

HL Biology Notes (2016 syllabus)

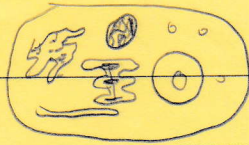
**“All life is nucleic acid, the rest is
commentary”
-Issac Asimov**

Contents

**Full core material (1-11)
C: Ecology and Conservation**

Ardon Moiz Pillay

Cell Biology [1.1 → 1.4]



Date

No.

Cell Theory

- 1) All Cells come from pre-existing cells
- 2) Smallest units of life
- 3) Cells can generate their own energy
- 4) Each cell is surrounded by a membrane

Magnification

$$(1 \times 10^6) \quad 1 \mu\text{m} = 1 \text{mm} \times 10^{-3} \text{ or } 1 \text{cm} \times 10^{-4}$$

$$(1 \times 10^9) \quad 1 \text{nm} = 1 \text{m} \times 10^{-9} \text{ or } 1 \text{mm} \times 10^{-6}$$

Exceptions to Cell Theory

- 1) **Striated Muscle Cell** → each cell is multinucleated and each cell is 30mm in length on average, most human cells are 0.03mm (30 μm)
- 2) **Aseptate Hypha** - Hypha are thread like structures that make up fungi. The Aseptate means no dividing walls between cells [septate], hence hypha are multinucleated, since each hypha is an uninterrupted tube structure with many nuclei along it
- 3) **Algae** → made of one cell that is very large. Even with one nucleus, it can be 100mm (100,000 μm) long.

Functions of Life in Unicellular Organisms

M - Metabolism → ability to carry out biochemical reactions (web of enzyme catalysed biological reactions)

R - Reproduction → ability to produce offspring

S - Sensitivity → Response to external stimuli

G - Growth → ^{irreversible} ability to increase in dry mass

R - Respiration → Production of energy

E - Excretion → removal of metabolic waste

N - Nutrition → obtaining food to provide energy + nutrients for growth

Surface to Volume Ratio

⇒ **Large S to V ratio** (small cells)

- More surface area for the removal of waste products and for the import of nutrients into cell
- Increased transport of materials in and out of cell

Small/Unsuitable S to V ratio (large cells)

- Less surface area for removal of waste → build up of metabolic waste
- Less S.A for transport of needed nutrients → cell eventually dies

Differentiation Emergent Properties

Date

No.

Definition: Properties arising from the interaction of component parts

^{group of similar cells} Cells group to form tissues → tissues form organs → organs form organ systems that carry out specific functions (emergent properties) (e.g. muscle contraction from striated muscle cells)

Differentiation

Def: Process by which cells ~~sp~~ develop specialised functions

- Involves the expression of certain genes but not others [however all genes are present]
- Chemical signals lead to differential gene expression → endocrine cells in pancreas ^{liver pancreas} such as morphogens

Stem Cells

- † Def: Cells that can differentiate along different pathways into different cell types
- can divide repeatedly and are pluripotent [can diff into anything but ~~cannot create organism~~] → can repair damaged + replace dead

Table of Stem Cell Types

	<u>Embryonic Stem Cells</u>	<u>Cord Stem Cells</u>	<u>Adult Stem Cells</u>
+	• pluripotent (unlimited)	• Easily obtained + stored	• Same antigens as adults
+	• unlimited growth	• Same antigens as adult	• Less chance of tumor formation
+	• low chance of mutation	• Limited derivative ability	• Very limited derivative ability
-	• Only one or 2 cells can be taken from a dividing zygote	• Limited cells in cord	
-	• Risk of tumor formation		
-	• Different antigens to adult cell		

Therapeutic Uses

1) Leukemia

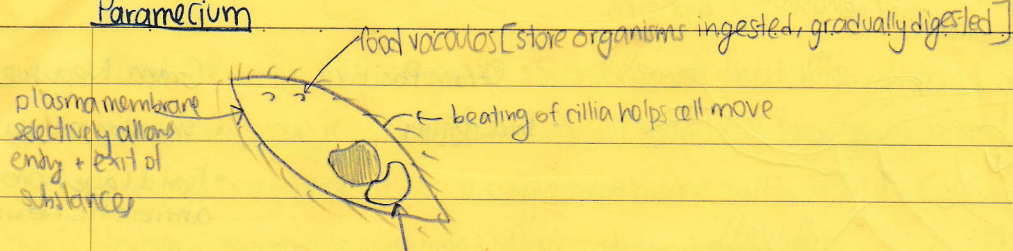
- WBCs produced in bone marrow, then released into blood
- Stem cells are taken from bone marrow fluid drawn from the pelvis
- Chemotherapy kills all cancer cells in the bone marrow, stopping it from producing cells
- Stem cells are introduced into the marrow to ~~to~~, they multiply to produce healthy WBCs and RBCs

2) Stargardt's Disease

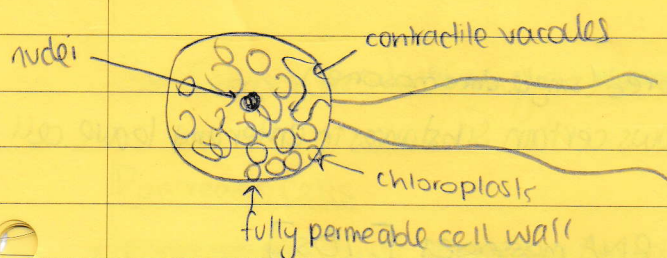
- genetic disease causing ~~ma~~ degeneration of photoreceptive retina cells [worse vision]
- Can be treated by adding embryonic stem cells

2, 2 daughter cells form

Paramecium



Chlamydomonas (unicellular alga)



Microscopes

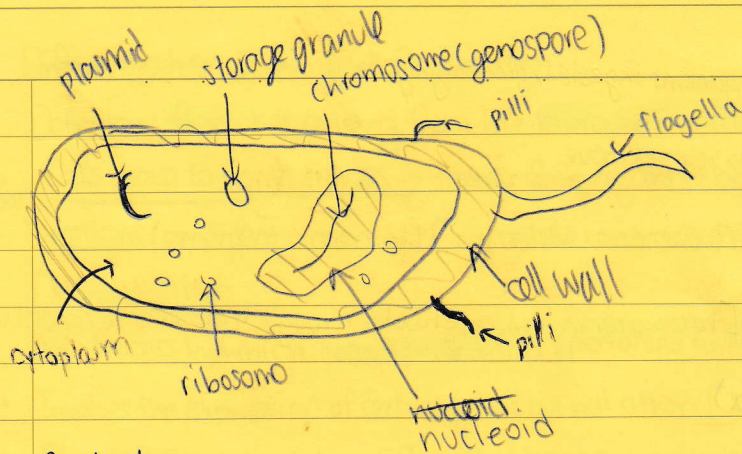
Electron Microscope

- view objects smaller than $0.001 \mu\text{m}$
- used to ^{see} ultrastructure of cells + prokaryotes
- Making separate parts distinguishable by eye = resolution
- Max of EM = $0.001 \mu\text{m}$, LM = $0.2 \mu\text{m}$
- better because wavelength of light used is smaller, hence better resolution is generated

Prokaryotes vs Eukaryotes

Feature			<u>Plants</u>	<u>Animal</u>
	Prokaryote	Eukaryote	Larger vacuole chloroplasts cell wall plasmodesmata	Steroids in plasma membrane Centrioles
Nucleus	Not Present	Present		
Chromosome	Only 1	More than 1		
Cell Type	unicellular	multicellular		
Lysosomes + Peroxisomes	No	Yes		
Microtubules and ER	No	Yes		
Mitochondria	No	Yes		
Ribosomes	70S	80S		
Flagella	Submicroscopic	Microscopic		
Steroid in membrane	No	Yes		
Cell size	1-10 μm	10-100 μm		

E. Coli



Gram Positive
• thick cell wall

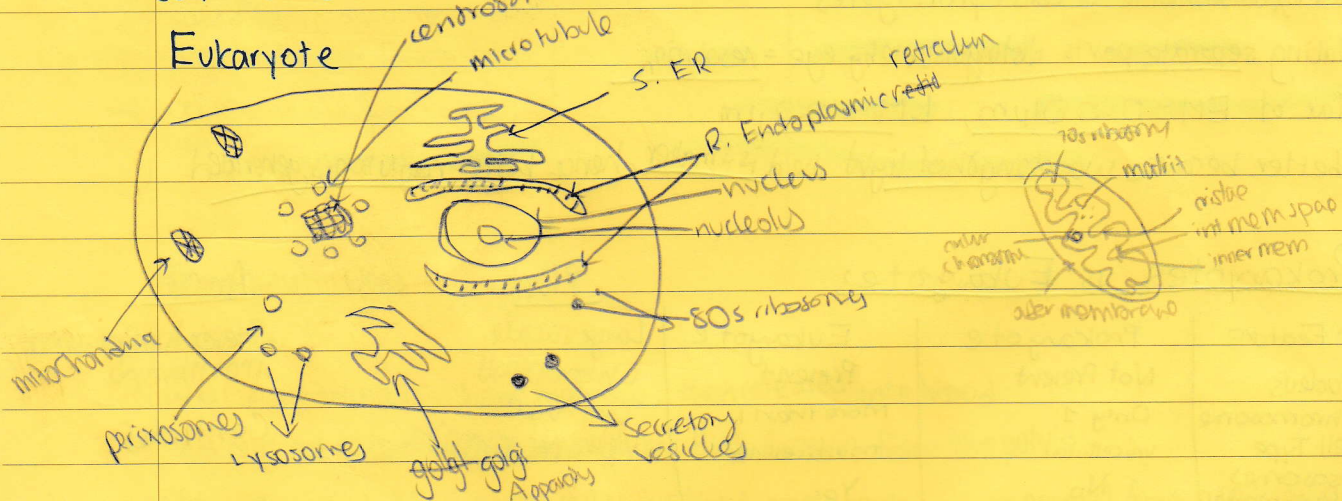
Gram Negative
• smaller cell wall
• lipid layer provides antibiotic resistance

Division is by binary fission

Contents

- Nucleoid → space where naked DNA is stored (single chromosome)
- Plasma Membrane → Lipid bilayers that allows certain substances to enter and leave cell
- Cell Wall → maintain cell shape
- Ribosome → ^{translate} transcribes proteins based on mRNA messages [70s]
- Cytoplasm (singular: cytosol) → place where metabolism occurs
- Plasmid → small circular DNA fragments
- Pili → hair like structures that allow cells to attach to each other
- Flagellum → tail like extensions that rotate to facilitate movement
- sometimes can have an inward fold.

Eukaryote



Contents

Nucleus - enclosed in double membrane, contains nuclear chromatin made of DNA

Nucleolus - produce ribosomes

Cytoplasm - where metabolism occurs

Golgi - Stack of membrane bound vesicles that package macromolecules for transport

Lysosomes - enzymes for digestion

Peroxisomes - Oxidative enzymes that break down H_2O_2 secreted by phagocytes to kill bacteria

Rough ER - The RER consists of flattened sacs that have attached ribosomes. Proteins synthesised by ribosomes move into sacs and bud off as vesicles to golgi apparatus → see chapter 7

Vacuoles - organelles of a single membrane with fluid. Can expel excess water (contractile)

Vesicles - membrane surrounded fluid used for transport

Smooth ER - produce hormones and substances like lipids + steroids

Cytoskeleton - maintain cell shape and motility (intracellular organelle movement)

See Textbook for identifying an electron micrograph

Pancreatic Cells

- exocrine cells secrete digestive enzymes to be carried into small intestine
- the cells have organelles that synthesize proteins in large quantities [link to exocytosis]

Compartmentalisation

- pH can be maintained in separate compartments
- Mobile organelles
- substances can become more concentrated (in a compartment) (e.g. enzymes for hydrolysis)
- Dangerous/harmful substances can be kept within membranes to prevent them from affecting others

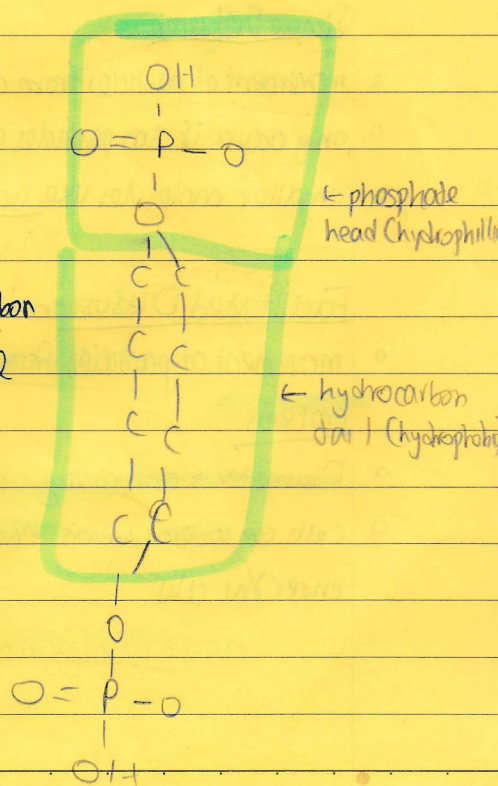
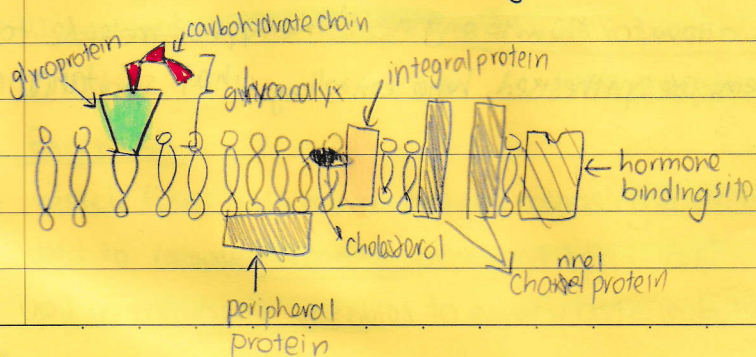
* Please practise electron micrograph identification

Membrane Structure

Membranes are amphipathic phospholipid bilayers

↓
molecule that has hydrophilic and hydrophobic parts

- ° In water, phosphate heads are attracted to water and the hydrocarbon tails attract each other, hence the heads face the water on either side of the molecule, with 2 tails linking them.



Functions

- 1) Glycocalyx → used for cell recognition [groupings of cells to form tissues]
- 2) Integral Proteins → hydrophobic - hence they are attracted to the tails. They are transmembrane (can extend across the whole membrane & they have hydrophilic parts)
- 3) Peripheral proteins → hydrophilic - hence attached to head by hydrocarbon tail. Can be reversibly attached to integral proteins
- 4) Enzymes → integral proteins for metabolic reactions
- 5) Channel Proteins → proteins used to transport substances in and out of the cell by facilitated diffusion
- 6) Fibrous proteins (hormone binding sites) → generate a response in cell when agonist molecule binds to it. Antagonist molecule prevents binding of certain hormones

8

Cholesterol

- lipid that is called a steroid
- the majority of it is hydrophobic, hence it is an integral structure that is transmembrane
- Disrupts regular packing of hydrocarbon tails, preventing the crystallisation of the bilayer
- It also restricts membrane fluidity by restricting molecular motion and decreasing permeability to hydrophilic particles
- gives membrane concave shape (reduced fluidity) → facilitates endocytosis and exocytosis

Movement through Membrane

Simple Diffusion

- movement of particles from an area of high to low concentration
- only occurs if particles are small and uncharged (would be repelled by hydrophilic parts)
- smaller molecules like urea and ethanol diffuse faster

Facilitated Diffusion

- movement of particles from an area of high concentration to low concentration through channel proteins
- Diameter + chemistry of proteins allow for them to only allow one type of molecule to enter
- cells can control what channel proteins are synthesised, hence controlling what substances can enter the cell

Osmosis

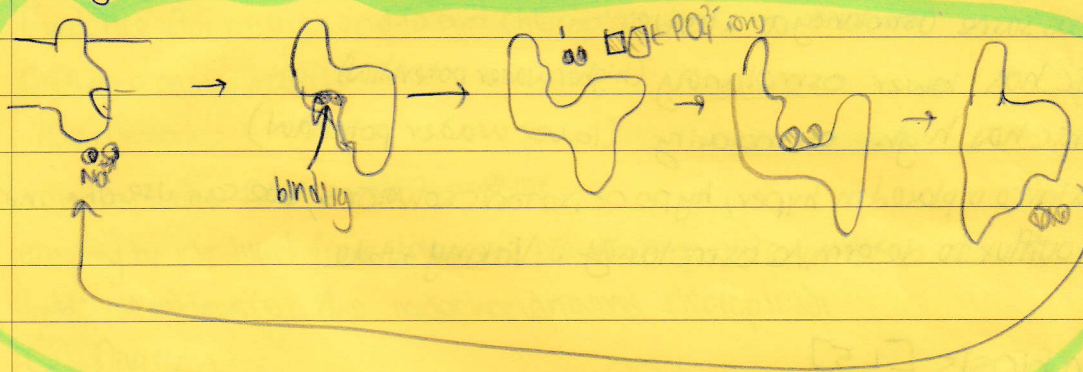
- movement of water from area of high concentration to area of low concentration
- can occur in all cells because water molecules are small enough to pass through lipid bilayer
- sometimes water moves in through aquaporins

Active Transport

- movement of a substance against a concentration gradient using ATP
- carried out by pump proteins
- Molecule enters protein and energy from ATP changes conformation of the protein, allowing for molecule to move into the cell.

Endocytosis Axons

- nerve impulse involves rapid movement of sodium then potassium to axon membrane
- sodium-potassium pumps pump 3 sodium ions out of axon and 2 phosphate ions in
- binding of sodium in pump alters conformation of pump protein, allowing the phosphate to enter



See textbook for facilitated diffusion in axons

Endocytosis

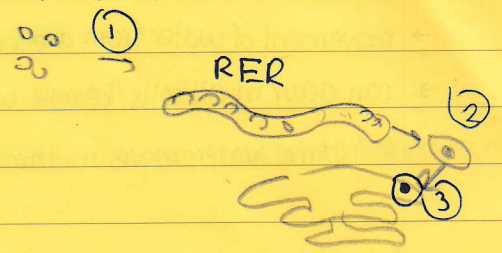
- small region of the membrane is pinched off to form a vesicle using ATP
- This brings in extracellular materials
- Used in placenta to transport antibodies + proteins to fetus

Exocytosis

- vesicle fuses with cell membrane, releasing contents into extracellular space.
- used to release hormones produced by S. ER
- used in contractile vacuoles to expel waste substances

Vesicle Movement

- 1) Proteins synthesised by ribosomes enter R. ER
- 2) Vesicle containing proteins bud off from R. ER
- 3) Travels to golgi and golgi modifies proteins
- 4) Vesicle buds off from Golgi and fuses with plasma membrane, releasing modified proteins into extracellular space
→ exocytosis



Osmosis in Organs

- If osmosis occurs and water enters donor organs, the organs would burst (hypotonic solution)
- If osmosis occurs and water leaves, indentations develop (hypertonic solution)
- Hence fluid of the same osmolarity as the organs must be used (isotonic), to prevent water movement.

Osmolarity

tonic = solutes

- total concentration of osmotically active ~~solvent~~ solutes
- isotonic has same osmolarity as a tissue
- hypotonic has lower osmolarity (higher water potential)
- hypertonic has high osmolarity (lower water potential)
- If a substance is placed in hyper, hypo or isotonic solutions, we can use the influx of water or outflux to determine osmolarity. Visking tube

Endosymbiosis [1.5]

- Cells come from pre-existing cells

→

Pasteur

- made nutrient broths by boiling water containing yeast and sugar
- kept in a sealed flask and no new organisms appeared
- He boiled some but not others
- When the boiled ones were exposed to air, no spontaneous generation occurred

Cell Origin

- 1) Deep Sea Vents
 - carry inorganic compounds that could be used as energy source for C. compounds assembly
- 2) Membrane formation
 - if amphipathic molecules previously existed, they would naturally form a lipid bilayer when in water

3) Miller's experiments

- lightning strikes through atmosphere simulation created amino acids needed for life

4) Inheritance Mechanism

- rRNA was genetic material as it stored information and acted as a catalyst

Endosymbiosis

- evolution of eukaryotic cells
- mitochondria ^{/ chloroplasts} were prokaryotes that could respire / fix sunlight
- Larger ^{prokaryotes} organisms lacked the ability to carry these processes out
- Larger prokaryotes allowed smaller prokaryotes to live in their cytoplasm
- small prokaryote would supply larger one with energy / C-compounds
- cells that had this system survived natural selection

Evidence (for mitochondria and chloroplasts)

- DNA on a circular molecule
- 70s ribosomes
- can transcribe DNA → rRNA → proteins
- can only be produced from division of pre-existing mito + chlo
- double membrane on the mitochondria and chloroplasts

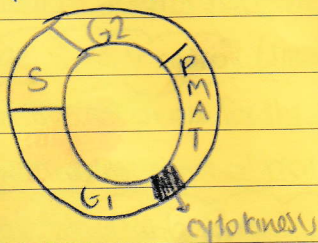
- replenish
- mutate
- 1 off from
- 1 SA:V
- spot
- diff

Cell Division

Mitosis: the division of the nucleus into 2 identical daughter nuclei

Why?

- cell replenishment (replace dead/damaged cells), mutated ras, myc or p53 gene
- increase efficiency of tissues/organs (e.g. muscle contraction), increase SA to volume ratio
- reproduction, allow differentiation



Interphase

- G₁ = general cellular growth, DNA transcription, DNA dependent
- S = DNA replication (23-246 chrom)
- G₂ = Growth until mitosis, replication of mitochondria and chloroplasts, cytoskeleton breaks down

Interphase is a stage where the cell prepares for mitosis, mitochondria v. active to produce energy for mitosis, includes protein synthesis and metabolic reactions

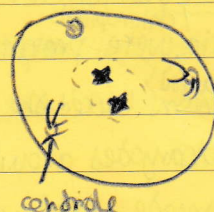
Cyclins

- proteins that ensure that cell division occurs in the correct manner while ensuring that the cell only proceeds to the next phase if it is ready
- Cyclins bind to cyclin dependent kinases that trigger proteins to carry out the next stage of the cycle
- E.g. cyclin A promotes DNA replication in S phase

Phases (P → M → ^A → T)

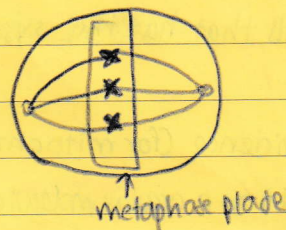
1) Prophase

- the sister chromatids supercoil (more visible)
- nuclear membrane dissolves
- centrioles move to poles and extend mitotic spindles



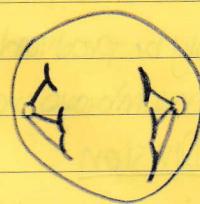
2) Metaphase

- spindles attach to centromere of each sister chromatid
- push them to centre of cell, forming the metaphase plate
- spindles put under tension to test if attachment is correct



3) Anaphase

- each centromere divides, separating the sister chromatids
- Spindle fibres pull them to poles
- hence, genetically identical cells formed



4) Telophase

- chromatids uncoil
- nuclear membranes form
- Cytokinesis begins

Cytokinesis

Animal Cells

- cleavage furrow forms in the middle of cell
- plasma membrane connects to ends of furrow
- contractile proteins cause furrow
- when furrow reaches cell centre, 2 daughter cells form

Plant Cells

Vesicles carrying cell wall material move to equator and fuse in a line to form 2 cell walls and plasma membrane. Then pectin and other substances split the 2 layers

Tumours

- abnormal groups of cells that can develop
- Benign tumours do not metastasise, whereas malignant tumours do
- formed from uncontrolled mitosis, due to mutations

Oncogenes

these are proto-oncogenes

- ~~cell~~ genes with the potential to become cancerous after mutation
- involved in control of cell cycle, e.g. TP53, a gene that is a tumour suppressant
- Carcinogens mutate genes like P53, resulting in continuous cell division
- carcinogen or from tobacco smoke causes the mutations.
- ~~Dr~~ Robert Weinberg identified that cancer cells had tumour suppressant genes that were mutated and could undergo sustained angiogenesis due to mutated oncogenes
- Resistance to anti growth chemical signals

Molecular Biology

- study of biology at molecular level
- uses reductionist approach (break down biochemical processes into molecular components)
- Does not consider emergent properties
- explains living processes in terms of chemicals involved

Organic vs Inorganic Compounds

Organic

- have C atoms
- in living organisms
- complex structures
- e.g.s [proteins, lipids, carbohydrates]

Inorganic

- have C atoms
- found in abiotic environment
- simple structures
- e.g.s = any oxides, any hydrogencarbonates, CO_2 , urea [$\text{CO}(\text{NH}_2)_2$]

Vitality Theory

- Theory that life begins because of a vital principle (not chemical/physical)
- Proven wrong by Wohler's synthesis of urea by reacting silver isocyanate and ammonium chloride to form ammonium cyanate that is heated to form $\text{CO}(\text{NH}_2)_2$ [$\text{NH}_4\text{CN} + \text{O}_2 \rightarrow 2\text{CO}(\text{NH}_2)_2$]
 $\uparrow$
 $\text{NH}_3(\text{g}) + \text{CO}_2(\text{g})$
- Miller simulated Earth's environment 4 billion years ago and used electricity to create amino acids
- Wohler showed that organic and inorganic molecules were the same, organic molecules can be artificially created

(web of all enzyme catalysed reactions in a cell/organism)

Metabolism (sum of all biochemical reactions occurring in an organism)

- Biochemical reactions that are needed for life, catalysed by enzymes
- composed of a series of reactions that transform one molecule into another
- Def: web of all enzyme catalysed reactions in the cell/organism

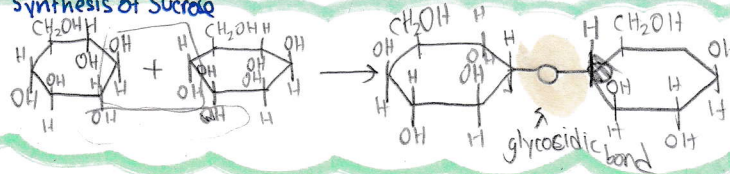
Anabolism

- synthesis of complex molecules from simpler molecules such as forming polymers from monomers
- Anabolic steroids promote body (molecule) building

both require ATP

- E.g. → Protein synthesis through ribosomes, DNA synthesis during mitosis, building polysaccharides (e.g. starch, cellulose) from disaccharides (e.g. sucrose/maltose)

Synthesis of Sucrose



(anabolic reaction)

Catabolism

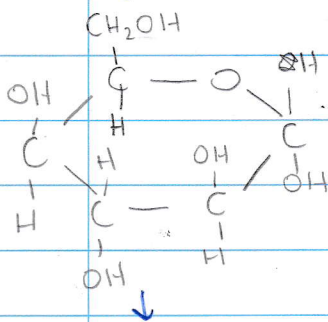
- The breakdown of complex molecules into simpler molecules including hydrolysis of macromolecules into monomers
- Releases energy (ΔH), can be released as ATP
- E.g = Cellular respiration where glucose is oxidised to CO_2 and H_2O , digestion by enzymes.

Elements and their uses

- N - make up amino acids + proteins
- Fe - used in production of haemoglobin
- P - phospholipid bilayer + DNA backbone + ATP
- Ca - Strengthens teeth and bones + initiate movement of neurotransmitters + initiate movement of tropomyosin off actin binding sites
- Na - used for generation of electrochemical gradients in nerve cells
- K - used for active transport of water → pumped in and out of cells

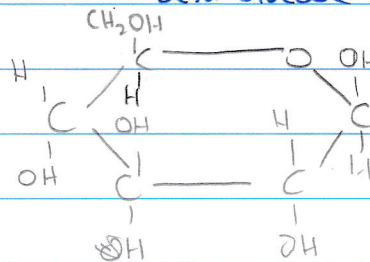
Molecular Structures

1) Alpha Glucose [$\text{C}_6\text{H}_{12}\text{O}_6$]



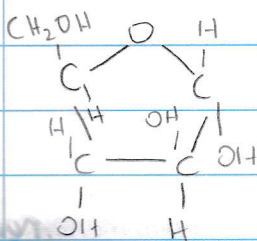
monomer unit in
Starch, glycogen

Beta Glucose [$\text{C}_6\text{H}_{12}\text{O}_6$]

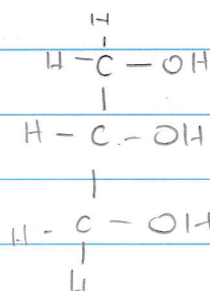


monomer unit in
cellulose, ~~glycogen~~

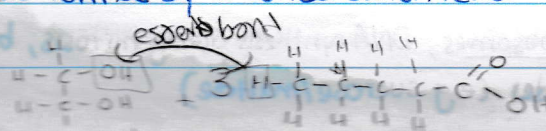
2) Ribose [$\text{C}_5\text{H}_{10}\text{O}_5$]



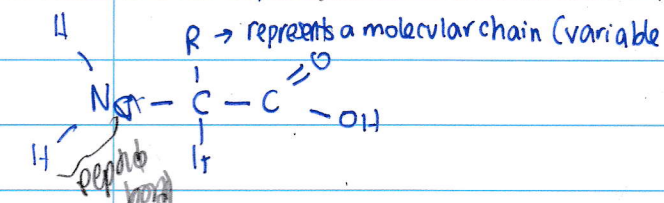
3) Glycerol



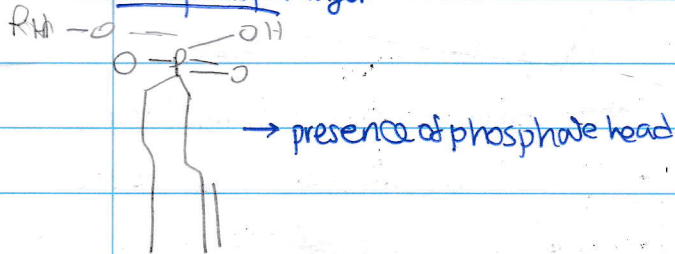
Triglycerides are formed by a condensation reaction between glycerol and 3 unsaturated fatty acids.



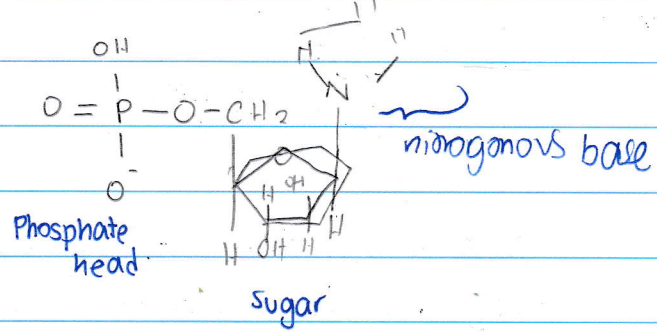
Amino Acids



Phospholipid layer



Nucleic Acid



cis → all branches on same side
trans → branches can be on either side

Carbohydrates → O-H ratios always 1:2. Can be monosaccharides (1 monomer), disaccharides (2 bonded monomers), polysaccharides (chain of monomers)

maltose

Lipids → insoluble molecules consisting of steroids, waxes, fatty acids + triglycerides

Fatty Acids → saturated = no double bonds between C atoms, unsaturated → double bonds between C atoms

Proteins → compounds composing of one or more amino acid chains. All have C, H, O, N, 2 of the 20 amino acids have Sulfur.

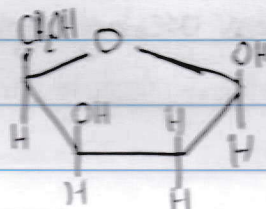
Nucleic Acids → consist of C, H, O, N and P, they are chains of nucleotides

Tests for Nutrients

- 1) Glucose → Benedict's solution. Turns [green, yellow or red] depending on amount of glucose for a positive result. Mix solution with sample and place in hot water bath
- 2) Protein → Biuret solution. Turns purple from blue in presence of proteins.
- 3) Starch → iodine. Turns blue black from brown if starch is present.
- 4) Lipid → ethanol → emulsification forms if lipids are present. Crush sample up using mortar + pestle. Add distilled water followed by distilled water

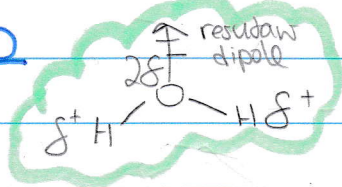
NOTE

Deoxyribose →



Water - 2.2

H₂O



Hydrogen bonding occurs when hydrogen is bonded to a highly electronegative element, resulting in a very strong intermolecular force being generated. The hydrogen bond between H₂O molecules results in attraction between molecules (cohesion). Hydrogen bonds between H₂O molecules and surrounding molecules (not H₂O) generate adhesion between the molecules. When water is drawn up a tube, ^{there is} adhesion between walls and molecules + cohesion → generates capillary rise/fall of water in a narrow tube.
Surface Tension due to high surface tension

Thermal

- H₂O has a high specific heat capacity (SHC)
- because most of the heat taken in is used to break bonds rather than ↑ AV KE (Temperature)
- Hence, water is a thermally stable medium, so its temperature only changes when it is very hot
- Therefore, suitable habitat for aquatic plants

Solvent

- water forms hydrogen bonds with polar molecules → O²⁻ attracts cations and 2H⁺ attract anions. This allows for the polar solute to dissolve as they become dissociated
- E.g water in cytoplasm is solvent for chemicals used in metabolic reactions.

Sweating/Coolant Properties

- When we sweat, water is transported to the skin surface
- when it evaporates, the molecules with highest kinetic energy are removed, hence removing heat energy
- the hydrogen bonds are broken → hence some of the molecules evaporate/leave

Hydrophilism

- describes substances that are chemically attracted to water
- all substances that can dissolve in water are hydrophilic
- Polar molecules and charged particles are hydrophilic

Hydrophobism

- no +ve or -ve charge or nonpolar
- water molecules attract each other rather than attracting hydrophobic particles
- Hydrophobic particles are attracted to each other by instantaneous dipoles (hydrophobic interaction)

Water vs Methane

- 1) Range of liquid temperatures - Higher in water because of hydrogen bonds that need to be broken $\frac{5}{5} \text{ HC}$
- 2) M.P-B.P - $\uparrow$ in H_2O because hydrogen bonds need to be broken
- 3) Density - $\uparrow$ in water because higher relative molecular mass

Transportation and solubility in blood plasma

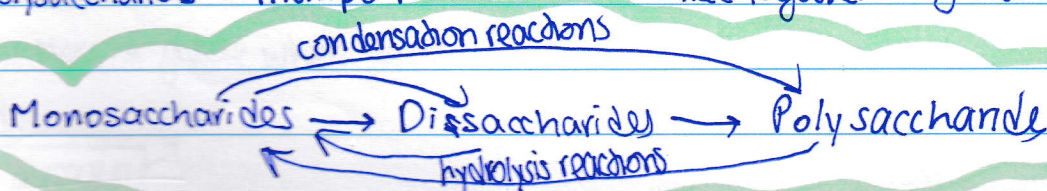
- 1) $\text{NaCl} \rightarrow$ dissociates into ions, hence can dissolve in blood plasma
- 2) Amino Acids $\rightarrow$ polar molecules but solubility varies with variable R group, dissolves in blood plasma
- 3) Glucose $\rightarrow$ polar, hence can dissolve in blood plasma
- 4) Oxygen $\rightarrow$ non-polar but small RMM allows little solubility, the higher the temp, lower solubility. Hence O_2 binds to haemoglobin, increasing blood's capacity to transport O_2
- 5) Fat molecules $\rightarrow$ non-polar, but large RMM, $\therefore$ totally insoluble. Carried in lipoprotein complexes that have a phospholipid on the outside and fats on inside. Lipoproteins are transport medium
- 6) Cholesterol $\rightarrow$ hydrophobic but some hydrophilic parts therefore it is a transmembrane integral protein. Not soluble, hence transported in lipoproteins. Placed in phospholipid compound

2.3 Carbohydrates and Lipids

Carbohydrates

Monosaccharides $\rightarrow$ single sugar units. Disaccharides are made of 2 monosaccharides (e.g. sucrose)

Polysaccharides $\rightarrow$ multiple monosaccharides linked together. E.g. starch, glycogen, cellulose



Condensation Reactions are anabolic and requires ATP, ATP supplied to monosaccharides and the energy is used when the reaction begins

Monosaccharides $\rightarrow$ galactose, glucose, fructose

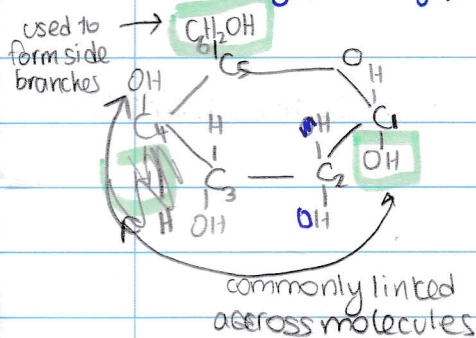
Disaccharides $\rightarrow$ lactose, sucrose and maltose

Polysaccharides $\rightarrow$ Starch, glycogen, cellulose

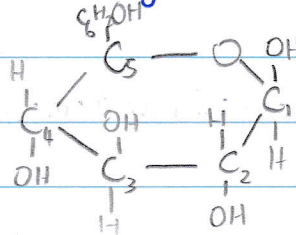
Polysaccharides

The monomer in glycogen, starch and cellulose is glucose but different isomers are used.

α -glucose (glycogen, starch)



β -glucose (cellulose)



→ Condensation reactions between the OH on C-1 and the OH on C-4 on an adjacent α glucose

→ Because both OHs point down, all glucose molecules have the same orientation, hence starch and glycogen are curved and there are branches → amylopectin

→ ~~Starch~~
In amylose

Starch

- Amylose → chain is unbranched and is a helix
- Amylopectin → branched chain, globular shape

→ For cellulose to form, the OH on C1 must ^{link} bond with the OH on Carbon - 4, but since the 2 OHs are in opposite directions, the each β -glucose molecules must be placed at 180° to one another. The glucose monomers are ~~not~~ alternately up and down.

→ Therefore cellulose is an unbranched straight chain allowing them to form bundles, through H-bonding, called cellulose microfibrils

→ Cellulose Microfibrils have high tensile strength and are used in cell walls as the tensile strength prevents the cell from bursting during water entry through osmosis. High pressure resistant

Starch is hydrophilic in both forms but too large to dissolve in water. Hence it is used as a store of lots of glucose in cells such that a concentrated glucose solution **IS NOT PRODUCED** to allow water to stop too much water from entering, maintain isotonic

Starch is also a store of energy in storage organs such as seeds and potato cells. Starch can be a temporary store of glucose when glucose is being produced too fast in a leaf and cannot be quickly exported.

