SNAPREVISE

THE ULTIMATE A-LEVEL OCR BIOLOGY CHEATSHEET PACK

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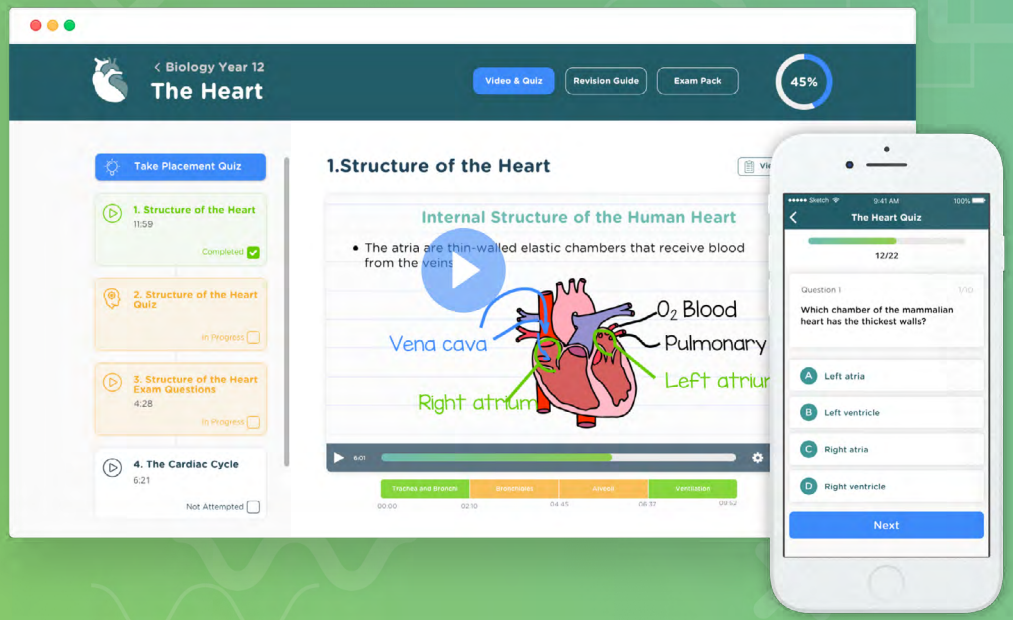

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How to Use

The aim of this pack is simple — we wanted to condense the A-level Biology course into a few super condensed pages. Now you have a concise summary of the entire course that focuses on the most important definitions, key terms, diagrams and concepts.

We've spent weeks working with top designers, academic writers and illustrators to ensure this is the best cheatsheet out there. Our promise to you is you won't find anything better. The cheatsheet pack has been built off the OCR specification to ensure no important information is missed — below is a table which summarises how our cheatsheets map to the OCR specification.

Specification Points	Cheatsheet
2.1.1	Cell Structure & Water
2.1.2	Carbohydrates, Lipids, Proteins & Inorganic Ions
2.1.3-2.1.4	Nucleic Acids, ATP, Genetic Information, Protein Synthesis & Enzymes
2.1.5 - 2.1.6	Cell Transport & Cell Division
3.1.1	Cell Specilisation & Gas Exchange
3.1.2 - 3.1.3	Mass Transport & The Heart
4.1.1	Disease & Immunity
4.2.1 - 4.2.2	Biodiversity, Classification & Natural Selection
5.1.1 - 5.1.2	Energy, Ecosystems & Nutrient Cycles
5.1.3 - 5.1.4	Receptors, Neurones, Synapses & The Endocrine System
5.1.5	Blood Glucose, Plant Responses & The Nervous System
5.2.1	Muscles & Photosynthesis
5.2.2	Respiration & Mutations
6.1.1	Gene Regulation & The Body Plan
6.1.2	Inheritance
6.1.2	Populations, Evolution, Speciation & Sequencing
6.1.3 - 6.2.1	Gene Technology & Biotechnology
6.3.1 - 6.2.3	Ecosystems, Nutrient Cycles & Conservation

We hope you enjoy using it and wish you the best of luck in your A-levels.

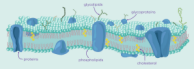
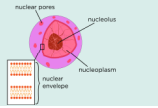
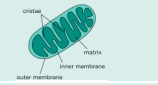
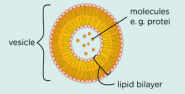
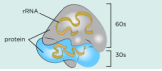
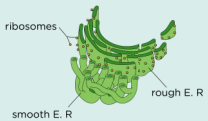
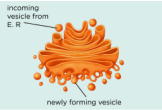
SnapRevise

CELL STRUCTURE & WATER
CHEAT SHEET

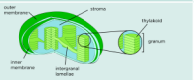
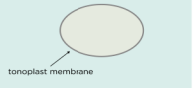
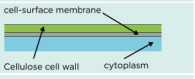
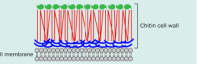
SNAPREVISE

Eukaryotic Cells

- Eukaryotes include animal, plant & fungal cells.
- The following organelles are presents in eukaryotic cells:

Organelle	Structure	Function
Cell surface membrane		• Controls passage of entry of substance into the cell • Site of cell communication via receptors
Nucleus		• Stores DNA • Nuclear pores allow mRNA & ribosomes to pass through
Mitochondria		• Carry out aerobic respiration to produce ATP
Lysosomes		• Contains digestive enzymes to break down pathogens, old organelles, cells & food molecules
Ribosomes		• Site of protein synthesis
Rough endoplasmic reticulum		• Provide a large surface area for protein synthesis
Smooth endoplasmic reticulum		• Synthesise, store and transport lipids and carbohydrates.
Golgi Apparatus		• Modifies proteins • Sort, package, and transport molecules around the cell

- There are additional organelles in plants, algae & fungi:

Organelle	Structure	Function	Present in which organism
Chloroplasts		• Site of photosynthesis	Plants & algae
Cell vacuole		• Maintains cell structure • Act as a tempo-rary energy store	Plants
Cell wall		• Provides support & mechanical strength	Plants & algae
			Fungi

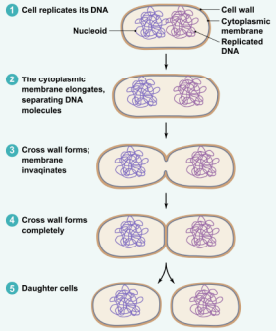
- In complex multicellular organisms, eukaryotic cells become
- Specialised for specific functions.
- Specialised cells are organised into tissues, tissues into organs and organs into systems.

Prokaryotic Cells

- Prokaryotes are smaller and simpler than eukaryotes.

Feature	Eukaryotic Cell	Prokaryotic Cell
Nucleus	Present	Absent
DNA	Linear and packaged into chromosomes in nucleus	Circular and freely floating in cytoplasm
Cell Membrane	Present	Present
Membrane-bound organelles	Present	Absent
Ribosomes	Present (80S)	Present (70S)
Cell Wall	Sometimes (cellulose or chitin)	Present (peptidoglycan)
Chloroplasts	Sometimes	Absent
Flagellum	Absent	Sometimes
Capsule	Absent	Sometimes
Plasmid	Absent	Sometimes

- Bacteria replicate by binary fission.



Methods of Studying Cells

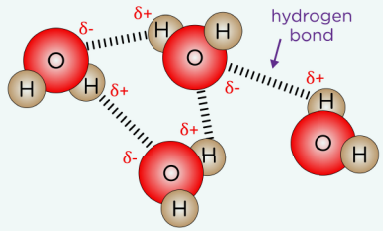
- There are 3 main types of microscopes used to observe cells:

	Light Microscope	Scanning Electron Microscope	Transmission Electron Microscope
Medium	Light Beam	Electron Beam	Electron Beam
Dimensions	2D	3D	2D
Max Magnification	X1,500	X200,000	X2,000,000
Max Resolution	200 nm	20 nm	0.1 nm

- Magnification is how much bigger the image is compared to the original object viewed with the naked eye
- Magnification = (size of image)/(size of object)
- Resolution is how well a microscope distinguishes between two points that are close together.
- Cell fractionation can be used to separate organelles.
  - Homogenisation - grinding cells release the organelles into solution
  - Filtration - separates organelles & debris
  - Ultracentrifugation - using a centrifuge the organelles are separated out in order of mass

Water

- Water molecules consist of 2 hydrogen molecules covalently to an oxygen molecule.



- The molecules are slightly polar because the oxygen nucleus pulls the shared electrons away from the hydrogen nuclei. Giving the oxygen nuclei a δ- charge, and the hydrogen nuclei a δ+ charge.
- The polarity of water causes attraction between water molecules. This force of attraction is called a hydrogen bond.

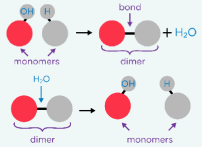
Property of water	Why it is useful
Liquid medium	Provides habitats for aquatic organisms, medium for chemical reactions & used for transport
Important metabolite	Used in hydrolysis & condensation reactions
High specific heat capacity	Keeps aquatic & cellular environments stable
High latent heat of vaporisation	Evaporation has a cooling effect on organisms
Cohesion of molecules	Water is drawn up the xylem
Surface tension	Allows pond-skaters to walk on the surface
Good solvent and transport medium	Dissolves ionic and polar molecules, allowing them to easily be transported
Good reaction medium	The cytoplasm in cells is an aqueous solution where many chemical reactions happen
Incompressible	Can prevent plants from wilting & act as a hydrostatic skeleton for invertebrates

CARBOHYDRATES, LIPIDS & PROTEINS
CHEAT SHEET

SNAPREVISE

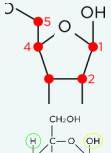
Monomers & Polymers

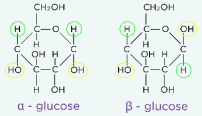
- Monomers are individual molecules that make up a polymer.
- Polymers are long chains that are composed of many individual monomers that have been bonded together in a repeating pattern.
- Condensation Reactions occurs when two molecules combine to form a more complex molecule with the removal of water.
- Hydrolysis Reactions occurs when larger molecules are broken down into smaller molecules with the addition of water.



Carbohydrates

- Monosaccharides are the simplest carbohydrates, consisting of only one sugar molecule (e.g. Glucose, Fructose & Galactose).
- Ribose sugars (pentose) are found in many important biological molecules such as ribonucleic acid (RNA), ATP, NAD
- Glucose is a hexose sugar with 2 isomers
- Disaccharides are sugars that are composed of two monosaccharides joined together in a condensation reaction, forming a glycosidic bond.





Disaccharide	Constituent monosaccharides
Maltose	2 × α-glucose
Sucrose	α-glucose and fructose
Lactose	β-glucose and galactose

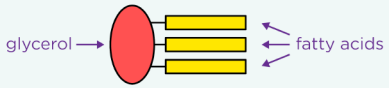
- Polysaccharides are formed by many monosaccharides joined together.
  - Amylose, amylopectin (starch) is the main polysaccharide energy store in plants, is composed of α-glucose.
  - In animals, the polysaccharide energy store is called glycogen, composed of α-glucose.
  - Cellulose is a structural component of plant cell walls, composed of long unbranched chains of β-glucose.

Biochemical Tests

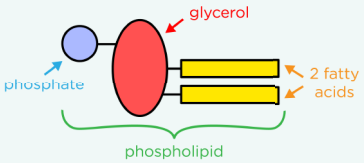
Molecule	Reagent	Positive Result
Reducing sugars	Benedict's reagent → Heat	Red/orange precipitate
	Reagent test strip	Compare with calibration card
Non-reducing sugars	Hydrochloric acid → Heat Sodium hydrogencarbonate Benedict's reagent → Heat	Red/orange precipitate
Starch	Iodine in potassium iodide solution	Blue/black
Proteins	Sodium hydroxide Copper (II) sulphate	Purple
Lipids	Ethanol Water → Shake	Cloudy white

Lipids

- Fatty acids can be:
  - Saturated – there are no C=C bonds and the molecule has as many hydrogen atoms as possible.
  - Unsaturated – there is at least one C=C bond, therefore the molecule contains fewer hydrogen atoms than is maximally possible.
- A triglyceride molecule is formed by joining one molecule of glycerol to three fatty acids through three condensation reactions, forming ester bonds.
- Triglycerides have key roles in respiration and energy storage due to its insolubility and high carbon to hydrogen ratio.

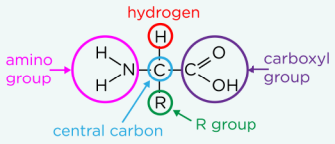


- Phospholipids replace one of the fatty acid chains in triglycerides with a phosphate molecule.
- The hydrophobic tails and hydrophilic heads of phospholipids allow them to form phospholipid bilayers.



Proteins

- Amino acids are the monomer units used to make proteins.
- The 20 naturally occurring amino acids only differ in their R groups.
- Dipeptides are formed when two amino acids are joined together by a condensation reaction, forming a peptide bond.
- A polypeptide is a polymer made of many amino acids joined together by peptide bonds.



- A protein may contain one or more polypeptide chains.
- There are four structural levels:

Level	Definition	Bond type
Primary	The specific sequence of amino acids in a polypeptide chain	Peptide bonds
Secondary	The curling or folding of the polypeptide chain into α-helices and β-pleated sheets due to the formation of hydrogen bonds	Hydrogen bonds
Tertiary	The overall specific 3-D shape of a protein, which is determined by interactions between R groups and the properties of R groups	Hydrogen bonds Ionic bonds Disulphide bridges
Quaternary	The specific 3-D shape of a protein that is determined by the multiple polypeptide chains and/or prosthetic groups bonded together	Hydrogen bonds Ionic bonds Disulphide bridges

Inorganic Ions

- Inorganic ions are atoms or molecules with an electric charge, containing no carbon.
- Cations are positively charged ions
- Anions are negatively charged ions
- Inorganic ions occur in solution in the cytoplasm and body fluids of organisms, some in high concentrations and others in very low concentrations
- Each type of ion has a specific role, depending on its properties
  - Hydrogen ions determine the pH of bodily fluids. The higher the concentration, the lower the pH
  - Sodium ions are used in the co-transport of glucose and amino acids across cell membranes and transmission of nervous impulses
  - Phosphate ions are essential components of DNA, RNA, nucleotides & ATP
  - Calcium ions regulate protein channels, impulse transmission and harden body parts like teeth.
  - Potassium ions play a role in muscle contraction, nervous transmission. active transport and maintaining turgidity in plant cells.
  - Ammonium ions and Nitrate ions are part of the nitrogen cycle and a source of nitrogen for biological molecules
  - Hydrogencarbonate ions are formed when carbon dioxide dissolves in blood. They are important in the transport of carbon dioxide in the blood and the regulation of blood pH

$$CO_2 + H_2O \rightleftharpoons HCO_3^- + H^+$$

Globular Proteins

- A globular protein is protein with a spherical shape that is soluble in water; they typically have metabolic roles
- Globular proteins have a few important properties:
  - They are roughly spherical in shape, with hydrophobic R groups on the inside and hydrophilic R groups on the outside. They are therefore soluble in water
  - They have very specific shapes; this allows them to carry out very specific functions
- Haemoglobin is a conjugated globular protein, made of 4 polypeptide chains and 4 haem prosthetic groups which contain Fe^{2+}.
- Insulin is composed of two polypeptide chains, joined together by disulphide links. The specificity of the shape allows binding to cell membrane receptors.
- Pepsin has hydrogen bonds, disulphide link and few basic R groups to keep it functional in low pH stomach acid.

