damage
- Patellar reflex (knee jerk response) —> occurs when the patellar tendon is tapped —> common test employed by doctors to determine the presence of spinal lesion

## Summation:

- Presynaptic neurons release neurotransmitters into the synapse to trigger graded potentials in post-synaptic neurons
- Some generate excitatory post-synaptic potentials (EPSPs) —> trigger depolarisation in the post-synaptic membrane
- Some produce inhibitory post-synaptic potentials (IPSPs) —> trigger hyperpolarisation in the post-synaptic membrane
- If the combination of signals reaches a threshold level —> action potential will be triggered in the post-synaptic neuron —> combination of graded potential is known as summation




Types of neurotransmitters:

- Neurotransmitters are chemical messengers released into the synaptic cleft by neurons
- They maintain signals in the nervous system by bind to receptors on post-synaptic neurons and triggering electrical impulses + activate responses by effector organs

**Adrenaline:**
- Primarily hormone released by the adrenal gland, but some neurons secrete it as neurotransmitter
- Increases heart rate and blood flow, leading to a physical boost and heightened awareness
- It is produced during stressful or exciting situations

**Noradrenaline:**
- Noradrenaline is predominantly a neurotransmitter that is occasionally released as a hormone
- Contracts blood vessels and increases blood flow —> improves attention and speed at which responsive actions occur

**Dopamine:**
- Primarily responsible for feelings of pleasure, but is also involved in movement and motivation
- People tend to repeat behaviours that lead to dopamine release, leading to addictions
- Abnormal dopamine secretion is common in specific movement disorders (Parkinson's disease,..)

**Serotonin:**
- Contributes to feelings of well-being and happiness —> affected by exercise and light exposure and plays a role in sleep cycle and digestive system regulation

**GABA:**
- Inhibits neuron firing in the CNS —> high levels improve focus whereas low levels cause anxiety —> also contributes to motor control and vision

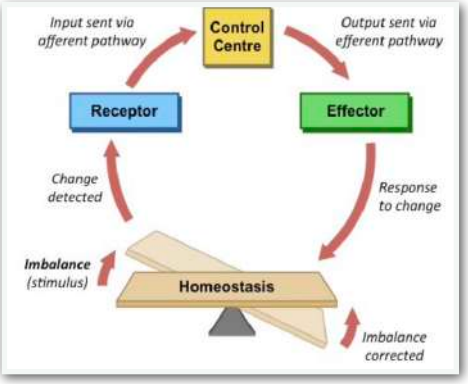
**Acetylcholine:**
- Involved in thought, learning and memory within the brain
- Activates muscle contraction in the body and is also associated with attention and awakening

**Glutamate:**
- Most common brain neurotransmitter —> regulates development and creation of new nerve pathways and hence is involved in learning and memory

**Endorphins:**
- Release is associated with feelings of euphoria and a reduction in pain (body's natural 'pain killers') —> is released during exercise, excitement and sex

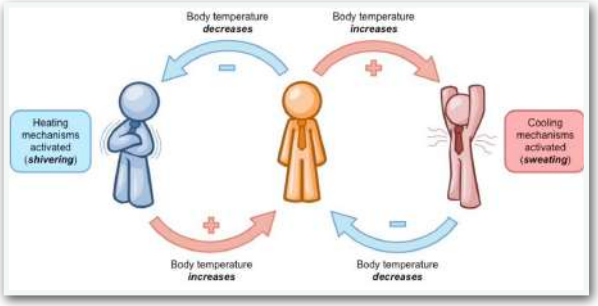
## Homeostasis:

- Tendency for an organism or cell to keep a constant internal environment within tolerance limits
- Internal equilibrium is maintained by adjusting physiological processes such as:
  - —> body temperature —> normally between 36°- 38°C
  - —> carbon dioxide concentration —> normally 35 - 45 mmHg
  - —> blood pH —> normally 7.35 - 7.45
  - —> blood glucose levels —> normally 75 - 95 mg/dL
  - —> water balance —> depends on individual body size
- Most homeostatic responses involve an effect that is antagonistic to the detected stimulus —> negative feedback