→ Ditto for glycogen

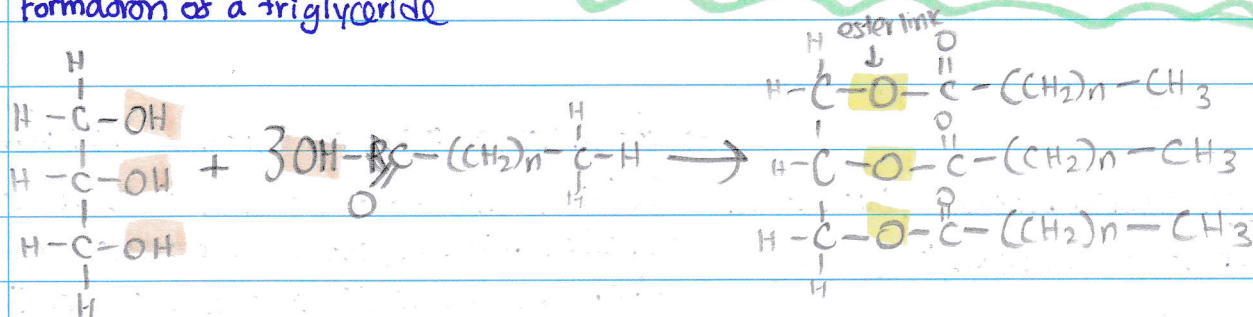
Starch and Glycogen

- easy to add/remove glucose molecules ^{from} both ends of unbranched or any end of branched
- No fixed no. of glucose monomers.

Lipids

- diverse group of insoluble carbon compounds
- e.g. triglyceride in human adipose tissue (fatty tissues whose cells synthesise fat globules) and oil in sunflower seeds
- Fats are liquid at 37°C but solid at room temp (20°C). Oils are liquids in both situations

Formation of a triglyceride



Ester bond: When a link is formed between an OH of an alcohol and an OH of an acid

Triglycerides are used as energy stores, the energy in them is released through aerobic cellular respiration. Since they are poor conductors of heat, they are used in blubber as insulation.

can be used in link reaction

Energy Storage

- Lipids (fats in this case) are used as long-term energy storage in specialised tissue called adipose tissue
- Adipose tissue is located under skin and behind organs like kidneys

Why Lipids?

- ① Energy released during respiration $\rightarrow$ double to that of carbohydrates. Same amount of energy stored as lipid rather than carbohydrates adds half as much to body mass. Fats from lipids also form pure droplets with no water whereas one gram of glucose is associated with 2 grams of water.

- ② Lipids have other roles to play $\rightarrow$ adipose tissue used to insulate body. Because fat is a liquid at body temperature, it acts as a shock absorption tissue, hence adipose tissue surrounds the vital organs like kidneys.

- ③ Glycogen is short term $\rightarrow$ can be broken down to glucose rapidly and used in aerobic or anaerobic respiration. Glucose can be used in aerobic or anaerobic respiration whereas fats can only be used in aerobic respiration.

Body Mass Index (BMI)

$$BMI = \frac{\text{Mass (kg)}}{[\text{height (m)}]^2}$$

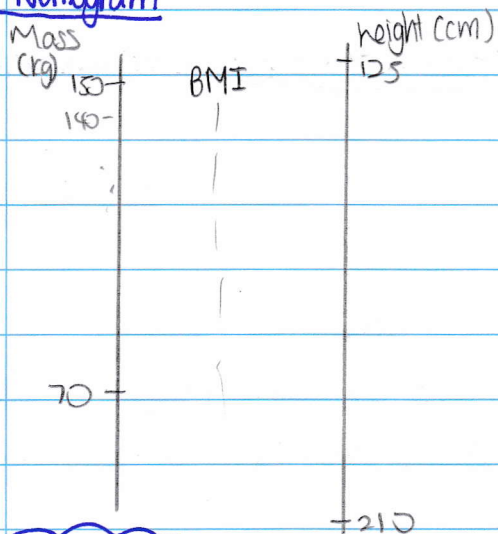
BMI	Status
< 18.5	underweight
$18.5 - 24.9$	normal weight
$25.0 - 29.9$	overweight
> 30	obese

Underweight $\rightarrow$ lack of food in countries, uneven distribution of food or anorexia nervosa

Obesity → Excessive food intake, lack of exercise cause accumulation of fats in adipose tissue

Body fat can be estimated using skin fold calipers. Obesity increases risk of contracting type 2 diabetes and coronary heart disease.

Nomogram

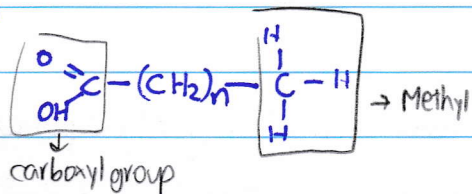


Steps

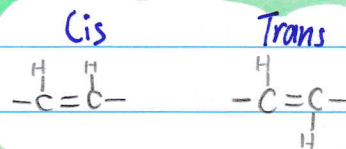
1) Draw a line between ^{given} mass and given height. Where this intersects BMI is the BMI of the person

Fatty Acids

Basic Structure =
of a saturated
fatty acid



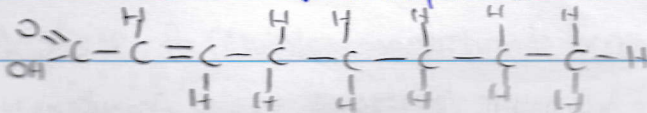
Only pertains to Cs with =



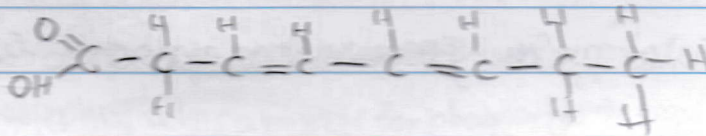
Saturated Fatty Acids - Single bonds between all of its carbon atom, with 4 bonds per C atom

Unsaturated fatty acid $\rightarrow$ At least one double bond between C atoms. If it is just one, it is a monounsaturated fat. If there are more than one ~~or~~ double bonds, it is polyunsaturated.

Monounsaturated -
(trans)



Polysaturated (cis) -



Cis vs Trans

Cis

- There is a bend at the site of the double bond
- Hence, triglycerides holding cis fatty acids pack together to a lower extent
- This leads to a lower melting point due to weaker LDFs
- Triglycerides with cis isomers are (oils).

Trans

- No bend at double bond site
- Hence triglycerides pack together to a greater extent
- ~~Low~~ Higher LDFs, higher m.p., solidifies at RTP
- Produced artificially by partial hydrogenation of fish oils → used for margarine and other processed foods

Health Risks

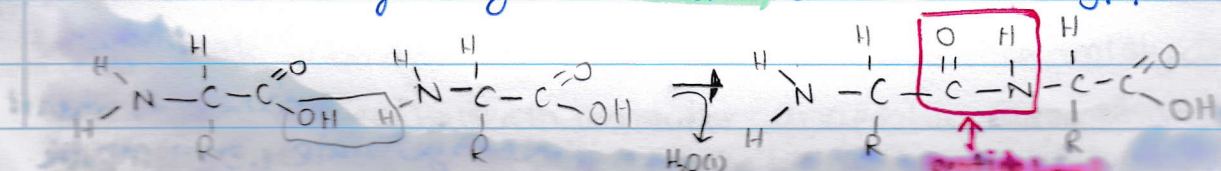
- CHD → blockage of coronary arteries by fatty deposits → blood clots and heart attacks
- positive correlation between saturated fat intake and CHD rates, but does not imply causation
- Furthermore, Maasai in Kenya have high quantities of saturated fats in their diet, but no incidence of CHD.
- Olive oil - cis monounsaturated fats → low CHD rates, but other dietary aspects could explain it
- The nail in the coffin - arteries of CHD patients contained fatty deposits consisting of trans fats (causal + causation demonstrated)

Evaluation of claims

- Low sample size, standard σ^2 , methodology, link to claim, statistical tests, reliable apparatus?

24: Proteins

- Amino Acids are linked together by condensation reactions to form polypeptides



Diversity

- 20 different amino acids, R groups give each their own character → ∴ the 20 are very diverse
- Some amino acids are not in the 20 → e.g. prolines in collagen polypeptides are sometimes converted to hydroxyproline to stabilise the collagen, ascorbic acid (vitamin C) does this → link to rickets and poor muscle development
- The sequence and number of amino acids in polypeptides [primary structure] also offer variety, 20^n combos, where n is the number of amino acids
- Proteins can be made of ≥ 1 polypeptide → ∴ have quaternary structure
- Conformation (3-D shape) is influenced by amino acid sequence and constituent polypeptides and tertiary structure influenced by R group interactions

Denaturation

- Heat - vibration within molecule breaks intermolecular interactions, causing a change in the protein's conformation (irreversible)
- pH → charge change on groups, breaking ionic bonds or causing new ones to form, changing the 3D structure of protein. (see enzymes)

Functions

- ① Catalysis by enzymes
- ② Muscle contractions → actin and myosin filaments slide over each other
- ③ Tensile Strength - fibrous proteins in skins/tendons
- ④ Blood Clotting → fibrinogens as clotting factors
- ⑤ Cell adhesion → membrane protein
- ⑥ Membrane transport → channel proteins, pump proteins
- ⑦ Immunity → glycocalyx in cells
- ⑧ DNA packing → histones in nucleosome

Examples

- ① Rubisco - ribulose biphosphate - fix CO_2 into monosaccharide form → root of all chemical energy
- ② Insulin - hormone signalling for glucose absorption, shape and size correspond to receptor binding site of the specific receptor. Insulin secreted by β -cells in pancreas
- ③ Immunoglobulin - antibodies that act as a marker for phagocytes to engulf pathogens (opsonins)
- ④ Rhodopsin - membrane protein in the retina, made of a light sensitive ^{retinal} molecule, when it absorbs a photon of light, changing opsin polypeptide → generates nerve impulse. Also low light intensities to be generated

⑤ Collagen - rope like proteins - 3 polypeptide - v. abundant, forms mesh fibres in skin and blood walls to resist tearing, part of teeth and bones to prevent cracks

⑥ Spider silk - dragline silk is stronger than steel

Proteome

- all proteins produced by a cell, tissue or organism
- mixture of proteins extracted and checked by gel electrophoresis
- Proteome representative of the present proteins, because proteins vary over time depending of cells activities

2.5 Enzymes

Enzymes → globular proteins that act as biological catalysts of reaction
Features

← 2 or more polypeptide chains

- 1) Left chemically unchanged
- 2) Have specific active site (where substrate binding occurs) → allows specificity
- 3) Enzyme substrate specificity → active site shape complementary to the substrate

Enzyme Activity

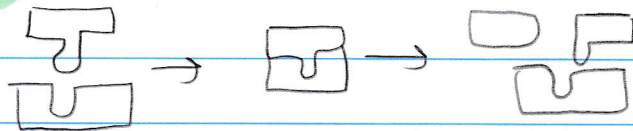
- Substrate binds to active site when enzyme and substrate particles collide with sufficient activation energy and correct orientation. Normally particles move randomly
- An enzyme substrate complex is formed and the substrate is converted to product
- Products move from active site

Notes

- Substrate dissolved in aqueous form around enzyme in water.
- Substrate particles are in continuous motion and stochastic motion.

Hypothesis

① Lock and Key



- Active site has a unique shape and the substrate has a shape complementary to the active site
- Hence the substrate fits the active site like a key into a lock
- Therefore only 1 specific structure substrate can bind to an enzyme
- Enzyme left chemically unchanged

② Induced Fit

- Active site initially does not fit the substrate
- When substrate approaches, it induces the enzyme to undergo a conformation change
- This allows the substrate to fit tightly into the active site and the fit weakens substrate bonds, reducing the E_a
- The original conformation is restored once products leave
• allows for enzymes to have many several similar substrates

Recall Kinetics

- 1) Substrate and enzymes must collide with sufficient orientation and energy
- 2) Collisions are random (stochastic)

Transition State Theory

- ① Initiation → Reactants (substrates) bind to active site in specific orientation to form a enzyme substrate complex
- ② Transition state facilitation → ^{reacts better here} enzyme-substrate interaction reduces E_a
- ③ Termination → Products have low affinity for active site and hence are released

How E_a is lowered.

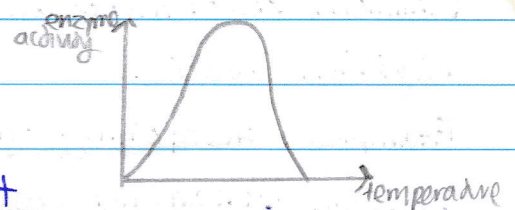
E_a : energy that particles need to collide successfully leading to reaction

Enzymes bring the substrate molecules closer together, providing an alternative reaction pathway, decreasing E_a in the process.

Factors Affecting Enzyme Activity

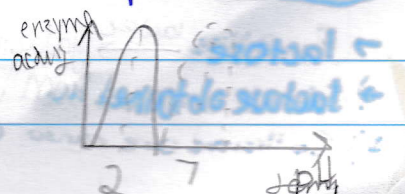
1) Temperature

- Low T → insufficient K.E of substrate molecules results in no fewer collisions between substrate and enzymes per unit time, hence there is no catalytic activity
- Increasing the T would increase K.E of substrate and enzyme molecules, increasing frequency of successful collisions, increasing enzyme activity
- When the optimal T is reached, enzyme activity has reached its maximum
- Temperature increase above optimum decreases enzyme stability due to very high K.E ~~of~~ of enzyme molecule breaks hydrogen bonds keeping that maintain the shape of the active site
- The enzyme loses its 3D shape (conformation). The substrate can no longer bind to the active site, causing a loss of activity



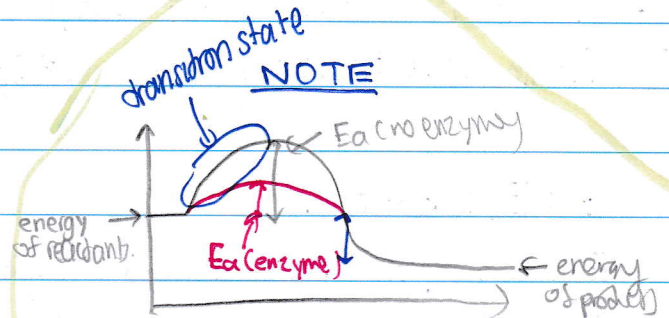
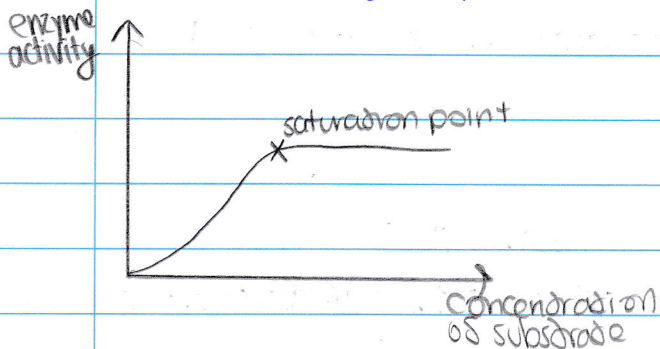
2) pH

- If the environment is too basic (OH^-) or too acidic (H^+), the charge of the amino acids R groups will change, interrupting H bondings in the tertiary structures, changing the shape of the molecule.
- The change in conformation breaks H bonds, changing the shape of the active site, inhibiting enzyme activity due to denaturing



3) Substrate concentration

- ↑ substrate concentration, more successful collisions per unit time, leading to ↑ enzyme activity
- However, plateaus at the saturation point, where all the active sites are occupied and rate is limited by enzyme concentration



Exergonic: exothermic [energy released]
Endogonic: endothermic [energy released]

Denaturation

Definition: ^{Permanent} Loss of the precise conformation of the active site such that it can no longer bind substrate.

Examples → the spoiling of milk when bacteria respire anaerobically, producing lactic acid, ↓ pH and hence denaturing lactase, causing curdling, pasteurising milk (70°C) denatures enzymes - makes it last longer

PPQs

- 1) Explain enzyme-substrate specificity.
 - The active site's shape is complementary to that of the substrate, in terms of shape, charge and chemistry
 - The substrate can therefore bind to ^{enzyme} substrate and form enzyme-substrate complex
 - catalyses reaction to make enzyme-product complex

Immobilised Enzymes

- Attachment of enzymes to another material or into aggregations
- Used commercially
- Easier to remove [separate from product] and ^{+ stop reaction at ideal time} recycle, increases enzyme stability, reduces rate of degradation of enzymes, higher [enzyme], ∴ faster rate

Lactase

- lactose $\xrightarrow{\text{lactase}}$ galactose + glucose
- lactase obtained from yeast

Why use it?

- ① for lactose intolerance - so they can eat products
- ② Glucose and galactose are sweeter than lactose, no need for flavouring
- ③ In ice cream, lactose adds with texture more with galactose + glucose

2.6: DNA and RNA structure

Nucleic Acids vs Nucleotides

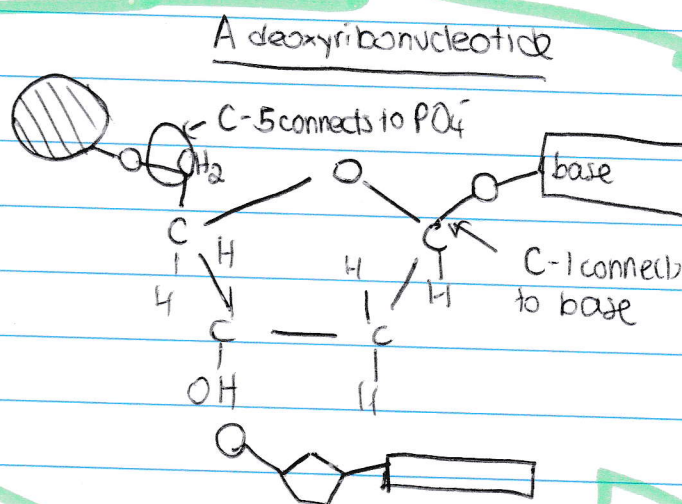
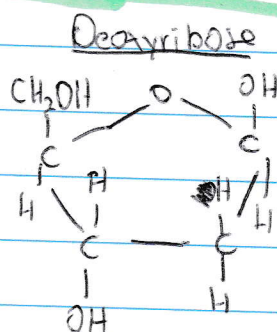
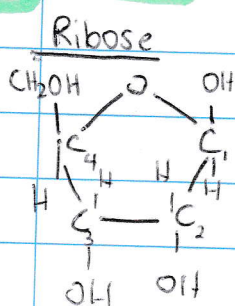
DNA and RNA are nucleic acids, in fact, they are polymers of nucleotides.

Nucleotides are primarily made of 3 parts.

- 1) A Pentose Sugar (5 Carbons)
- 2) A phosphate group, which is the acidic part connected to Carbon 5
- 3) Base - a nitrogenous base with a double or single ringed structure

DNA vs RNA

- 1) RNA is single stranded [1 polymer], DNA is double stranded [2 polymers]
- 2) RNA has uracil, adenine, cytosine and guanine, whereas DNA has no uracil [Th]
- 3) The sugar in DNA is deoxyribose, in RNA it is ribose



Bases

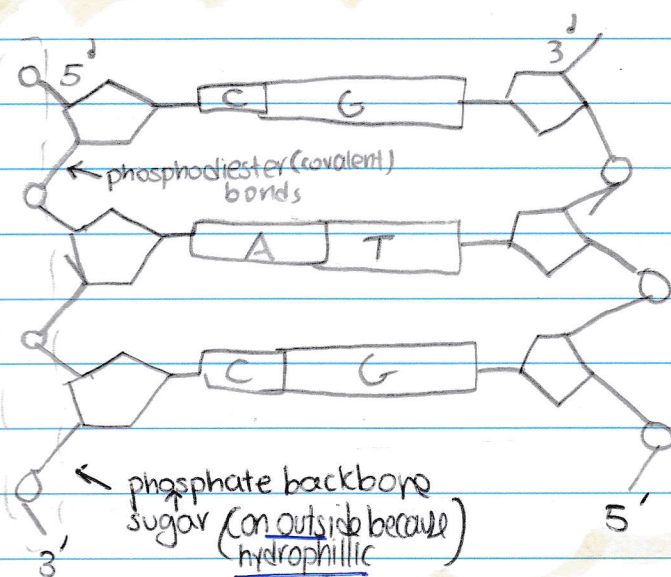
A - T, G - C

2 H bonds 3 H bonds

- Pyrimidines - bases that are made of 1 ring, have "y" in their names → Cytosine and Thymine (also Uracil)
- Purine [small name, large molecule] - bases made of 2 rings, adenine and guanine

DNA

- Def: A double helix made of anti parallel strands of nucleotides linked by hydrogen bonding between complementary base pairs
- Each strand is a chain of nucleotides covalently bonded to each other, through condensation reactions between phosphates to form the bond and a pyrophosphate
- Helical shape reduces risk of mutation by keeping bases on inside



C-1 → bonds to base

C-2 → has H on bottom, not OH

C-3 → phosphodiester bond with a C5

C-4 → links to C-5

C-5 → phosphate phosphodiester bond

Bases on inside because they are very reactive.

Full twist every 10 base pairs, this is because of the antiparallel nature, opposing running directions, causes twisting

allows for replication as base pairing is exclusive → ∴ complementary strands

Crick and Watson

1st Model → Triple helix, bases on outside, with ionic bonds holding strand together

This matched the results of Rosalind Franklin's X-ray diffraction experiment.

Falsified when it was discovered that there would be insufficient Mg for the ionic bonds + A and T, C-G amounts not equal, ex dissimilar to Chargaff,

2nd Model → antiparallel stranded double helix with complementary base pairing H-bonds holding it together

Hershey Chase Experiment → proved DNA was genetic material

- Viruses known to inject genetic material into host cells, non genetic bits left outside
- genetic material has no sulfur, hence 2 cultures, one with radioactive phosphorus (P) another with sulfur (S).
- if infected cells were radioactive, DNA was the genetic material
- centrifuged cultures, supernatant is the top, pellet is bottom of the centrifuged sample.
- pellet would hold genetic material as it would hold the newly infected cell

Nucleosomes

in mitosis/meiosis

they help to supercoil DNA exclusive to eukaryotes

batch of 8 histones wrapped in 2 turns by DNA. Held in place by the H1 histone.

Regulates transcription

2.7: DNA Replication

- replication is semi-conservative and depends on complementary base pairing
- It is semiconservative because the 2 final DNA molecules are each made of one original strand and one newly synthesised strand

Why base pairing is needed?

- 1) C. base pairs form H-bonds between them, stabilising the DNA double helix
- 2) Ensures that few mutations occur as H bonds would not form between the wrong base
- 3) and the new nucleotides would be added
- 3) Allows for supercoiling
- 4) ~~Prevents mutation~~ Replication

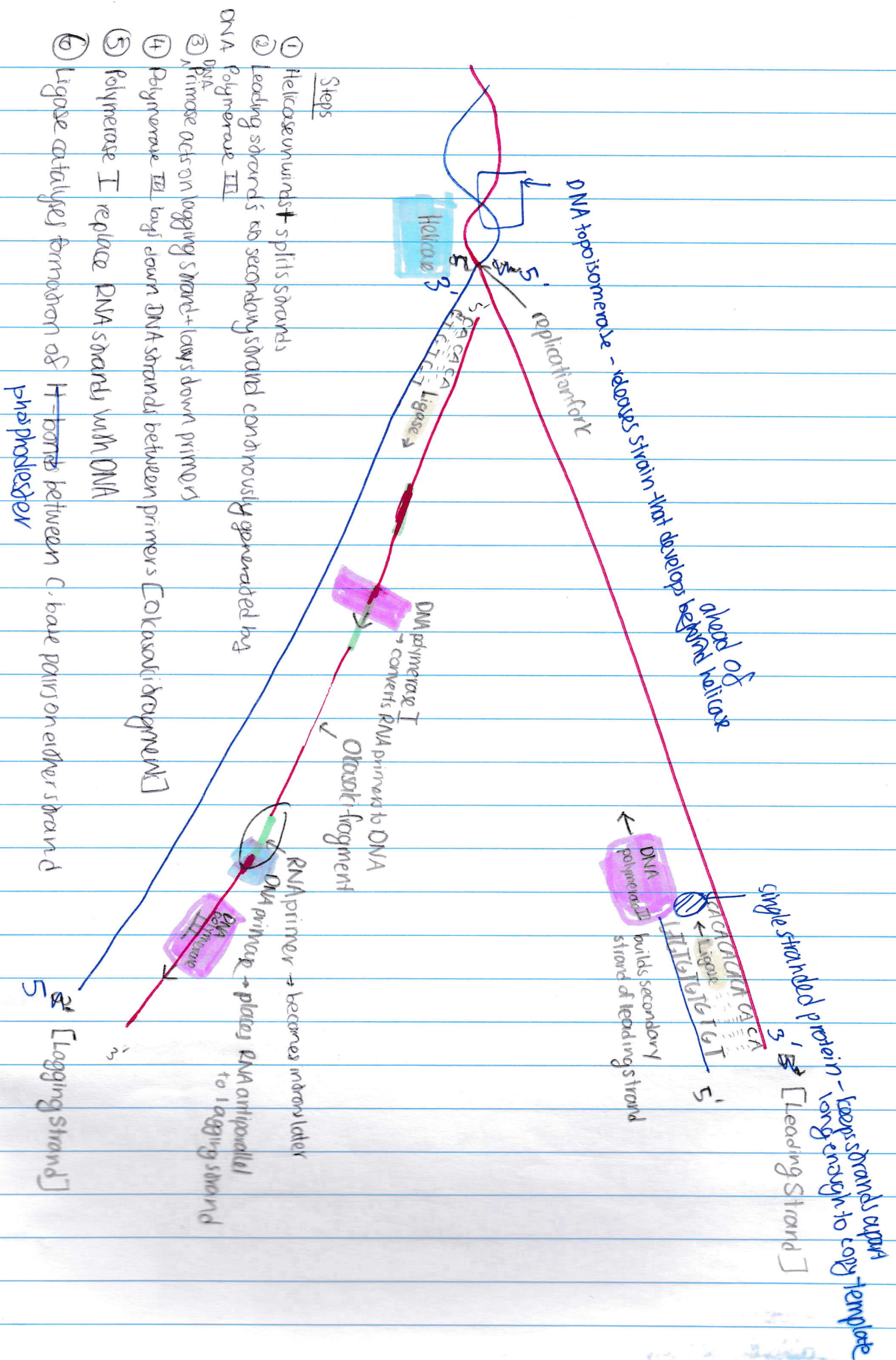
Enzymes

- 1) Helicase - unwinds the double helix and separates strands using the breaking of H bonds.
- uses ATP, the unwinding and breaking is simultaneous
- 2) DNA Polymerase III - acts in a 5' to 3' direction, moving along template strand and adding 1 nucleotide at a time. The addition along the leading strand is continuous because it is a 5' from the end to a 3'. For the lagging strand, DNA polymerase III connects RNA primers with DNA strands, creating Okazaki fragments
- 3) DNA primase - lays RNA primers down to guide polymerase III to lay down Okazaki fragments (5' to 3')
- 4) DNA polymerase I → acts from 5' to 3', removes RNA primers and replaces them with DNA.
- 5) Ligase - catalyses the formation of phosphodiester bonds between C. base pairs.

RNA primers become introns

Okazaki fragments become exons

The primers have nucleotides added to their 3' ends by DNA polymerase III ^{going from 5' to 3'} because ~~it acts from 5' to 3', and because of the antiparallel nature of the primer, it adds the primer moving away from the replication fork~~



Evidence for Semi Conservative Replication

Case Study: Meselson and Stahl

- Used a ^{15}N isotope that is heavier than ^{14}N
- Cultured bacteria for 14 generations where only N source was ^{15}N (so all DNA had ^{15}N)
- Changed solution to one with ^{14}N
- After sev. Every couple of hours, DNA samples collected.
- Lower density because N-14 incorporated into the newly synthesised strands

HAVE A LOOK AT THE TEXTBOOK [page 114]

PCR (polymerase chain reaction)

- In a PCR, we need to synthesize new, double stranded DNA
- First, a DNA ^{with desired sequence} present is heated to 95°C for 15s to split strands (as H bonds are weak)
- Then, it is cooled to 54°C to allow re-annealing of parent strands to form DNA
- However, extra DNA primers (single stranded DNA) will be present in excess
- This prevents reannealing of parent strands, as the primers will attract parent strands
- Taq Polymerase (which is present from the start) synthesises new strands based on primer templates, replicating the first DNA sequence, when temp raised to 72°C
- Taq Polymerase can add 1000 nucleotides per minute at this temp
- Once fully replicated, $T \uparrow$ to 95°C again to start cycle

Back to DNA structure

Non Coding DNA

- coding sequences code for polypeptide production
- Telomeres - highly repetitive sequences at the end of eukaryotic chromosomes.
 - has a protective function → lost in interphase; enzymes in DNA replication cannot continue until the ends of the chromosome. Hence, the repetitive sequences are sacrificed
- Introns - intervening sequences [RNA primers]
- Satellite DNA - highly repetitive sequences
- Transcription Related Sequences (non-coding)
 - Promoter - site at which RNA polymerase binds, if the enzyme catalyses the formation of covalent bonds between nucleotides in the synthesis of mRNA. Note: The promoter is not transcribed
 - Terminator - base sequence that causes RNA polymerase to stop transcription

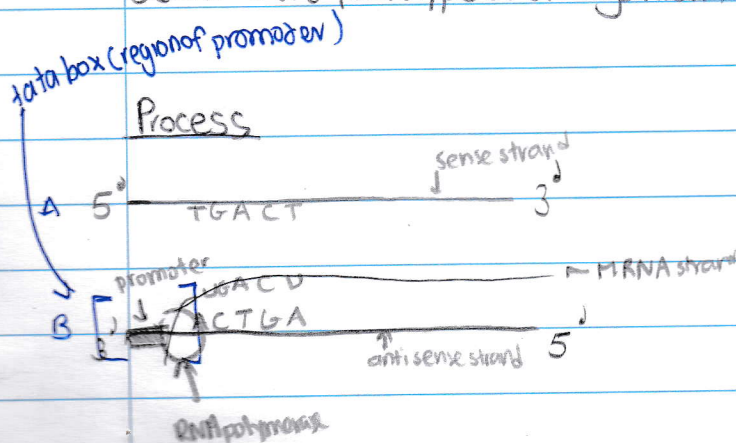
Proteins that affect Transcription

- Enhancers - Regulatory sequences that, when proteins bind to them, increase the rate of transcription
- Silencers - sequences that, when proteins bind to them, decrease the rate of transcription
- Promoter-Proximal Elements - binding of proteins to these sequences is necessary to start transcription.

Transcription

Definition: DNA directed mRNA synthesis by RNA polymerase.

Produces mRNA that translates specific proteins based on the genes in the DNA. These proteins directly or indirectly determine the phenotype of an organism. Occurs in the nucleus (for eukaryotes)



RNA polymerase binds to a terminator strand
the strand of mRNA is separated and released

1) RNA polymerase binds to the promoter sequence and unzips the double helix

2) Acts 5' to 3'; hence it copies the antisense [3' to 5'] because the anti-parallel version of it is 5' to 3'

3) The antisense is the template for synthesis

4) New mRNA is identical to sense, but U replaces T

5) Free nucleoside triphosphates are added to the mRNA strand and this reaction is complementary. RNA polymerase catalyses the formation of phosphodiester bonds between them.

6) RNA transcribes anti-sense but copies sense strand

7.2 : Transcription and Gene Expression

Regulation

- production of proteins at certain times and certain amounts
- can be regulated by variations in environmental factors [in prokaryotes as well]
- Example: Genes responsible for absorption and metabolism of lactose in *E. coli* are expressed in the presence of lactose and are not expressed in its absence. [For detailed mechanism, see page 355] Relies on negative feedback. When lactose is present, a repressor protein is deactivated. However, in its absence, the protein becomes active and blocks the expression of lactose metabolism + absorption genes.
- In eukaryotes, regulation is a critical part of differentiation and development

Impact of the environment

- Environmental factors can affect gene expression, like production of skin pigmentation during UV exposure
- In embryos, chemicals called morphogens are unevenly distributed and their concentrations affect gene expression. Hence, different embryonic cells will have different functions.

Nucleosomes

- made of 8 histones that DNA wraps around x2 and a H-1 histone
- Chemical modifications to histone tails determine gene expression
- Possibilities: addition of acetyl group, methyl group or phosphate group
- Example: Residues of lysine (amino acid) can allow for the addition or removal of acetyl groups. The residues are +ve and bind to -ve DNA to condense structure further, inhibiting transcription. Histone acetylation neutralises the +ves to allow for a less condensed structure, promoting transcription by increasing the accessibility of genes to transcription patterns.

Methylation Patterns in DNA [on bases]

- direct methylation of DNA inhibits the accessibility of genes to transcription factors.
- It varies with environmental factors

Epigenetics

- The chemical modifications of chromatin (e.g. acetylation of amino acid tails) are epigenetic tags.
- The sum of the epigenetic tags = epigenome

splice

- Different cells have their own epigenomes due to, for instance, a different methylation pattern
- ^{will} can be passed to daughter cells in mitosis
- However, the sperm and egg, when they fuse to form a zygote, have their epigenome erased through "reprogramming."
- 1% of epigenome survives, this survival is called imprinting

Modifications to allow transcription

- 1) open chromatin
- 2) unmethylated cytosine
- 3) acetylated histone tails

Modifications to block transcription

- 1) condensed chromatin
- 2) methylated cytosine
- 3) unacetylated histone tails

Post-Transcription Modification of mRNA

- occurs in eukaryotes only
- absent in prokaryotes, but modifications occur during transcription so translation can start immediately [because prokaryotes have naked DNA]
- initial product of transcription = pre mRNA

RNA splicing

- Spliceosomes are formed by intermolecular proteins called snurps
- The spliceosomes splice exons together and remove intervening sequences (introns)

Caps

- 5' cap added to 5' end of mRNA, usually occurs before transcription ends
- A poly-A tail consisting of 250 Adenines is added to 3' after transcription

Alternative Splicing

- process during gene expression when one gene codes for multiple proteins
- occurs in exon rich genes
- Certain exons may or may not be excluded in final mRNA, hence spliced mRNA would produce different proteins

- for example, tropomyosin pre mRNA is spliced differently, resulting in 5 different forms of the protein.

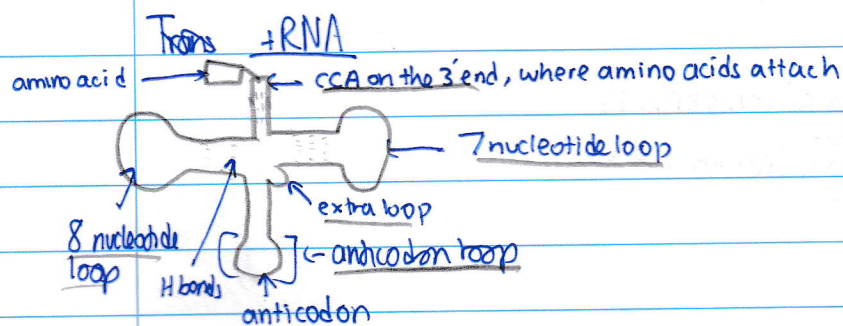
2.7 + 7.3 : Translation + Basic Proteins

Definition: mRNA directed polypeptide synthesis on a ribosome

- Takes place on ribosomes in the cytoplasm
- Ribosomes have 1 small subunit [1 rRNA and 20 proteins] and 1 large [2 rRNA + 33 proteins]
- 3 tRNA binding sites, aminoacyl (A), Peptidyl (P) and Exit (E). Can hold 2 tRNA at a time

Codons

- The codons [triplet base sequence] on mRNA each code for a specific protein to be added to a polypeptide chain
- AUG - start codon (also codes for methionine), starts translation
- UGA - stop
- codons that code for the same ~~prote~~ amino acid are said to be degenerate
- The amino acids are carried on tRNA that have a 3 base "anti-codon" that is complementary to the codon that codes for the carried amino acid

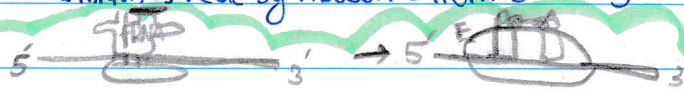


Has the following features

- 1) Double stranded sections [by base pairing]
- 2) anti-codon
- 3) loops of 7 and 8 nucleotides
- 4) CCA at 3' end where an amino acid is attached

Translation

Note: the mRNA is read by ribosome from 5' to 3'



1) Initiation: assembly of components that carry out the process

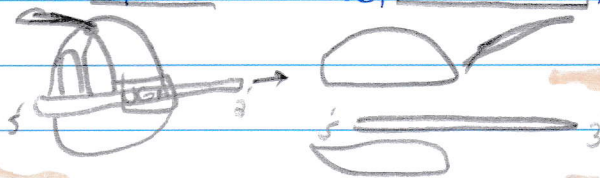
- mRNA binds to the mRNA binding site on small subunit
- tRNA with anticodon UAC binds to the AUG start codon on mRNA
- Small subunit binds to large subunit
- The first tRNA: initiator tRNA, enters the P site.
- A tRNA molecule with a complementary anticodon to the next mRNA codon is attracted by H bonds and occupies the A site
- A peptide bond is formed between the amino acid in A and that in P

2) Elongation: repeated addition of amino acids to the polypeptide chain

- process
- ribosome translocates 3 base ^{down} from mRNA towards 3'
 - This moves tRNA in P to E and tRNA in A to P.
 - A new tRNA molecule with a complementary codon binds to the A site and its amino acid forms a peptide bond to the amino acid in P
 - This process repeats itself

3) Termination: followed by disassembly of components

- when stop codon is reached, no tRNA binds, free polypeptide is released



Types of Ribosomes

1) Free

- free moving ribosomes in the cytoplasm
- more commonly used for translation than bound ribosomes
- produces proteins to be used in cytoplasm, mitochondria and chloroplasts

Translation

Note: the mRNA is read by ribosome from 5' to 3'



1) Initiation: assembly of components that carry out the process

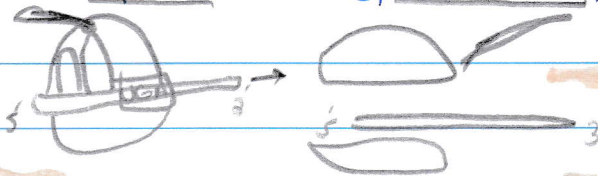
- mRNA binds to the mRNA binding site on small subunit
- tRNA with anticodon UAC binds to the AUG start codon on mRNA
- Small subunit binds to large subunit
- The first tRNA: initiator tRNA, enters the P site.
- A tRNA molecule with a complementary anticodon to the next mRNA codon is attracted by H bonds and occupies the A site
- A peptide bond is formed between the amino acid in A and that in P

2) Elongation: repeated addition of amino acids to the polypeptide chain

- process
- ribosome translocates 3 base ^{down} from mRNA towards 3'
 - This moves tRNA in P to E and tRNA in A to P.
 - A new tRNA molecule with a complementary codon binds to the A site and its amino acid forms a peptide bond to the amino acid in P
 - This process repeats itself

3) Termination: followed by disassembly of components

- when stop codon is reached, no tRNA binds, free polypeptide is released



Types of Ribosomes

1) Free

- free moving ribosomes in the cytoplasm
- more commonly used for translation than bound ribosomes
- produces proteins to be used in cytoplasm, mitochondria and chloroplasts

2) Bound

- ribosomes attached to cisternia in the rough endoplasmic reticulum
- produce proteins meant for ER, golgi apparatus, lysosomes, plasma membrane and out of cell.