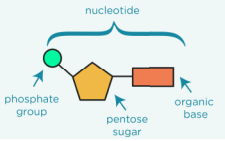
Fibrous Proteins

- Fibrous proteins have some similar properties to each other:
  - They contain long polypeptide chains with repeating sequences of amino acids
  - The amino acids have non-polar R groups, so the proteins are insoluble in water
  - The polypeptide chains are able to form fibres which make the proteins stronger
- Collagen is used to make bones, tendons and are found in artery walls to help resist the high pressure
- Keratin contains high amounts of cysteine, resulting in disulphide links forming between the two polypeptide chains, which makes the molecule very hard and strong. It is found in fingernails, hooves and horns.
- Elastin has the ability to stretch and recoil. Elastin is stretchy due to coiling of the elastin molecules and cross-links that keep the molecules together. It is found in the lungs, bladder and blood vessel walls.

NUCLEIC ACIDS, ATP, GENETIC INFORMATION, PROTEIN SYNTHESIS & ENZYMES
CHEAT SHEET

SNAPREVISE

DNA & RNA

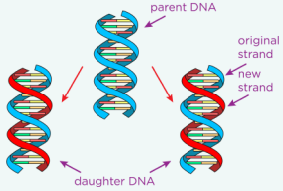


- DNA & RNA are both polynucleotides.
- The basic structure of a nucleotide is:

	DNA	RNA
Number of Strands	Two antiparallel strands	One strand
Length	Very long	Relatively short
Pentose Sugar	Deoxyribose	Ribose
Nitrogenous Bases	Adenine, Cytosine, Guanine & Thymine	Adenine, Cytosine, Guanine & Uracil
Function	Store genetic information	Transfer genetic information & forms ribosomes with proteins

DNA Double Helix & Replication

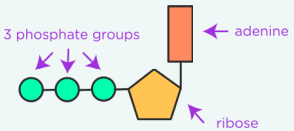
- Polynucleotides are polymers made up of many nucleotide monomers joined together by a series of condensation reactions, forming phosphodiester bonds.
- The DNA double helix is held together by hydrogen (H) bonds between complementary base pairs.
  - 2 H bonds between Adenine & Thymine
  - 3 H bonds between Cysteine and Guanine
- Semi conservative replication is the method in which DNA replicates, creating two molecules of DNA that consist of one original DNA strand and one newly synthesised DNA strand.
  - DNA helicase breaks H bonds between the two strands
  - Free nucleotides complementary base pair to the exposed strands
  - DNA polymerase catalyses condensation reactions to join adjacent nucleotides, forming phosphodiester bonds.



Genetic Information

- In prokaryotic cells, DNA molecules are short, circular and not associated with proteins.
- In eukaryotes, the nucleus contains very long, linear DNA molecules associated with proteins, called histones. Together a DNA molecule and its associated proteins form a chromosome.
- The mitochondria and chloroplasts of eukaryotic cells also contain DNA which, like the DNA of prokaryotes, is short, circular and not associated with protein.
- The genome is the full set of DNA found in an organism.
- The proteasome is the full range of proteins that can be synthesised from the genome.
- A gene is a section of DNA that code for polypeptides and functional RNA and are located at a fixed locus on a DNA molecule.
- A sequence of three DNA bases, called a codon, codes for a specific amino acid. The genetic code is universal, non-overlapping and degenerate.
- In eukaryotes, sections of the nuclear DNA do not code for polypeptides (introns). Exons are sections of DNA that code for amino acid sequences.

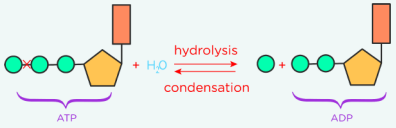
ATP



- The structure of ATP is:

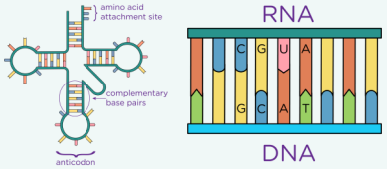
	ATP → ADP	ADP → ATP
Reaction type	Hydrolysis	Condensation
Enzyme involved	ATP hydrolase	ATP synthase
Energy profile of reaction	Releases energy	Requires energy

- The hydrolysis of ATP can be coupled to energy-requiring reaction and used to phosphorylate compounds.
- The condensation of ADP to form ATP can occur during respiration and photosynthesis.

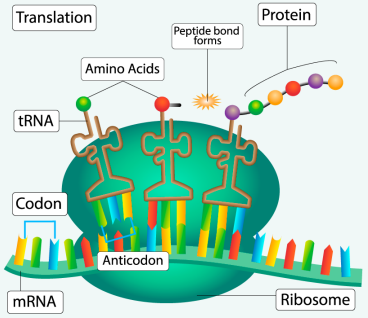


Protein Synthesis

- Structure of tRNA & mRNA:
- Transcription is the process of making messenger RNA from a DNA template.
- DNA helicase breaks the hydrogen bonds between the DNA helix, free RNA nucleotides base pair with the exposed DNA template strand.

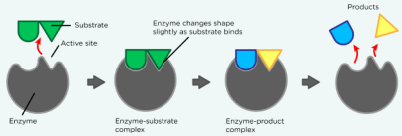


- In prokaryotes, transcription results directly in the production of mRNA from DNA.
- In eukaryotes, transcription results in the production of pre-mRNA; this is then spliced to form mRNA.
- Translation is the process of making proteins by forming a specific sequence of amino acids based on coded instructions in mRNA. RNA polymerase catalyses phosphodiester bonds between adjacent RNA nucleotides and the mRNA strand detaches, allowing the DNA helix to reform.
- mRNA attaches to a ribosome on the rough endoplasmic reticulum, tRNA carries the corresponding amino acid to each codon on the mRNA one at a time, with an enzyme catalysing the formation of a peptide bond between amino acids using ATP, until a stop codon is reached and the peptide is released, folding into its tertiary structure.



Enzymes

- Enzymes are biological catalysts that speeds up the rate of reaction and remains unchanged and reusable at the end of the reaction.
- They lower the activation energy of the reaction.
- The lock and key model proposed that each substrate is a key that only fits a specific lock or enzyme. The alternative induced fit model has been proposed (below)

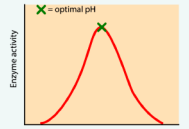


- The specificity of enzymes is due to the tertiary structure of its active site, allowing complementary binding to substrates.
- Enzymes catalyse both intracellular and extracellular reactions that determine structures and functions from cellular to whole organism level.
  - Catalase intracellularly breaks down hydrogen peroxide into water and oxygen
  - Amylase is secreted from the salivary glands and pancreas to extracellularly break down starch. Requires Cl^- cofactor
  - Trypsin is secreted from the pancreas to extracellularly break down proteins
- Some enzymes are synthesised in an inactive precursor form and need to be activated e.g. another enzyme removes part of the molecule in trypsin, forming the correct active site shape
- Some enzymes require a cofactor, which is a substance which must be present to enable an enzyme to catalyse a reaction at the appropriate rate.
  - A prosthetic group is permanently bound e.g. Zn^{2+} bound to carbonic anhydrase

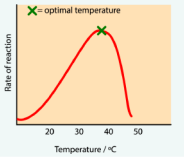
$$CO_2 + H_2O \longleftrightarrow H_2CO_3 \longleftrightarrow H^+ + HCO_3^-$$

  - A coenzyme forms temporary associations and are derived from vitamins.
- Factors affecting enzyme activity include:

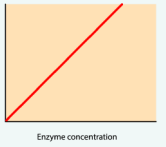
pH:



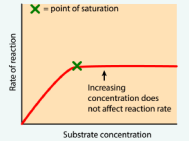
Temperature



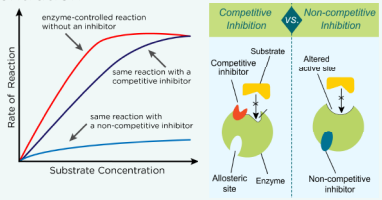
Enzyme concentration



Substrate concentration



Competitive & non-competitive inhibitor concentration



- The temperature coefficient (Q_{10}) for a specific reaction is the effect of a 10°C rise in temperature on the rate of the reaction

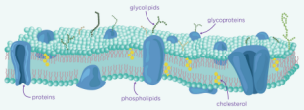
$$Q_{10} = \frac{rate\ of\ reaction\ at\ (T+10)°C}{rate\ of\ reaction\ at\ T°C}$$

CELL TRANSPORT & CELL DIVISION
CHEAT SHEET

SNAPREVISE

Cell Membranes

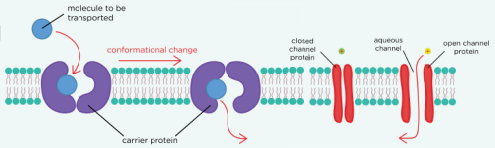
- Cell membranes act as barriers and can control what passes into and out of cells and organelles
- The cell membrane is composed of phospholipids, proteins, glycoproteins, glycolipids and cholesterol.



- Glycolipids and glycoproteins allow cell adherence, stability and act as recognition sites
- Cholesterol has a hydrophilic end and a hydrophobic end & regulates membrane fluidity by intercalating between the phospholipids.
- At high temperatures the phospholipid bilayer increases its fluidity and permeability, increasing the risk of the proteins becoming denatured. At low temperatures, the phospholipids are compressed, making the membrane stiff
- Organic solvents disrupt the bilayer and dissolve the membrane

Passive Transport

- Passive transport involves exchange of substances without requiring metabolic energy from the cell
- Diffusion is the net movement of particles from an area of higher concentration to an area of lower concentration (down their concentration gradient).
- Facilitated diffusion is the net movement of particles down their concentration gradient across a partially permeable cell membrane via carrier or channel proteins.



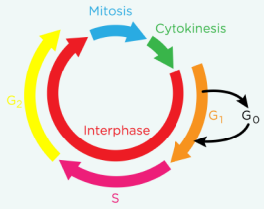
- Water potential is a measure of the tendency of water molecules to move from one area to another area and describes the pressure created by these water molecules; the more dilute a solution, the higher (less negative) the water potential (Ψ).
- Osmosis is the net movement of water from an area of higher water potential to an area of lower water potential across a partially permeable membrane.
- The rate of diffusion can be increased by increasing the number of channel & carrier proteins, the surface area of the cell membrane, reducing the diffusion distance and creating a steeper concentration gradient.

Active Transport

- Active transport is the movement of particles from an area of low concentration to an area of high concentration (against their concentration gradient) across a cell membrane, using ATP and carrier proteins.
- Bulk transport transports large substances across the cell membrane
- Endocytosis is the bulk transport of large molecules into a cell. The membrane invaginates and encloses the material being taken up into a vesicle, which pinches off.
- Exocytosis is the bulk transport of large molecules out of a cell. A vesicle fuses with the cell membrane, releasing its material.

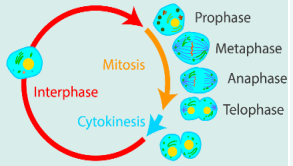
Mitosis

- Within multicellular organisms, not all cells retain the ability to divide
- Mitosis produces genetically identical daughter cells, which is useful for growth, repair and asexual reproduction
- The eukaryotic cell cycle has three main stages:
- Interphase consists of two growth phases (G_1&G_2) and a DNA synthesis stage (S). The cell may exit the cell cycle at G0



- Mitosis is the nuclear division
- Cytokinesis is when the cell splits in two, forming two identical daughter cells.
  - In animal cells, the plasma membrane folds inwards until the two dents meet to separate the two daughter cells
  - In plant cells, cellulose starts to build up at the equator (the end plate). Plasma membrane forms in the middle of the end plate resulting in two fully separated plant cells

Stage	Description
Prophase	DNA condenses & coils, nuclear envelope breaks down, centrioles move to opposite poles
Metaphase	Spindle fibres attach to centromeres & chromosomes line at the equator
Anaphase	Centromeres divides, chromatids move to opposite poles
Telophase	Chromosomes uncoil, nuclear envelope reforms

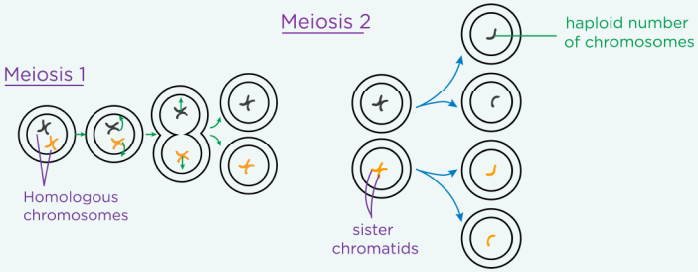


- Cell cycle checkpoints ensure the cell only divide at the appropriate time when ready and helps detect DNA damage.

	Checkpoint Location	Function
Restriction Point or G_1/S Checkpoint	Between G_1 and S	Decides whether cell proceeds to S-Phase..
G_1 Checkpoint	End of G_1	Checks cell is ready for S-Phase
G_2/M Checkpoint	Between G_2 and mitosis	Checks and repairs all of the DNA before the cell enters mitosis.
Mitosis Checkpoint	In the middle of mitosis	Checks cell is ready to proceed in mitosis. Ensures that the cell doesn't proceed to the next stage before it's ready.

Meiosis

- Meiosis produces 4 haploid daughter cells (gametes) that are genetically different from each other.



- In meiosis 1, homologous chromosomes are separated from each other, with one chromosome from each pair going into one of the two daughter cells. In the second meiotic division, the sister chromatids from each chromosome are separated

Stage	Description
Prophase 1	Chromatin condenses & coils, nuclear envelope breaks down, centrioles move to opposite poles. Crossing over occurs between homologous chromosomes
Metaphase 1	Spindle fibres attach to centromeres & chromosomes line at the equator
Anaphase 1	Homologous chromosomes move to opposite poles
Telophase 1 and cytokinesis	Chromosomes uncoil, nuclear envelope reforms. Animal cells divide by cytokinesis
Prophase 2	Chromatin condenses & coils, nuclear envelope breaks down, centrioles move to opposite poles.
Metaphase 2	Spindle fibres attach to the centromeres & chromosomes lines up at the equator
Anaphase 2	The centromeres divide and the chromatids are pulled to opposite poles
Telophase 2 and cytokinesis	Chromosomes uncoil, nuclear envelope reforms. Cells divide to form 4 haploid cells.

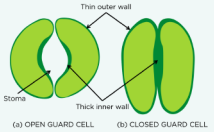
- Variation results from independent assortment of chromosomes and crossing over during meiosis 1. Also, random fertilisation of the gametes.

CELL SPECALISATION & GAS EXCHANGE
CHEAT SHEET

SNAPREVISE

Specialised Cells

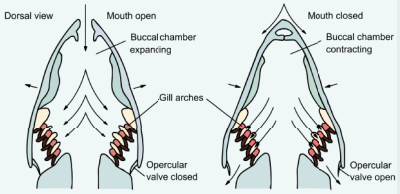
- Erythrocytes have a large SA:V, with their biconcave shape. They lack a nucleus, so more haemoglobin can be stored
- Neutrophils have a multilobed nucleus allowing them to move and engulf material more easily
- Sperm cells have a tail to allow movement. There is a high density of mitochondria to provide ATP to the tail. Sperm cells have a streamline shape and a specialised lysosome (acrosome) that contains digestive enzymes to enter an egg cell
- Squamous epithelial cells are thin and flat to reduce the diffusion distance for gas exchange.
- Ciliated epithelial cells in the trachea have cilia to move mucus along the trachea
- Palisade cells contain lots of chloroplasts, are long and cylindrical allowing close packing. The chloroplast can be moved by the cytoskeleton to maximise light absorption
- Guard cells control the opening and closing of the stomata. ATP is used to pump K^+ ions into the cell, making water move in by osmosis in order to open the stomata for gas exchange.