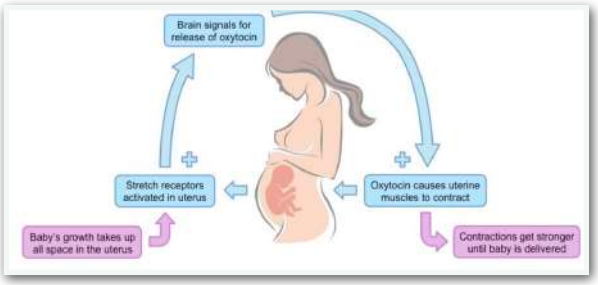


## Feedback loops:

- Physiological processes are commonly moderated via two distinct feedback mechanisms —> positive and negative feedback —> homeostatic processes are controlled by negative feedback —> occur more commonly within the body




**Negative feedbacks:**
- Involves a response that is the reverse of the change detected —> functions to reduce the change —> promotes equilibrium
- Change is detected by a receptor and an effector is activated to induce opposite effect
- Thermoregulation, blood sugar regulation (insulin and glucagon), osmoregulation (ADH), …




**Positive feedback:**
- Involves a response that reinforces change detected —> functions to amplify the change
- Change is detected by a receptor and an effector is activated to induce the same effect
- Will continue to amplify the initial change until the stimulus is removed
- Childbirth —> stretching of uterine walls cause contractions that further stretch the walls (continues until birth)
- Lactation —> child feeding stimulates milk production —> causes further feeding (continues until baby stops feeding)
- Ovulation —> the dominant follicle releases oestrogen which stimulates LH and FSH release to promote further follicular growth
- Blood clotting —> platelets release clotting factors —> + platelets will aggregate at site of injury

## Endocrine system:

- System of ductless glands that release chemicals (hormones) into blood to regulate body function
- Hormone —> chemical messenger transported via the bloodstream to act on distant target cells —> specific and will only activate cells / tissues possessing appropriate target receptor
- The endocrine system is slower to initiate compare to the nervous system, but has a more prolonged response

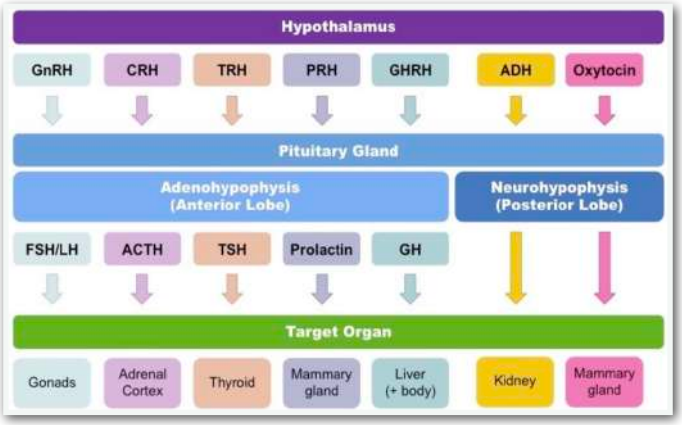
**Endocrine glands:**
- Secrete their product (hormones) directly into bloodstream rather than through a duct (exocrine gland)
- Include pancreas, adrenal gland, thyroid gland, pineal gland and the gonads
- Hypothalamus and pituitary gland are neuroendocrine glands —> function to link the nervous and endocrine systems
- Some organs may also secrete hormones despite not being endocrine glands (adipose tissue secretes leptin, …)

| Gland | Hormone | Target Organ | Function |
|---|---|---|---|
| Pineal gland | melatonin | many | biological clock |
| Pituitary gland | FSH / LH<br>ADH<br>growth hormone<br>oxytocin<br>prolactin | ovaries<br>kidneys<br>many<br>uterus<br>breast tissue | menstrual cycle<br>osmoregulation<br>growth & division<br>birth contractions<br>milk production |
| Thyroid gland | thyroxin | liver | metabolic rate |
| Adrenal glands | adrenaline<br>cortisol | many<br>many | fight or flight<br>anti-stress |
| Pancreas | insulin / glucagon | liver | blood sugar levels |
| Ovaries | estrogen / progesterone | uterus | menstrual cycle |
| Testes | testosterone | many | male characteristics |

**Hypothalamus:**

- Section of brain that links the nervous and endocrine systems in order to maintain homeostasis
- Receives info from nerves throughout the body and other parts of the brain and initiates endocrine responses
- It secretes certain neurochemicals (releasing factors) into a portal system which stimulates or inhibits the pituitary gland + it also secretes certain hormones directly into the bloodstream via neurosecretory cells that extend into the pituitary gland