Bound	Free
ER	mitochondria
Golgi	cytoplasm
Lysosomes	chloroplasts
Plasma Membrane	
Out of cell	

How ribosomes become bound

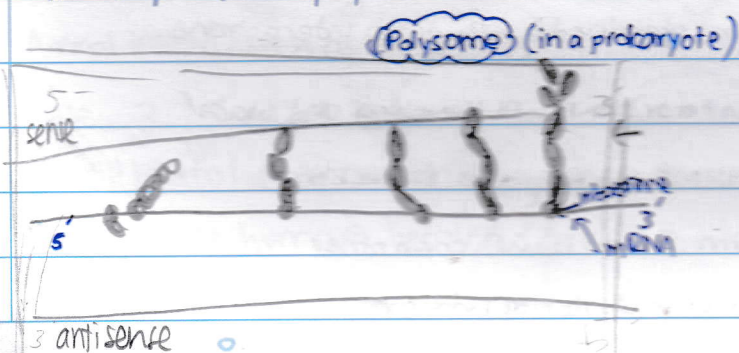
- caused by a signal sequence and the polypeptide being synthesised
- This is translated 1st
- It is bound to a ^{signal} surface recognition protein that stops translation till the ^{protein} ~~ribosome~~ binds to ER.
- Polypeptide moves into lumen of ER as it is being built, so it can bud off as a vesicle from the cisterniae

Transcription + Translation in Prokaryotes

- unlike eukaryotes, no compartmentalisation
- translation can begin immediately, no nucleus separating mRNA and ribosome

Polysomes

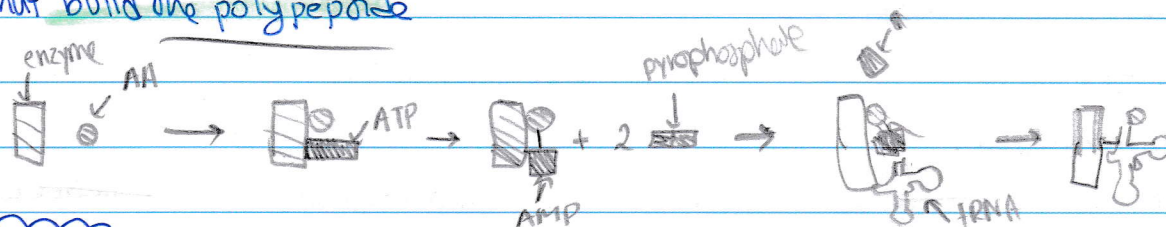
- multiple ribosomes attached to a single mRNA → increase efficiency
- In eukaryotes, in cytoplasm and next ^{to} ER.



Bioinformatics

tRNA enzymes [20 types]

- each tRNA molecule is recognised by a specific tRNA enzyme
- Specificity because base sequence (ergo structure) of each tRNA varies
- Active site of tRNA activating enzymes is suited specific to tRNA shape and the amino acid it should carry
- In short, tRNA activating enzymes catalyse the formation of an attachment of an amino acid to the 3' end of tRNA.
- Long: ATP and amino acid attach to the active site and the amino acid is activated by the formation of a bond between enzyme and adenosine monophosphate (AMP), releasing pyrophosphates. Hence, this is phosphorylation. AMP then released
- The enzyme then catalyses the formation of a strong covalent bond between the amino acid and tRNA. The energy from this bond is used to provide energy for the anabolic reactions that build the polypeptide



Structures

- 1) Primary - sequence + no of amino acids
 - sequence, number and identity of amino acids
 - 20^{∞} possibilities [assuming we have an ∞ chain]
- 2) Secondary - formation of α -helices and β -pleated sheets
 - consists of alpha helices + beta pleated sheets
 - formed by H-bonds between carbonyl group of one amino acid and the amine group of another
 - caused by folding by polar covalent bonds in backbone of amino acid chain

A diagram showing a coiled alpha-helix structure. A label 'stabilised by H-bonds' points to the structure. Another label 'H-bond' points to a specific hydrogen bond between a carbonyl group and an amine group within the helix.
- 3) Tertiary - further folding of protein, stabilised by R-group interactions
 - overall 3D shape, formed by R-group interactions with themselves and water
 - 4 possibilities -
 - 1) +ve R groups attract -ve R groups (ionic bond)
 - 2) Polar R groups form H-bonds with each other
 - 3) Cysteine - Cysteine disulphide bridge
 - 4) Hydrophobic R's orientate to centre, hydrophilic to exterior

4) Quaternary Structure - exists in proteins with > 1 polypeptide chain

- refers to how polypeptides fit together when there is > 1 chain
- E.g quaternary structure of haemoglobin, 4 chains, 4 heme groups.

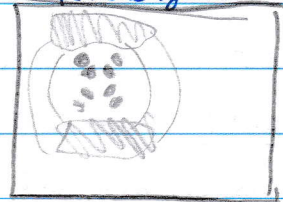
Rosalind Franklin

- used X-ray diffraction to deduce DNA's structure

Observations

- 1) cross in the centre indicated a helical shape
 - 2) angle of the cross showed steepness of helix
 - 3) distance between the horizontal bars - turns were 3.4 nm apart
 - 4) Distance between middle and top = vertical dist between adjacent base pairs
- These deductions were used by W + C to perfect the model

Shape found by R. Franklin



Scientists to know with respect to DNA

- 1) Watson and Crick - DNA was a double helix, 2 strands that were anti-parallel, linked by complementary base pairing
- 2) Franklin - X-ray diffraction indicated helical shape, steepness of helix and repetitive structure
- 3) Meselson and Stahl - proved semi conservative replication through density experiments (N-14 and N-15)
- 4) Hershey-chase - DNA was the genetic material
- 5) Sanger + Chargaff - DNA Sequencing

Insulin

Diabetes - 1

- destruction of cells that secrete insulin (autoimmune disease)
- Treatment: introducing insulin into the body
- Animal insulin, such as ^{bovine} ~~bovine~~ insulin, have differences in ~~am~~ primary structures, in the case, 3
- All still bind to human insulin receptor to reduce $[C_6H_{12}O_6]$
- Better to use human because diabetes can become allergic to animal insulin

- All living things use the same bases and genetic code
- $\therefore$ a codon in a human genome would code for the same thing in another animal

Insulin production

- 1) Restriction enzymes cut the gene sequence that, when transcribed + translated, produces insulin
- 2) The enzymes then remove a section of a plasmid in a bacteria
- 3) The sticky ends of the recombinant DNA (cut plasmid) become exposed
- 4) Ligase joins the sticky ends of the cut DNA [insulin sequence], by catalysing phosphodiester bonds between the insulin gene and sticky DNA
- 5) This recombinant plasmid is placed into the host cell so it can express the new gene

2.8: Respiration

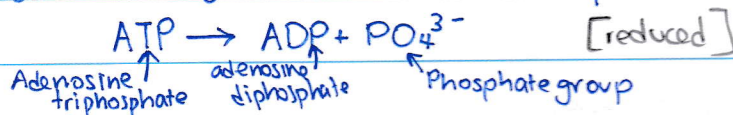
Definition: Cell Respiration is the controlled release of energy from organic compounds to produce ATP

Uses

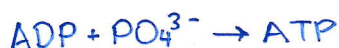
- ① Transport Synthesising large molecules like DNA, RNA or proteins (anabolism)
- ② Pumping molecules and ions across membranes by active transport
- ③ Moving substances in the cell, such as chromosomes, or in the case of muscle cells, the protein fibres that cause muscle contraction. (actin and myosin)

ATP

- ATP from cell respiration is immediately available as a source of energy in a cell
- Energy released by Oxidation (loss of e^- but ^{reduction} production of oxygen, ~~produce energy~~) of ATP



- This ADP can be converted into ATP in cell respiration by ^{oxidation} ~~reduction~~ (gain e^- , lose oxygen)



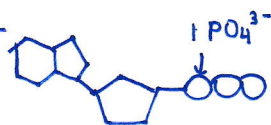
- energy from ATP always lost as heat, which cannot be reused for cell activity.
- This is why cells need a continuous source of ATP

Control

• by enzymes
• using end product inhibition, metabolic pathways and cycles controlled

NOTE

ATP -



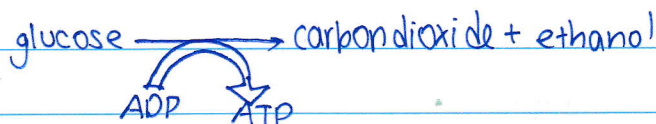
Anaerobic Respiration

- provides a small yield of ATP from glucose - 2 ATP per glucose
- However, this small yield is still produced quickly - rapid ATP generation maximises power of muscle contractions
- When do we need it?
 - 1) short but rapid burst of ATP needed [e.g. high intensity sport]
 - 2) Lack of oxygen in respiring cells ← sama sama
 - 3) waterlogged or anaerobic environments, such as swamps.

Humans



Yeasts and Plants



- Both lactate (in humans) and ethanol are toxic and must be removed, or produced in strictly limited quantities

More on Humans

Anaerobic respiration is used in training or sport that is of high intensity, such as sprinting and weight lifting.

[lactate] $\uparrow$ as anaerobic respiration occurs in a muscle. As lactate is toxic, we cannot have too much [lactate], this limits our ability to anaerobically respire

Task

To break lactate down, it must be oxidised by O_2 , which takes a while. The demand for O_2 to oxidise lactate during anaerobic respiration = oxygen debt

More on Yeast and Plants

Bread

- 1) Water added to flour, the mixture is then kneaded
- 2) Dough kept warm to encourage yeast to respire
- 3) Oxygen in dough used up fast, $\therefore$ yeast forced to respire anaerobically
- 4) CO_2 produced from bubbles that result in bread rising, ethanol evaporates

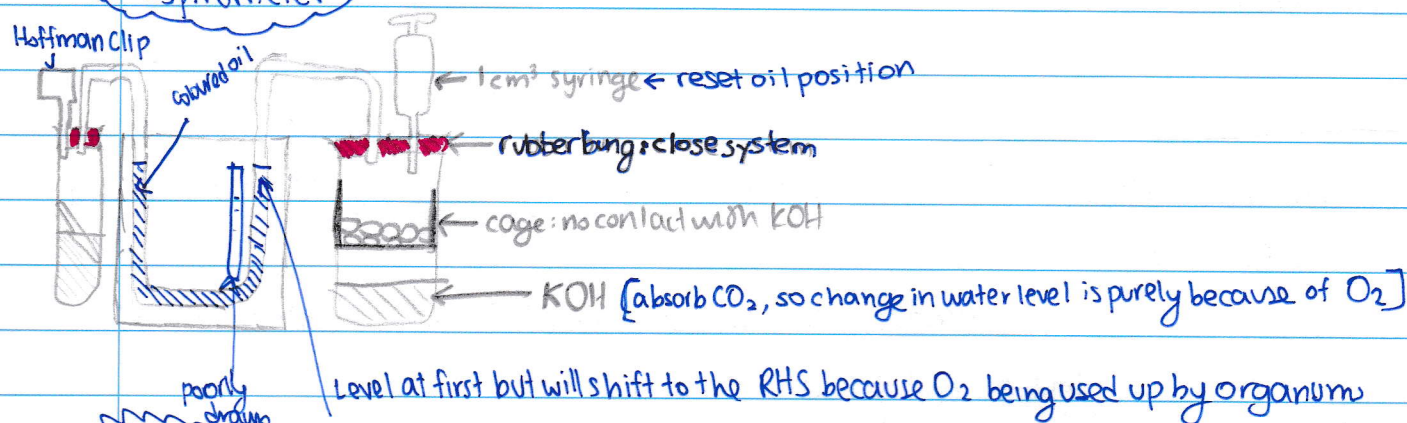
Bioethanol - a renewable fuel

- made from sugarcane + maize
- starch and cellulose broken down by enzymes into sugars
- Fermenters keep yeast at optimum, they anaerobically respire using sugars to produce ethanol
- Ethanol distilled to purify it and water is removed to improve combustion

Aerobic Cell Respiration

- glucose + oxygen $\xrightarrow[\text{ADP} \rightarrow \text{ATP}]{} \text{carbon dioxide} + \text{water}$
- $\text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \rightarrow 6\text{CO}_2 + 6\text{H}_2\text{O}$
- occurs in mitochondria (link reactions, Krebs cycle, electron transport chain)
- Root hair cells and muscle cells have a large amount of mitochondria
 - for active transport of mineral ions
- yield greater than anaerobic → 36 glc ATP per glucose

Respirometer



Notes

- 1) Hoffman Clip: seals respirometer and can be opened to reset reduced volume by $\text{O}_2 \downarrow$
 - ↳ must be left open until temperature equalises, otherwise explosion
- 2) Temperature Control: In water bath to prevent temp from affecting the rate of respiration
- 3) Can't use photosynthetic organism - would be affected by changing by production of O_2 as well. Only in dark. So no photosynthesis
- 3) Measured in cm^3/time → $\frac{\Delta \text{cm}}{\Delta \text{Time}}$

Ethical Considerations

- 1) Is there harm to the organism?
- 2) Is there trauma to the organism?
- 3) Are they out of their natural habitat?
- 4) Will they die?
- 5) Any alternatives?

8.2: Aerobic Respiration [AHL]

Oxidation and Reduction

- Always occur concurrently
- Because when electrons are lost from one substance (oxidation), they go to another (reduction)

Benedict's Test

- 1) Made of CuSO_4 [II]
- 2) Cu^{2+} ions are reduced by the additional e^- from simple sugars, resulting in $[\text{Cu}^{2+} + 2e^- \rightarrow \text{Cu} + \text{Cu}]$
- 3) Cu atoms are insoluble and form a red precipitate

Oxidation

- oxidation of $\text{ADP} + \text{PO}_4^{3-}$ to ATP
- Oxidation of $\text{NADH} + \text{H}^+$ to $\text{NAD}^+ + 2\text{H}^+$

Reduction

- reduction of ATP to $\text{ADP} + \text{PO}_4^{3-}$
- reduction of $\text{NAD}^+ + 2\text{H}^+$ to $\text{NADH} + \text{H}^+$

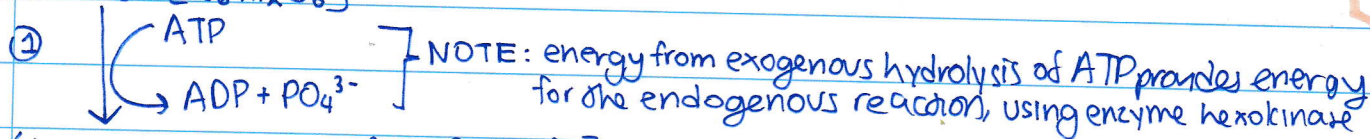
Phosphorylation $+\Delta H$ and $-\Delta H$

- addition of a phosphate group (PO_4^{3-}) to an organic molecule
- makes phosphorylated molecule less stable i.e., more likely to react.
- Hydrolysis of ATP releases energy into the environment (exogenic reaction)
- This energy release from the ^{exergonic} hydrolysis of ATP is used in endergonic reactions that require energy from their surrounds.

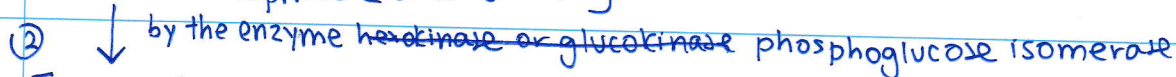
Glycolysis

- gives a small net gain of ATP without oxygen
- 2 ATP molecules produced per glucose [in cytoplasm]

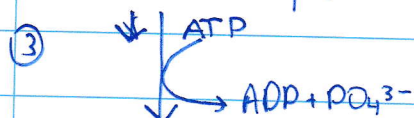
Glucose [$C_6H_{12}O_6$]



Glucose-6-Phosphate [$C_6H_{12}O_6\text{PO}_4^{3-}$]



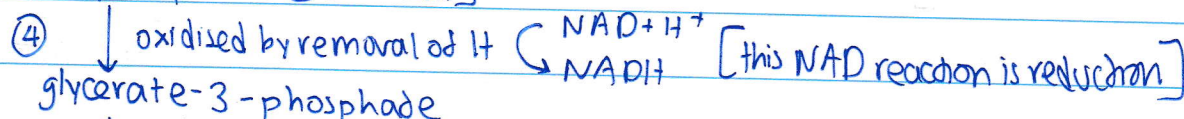
Fructose-6-Phosphate



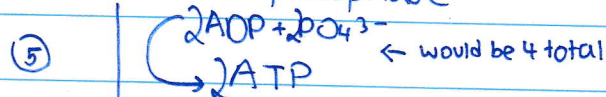
Fructose-1,6-Biphosphate

Lysis

2 x triosephosphate [3 carbon]



glycerate-3-phosphate



pyruvate

Stages 1 to 3 $\rightarrow$ Phosphorylation

Stages 4 to 5 $\rightarrow$ ATP production

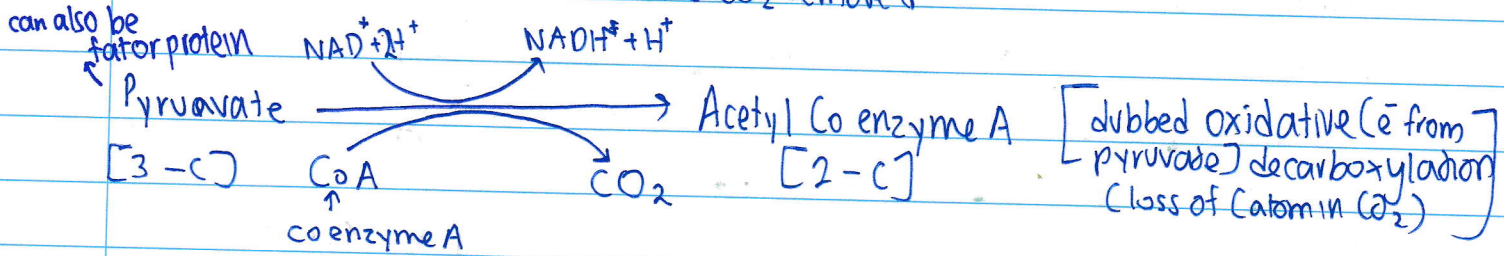
Stage 4 - oxidation

Summary

- 1) Glucose is phosphorylated by the reduction of ATP to ADP, to form glucose 6 phosphate
- 2) Using phosphoglucose isomerase, glucose-6-phosphate forms fructose-6-phosphate
- 3) Next, the fructose-6-phosphate is phosphorylated to form fructose-(1,6)-phosphate
- 4) Lysis occurs consequently, the compound is split into 2 triosephosphates.
- 5) The triosephosphates are oxidised simultaneously with the reduction of $\text{NAD}^+ + H^+$ to NADH. (The H^+ comes from the triosephosphate). This forms 2 x [glycerate 3 phosphate]
- 6) The glycerate-3 phosphate is subsequently ~~dephosphorylated~~ ^{acted on} by the oxidation of $\text{ADP} + \text{PO}_4^{3-}$ to form ATP
- 7) This happens x2 for each glycerate $\rightarrow$ to form 2 pyruvate

The Link Reaction

- occurs in the mitochondrial matrix
- pyruvate enters mitochondrion and CO_2 removed

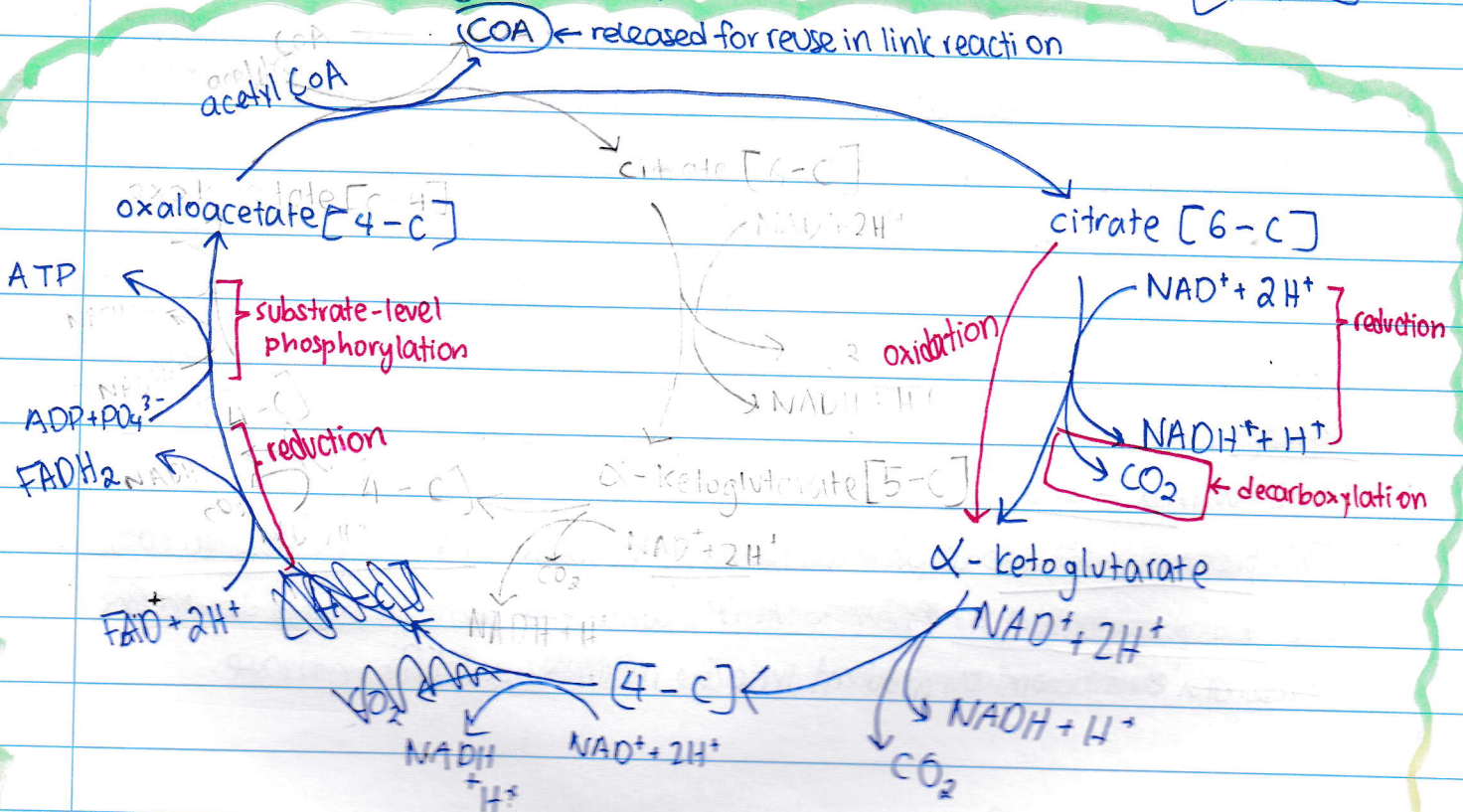


Summary

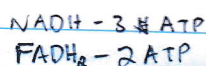
- pyruvate is oxidised, and loses 2e^- to react & allow the reduction of NAD^+ to NADH
- coenzyme A is reacted with the pyruvate to form CO_2 and 2 carbon acetyl coenzyme A
- called the link reaction because it links glycolysis with the electron transport chain and Krebs cycle
- NOTE: 2 Link reactions per glucose because 2 pyruvates

Krebs Cycle

- oxidation of acetyl groups is coupled to the reduction of H carriers [NAD^+]



- The FAD^+ and NAD^+ are the hydrogen carriers and are reduced to form compounds that are used later in the electron transport chain



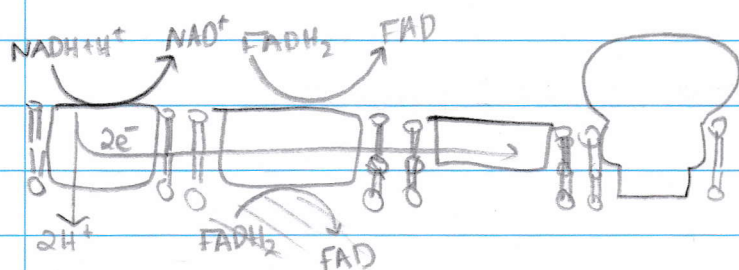
Electron Transport Chain

- The transfer of electrons between carriers in the ETC is coupled to proton pumping
- NADH^+ and FADH_2 are oxidised, donating their electrons to electron carriers.
- The movement of electrons across the carriers generate energy.
- This energy allows for the transfer of protons ^{from the} ~~across the~~ ~~non~~ matrix to the intermembrane space via the inner membrane of the cristae.

Thrs

Chemiosmosis

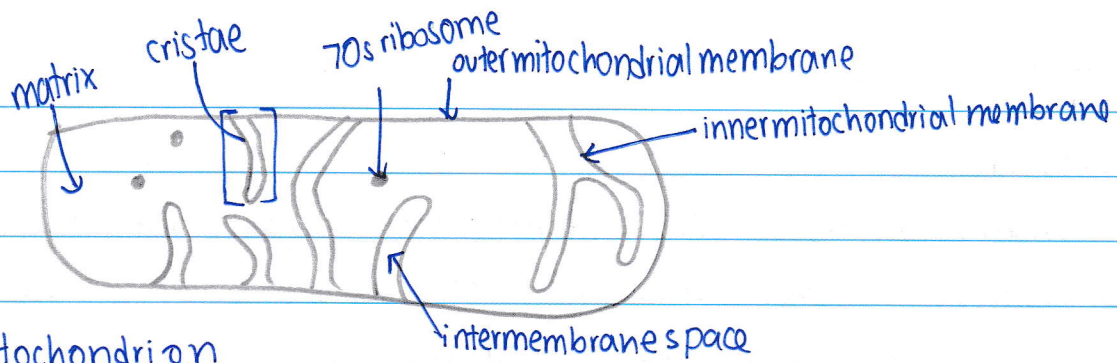
- movement of a chemical substance (H^+) across a membrane, down a concentration gradient
- This movement When the H^+ move down their concentration gradient, out of the intermembrane space, they release energy that is utilised by ATP Synthase to phosphorylate $\text{ADP} \rightarrow \text{ATP}$



- 1) $\text{NADH}^+ + \text{H}^+$ provides ^{a pair of H atoms} 2H^+ ions to the first electron carrier and ~~con~~ are oxidised to provide 2e^-
- 2) The electrons travel from carrier to carrier and the energy generated by this movement is used by 3 carriers per $\text{NADH} + \text{H}^+$ / 2 carriers + per FADH_2 to pump protons from the matrix into the inter-membrane space against their concentration gradient
- 3) As more e^- flow through the carriers, more H^+ ions are pumped into the intermembrane space
- 4) This builds an ^{electrochemical} ~~concentration~~ gradient for the protons, generating a proton-motive force. [Because the intermembrane space has a build up of + and by contrast, matrix is left with a - charge]
- 5) This proton motive force provides the energy needed for ATP synthase to catalyse the phosphorylation of ADP to ATP, when the protons move down their ~~concentra~~ electrochemical gradient into the matrix via ATP synthase.

The role of Oxygen

- For the maintenance of an electrochemical gradient, electrons must be transferred to a terminal acceptor at the end of the chain.
- O_2 is reduced to O_2^- , which then covalently bonds to 4H^+ ions to form water



Mitochondrion

- semi-autonomous organelle that can grow + reproduce by itself but depends on resources from the rest of the cell
- Has 70s ribosomes and a naked loop of DNA in the matrix
- Inner mitochondrial ~~matrix~~^{membrane} is the site of oxidative phosphorylation (where NADH and $FADH_2$ are oxidized to give the PMF that allows for the phosphorylation of ADP)
- Holds ETCs and ATP Synthase
- The S.A of the inner membrane is extended by cristae, tubular projections of the inner membrane.
- Intermembrane space: protons pumped into this area, small size means an increased rate of concentration increase
- Outer Mitochondrial Membrane: separates contents of the mitochondrion from the rest of the cell, to create a cellular compartment with optimum conditions for aerobic respiration
- Matrix: location for link reaction and Krebs Cycle, has enzymes for the catalysis of these processes.
- we use electron tomography to produce images of active mitochondrion
- The cristae, inner and outer membranes are dynamic and change according to internal diffusion pathways

DNA Sequencing

- copies of unknown DNA placed into test-tubes with raw materials like deoxyribonucleotides + enzymes
- Then dideoxynucleotides with fluorescent markings are added
- Then incorporated into the new DNA but ^{replication} ends when they are added
- colour of fluorescence compared ^{the} length of fragment to find the sequence
- This method is called the Sanger method

8.1: Metabolism

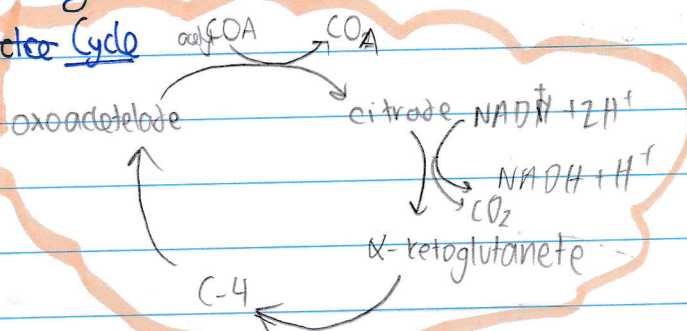
Metabolic Pathways

- consist of chains and cycles of enzyme catalysed reactions
- 3 Main Properties
 - Most chemical changes occur in a sequence of small steps to form a metabolic pathway
 - Involve a chain of reactions
 - OR - a cycle of reactions. In cyclic metabolic pathways, the end product of one reaction is the reactant that starts the pathway

Chain

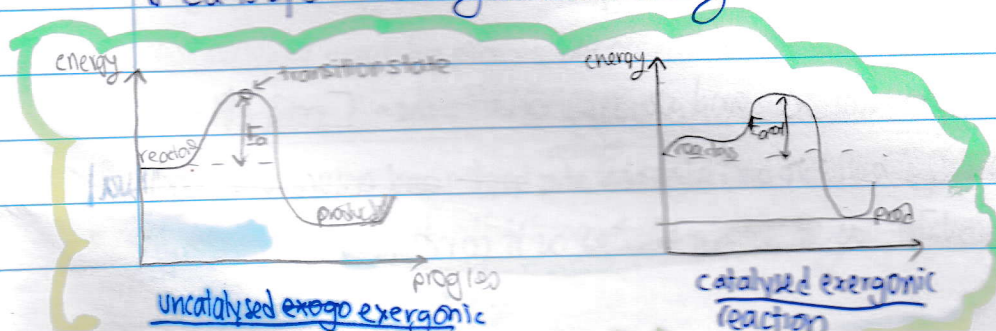
phenylalanine
↓
tyrosine
↓
hydroxylphenyl pyruvate
↓
homogentisate

Cycle Cycle



E_a

- Enzymes lower the E_a of the chemical reactions they catalyse
- Substrates move through a transition state before being converted to products
- E_a = energy required to reach the transition state
- E_a is spent breaking or weakening substrate bonds

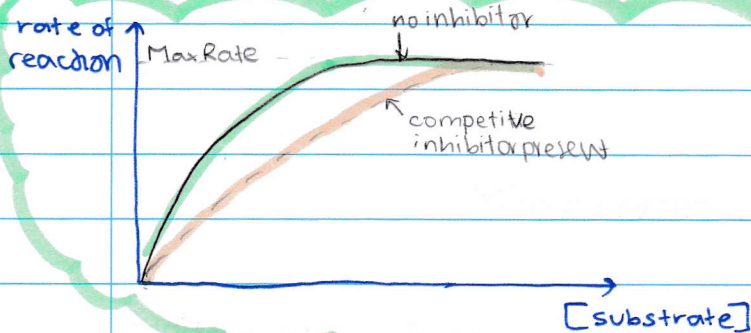


Types of Inhibitors

Definition: chemical substances that bind to enzymes and reduce their activity

Competitive

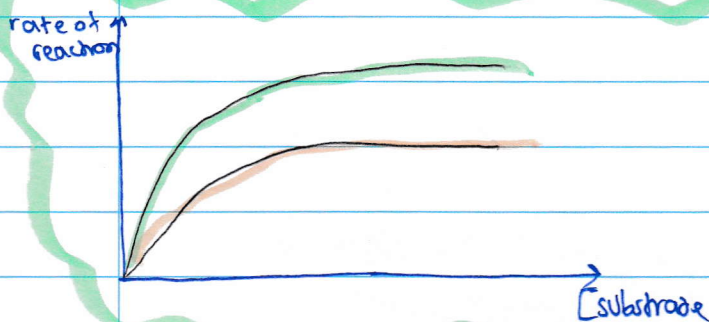
- dubbed "competitive," because compete with regular substrate for binding to the active site
- Interfere with active site temporarily to block substrate by occupying the active site
- e.g. Mercury, chemically similar to substrate (tamiflu, which acts on neuraminidase)



- when $[substrate] > [inhibitor]$, maximum rate achieved
- However, greater $[substrate]$ needed to allow max rate

Non-competitive

- bind to a location other than active site, not chemically similar to substrate
- induce a conformational change (temporarily)
- enzyme can no longer bind to substrate → because substrate dimensions no longer complementary to a site

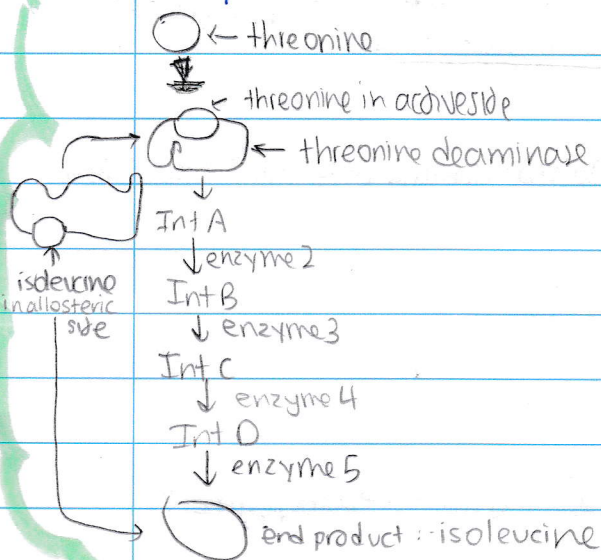


- doesn't reach same max because n.com. ^{inhibitor} prevents some enzymes from being able to react, irrespective of [substrate].
- Same rate of $\uparrow$ as $[sub] \uparrow$.

End Product Inhibition (Negative feedback)

- binding to allosteric sites (sites other than active site)
- Enzyme catalyses first reaction in a pathway
- End product of the pathway then acts as a non competitive inhibitor and binds to the allosteric site of 1st enzyme
- $\therefore$ pathway is fastest when $[products] \downarrow$ and slowest or off when $[prod] \uparrow$
- End product inhibition prevents the build up of intermediates and ensures the pathway by stopping reaction when $[prod] \uparrow$ as $\uparrow$ intermediates as it continues

Example



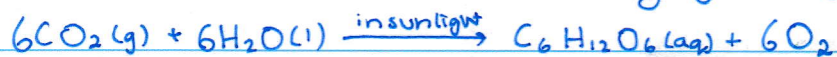
- Through 5 enzyme catalysed reactions threonine is converted to isoleucine.
- As [isoleucine] $\uparrow$, it binds to the allosteric site of threonine deaminase, changing its conformation
- $\therefore$ threonine cannot bind, $\downarrow$ enzyme activity, preventing build up of intermediate.

Databases and Anti Malaria Drugs

- Malaria caused by *P. falciparum*
- 310,000 chemicals screened against drug resistant malaria using chemogenomics
- 19 Chemicals found to inhibit enzymes targeted by malaria
- 15 chemicals that can bind to 61 malaria proteins.

2.9 + 8.3: Photosynthesis

- Definition: production of carbon compounds in cells using light energy



- Light energy is converted to chemical energy in the carbon compounds
- E.g.s of carbon compounds: carbohydrates, lipids and proteins

Wavelengths : Recall λ = wavelength

- Visible light has a range of wavelengths, the shortest of which being violet, the longest being red
- $\downarrow \lambda$, $\uparrow$ energy
- Range of visible light = 400nm - 700nm
- Visible light used by plants because they are emitted in large quantities by the sun and they penetrate the atmosphere more than other wavelengths, so they are primarily abundant
- Pigments are substances that ~~absorb~~ ^{reflect} light and therefore appear coloured.
- Pigments that absorb all VL appear black as they do not reflect any λ s of VL.