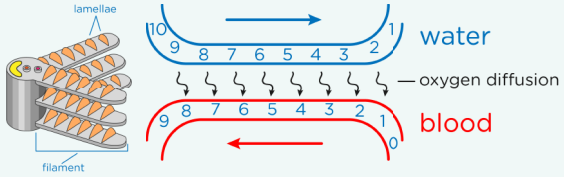


- Root hair cells have protrusion to increase their surface area for water absorption. They also have protein pumps and lots of mitochondria to transport minerals into the cell in order to lower the cells water potential

Gas Exchange

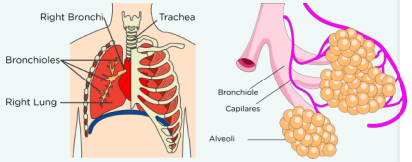
- Single celled organisms can exchange oxygen and carbon dioxide directly through their plasma membrane via diffusion.
- Insects exchange gas in their tracheal system. Air enters via spiracles, travels through trachea and tracheoles, delivering oxygen directly to every tissue. Tracheal fluid limits diffusion to cells. Larger insects can also ventilate by movement of the abdomen, flight muscles changing the volume of the thorax and the presence of air sacs.
- Gas exchange in fish occur via gills.
  - They ventilate their gills by a buccal-opercular pump
  - The orientation of the gill filaments and lamellae ensures that the water flowing over them moves in the opposite direction to the flow of blood through the capillaries (countercurrent flow), maintaining a diffusion gradient.



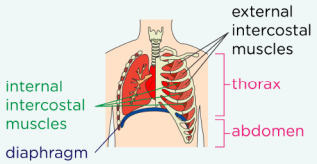


Human Gas Exchange System

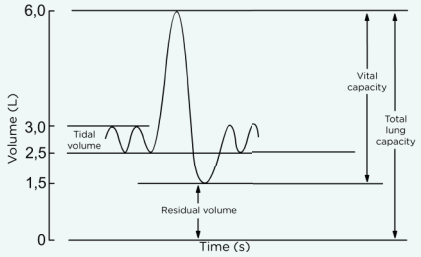
- In humans, gas exchange occurs via the lungs
- The alveolar epithelium is adapted for gas exchange by having a large surface area, good blood supply, thin walls & elastic fibres which help recoil



- Ventilation is the process of breathing in (inspiration) and out (expiration).
- Inspiration: external intercostal muscles contract, rib cage moves up & out, diaphragm contracts, volume of the thorax is increased, atmospheric pressure is greater than pulmonary pressure and air is forced into the lungs.

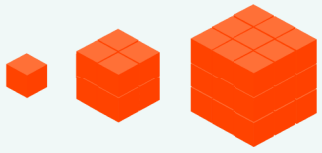


- Expiration: internal intercostal muscles contract, ribs move down and inwards, diaphragm relaxes, volume of the thorax is decreased, pulmonary pressure is greater than atmospheric pressure, air is forced out of the lungs
- Spirometers measure the volume and function of the lungs. Inhalation and expiration moves the lid of the spirometer which is recorded by the datalogger. Carbon dioxide is absorbed by soda lime in the chamber.
- Vital capacity is the maximum amount of air that can be moved by the lungs in one breath
- Residual volume is the volume of air left in the lungs after a forced expiration
- Tidal volume is the volume of air moved in and out of the lungs with a normal breath.



Surface Area to Volume Ratio

- The greater the size of an organism, the smaller its surface area: volume ratio
- Larger organisms therefore require specialised exchange surfaces and transport mechanisms to meet their metabolic requirements

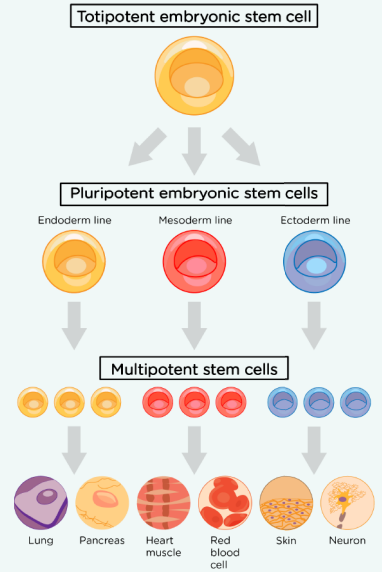


- Specalised exchange surface have: a large surface area, thin barriers and associated transport systems to maintain a steep diffusion gradient.
- Also, organisms with a higher metabolic rate require more nutrients and produce more waste, therefore require a specialised exchange surface

Stem Cells

- Stem cells are undifferentiated cells that are able to express all of their genes and divide by mitosis.
- During development, the stem cells undergo cell differentiation. This is the process by which cells become specialised for different functions.
- Fully developed cells are unable to divide by mitosis.

Stem Cell	Ability
Totipotent	Can divide and differentiate into any type of cell.
Pluripotent	Can self-renew and differentiate into any type of cell except the cells that make up the placenta.
Multipotent	Can only differentiate and divide into a limited number of cell types
Unipotent	Can only differentiate into a single type of cell e.g. cardiomyoblasts can only differentiate into cardiomyocytes.



- Totipotent stem cells are only present in mammals in the first few cell divisions of an embryo. During development, totipotent cells become specialised by expressing different genes and producing different proteins.
- Induced pluripotent stem cells are unipotent stem cells that have been reprogrammed to become pluripotent by using protein transcription factors to express genes associated with pluripotency.
- Pluripotent stem cells can be used to replace cells and treat human disorders like leukaemia and diabetes.
- Bone marrow stem cells can differentiate into any type of blood cell
- Meristem cells in plants are involved in the production of new xylem and phloem tissue

MASS TRANSPORT & THE HEART
CHEAT SHEET

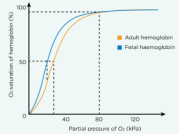
SNAPREVISE

Mass Transport in Animals

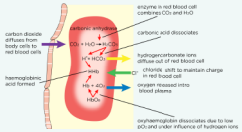
- Red blood cells transport oxygen using the protein haemoglobin

$$\text{oxygen} + \text{haemoglobin} \underset{\text{DISSOCIATION}}{\overset{\text{ASSOCIATION}}{\rightleftharpoons}} \text{oxyhaemoglobin}$$

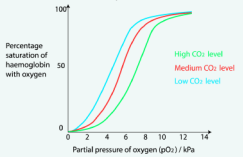
- Haemoglobin is made up of four polypeptide chains, each containing a prosthetic haem group. Each haem group binds one oxygen molecule
- Haemoglobin saturation depends on the partial pressure of oxygen (pO_2). Binding of the first O_2 molecule causes a conformational change in the haemoglobin, making the haem groups more accessible to oxygen.
- Fetal haemoglobin has a higher oxygen affinity than adult haemoglobin because fetal haemoglobin must be able to bind oxygen from adult haemoglobin in the placenta.



- Carbon dioxide is transported in the blood for release from the lungs.
  - 5% of the carbon dioxide transported is dissolved in the blood plasma
  - 10% of the carbon dioxide transported is combined with haemoglobin to form carbaminohaemoglobin
  - 85% is transported as hydrogencarbonate ions (HCO_3^-) dissolved in blood plasma

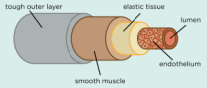


- Bohr affect — haemoglobin's oxygen binding affinity is inversely related to the concentration of carbon dioxide, causing the oxygen dissociation curve to shift



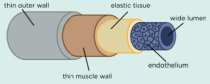
- A good transport system has
  - A fluid medium to transport substances
  - A pump to create pressure for the circulation of the transport fluid
  - Exchange surfaces
- An open circulatory system is one in which the blood is not held in vessels e.g. in insects.
- A close circulatory system the blood is contained within vessels.
- A single circulatory system the blood flows through the heart once for each circuit of the body.
- A double circulatory system blood within double circulatory systems flows through the heart twice for each circuit of the body
- Circulatory system:

Arteries & Arterioles
transports blood away from the heart

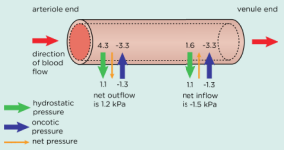


Capillaries — area of metabolic substance exchange

Veins and Venules
transports blood towards from the heart

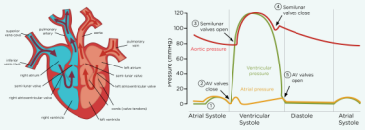


Tissue fluid

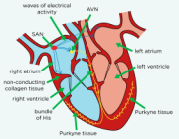


Tissue fluid formation:
Arteriole: Hydrostatic pressure > oncotic pressure, so fluid moves out
Venule: Hydrostatic pressure < oncotic pressure, so fluid moves in
Remaining fluid returns to circulation via the lymphatics system

The Heart



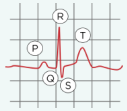
- The cardiac cycle is the sequence of events that occur within one full beat of the heart.
- Systole is the contraction stage and diastole is the relaxation stage
- Cardiac muscle is myogenic, meaning it can contract and relax without receiving signals from the nervous system
- The sinoatrial node (SAN) sends out regular waves of electrical activity to the left & right atrial wall causing contraction. The electrical waves are then passed onto the atrioventricular node (AVN), then to the bundle of His, with a slight delay. The bundle of His splits into the Purkynge tissue, causing contraction of the left & right ventricles from the bottom up.



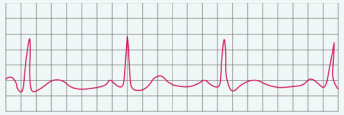
- The rate at which the SAN fires is controlled unconsciously by the medulla oblongata in the autonomic nervous system

Stimulus	Receptor	Effect
High blood pressure	Baroreceptors in the aorta & carotid arteries	Medulla sends impulses along parasympathetic neurones, using acetylcholine to reduce the heart rate
Low blood pressure		Medulla sends impulses along sympathetic neurones, using noradrenaline to increase the heart rate
High blood O_2, pH or low CO_2	Chemoreceptors in the aorta, carotid arteries & medulla	Medulla sends impulses along parasympathetic neurones, using acetylcholine to reduce the heart rate
Low blood O_2, pH or high CO_2		Medulla sends impulses along sympathetic neurones, using noradrenaline to increase the heart rate

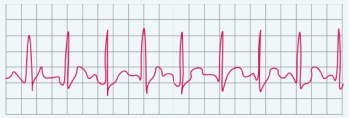
- ECGs can detect the electrical signals through the skin
  - P wave shows atrial systole
  - QRS complex shows ventricular contraction
  - T wave shows diastole



- Bradycardia — slow heart rate:

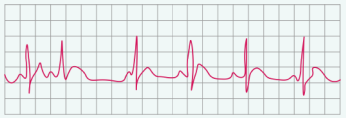


- Tachycardia — fast heart rate:



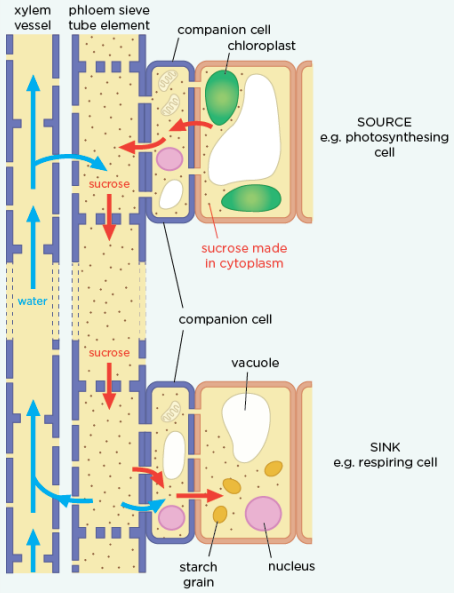
- Atrial fibrillation — atria beats more rapidly than the ventricles:

- Ectopia — irregular heartbeat:



The Phloem

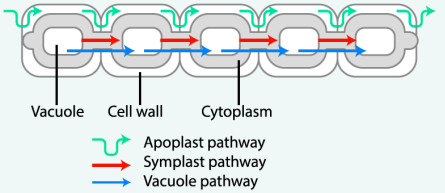
- The phloem transports assimilates from sources to sinks via translocation



- Sucrose is actively transported into the companion cells and moves via diffusion into the sieve tube followed by water. Assimilates move from area of high to low pressure (mass flow). At the sink the solutes are removed, water leaving by osmosis.

Water Transport in Plants

- Water moves through plant tissue via 3 pathways:



- The xylem transports water & mineral ions up the plant against gravity. It is made of dead cells and lignified.
- Water evaporates from the leaves creating tension (transpiration), and the cohesive nature of water moves the whole column of water up the xylem (cohesion-tension theory)
- Water moves up the xylem due to capillary actin, root pressure and transpiration pull
- The rate of transpiration is affected by: light, temperature, humidity & wind.
- Xerophytes are plants adapted to living in dry conditions. They can reduce water loss by having: hairs, waxy cuticle, small leaves, sunken stomata, rolled leaves.
- Hydrophytes are plants adapted to living in water. Their adaptations include: stomata on the upper epidermis, using hydathodes, large air spaces for buoyancy and oxygen diffusion.

DISEASE & IMMUNITY
CHEAT SHEET

SNAPREVISE

Disease

- Communicable disease are caused by pathogens (viruses, bacteria, fungi & protoctista) and can be transmitted from one person to another. They are infectious.
- Pathogens can be transmitted directly (e.g. physical contact, ingestion, droplet infection) or indirectly (e.g. via vectors)
- Bacteria are prokaryotes that can usually damage cells directly or release toxins
- Protoctists are unicellular eukaryotic organisms, which can produce sexually and asexually
- Fungi are eukaryotic organism which cannot photosynthesis therefore are parasties
- Viruses are acellular, non-living particles, they can only replicate inside living host cells where they hijack the host machinery to replicate and then burst the cell to be released.

Disease	Pathogen	Description
HIV/AIDs	Virus	Attacks immune cells
Influenza	Virus	Attack mucous membrane in the respiratory system
Tobacco mosaic virus	Virus	Moult and discolour leaves on tobacco and tomato plants
Ringworm	Fungi	Causes a skin rash in cattle
Athletes foot	Fungi	Causes a rash on the foot of humans
Black Sigatoka	Fungi	Causes leaf spots in banana plants
Blight	Protoctista	Affects potato tubers and tomato and potatoes leaves
Malaria	Protoctista	Blood parasite Plasmodium spread by mosquitos
Tuberculosis	Bacteria	Kills cells and tissues, mainly in the lungs
Bacterial meningitis	Bacteria	Causes swelling of the meninges damaging the brain and nerves
Ring rot	Bacteria	Decays vascular tissue in tomato and potato plants

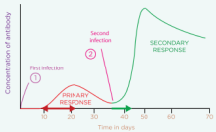
- Autoimmune diseases occur when the immune system mistakenly attacks its own antigens
  - In Arthritis, antibodies attack membranes around the joints
  - In Lupus antibodies attack proteins in the nucleus of cells.

Cell-mediated Immunity

- Antigen from the pathogen is displayed on the cell surface of body cells or phagocytes after phagocytosis
- T cells with the correct specific receptor bind with the antigen and are activated
- They divide by mitosis (clonal expansion) and differentiate into T helper, cytotoxic and memory cells.

Primary & Secondary Response

- The primary immune response is when a pathogen infects the body for the first time the initial immune response is slow
- The secondary immune response is a more rapid and vigorous response caused by a second or subsequent infection by the same pathogens. This is due to the presence of memory cells.