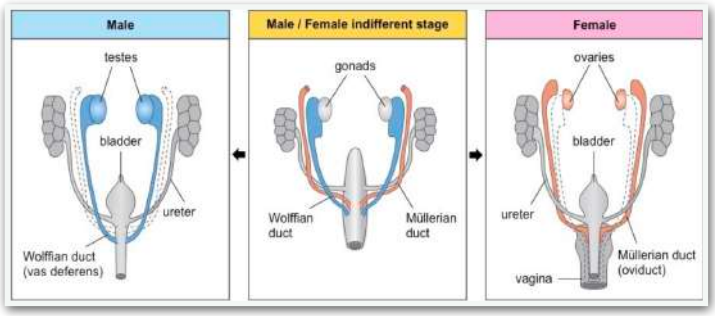
- Pituitary gland (master gland) —> lies adjacent to the hypothalamus and is in direct contact due to a portal blood system
- Pituitary gland receives instructions from the hypothalamus and consists of two lobes
  —> anterior lobe (adenohypophysis)—> releases hormones in response to releasing factors
  —> posterior lobe (neurohypophysis) —> releases hormones produced by the hypothalamus itself —> via neurosecretory cells




| | Peptide | Steroid | Amino acid derivative |
|---|---|---|---|
| Synthesis | Synthesised as **prohormones**, requiring further processing (e.g. cleavage) to activate | Synthesised in a series of reactions from **cholesterol** | Synthesised from the amino acid **tyrosine** |
| Storage | Stored in vesicles (regulatory secretion) | Released immediately (constitutive secretion) | Stored before release (storage mechanism varies) |
| Solubility | Most are polar and water soluble, can travel freely in the blood | Generally non-polar and require carrier proteins to travel in blood | Some are polar (adrenaline), others must be protein-bound |
| Receptors | Bind receptors on cell membrane and transduce signal via the use of second messenger systems | Bind to intracellular receptors to change gene expression directly | Adrenaline acts on membrane receptors, while thyroid hormones act directly on nuclear receptors |
| Effects | Often fast onset transient changes in protein activity, though gene expression changes can occur | Alterations in gene expression; slower onset but longer duration than peptide hormones | Adrenaline functions like peptides, thyroid hormones function in a similar manner to steroids |
| Examples | Insulin, glucagon, prolactin, ACTH, gastrin parathyroid hormone | Cortisol, aldosterone, estrogen, progesterone, testosterone | Adrenaline, thyroxin, triiodothyronine |

## Gender issues:

- Sex —> describes the biological differences between males and females
- Gender —> describes the characteristics that society delineates as masculine or feminine
- Males —> possess the SRY gene which synthesises testis determining factor TDF
  —> the testis produces testosterone (promotes male sex characteristics) and a hormone called MIF (Mullein Inhibiting Factor) —> causes degeneration of female organs
- Females —> MIF is not produced and the female organs are allowed to develop (ovaries form)
  —> ovaries do not produce testosterone so female sex characteristics develop
- Sometimes errors occur during this prenatal development of sex characteristics —> issues in the assignment of gender —> androgen insensitivity syndrome and guevedoces are examples




**Androgen Insensitivity syndrome:**

- Individuals with AIS do not respond to the production of testosterone —> do not develop external male genitalia despite having internal testes and develop female sex characteristics
- Despite being genetically male, individuals physically resemble females and identify this gender

**Guevedoces:**

- Girls who turn into boys at puberty —> possess a rare genetic mutation which prevents the synthesis of the enzyme 5-alpha-reductase —> converts testosterone into dihydrotestosterone (DHT) triggering a hormone surge that develops male genitalia
- Without this enzyme, genetic males do not initially develop male genitals so are females —> with this second hormone surge occurring with the onset of puberty they develop male genitals

Menstrual events:

- The changes in reproductive hormones over the menstrual cycle trigger many physiological and behavioural responses

- 1 - 5 —> Period time during which the body may release prostaglandins which cause cramps
- 6 - 11 —> Estrogen levels rise during the follicular phase —> woman confident and flirtatious
- 12 - 15 —> Near ovulation (woman most fertile)
- 14 - 15 —> Ovulation —> estranged levels drop temporarily —> may fell cranky or emotional
- 16 - 19 —> Estrogen and progesterone release prepare for pregnancy (breast tenderness)
- 20 - 21 —> If fertilisation hasn't occurred, the ovaries stop producing estrogen and progesterone
- 22 - 28 —> falling levels of hormones will cause irritability and leads to will for sugary foods