- Photosynthesis uses the 3 pigments; chlorophyll a, b and carotenoids.
- Main pigment = chlorophyll
- All chlorophyll pigments appear green because they absorb red and blue light effectively, but cannot absorb green-light, hence it reflects it

accessory pigments that pass photon to CEA to increase the spectrum that drives photosynthesis

Absorption and Activity Spectrums

Absorption Spectrum

- a graph showing the percentage of light absorbed at each wavelength by each pigment

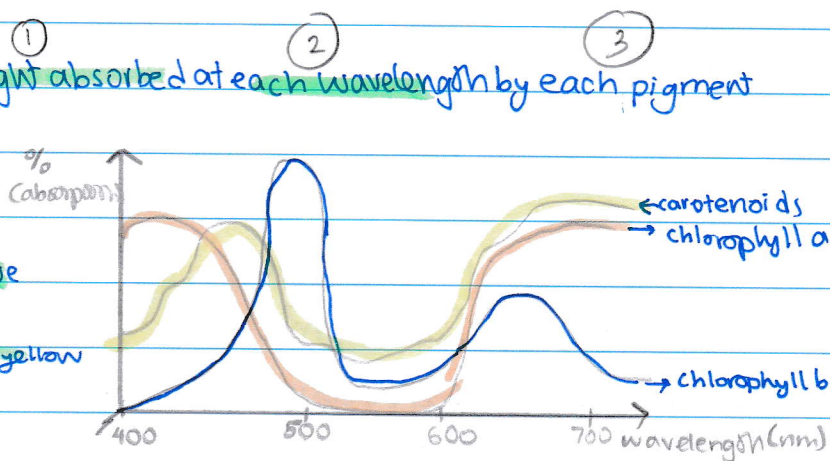
x axis = wavelength (nm)

y axis = % absorption

- Rough guide - 400-500 → red/blue

600-700 → red

500-600 → green-yellow



Action Spectrum

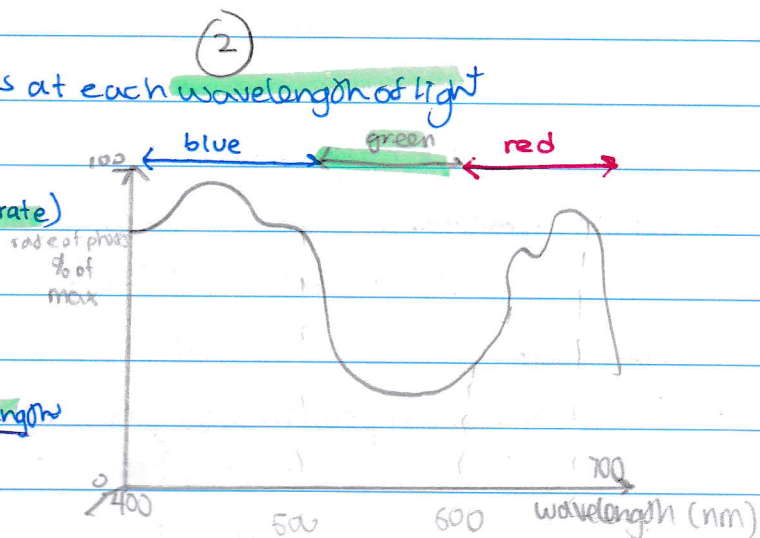
- a graph showing the rate of photosynthesis at each wavelength of light

x axis - wavelength (nm)

y axis - photosynthesis (% of max rate)

- Remember, dips at 500 and 700

- Similar to absorption spectrum because photosynthesis can only occur in wavelength of light that photosynthetic pigments can effectively absorb



Photolysis [SL]

- it is a essential step to split water molecules to release electrons needed in light dependent reaction
- $2\text{H}_2\text{O} \rightarrow 4\text{H}^+ + 4\text{e}^- + \text{O}_2$ [oxidation]
- [photo] → takes place in light, [lysis] → splitting of H_2O
- Oxygen from photosynthesis comes from photolysis and is a waste product

Effects of Photosynthesis [this is essentially Geography]

- ① Rise in $[O_2(g)] \rightarrow$ dubbed the Great Oxidation event, $[O_2]$ raised to 2% within 200 million years
- ② Glaciation $\rightarrow$ reduction in greenhouse effect because CH_4 oxidised by O_2 , $\downarrow CH_4$ and CO_2 used in photosynthesis. This decreased the conc of the 2 greenhouse gases, reducing the greenhouse effect
- ③ Iron rock formation $\rightarrow \uparrow O_2$, Fe ~~was~~ ^{to FeO_s} oxidised, and precipitated onto the sea bed. Resulted in the formation of the banded Fe formation, with layers of FeO_s alternating with other minerals. Banded Fe formations are ~~a~~ ^{the} main supply of Fe , so we can have loads of steel because of photo

Production of Carbohydrates

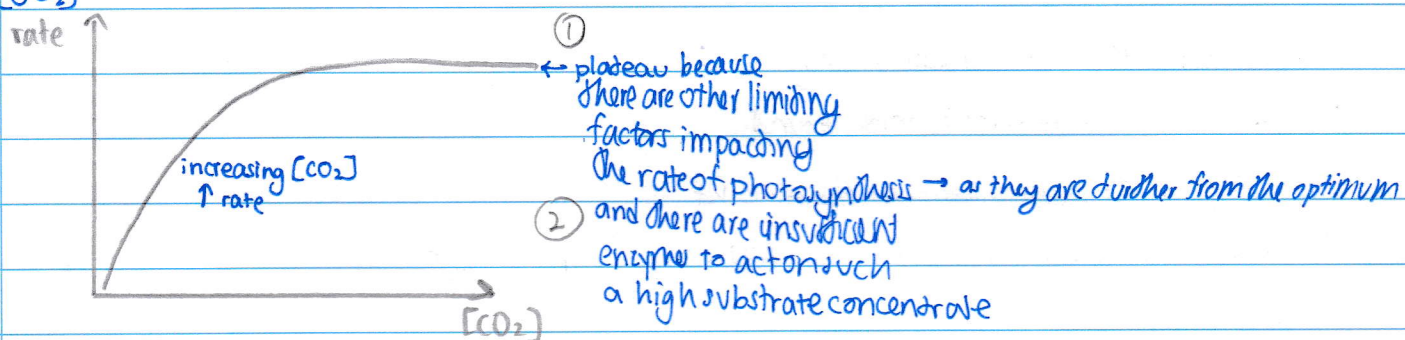
- energy is needed to produce carbohydrates and other carbon compounds in photosynthesis
- $\therefore$ endo/endergonic reaction, because you combine smaller molecules to form large ones
- The source of energy is light and is converted to chemical energy in the compound

Limiting Factors

discuss what happens when these factors are absent

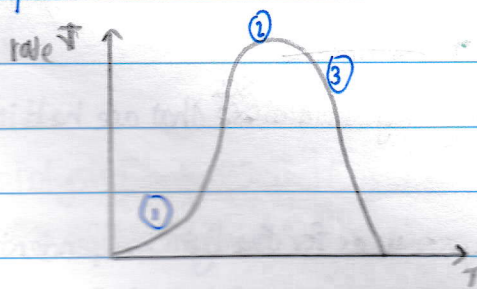
$\rightarrow$ factors furthest from the optimum

① $[CO_2]$



② Light intensity - see above graph, it is identical

③ Temperature



①: $\uparrow T$, $\uparrow$ k.E of substrate and enzyme particles, increasing the number of collisions per unit time

② Reaches optimum

③ Enzyme denatures $\rightarrow$ high T's permanently change conformation such that the substrate can no longer fit active site.

We reach a plateau because a LF

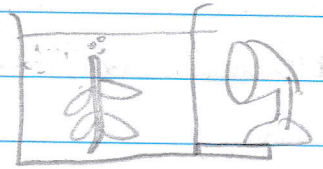
gets closer to the optimum, another factor is relatively further from the optimum, making it the new limiting factor. Example: At night, light is the LF, but when it becomes day, light intensity $\uparrow$,

T becomes LF. As T gets closer to optimum, light becomes LF.

Read in Lab report

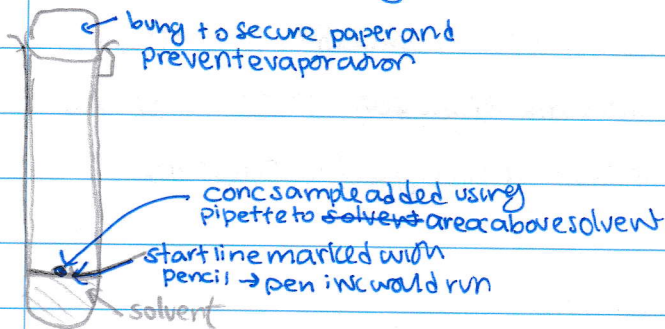
Designing Experiments

- 1) Boil water and cool it to remove aqueous gases
- 2) Pour this water beaker to beaker to $\uparrow [CO_2(aq)]$
- 3) Place stem of plant you are interested in upside down in water
- 4) Cut stem and keep T [at $25^\circ C$ if necessary + light] $\rightarrow$ allow photo
- 5) Add amounts of $NaHCO_3$ [fixed if th $(CO_2(aq))$ controlled, if it is the independent variable, vary]
- 6) Set to desired temperature(s)
- 7) Count no of bubbles, repeat to increase accuracy and give consistent results.



Chromatography - used to separate a mixture of molecules

- pass a mixture dissolved in a solvent through a stationary phase
- porous paper = stationary phase and ethanol/water = solvent



$$R_f = \frac{\text{distance travelled by spot}}{\text{distance travelled by solvent}}$$

- pigments from leaves extracted using acetone
- 2 chloro and 2 carotenoids found
- Compare R_f values of each with calc R_f
- The spot is the pigment and the solvent brings it up as it goes up

8.3: Photosynthesis HL

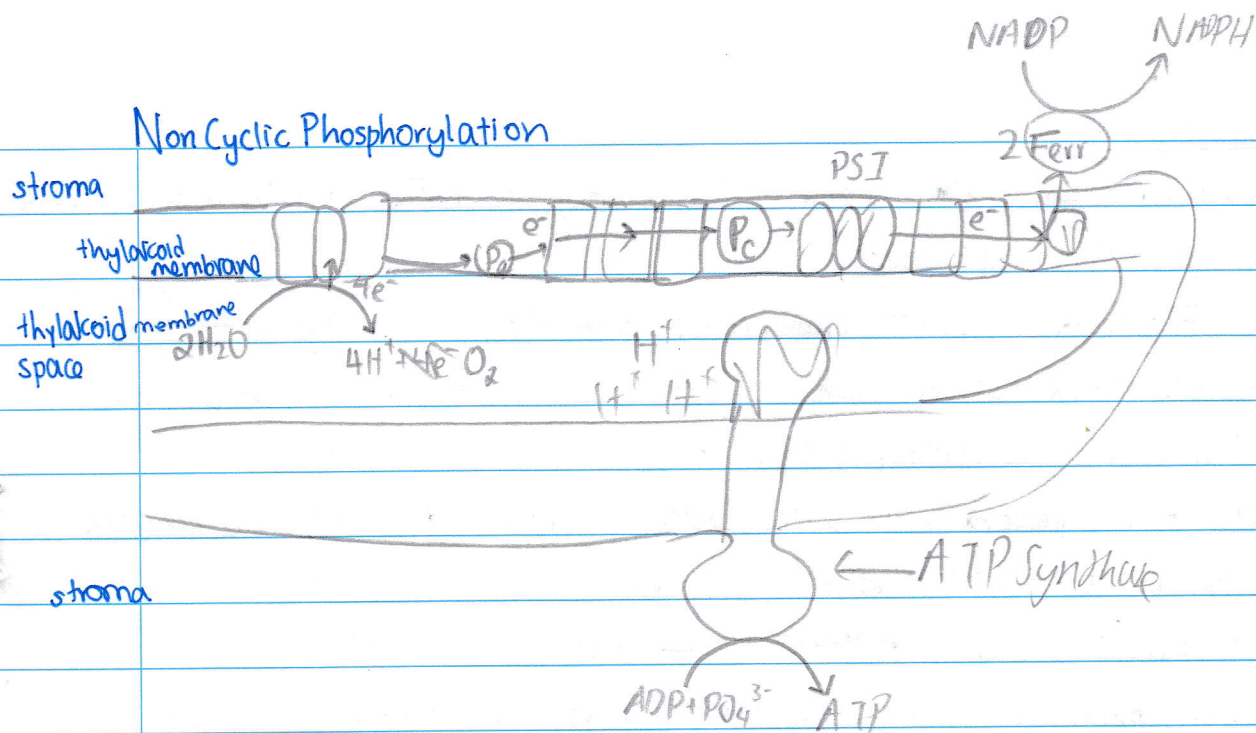
Light Dependent Reactions

- takes place in the intermembrane space of the thylakoid membrane
- Thylakoids: membrane bound compartments holding thylakoid discs that are held in stacks called grana

?

- produces NADPH and ATP, which serve as energy sources for the light independent reaction
- energy from photons of light drive reduction of NADP to NADPH and the prod of ATP
- commonly involve non-cyclic photophosphorylation, where ATP and NADPH produced together

- Cyclic - electrons lost from photosystem II replaced by PS I, no NADPH prod, only ATP



1) Photoactivation

- ~~Light harvesting arrays = photosystems~~ Photosystems have light harvesting arrays and reaction centres
- Both photosystems have many chlorophyll molecules in the LHAs, when they absorb light energy, they pass it to ² special chlorophyll molecules at the reaction centre
- These chlorophylls, when they absorb photons, ^{excite} release a electron. This chlorophyll is therefore photoactivated
- The special chlorophylls can now donate these excited electrons to an electron acceptor
- **Photosystem II**
 - special chlorophylls donate 2e^- total to plastoquinone, which subsequently moves across the membrane, having been reduced (because 2e^- added), and because hydrophobic
- **Photosystem I**
 - only one electron excited to a higher energy level, only one ^{special} chlorophyll affected, but higher ^E than PS II
 - Passed along a series of carriers in the PS and used to reduce Ferredoxin, a protein in stroma fluid

2) Photolysis [only PS II] [in the thylakoid space]

- The chlorophyll in the reaction centre is now more unstable and acts as a powerful oxidising agent
- Induces water molecules to oxidise to $4\text{H}^+ + 4\text{e}^- + \text{O}_2$, 4e^- go to chlorophyll
- O_2 is waste and diffuses away, but $[\text{H}^+] \uparrow$

3) Electron Transport Chain

- Reduced plastoquinone carries e^- to the start of the electron carriers [all within thylakoid membrane]
- e^- lost and passed from carrier to carrier
- as they do so, E released and used to pump protons from stroma into thylakoid space
- concentration gradient of protons builds across the thylakoid membrane, generating a potential difference and a proton motive force
- Via chemiosmosis, protons travel across the t. membrane, down their electrochemical concentration gradient through ATP synthase
- E from this movement is used for $ADP + P_i \rightarrow ATP$
- This is dubbed photophosphorylation = the production of ~~ener~~ ATP using energy derived from light
- The e^- from reduced plastoquinone now reduce plastocyanin, a ~~electron~~ ^a soluble e^- acceptor in the fluid in the thylakoid space

4) Reduction of NADP

- excited e^- from PSI are used to reduce NADP
- First, PSI is photoactivated. The light energy absorbed by the chlorophyll in the light harvesting arrays are passed to the special chlorophylls, one of which has an electron promoted to a higher level.
- It is passed through carriers in PSI until it is used to reduce ferredoxin, a protein in the fluid outside the thylakoid membrane
- 2 molecules of ferredoxin are used to reduce NADP to NADPH
- ~~plastoquinone~~ plastocyanin then provides $2e^-$ to make up for the loss, ~~re~~ they are re-excited with light energy and used to reduce NADP

Cyclic

- If $[NADP] = 0$, e^- return to the chain of electron carriers linking PS I and PS II.
- e^- flow to PS II and via ETC, lose energy to pump more protons to $\uparrow$ ATP

Light Independent Reactions

- take place in the liquid stroma, which houses the enzymes needed
- Stroma: thick protein rich medium
- Calvin Cycle is a ^{series of} light independent reactions
- It is an anabolic pathway, requiring endergonic reactions to be coupled to ATP hydrolysis and oxidation of NADPH

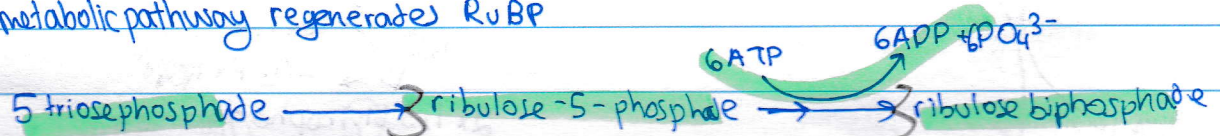
The Calvin Cycle

④ Carbon fixation

- a carboxylase catalyses the carboxylation of ribulose biphosphate by CO_2 fixation
- The carboxylase is ribulose biphosphate carboxylase [RuBis Co]
- Ribulose biphosphate is carboxylated to 2 glycerate-3-phosphate molecules
- the stroma has large amounts of RuBis Co to facilitate the Carbon fixation

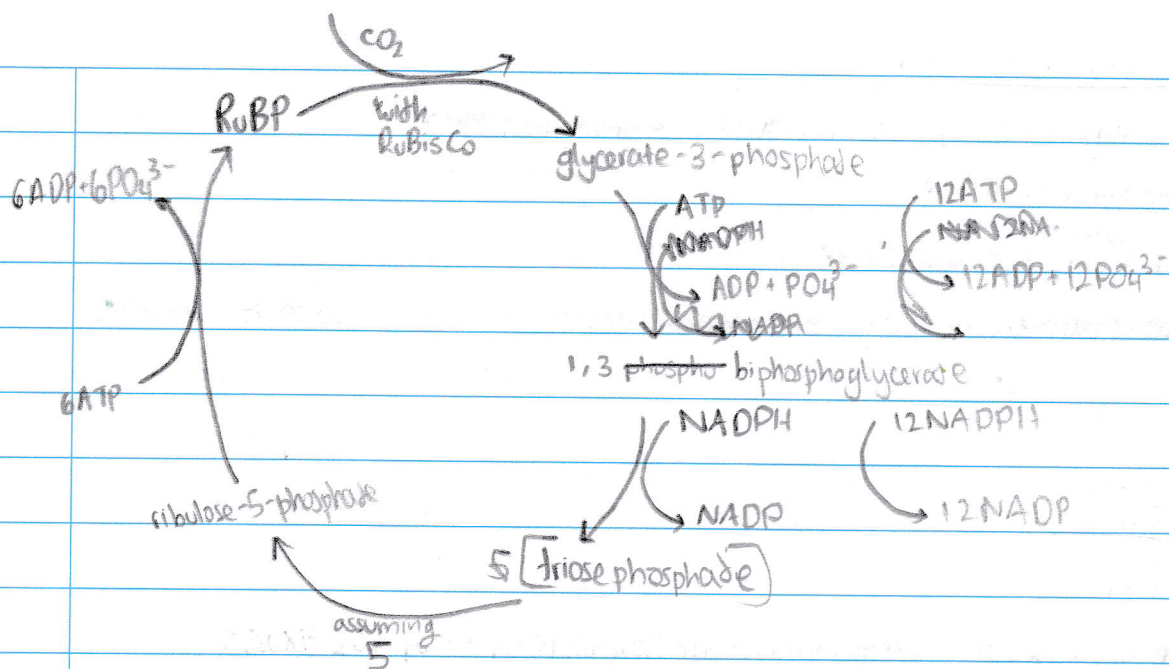


- Next, each glycerate-3-phosphate has an ATP and a NADPH used up to oxidise it to 1,3-biphosphoglycerate
- Then, an NADPH is oxidised to NADP to convert 1,3-biphosphoglycerate to triosephosphate
- 2 triosephosphates form a hexose sugar which can be, using ^{via} condensation reactions, be used to form starch.
- We need to leave triose phosphates (only some) to regenerate ribulose biphosphate
- Calvin proved that 6 turns of the Calvin cycle produce 1 hexose sugar
- This is because, if 3 RuBPs are used, 6 triosephosphates formed, but 5 are needed to regenerate RuBP. $\therefore$ 6 RuBPs a.k.a 6 cycles needed
- This metabolic pathway regenerates RuBP



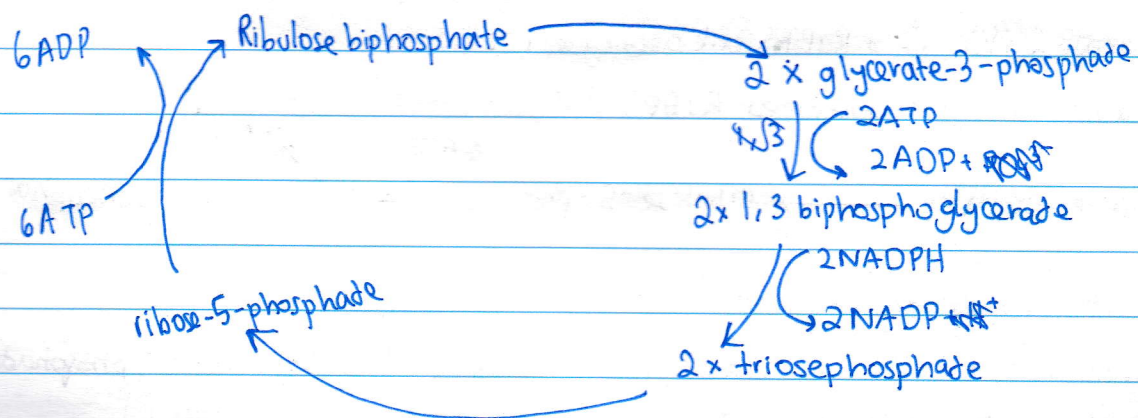
Reduction of glycerate-3-phosphate

- The conversion of RuBP to glycerate-3 phosphate means that in Glycerate-3 phosphate, we do not have the $2:1 \frac{\text{H}}{\text{C}} \rightarrow \frac{\text{O}}{\text{C}}$ ratio.
- NADPH oxidation provides the H atoms and ATP hydrolysis provides the energy for it



Question: How are light independent reactions dependent on light dependent reactions

- 1) We need ATP to regenerate RuBP in Calvin Cycle, this is produced in the light dependent reactions in photophosphorylation, where the movement of excited electrons originating from PS II [and PS I if cyclic] through electron carriers facilitate ~~chemo~~ proton pumping into thylakoid space. Generates a proton motive force that leads to chemosmosis ~~thru~~ ATP synthase $\rightarrow$ produces ATP for regen + the conversion of glycerate-3-phosphate to 1,3-bisphosphoglycerate.
- 2) Produce NADPH needed for 1,3-bisphosphoglycerate to triose phosphate to ensure a 2:1 $H \rightarrow O$ ratio. Excited e^- from PS I donated to ferredoxin, 2 ferredoxin molecules reduce NADP to NADPH. ~~is~~

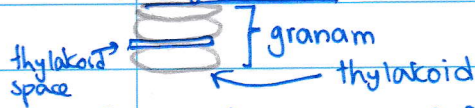


RECALL → Stomata close in dark, ∴ no CO_2 , hence no light independent reactions

Chloroplasts

- Palisade mesophyll cells are found close to the surface, have high chloroplast density to enable efficient absorption of light

Thylakoids



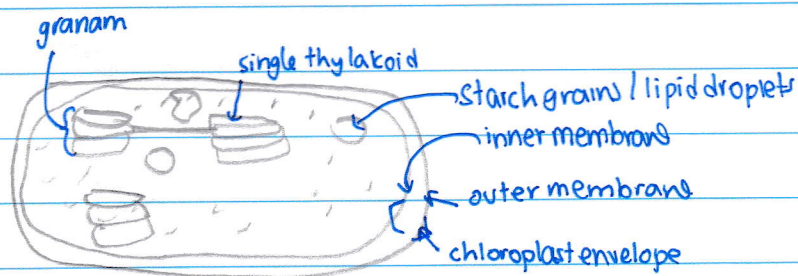
- provide a large S.A for light absorption and light dependent reactions
- Chlorophyll and other photosynthetic pigments are grouped to form photosystems
- Electron carriers, ATP synthase, photosystems, proton pumps are in thylakoid membrane
- a stack of thylakoid discs is a granum → ↑ S.A
- Thylakoid spaces have small volumes to allow fast build up of $[\text{H}^+]$, like the intermembrane area of the mitochondrion
- Thylakoids ordered so they do not shade each other

Stroma

- liquid medium holding enzymes, like RuBisCo for carboxylation of ribulose biphosphate
- found beyond thylakoids

Chloroplast

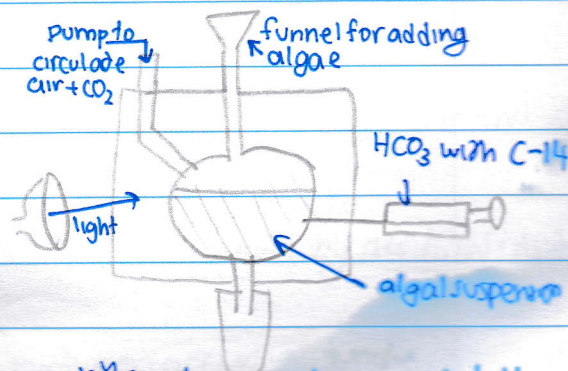
- usually lie parallel to each other to ↑ S.A for light absorption



NOTE: Starch granules are always massive, lipids are smaller. In a photo, the tiny threads are the thylakoids

Calvin's Lollipop Apparatus

- His experiment deduced the stages of the Calvin cycle
- Used C-14 CO_2 to allow for observation
- Noted radioactivity of samples at certain points
- Radioactivity was highest for glyceraldehyde-3 phosphate at the start, so he could tell that it was the first product



③ Genetics

Genes

- heritable factors that consist of a length of DNA and influence or control a specific characteristic
- part of a chromosome, which is one DNA molecule, albeit a tiny part
- Comparing numbers of genes in humans with other species

→ Humans [Eukaryotes] = 23,000 *

→ E. coli [prokaryote] = 3,200 *

→ T. vaginalis [protocista] = 60,000 *

→ Rice [plants] = 41,000 *

→ Water flea (animal) = 31,000

Remember

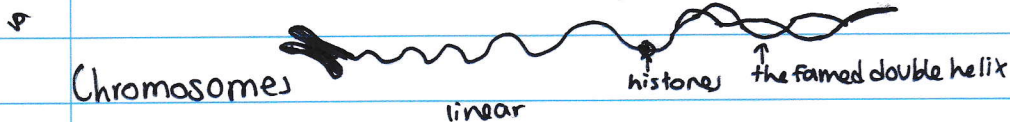
humans	- 23,000
T. vaginalis	- 60,000
E. coli	- 3,200
Rice	- 41,000

- each gene and its alleles occupy specific locations on one chromosome

- The position = locus

- Alleles = variants of a gene that differ by only a few base pairs but occupy the same locus and have the same length

→ can be created by single nucleotide polymorphisms, when there are more than one possible bases that can be found in a position.



- (Eukaryotic) - A single DNA molecule associated with histones
- essentially, a massive DNA molecule with histones to facilitate supercoiling

Mutations

- New alleles are formed by mutation
- Def: A permanent change in a DNA base sequence
- A random process → sometimes it is heritable. If cells that become gametes have mutations, the mutations will be present in zygotes formed
- Most common type: Base Substitution Mutation, where 1 base is replaced by another one
- Sometimes, mutations are "silent." Because the codon might still code for the same protein, ∴ no change, ergo silent

Sickle Cell Anaemia

- caused by a mutation in the Hb gene [specifically HBB on chromosome 11]
- A base substitution mutation converts CTC on the DNA in HBB to CAC
- $\therefore$ mRNA transcribed when anti-sense is transcribed is GUG codon, instead of GAG
- $\therefore$ GUG attracts the complementary anticodon CAC on tRNA, which carries valine, instead of glutamic acid.
- Valine is not polar, unlike glutamic acid, this results in irregular folding of the haemoglobin polypeptide
- Causes the haemoglobin molecules to stick together, leads to sickle shaped RBCs that have a reduced capacity to carry O_2

DNA	[CAC]	[CTC]
mRNA	[GUG]	[GAG]
tRNA	[CAC]	[GUC]
a.a. acid	Valine [Hb^S allele]	glutamic acid [Hb^A allele]

Symptoms + Why

- the sickle cells become trapped in capillaries, restricting blood flow
- Because they tend to clump
- Sickle RBCs decay within 4 days, cannot replace fast enough = anaemia

Malarial Resistance

- Some people have heterozygous sickle cell [$Hb^A Hb^S$]
- grants them resistance to malaria
- common in East Africa because of natural selection

Human Genome Project

- aimed to find sequence of the human genome
- drove improvements in base sequencing techniques $\rightarrow$ mapping $\rightarrow$ genetic screening
- Draft - 2000, final - 2003, could predict which base sequences are exons (protein coding)
- discovered satellite DNA
- The genome sequenced was the chromosomes of an individual $\therefore$ not a reflection of human genome, a lot of genes shared, but there is diversity

Genome

- The whole genetic information of an organism
- entirety of the base sequences of each chromosome
- Humans: chromosomes in mitochondria + 46 chromosomes in nucleus

◦ Plants: DNA in chloroplast + mitochondrion + nucleus

◦ Prokaryotes: DNA in single circular chromosome + any plasmids

3.2: Chromosomes

Prokaryotes

- have one, single chromosome that is essentially a circular DNA molecule
- Not associated with proteins such as histones, hence dubbed naked DNA
- Only a single copy of each gene, two are only briefly present after binary fission
- The two $\times$ homologous chromosomes move to either pole before splitting
- They have plasmids, small, circular, fragments of DNA
- Usually contain genes that are not essential for life processes, e.g. antibiotic resistance
- Plasmids not replicated at the same time as chromosomes
- plasmids are not necessarily passed to both cells after division
- Plasmids can go past the species barrier, if a prokaryotic cell dies and is absorbed by a cell of a different species
- Used to transfer genes artificially using restriction enzymes [e.g. insulin production]

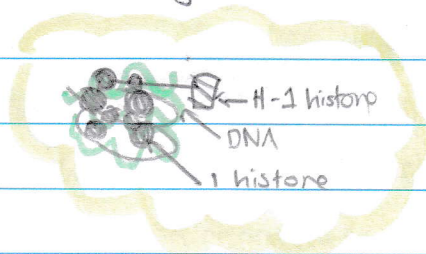
Autoradiography



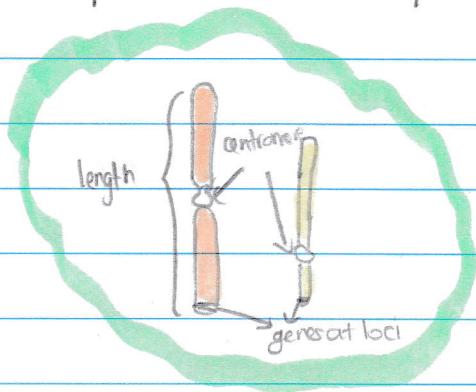
- cells grown in a medium holding tritiated thymidine, a compound which consists of thymine, which is used to produce new ~~nucleotides~~ nucleotides in DNA replication.
- Tritiated = tritium [$H-3$], a radioactive isotope of H, hence new DNA radioactively labelled
- cells placed on a dialysis membrane and cell walls digested by lysozyme, gently burst to release DNA on dialysis membrane
- Thin film of photographic emulsion applied to surface of dialysis membrane for 2 months in the dark. The tritium undergoes beta decay, releasing high energy electrons ^{+ neutrinos}, which react with
- Film developed and examined under a microscope. The dark grains are the sites of beta decay. Indicate DNA positions, Δ indicating length and was circular
- John Cairns showed that the chromosome in E. coli has a length of 1,100 μm , despite the E. coli's length of 2 μm
- Eukaryotic chromosomes found to be longer + linear

Eukaryotic Chromosomes

- ~~chrom~~ Eukaryotic chromosomes are linear DNA molecules associated with histone proteins
- The DNA molecules are very long, hence globular histones form a complex called nucleosomes to supercoil DNA to save space
- ~~DNA~~ A chromosome looks like a string of beads in interphase because small segments of DNA link adjacent histones



- Eukaryotic chromosomes vary in terms of length, centromere position and genes at a particular



- Homologous chromosomes are chromosomes that carry the same sequence of genes but have possibly different alleles of the genes
- If we have 2 eukaryotes of the same species, we can expect each chromosome in one of them to be homologous with one in the other. This allows interbreeding
- one pair maternal, other paternal, same size, structure, same genes same loci

Comparing Genome Sizes

- genome size is correlated with the complexity of an organism, not directly proportional
- This is because the proportion of coding DNA varies and level of gene duplication varies

T-2 phage	0.18 million b.p	
E. coli	5 million b.p	→ 5 million
Fruit Fly	140 million b.p	
Homo sapiens	3,000 million b.p	→ 3 billion
Woodland plant	150,000 million b.p	→ 150 billion

Human Genes

- 1) DRD4 → a gene that codes for a dopamine receptor, one that is linked to neurological + psych conditions
- 2) CFTR → a gene coding for channel proteins. An allele of CFTR causes cystic fibrosis [see 3.4]
- 3) HBB → gene that codes for the beta globin subunit of haemoglobin. Allele causes sickle cell anaemia
- 4) F8 → gene coding for factor VIII, which is needed for blood clotting. Allele causes haemophilia

Haploid Nuclei (N)

- only have one chromosome ^{of} each homologous set
- e.g humans are 23
- gametes only
- number of chromosomes in haploid denoted by N

Diploid Cells (2N)

- pairs of homologous chromosomes (2 of each chromosome)
- 2 copies of each gene, save genes on ^{sex} homologous chromosomes
- All somatic cells are diploid, less susceptible to genetic diseases, because at least one healthy copy would be present. Also, it means that it's likely that there will be dominant alleles present should a recessive mutation develop.
- Organisms are known to be more vigorous with 2 different alleles of genes, because of hybrid vigour. This is why F₁ hybrid crops grow well

Chromosome Number

- it is a characteristic feature of members of a species
- all interbreeding can only result in fertile offspring if somatic cells have same 2N
- Validity: ① chromosomes tend to fuse or split during evolution, changing the chromosome number, however, these events are rare, hence it is a reasonable assumption to assume that it stays constant
- VIP: Refers to 2N number

rice	24
humans	46
chimpanzees	48
dog	78

Sex Determination

- autosomes are non-sex chromosomes
 - XY → male, XX → female
 - X is bigger than Y
 - X has chromosomes for survival, hence no YYs
 - small part of Y has same genes as X, remainder on Y for male development [SRY gene]
 - SRY initiates development of male features like testes + testosterone, hence XY = male
 - absence of SRY on Y leads to development of ovaries + female hormones
- or Punnett Square showing probabilities

	X	X
X	XX	XX
Y	XY	XY

} ~~50%~~ of
0.50 for male, 0.50 for female

Karyograms

- a karyogram is a diagram showing the chromosomes of an organism in homologous pairs of decreasing length
- chromosomes visible in mitosis, most clear in metaphase
- staining used to see banding pattern and make chromosomes visible
- Stain dividing cells, place on microscope, bust using the slides
- This causes the chromosomes to spread, potential overlapping
- Micrograph of stained chromosomes taken, and chromosomes arranged in descending order, longest to shortest pair
- Karyotype: property of a cell defined by number + type of chromosomes
- Chromosomes identified by size, centromere position and banding pattern
- Sex chromosomes are last

Identifying features using karyograms

- determine XY or XX
- if 3 chromosomes for one homologous pair → trisomy (chromosome no)
- Down syndrome is trisomy 21,

Meiosis

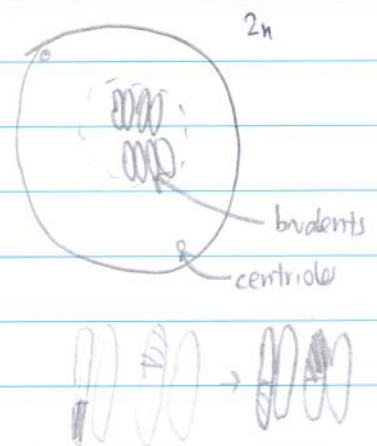
- Definition: a reduction division of the nucleus to form haploid gametes
- 1 diploid cell $\rightarrow$ 4 haploid cells
- starts off with duplicated DNA, i.e. 2 homologous pairs for every pair (4 chromatids)
- halving of chromosome N happens in division 1
- haploid cells are needed for fertilisation in sexual reproduction
- critical in origin of eukaryotes $\rightarrow$ because without it, no fusion of gametes to begin fertilisation

Interphase

- DNA replication occurs, each homologous pair is duplicated and new pair synthesised in S.
- The DNA is uncoiled at this point
- ✗ Homologous chromosomes pair up as bivalents in synapsis, they are connected by chiasmata

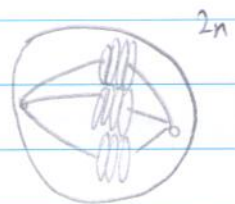
Prophase I

- The nuclear membrane dissolves + chromosomes supercoil
- Crossing over occurs, non-sister chromatids exchange information by breaking off and swapping positions $\rightarrow$ source of genetic variation + stabilises bivalent and unlinks linked genes



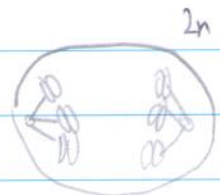
Metaphase I

- Random orientation $\rightarrow$ bivalents are pushed to cell's equator by microtubules, but are aligned independently, hence diff pairs pulled to either lateral side depending on orientation, 2^{23} combinations for humans
- The two homologous pairs are attached to diff microtubules



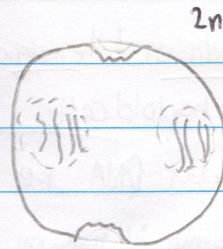
Anaphase I

- Microtubule/spindle fibres contract + pull h. pairs to either pole
- This is the reduction division - bivalents split (disjunction) by movement of chiasmata to ends of chromosomes.
- This is disjunction



Telophase I

- cleavage furrow forms
- chromosomes uncoil
- nuclear membranes form
- followed by cytokinesis

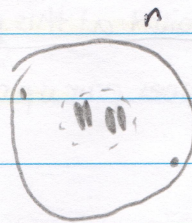


Interphase II

- no replication occur
- both daughter cells are haploid

Prophase II

- nuclear membrane dissolves
- centrioles move to poles
- chromosomes supercoil



Metaphase II

- spindle fibres extend + push chromosomes to equator

Anaphase II

- centromere connecting homologous C.S divides
- splits h. pair, chromatids pulled to opposite end

Telophase II

- nuclear mem forms
- chromosomes uncoil
- 4 gamete cells produced after cyto

Genetic Variation

- 1) Crossing Over → allows for exchange of genes between sister pairs, different combinations of gene on each chromatid created, increases the number of allele combinations. [Prophase I] [infinite prob]
- 2) Random Orientation → random orientation of bivalents in metaphase I results in different combos of genes. It is 2^{23} for humans because there are 23 bivalents and 2 homologous chromosomes per bivalent and there are 23 bivalents, hence 2 possibilities per ~~chromosome~~ bivalent → $\therefore 2^{23}$ or 2^n

Fertilisation

- significant as it creates a new organism
- combination of alleles in a new individual
- unique allele combo created $\therefore$ ↑ diversity, which is needed for evolution