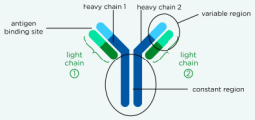


Components of the Immune System

- Antigens are any part of an organism/substance which is recognised as foreign by the immune system and goes on to trigger an immune response.

Cell		Function
Phagocytes	Macrophages	Engulfs and digests pathogens by fusion of the phagosome with lysosomes
	Neutrophils	
T cells	T helper cells	Stimulates B cells to divide and secrete antibodies
	Cytotoxic T cells	kill abnormal cells and infected body cells via perforin
	T memory cell	Remain in the blood for years and provide long term protection
B cells	Plasma cell	Secrete antibodies
	B memory cell	Remain in the blood for years and provide long term protection

- Antibodies are a protein produced by lymphocytes in response to the presence of the corresponding antigen.
- Antibodies agglutinate pathogens by forming antigen-antibody complexes, leading to phagocytosis & neutralise toxins.



Defences

- Human primary defences include:
  - The skin acting as a barrier
  - Blood clotting and skin repair
  - Mucous membranes
  - Coughing and sneezing
  - inflammation
- Plant passive defences include:
  - Cellulose barrier
  - Lignin
  - Waxy cuticle
  - Bark
  - Callose blocking flow in sieve tubes
- Plant active defences include:
  - Deposit callose
  - Close stomata
  - Add cellulose
  - Induce cell necrosis
  - Increase the number of oxidative bursts
  - Produce chemical defences

Chemical	Action
Phenols	Antibiotic and antifungal proteins. One example is the tannins present in tree bark
Alkaloids	Compounds containing nitrogen (e.g. caffeine, nicotine, cocaine and morphine) are bitter to stop herbivores feeding on them and affect enzyme action.
Defensins	These cysteine-rich, defensive proteins have anti-microbial activity. They appear to affect the functioning of ion transport channels in the plasma membrane.
Hydrolytic enzymes	Present in the spaces between cells, they can have a variety of effects. Chitinases break down the chitin in fungal cell walls, glucanases hydrolyse the glycosidic bonds in glucans, and lysozymes destroy bacterial cell walls.

Humoral immunity

- The humoral response is best at fighting pathogens which are free in the bodily fluids
- Free antigen binds to a complementary B cell receptor, activating the B cell (clonal selection)
- The pathogen is endocytosed, and the antigen presented on the plasma membrane
- T helper cell binds to the presented antigen and stimulates the B cell to divide by mitosis (clonal expansion)
- The B cell differentiates to plasma and memory cells

Vaccination & Medicines

- Vaccination is the introduction into the body of a vaccine containing disease antigens, by injection or mouth, in order to induce artificial immunity
- Vaccines work by injecting weakened/dead pathogens into the body to stimulate an immune response, to form memory cells against the specific antigen, which destroy the pathogen quickly upon infection.
- Herd immunity is when the vaccination of a significant proportion of the population provides protection for individuals who have not developed immunity
- Pathogen may mutate so that its antigens change suddenly (antigenic variability) So the vaccine is now ineffective to the new antigens.
- Ethical considerations: side effects, financial cost, right to choose, animal testing of vaccines, human trials
- Active immunity occurs when specific antibodies are produced by the individual's own immune system
- Passive immunity occurs when specific antibodies are introduced to the individual from an outside source.

Immunity	Example
Natural Active	Direct contact with pathogen
Natural Passive	Antibodies through breastmilk
Artificial Active	Vaccination
Artificial Passive	Injection of antibodies

- Antibiotics prevent the growth of bacteria. They are effective because they show specificity in killing bacteria without harming human cells. However, overuse has led to the spread of resistance in bacteria e.g. MRSA. To reduce spread prescription of antibiotics is controlled, patients must finish their course and prevent spread by control measures
- New medicines can be discovered from plant compounds using DNA sequencing to screen plants and organisms for potential medical compounds. DNA sequencing can also be used to develop a specific drug suited to persons genome.

BIODIVERSITY, CLASSIFICATION & NATURAL SELECTION
CHEAT SHEET

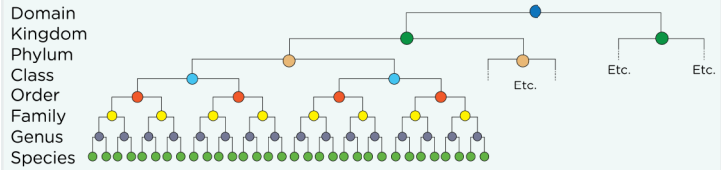
SNAPREVISE

Biodiversity

- Biodiversity is the variety of organisms in an area. It can be considered on different levels including habitat, species and genetic diversity of an area
- Habitat diversity refers to the range of habitats present in a region
- Species diversity is the number of species and the number of individuals within each species in a specified area. It takes into account species richness and species evenness.
- Species richness is a measure of the number of different species in a community.
- Species evenness is a measure of the relative abundances of different species in an area.
- Genetic diversity is the variety of all the genes (number of different alleles of genes) possessed by the individuals in a population or whole species
- Alleles are different forms of the same gene
- The greater the genetic diversity, the greater the ability of the species to adapt to a changing environment.
- Genetic diversity can be estimated by comparing physical characteristics or by analysing genomes.
- Species with a greater number of polymorphic genes tend to have greater genetic diversity
- $\textbf{Genetic Diversity} = \frac{\textbf{no.of loci with more than one allele}}{\textbf{total no.of loci}} \times 100$
- Simpson's diversity index (D) measure biodiversity taking into account species richness and evenness .
- $D = 1 - \left(\sum \left(\frac{n}{N}\right)^2\right)$
  - N = total number of organisms of all species
  - n = total number of organisms of each species
- Factors affecting biodiversity include:
  - Human population growth increases the demand for resources from the environment
  - Agriculture reduces biodiversity by monoculture, use of herbicide & pesticides, hedgerow removal and woodland clearance
  - Climate change is causing animals to migrate or die
- Reasons for maintaining biodiversity can be:
  - Ecological — ecosystems are more stable when biodiversity is high. Keystone species are a species which has a disproportionate effect on its environment relative to its abundance, their removal will greatly reduce the ability of an ecosystem to function
  - Economical — provides resources
  - Aesthetic
  - Ethical
- Conservationists protect biodiversity with methods such as: giving endangered species legal protection, creating protected area & The Environmental Stewardship Scheme.
- A balance between conservation and agriculture is needed.

Classification

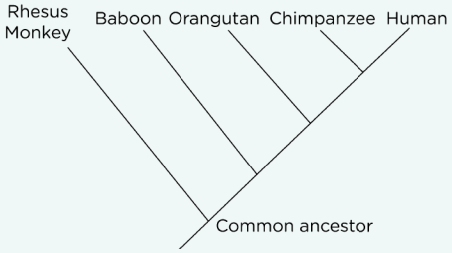
- The Biological Species Concept- a species contains all organisms that are capable of breeding together to produce living, fertile offspring.
- Classification is the process of sorting living things into groups.
- Classification hierarchy comprises the taxa: domain, kingdom, phylum, class, order, family, genus and species.



- Classifications are constantly updated as new methods are discovered to infer relationships e.g. physical characteristics to DNA sequencing, amino acid sequencing or cytochrome C comparisons.

Animalia	Animals are eukaryotic, multicellular, heterotrophic and usually able to move around
Plantae	Plants are eukaryotic, autotrophic, multicellular, have a cellulose cell wall, and contain chlorophyll
Fungi	Fungi are eukaryotic, single-celled or multicellular, saprophytic, have a chitin cell wall and a multinucleate cytoplasm
Protoctista	Protoctists are eukaryotic, mostly free living, single-celled or multicellular, autotrophic or heterotrophic,
Prokaryotae	Prokaryotes have smaller ribosomes, a naked loop of DNA, free living or parasitic, no nucleus or no other membrane bound organelles,

- The binomial naming system names species by their genus and species name.
- Phylogeny is the study of evolutionary relationships between organisms.
- In a phylogenetic diagram, branch tips represent species at the end of their specific lineage, branching points represent common ancestors & The closer the branches, the closer the evolutionary relationship.



Natural Selection

- Predation, disease and competition means that not all individuals within a population survive to get a chance to reproduce. This differential survival and reproduction is the process by which natural selection acts.
  Genetic variation within a population creates intraspecific competition. The organisms with phenotypes that provides a selective advantage are more likely to survive and reproduce and thus pass on their favourable alleles to the next generation. This means that the proportional of individuals with the favourable allele will increase in the next generation (increase the allele frequency) within the population. This is evolution by natural selection.
- Evolution is the change in allele frequencies in a population over time.
- An adaptation is a trait that enhances survival in a habitat
  - Anatomical adaptations are structural features e.g. roots with a large surface area
  - Behavioural adaptations e.g. hibernation
  - Physiological adaptations are changes to cellular processes e.g. fight or flight adrenaline response
- Convergent evolution occurs when organisms that live in similar conditions are subject to the same selection pressures, resulting in similar adaptations
- Evidence for the theory of natural selection comes from the fossil record and biological molecules, including mDNA
- Evolution by natural selection has resulted in antibiotic resistance bacteria and pesticide resistance in insects

Variation

- Interspecific variation is the differences between any two species
- Intraspecific variation is the differences between members of the same species
- Characteristics that show continuous variation are normally polygenic (determined by many gene loci that have additive effects on each other).
- Characteristics that show discontinuous variation are usually monogenic (determined by a single gene loci).
- Variation is due to genetic and environmental factors.
- The main source of genetic variation is mutations, which can produce different alleles of genes.
- Further sources of genetic variation include meiosis (independent assortment and crossing over) and the random fertilisation of gametes during sexual reproduction to create new allele combinations.
- The environment can influence the way an organism's genes are expressed. This can be because of biological factors such as predators or non-biological factors such as sunlight.

HOMEOSTASIS & EXCRETION
CHEAT SHEET

SNAPREVISE

Communication Systems

- The neuronal system uses neurones to carry signals very rapidly through the body to produce short-term responses
- The hormonal system uses blood to carry hormones from endocrine glands to target cell with the specific receptors. This usually produces long-term responses.
  - Peptide hormones are made of amino acids and must bind to receptors on the cell surface, activating second messengers which control transcription.
  - Steroid hormones are formed from lipids and soluble in the plasma membrane, therefore entering cells and binding to proteins to enter the nucleus and have an effect on the DNA.

Homeostasis

- Homeostasis is the maintenance of a constant internal environment despite internal or external changes.

Stimulus → Receptor → Co-ordinator → Effector → Response

- Receptors detect a change; coordinators transmit the information and effectors bring about a response
- Negative feedback is the body's mechanism for reversing a change so that it returns back to the optimum.:
- Positive feedback is a deviation from the optimum which causes changes resulting in an even greater deviation from the norm. This is usually harmful due to the large, unstable change in the body.

Kidney Failure

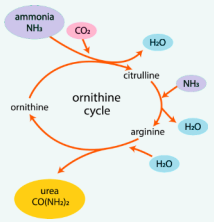
- Kidney failure hypertension, diabetes, infection or heart disease
- Kidney failure can be assessed by measuring the glomerular filtration rate, which is the volume (cm^3) of fluid passing into the nephrons every minute.
- One treatment is renal dialysis, which is a mechanism utilised to artificially regulate the concentrations of solutes in the blood
  - Haemodialysis — blood is removed and passed through a machine containing an artificial dialysis membrane, which allows countercurrent substance exchange. Heparin stops blood clots.,
  - Peritoneal dialysis — dialysis fluid is inserted into the abdomen; exchange occurs across the peritoneum.
- Kidney transplant can treat kidney failure but requires the use of immunosuppressants because of the risk of rejection.
- Pregnancy tests work by detecting the hormone human chorionic gonadotrophin (hCG) in urine.
- Coloured monoclonal antibodies complementary to hCG form a complex. Which moves up the strip and binds to immobilised antibodies complementary to hCG resulting in the presence of a blue line, indicating pregnancy.

Control of Temperature

- Internal body temperature needs to be regulated to ensure reactions can happen as efficiently as possible without denaturation of proteins.
- Ectotherms are organisms that rely on external sources of heat to regulate its body temperature
  - If its too cold, they can move into the sun, move to a warm surface or expose more surface area to the sun
  - If its too hot, they can, move into the shade, move underground or expose less surface area to the sun
- Endotherms are organisms that rely on metabolic reactions to regulate its body temperature
  - If its too cold, they can shiver, increase respiration rate, vasoconstrict and erect hairs or feathers
  - If its too hot, they can sweat, pant, vasodilate.
- Endotherms can be active in colder habitats however they need more food and use more energy than ectotherms.

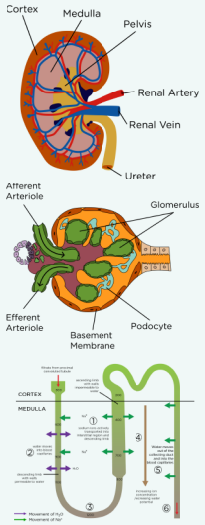
amino acid + oxygen ⟶ keto acid + ammonia

(DEAMINATION REACTION)



The Role of the Kidneys in Osmoregulation

- Osmoregulation is maintaining a constant water potential of the blood, despite changes in the level of water and salt intake.
- The kidneys are made if nephrons which help filter the blood. The blood undergoes ultrafiltration at the glomerulus due to the smaller diameter of the efferent arteriole than the afferent arteriole, creating high hydrostatic pressure.
- The filtrate passes into the Bowman's capsule and travels around the entire nephron, where certain ions and water are reabsorbed into the blood whilst the remaining filtrate is excreted as urine.
- Sodium is actively transported out of the proximal convoluted tubule and into the blood
- Glucose & amino acids are co-transported out of the proximal convoluted tubule via sodium ions diffusing into the epithelial cells.

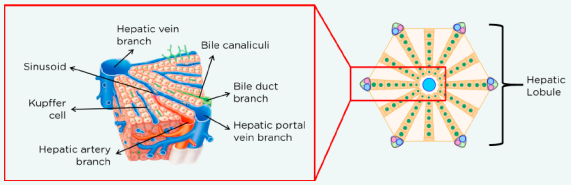


The Role of the Hypothalamus in Osmoregulation

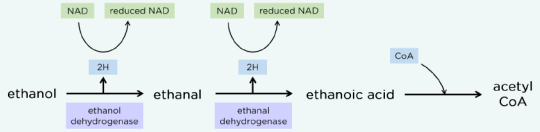
- The hypothalamus contains osmoreceptors which signal to specialised neurosecretory cells. A fall in water potential causes the release of antidiuretic hormone (ADH) from the posterior pituitary gland.
- ADH travels in the blood to the kidneys, attaching to ADH receptors, activating the intracellular enzyme phosphorylase. This causes vesicles containing aquaporins to fuse with the plasma membrane, reducing water loss by increasing the permeability of the collecting duct and distal convoluted tubule.

Excretion & The Liver

- Excretion is the removal of metabolic waste products from the body
- The main waste products are carbon dioxide, bile pigments and nitrogen containing compounds
- Amino acids are deaminated, so the keto acid can be used in respiration, while the toxic amino group can be excreted as urea
- The liver has three main blood vessels
  - Hepatic artery — carries oxygenated blood from the heart to the liver
  - Hepatic portal vein carries deoxygenated blood from the small intestine to the liver
  - Hepatic vein carries deoxygenated blood away from the liver to the heart
- Hepatocytes remove excess substances and wastes, and secrete substances back into the blood to maintain their concentration within it, while it travels down the sinusoids
- Bile travels down the bile canaliculi to the gall bladder.



- Kupffer cells are present within the sinusoids to protect the liver from disease and break down red blood cells.
- Other liver functions include:
  - Glycogen storage
  - Detoxification e.g. catalase breaks down hydrogen peroxide to water and oxygen. Cytochrome P450 breaks down drugs
  - Detoxification of alcohol



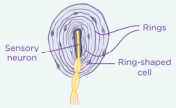
- Excessive alcohol consumption can lead to cirrhosis as NAD is used to detoxify alcohol instead of breaking down fatty acids, which are stored as lipids in hepatocytes.

RECEPTORS, NEURONES, SYNAPSES & THE ENDOCRINE SYSTEM
CHEAT SHEET

SNAPREVISE

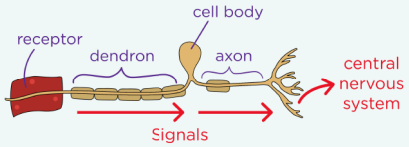
Receptors

- Sensory receptors are specialised cells in the nervous system that detect physical stimuli and convert them into electrical signals (the generator potential)
- Sensory receptors tend to be specific to one type of stimulus because they have specialised structures that are specific to one type of physical property
- Pacinian corpuscles detect changes in pressure in the skin.
- Increases in pressure cause a deformation of the concentric rings of the Pacinian corpuscle, opening stretch-mediated sodium channels in the membrane. Sodium ions enter the sensory neuron, causing a generator potential which can trigger an action potential

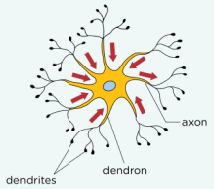


Neurones & The Resting Potential

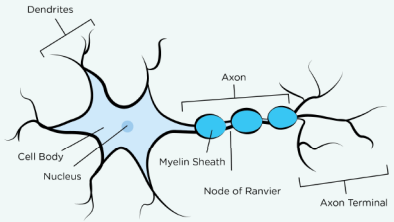
- Sensory neurons transmit information from sensory receptors to the CNS



- Relay neurons carry electrical signals from sensor neurones to motor neurones.



- A myelinated motor neurone transmit information to effectors.



- The resting potential is the difference in electrical charge across the membrane while the neurone is at rest
- The sodium-potassium pump uses ATP to pump 3 sodium (Na^+) ions out of the cell and 2 potassium (K^+) ions into the cell. The membrane is permeable to K^+ but impermeable to Na^+ ions. These factors allow an electrochemical gradient to be set up, with the cell negatively charged at -70mV.

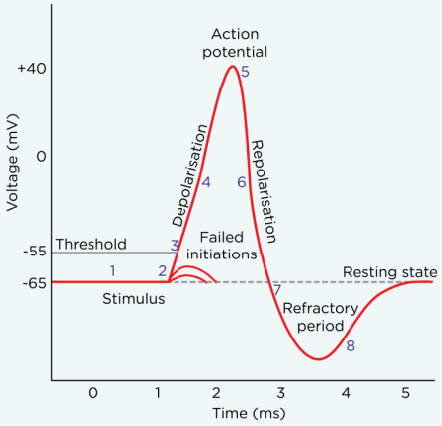
Transmission of Action Potentials

- Action potential are transmitted in non-myelinated axons because when a depolarisation happens, it causes voltage-gated sodium channels to open further down the axon. By the time the depolarisation has spread, part of the axon is repolarising
- In myelinated axons, action potentials only occur at the nodes of Ranvier, with charge diffusing along the cell where myelin is present (saltatory conduction).
- Factors affecting transmission speed:

	Faster	Slower
Myelination	Myelinated	Unmyelinated
Axon Diameter	Wider	Narrower
Temperature	Warmer (Until Denaturing)	Colder

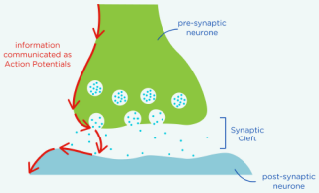
Action Potentials

- When the neurone receives an impulse from sensory receptors, sodium channels on the dendrites open, leading to the movement of Na^+ ions into the cell causing depolarisation. If this depolarisation reaches the threshold potential it activates voltage-gated sodium channels causing an action potential. After Voltage-gated sodium ion channels close, and voltage-gated potassium channels open, causing Repolarisation as K^+ ions leave the cell. Outward diffusion of K^+ ions causes hyperpolarisation and the voltage-gated potassium channels close. Finally, the Sodium-potassium pump returns the cell to the resting membrane potential.



- Action potentials are an all or nothing response because once the threshold is reached each action potential always depolarises the axon to the same voltage by voltage-gated sodium channels.
- The refractory period is the period in an action potential where the axon can't be depolarised to initiate a new action potential. It limits the frequency of action potentials and ensures action potential are discrete & only travel in one direction.

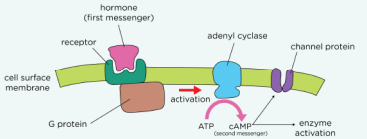
Cholinergic Synapse



- Structure of a synapse:
- At a cholinergic synapse (acetylcholine is the neurotransmitter), an action potential arrives at the pre-synaptic knob, depolarising the membrane and causes voltage-gated calcium ion channels to open. The influx of Ca^{2+} ions causes the synaptic vesicles to fuse with the membrane, releasing the neurotransmitter into the synaptic cleft. The neurotransmitter diffuses and binds receptors on the post synaptic membrane, causing an action potential.
- Acetylcholinesterase breaks down acetyl choline in the cleft.
- The synapses can be excitatory if the neurotransmitter opens Na^+ channels or inhibitory if the neurotransmitter opens chloride or potassium channels causing hyperpolarisation.
- Spatial summation is when action potentials from multiple presynaptic neurones are added together in a post-synaptic neurone
- Temporal summation is when multiple action potentials from a single presynaptic neurone are added together in a post-synaptic neurone over time.

The Endocrine System

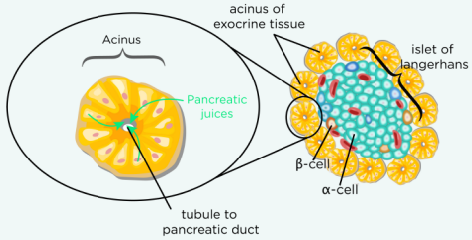
- The endocrine system is a communication system that uses hormones as signalling molecules
- Hormones only affect target cells which have a specific receptor for a given hormone
- Endocrine glands are ductless glands and include the pancreas, pituitary gland, testes and ovaries.
- The adrenal glands are endocrine glands that sit just above the kidney
  - The adrenal medulla is responsible for the secretion of adrenaline
  - The adrenal cortex is made up of the zona glomerulosa, the zona fasciculata and the zona reticularis
- The zona glomerulosa secretes mineralocorticoids involved in controlling the levels of Na+ and k+ in the blood. E.g. aldosterone increases Na+ absorption and decreases k+ absorption via the distal tubules and collecting ducts in the kidney
- The zona fasciculata secretes glucocorticoids hormones which control the metabolism of different respiratory substrates in the body e.g. cortisol stimulates glucose production from glycogen
- The zona reticularis can secrete cortisol and precursor androgens which are converted to sex hormones
- Adrenaline is a peptide hormone and activates G-proteins, which usually activates cAMP as a second messenger.



BLOOD GLUCOSE, PLANT RESPONSES & THE NERVOUS SYSTEM
CHEAT SHEET

SNAPREVISE

Control of Blood Glucose Concentration



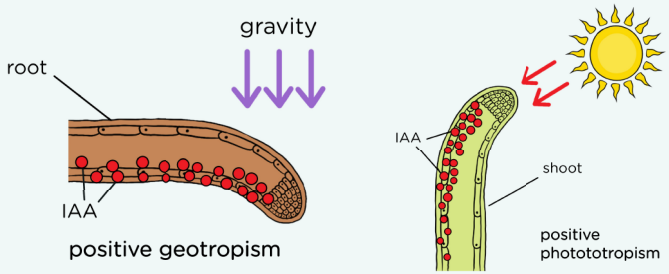
- The pancreas acts as an exocrine gland by synthesising and secreting pancreatic juices (lipase, amylase, trypsinogen, NaOH) within acini. It also acts as an endocrine gland by synthesising and secreting hormones into blood vessels.
- Cells within islets of Langerhans monitor blood glucose concentration
- Insulin is a hormone released from β-cells in the pancreas when blood glucose concentration rises in order to lower the concentration back to its optimum via negative feedback.
- Mechanism of insulin release:
  - At rest in β-cells, K^+ channels are open, resulting in a negative resting potential.
  - When glucose concentration rises, glucose diffuses into the cell and is phosphorylated. It is converted to ATP via respiration causing k+ channels to close and Ca^{2+} open. The Ca^{2+} causes vesicle of insulin to be exocytosed.
- When insulin binds to an insulin receptor, tyrosine kinase is activated which phosphorylates enzymes. The cascade of enzyme controlled intracellular reactions results in vesicles of glucose transporters fuse with the plasma membrane to allow more glucose to enter the cell. The cell also uses more glucose in respiration and activated enzymes covert glucose into glycogen (glycogenesis).
- Glucagon is a hormone released from α-cells in the pancreas in response to low glucose concentration in order to increase the concentration back to its optimum. Binding of glucagon to its receptor activates G proteins and adenyl cyclase, resulting in increased level of cAMP. It return glucose concentration back to its optimum by:
  - Activating enzymes which break down glycogen into glucose (glycogenesis).
  - Producing glucose from other molecules
  - Activating enzymes that convert glycerol (from lipids) and amino acids into glucose (gluconeogenesis)

Diabetes

- Diabetes is a condition where the concentration of glucose in the blood cannot be controlled effectively. It can lead to hyperglycaemia after meals and hypoglycaemia after exercising.
- Type 1 diabetes is caused by an autoimmune attack on the β-cells of the pancreas, so the body cannot produce insulin. It can be treated by insulin injections.
- Type 2 diabetes is caused because the body does not produce enough insulin & the insulin receptors become less responsive. It can be treated by lifestyle changes (losing weight & exercising), drugs to stimulate insulin production and reduce glucose absorption and insulin injections in severe cases.

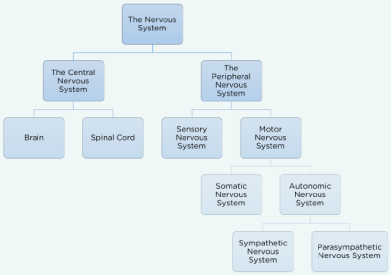
Plant Responses & Hormones

- All multicellular organisms need to respond to changes in their environment (stimuli) in order to survive
- Tropisms are a directional growth response in plants, in which the direction of the response is determined by the direction of the external stimulus e.g. phototropism, geotropism, chemotropism & thigomotropism
- Growth only occurs at the meristems.
  - The apical meristem is at the tip of the roots and shoots
  - The lateral bud meristem is present in buds and gives rise to side shoots
  - The lateral meristem forms a cylinder outside the roots and shoots and are responsible for the widening of the roots and shoots
  - Intercalary meristems are between nodes and cause shoot elongation
- Plants respond to directional stimuli using specific hormones, which move to regions where they are needed from growing regions
- Auxins causes elongation of shoot cells, while it also inhibits root cell elongation in order to cause positive geotropism & phototropism.



- Auxins cause protons to be actively transported into spaces in the cell wall, activating expansins which loosen cellulose in the cell wall. Increasing plasticity of the cell wall for elongation.
- Cytokinins delay leaf senescence. Can also be used commercially in tissue culture to promote bud and shoot growth.
- Abscisic acid causes stomatal closure when there is low water availability. It also inhibits seed germination and growth
- Gibberellins cause stem elongation and seed germination. Commercially it can be used in fruit production by elongating the stem, also used to induce seed formation and barley seed germination
- Ethene is used commercially to promote fruit drop and ripening
- Auxins also promote elongation, inhibit side-shoot growth (apical dominance) and inhibit leaf abscission. Can be used commercially to prevent fruit drop, produce seedless fruits, as a herbicide and encourage root growth.

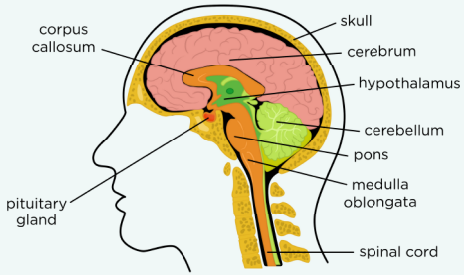
The Nervous System



- The central nervous system is the central part of the nervous system is composed of the brain and spinal cord.
- The peripheral nervous system is made up of sensory and motor nerves connecting the sensory receptors and effectors to the CNS
- The somatic nervous system voluntarily controls skeletal muscle
- The autonomic nervous system controls unconscious activities including heart rate, smooth muscle in the digestive system, airways and glands.
- The sympathetic system is active when the body is under physical or psychological stress. Many sympathetic nerves leave the spinal cord and they don't have to split as much
- The parasympathetic system is active under normal conditions of rest and conserves energy. Only a few parasympathetic nerves leave the spinal cord. These split so that they contact multiple effectors

	Sympathetic System	Parasympathetic System
Neurone Structure	Short pre-ganglionic neurones Long post-ganglionic neurones	Long pre-ganglionic neurones Short post-ganglionic neurones in the effector
Neurotransmitter	Noradrenalin	Acetylcholine
Heart Rate	Increases	Decreases
Pupil Diameter	Increases	Decreases
Digestive System	Decreases activity	Increases activity

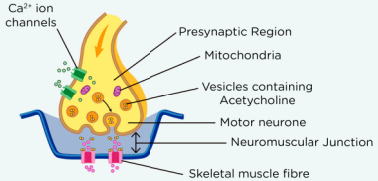
- The medulla oblongata controls cardiac and smooth muscles via the autonomic nervous system. E.g. respiratory, cardiac and vasomotor centres.
- The hypothalamus and pituitary gland control various bodily functions and homeostatic mechanisms. E.g. it controls water potential and temperature
- The cerebrum carries out the higher brain functions such as thought, language, vision, emotional responses and factual memory.
- The cerebellum control balance and fine motor movements. It stores the detailed information about how to carry out the movement which is updated by practice and learning.