Non-disjunction

- occurs in ^{anaphase} ~~prophase~~ I, bivalents fail to separate, pulled to either single pole
- gametes produced either have additional chromosomes or one less chromosome [because of ~~division~~ centromere division in anaphase II] could also be in anaphase II, centromere does not divide
- Trisomy 21 → Down's Syndrome → mental, growth retardation, heart + vision disorders
- Other trisomies more serious, result in offspring death
- Not limited to autosomes, can have XXV, [Klinefelter's syndrome] or Y [Turner's syndrome]
- prob of ^{non-}disjunction ↑ with maternal age

3.4: Inheritance

Mendel

- cross bred pea plants, transferring specific male pollen to specific females
- repeated each cross, each cross related to one of 7 characteristics being investigated
- Once further cross breeding conducted, Mendel's work proven correct

Gametes

- haploid cells that have a single copy of each gene allele
- Male gametes smaller + more mobile
- When 2 gametes fused, diploid zygotes formed with 2 alleles of each gene
- We determine possible allele combos by a Punnett Square

Segregation of alleles

- If 2 alleles were present, each haploid nuclei gets one of the 2. E.g PP, each will have P, Pp, 50% have p, 50% have P
- This breaks up existing combinations in parents

Definitions

- 1) Genotype: the alleles of an organism
- 2) Phenotype: the characteristics of an organism
- 3) Dominant allele: an allele that is expressed in the phenotype if present in homo or hetero-zygous
- 4) Recessive allele: an allele only expressed in phenotype if present in homozygous state
- 5) Codominant alleles: pairs of alleles that both affect the phenotype when present in heterozygous
- 6) Carrier: has one copy of a recessive allele

Note: if asked how to determine if an allele is recessive or dominant: Say Test Cross

- 7) F_1 : Offspring obtained by crossing parents, referred to as hybrid
- 8) F_2 : Offspring obtained by crossing F_1 hybrids

Punnett Square Technique

Parents: Tall Short (pheno)

Tt tt (geno)
 Tt tt

	T	t
T	TT	Tt
t	Tt	tt

$\therefore$ short : tall
1 : 1

Blood Types

- A: $I^A I^A$
- B: $I^B I^B$
- O: ii
- AB: $I^A I^B$
- i is recessive

→ all 3 alleles code for production of glycoprotein in RBC

→ I^A adds acetyl galactosamine. People without I^A , when they encounter the acetyl galactosamine antigen, produce anti-A antibodies

→ I^B adds galactose to the glycoprotein. People without I^B respond to the antigen by producing anti-B antibodies

- $I^A I^B$ → both acetyl galactosamine and galactose added to the glycoprotein, hence neither anti A or B produced. [Note I^A = anti B, I^B = anti A]. Different phenotype to I^A or I^B , hence the alleles are co-dominant
- i is recessive because it allows production of the basic glycoprotein, which is altered if I^A or I^B is present. Hence $I^A I^A = I^A$; and $I^B I^B = I^B$; [speaking in terms of phenotype]

(Genetic Disease)

Autosomal

- illness caused by a gene
- caused by recessive alleles
- Individuals who are heterozygous are carriers
- some are caused by dominant alleles → such as Huntington's Disease
- Some, like sickle cell malaria are caused by co-dominant alleles

~~H^AH^A~~ $Hb^A Hb^A$ → normal, no anaemia

$Hb^A Hb^S$ → carrier, mild anaemia, resistance to malaria

$Hb^S Hb^S$ → severe anaemia, susceptible to malaria

① Cystic Fibrosis

- caused by a recessive allele of CFTR gene [78 exons, 79 introns]
- gene codes for production of chloride ion transport involved in sweat, mucus and digestive secretions; the recessive allele degrades the ability of the channel channels
- Sweat becomes increasingly concentrated with NaCl and digestive juices and mucus have insufficient ~~water~~ NaCl. This decreases the ^{osmolarity} osmotic potential, and reduces the amount of water that can enter the secretions.
- This increases the viscosity of the secretions.
- Sticky mucus blocks airways and pancreatic duct is blocked, so no digestion in small intestine
- Dominant = C, recessive = c

(2) Huntington's Disease

- dominant allele of HTT
- produces huntingtin
- causes brain degeneration → heart failure, pneumonia
- Dominant = H , recessive = h

Sex Chromosomes + Genetic Diseases

- inheritance patterns where the ratios vary between males and females = sex linkage

(1) Red Green Colour Blindness

- caused by a recessive allele for a photoreceptor protein, made by cone cells in the retina. Denoted by X^c
- Recall: Males have XY, females have XX

∴ if we have a carrier female and normal male

	X^c	Y	
X^c	$X^c X^c$	$X^c Y$	← $\frac{1}{4}$ chance of a male with red green colour blindness
X^C	$X^C X^c$	$X^C Y$	

(2) Haemophilia

- most caused by an inability to produce Factor VIII, a blood clotting factor
- Recessive X^h

∴ if $X^h Y$ and $X^H X^H$

$X^h \swarrow \quad \searrow Y \quad X^H \swarrow \quad \searrow X^H$

	X^h	X^H	
X^h	$X^h X^h$	$X^h X^H$	← 50% chance of infected $\frac{1}{2}$ or $\frac{2}{3}$ of males infected
Y	$X^h Y$	$X^H Y$	

* See worksheets for pedigree charts

Genetic Diseases in Humans

- 4 000 at present
- v. rare → because of rare dearth of recessive alleles
- because of how rare the recessive alleles are and the fact that majority are dominant ~~recessive~~, need 2 for expression in phenotype, statistically unlikely

Mutation

- Radiation + mutagenic chemicals increase the mutation rate + cause genetic disease + cancer
- Mutation: random & permanent change to DNA base sequence
- Radiation ↑ mutation rate if it has enough energy to cause chemical changes in DNA, such as alpha and gamma radiation from isotopes, X-rays, short wave UV
- Some chemical substances such as nitrosamines [in mustard gas] and benzo(a)pyrene are mutagenic
- Mutations can be silent [no change in a-cod sequence] or harmful
- Mutations in cells that develop into gametes are passed on to the next generation.
- ∴ dangerous to have mutations in ovum + testes

Nuclear Radiation

- health of 100,000 survivors from Hiroshima and Nagasaki monitored
- 853 tumours attributed to the radiation
- led to stillbirths, malformation + death
- social impact: survivors stigmatised for potentially carrying genetic diseases
- Chernobyl
 - Radioactive isotopes of krypton, ~~uranium~~ iodine, xenon released into atmosphere
 - 4 km² of pine forest turned g brown + died
 - horses + cattle died due to damage to thyroid gland
 - Bioaccumulation of caesium in fish in Scandinavia + GY
 - [I₂] radioisotope ↑ in milk + water

Karyotype Analysis

- need fetal chromosomes sometimes

→ determine XY or trisomy

(1) Amniocentesis

- needle inserted through mother's abdomen wall, ultrasound used to guide it
- sample of amniotic fluid holding fetal cells taken
- risk of miscarriage is 1%

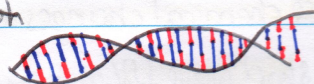
(2) Chorionic villus sampling

- enters through vagina to sample chorion cells, a membrane from which placenta develops
- can do earlier in pregnancy
- 2% miscarriage risk

3.5: Genetic modification and biotechnology

Gel Electrophoresis

PCR

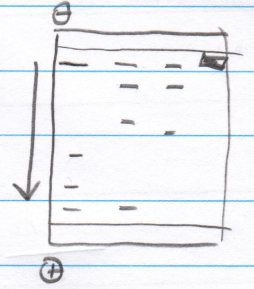


- A sample of DNA is found and placed in PCR solution
- Heated to 95°C to separate DNA strands
- Cooled to 54°C to allow reannealing
- Primers bind to certain sequences that do not reanneal as they are complementary to those sequences [by complementary base pairing]
- Taq polymerase then adds nucleotides to the desired sequence, adds 1,000 nucleotides per cycle
- Then at 72°C to allow the Taq polymerase to act
- Amplifies a particular base sequence or gene
- Can test for GM food, use a primer that binds to the genetically modified gene, an absence of any DNA after PCR cycles indicate no GM and vice-versa
- Gel Electrophoresis can then be utilised

Gel +

Gel Electrophoresis

- used to separate DNA fragments or proteins according to size
- samples are placed in wells cast into a gel, within a conducting fluid
- Electrical field applied ^{to gel matrix} + charge opposite samples
- The negatively charged DNA moves to the +ve charge, with the smallest fragments moving furthest, creating a banding pattern of sorts
- +ve proteins move to the -ve charge
- Note that the gel used resists molecular movement, hence small sample of DNA ^{must} ~~can~~ be used. Can be extracted directly through PCR or we can use an endonuclease / restriction enzyme to remove desired base sequence

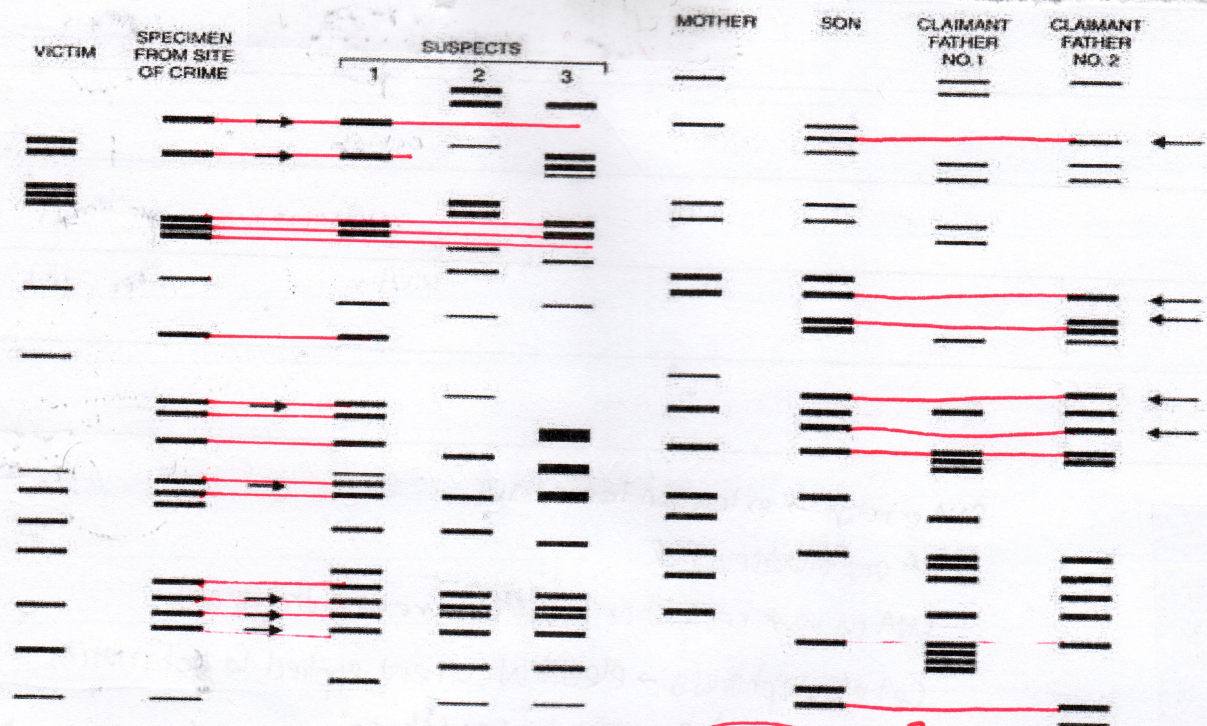


DNA profiling

- sample of DNA taken (e.g. fossil / crime scene) [extraction]
- Sequences of DNA that ~~can~~ tend to vary between individuals taken by restriction enzymes / primers in PCR + amplified
- Fragments of DNA separated by Gel gel electrophoresis
- Produces a unique gel pattern: DNA profile
- Sources - ① Bloodstain
② Hair
③ Semen
- The band structure can have a few differences for suspect identification.
- For paternity testing → need mother, father, child. If a single band doesn't match, not the father.
- See textbook examples + next page

Uses

- Paternity Test + Forensics
- ~~Plant variation protection~~ → ~~genetics~~ genetic screening
- Biodiversity studies
- Genetic purity test
- Tracking GM crops



Identification of a criminal through DNA finger printing. Suspect number one is real culprit, as its VNTR bands are matching with specimen from site of crime.

DNA fingerprints of mother under consideration, the child and two claimant fathers. Claimant father No. 2 proved to be the real/biological father.

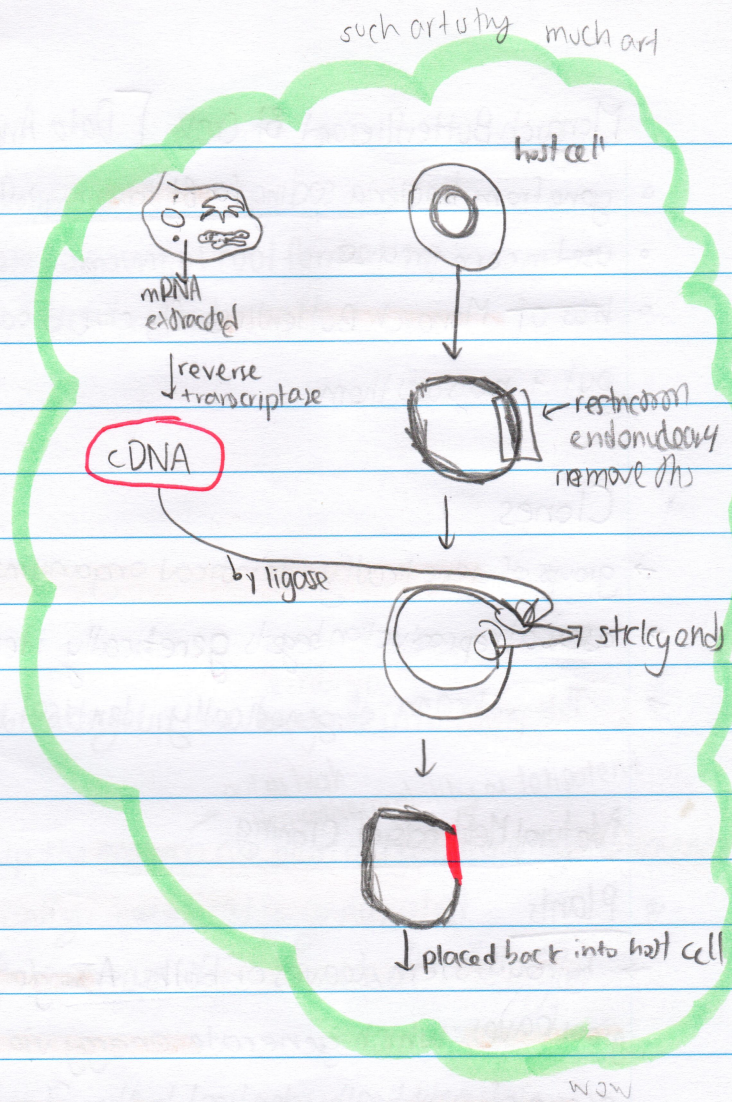
all apart from some match, remainder matched mother $\therefore$ father 2

Genetic Modification

- Transfer of genes from 1 species to another
- works because genetic code is universal, $\therefore$ amino acid sequence translated is the same, ergo same polypeptide
- Uses $\rightarrow$ making GM crops, e.g. production of golden rice: transfer of 2 genes from daffodil, one from bacteria to produce the yellow pigment β -carotene in rice. Mass produce compounds $\rightarrow$ insulin production using bacteria for diabetics. Introduce new characteristics: spider silk protein in goat milk for commercial production

Process behind gene transfer

- 1) restriction enzymes (endonucleases) cut DNA molecules at specific base sequences, to remove that sequence from a DNA molecule or plasmid.
- 2) Creates single stranded ends ~~should~~ ^{as} 2 strands be cut at different points. These are dubbed "sticky ends." Can undergo H-bonding with new sequence.
- 3) Now, gene to be inserted is copied. mRNA extracted from cell, then reverse transcriptase acts on mRNA to form cDNA (complementary DNA), which is then joined to sticky ends using DNA ligase. (splicing)

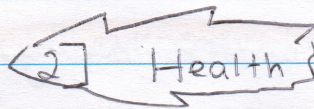


GM crops

1) Environmental Effects

Benefit Claims

- some have ~~not~~ pest resistant varieties, fewer insects killed as less insecticides sprayed
- Use of GM ↓ use of ploughs and other machines, ↓ fuel usage
- shelf life improved
- faster



2) Health Benefits

- edible vaccines
- increased nutritional value
- fewer allergens/toxins

3) Agriculture

Benefit Claims

- disease resistant, ↑ yield
- drought, cold, salinity resistant → ↑ total yield

Risk Claims

- non target organisms are affected
- herbicide resistance genes could spread to weeds or wild plants
- Lower biodiversity (less sunlight energy to pests and weeds)

Risk Claims

- protein produced could cause allergic reactions
- Antibiotic resistance genes used as markers in gene transfer could spread to bacteria
- could cause mutagenicity

Risk Claims

- seeds split, unwanted plants formed difficult to exterminate
- Use of toxins in the GM plants helps resistance

Monarch Butterflies and Bt Crop [Data Analysis]

- gene from bacteria coding for Bt toxin employed in GM crops as biological insecticide
- Used in corn + maize
- lots of Monarch Butterflies fly close to corn crops, pollen holding Bt toxin & move it out + poison them.

Clones

- groups of genetically identical organisms, derived from a single, original parent cell
- asexual reproduction begets genetically identical organism
- The production of genetically identical organisms is called cloning

Natural Methods of Cloning

Plants

- by roots, stem, leaves or bulbs. A single garlic bulb uses its food reserves to grow leaves, which generate energy via photosynthesis, which is used to grow a group of genetically identical bulbs. Strawberries grow horizontal stems with plantlets, which grow into soil and photosynthesise using own leaves, ∴ independent of parent and genetically identical

Others

- Hydra clones itself by budding
- Female aphids produce young from diploid cells produced by mitosis ∴ genetically identical to mother



Stem-Cutting

- artificial cloning, cutting a portion from stem, if roots develop, the cutting can develop into a new plant.
- cut below a node, which is the position on the stem where leaves are attached
- Leaves removed from lower half
- Lowest third of the stem is placed into compost / water to grow [should have air + water]
- Place clear plastic bag with a few holes → reduce water loss
- Growing of new leaves indicates root growth
→ metric

Potential Factors

- compost vs water
- compost type
- holes in plastic bag
- Temperature
- pH
- use of hormone rooting powder

Dependent Variable

- rate / amount of root formation
- measure by root length
- c'

Cloning Human Embryos

- Animals can be cloned at the embryo stage by breaking up the ^{embryo} ~~zygote~~ into more than 1 group of cells
- During early stages, the cells ~~com~~ making up the embryo are pluripotent, ^{not as high derivative capability as totipotent} hence by fragmenting, a new embryo that is genetically identical is generated
- Coral embryos break up into groups of cells to increase the chance of a single embryo surviving
- Livestock: egg fertilised in-vitro and allowed to develop into a multicellular embryo. The individual cells in the embryo are separated and, as they are pluripotent, they develop into genetically identical organisms.
- Limited no of clones because after a certain number of divisions, the cells do not stay pluripotent, ∴ splitting of embryo most successful at 8-cell stage

Cloning adult animals by differentiated $\left[\text{not } \frac{dy}{dx} \right]$ cells $\frac{d[\text{cell}]}{dx}$

- Limitation with embryo cloning → uncertainty within the phenotype of clones, adult animals better for this because their cells are differentiated
-

Dolly

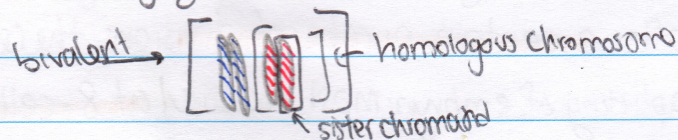
- method → somatic cell nuclear transfer
- ^{differentiated} Adult cells taken from the udder of a sheep and cultured in low [nutrients], inactivate genes, so differentiation pattern lost. The animal this was taken from will be cloned
- Unfertilised eggs taken from another sheep and one of them placed next to the cultured first cells, electrical pulse used to induce fusion. 10% zygote formation
- Embryos then injected into uteri of other sheep. One came to fruition, Dolly born.

10: Genetics and Evolution [AHL]

10.1: Meiosis

Chromosome Replication

- chromosomes replicate in interphase [S], before meiosis.
- each chromosome is replicated such that it consists of 2 sister chromatids
- Next [still in interphase, when chromosomes are uncoiled], homologous chromosomes undergo synapsis, where they align next to each other
- The pair is called a bivalent → held together by protein based synaptonemal complex
- Diagram displaying the tetrad/bivalent structure



Crossing Over

- The exchange of genetic material between non-sister homologous chromatids
- In prophase I, breaks form in the DNA, and non-sister chromatids move in and bind to the region of the break, crossing over.
- This forms a cross shaped connection point called the chiasma [singular], which allow for the h. chromosomes to adhere to one another ^{at region of the break}
- Consequences -
 - ①: increased bivalent stability
 - ②: ↑ genetic variety by creating new combinations
 - ③: Can separate linked genes, allow for independent assortment

Requirements for Sustainable Ecosystem

- 1) nutrient availability
- 2) energy availability
- 3) detoxification of waste

Definitions of Ecology

^{including factors}
Biotic - living things in an environment (living components of an ecosystem)

Abiotic - including non living factors in an environment (non living components of an ecosystem)

Habitat - location where the environment in which a species normally lives

Community - populations of different species living together and interacting with each other

Ecosystem - A community forms an ecosystem by its interactions with the abiotic environment

Autotroph - organisms that are self-feeding, they make C compounds from CO_2 and other substances

Heterotroph - organisms that feed on each other, they obtain C compounds from other organisms

^{Detritivore}
^(e.g. millipede) Ecology - heterotrophs that break down waste (detritus) by internal digestion for nutrients

Consumer - heterotrophs that feed on living organisms by ~~digestion~~ ingestion

^{Ecology}
Detritivore - Study of relationships between organisms and their environment.

Population - a group of organisms that are of the same species that live in the same place at the same time

Saprotroph - heterotrophs that get nutrients from dead organic matter by external digestion

Mixotroph - Organisms that are not exclusively autotrophic or heterotrophic

Organic ^{nutrients} - nutrients from the biotic environment

Inorganic ^{nutrients} - nutrients that originate from the abiotic environment (e.g. C, N)

Producer - Autotrophs that convert light energy to chemical energy

Species - groups of organisms that can potentially interbreed to produce fertile offspring

Mesocosm - small areas that are set up as ecological experiments

Quadrat - square sample areas

Chi-Squared - 1

(CHI)² test

Chi Squared Test → A statistical test designed to establish a relationship between 2 groups.

The (chi)² test is used to test one of 2 hypothesis

H₀: The 2 species are distributed independently [null hypothesis]

H₁: The 2 species are associated [positive → occur together, negative → occur apart]

Method

	Species A present	Species A absent	Row Totals
Species B present			
Species B absent			
Column Totals			

1) → Draw a table of observed frequencies, which are the number of quadrats containing or not containing the 2 species

2) → Calculate the row and column totals. Add both up (e.g. row + row) and place it in the lower right cell (grand total)

3) Calculate expected frequencies [EF] for each combo.

$$EF = \frac{\text{row total} \times \text{column total}}{\text{grand total}}$$

(e.g. B⁺, A⁻)

(average basically for testing H₀, use info in hypothesis [CHI] to create expected value is provided)

4) Calculate the degrees of freedom (to find probability)

$$(m - 1)(n - 1)$$

m → row number (number of rows) in table

n → number of columns in table

Check degrees of freedom against Chi Squared table

5) ~~for~~

6) Finding Chi-Squared

$$\chi^2 = \sum \left[\frac{(f_o - f_e)^2}{f_e} \right]$$

When f_o = observed frequency

f_e = expected frequency

Σ = sum of all the values

find what is in the brackets for each scenario and add those

7) Check degrees of freedom against chi

See where

the table under those degrees of freedom

← squared table. See whether the 0.01 or

0.05 value is closest to value for

χ² (chi-squared). If the probability

value is < than 0.05, H₁ must

be accepted and H₀ must be rejected

* always round up

* find H₀ and test if it is true

* Must be 20 total sample

- 1) Write Null Hyp
- 2) Write Observed F
- 3) Find degrees of freedom
- 4) $\text{expected} = \frac{\text{total observed}}{\text{number of groups}}$
- 5) $\frac{(O-E)^2}{E}$
- 6) $\sum \frac{(O-E)^2}{E}$ for χ^2
- 7) if $\chi^2 > p 0.05$ null rejected
- 8) if $\chi^2 < p 0.05$ null accepted

Notes on χ^2

- χ^2 test is used to study differences between data sets
- Used purely for frequencies
- compare experimental result with an expected theoretical outcome
- total frequencies > 20

Sunlight

- The initial source of energy for most biological communities is sunlight
- Producers Autotrophs like plants, algae and seaweed carry out photosynthesis
- Heterotrophs are indirectly dependent on sunlight, as they depend on carbon compounds in their food as a source of energy
- In most ecosystems, all these ^{carbon} compounds will have originally be harvested by photosynthesis in producers
- energy is non-cyclic, so it cannot be recycled, so the sun must always supply it.

Energy Conversion

- in photosynthesis, light energy is converted to chemical energy in carbon compounds by photosynthesis
- sunlight is ~~converted~~ absorbed using chlorophyll and other photosynthetic pigments. This converts the light energy to chemical energy

Energy in food chains

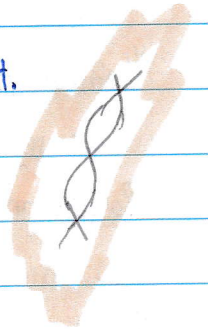
- A food chain is a sequence of organisms, each of which feeds on ^{the} previous one
- producers are always the first organisms on food chain
- The arrows in a food chain represent energy flow
- Number of trophic levels restricted by decreasing energy availability due to loss of energy by excretion, egestion, respiration or uneaten food

Respiration and Energy

Energy released by respiration is used in living organisms and converted to heat.

Living organisms need energy for cell activities such as

- 1) Synthesizing large molecules like DNA, RNA, polypeptides and proteins → anabolic reaction
- 2) Pumping molecules or ions across membranes by active transport
- 3) Moving items around the inside of the cell, e.g. endocytosis



All cells produce ATP (Adenosine Triphosphate) through respiration. In this process, carbon compounds such as carbohydrates and lipids are oxidised. These oxidation reactions are exothermic and energy released is used in endothermic reactions to make ATP. Hence, cell respiration transfers chemical energy from glucose and other carbon compounds to ATP.

Why use ATP? Chemical energy in carbon compounds such as glucose is not immediately usable by the cell. The ~~the~~ chemical energy in ATP can be directly used for different activities. ATP $\xrightarrow{\text{direct source of E}}$ hydrolysed to release heat $\rightarrow$ used for endergonic

Heat Losses

✓ second law of thermodynamics

- Energy transformations are never 100% efficient (some is lost as heat)
- e.g. not all energy from oxidation of carbon compounds in cell respiration is transferred to ATP, some is lost as heat.

Energy conversions in living organisms

- Light to heat energy in photosynthesis
- Chem to kinetic in muscular contraction
- Chem to electrical in nerve cells
- Chem to heat in heat generation

* NOTE: Biomass is a measure of energy, because biomass consists of the carbohydrates and other carbon compounds that have chemical energy. Hence, a value of biomass shows energy.

4 Ways of Energy Loss

Feces: some food ingested by organisms in a trophic level is indigestible, hence it is egested in faeces and the energy in it passes to detritivores or saprotrophs.

"Leftovers"/Uneaten food: predators may not eat some parts of their prey. These parts are consumed by detritivores and saprotrophs.

Respiration: Most of the reactant energy in respiration is changed into heat energy and is lost from the food chain.

Excretion: releases metabolic waste with chemical energy into the atmosphere. Other organisms absorb these substances and use them for their own exothermic metabolic processes, releasing heat energy in the process.

Due to all these losses, only a small amount of energy from one trophic level will pass to the next [usually 10%]. As a result, there ~~are~~ is less and less energy remaining ~~would not~~ in the next few trophic levels, so little that sometimes it is not enough to support another trophic level. Hence, the number of trophic levels in food chains is restricted.

Biomass also ^{diminishes} along food chains, due to loss of CO₂ and water through respiration and loss from the food chain of uneaten or undigested parts of organisms.

→ these are compounds with chemical energy
in a food chain

Pyramids of Energy are quantitative representations of energy flow. ~~Using pyramids of energy~~ → be careful with this, draw as steps and mark as producers, primary consumers, e.t.c

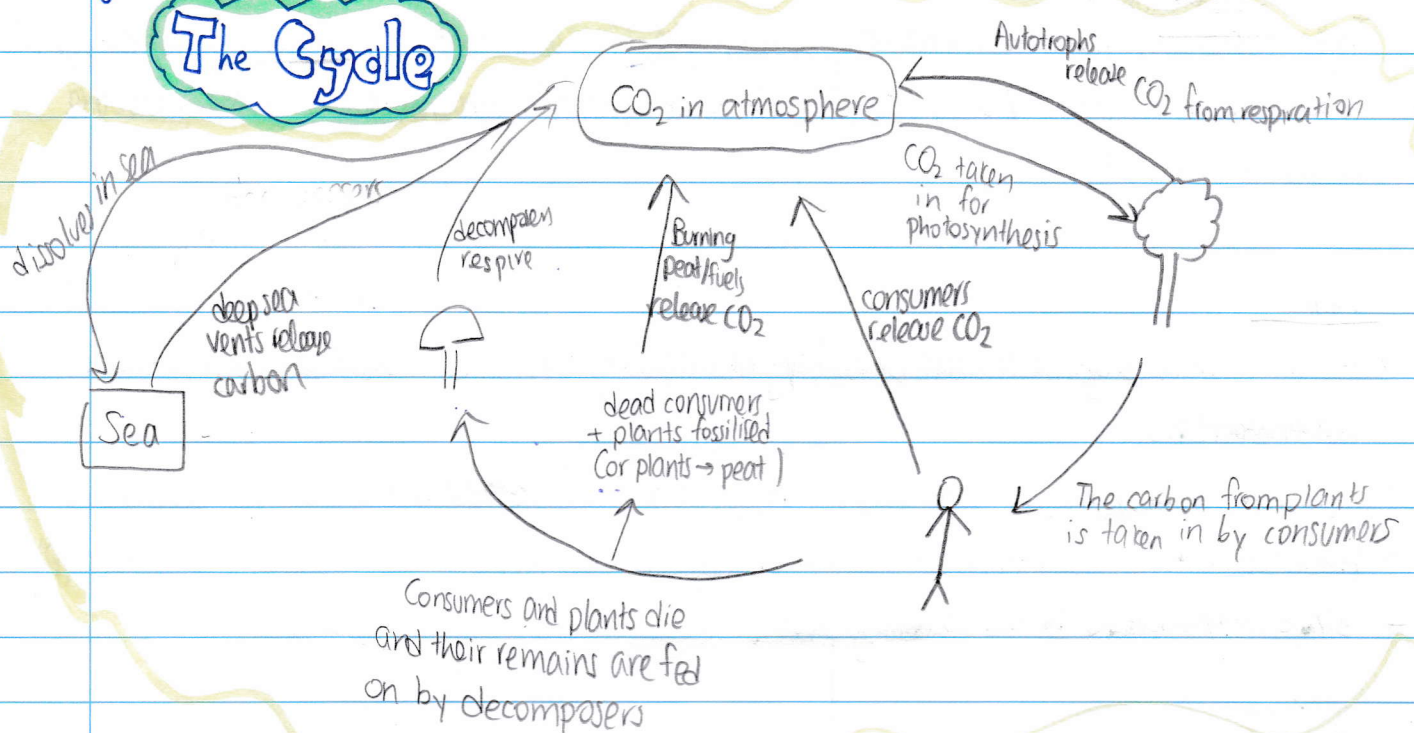
Note: Insolation is a measure of sunlight hitting the Earth [W/m^2]

Carbon Cycling

Any organism's supply of C comes via the food chain, from autotrophs who convert carbon dioxide (CO_2) into carbohydrates and other C compounds. Autotrophs fix carbon into the carbon compounds they require (such as lipids, carbohydrates)

CO_2 , when dissolved in water, forms H_2CO_3 (H^+ , HCO_3^-). It can stay as a dissolved gas.

The Cycle



Carbon sinks

- Oceans
- Forests [photosynthesis]

Carbon Sources

- respiration $\rightarrow$ e.g. non photosynthetic cells / animal cells / saprophytes
- loss from ocean
- combustion
- deforestation

Methanogenesis

obligate anaerobes

Archaea produce $\rightarrow$ Archaeans produce methane from carbon dioxide, hydrogen and acetate produced by bacteria.



Bacteria first respire anaerobically to produce organic acids, alcohol, hydrogen and CO_2 . They then used the organic acid and alcohol to produce the acetate.

The anaerobic environments where methane can be produced are listed below

- 1) Mud along shores + bed of lakes
- 2) Swamps / wetlands
- 3) Guts of termites and ruminant mammals like cow
- 4) Landfill sites holding organic matter.

In the ^{stratosphere} atmosphere, methane is naturally oxidised into CO_2 and H_2O by monoatomic oxygen and reactive hydroxyl radicals ($\text{OH}^\bullet$). Hence, atmospheric concentrations of methane are relatively low.

Peat

- formed when organic matter is not fully decomposed because of anaerobic conditions in waterlogged soils.
- Saprotrophs cannot thrive in anaerobic conditions, hence not all matter is fully decomposed
- Acidic conditions could also form, inhibiting the archaeans as well as the saprotrophy
- 3% of land surface is covered by peat

Fossilized Organic Matter

Formation of coal

- layers of peat are buried under other sediments
- when they are heated and compressed, coal forms gradually

Formation of oil and natural gas

- formed in mud in water bodies (anaerobic)
- hence lots of peat
- As more mud is deposited, the peat is compressed and heated
- It reacts chemically with other compounds to form natural gas + oil
(mainly methane)

Combustion

- CO_2 is produced by the combustion of biomass and fossilised organic matter
- Complete combustion produces CO_2 and H_2O
- deforestation by fire releases CO_2
- Burning fossilised organic matter (coal, gas, oil) releases CO_2 into the atmosphere as they have carbon in them

Limestone

- Some animals have hard body parts made of CaCO_3 [e.g. mollusc shells]
- When they die, their soft parts decompose and in neutral or alkaline conditions, the calcium carbonate deposits on the sea bed (if sea animal). The result is limestone
- 10% of all sedimentary rock on Earth is Limestone
- 12% of CaCO_3 is C.

Note:

Carbon flux into _____ = carbon moving into that place [sink]

Carbon flux out of _____ = carbon moving out of that place (source)

4.4 Climate Change

Greenhouse gases

Most Significant Gases

- 1) CO_2 → released by respiration and combustion of biomass and fossil fuels
removed by photosynthesis and dissolving in oceans
- 2) H_2O vapour → released by evaporation from oceans and transpiration in plants. Removed by rainfall/snow

Other greenhouse gases.

- 3) Methane → released from marshes and other waterlogged habitats. Also from organic waste
→ also emitted from melting of ice in polar areas and extraction of fossil fuels
- 4) Nitrous oxides → released by bacteria naturally + from vehicle exhaust

The 2 most abundant gases in Earth's atmosphere, Oxygen + Nitrogen, are not greenhouse gases, hence all the greenhouse gases only make up $< 1\%$ of the atmosphere

The impact of a gas depends on its ability to absorb long-wave radiation as well as its concentration in the atmosphere.

e.g.) CH_4 can absorb more LW radiation than CO_2 , but CO_2 is more concentrated in the atmosphere.

Concentration of a gas in the atmosphere varies with the rate at which it is released into the atmosphere and how long on average it remains there.

The earth, when warmed, emits long wave radiation. The wavelength of solar radiation at its peak, is 400nm. However, the infrared radiation emitted back by the Earth has a wavelength of 10,000nm.

This long wave radiation emitted by the Earth is mostly absorbed by greenhouse gases [between 70% - 85% of all radiation] and the greenhouse gases reemit that radiation back towards the Earth, warming it further as a result.



Without global warming, the mean temperature at the Earth's surface would be -18°C .

However, greenhouse gases only absorb radiation in specific wavelengths. The wavelengths emitted by greenhouse gases (G.G.) are between 5 and 70 nm.

Graph displaying the wavelengths of light absorbed by CO_2 , H_2O , CH_4 and Nitrous Oxide.

Correlations between global temperatures and CO_2 concentrations.

Hypothesis: If the concentration of a greenhouse gas (e.g. CO_2) rises or falls, the size of its contribution to the greenhouse effect changes, hence global temperatures will either rise or fall.

Testing the hypothesis: By drilling up ice in the ~~Antart~~ Antarctic, we can deduce CO_2 concentrations over the last few millenia. The ice has built up over a long time, so ice deeper down is older than ice at the surface. Bubbles of air in the ice can be extracted and analysed to find CO_2 concentration and global temperatures can be estimated by using ratios of hydrogen isotopes in water.

From data obtained via the ice, we can see that periods of higher CO_2 concentrations coincide with periods when the Earth was warmer. This trend has been found in other ice cores.

Changes in Climate as a result of increased GG concentration

- ↑ concentration of a GG, ↑ global temperatures [although other factors like sunspot activity affect global temp]
- more frequent and Consequences [basically examples of climate change]
 - frequent + increased heatwaves
 - increased evaporation from oceans, hence frequent ^{and protracted} periods of rain
 - amount of rain in thunderstorms increases
 - More tropical storms and hurricanes with faster wind speeds
 - Change in rainfall distribution [flooding in place A, drought in place B]

Industrialization and Climate Change

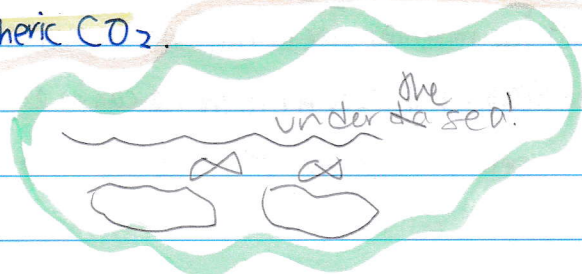
- When the industrial revolution started late in 18th century, the carbon dioxide concentrations started to rise above natural levels.
- This is because the revolution caused the combustion of coal/oil/natural gas to increase, increasing atmospheric CO₂

Burning fossil fuels

- Recent increases in atmospheric CO₂ are largely due to increases in the combustion of fossilized organic matter
- Increases in burning of fossil fuels were most rapid from the 1950s onward, coinciding with the period of steepest rises in atmospheric CO₂

Coral Reefs and CO₂

- CO₂ has dissolved in oceans for centuries
- pH of oceans have been decreasing over centuries due to an increase in atmospheric CO₂
- When CO₂ dissolves in water, it forms carbonic acid [H₂CO₃] but then dissociates into H⁺ and HCO₃⁻ ions.
- Reef building corals need carbonate ions in the water to build up their skeletons.
- However, the H⁺ ions combine with available CO₃⁻ to form HCO₃⁻
- Hence, carbonate ion concentration decrease, and due to this, existing calcium carbonate skeletons of reefs dissolve.