MUSCLES & PHOTOSYNTHESIS
CHEAT SHEET

SNAPREVISE

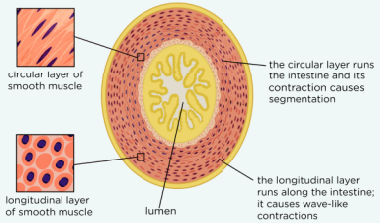
Neuromuscular Junction



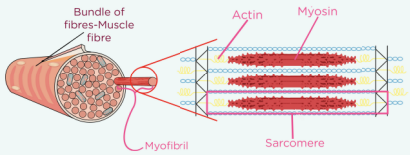
- Structure of the neuromuscular junction:
- When an action potential reaches the junction, voltage-gated calcium channels open, causing calcium ions to diffuse into the neurone. Synaptic vessels to fuse with the presynaptic membrane and release acetylcholine into the synapse. It diffuses across the synapse and binds with receptors on the muscle cell surface membrane, opening sodium channels. The muscle fibre depolarisation causes an action potential and muscle contraction.
- Acetylcholinesterase breaks down acetyl choline
- Neuromuscular junction & cholinergic synapse differences

Neuromuscular Junction	Cholinergic Synapse
Only excitatory	Can be excitatory or inhibitory
Links neurones to muscle	Links either neurones to neurones or neurones to other effectors
The action potential ends here	Another action potential may be generated along the post-synaptic neurones
Only motor neurones are involved	Intermediate, motor and sensory neurones may be involved
Acetylcholine binds to receptors on the membrane of the muscle fibre	Acetylcholine binds to receptors on membrane of post-synaptic neurone

Muscles

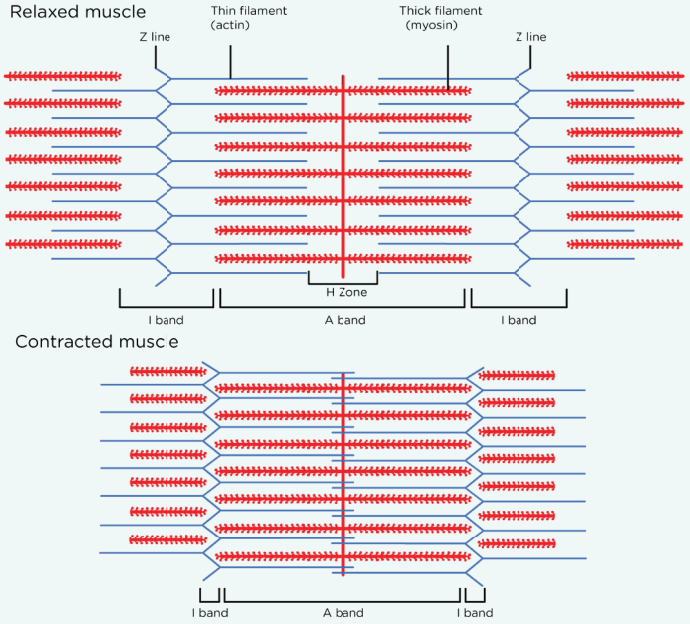


- Cardiac muscle cells are myogenic, joined by intercalated discs and form branches to allow electrical stimulation to spread evenly. It can contract powerfully without fatiguing.
- Smooth muscle contracts slowly and regularly and is controlled by the autonomic nervous system.
- Skeletal muscles act in antagonistic pairs against an incompressible skeleton to allow movement
- Skeletal muscle is made up of fibres called myofibrils, which in turn are made up of many repeating units, called sarcomeres
- Myofibrils are made up of two types of protein filaments, the thinner actin and the thicker myosin

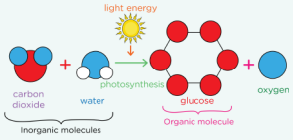


Muscle Contraction

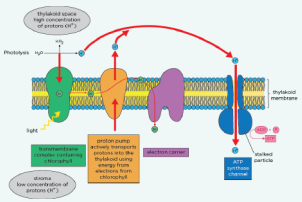
- The sliding filament theory describes how muscle contraction occurs
- An action potential travels into the muscle fibre via T tubules, causing release of calcium ions from the sarcoplasmic reticulum. The calcium ions bind to the tropomyosin molecules and cause them to move, exposing the myosin binding site on the actin filament. Myosin attaches to actin forming a actin-myosin cross-bridge. ATPases hydrolyse ATP to detach the myosin head, allowing reattachment at a further site. This cycle continues, causing sarcomeres to shorten.
- When nervous stimulation stops, Ca^{2+} ions are actively transported back into the sarcoplasmic reticulum using energy from ATP hydrolysis. This allows tropomyosin to block the actin filament from binding to myosin and muscle contraction stops.
- ATP can be generation via aerobic or anaerobic respiration
- Phosphocreatine generates ATP quickly by adding phosphate to a molecule of ADP released by the contracting muscle



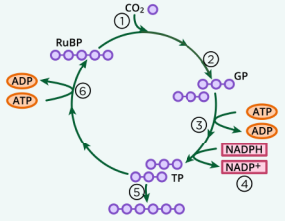
Photosynthesis



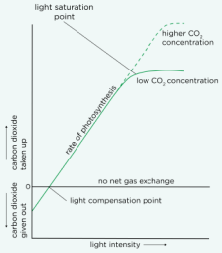
- Photosynthesis is the process in plants, from which energy from sunlight is used to convert inorganic molecules into organic molecules.
- The light-dependent reaction occurs in the thylakoids of the grana in chloroplasts
  - Photolysis of water requires light energy to break the bonds between oxygen and hydrogen atoms
    $$2H_2O \rightarrow 4H^+ + 4e^- + O_2$$
  - Chlorophyll molecules absorb light energy via photosystem II, exciting a pair of electrons to a higher energy level, leaving the chlorophyll molecules ionized. The electron passes through an electron transfer chain to produce ATP, and reaches photosystem I.

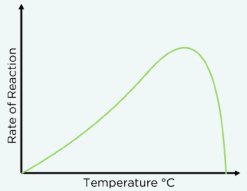


  - The electrons replace the electrons lost in photosystem I when it absorbs light to reduce NADP with the protons created from photolysis
  - The photoionized chlorophylls electrons in photosystem II are replaced by the electrons from photolysis of water
  - Cyclic photophosphorylation only uses photosystem I, where the electrons are passed back to photosystem I rather than NADP via electron carriers, producing small amounts of ATP
- The light-independent reaction occurs in the stroma of chloroplasts
  - The Calvin cycle depends on the products from the light dependant stage
  - The fixation of carbon dioxide is catalysed by RuBisCo
  - 5 out of every 6 TP molecules are used to regenerate RuBP instead of producing hexose sugars



- The rate of photosynthesis is limited by temperature and the availability of carbon dioxide, water & light energy.
- The law of limiting factors states that at any given moment, the rate of a physiological process is limited by the factor that is at its least favourable value.





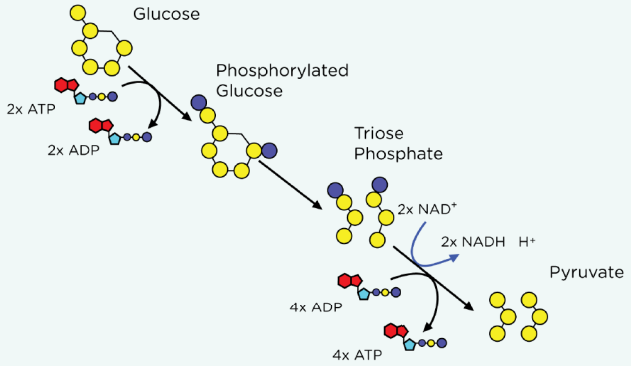
- Chromatography can be used to separate out photosynthetic pigments, identifying them by their R_f value
- $R_f\ value = \frac{Distance\ travelled\ by\ spot}{Distance\ travelled\ by\ solvent}$

RESPIRATION & MUTATIONS
CHEAT SHEET

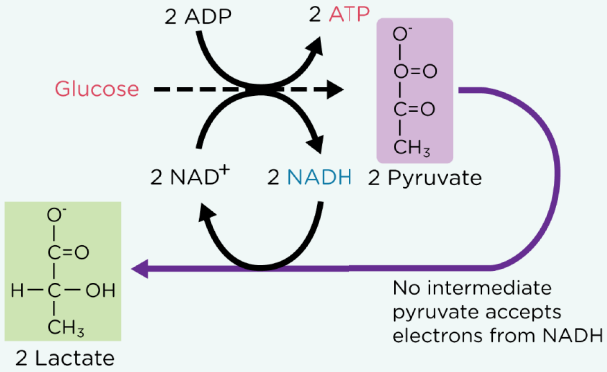
SNAPREVISE

Anaerobic Respiration

- Respiration is the process, which occurs in living cells, that releases energy stored in organic molecules such as glucose.
- The energy released during respiration is used to synthesise molecules of ATP, which can be used as an immediate source of energy.
- The first stage of respiration is glycolysis which occurs in the cytoplasm of cells.
  - There is a net yield of 2 pyruvate, 2 reduced NAD and 2 ATP molecules



- If oxygen is not available as the final electron acceptor, glycolysis can continue in anaerobic respiration.
- Glycolysis can continue if reduce NAD is reoxidised so that NAD is available to accept a hydrogen atom again.
- In mammals, the lactate fermentation pathway is used:

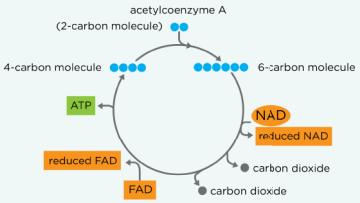


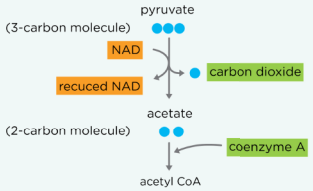
Lactate can be converted to glycogen in the liver or oxidised further to release energy, when oxygen is available.

- In plants and fungi, the ethanol fermentation pathway is used:
  - pyruvate + reduced NAD → ethanol + carbon dioxide + oxidised NAD

Aerobic Respiration

- If respiration is aerobic, pyruvate enters the mitochondrial matrix by active transport.
- Next, the link reaction occurs:
- Following the link reaction, the Krebs cycle occurs.

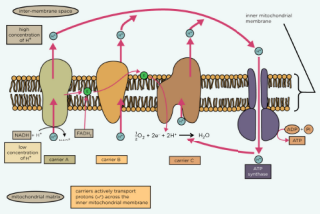




- The final stage of aerobic respiration is oxidative phosphorylation.
- Reduced NAD and FAD donate electrons to the electron transfer chain in the inner mitochondrial membrane. The release of energy as the electrons pass down the electron transfer chain is used to create a proton gradient across the inner mitochondrial membrane into the inter-membranal space. The proton gradient is used to synthesis ATP by oxidative phosphorylation, catalysed by ATP synthase (chemiosmotic theory).
- Oxygen combines with the protons that have diffused through the ATP synthase channel and the electrons that have been passed along the electron transfer chain, acting as the final electron acceptor. It helps maintain the proton gradient for the electron transfer chain to continue.

$$\frac{1}{2}O_2 + 2e^- + 2H+ \rightarrow H_2O$$

- Aerobic respiration produces 32 ATP. 30 more than anaerobic respiration.
- Sugars such as glucose are not the only substances that can be used as a respiratory substrate.
- Lipids release more energy than carbohydrates, due to more carbon-hydrogen bonds



Substrate	Process in respiration
Lipid	Hydrolysed to fatty acids and glycerol. Glycerol is phosphorylated and converted to triose phosphate, which enters the glycolysis pathway The fatty acid part is broken down into 2-carbon fragments which are subsequently converted into acetyl CoA, also generating reduce NAD & FAD
Protein	Protein is hydrolysed to amino acids. In the liver, the amino group is removed (deamination), and the amino group is converted to urea and removed in the urine. The remaining amino acid can then be converted to an intermediate

- The respiratory quotient (RQ) indicates anaerobic respiration is occurring if the value is greater than 1

$$RQ = \frac{CO_2\ produced}{O_2\ produced}$$

Mutations

- Gene mutations are changes to the base sequence or quantity of DNA within a gene or section of DNA.
- Gene mutations occur spontaneously during the process of DNA replication.
- The mutation rate is increased by mutagenic agents, which are chemical, physical or biological agent that causes mutations e.g. UV light

Type of Mutation	Description
Addition	Addition of one or more nucleotides
Deletion	Removal of one or more nucleotides
Substitution	A nucleotide is replaced by a different nucleotide
Inversion	A sequence of bases is separated and then reattached in the inverse order
Duplication	One or multiple bases are repeated
Translocation	A piece of DNA breaks off and doesn't reattach to itself or its homologous pair.

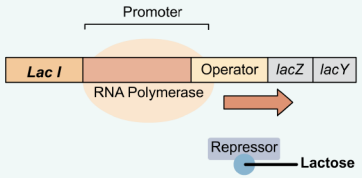
- Some mutations may only affect a single codon, changing a single amino acid in a protein, therefore the protein may remain functional. Other may have no effect on protein structure due to the genetic code being degenerate (silent mutation).
- Mutations such as insertions and deletions can cause frame shifts, changing all the codons and amino acids downstream from the mutation. This results in a unfunctional protein.

GENE REGULATION & THE BODY PLAN
CHEAT SHEET

SNAPREVISE

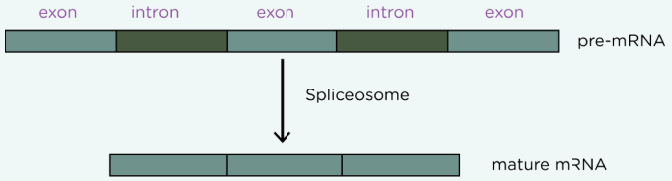
Transcription Factors

- In eukaryotes, transcription of target genes can be regulated by DNA-binding proteins (transcription factors). They can be help RNA polymerase bind (activators) or prevent it binding (repressors).
- In prokaryotes, lactose induces the production of lactose permease and β-galactosidase. Which allows lactose to enter the cell and hydrolyses lactose to glucose and galactose, respectively.
- The lac I gene in the Lac operon codes for a repressor protein, which binds to the operator sequence, preventing RNA polymerase from binding to the promoter. When lactose is present, it bind to the repressor protein, allowing RNA polymerase to carry out transcription of the enzymes.

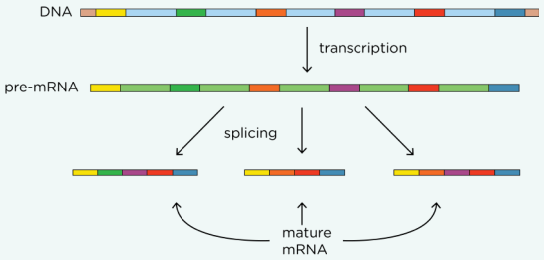


Post-Transcriptional Regulation

- In eukaryotes, gene expression can also be regulated after the gene has been transcribed but before it is translated- post-transcriptional modification
- Transcription results in the synthesis of pre-mRNA which must be modified to form mature mRNA, as it contains introns and exons
- Introns are sections of DNA that code for proteins
- Exons are sections of DNA that do not code for proteins
- Splicing occurs which involves the removal of introns and joining the exons back together. It is catalysed by an enzyme-RNA complex called a spliceosome.

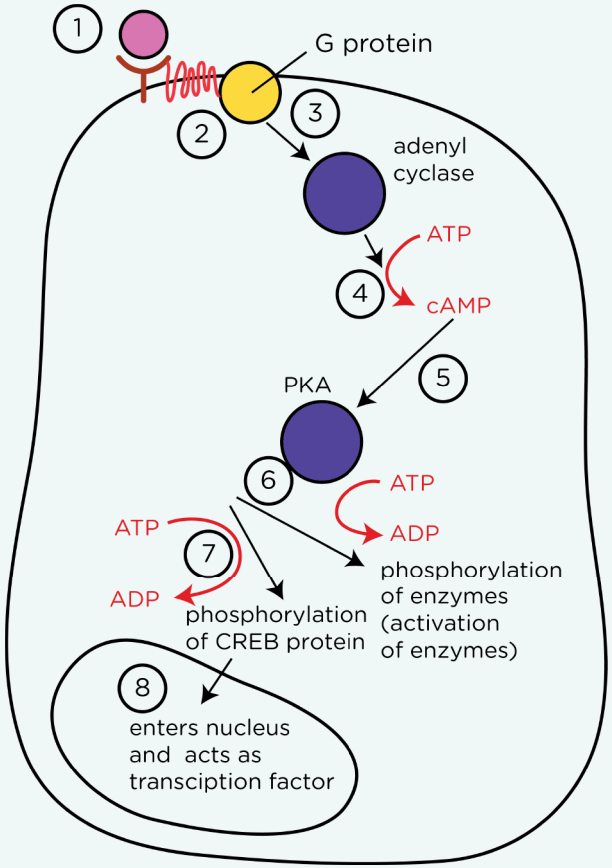


- The process of splicing does not always just remove the introns from the pre-mRNA — some of the exons may also be removed
- Depending on which exons are removed, different combinations of mature RNA are formed (alternative splicing) This means that one gene can produce many different mRNAs and code for many different proteins.



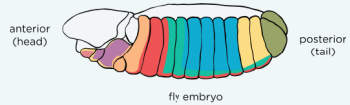
Regulating Translation

- The final level of regulating gene expression occurs after the protein has been synthesised — this is post-translational control
- Proteins can be modified in many ways, including:
  - Carbohydrate chains can be attached to form glycoproteins
  - Lipids can be attached which target the protein to cell membranes
  - Proteins can be activated by the addition of a phosphate group
- Many proteins can be activated by signalling from hormone.



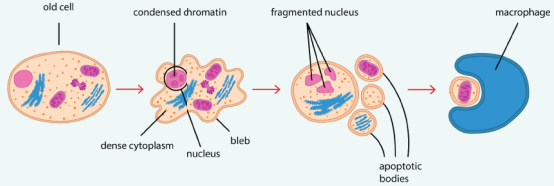
Control of Body Plan Development

- DNA contains homeotic genes which regulate morphogenesis
- A subset of homeotic genes are called homeobox genes which contain a 180 base pair length of DNA called a homeobox
- The homeobox sequence is highly conserved in plants, animals and fungi
- The homeobox sequence codes for a specific sequence of 60 amino acids within the synthesised protein called a homeodomain
- The homeodomain sequence folds into a specific shape consisting of three α-helices
- The helix-turn helix shape allows the protein to bind to DNA and regulate the transcription of nearby genes
- The proteins that contain a homeodomain are therefore transcription factors
- A subset of homeobox genes are called Hox genes
- Hox genes are homeobox genes that are only found in animals. They involved in the correct positioning of body parts in an organism
- In some animal lineages, including vertebrates, Hox genes have been duplicated, resulting in multiple Hox clusters
- When a Hox gene is mutated, body parts end up developing in the wrong place on the body (e.g. legs in place of the antennae in flies) — these are called homeotic mutations
- Hox genes are expressed in early embryonic development along the anterior-posterior (head-tail) axis of the organism



- Hox genes show colinerality, where the order of the genes on the chromosomes matches their temporal order and spatial order of expression.

- Apoptosis is the process of carrying out programmed cell death. It is important to remove old, damaged or unwanted cells.
- Apoptosis involves enzymes breaking down the cytoskeleton, forming blebs. Chromatin condenses and the nuclear envelope and the DNA breaks up. The cell is broken into apoptotic bodies, which are phagocytosed by macrophages.



- Apoptosis plays an important role during development, removing the surplus cells allowing different body parts to be shaped e.g. allowing separation of digits of hands and feet.
- Apoptosis is controlled by internal signals in response to stimuli such as cellular stress or by external signalling molecules such as cytokines which bind to the target cell to initiate apoptosis.

INHERITANCE
CHEAT SHEET

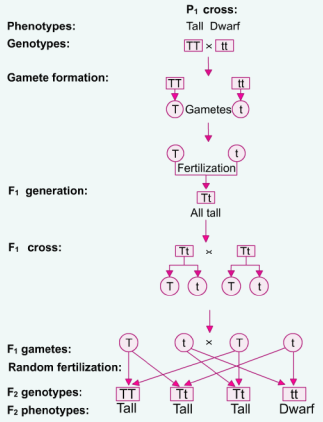
SNAPREVISE

Genes & Alleles

- The genotype is an organism's genetic composition.
- The phenotype is an organism's characteristics, often visible, which occur as a result of both its genotype and the impact of its environment.
- Genes are a sequence of DNA that code for a polypeptide.
- Genes can exist in 2 or more different forms called alleles.
- In diploid cells, chromosomes occur in pairs called homologous chromosomes. This means the alleles at a specific locus can be homozygous if they are both the same type of allele or heterozygous, if both the alleles are different.
- An allele is dominant if it is expressed in the phenotype of an heterozygous individual.
- An allele is recessive if it is not expressed in the phenotype of an heterozygous individual.
- An allele is codominant if it is expressed, along with the other allele, in the phenotype of a heterozygous individual.

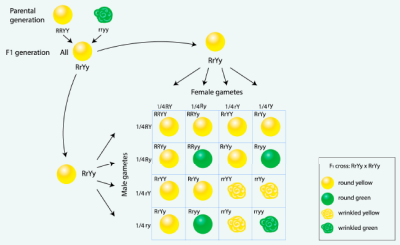
Monohybrid Inheritance

- Monohybrid inheritance is the inheritance of a single gene.
- A test cross be used to work out the unknown genotypes of individual organisms.
- In the test cross the unknown genotype is crossed with a homozygous recessive individual. If all the offspring have the dominant phenotype, the unknown genotype was homozygous dominant for the trait. If half the offspring have the recessive phenotype, the unknown genotype was heterozygous.



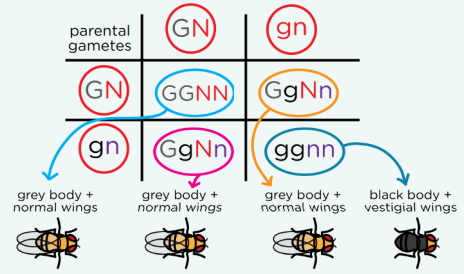
Dihybrid Inheritance

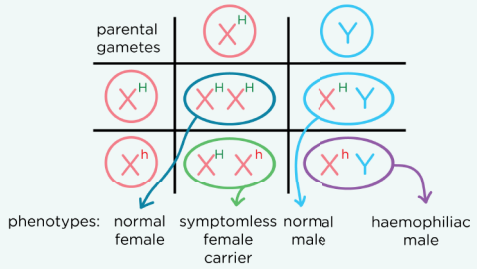
- Dihybrid inheritance involves the inheritance of two different characteristics simultaneously.
- During a dihybrid cross, alleles are independently assorted during gamete formation. A punnet square can show all possible genotype and phenotypes of offspring:
- In a dihybrid F1 generation cross, the phenotypic ratio for the F2 generation is always 9:3:3:1.



Linkage

- Autosomal linkage occurs if two or more genes are located on the same autosome (non-sex chromosome). The two genes are less likely to be separated during crossing over, resulting in the alleles of the linked genes being inherited together.
- For example, if GN & gn are linked in heterozygous grey bodies and normal winged individuals (GgNn), you get a 3:1 phenotypic ratio
- Sex linkage occurs when there is a gene on the X chromosome, not present on the Y chromosome.
- This means that males are more likely to exhibit recessive disorders like haemophilia





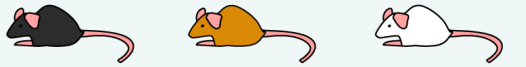
Epistasis

- Epistasis is the interaction between two non-linked genes which causes one gene to mask the expression of the other in the phenotype.
- Epistatic genes can work antagonistically (against each other) or in a complementary fashion.
- When a gene suppresses another gene, the gene doing the suppressing is called the epistatic gene. The gene which is being suppressed is called the hypostatic gene.
- Antagonistic epistasis can be either recessive or dominant.
- In dominant antagonistic epistasis, the expression of the dominant allele of the epistatic gene prevents the expression of the hypostatic gene. This means that any genotypic combination with either one or two of the dominant alleles for the epistatic gene will suppress the expression of the hypostatic gene.
- Recessive epistasis occurs when the presence of two copies of the recessive allele at the first locus prevents the expression of another allele at a second locus.
- In complementary epistasis, the two genes work together, for example, they may encode two enzymes that work in succession.

Complementary Epistasis Example

- An example of complementary epistasis is in the inheritance of coat colour in mice.
  A/a is the epistatic gene
  AA & Aa produces coloured fur
  aa produces no pigment-white fur
  B/b is the hypostatic gene
  BB & Bb encodes for black coloured fur
  bb produces encodes for agouti coloured fur

	AB	Ab	aB	ab
AB	AABB	AABb	AaBB	AaBb
Ab	AABb	AAbb	AaBb	Aabb
aB	AaBB	AaBb	aaBB	aaBb
ab	AaBb	Aabb	aaBb	aabb



This produces a 9:4:3 phenotypic ratio

Chi-squared Test

- If during an experiment, an unexpected result is obtained, we need to determine whether this unexpected result is due to chance or attributable to a specific cause (significant or not).
- The chi-squared test is a type of statistical test that allows us to calculate whether the difference between the results we observe and the results we expected is significant.
- The null hypothesis assumes that any difference that occurs between the expected and observed results is due to chance.

  Chi-Squared Test $\chi^2 = \sum \frac{(O-E)^2}{E}$

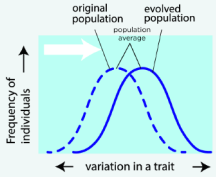
  O is the observed numbers (no units)
  E is the expected numbers (no units)
- The χ^2 value is then compared to a critical value, found from a chi-squared table by looking at the p-value and degrees of freedom
  - The degrees of freedom is the number of categories (or classes) minus one
  - The p-value is normally taken as 0.05, meaning that there is a 5% probability that the result is due to chance only
- If χ^2 < critical value, then the results are not significant (are due to chance). The null hypothesis is accepted.
- If χ^2 > critical value, then the results are significant (are attributable to a specific cause). The null hypothesis is rejected.

POPULATIONS, EVOLUTION, SPECIATION & SEQUENCING
CHEAT SHEET

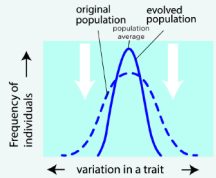
SNAPREVISE

Factors Affecting Evolution

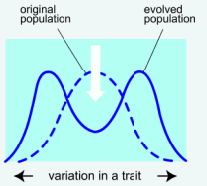
- Genetic drift describes change in allele frequencies in the gene pool of a population (evolution) due purely to chance events and not selection pressures.
- Due to the random nature of gamete production and fertilisation, certain alleles may increase in the population due to chance.
- The effect of genetic drift is more prominent within small populations because chance has a greater influence, whereas in larger populations the random fluctuations even out across the whole population.
- A genetic bottleneck is when an event causes a big reduction in a population's size and gene pool. Certain alleles may be due to the event and the population will also be subject to genetic drift.
- When a new population is established by a small number of individuals, the founding population will have low genetic diversity and be heavily influenced by genetic drift. This is the founder effect.
- Directional selection results in the increase of a favoured allele over time



- Stabilising selection maintains genetic polymorphisms in the population



- Disruptive selection also maintains genetic polymorphisms in the population



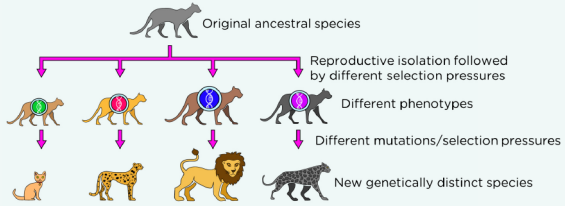
Disruptive selection

Populations

- A species is a is a group of individuals that have common ancestry and are capable of breeding with each other and producing fertile offspring.
- Species exist as one or more populations
- A population is a group of organisms of the same species occupying a particular space at a particular time that can potentially interbreed.
- A gene pool is all of the alleles of all the genes of all the individuals of a population
- Allele frequency is the proportion of the individuals that have one copy of an allele
- Allele frequencies change in response to selection pressures by natural selection between and within populations.

Speciation

- Speciation is the evolution of new species from existing ones.
- Reproductive isolation followed by accumulation of genetic changes through natural selection can result in the formation of a new species. This is because the populations become genetically distinct with different allele combinations, making them unable to breed to produce fertile offspring.



- Allopatric speciation is the formation of two species from an original one due to geographical isolation.
- Sympatric speciation is the formation of two species from one original species due to reproductive isolation whilst occupying the same geographical location. This can be by:
  - Temporal variation — breeding seasons at different times.
  - Behavioural variation — mutations affecting courtship.
  - Mechanical variation — anatomical differences preventing mating.
  - Gametic variation — results in genetic or biochemical incompatibility.
  - Hybrid sterility — cannot produce viable gametes.

Population Genetics

- Populations can be imagined as gene pools consisting of all the alleles of all the genes of all the individuals in the population
- Populations change and evolve as allele frequencies change across generations
- The frequency of alleles of a particular gene in a population can be determined using the equation encompassed by the Hardy-Weinberg Principle
- Hardy-Weinberg equations: $p + q = 1$, $p^2 + 2pq + q^2 = 1$
- Where:
  p is the frequency of dominant allele
  q is the frequency of recessive allele
  p^2 is the proportion of individuals that are homozygous dominant (AA)
  q^2 is the proportion of individuals that are homozygous recessive (aa)
  2pq is the proportion of individuals that are heterozygous (Aa)
- Using the equations, the allele frequencies of a specific gene, genotypes & phenotypes in a population can be estimate.
- The Hardy-Weinberg Principle assumes that the proportion of dominant and recessive alleles of any gene in a population remains the same from one generation to the next. The conditions for this are that:
  - The population is large
  - There are no mutations
  - There is no selection
  - Mating is random within the population
  - The population is isolated

Artificial Selection

- Artificial selection is selective breeding of organisms which involves humans selecting desired characteristics (phenotypes), interbreeding those phenotypes, and therefore selecting the genotypes which contribute to the gene pool of the next generation.
- In a plant selective breeding programme, plants may be grown under certain conditions e.g. low light. Those which grow best and cross-pollinated, and the seeds are grown again under the unfavourable conditions. This is repeated over many generations to produce offspring with advantageous characteristics
- Artificial selection reduces the diversity of the gene pool, resulting in inbreeding depression, this increases the chance of inheriting a recessive disorder, and reduces the ability of the species to adapt to environmental changes.
- Hybrid vigour is crossing individuals from two separate, inbred gene pools created healthy offspring, heterozygous at many gene loci

Genetic Sequencing

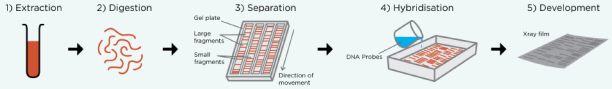
- DNA sequencing is the process used to determine the precise sequence of nucleotides in a length of DNA.
- Sanger sequencing involves:
  - The DNA to be sequenced is placed in 4 tubes and mixed with primers, DNA polymerase and free nucleotides
  - In each of the tubes, chain-terminating nucleotides for one specific base were also added. The 4 tubes are then placed in a thermocycler and PCR begins
  - DNA polymerase binds to the template DNA and DNA synthesis of the complementary strand began. Chain-terminating nucleotides were randomly incorporated into the growing DNA chains, stopping DNA synthesis
  - The many cycles of PCR resulted in the production of thousands of fragments of DNA that all differed in length by one base, which are electrophoresed, and the sequence of DNA is determined.
- Pyrosequencing involves:
  - The DNA is fragmented and separated into single-stranded DNA (ssDNA) and one of these strands is fixed to a flow cell (a plastic slide)
  - The flow cell contains millions of DNA strands, each ssDNA acting as a template for the sequencing reaction, and they are each fixed in their own well in the flow cell
  - The flow cell is then incubated in a reaction mixture containing primers, DNA polymerase, ATP sulfurylase, luciferase, apyrase, Adenosine 5' phosphosulfate (APS) and luciferin
  - The first reaction takes place by adding activated nucleotides that contain only one of the four bases A, G, C or T to the flow cell. If the first base of the template DNA is complementary to the base added, the nucleotide is then added into the DNA chain by DNA polymerase. This results in the release of diphosphate (PPi), also knows a pyrophosphate
  - Pyrophosphate reacts with APS to form ATP, in a process catalysed by the ATP sulfurylase
  - Luciferase then uses ATP to convert luciferin to oxyluciferin, generating visible light which is detected by a camera
  - Any nucleotides that were not incorporated into the DNA are degraded by apyrase
  - A different activated nucleotide is then washed across the flow cell resulting in another flash of light if incorporated
  - This cycle repeats until all of the DNA fragments have been fully synthesised

GENE TECHNOLOGY & BIOTECHNOLOGY
CHEAT SHEET

SNAPREVISE

Genetic Fingerprinting

- Genetic fingerprinting is a method used to produce a specific pattern of DNA bands from an individual's genome.
- The non-coding regions of DNA contain short, repeating sequences called variable number tandem repeats (VNTRs).
- VNTRs are found at many locations in the genome. In every individual, they vary in length and the in the number of repeats at different loci. Therefore, the probability of two individuals having the same VNTRs is very low.
- The steps in DNA fingerprinting include:
  - Extraction of DNA & amplification using PCR
  - DNA digestion using specific restriction endonucleases, leaving the VNTRs intact
  - Separation of DNA fragment by gel electrophoresis. Smaller fragments travel faster and therefore move further down the gel
  - Hybridisation of the VNTRs at specific (complementary) base sequences with Radioactive or fluorescent DNA probes
  - Development. The banding pattern can then be visualised as radiation, emitted by fragments, exposes X-ray film (placed over the gel) and reveals their final positions.