Causes of the enhanced greenhouse effect

- ① burning of fossil fuels
- ② deforestation
- ③ Methane production (e.g. methanogenesis)
- ④ use of CFCs
- ⑤ Production of nitrous oxide by cars

⑥

Effects

- ① $\uparrow$ CO_2 concentration
- ② increase in global temperatures
- ③ changing climate [see consequences]
- ④ melting of ice caps / rise in sea levels
- ⑤ Extinctions of species

Effects of Rising CO_2

- ① $\uparrow$ rates of photosynthesis in plants
- ② global temperature $\uparrow$
- ③ Loss of habitats of polar bears
- ④ Mass extinction of species
- ⑤ Disturb food webs / chains
- ⑥ Melting permafrost + rise in sea levels

Good Questions

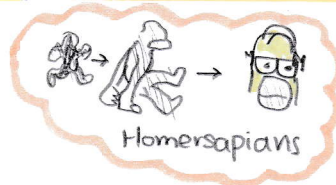
1) Outline the importance of plants to populations of other organisms in higher trophic levels

- plants absorb light and use it for photosynthesis
- convert light to chem energy and pass it along trophic levels in a food chain
- primary consumers eat plants [that are producers] and secondary consumers eat primary consumers who ate plants
- plants produce O_2
- O_2 is needed for respiration in many organisms
- dead plants available to saprotrophs + detritivores
- provide habitat to other organisms.

2) Why is it difficult to place organisms in higher trophic levels?

- organisms can occupy 2 trophic levels
- eat prey from various trophic levels + feeding habits fluctuate
- not all feeding habits are known

Evolution



5:1: Evidence for Evolution

Definition: Evolution: When heritable characteristics of a species change (cumulative)

- DOES NOT include acquired characteristics like tans
- mechanism for evolution: Natural Selection

1

Fossils

- deposits of rock layers (strata) analysed
- We will find a sequence of fossils
- Using radioisotopes
- Major Evidence

matches law of fossil succession

- * 1) Sequence of fossils matches expected sequence of evolution. The oldest fossils are bacteria and simple algae, followed by fungi and worms, then vertebrate land creatures
- 2) Sequence of fossils matches ecology → fossils appear in order with ecology. Eg: plant fossils older than animals, plants on land before animals, e.t.c. Pre date
- * 3) The fossil record shows us that, over time, evolution has occurred. We find different species in rocks of certain ages in a particular + consistent order [Law of fossil succession]. This suggests that an ancestral species was responsible for subsequent species. In addition, the existence of transitional fossils show intermediate forms over evolutionary pathway of the ancestral species.

• Limitations

- * 1) Fossil record is incomplete, conditions needed for fossilisation are very specific. ∴ we have gaps in the fossil record, culminating in a series of missing links.

2

Selective Breeding

- We have deliberately bred particular animals for 1000s of years

• Evidence

- If we compare domesticated species with their wild counterparts (eg hens and junglefowl), we will see significant variation
- This demonstrates evolutionary change that have been catalysed by artificial selection

• Limitations

- 1) It shows how selection causes evolution but not how evolution occurs naturally. This is a massive flaw, as evolution occurs via natural selection, a process which occurs via without external intervention

3

Homologous + Analogous

Evidence

Homologous structures

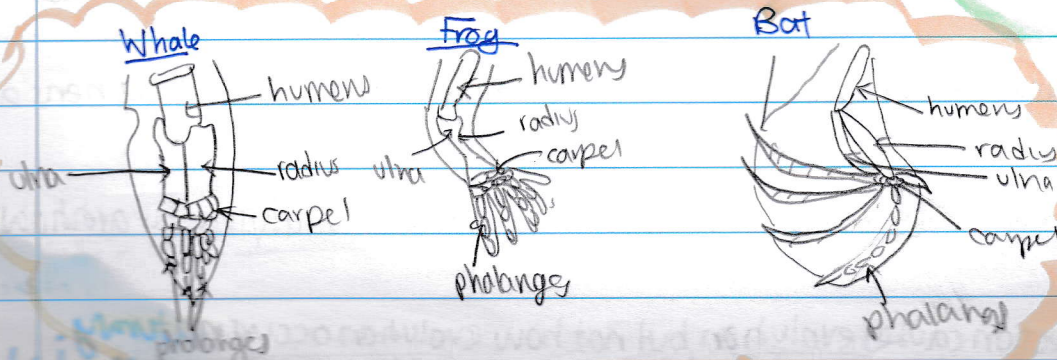
- structures that have superficial similarities in structure
- e.g. tail fins of whales and fishes
- They had different origins but converge to form similar structures because they perform the same function. This evolution is dubbed convergent evolution

Homologous structures

- structures that appear superficially different
- e.g. pentadactyl limb → same bones but the sizes and functions vary → structural similarities ∴ common ancestor
- They may too had the same origin but have diverged to perform different functions. This is dubbed adaptive radiation

Evidence

- comparative anatomy of plants or animals show similar structural features, implying a common ancestry
- Example: Frogs, birds, ~~animals~~ ^{human}, bats all have pentadactyl limbs [homologous structure]
- Homologous structures: structures that appear superficially similar ^{different} but have same origin
- Pentadactyl limb in vertebrates have common bone composition, despite different uses for locomotion [whales - swim, birds - fly, human - (take a pic)]
- This illustrates adaptive radiation → as the same limb has adapted to suit different environmental niches
- The more similar the homologous features are, the more closely related they are





Speciation - formation of a new species by the split of a population

Def: Gradual divergence of populations of a species into separate species

Evidence

- Natural selection acts differently on populations of the same species
- $\therefore$ characteristics diverge
- To prove that they have diverged into separate species, we get them to interbreed
- If offspring is not fertile, new species
- E.g. Lava Lizard on Galapagos Islands (all). But, we have closely related but diff species on 6 nearby islands

willow ptarmigan - red grouse



Variation

- gradual divergence of pops over time leads to continuous variation

Evidence

- Because divergence is gradual, we can see individual stages of change
- Therefore, the variation in stages is continuous
- Example: Red Grouse in Br and willow ptarmigan in Norway
- We can see a continuous range in variation between stages.
- This evidence proves evolution and the development of a new species via evolution

Melanism

- Melanistic (dark coloured because of an abundance of melanin) insects are found in polluted areas, as they can be camouflaged
- Soot from burning blackens trees, enabling camouflage for melanistic insects
- Melanistic moths gradually replaced the peppered moths fast, evidence of evolution
- Found that industrialism caused it (disruptive selection)

Evidence from Homologous Structures

- structures that are superficially different but have the same basic structure
- have a similar origin, their variations in terms of function (e.g. pentadactyl limb, where same bones, but diff function + size). Because of adaptive radiation, they vary in terms of function to suit niches
- suggests divergence from a common ancestor.

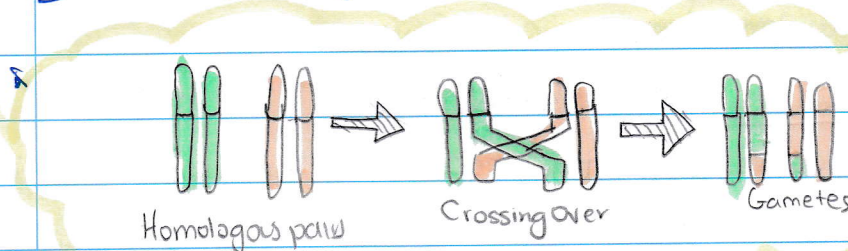
5.2: Natural Selection

Variation

- Natural selection cannot occur unless there is variation in the species
- Darwin proposed this idea in the "Origin of all Species,"
- If all organisms had identical phenotypes/genotypes, none would be favoured more than others.

How do we get variation?

- 1) Mutation: new alleles are produced, hence the gene pool is enlarged = variation
- 2) Meiosis (sexual reproduction)
 - Produces new combinations of alleles by breaking up existing combinations in diploid cells. Each cell would carry new sets of alleles because of crossover + independent assortment
 - Crossover
 - during prophase I, when homologous chromosomes pair up as bivalents, genetic information is shared between non sister chromatids - ↑ potential gamete variation because ↑ genetic variation
 - [the further apart 2 genes are on a chromosome, the more likely they are to recombine]



+ can unlink linked genes if they are far apart

- Independent Assortment
 - in metaphase I, when homologous chromosomes align at the equator, the paired chromosomes randomly arrange themselves in Paternal / Maternal or Maternal / Paternal
 - When the chromosomes separate in anaphase I, final gametes differ by whether mat or pat chromosomes
 - $\therefore 2^n$ combinations, where n is the number of haploid chromosomes
- 3) Random Fertilisation: fusion of maternal and paternal gametes that are varied
 - as they have a combo of genes and fertilisation is random, diff combos of phenotype each type $\rightarrow$ near infinite variability (recombination)

NOTE: If no sexual reproduction, mutation only source of variation.

This generates insufficient variation for quick evolution during times of change.

Adaptations

- Def: characteristics that suit an individual to its environment and niche
- These do not include characteristics developed over a lifetime.
- see later examples

Overproduction of offspring

- species tend to produce more offspring than the environment can support
- The ~~Malthusian~~ Malthusian dilemma states that populations multiply geometrically, while food sources multiply arithmetically.
- This leads to a struggle for existence, stemming from competition for resources
- ↑ offspring, less resources available for the rest of the population
- Intraspecific competition (same species compete for same resources in same ecosystem)
- ↑ mortality rate, S pop curve, reaches + oscillates around carrying capacity

Differential Survival and Reproduction

- The better adapted individuals will survive and produce more offspring
- The less adapted tend to die or produce fewer offspring

Evidence

- giraffes have long necks to eat leaves on tree leaves
- In dry season, no leaves on ground, so those with high necks could access the food source, whereas those with short necks could not. Better adapted to access food
- ∴ those with long necks survived and produced more offspring, those without died

Inheritance

- Individuals that reproduce pass their ^{phenotype} genes on to their offspring
- Variation is heritable
- Behaviour: bird migration patterns
- Body: Europeans have light skin, Indians don't.
- Recall: Acquired characteristics during the lifetime of an individual is not heritable

Progressive Change

- Natural selection increases the frequency of characteristics that make individuals better adapted and decrease the frequency of other characteristics
- If an individual is well adapted, it will survive and pass the desirable phenotype to its offspring.
- ↑ proportions of individuals with good / desirable characteristics
- ↓ proportions of individuals less well adapted
- Characteristics of pop gradually change [macroevolution by natural selection]

Sample Question: Explain how natural selection leads to evolution

- Define natural selection as a theory postulated by Charles Darwin, who ^{described} named it as 'the survival of the fittest.'
- There is inheritable genetic variation in a population
- intraspecific competition for resources leads to differential reproduction
- Organisms with beneficial adaptations are more suited to their niche and will ~~rep~~ survive + reproduce
- The genes responsible for the desirable phenotype will be passed down to subsequent generations
- Over generations, there will be a change in heritable characteristics and allele frequencies in a species = evolution

Case Studies

1) Galapagos Finches [see DBQs]

- Darwin noted variation in the beak + shapes of the Ga bird on Daphne Major
- G. fortis, the medium ground finch, together with the small ground finch, feed on small seeds, but G. fortis can eat large seeds
- In absence of competition, G. fortis is small and has small beak
- 1977 - shortage of small seeds - so G. fortis fed on larger seeds that it could crack open with its large beak.
- El Nino 1982 - more soft seeds - G. fortis ↑ exponentially because ↑ food availability
- Variation caused by genes
- Developed wider and stronger beaks

Antibiotic Resistance

- After an antibiotic is introduced, bacterial resistance appears in a few years
- Proportions of infections caused by resistant strains ↑, resistance spreads to more and more species
- Resistance because of bacterial genes, can be inherited or passed via sex pilli
- caused by a mutation in a single bacterium, then when antibiotic administered, there is strong natural selection for resistance, therefore, we have a pop with a great deal of resistant bacteria
- Why? 1) Widespread AB use, ↑ opportunities for development of resistant genes [by treating disease/animals]
2) Fast bacterial reproduction → generation time < 1 hour
3) Large populations → ↑ risk of a gene mutation
* 4) Can pass genes to each other → by plasmids or pilli to pass resistance genes
↑
most important reason (if asked)

5.3: Classification

Binomial system (not $nCr \cdot (ax)^r \cdot (b)^{n-r}$)

- This system is called binomial ^{nomenclature} ~~nomenclature~~.
- tells us the genus and species
- Genus name first, then species name
- Genus: group of species that share certain characteristics
- Rules
 - All italicized
 - genus name is capitalized
 - After full name used once, we abbreviate from *Xaenise Sapians* to *X. sapians*
 - We use the earliest published name [1753 onwards for plants and 1758 for animals]

Hierarchy of Taxa

- a taxon is a group of something
- plural = taxa
- ~~K~~ Domain > Kingdom > Phylum > Class > Order > Family > Genus > Species
- ‡ As you go from species to domain, ↑ no. of species + fewer shared features

Domains

- Previously, only prokaryotes and eukaryotes
- When RNA base sequence determined, 2 distinct groups of prokaryotes found - Eubacteria and Archaea
- The 3 domains are bacteria, archaea and eukaryota

Feature	Bacteria	Archaea	Eukaryota
Histones in DNA	absent	proteins similar to histones present	present
Introns	rare/absent	Only present in some genes	abundant
Cell Walls	peptidoglycan	Not peptidoglycan	Some Sometimes peptidoglycan
Cell Membranes (all unbranched side)	Glycerol-ester lipids, d-glycerol	glycerol-ether lipids, L-glycerol	glycerol-ester lipids, d-glycerol

Archaea vs Bacteria

A

- L-glycerol and ~~with ester~~ ester lipids
- not peptidoglycan
- introns possible
- proteins similar to histones

B

- d-glycerol ~~with ether~~ ester lipids
- ~~no~~ peptidoglycan cell wall
- introns v. rare
- no histones

Archaea

- broad range of habitats, e.g. oil deposits
- fairly extreme environments, high [salt] water or $T = 100^{\circ}\text{C}$
- methanogens are obligate anaerobes and give off methane when they metabolise in cow guts

Why are viruses left out?

- Too few of the characteristics of life to be regarded as living organisms
- Despite this, they have genes that code for proteins using the universal genetic code

Eukaryote Classification

- The principal taxa are kingdom, phylum, class, order, family, genus, species
- King Peter Crawls On Family's Guest Sofa
- 4 Kingdoms are Plantae, Animalia, Fungi and Protista
- Protista is a grey area - name it but don't discuss too much!

Plantae

- multicellular organisms that make their own food

Animalia

- multicellular organisms that take in their own food

Fungi

- unicellular or multicellular organisms that absorb food

Protista

- unicellular organisms more complex than bacteria or Archaea

Animalia chordata mammalia Primata Hominidae Homosapien
K P C O F G S

VIP: Examples.

Grey Wolf

Kingdom → Phylum → Class → Order → Family → Genus → Species

Animalia → Chordata → Mammalia → Carnivora → Canidae → Canis → lupus

Dandelion

Plantae → tracheophyta → angiospermae → asterales → Asteraceae → taraxacum → officinale

Natural Classification

- In NC, the genus + higher taxa consist of organisms all the species that have evolved from a common ancestor
- because of common ancestry → similar characteristics
- plants and ~~am~~ fungi were once classified together, as they both had cell walls and did not move. This is artificial classification
- Convergent evolution makes distantly related organisms superficially similar
- Adaptive radiation make closely related organism appear different

Advantages

- 1) Identification of Species → if an organism is found, and the species is unknown, we assign it to its Kingdom, then phylum and down to species level. The logic behind this is that because an organism appears to have a similar ancestor to another, it follows a similar taxonomy. Cannot use with artificial classification: as it does not look beyond superficial details.
- 2) Prediction of Characteristics → because all members in a taxon have evolved from a similar ancestor, they have similar characteristics, so we can predict the characteristics of a species in a group. E.g, we can predict a new bat species has a 4 chambered heart and pentadactyl limbs

→ accurate prediction of characteristics
→ identify new species

Reviewing Classification

- done when a previous taxon is shown to have species that have evolved from different ancestral species
- If this is the case, taxa are split
- Conversely, if species are found to share a common ancestral species → taxa merged

Humans

- We are in O: Primates and F: Hominidae
- Debate over if great apes are in Hominidae
- Originally, all great apes were placed in F: Pongidae
- However, chimpanzees and gorillas were found to be closer to humans than orang-utans
- Only orang-utans in Pongidae
- However, ^{gorillas} apes and orang-utans are closer than gorillas and human

Dichotomous Keys

- dichotomy = division into 2
- Numbered series of pairs of descriptions
- See page 265

External Recognition Features of Plant Phyla

	Bryophyta	Filicinophyta	Coniferophyta	Angiospermophyta
Vegetative Organs [parts concerned with growth, not reproduction]	Rhizoids but no true roots, some with stem + leaves, others = thallus	Roots, stem leaves present		→
* Vascular Tissue	No xylem or phloem	xylem + phloem present		→
Cambium	None	None	Present - allow dev into trees + shrubs	→
Pollen - structure holding male gametes	None produced	None produced	Produced in male cones	produced by anthers
Ovules - holds female gametes	None present	None present	Produced in female cones	Held in ovaries
Seeds	None	None	Seeds produced + dispersed	Seeds produced + dispersed
Fruits	None	None	None	Produced for seed dispersal

- 1) Bryophyta - mosses, liverworts, hornworts
- 2) Filicinophyta - ferns
- 3) Coniferophyta - conifers
- 4) Angiospermophyta - flowering plants

Invertebrate Animal Phyla

Porifera - fonsponges,
 cup sponges, tube sponges,
 glass sponges
 Cnidaria - hydras,
 jellyfish, corals
 Platyhelminthes - flatworms,
 tapeworms, flukes
 Mollusca - bivalves
 gastropods, snails,
 chiton, squid
 Annelida - bristlaworms,
 leeches
 Arthropoda - insects,
 arachnids, myriapods,
 crustaceans

Mouth / Anus

Neither (filter feed)

Mouth only

Mouth only

Mouth and
anus

Mouth and
anus

Mouth and
Anus

Symmetry

None

Radial

Bilateral

Bilateral

Bilateral

Bilateral

Skeleton

internal spicules
(skeletal needles)

Soft, but hard
corals secrete
 $CaCO_3$

Soft, no skeleton

Most have $CaCO_3$
shell

Internal cavity
with fluid under
pressure

External skeleton
comprised of chitin
plates

Others

Varied shapes

stinging cells

No blood system + flat bodies

With

Visible Bristles + Segmented

Segmented, and jointed
appendages

Cnidaria

5.4 : Cladistics

- Clades

- a clade is a group of organisms that have evolved from a common ancestor
- species evolve over time to split into different species by way of adaptive radiation
- Clades are identified by looking for shared characteristics
- Include living species, the common ancestor and extinct species

- Evidence for identifying clades

- base sequence of genes ; species with a common ancestor will have few differences in the gene base sequences
- amino acid sequence of proteins for the same reason
- using these difference, we can identify points of divergence
- In addition, using DNA techniques, we can distinguish between adaptive radiation and convergent evolution (which would have more differences or difference)

↘

- Molecular Clocks [Method]

- The use of a constant rate of mutation to determine the time since species split from ancestral species in a clade
- base sequence and A. acid sequence differences gradually accumulate, hence there is a positive correlation between the number of differences between 2 species and the time since they diverged from a common ancestor
- Since mutations occur at a regular rate, we can predict the time since the first difference to discover when the species diverged
- This logic applies because the differences in amino acid and base sequence are the result of mutation

Analogous vs Homologous

1) Analogous

- similar because of convergent evolution, evolved independently to form similar structure
- Example: Octopus and human eye → similar morphology (form + structure)

2) Homologous

- similar because of similar ancestry
- e.g: pentadactyl limb in humans + chickens

NOTE: Because it is difficult to distinguish between homologous and analogous purely by morphology, we use amino acid + DNA base sequencing to test if they are homologous or analogous

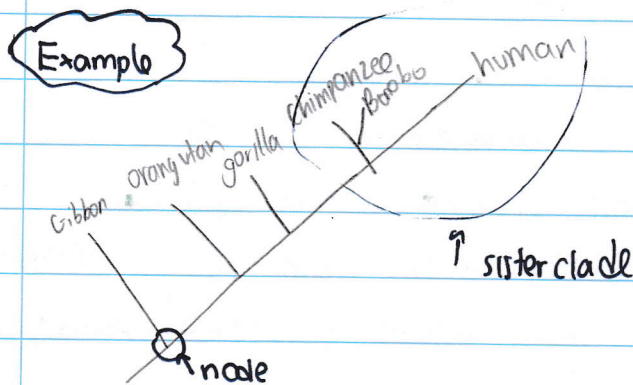
Cladograms

Definition: Tree diagrams that show the most probable sequence of divergence in clades

- based on amino acid + base sequences
- Uses the principle of parsimony; that species evolve with the minimum changes in base sequence
- Not entirely accurate all the time, but most probable
- Branching point = node, which is a hypothetical ancestral species

Why?

- determine relative relatedness of species
- order of nesting of sister clades



What define primates?

- 1) teeth arrangements allowing omnivorous diet
- 2) Larger, complex brain
- 3) Nails
- 4) Finger and paw pads
- 5) short snout
- 6) forward facing eyes

This is a primate cladogram, which was made by sequencing the genome of each of the primate genera. The further 2 species are, the less related they are. E.g: Humans are closely related to Bonobos and Chimpanzees because they are linked at a node. Conversely, humans are distantly related to Gibbons, since they are connected via a series of nodes.

Constructing cladograms

Back to cladograms

- usually drawn on time scales
- Assumes the smallest number of possible mutations to account for current amino acid / base sequence differences. This is flawed, evolution pathways can be more convoluted than this.

Reclassification

- Evidence from cladistics has shown that the classification of some groups based on morphology did not correspond with the evolutionary origins of a species group of species
- Cladistics: construction of cladograms and identification of clades
- Showed that morphology based cladistics does not match the evolutionary origins
- Changes → groups reclassified by
 - groups merged
 - group split
 - movement of species between groups
- Why reclassify? → reveal unnoticed similarities or differences between previously ~~unconnected~~ groups and species previously assumed to be similar

Figwort Family

- Previously, the figwort family was the ^{eighth} ~~second~~ largest family in the angiosperm ^{order} ~~class~~.
- Had 275 genera, over 5000 species
- A project compared base sequences of 3 chloroplast genes in a large number of species in genera assigned to the figwort family and closely related family
- Results: The species in the figwort family were not a true clade. Made of 5 clades, not one.
- Now: Less than half of the original species remain in the figwort family, 50 genera moved to plantain family, 12 genera of parasitic plants moved to broomrape family. New family created and 2 genera inserted.

Making cladograms

- 1) Make a table showing each species and the presence of selected traits

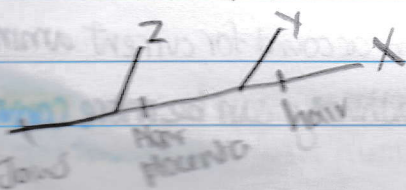
e.g.

Animal	Jaws	Placenta	Hair
X	+	+	+
Y	+	+	-
Z	+	-	-

place at end

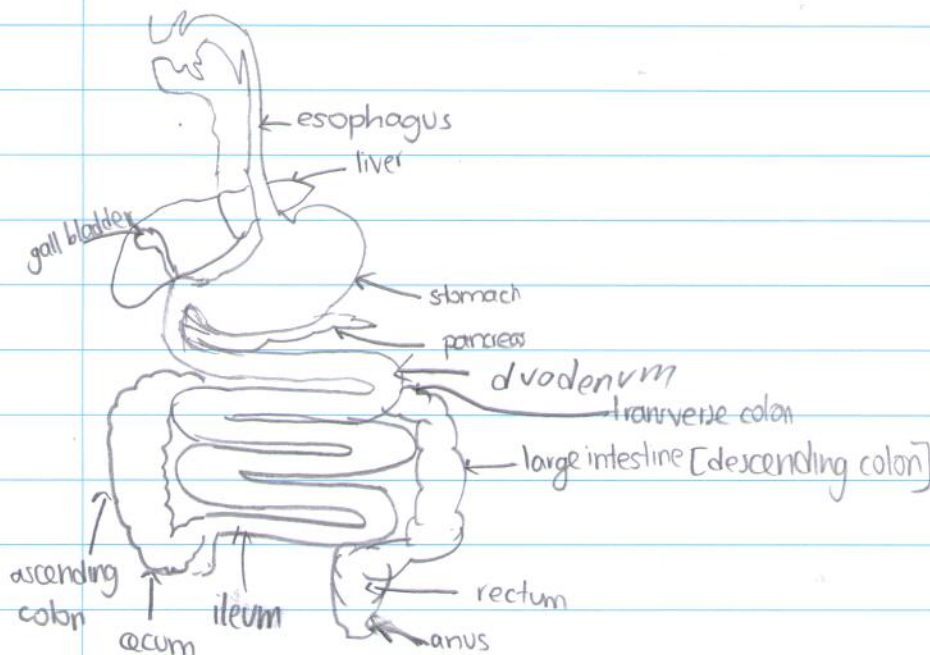
← arrange animals in this order

- 2) Now we construct it



6.1: Digestion

The Structure of the digestive system



Mouth → chemical (amylase + lipase) and physical/mechanical (by chewing) digestion occur. A bolus is formed here because of mixing with saliva, which also contains lubricants

Esophagus → movement of food by peristalsis

Stomach → mix with acid (kill foreign pathogens) + protein digestion by proteases

Pancreas → produces amylase, lipase and proteases

Liver → produce surfactants in bile that emulsify ^{lipids} fats into droplets, stored in gall bladder

Small Intestine → site of digestion of carbohydrates, proteins, fats, nucleic acids and neutralise acidic chyme from the stomach + reabsorb nutrients

Large Intestine → reabsorb water + further digestion of carbohydrates by symbiotic bacteria + formation + storage of feces (rectum).

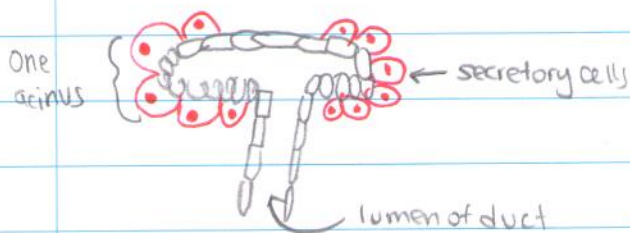
Peristalsis

- muscle in digestive system is smooth, not striated, hence it exerts continuous moderate force, rather than a basic, binary contract-relax system
- The contraction of circular and longitudinal muscle layers enable the small intestine to mix food with enzymes and move it along the gut
- Peristalsis = waves of muscle contraction
- Contracting the circular muscles in the gut constricts it, forcing food down + prevent upwards movement
- Contracting the longitudinal muscles move the food along the gut

- note that these waves of contractions are initiated by the enteric nervous system
- swallowed food moves from the mouth to stomach by a peristaltic wave
- In the intestine, the movement of digested food is slow, hence the peristalsis in the S. intestine primarily mixes enzymes with the semi-digested food, speeding up digestion

The Pancreas

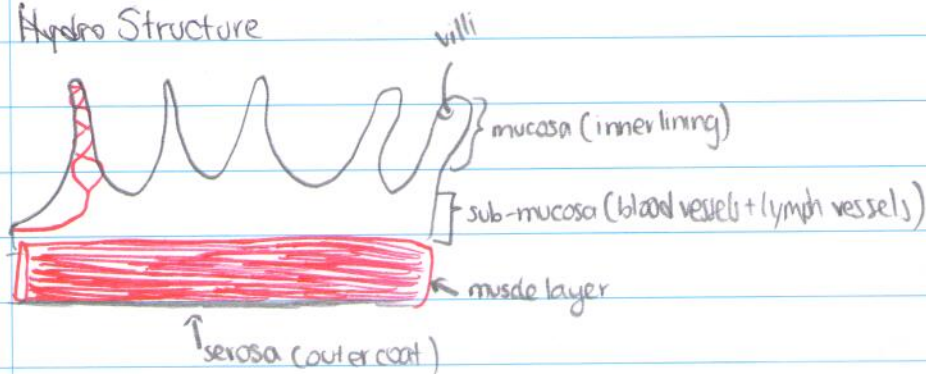
- secretes enzymes into the lumen of the small intestine
- some cells secrete insulin and glucagon, but the remainder produce + secrete digestive enzymes.
- Production is controlled by hormones synthesised and secreted by the stomach and the enteric nervous system
- Small groups of cells cluster around the ducts of the lumen, as shown below



- The enzymes are synthesised by bound ribosomes and are subsequently processed by the Golgi. They are released by exocytosis into the ducts
- Amylase → starch, proteases → proteins + peptides, lipases → triglycerides + phospholipids

The Small Intestine

Hydro Structure



Hydrolysis Reactions

- ① starch $\xrightarrow{\text{amylase}}$ maltose
- ② proteins/polypeptides $\xrightarrow{\text{proteases}}$ shorter peptides
- ③ triglycerides $\xrightarrow{\text{lipases}}$ fatty acids + glycerols/monoglycerides
- ④ phospholipids $\xrightarrow{\text{phospholipase}}$ fatty acids + glycerol + phosphate

Glandular cells in the s. intestine produce the enzymes required for the digestion of other substances. Most are immobilised in the epithelium's cells plasma membranes

- ① DNA/RNA $\xrightarrow{\text{nucleases}}$ nucleotides
- ② Maltose $\xrightarrow{\text{maltase}}$ glucose
- ③ Lactose $\xrightarrow{\text{lactase}}$ glucose + galactose
- ④ Sucrose $\xrightarrow{\text{sucrase}}$ glucose + fructose

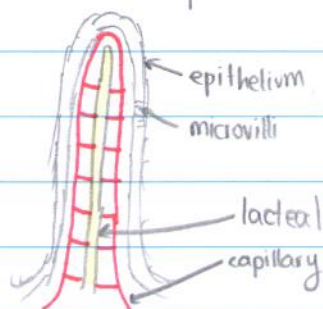
Important enzymes

- exopeptidases remove individual amino acids from polypeptides, leaving dipeptides
- dipeptidases hydrolyse dipeptides into amino acids

The long time spent by semi-digested food in the small intestine allows for most food to be macromolecules to be completely digested. Some substances, like cellulose, cannot be digested due to the lack of appropriate enzymes, resulting in them moving into the large intestine.

Villi

- increase the S.A of the epithelium over which absorption is carried out
- Small intestine already has large S.A (7m long + inner mucosal folds)
- ↑ S.A for absorption ∴ ↑ rate



Adaptations

- ① Microvilli
- ② Potrude into lumen
- ③ small layer of epithelial cells
- ④ Rich blood supply
- ⑤ Close capillaries

- absorb bases, a. acids, fatty acids, monoglycerides, glycerol, glucose, fructose, ~~sucrose~~, galactose or other monosaccharides [basically products of c. digestion in the s. intestine]
- absorb mineral ions + vitamins

- harmful substances can still pass through the epithelium but are removed from blood + detoxified by the liver

Absorption Methods

- for absorption → must be absorbed into epithelial cells, and subsequently into lacteal / blood capillaries

(1) Triglycerides

- broken down into fatty acids + monoglycerides / glycerol, which are non-polar and can pass into the villus epithelial cells by simple diffusion, as can pass through phospholipids
- Fatty acids can also be absorbed by facilitated diffusion, due to the presence of fatty acid transporters (channel proteins)
- Triglycerides reformed in epithelial cells
- Form lipoprotein complexes with cholesterol, with ~~glycerol~~ ^{triglycerides} on the inside and cholesterol and phospholipids on the outside
- Lipoprotein complexes are released by exocytosis on the inner side of the villus epithelial cells, either enter lacteal or blood capillaries

(2) Glucose

- polar and hydrophilic, cannot pass through phospholipid bilayer
- First, by active transport, Na^+ moves from the cytoplasm to interstitial spaces in the villus, and K^+ moves in the opposite direction $\therefore \downarrow [\text{Na}^+]$ in cytoplasm
- Na^+ -glucose cotransport proteins transport a Na^+ and $\text{C}_6\text{H}_{12}\text{O}_6$ molecule from the lumen into the villus epithelial cells. (facilitated diffusion)
- Channel proteins allow movement of glucose by facilitated diffusion from the cytoplasm to interstitial spaces and subsequently into the blood capillaries

The Digestion of Starch

RECALL → α -glucose polymer, branched chain, amylose (alpha helix) and ~~amyl~~ amylopectin (globular branched) because of 1-6 bonds

- Most starch digestion occurs in s. intestine by pancreatic amylase [only works on 1-4 bonds]
 - broken down into maltose and maltotriose [for amylose]
 - Dextrins → parts of amylopectin with 1-6 bonds, not a complementary fit to amylase's a-site
 - Maltase ~~acts~~ acts on maltose
 - Dextrinase acts on dextrins
 - ~~Ma~~ glucosidase acts on ~~malt~~ maltotriose
 - blood carrying glucose is carried by the hepatic portal vein to the liver, where excess glucose is stored as glycogen.
- } all produce glucose

Model for the Small Intestine (Skill + NoS)

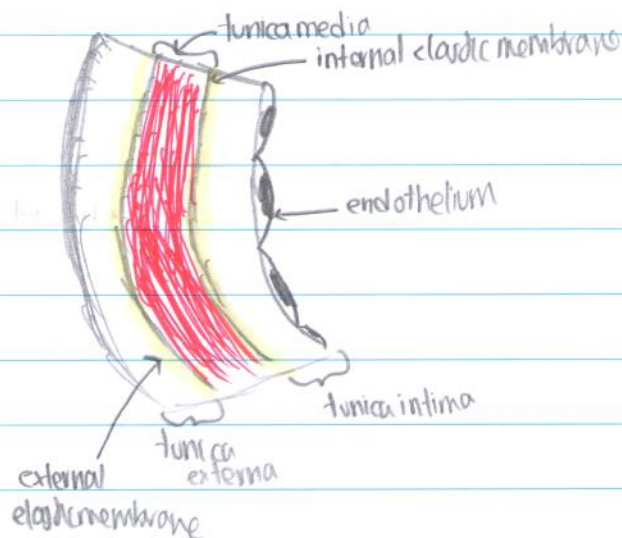
6.2: Circulation

William Harvey

- blood flow was unidirectional
- Showed that blood returns to the heart to be recycled
- Predicted capillaries as a nexus point for veins and arteries
- falsified previous theories

Arteries

- blood from heart to the rest of the body
- Ventricles have thick, strong muscles that result in blood being pumped out of the heart at extremely high pressure
- Elastic tissues have elastic fibre which store the energy generated by the pressure peak at the start of the cardiac cycle. Their recoil helps to propel blood down the artery
- The smooth muscle determines the diameter of the lumen. When the tunica media smooth muscle contracts, the diameter decreases, increasing blood pressure to maintain high blood pressure between high pressure pulses ~~between~~ from the heart. (vasoconstriction)
- The elastic fibres stretch to increase the lumen with each pulse, the recoiling of the fibres after the pulse helps to maintain high pressure.



Note → smaller arteries are known as arterioles

→ peak pressure point and is dubbed systolic pressure

- Both the elasticity of the tunica intima/externa and the smooth muscle increase the tensile strength of the vessel. Needed to withstand constantly changing and intermittently high blood pressure without outward bulges (aneurysm)
- blood movement is pulsatile, not continuous due to the steps involved in the movement of blood

e.g.s

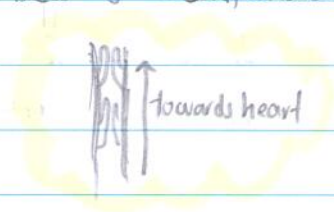
- renal artery
- hepatic artery
- coronary arteries

Blood Pressure in Arteries

- objective: keep b.p high between pulses, keep diastolic pressure ~~low~~ high
- The systolic pressure stretches fibres + widens lumen, gives elastic potential energy in elastic fibres.
- When ↓ pressure, fibres recoil to increase pressure, keeps blood flow steady
- circular smooth muscles allow vasoconstriction when they contract, ↑ b.p by decreasing lumen radius. Also used to restrict blood flow to areas, have muscle cells that respond to hormone signalling.

Veins

- collect blood at low pressure from tissues and return it to the atria
- fewer muscle and elastic fibres due to lower pressure, ∴ wider lumen, ergo larger volume
- 80% of sedentary blood in veins
- Blood flow dependent on surrounding tissue, movement of bones e.t.c
- Muscle contraction applies pressure by on adjacent veins as it becomes wider, enabling blood flow
- Subclavian → arms
- Jugular → brain/heart
- Hepatic portal vein → small intestine to liver
- Low pressure has the potential to cause backflow; Hence, valves are present to ensure unidirectional flow. These are pocket valves ~~and~~ which have 3 - tissue based cup flaps
- If the blood is flowing towards the heart, the ^{flaps} valves are pressed against the sides of the vessel, enabling normal flow, as the pocket valve opens
- If blood starts flowing away from the heart, the flow causes the flaps to rise up and ~~fill~~ block blood flow. Pocket valves fill with blood, blocking the lumen



Capillaries

- permeable walls to enable exchange of materials between blood and cells in surrounding tissue
- branch and rejoin $\therefore$ network formed
- present in all tissues, save the cornea and lens (need to be transparent)
- ~~very thin~~ The layer is a thin wall of layer of small endothelium cells.
- coated by filter like protein gel with pores between the cells $\therefore$ permeable
- This allows plasma to leak into tissues and form tissue fluid
- Plasma $\rightarrow$ fluid in which blood cells are suspended
- Tissue fluid holds oxygen, glucose and all other substances in the plasma, except for large proteins, which cannot pass through the capillary walls.
- Flows between cells in tissues, allows them to absorb + excrete.
- Tissue fluid then re-enters capillary network
- Capillary permeability varies between tissues and changes over time

Overview of Blood Vessels

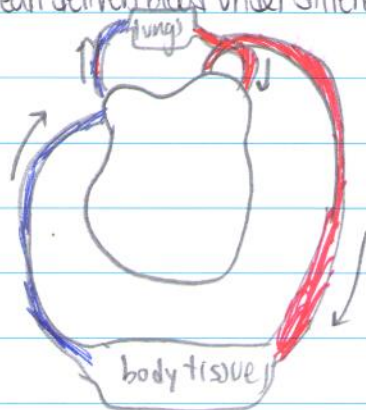
	Arteries	Veins	Capillaries
Diameter	$>10\mu\text{m}$	$\approx 10\mu\text{m}$	$\leq 10\mu\text{m}$
Thickness	Very Thick	Moderately thick, relatively thin	Extremely thin
Lumen	narrow	wide	N.A
Layers	tunica externa, media + intima, muscle + elastic	Tunica intima, an endothelium with thin cells See Arteries	one-cell thick, tunica intima, endothelium with thin cells
Muscle + Elastic	Abundant	Common	Never
Valves	No	Yes	No

Double Circulation

Why?

- blood is pumped to the lungs at low pressure because of potential damage to capillary system
- insufficient pressure to transport the oxygenated blood to tissues
- $\therefore$ must return to heart to be pumped again to generate higher pressure
- So there is a ~~the~~ ~~sp~~ pulmonary circulation - transport from + to lungs and systemic circulation - to and from body tissues (including heart muscles)

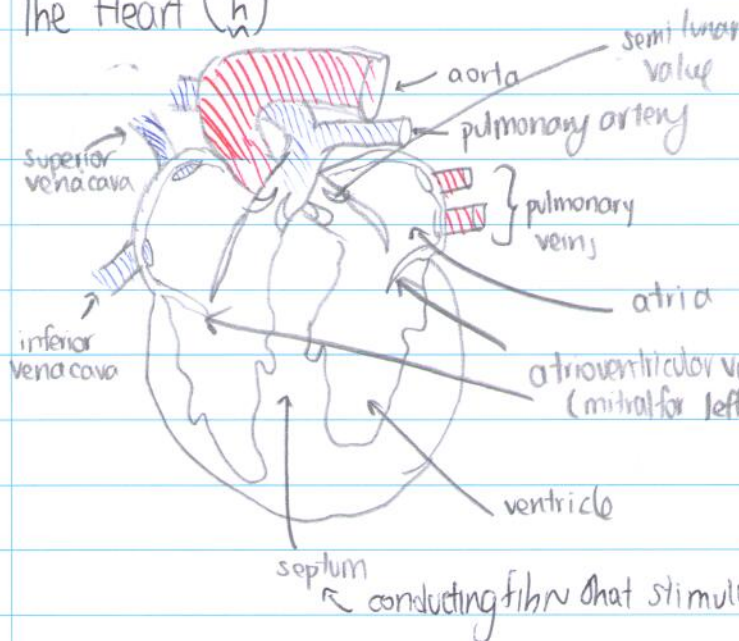
- heart delivers blood under different pressures



■ → oxygenated
■ → deoxygenated

- pulmonary circulation first receives deoxygenated blood from the superior vena cava, and transports it to the lungs. Note that the deoxygenated blood originates from the systemic circulation
- Systemic circulation receives oxygenated blood from the pulmonary circulation
- Must not mix, drastic changes in $[O_2]$.

The Heart (h)



L Heart Side → oxygenated + thicker for strong contractions to pump for systemic circulation

atrioventricular valves → tendons on L ventricle prevent valve from opening a ma
 (mitral for left side, tricuspid for right)

septum → conducting fibers that stimulate ventricles to contract

Atherosclerosis [link to 6.3]

- development of fatty tissue (atheroma) in artery wall adjacent to endothelium
- Low density lipoproteins (LDL) accumulate and phagocytes are attracted by signals from the endothelium and smooth muscle
- Engulf fats and cholesterol, ↑ size, smooth muscle cells form a tough cap on the atheroma
- Bulges into lumen, narrowing it [coronary occlusion for coronary artery]
- lack of O_2 (anoxia) → pain (angina), impairs contractions

→ The smooth muscle, fibrous caps can rupture, leading to blood clot formation

Causes

- ① High low density lipoprotein concentration
- ② Chronic high blood glucose concentration →
- ③ Chronic high b.p (smoking, stress)
- ④ Trans fat - damage endothelium
- ⑤ Production of trimethylamine^N oxide by microbes in S. intestine

Sinoatrial Node

- heart contractions are myogenic; they require no stimulation from motor neurones
- Membranes of contracting cells depolarise, activating the surrounding muscle cells.
- The sinoatrial node is a group of specialised muscle cells located in the wall of the right atrium.
- These cells have the highest rate of spontaneous beating
- have extensive membranes and are the first to depolarise, hence initiating the heartbeat
- acts as a pacemaker, controlling pace for heartbeats
- Easily replaced by a pacemaker, whose electrodes can initiate muscle cell depolarisation.

Atrial + Ventricular Contraction

- In addition to depolarising, the sinoatrial node sends out an electrical impulse that is first propagated through the atria walls and subsequently, the ventricle walls
- The impulse travels through the interconnections between muscle fibres, which are also branched, allowing for more cells to receive the signal per unit time, as ~~the signal~~ each fibre passes the signal on to many more
- First, both atria contract
- 0.1 seconds later, the ventricles contract, pumping blood into arteries
- The delay allows for the blood pumped from the atria to reach the ventricles
- More time as more muscle fibres

Cardiac Cycle

0 - 0.1 seconds

- atria contract, small pressure increase, opening atrioventricular valves
- semi-lunar valves are closed, min pressure as no more blood is pumped in

0.1 - 0.15 seconds

- Ventricles contract, rapid ↑ pressure, causing the atrioventricular valves to close

0.15 - 0.4

- Pressure in ventricles becomes greater than pressure in arteries
- blood is pumped ^{into} arteries as semi-lunar valves open
- Max pressure
- ↑ atria pressure as blood flows into them from the veins

0.45 - 0.8 seconds

- ↓ pressure in ventricles, closing semi-lunar valves

0.85 - 0.8

- ↓ pressure in ventricle relative to atria
∴ opening the atrioventricular valves for stage 0 - 0.1
- Blood from veins drains into atria, ↑ pressure

Changing the heart rate

- the sinoatrial nerve responds to signals ^{through} brought to the heart from 2 nerves from the medulla
- One nerve causes increase in frequency of heart beats, vice versa
- The cardiovascular centre receives input from receptors monitoring blood pH ~~and~~, oxygen conc and pressure. pH used as metric for $[CO_2]$
- Low b.p. pressure, pH and $[O_2]$ = ↑ heart beat to remove CO_2 and ↑ O_2 + ↑ rate of flow
- High $\times 3$ = ↓ heart beat

Guide

- 1) Atrioventricular valve open if atrial pressure > ventricular and vice versa
- 2) Semi-lunar valves open ~~when~~ when ventricular pressure > arterial pressure

Epinephrine

- increases heart rate to prepare for vigorous physical activity (fight or flight)
- adrenaline - adrenal glands
- secretion controlled by brain
- e.g. rock climbing, running from Azhar (flight)

6.3: Defence against infectious disease.

Skin

- physical barrier against the entry of pathogen and part of primary defence against pathogens
- Note: Pathogens are disease causing organisms
- Sebaceous glands on the skin secrete sebum, a chemical that moistens the skin and lowers pH, rendering the environment unsuitable for pathogens + dry and have lysozymes

Mucous Membrane

- lysozymes also present to digest pathogens, hence antiseptic
- ~~mouth~~ ~~intest~~ nasal passages, airways, head of penis + vagina
- consist of sticky solution of glycoproteins
- trap pathogens, which are then either swallowed or expelled
- low pH

Cuts and Clotting

- blood emerging from cut becomes a semi solid gel to seal the wound to prevent further blood loss and prevent entry of pathogens until new tissue grows
- Blood clotting involves a ~~series~~ cascade of reactions, each of which produces a catalyst for the next reaction.
- Platelets ~~release clotting~~, tiny cellular fragments, aggregate at the site of the cut to form a temporary ~~block~~ plug.
- Next, they release clotting factors that initiate the cascade of reactions
- Thrombin is produced and catalyzes the ~~breakdown~~ of soluble fibrinogen into insoluble fibrin
- forms a mesh that traps erythrocytes (RBCs) that dries ~~on~~ in air to form a hard scab

Coronary Thrombosis

- formation of blood clots in coronary arteries
- Thrombus = blood clot
- Blockage results in insufficient O_2 and nutrients being transported to the cardiac muscles
- insufficient ATP production, erratic contractions, leading to quivering movements (fibrillation)
- can be fatal as it is a form of coronary occlusion

~~Atherosclerosis~~

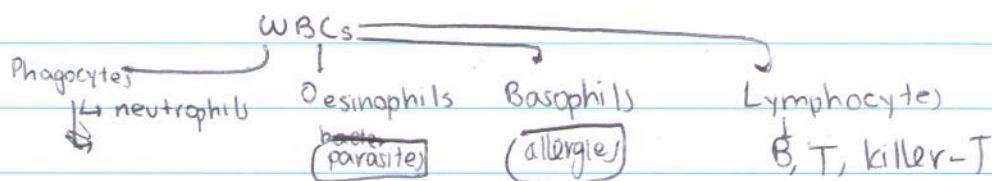
Atherosclerosis

- the LDL deposits [atheromas] can potentially rupture, causing lesions to form, which leads to coronary thrombosis, in conjunction with the hardening of arteries and damage to endothelium

* CHD Risk Factors

Genetics

Leukocytes



Phagocytes

- provide non specific immunity to disease
- engulf pathogens by endocytosis and digest them using lysosome synthesised enzymes
- Pus is formed by large groups/clusters of phagocyte
- Move to pathogens by chemotaxis (movement in response to chemicals) in response to protein or phospholipid released by the pathogen.
- Phagosome formed upon endocytosis, lysozymes break pathogen down and excrete products by exocytosis

Lymphocytes

- if pathogens are recognised as foreign, they stimulate an immune response
- Antigen = a chemical that stimulates an immune response
- The immune response is the production of antibodies, ~~are~~ which bind to an antigen or a pathogen

- ^{type of} each antibody is produced by a specific lymphocyte
- Antigens on the pathogen stimulate cell division of the lymphocytes that produce the appropriate plasma and
- This leads to clusters of ~~the lymphocytes~~ ^{clones}
- Large clones of these particular lymphocytes called plasma cells produce sufficient antibodies to kill and control the pathogen

Antibodies

- Proteins with 2 regions, a hypervariable region and that binds to a particular antigen and a region that helps the body fight the pathogen
- E.g. make pathogens more recognisable to phagocytes → readily engulfed, prevent viruses from docking to host cells - prevent entry
- Antibodies only persist for a few weeks or months and the plasma cells ~~early die~~ are lost following overcoming the infection + antigens no longer present.
- Some of the lymphocytes become memory cells, which live for very long
- Inactive until the same pathogen infects again, when they divide rapidly to produce plasma cells. This grants a degree of immunity.

HIV and AIDS

- HIV invades and destroys helper-T lymphocytes
- progressive loss of the ability to produce antibodies
- HIV positive if specific antibodies detected; they are produced in response to HIV
- retrovirus that uses reverse transcriptase to convert its RNA into DNA copies in a host cell.
- Eventually, antibody production is so ineffective such that a group of opportunistic infections strike
- "Opportunistic" → because only affect a weakened immune system
- Usually rare, e.g. Kaposi's sarcoma
- Collection of diseases or conditions → syndrome → AIDS
- Spread by
 - 1) Sex Contact - abrasions to mucous membranes lead to bleeding
 - 2) Transfusions → even proteins like Factor VIII
 - 3) Hypodermic needles → intravenous parenterals

Antibiotics

- a chemical that inhibits the growth of microorganisms
- Block processes occurring in prokaryotes, but not ~~Eukaryotes~~ eukaryotes
- No harm to human cells
- Target
 - 1) Replication
 - 2) Transcription
 - 3) Translation
 - 4) Cell wall formation (transpeptidase)
 - 5) Ribosome function [extra point]
- Naturally occurring in saprotrophic fungi. Can be explained by the competitive exclusion principle
- Occupied the same niche as several bacteria, compete for dead organic matter, ~~are~~ eliminate from niche using antibacterial antibiotics to inhibit growth → e.g. penicillin G.

Florey and ~~Chase~~ Chain

- method of growing penicillium under optimum conditions in ^a liquid medium → also got purer penicillin
- Deliberately infected mice, killed 4 undressed saved the 4 dressed
- Insufficient supply resulted in first patient's death, initially successful
- no known side effects in testing, not ethical by using deontological logic
- risk takers [IBO would like them]
- saved 96/100 wounded soldiers in WW2

Viruses

- not affected by antibiotics as they lack a metabolism
- Use met of host cell [a eukaryote]
- No translation, transcription or protein synthesis
- Use of AB to treat viruses contributes to the issue of overuse of antibiotics
- Anti virus better → use viral enzymes as target.

Resistance

- tuberculosis particularly resistant ~~EMSA~~ also MRSA

Measures

- ① ~~Stop~~ Only Antibiotics only for serious bacterial infections
- ② Complete course
- ③ Stop use in feed $\rightarrow$ enters food chain
- ④ high hygiene $\rightarrow$ no cross-infection
- ⑤ More types made

(6.4: Gas Exchange)

Ventilation

- $\rightarrow$ maintains concentration gradients of $O_2(g)$ and $CO_2(g)$ between the air in the alveoli and the blood in adjacent capillaries
- $\rightarrow$ Gas exchange: absorbing one gas from the environment and removing another
- $\rightarrow$ Site of gas exchange in humans $\rightarrow$ alveoli
- $\rightarrow$ The aforementioned concentration gradient must be maintained because it gas exchange occurs by diffusion
- $\rightarrow$ Hence, the alveoli must have a higher $[O_2]$ and lower $[CO_2(g)]$ than the blood in the capillaries in order to allow the entry of O_2 into the blood and remove CO_2 .
- $\rightarrow$ Ventilation is the pumping of fresh air into the alveoli and the removal of stale air

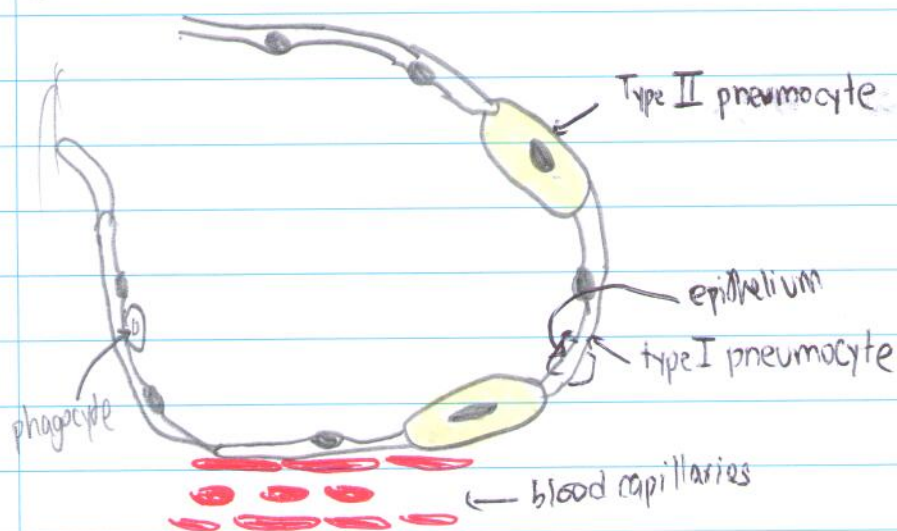
Investigating Ventilation

- $\rightarrow$ can correlate ventilation with exercise
- $\rightarrow$ treadmill, fixed speed, hence can directly correlate work rate with work rate ($J \cdot min^{-1}$)
- $\rightarrow$ The ventilation rate is the number of times breath is drawn in OR expelled per unit time
- $\rightarrow$ Can do it by basic counting or placing an inflatable chest on thorax and pump air in, pressure sensor will be able to detect pressure variations involved in inspiration and expiration allowing for the calculation of ventilation rate
- $\rightarrow$ Tidal volume $\rightarrow$ volume of air drawn in and expelled
- $\rightarrow$ Measured using delivery tube. One shot deal, because high $[CO_2]$ for further ^{inhalation} ~~inhalation~~



- $\rightarrow$ A spirometer works too.

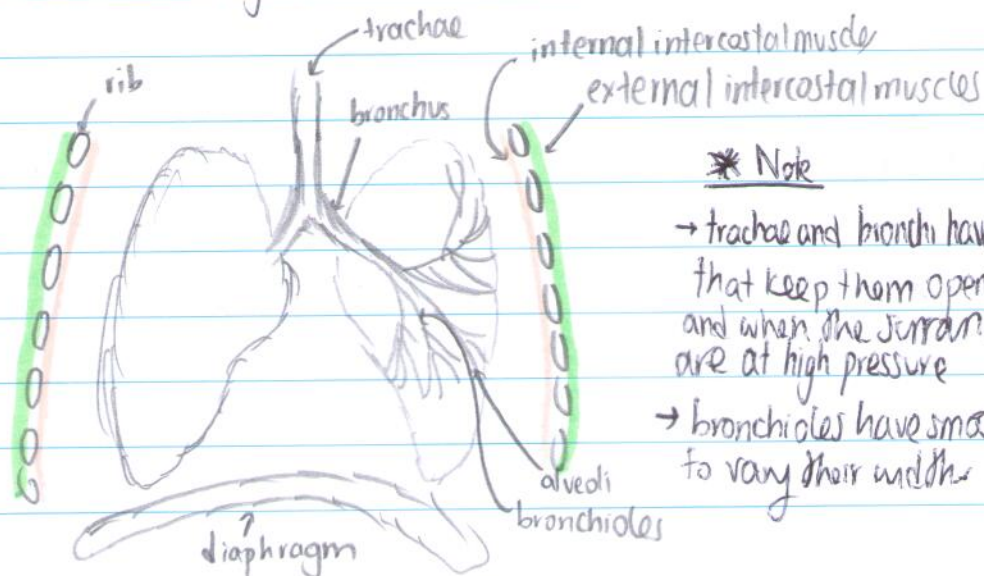
The Alveoli



Cells

- **Type I pneumocytes:** thin alveolar cells that have very thin walls, enabling efficient gas exchange. Flattened cells, reduced cytoplasm, reducing diffusion distance, given the one cell thick capillary walls, increasing rate of gas exchange.
- **Type II Pneumocytes:** secrete a solution containing a ~~surface~~ surfactant to provide a moist surface in the alveoli and prevent the sides of the alveolus from adhering to each other. Only occupy 5% of alveoli surface, rounded. The moisture they secrete allows for O_2 to dissolve, enabling more efficient diffusion between the ~~the~~ epithelium and cells in the capillary walls + CO_2 can evaporate. The pulmonary surfactant forms a monolayer on the epithelium's moist surface, the phosphate heads face inwards and the hydrophobic hydrocarbon ~~tails~~ tails face outwards. This reduces surface tension and prevents the alveolar walls from adhering to each other. Prevents lung collapse. Premature babies usually born without the surfactant.

Airways



* Note

- trachea and bronchi have rings of cartilage that keep them open in low pressure and when the surrounding tissue are at high pressure
- bronchioles have smooth muscle to vary their width

The Process of Ventilation

Note: each point refers to an antagonistic muscle

Inspiration

- Muscle contractions in the thorax cause thorax air pressure to fall below 1 atm
- The diaphragm then contracts and flattens while the abdominal muscles relax to accommodate the new position of the diaphragm, allowing the pressure from the contraction to act on it [$\uparrow V$]
- The ~~int~~ external intercostal muscles contract, pulling the ribcage upwards and outwards. The internal intercostal muscles relax and are elongated.
- Hence, the volume of the thorax increases, decreasing pressure, causing air to flow from an area of high pressure to low pressure [Environment into thorax]

Expiration

- Thorax muscles contract tighter to increase thorax pressure $> 1 \text{ atm}$
- Diaphragm relaxes and returns to curved shape and the ~~abd~~ abdominal muscles contract, to push the diaphragm upwards ($\downarrow V, \uparrow P$)
- The external intercostal muscles relax and elongate while the internal intercostal muscles ~~to~~ pull the ribcage downwards + inwards.

Antagonistic Muscles

- muscles only do work when they contract, they shorten as well
- When relaxing, they elongate.
- Hence a lone muscle can only bring about one movement.
- Movement in opposite directions requires an antagonistic pair.
- $IC \rightarrow IR, IR \rightarrow IC$.
- Inspiration and expiration are opposite actions, hence they rely on antagonistic pairs.

Lung Cancer

- smoking - carcinogenic compounds encourage tumour formation + growth
- second hand smoke
- Air pollution $\rightarrow NO_x$ + diesel fumes can cause mutations
- Asbestos $\rightarrow$ prompt hyperplasia

Symptoms

- chest pain + breathing problems + coughing blood
- loss of appetite
- Weight loss + lethargy

Problems

- metastasis
- 15% 5 year mortality
- Chemo + surgical removal
- LT → possible metastasis, pain + fatigue

Emphysema

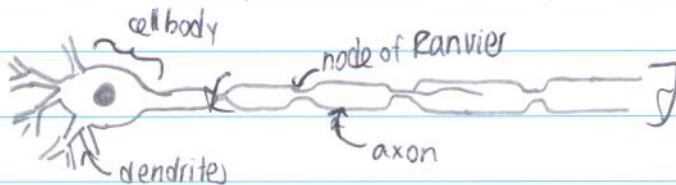
What?

- When we have larger, thicker walled alveoli, ↓ S-A for gas exchange + increased diffusion distance
- less lower elasticity
- Enzyme inhibitors inhibit the activity of elastase and proteases in phagocytes. This leads to an increase in the number of phagocytes to compensate, leading to more elastase, which digests the elastic lining
- Smoking destroys alveolar walls
- Chronic as damage to alveoli is irreversible
- ↓ $[O_2]$, ↑ $[CO_2]$, lethargy, normal tasks onerous.
- Rapid breathing to compensate.

6.5: Neurons and Synapses

Neurons

- transmit electrical impulses, which are nerve impulses



(a typical motor neuron)

- dendrites are short, branched nerve fibres, like those used in transmitting nerve impulses in the brain or spinal cord
- axons are elongated nerve fibres that transmit impulses over considerable distances, such as from the fingers to spinal cord

Myelinated Myelination

- basic nerve fibres have a plasma membrane enclosing a small cytoplasm.
- 1 ms^{-1} speed for this. Myelinated nerve cells have myelin, a large number of phospholipid bilayers wrapped coated nerve fibres

- Schwann cells deposit them and grow ~~and~~ round and round nerve fibres to form multiple layers
- Double layer deposited each time, up to 20 layers deposited
- Gaps between myelin deposits culminate in nodes of Ranvier
- Because of myelination, nerve impulses can jump from one node to the next (saltatory conduction)
- Much faster, $\times 100$

Resting Potential

- a neuron at rest (not transmitting a signal) has a pd called the resting potential, which arises due to a charge imbalance
- At rest, Na^+ are pumped out, K^+ pumped in, 3 Na^+ for every 2 K^+ , contributing to this charge imbalance and setting up ~~pot~~ concentration gradients for the depolarisation
- axon membrane is $50\times$ more permeable to K^+ than Na^+ , ~~more~~ K^+ leak across membrane faster than Na^+ , steeper concentration ~~for~~ Na^+ , therefore charge imbalance
- Negatively charged molecules ^{e.g. proteins} in the membrane ~~or~~ contribute to the charge imbalance
- -70 mV

Action Potentials

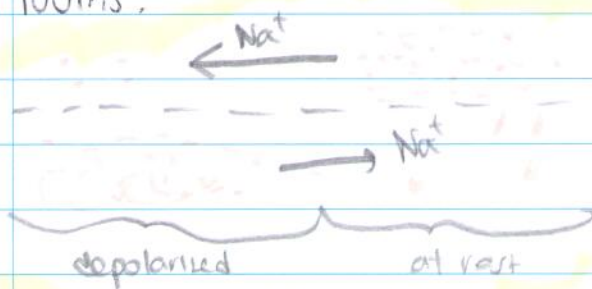
- rapid change in membrane potential
- depolarisation (+V) succeeded by repolarisation (-V)
- Depolarisation occurs because of the opening of the voltage-gated sodium channels, allowing facilitated diffusion of Na^+ into the ~~on~~ neuron, which reverses the charge imbalance inside positive relative to outside $\therefore$ approx $+30$ $+30\text{ mV}$
- ~~total~~ Repolarisation caused by closing of Na^+ channels and opening of K^+ channels
- allows K^+ to diffuse out by facilitated diffusion, negative relative to outside again
- close to -70 mV
- IT HAS NOT RESTORED THE RESTING POTENTIAL
- conc gradients not yet ~~estab~~ re-established

Propagation of Action Potentials

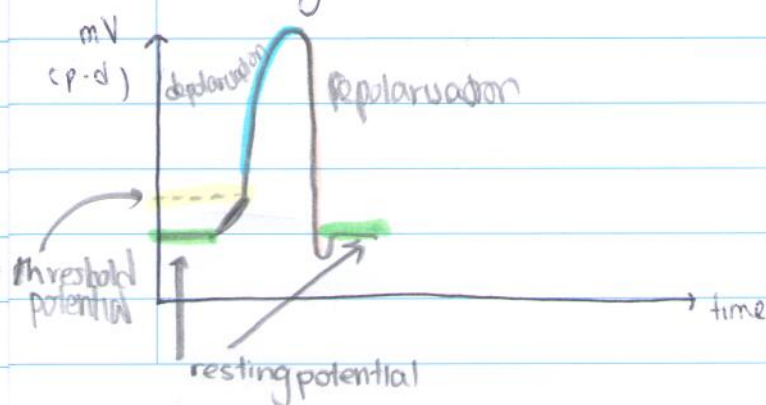
- a nerve impulse is an action potential propagated along axons
- ion movements that start depolarisation trigger depolarisation in neighbouring axons
- unidirectional because can only be initiated at one terminal and can only be passed to other neurons or cell types at the other terminals.
- Refractive period ~~prevents~~ after depolarisation prevents propagation of an action potential backwards

Local Currents

- depolarisation decreases $[Na^+]$ outside of the axon, hence conc gradient outside established, Na^+ outside ~~potent~~ ^{axon} at rest diffuses to the area outside the depolarised axon
- $\uparrow [Na^+]$ within depolarised axon, so they diffuse to a neighbouring axon at rest.
- These movements generate local currents
- Local currents $\downarrow$ conc gradient for Na^+ , increasing ^{membrane} potential from $-70mV$ to $-50mV$, which allows for the threshold potential to be reached
- Open voltage gated sodium channels to initiate depolarisation
- Hence local currents produce waves of depolarisation propagated along axons at $1p$ to $100ms^{-1}$



Analysing Oscilloscope Traces



Synapses

- junctions between neurons and between neurons and effector or receptor cells
- neurotransmitters such as acetylcholine are used to send signals across synapses.
- Pre and post-synaptic cells separated by a fluid filled gap (synaptic cleft)
- When a nerve impulse reaches the pre-synaptic neuron's end, depolarisation is initiated
- Causes Ca^{2+} to diffuse via channels into synaptic knob
- Influx of Ca^{2+} results in ^{synaptic} vesicles holding neurotransmitters moving to the membrane and fusing with it
- releases neurotransmitter into synaptic cleft by exocytosis
- Diffuses across cleft and binds to receptors on post-synaptic neuron
- Causes Na^+ channels to open, allow it to reach threshold potential because lower Na^+ concentration gradient, triggering an action potential
- Neurotransmitter broken down

Acetylcholine

- neurotransmitter e.g. muscles and neurones
- produced in pre-synaptic by reacting choline (from diet) with an acetyl group from aerobic respiration (acetyl CoA)
- loaded into synaptic vesicles following stimulation by Ca^{2+}
- acetylcholine binds to the post-synaptic receptors for a short time, rapidly broken down by acetylcholinesterase into choline and an acetate salt
- Reabsorbed by pre-synaptic neuron to reform neurotransmitter (choline only)

Neonicotinoids

- similar to nicotine, bind to acetylcholine receptors in post-synaptic neuron in cholinergic insects
- Irreversible binding as acetylcholinesterase cannot break it down
- acetylcholine can no longer bind, no synaptic transmission — paralysis or death
- effective insecticides
- Not dangerous for mammals, fewer cholinergic synapses, bind less strongly to mammal acetylcholine receptors
- One type is most common insecticide but can affect non-target insects e.g. honeybees

Threshold Potentials

- only at threshold potentials do voltage gated Na^+ open to enable depolarisation
- positive feedback by local currents
- sufficient neurotransmitter must bind to receptors in the post synaptic neurone to $\uparrow$ to threshold potential.
- Insufficient $\rightarrow$ any Na^+ that entered pumped out - resting potential reached
- ~~Soma~~ Post synaptic neurones in the brain have many presynaptic neurones. Need to release at same time and in correct quantities $\rightarrow$ allows brain to process info from different avenues of sense perception

6.6: Hormones, Homeostasis and Reproduction

Controlling Blood Glucose

- set point: 5 mmol dm^{-3}
- pancreas has mostly exocrine glands that secrete enzymes for digestion
- Small regions of endocrine tissue called Islets of Langerhans that have α and β cells
- $\alpha \rightarrow$ secrete glucagon if blood glucose level falls below 5 mmol dm^{-3} . Stimulates breakdown of glycogen into glucose in liver and release into blood, $\uparrow [\text{C}_6\text{H}_{12}\text{O}_6]$
- $\beta \rightarrow$ secrete insulin when $[\text{C}_6\text{H}_{12}\text{O}_6] > 5 \text{ mmol dm}^{-3}$. Stimulates uptake of glucose by tissues such as skeletal tissue and the liver. Stimulates conversion of glucose into glycogen, $\downarrow [\text{C}_6\text{H}_{12}\text{O}_6]$. However, insulin is broken down as soon as it binds to an insulin receptor.
- $\therefore$ must have continuous secretion

Diabetes

- consistently elevated blood glucose levels even during prolonged fasting
- glucose in urine + damages tissues and their urine, impairs water reabsorption in kidneys, $\uparrow \text{V}$ and resulting in dehydration

Type I

- early onset diabetes, inability to produce sufficient insulin, autoimmune disease due to destruction of β cells by immune system in Islets of Langerhans
- sudden start

Treatment

- insulin injections when $[C_{6}H_{12}O_6]$ is too high
- Timing is imperative; does not last long
- implanted device or stem cells

Type II

- late onset, inability to process or respond to insulin, ~~infect~~ deficiency of receptors or glucose transporters
- slow onset
- sugary diet, fatty foods, lack of exercise + obesity

Treatment

- lower glycaemic index food
- exercise + weight loss → improve insulin uptake
- Avoid sugary food

Thyroxine

- secreted by thyroid gland to ^{regulate} ~~control~~ metabolic rate and control temperature
- 4 I atoms, hence iodine needed in diet
- almost all cells are targets as all cells are involved in metabolism
- All cells respond, main targets are those that are most metabolically active, e.g. brain, muscle
- ↑ metabolic rate, ↑ protein synthesis → generate heat
- In low T, thyroxine secreted, heat production
- Hypothyroidism → depression, lethargy, weight gain, cold feeling, forgetfulness, impaired brain development in children

Leptin

- secreted in ~~adipose~~ by cells in adipose tissue and acts on the hypothalamus to inhibit appetite
- Ooreating = more adipose tissue cells → ^{higher blood leptin conc} ~~more leptin~~ → appetite inhibition, reduced food intake

- With less adipose tissue, lower blood leptin conc → lower inhibition → more eating due to hunger
- Obese people have consistently elevated blood leptin concs, body becomes progressively desensitised to it, e.g. receptor binding is not as effective
- As a result, overeating persists in the obese, due to lower inhibition, resistance also develops over lifespan, higher age higher risk.

Experiments With Leptin

- hypothesised that increased blood leptin concs by intravenous parenterals could combat obesity
- induced skin irritation + swelling
- high $\text{Var}(X)$ in sample, shown to be statistically insignificant
- Any mass lost in trial was rapidly regained later
- Worked for mice, not for humans
- Humans have higher blood leptin concentrations, target cell in hypothalamus become resistant, even at high concs
- Hence adding more leptin has a limited effect, like how insulin injections do not help Type II Dia
- Leptin needs to be injected several times a day
- can affect development and functioning of the reproductive system

Melatonin

- secreted by pineal gland to control circadian rhythms
- Circadian rhythms are rhythms that allow humans to live in a 24 hour cycle
- Continue even in continuous darkness/light
- Suprachiasmatic nuclei control the secretion of melatonin by the pineal gland.
- High secretion in evening, because secretion is suppressed by bright light
- Causes drowsiness and promote sleep, falling level results in waking up
- Contributes to nighttime drop in core body temperature → artificial melatonin administration proved it
- Melatonin receptors in kidneys → lower night time urine production.
- promotes activity in nocturnal animals
- Ganglion cells in the retina detect light of $\lambda = 460 - 480 \text{ nm}$ to indicate to the suprachiasmatic nuclei the timing of dusk to dawn. Allow adjustment of cycle

Jet Lag

- pineal gland continues to secrete melatonin according to the old time zone
- ∴ internal circadian rhythm not synchronised to new time zone
- fatigue, irritability, difficulty sleeping at night or staying awake during the day
- Take melatonin at the start of nighttime (within new TZ)

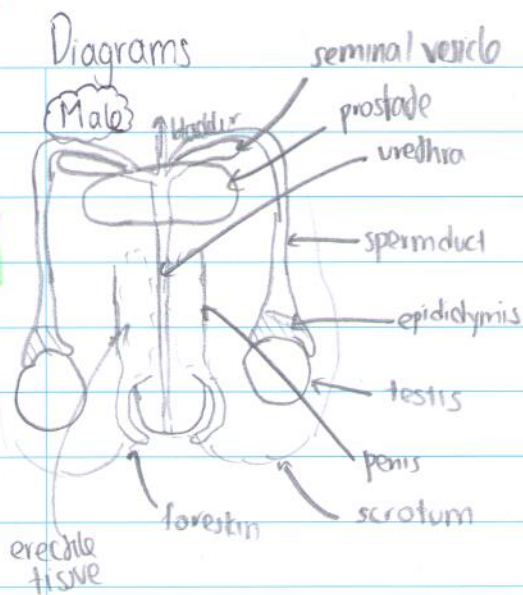
Sex Determination (Male)

- The SRY gene on Y causes embryonic gonads to develop into testes and secrete testosterone
- SRY codes for a DNA binding protein called testis determining factor (TDF), stimulating expression of genes responsible for testes development
- The testes produce testosterone secreting cells at an early stage, causing male genitalia to develop. Testosterone production stops by week 15
- ~~In~~ During puberty, ↑ testosterone secretion, causes the development of primary and secondary sexual characteristics
 - Primary → production of sperm in testes
 - Secondary → enlargement of penis, facial + pubic hair, deepening of voice (+ growth of larynx)

Sex Determination (Female)

- absence of Y (by extension, SRY) means no TDF ~~not~~ coded for, so embryonic gonads develop as ovaries
- Estrogen and Progesterone secreted during pregnancy → first ovaries, later placenta
- In the presence of these 2 hormones and absence of TDF, embryonic gonads develop as ovaries
- During puberty results in primary and secondary sexual characteristics developing
 - ① enlargement of breasts
 - ② Growth of pubic + underarm hair

Diagrams



Testes - produce sperm and testosterone

Scrotum - store sperm at lower T

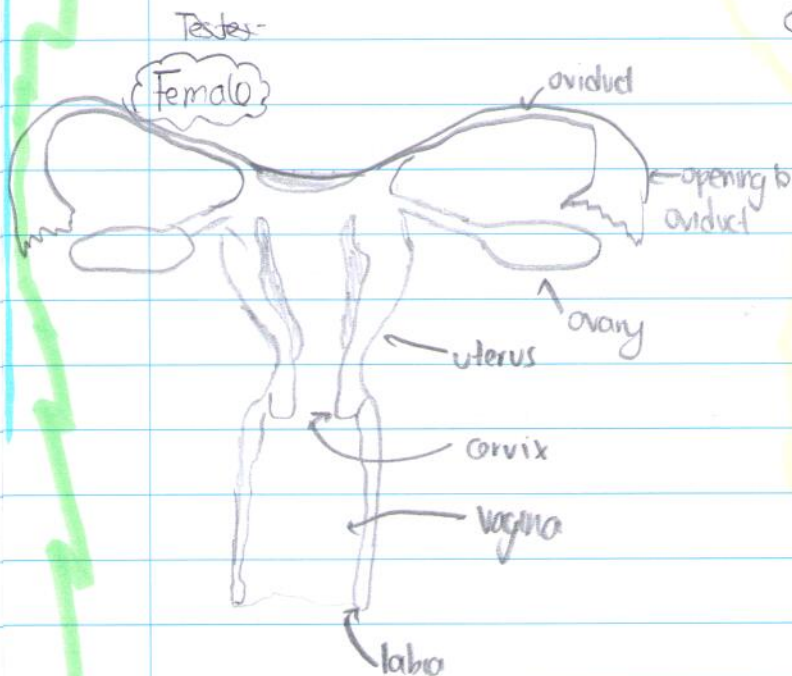
epididymis - store sperm before ejaculation

sperm duct - transfer sperm before ejaculation

Seminal + Prostate - produce alkaline solution with proteins or fructose, added to sperm to form semen

Urethra - transfer semen during ejaculation or urine

Penis - penetrate vagina for ejaculation near cervix



Ovary: produce egg, estrogen and progesterone

Oviduct: collect eggs at ovulation, site for fertilisation and move embryo to uterus

Uterus: provide for fetus needs

Cervix: Protection + dilate for birth canal

Vagina: stimulate penis + birth canal

Labia: Protect + internal components

NOTE: In reality, slightly tilted. See cross section 2 in textbook.