- The DNA profiles can be compared to determine genetic relationships by looking for similarities in the banding pattern.
- DNA profiles can also be used in:
  - Forensic science investigations — comparing the DNA profiles of suspects and DNA at the crime scene.
  - Medical diagnosis — DNA profiles can identify individuals at risk of developing specific diseases, as some VNTRs are correlated with an increased risk of disease e.g. Huntington's disease.
  - Animal and plant breeding — DNA profiles are used to prevent inbreeding by not breeding individuals with similar profiles.
  - Paternity determination — half the DNA profile of the child should match the father.

Polymerase Chain Reaction (PCR)

- PCR is a method of amplifying DNA by artificial replication in vitro.
- It requires: DNA sample of around 10,000 base pairs, nucleotides, Taq polymerase (stable at high temperatures), primers complementary to 3' of DNA sample and a thermocycler to carry out the automated process.

Electrophoresis

- Electrophoresis is the process of separating DNA fragments or other macromolecules, according to their size.
- The stages involved is as follows:
  - DNA loading dye is added to the DNA samples, and it is pipetted into the wells in the agarose gel plate
  - An electric current is applied across the plate, so DNA moves towards the anode. Smaller fragments travel faster
- Proteins can be separated according to their molecular mas if sodium dodecyl sulphate is added to give the proteins a uniform negative charge.
- The DNA bands can be visualised by using DNA probes, which are short sections of DNA that are complementary to a known DNA sequence. They can be fluorescent or radioactive.
- Microarrays can also be formed which contain a number of different probes on a fixed surface. This allows for the DNA to reveal the presence of mutated alleles if it matches the fixed probes.

Genetic Engineering

- Genetically modified organisms are organisms that have had their DNA altered through recombinant DNA technology.
- Recombinant DNA technology involves the transfer of fragments of DNA from one organism, or species, to another.
- Transgenic organisms can successfully express a gene from any organism, as the genetic code and mechanism of protein production (transcription and translation) are universal.
- DNA fragments are created by:
  - Using restriction endonucleases to cut at recognition sites near the desired gene
  - Converting the mRNA of the desired gene to cDNA, using reverse transcriptase. Double stranded DNA is then synthesised using DNA polymerase
  - Synthesising the gene using a gene machine. The gene sequence is determined by the primary protein structure.
- The isolated gene is then modified by the addition of a promoter and a terminator region.
- A vector is used to transfer the isolated gene into a host cell. This is mainly a plasmid.
- Restriction endonucleases are used to cut plasmids open, creating sticky ends. The same endonuclease isolates the gene, so the sticky ends of the desired gene and the plasmid are complementary. DNA ligase joins them together.
- To reintroduce the desired DNA into bacterial cells, the recombinant plasmid must pass through the cell surface membrane of a bacterial cell (transformation).
- Transformation involved mixing the bacteria and plasmids in a medium containing Ca^{2+} ions, which increased membrane permeability. Changes in temperature also make the bacterial cell surface more permeable.
- The transformed host cells can be cultured as an in vivo method to amplify DNA fragments.

The Use of Genetically Modified Organisms (GMOs)

GMO	Benefits	Issues
Plants	• Herbicide resistance • Pest resistance • Disease resistance • Drought resistance • Extended shelf-life • Increased nutrition	• Development of superweeds • Pests or pathogens evolving resistance • Potential transfer of antibiotic resistance to pathogens in the intestine of the consumer • Farmers must repeatedly buy seeds
Animals	• Disease resistance • Increased growth rates e.g. continuously producing growth hormones • Used to produce medicinal drugs and proteins	• Harmful side effect to animals • Ethical issue of insertion of human genes • Most GM animals die during development
Bacteria	• Used to produce medicine e.g. human insulin which is cheaper and has a lower risk of rejection and infection than pig insulin	• Potential antibiotic resistance genes being transferred to pathogens • May result in the production of more lethal pathogens

- The risk of GM bacteria can be reduced by modifying the bacteria so that they are unable to produce an essential nutrient or amino acid and cannot survive outside the lab.

Cloning Animals

- Embryo twinning is the process of splitting an early embryo in half to create two genetically identical embryos
- Somatic cell nuclear transfer is the method of cloning that is achieved by transferring the nucleus from a somatic (body) cell of an adult animal into an egg cell
  - Ovum is enucleated
  - Somatic cell is enucleated and transferred to enucleated ovum
  - An electric shock stimulated division
  - It is implanted into the uterus of a surrogate mother
- Non-reproductive cloning clones only tissues and cells

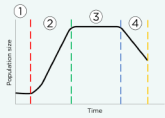
Gene Therapy

- Gene therapy is the mechanism by which genetic diseases are treated or cured by masking the effect of a faulty allele through the insertion of a functional allele.
- Firstly, a healthy allele from healthy cell tissue is isolated. The allele is inserted into the cells using vectors.
- If the mutated allele is recessive, a dominant allele is inserted. If the mutated allele is dominant, DNA is inserted into the middle of the allele to silence it.
- Somatic therapy involves altering the alleles in body cells. The altered allele is not passed onto the offspring
- Germ-line therapy altering the alleles in the sex cells. The altered alleles are passed onto offspring
- Germ-line therapy has ethical concerns such as the potential of designer babies or the potential impact gene insertion could have on other genes.

Cloning Plants

- Vegetative propagation is asexual reproduction from the vegetative parts of a plant rather than through specialised sexual reproductive structures
  - Overwinter organs such as bulbs and tubers
  - Runners and rhizomes
  - Stem cutting, with rooting hormones encouraging root growth
- Micropropagation is the process of growing large numbers of cloned plants from meristem tissue taken from a sample plant.
  - Explants from the meristem are acquired and sterilised
  - They are placed on a sterile culture medium, forming a callus
  - The callus is divided and moved onto separate culture mediums to stimulate the development of roots and shoots
  - The plantlets developed are potted in soil
- Tissue culture is the growth of tissues or cells in an artificial medium taken from tissues of a sample plant.

Microorganisms



- In a batch culture, the microorganisms in a fermenter do not have any exchange of nutrients or gases with the external environment. A closed culture:
- 1 is the lag phase. 2 is the log phase. 3 is the stationary phase and 4 is the decline phase
- Primary metabolites are produced during the log phase as they are made in continuous culture. In continuous culture the conditions are altered continuously to allow for optimal growth.
- Secondary metabolites are produced during the stationary phase when there are not enough nutrients for the whole population. This is because they are produced in stressful conditions and are therefore made in closed culture
- Microorganisms are used in biotechnology because theyre cheap, have a rapid growth rate, easily genetically modified, need simple nutrient, secrete products and make their own enzymes
- Bioremediation is the process in which microorganisms are used to clear toxic pollutants by converting them to less harmful substances
- Microorganisms are often used to produce drugs, such as in the production of penicillin. Commercial drug production takes place on a large-scale using fermenters, as this allows for certain conditions to be carefully controlled so that a high yield is obtained
- The fungus Fusarium veneatum directly produces mycoprotein, also known as single cell protein (SCP).
- Sterile conditions are necessary in order to prevent the growth of unwanted microorganisms which can reduce yield or produce toxins, killing the cultured microorganisms and destroying their products

Immobilised Enzymes

- Immobilised enzymes are not free to diffuse through a solution as it is held in place. This can be by adsorption, covalent bonding, entrapment and membrane separation.
- It reduces the cost of product separation from enzymes
- Glucose isomerase is used to convert glucose to fructose for sweeteners
- Glucoamylase converts dextrins to glucose
- Penicillin acylase use in the formation of semi-synthetic penicillin which provides a barrier against antibiotic resistance
- Aminoacylase synthesises L-amino acids from N-acyl amino acid, for use in the production of compounds.

ECOSYSTEMS, NUTRIENT CYCLES & CONSERVATION
CHEAT SHEET

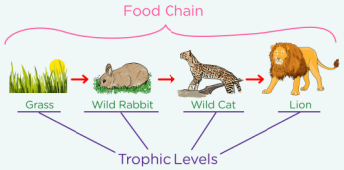
SNAPREVISE

Biomass

- Plants synthesise organic compounds from atmospheric, or aquatic, carbon dioxide.
- Most of the sugars synthesised by plants are used as respiratory substrates. The rest are used to make other groups of biological molecules, forming the biomass of the plant.
- Biomass is the total mass of living material in a specific area at a given time
- Dry biomass shows the chemical energy store in an organism and can be measured by the process of calorimetry. A dry sample is weighed and burnt in pure oxygen within a sealed chamber, the temperature increase of the fixed volume of water is used to calculate the energy released.

Production & Productivity

- Gross primary production (GPP) is the total quantity of chemical energy stored in plant biomass, in a given area or volume.
- Net primary production (NPP) is the chemical energy store in plant biomass after respiratory losses to the environment have been taken into account
- The NPP is available for plant growth and reproduction. It is also available for consumers in the food chain such as herbivores and decomposers.



- Net production (N) is the total chemical energy consumers store after energy losses to faeces, urine and respiration have been taken away from the chemical energy store of the ingested plant food
- Primary and secondary productivity is the rate of primary or secondary production, respectively. It is measured as biomass in a given area in a given time e.g. kJ ha^{-1} $year^{-1}$
- The percentage efficiency of energy transfer from one tropic level to another can be calculated as

$$\left(\frac{energy\ available\ after\ the\ transfer}{energy\ available\ before\ the\ transfer}\right) \times 100$$

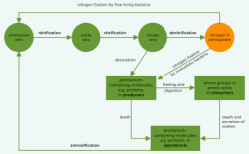
- Farming practices increase the efficiency of energy transfer to increase yields by:
  - Reducing respiratory loses in a human food chain e.g. reduce movement of animals
  - Simplifying food chains to reduce energy loss to non-human food chains e.g. killing weeds and pest using herbicides and insecticides

Succession

- Succession is the variety of processes that occur over time in a species that occupy a certain area.
- Primary succession is the progressive colonisation of bare rock or other barren terrain by living organisms.
  - The area is first colonised by the pioneer species, changing the abiotic factors to be less hostile for other species to survive.
  - Different species may be present at each stage, who change the environment so that it becomes more suitable for other species with different adaptations but less suitable for the previous species — changing biodiversity.
  - The climax community is when a stable state is reached, where there is high biodiversity and a number of new species.
- Secondary succession is the recolonization of an area after an earlier community has been removed or destroyed.

Nutrient Cycles

- There is a finite supply of nutrients on Earth, which are recycled within natural ecosystems.
- The Nitrogen cycle:
- The Phosphorus cycle:



Microorganisms in Nutrient Cycles

- Microorganism play a vital role in nutrient cycles

Microorganism	Role
Mycorrhizae	Certain types of fungi associate with roots of plants to increase the surface area for absorption of water and mineral ions, including phosphate ions.
Free-Living Nitrogen-Fixing Bacteria	In the soil, they reduce nitrogen gas to ammonia.
Mutualistic Nitrogen-Fixing Bacteria	Use nitrogen gas to produce amino acids
Saprobiontic organisms	Break down dead organism to release phosphate, ammonia or ammonium compounds
Nitrifying bacteria	Free living in soil, oxidise ammonium ions into nitrites and nitrites into nitrates
Anaerobic denitrifying bacteria	Use nitrates in respiration to produce nitrogen gas

Ecosystems & Population Size

- A community is all of the populations of different species living and interacting in a place at the same time.
- An ecosystem is the dynamic interaction between all the living (biotic) and non-living (abiotic) factors in a given area.
- Within an ecosystem, every organism occupies a specific ecological niche
- A niche includes all the abiotic and biotic conditions of the environment which organisms are adapted to.
- The carrying capacity is the maximum population size that can be maintained over a period in a particular habitat.
- The limiting factors of the carrying capacity include abiotic factors:
  - Temperature & pH — each species has its optimum levels, and deviations from this optimum reduces population growth
  - Light — low light levels reduce the carrying capacity of producers, reducing the population size of consumers
  - Water — low water availability reduces the population size
- The limiting factors of the carrying capacity include biotic factors:
  - Interspecific competition (between different species)
  - Intraspecific competition (within the same species)
  - Predation
- The size of a population can be estimated by:
  - Randomly placing quadrats, or quadrats along a belt transect, for slow-moving or non-motile organisms. Can count the number of individuals of each species in the quadrat or percentage cover.
  - The mark-release-recapture method for motile organisms.

$$Population\ size = \frac{sample\ 1\ size\ \times sample\ 2\ size}{\#\ of\ marked\ in\ sample\ 2}$$

It assumes there is no deaths, births, migration, marking has no effect and enough time for the animals to mix.

Conservation

- Conversations is the maintenance of biodiversity, including diversity between species, genetic diversity within species and maintenance of a variety of habitats and ecosystems.
- Preservation is the maintenance of habitats and ecosystems in their present condition, minimising human impact
- The rate of growth of the human population creates an increasing demand for raw material and food. A balance between conversation and human needs is necessary in order to maintain the sustainability of natural resources.
- Timber can be managed by:
  - Coppicing — cutting tree stems close to the ground
  - Pollarding — cutting the stem higher from the ground to prevent animals eating the shoots
  - Rotational coppicing — coppicing different areas each time, to allow time for growth
- Fish stocks can be managed by:
  - Preventing overfishing
  - Aquacultures
- In in situ conservation species are conserved within (inside) their natural habitat, maintaining biodiversity. This includes creating legislations, wildlife reserves and repopulating areas via reintroduction.

Advantages	Disadvantages
Conserves species without removing them from their habitat	The habitat may be too fragmented to ensure a sustainable population
Ecosystem integrity is also maintained as the species are able to play a vital role in the functioning of the ecosystem	Too much genetic diversity may have already been lost to allow the species to adapt to change in their natural environment
Cheaper than ex situ conservation	Wildlife reserves may be damaged by ecotourism
Protects the biodiversity and the crucial elements of the ecosystem	The conditions that caused the area to have a loss of species may still be present

- In ex situ conservation species are conserved outside their natural habitat, maintaining biodiversity. This can occur in zoos, botanic gardens and seed banks.

Advantages	Disadvantages
Protects organisms from predation and poaching	Limited genetic diversity
Help attract funding and awareness	It may be difficult to provide a suitable environment
Techniques such as artificial insemination are used to maximise reproductive success and genetic diversity	Many animals may also be unable to be re-introduced into the wild as they will not have learnt the necessary behaviour