The Menstrual Cycle

- occurs in all women from puberty to menopause continuously (ignoring pregnancy)
- controlled by negative and positive feedback
- Hormones involved are pituitary (FSH and luteinising hormone (LH)) or ovarian (estrogen and progesterone)

Stages

① Follicular Phase

- FSH secreted by anterior pituitary gland and stimulates growth of ovarian follicle
- The dominant follicle releases estrogen, which leads to the thickening of the endometrium (uterus lining) and its repair
- Negative feedback as estrogen inhibits FSH secretion prevents further follicles

② Ovulation

- ~~dominant follicle~~ By day 12, estrogen stimulates the anterior pituitary to release luteinising hormone (LH) [positive feedback] in a surge and ^{small} ~~lower~~ FSH secretion
- The LH causes the dominant follicle to break and release an egg on day 14
- This corresponds with an LH peak and a tiny 1 for FSH

③ Luteal Phase

- wall of the broken follicle forms the corpus luteum
- releases ~~pre~~ high levels of progesterone and a small amount of estrogen to thicken endometrium
- inhibit FSH and LH secretion (N-feedback) to stop new follicles developing

④ Menstruation

- if fertilisation occurs, embryo implants itself into the endometrium and releases hCG to sustain the corpus luteum
- If not, C. luteum degenerates, ^{forms corpus albicans} ↓ progesterone + estrogen across 2 weeks
- endometrium cannot be maintained, shedding of endometrial layer, to start menstrual
- Low estrogen + progesterone mean lower inhibition on anterior pituitary, FSH

Overview of Hormones

FSH (anterior pituitary)

- peak at the end
- stimulate development of follicles which hold an oocyte and follicular fluid
- indirectly stimulates production of estrogen by follicle wall

LH (anterior pituitary)

- sharp + sudden peak at the end of the follicular phase [ovulation]
- stimulates completion of meiosis in oocyte and ~~breaks~~ partial digestion of follicle wall
- promotes development of follicle wall after ovulation in c. luteum, which secretes progesterone & FSH (positive feedback) and estrogen

Estrogen (c. luteum + follicle)

- peak at end of follicular
- repair and build up of endometrium
- inhibits FSH and stimulates LH secretion

Progesterone (c. luteum)

- high at luteal phase, then drops at end
- promotes thickening + maintenance of endometrium
- inhibits FSH and LH (negative feedback)

Graphs

IVF

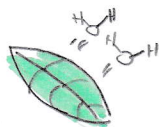
→ in vitro → out of body fertilisation, opposite is in vivo

- ① Down regulation - nasal spray to stop production of FSH and LH, causing estrogen and progesterone production to halt. Suspends cycle. Increase control over timing and quantity of egg production
- ② Producing follicles - intramuscular FSH + LH injection for ten days daily, higher [FSH] than normal, more follicles [superovulation]
- ③ Egg production - HCG injection to mature follicles, micropipette guided by ultrasound ~~allows~~ passed through uterus to wash eggs out of follicles
- ④ Fertilisation → eggs mixed with 50-100k sperm cells in sterile condition at 37°C. One or more embryos placed in uterus at 48hr mark. Progesterone tablets given to ensure thick endometrium

Harvey (again)

- disproved Aristotle's theory that male produced "seed," forms an egg when mixed with menstrual blood.
- ~~Surveyed~~ Observed deer, seasonal breeders
- no eggs developing immediately after, developing biological material only 2-3 months later
- he said that corpus is not responsible for fetus formation (wrong!)

N4 Sexual P

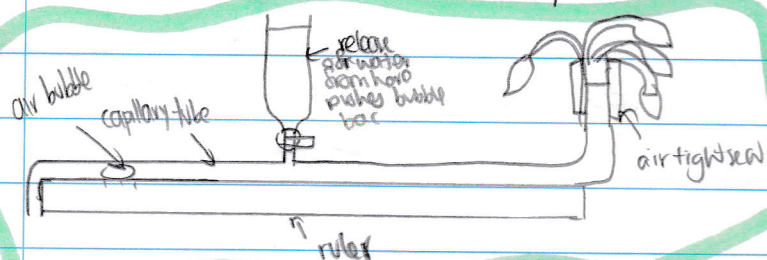


Transpiration → consequence of gas exchange

Def: The loss of water vapour from the leaves and stems of plants

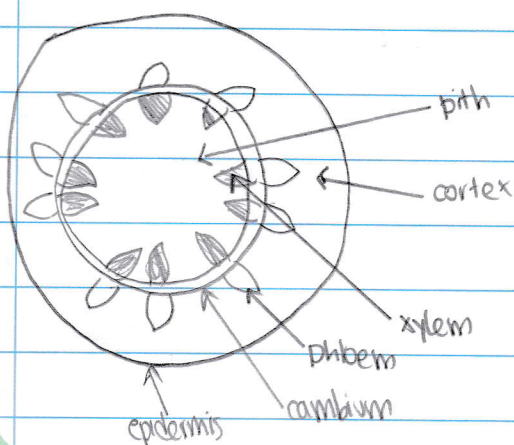
Transpiration occurs because of gas exchange in leaves, as when stomata are open to let CO_2 in, H_2O vapour goes out. Guard cells minimise water loss as they control the aperture of the stoma, can change from wide open to fully closed. The only plants without stomatas are called liverworts. Stomata are necessary for CO_2 absorption because waxy cuticle permeability is too low

Potometer (as a measurement of transpiration)



- Air bubble moves along as water is absorbed by the shoot
- Shoot must be cut under water to avoid introducing air bubbles
- cm/minute

Vascular bundles



Xylem: transports water and mineral nutrients

Phloem: transport sucrose

Cambium: produces new xylem and phloem cells

pith:

cortex:

Xylem features

- 1) Thickened walls, filled with lignin polymer to strengthened walls to handle low pressures → rigidity prevents collapse
- 2) Formed by files of cells, arranged end to end
- 3) When mature, xylem cells are non living → H_2O movement is passive
- 4) Pressure inside lower than atmospheric pressure

Adhesion

Water molecules are polar and the more electronegative O atoms in a water molecule are attracted to the hydrophilic parts of xylem cell walls. Formation of hydrogen bonds

Cohesion

- O^- atoms are attracted to the H^+ atom in another water molecule
- attraction between H_2O molecules, allows water to be drawn up in a continuous stream

Surface tension is created by the cohesive forces between water molecules.

Models for water movement

- Capillary Tube
- models adhesion between water molecules and glass molecules
- Filter paper → adhesion
-
- Porous material → water fills the pores, adhesion to the clay demonstrated, movement of water through capillary tube as an uninterrupted chain demonstrates cohesion

Tension forces

- When water evaporates from the surface of the wall in a cell, ^{cohesion} adhesion causes water to be drawn from the xylem vessels in the leaf veins to replenish the water lost by evaporation
- The forces of ^{adhesion} adhesion between water and leaf cell walls further reduce pressure in the xylem
- The low pressure generates a pulling force transmitted through the water in the xylem vessels down the stem and to the ends of the xylem in the roots
- This generates a transpiration pull, a passive process.

Active Transport in the roots

- water is absorbed into the root cells by osmosis
- Mineral ions are more concentrated in the ~~soil~~ roots than in the soil.
- Mineral ions can only be absorbed by active transport if they make contact with the appropriate protein pumps in membranes. They make contact by diffusing into the protein or by mass flow (water carrying ions down through the soil).

Adaptations

- ① Root hair cells - $\uparrow$ S.A
- ② Root network that branches
- ③ $\uparrow$ pump proteins and mitochondria, use ATP maximisation for use in active transport
- ④ Symbiotic/Mutualistic (fungi) relationship which can absorb mineral ions bound to soil particles and pass the former to plants

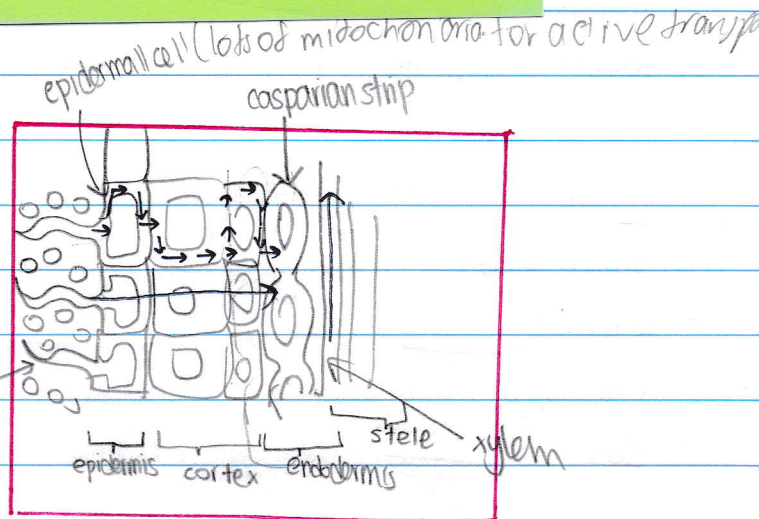
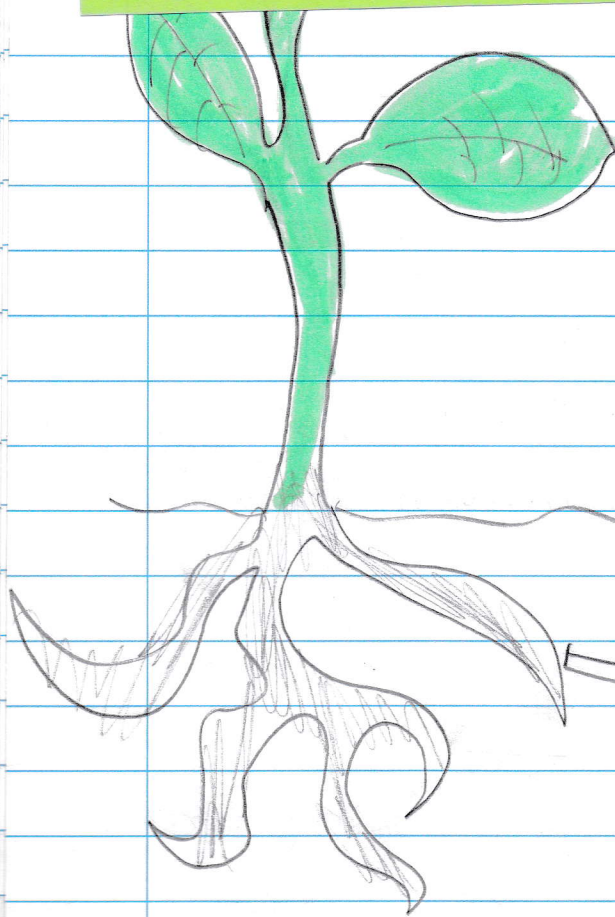
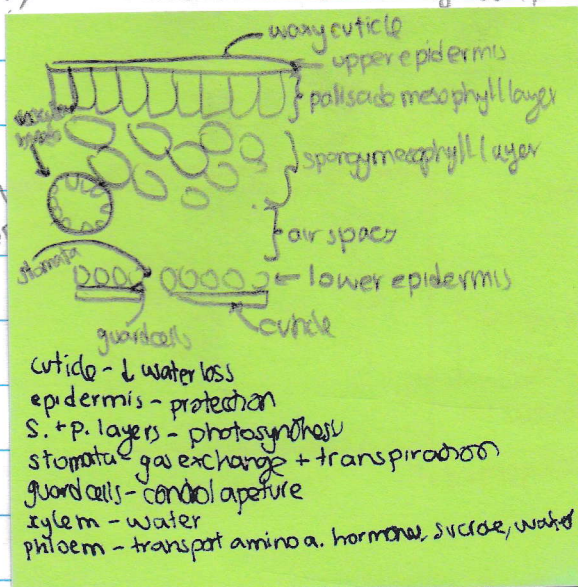
hair cells to max S.A
proteins + mitochondria for ATP

ions bind to the surface of soil particles.

hyphae grow into the soil and absorb mineral ions

but only apoplastic pathway

transport, $\uparrow$ solute conc of surrounding soil, ions allow small



Movement of water through the roots

- Apoplastic pathway = movement of water to the xylem through the cell walls
- Symplast pathway = movement of water to the xylem through the cytoplasm and plasmodesmata
- Caspian strip = impermeable to water, so water must travel through the cytoplasm of the endodermis cells (symplastic route), regulating the water entering the xylem

Support

- Turgor pressure is created by vacuoles full of water pushing on cell walls. Lignin is a strong polysaccharide that strengthens them. Support is necessary for growing towards sunlight. Turgor pressure maintains cell shape - prevents wilting

How transpiration occurs

- 1) Water evaporates from spongy mesophyll cells into air spaces
- 2) Water vapour diffuses out of the stomata of leaves, down their concentration gradient
- 3) As spongy cells become more concentrated, * water diffuses from xylem vessels into the spongy mesophyll cells
- * 4) Water molecules are polar and its charged atoms are attracted to the hydrophilic parts of ^{leaf} ~~xylem cell~~ walls and these forces of adhesion further reduce pressure in the xylem
- 5) This generates a transpiration pull, affecting all water in the xylem since the cohesion between water molecules form an unbroken chain of molecules, due to the hydrogen bonding in water.
- 6) Loss of water from the cortex and roots cause cells to become more concentrated, hence water from the soil enters through osmosis

Factors affecting rate of transpiration

(features $\rightarrow$ diameter of xylem, no of stomata, size, shape of leaf)

- 1) Light $\rightarrow$ $\uparrow$ light intensity, $\uparrow$ rate of transpiration. Plants open their stomata ^{to a wider aperture} in high light intensity to absorb CO_2 for photosynthesis that would occur faster because of higher light intensity, but $\uparrow$ water loss per unit time
- 2) Temperature - $\uparrow$ temperature, $\uparrow$ rate of transpiration. Heat energy is converted into kinetic energy of water molecules. The greater motion breaks hydrogen bonds between H_2O molecules, allowing water to evaporate out of the stomata faster
- 3) Wind - $\uparrow$ wind speed, $\uparrow$ transpiration. Moving air removes water molecules surrounding the leaf, creating a steeper concentration gradient that water moves down out of the leaf.
- 4) Humidity - $\uparrow$ humidity, $\downarrow$ transpiration. There are more water molecules in the surrounding air, ^{steepness on} decreasing the conc gradient between ~~water in the~~ air spaces and air outside the leaf.
check (With a decreased conc gradient, the rate of transpiration decreases)

xylem network keeps sugar pressure high, keeps plant supported

Transport in Phloem

Identifying xylem and phloem

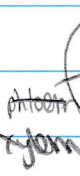
Stem



phloem
xylem

vascular bundle in the middle so it can grow around roots and obstacles

Roots

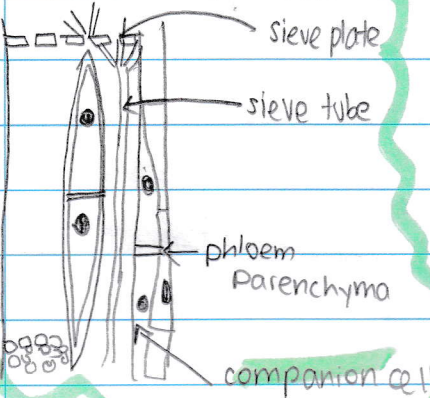


endodermis
epidermis
stole
phloem
xylem

(dicotyledonous examples)

monocots have randomly scattered vascular bundles

Structure of the Phloem



Sieve tubes → elongated ranks of individual cells that are arranged end to end, conduct food materials through plant, no nucleus, reduced cytoplasm, has a membrane of reduced resistance to flow of phloem

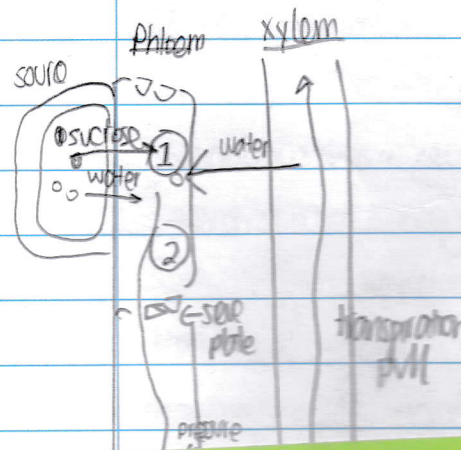
Sieve plates → connect sieve tubes and sieve tube cells

Companion cells → provide ATP, proteins and other substances to the sieve tube elements, whose cytoplasmic structures needed for cell maintenance, maintain viability of sieve tube elements.

Translocation

- transportation of the organic products of photosynthesis through the plant.
- movement of phloem sap is from source (where sugar is made or mobilised) to sink (organ where sugar is used or stored)
- Phloem sap mainly consists of water, sucrose, hormones and amino acids.

Pressure Flow hypothesis



① Moving sucrose into the phloem from source increases the solute concentration in the sieve tube cells, hence the cells take up water from the surrounding xylem tissue by osmosis

② The water absorption creates a hydrostatic pressure that forces the sap to move along the tube

③ The gradient of pressure in the Sieve tube is reinforced by the unloading of sucrose and loss of water by osmosis (creating a lack of pressure)

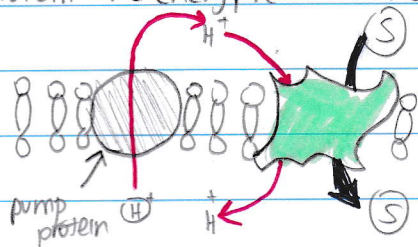
④ Xylem recycles the water used, as with a lower solute concentration in the phloem, water moves into the xylem by osmosis

Outline the translocation of biochemicals in the phloem.

- do the basics + amino acids, water, sucrose + hormones transported
- from source (site of production or mobilisation) to sink (site of use or storage)
- active transport

Phloem Loading (Mass Flow)

- at the source, active transport is used to load organic compounds into phloem sieve tubes
- can load apoplastically or symplastically (through plasmodesmata)
- H^+ (protons) are transported out of a companion cell using active transport through a pump protein. The build up of protons then goes down its electrochemical ~~concentration~~ gradient, through a co-transport protein. The energy released is used to carry sucrose into the companion cell-sieve tube complex



Hydrostatic Pressure

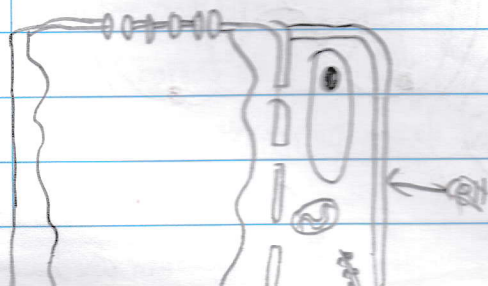
- The build up of sucrose and other carbohydrates draw water into companion cells
- Hence, water enters the cells through osmosis.
- The rigid cell walls combined with the incompressibility of water result in a build up of pressure
- Water flows from a area of high pressure to low pressure
sucrose + phloem sap

Aphids and Radioisotopes

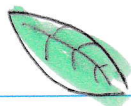
- Aphids penetrate plant tissue to reach the phloem using mouth parts called stylets.
- If the aphid is anaesthetized and has its stylet severed, phloem will continue to flow out of the stylet. (only stylet attached to the stem)
- This lets us analyse rate of flow and composition of the phloem sap
- The closer the stylet is to the sink, the slower the rate of flow of phloem.

C-14

- C-14 in CO_2 can be fixed by plants during photosynthesis
- As the carbon is metabolised, it is converted into many forms, such as sucrose
- Hence, a geiger counter can track the movement of the radioactive molecules



Growth in Plants



- growth is confined to regions called Meristems
- Meristems are composed of undifferentiated cells that are undergoing active cell division
- Primary / Apical Meristems are at the tips of roots and shoots that are responsible for root and shoot growth
- Secondary / Lateral Meristems are located along lengths of roots and stems and ~~the~~ cause an increase of girth.

	Apical Meristem	Lateral Meristem
Position	Tips of roots and stems	cambium, in vascular bundle
Products of growth	Produces initial tissues of actively growing plant	Forms secondary xylem and phloem
Outcome of growth	↑ length + height	Increases girth and length of stem

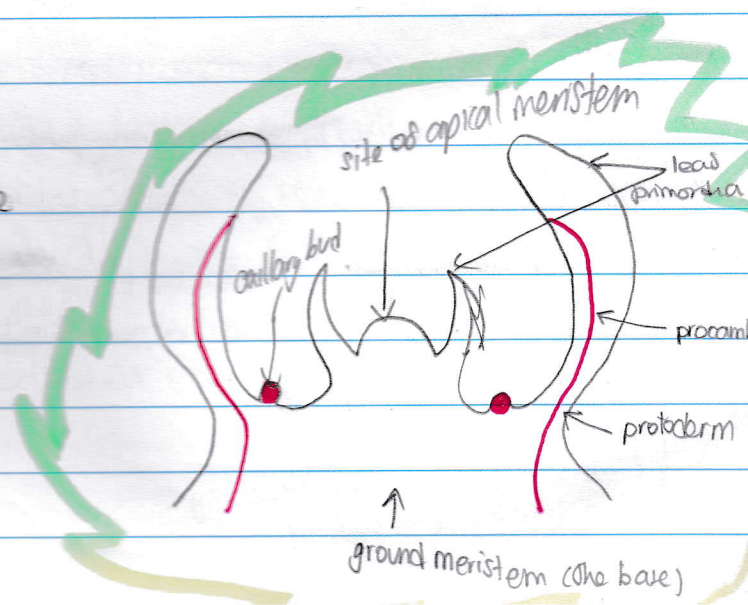
totipotent - can create new organism
 pluripotent - grow

Shoot Apical Meristem

- With each cell division, only one cell remains in the meristem
- The others differentiate into other groups of cells, like those that will develop into leaves and flowers, and increase in size due to their absorption of nutrients and water
- All the other cells move away from the meristem region.

Mini-Meristems (in Apical)

- protoderm gives rise to the epidermis
- procambium gives rise to vascular tissue
- ground meristem gives rise to pith



Plant hormones

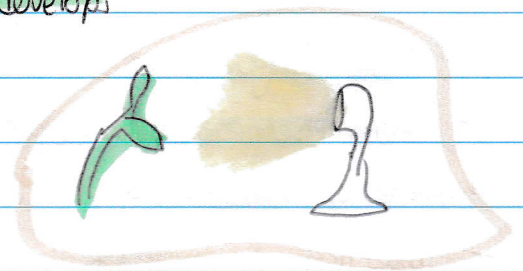
- a hormone is a chemical message that is produced and released in one part of an organism to have an effect in another part
- Auxins can initiate root growth, influence fruit development and regulating leaf development
- IAA (indole-3-acetic acid) is the most abundant auxin and it ~~produces~~ controls growth of the shoot
- At high concs, it can inhibit growth
- produced in apical meristem of shoot

Axillary buds

- shoots ~~can~~ form at the junction between the stem and the base of a leaf
- As the shoot apical meristem grows, other meristems are left at the node
- Axillary bud growth is inhibited by auxins produced by the shoot apical meristem [apical dominance]
- The further the node is from the shoot apical meristem (SAM), the lower the auxin conc, and the faster the growth of the axillary bud
- ~~Cytokinin~~ Cytokinins, hormones produced in the roots, promote axillary bud growth
- Ratio of cytokinins to auxins determine if the axillary bud develops

Tropism

- Directional responses to directional external stimuli
- Phototropism is growth towards light
- ~~Geotropism~~ Gravitropism is growth in response to gravitational force



How Auxin works

- Auxin changes the pattern of ^{gene} cell expression
- Light absorbed by phototropins in photoreceptors
- When phototropins absorb light of the right wavelength, their conformation changes
- They bind to receptors that control specific gene transcription → (DNA → RNA → proteins)
- The genes ^{transcribe} ~~activated code~~ for glycoproteins in plasma membranes to transport auxin from cell to cell
- The glycoproteins are called PIN3 proteins

Intracellular Pump

Phototropism

- Phototropins detect greater light intensity on one side of the shoot
- Auxin, by way of PIN3, is transported laterally from the side with brighter light to the shadier site.
- The higher auxin cones on the shadier side prompt cell elongation on that side, so the stem grows curving towards the light
- Hence, leaves get more light and photosynthesize at a faster rate.

Gravitropism

- when a root is on its side, statoliths accumulate on the lower side of every cell
- This leads to the distribution of PIN3 transporters that bring auxin to the bottom of cells
- The high cones of auxin inhibit root elongation, so the top of the root grows faster than the bottom, causing the root to bend downwards.

Micropropagation of plants

Root growth
→ grow species that are hard to germinate
→ Fast
→ propagate endangered species
→ no seasonal change

- an in vitro procedure that produces large numbers of identical plants.
- relies on totipotency of plants → ability to differentiate into any functional plant part
- tissues from plants are sterilized and cut into pieces called explants (sterilised using AgNO_3 , H_2O_2 , bleach)
- The least differentiated tissues (from meristem) serves as source tissue (callus)
- Explant placed into sterilized growth media including plant hormones + auxin + cytokinin
- If A:C ratio is less than 10:1, it is called shoot media and shoots develop
- If A:C ratio is more than 10:1, it is called rooting media and roots developed

Definitions

Meristem - regions of growth comprised of undifferentiated cells undergoing active cell division

Phototropism - directional response to light

Gravitropism - directional response to gravity

PIN3 - group of glycoproteins that transport auxin

Callus - a ring separating X and Y produces new X + Y

Auxin - plant hormone stimulating hypertrophy

Micro - cell division

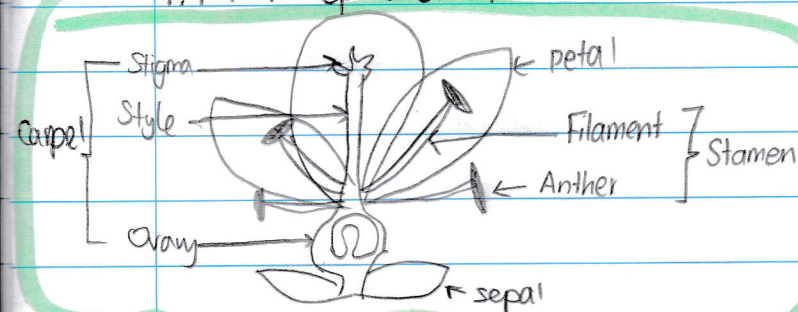
Apical growth - growth vertically

Lateral growth - horizontal growth

Undifferentiated cells

SEE 9.3 Booklet for advantages

9.4 Plant Reproduction



Filament: The structure that holds the Anther

Anther: Part of stamen that holds the pollen

Sepal: Serves as protection for the bud + support petals in bloom

Petal: attract pollinators and protect parts of the flower

Stigma: provides receptacle for pollen to land on and rehydrate before entering the style

Style: supports stigma and medium for pollen tubes to travel through

Ovary: contains female gametes (ovules)

Pollination

Def: The transfer of pollen from the anther of one plant to the stigma of the same or another plant

Adaptations

Insect Pollinated Plants - stamens enclosed within flowers, so insect can make contact, stigma also enclosed in flower. Stigma is sticky to catch pollen grains from insects. Large and colourful petals to attract insects

Nectar present to attract insects. Pollen is sticky to attach to insects

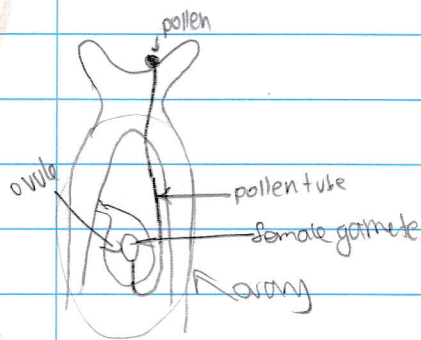
Wind Pollinated Plants - stamens and stigma exposed to catch and blow pollen. Feathery stigma to catch pollen blowing in the wind. Small, green (not brightly coloured) petals. No nectaries, small smooth pollen grains so wind can carry them

Mutualism between flowers and pollinators (transfer of pollen grains from anther to stigma)

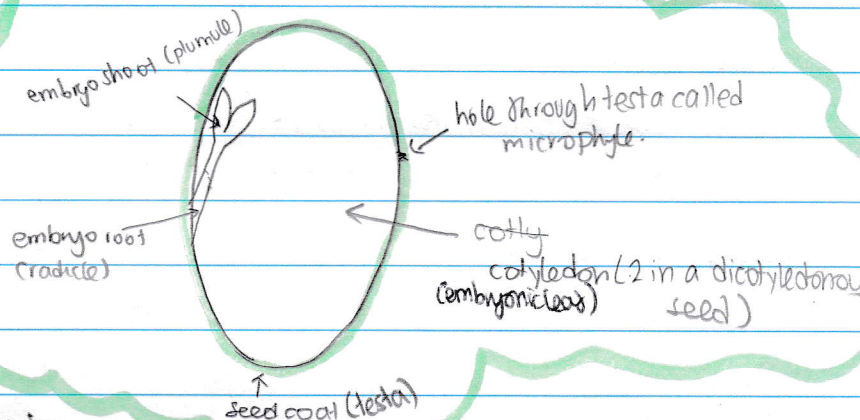
- a relationship between plant and pollinator through which both parties benefit
- Pollinators gain food in the form of nectar and the plant gains a way to transfer pollen to other plants.

Fertilisation

- from each pollen grain on the stigma, a pollen tube grows down the style to the ovary
- Male gametes are carried down to fertilise the ovule (tubes secrete enzymes that digest walls)
- The pollen tube enters the microphyle and the gametes eventually fuse, forming a zygote
- The fertilised ovule becomes a seed and the ovary becomes the fruit.



Seed Structure



Germination (process by which plant grows from a seed)

- aerobic cellular respiration begins after water enters through the microphyle (O_2 needed)
- synthesis of gibberellin begins (hormone that stimulates mitosis and production of amylase)
or transcription
- Amylase breaks down starch in food reserves into maltose maltose
- Other enzymes convert maltose into glucose, so it can be transported to other places in the germinating seed
- Plumule and radicle use the glucose for growth.

Seed Dispersal

- prevents competition between parent and juvenile plant
- by wind, water, animals (eating or hooking onto animal then falling off).

Factors affecting Germination

eg abscisic acid + ethylene

Water - must be present. Water washes out growth inhibiting hormones and aids in growth of plumule and radicle (needed for hydrolytic reaction for aerobic respiration), imbibition (swelling up of seed with water)

Temperature - must be suitable as germination relies mainly on enzyme catalysed metabolic reactions (must be optimal)

Oxygen - needed for aerobic respiration (that facilitates growth) by ATP production (cellular)

Flowering

- Vegetative state is before shoot meristems produce flowers instead of leaves
- Reproductive phase is when shoot meristems produce flowers instead of leaves
- Light plays a role in the production of activators or inhibitors of genes that control flowering

Photoperiods and flowering

- A photoperiod is the period of time each day over which an organism receives illumination
- Phytochrome is a pigment that plants use to measure the lengths of dark periods
- Long day plants flower in summer, when there are short nights
- Short day plants flower in winter, when there are long nights
- 2 types of phytochrome, P_{fr} and P_{fr} (far red)
- When P_r absorbs red light of wavelength 660 nm, it is converted into P_{fr}
- When P_{fr} absorbs far red light (more common at night) of λ 730 nm, it becomes P_r
- In darkness, P_{fr} slowly becomes P_r due to P_{fr} 's relative lack of stability.
- In long day plants, lots of P_{fr} remain at the end of nights and they bind to a receptor protein that promotes transcription of genes needed for flowering
- In short day plants, the receptor inhibits transcription of genes needed for flowering when P_{fr} binds to it. At the end of long nights, little P_{fr} remains so there is a lack of inhibition and the plant flowers.

Tracheids

ABA → hormone to close stomata, move K^+ out, remove water out.
boundary layer of air between stomata and outer area, blocks wind from blowing water away
Adaptations of xerophytes

Extra Stuff

Xerophytic adaptations

- 1) Rolled leaves - reduced exposure to abiotic condition
- 2) Spine Leaves - Lower S.A for transpiration
- 3) Deep roots - Access deeper water sources
- 4) Thickened waxy cuticle - reduce water loss through cuticle
- 5) Reduce no of stomata - reduce number of pores through which transpiration occurs
- 6) Stomata in pits surrounded by hair - moist air trapped outside stomata, ↑ humidity
- 7) Fleshy stems - water storage
- 8) Shallow roots - take advantage of sporadic rain or overnight condensation
- 9) CAM - Crassulacean Acid Metabolism → CO_2 absorbed at night and converted into malic acid, that releases CO_2 during the day. This allows photosynthesis to take place even with closed stomata

Halophytes

- Plants adapted to live in saline conditions

Adaptations

- 1) Salt glands - salt transported to leaf surface, where it is crystallised and is blown away. The salt is excreted from the leaf's surface
- 2) Salt avoidance - roots impervious to salt or salt can be pumped out of roots into soil
- 3) Salt storage vacuoles - they store salts
- 4) Sacrificial leaves - salt is concentrated in a leaf that dies, then drops from the plant
- 5) Vivipary - seeds germinate while still attached to the tree, allowing parent to provide water and other nutrients needed
- 6)

Stomata

• (ABA)

Opening - Abscissic acid concentration decreases hence potassium ions enter the guard cells, followed by water. ABA is made in the roots and is released when roots detect a lack of water in the soil. That happens w/ That results in the closing of the stomata.

NOTE: These are just my random scribbles, feel free to ignore them - they just have the same information as the preceding pages

Salt
 → sunken stomata → deep roots
 → succulent leaves
 → vivipary
 → salt avoidance
 → salt tolerance

collenchyma -

parenchyma - tissues for storage of food

sclerenchyma - tissues for support

- spiny leaves rolled leaf,
 ↓ no of stomata
 located in hairy pits
 thickened waxy cuticle
 the fleshy stem

Apical Meristems are totipotent (can create a full organism) and creates

primary vascular tissues (long and narrow)

Lateral Ms produce secondary vascular tissues (short

- CAM
 - deep roots - thin

Xerophytic Adaptations

Leaves → rolled (limit exposure to abiotic environment), spiny (↓ S.A for transpiration), ↓ number of stomata, stomata located in pits surrounded by hair (trap moisture ↑ humidity). Thickened cuticle

Stems → fleshy stems to store water

Roots → shallow (take advantage of overnight condensation) or deep (access deeper sources)

CAM → CO₂ absorbed at night and converted into malic acid, releases CO₂ during the day, photosyn can happen with stomata closed

Halophytic

- sacrificial leaves
- vivipary
- salt glands
- salt avoidance

Halophytes

- sunken stomata
- sacrificial leaves
- deep roots to gain water access
- salt glands
- salt avoidance

How water is used in Germination

Water [bursts testa by imbibation]
 [washes out growth inhibiting hormones]
 [hydrates cell] [allows for hydrolysis reactions]

O₂ → needed for aerobic cellular respiration
 produce ATP for plumule and radicle

T → suitable T for enzyme activity,
 T T breaks down inhibitors

Dolly

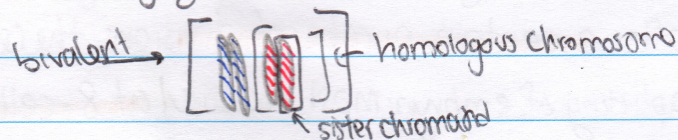
- method → somatic cell nuclear transfer
- ^{differentiated} Adult cells taken from the udder of a sheep and cultured in low [nutrients], inactivate genes, so differentiation pattern lost. The animal this was taken from will be cloned
- Unfertilised eggs taken from another sheep and one of them placed next to the cultured first cells, electrical pulse used to induce fusion. 10% zygote formation
- Embryos then injected into uteri of other sheep. One came to fruition, Dolly born.

10: Genetics and Evolution [AHL]

10.1: Meiosis

Chromosome Replication

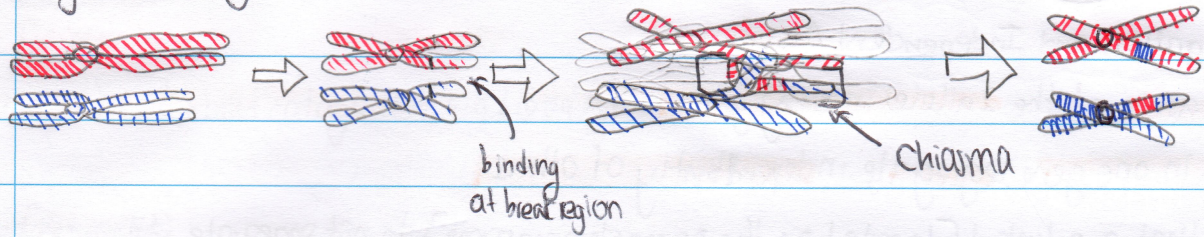
- chromosomes replicate in interphase [S], before meiosis.
- each chromosome is replicated such that it consists of 2 sister chromatids
- Next [still in interphase, when chromosomes are uncoiled], homologous chromosomes undergo synapsis, where they align next to each other
- The pair is called a bivalent → held together by protein based synaptonemal complex
- Diagram displaying the tetrad/bivalent structure



Crossing Over

- The exchange of genetic material between non-sister homologous chromatids
- In prophase I, breaks form in the DNA, and non-sister chromatids move in and bind to the region of the break, crossing over.
- This forms a cross shaped connection point called the chiasma [singular], which allow for the h. chromosomes to adhere to one another ^{at region of the break}
- Consequences -
 - ①: increased bivalent stability
 - ②: ↑ genetic variety by creating new combinations
 - ③: Can separate linked genes, allow for independent assortment

Diagrams showing chiasma formation



New Combinations of Alleles

- New allele combos produced in the haploid cell's chromosomes
- If we have linked genes, crossing over can unlink them, allowing for more allele combinations
- E.g: An individual with linked $AaBbDd$ can form aBD or abd or aBd or adb to show a few.

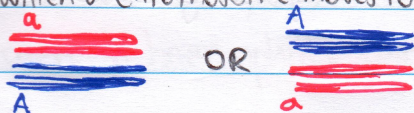
Meiosis I

- when homologous chromosomes separate
- sister chromatids remain associated via centromere connection
- Crossing over occurs in prophase I
- Reduction division: reduces number of chromosomes by half
- haploid cells with segregated homologous chromosomes produced in telophase I

Meiosis II

- non-sister chromatids separate here → not a reduction division as a result.

Random Orientation and Independent Assortment

- Independent Assortment of genes occurs because of random orientation of homologous chromosomes in metaphase I
- The pole to which a chromosome moves to varies with the orientation of the chromosome.
- E.g.  OR $\circ \circ$ & 2^n possibilities, n is haploid chromosome number
- Produce different types of gametes as an individual with $AaBb$ can form aB , ab , AB , Ab

10.2: Inheritance

Segregation and Independent Assortment

- separation of the 2 alleles in every gene
- alleles in one gene segregate independently of others
- Alleles that are linked (located on the same chromosome) do not segregate independently unless they are far apart. Crossing over more likely if their loci are far from each other, can unlike the genes.
- We assume all the alleles are unlinked in dihybrid crosses.

Dihybrid Crosses

- If $S \rightarrow$ dominant non-wrinkled, $Y \rightarrow$ dominant yellow, results when 2 heterozygous individuals are crossed are as follows.

	Sy	SY	sy	sY
Sy	$SySy$	$SYSy$	$SySy$	$SySY$
SY	$SYSy$	$SYSY$	$SySY$	$SYSY$
sy	$SySy$	$SySY$	$sySy$	$sySY$
sY	$SySY$	$SySY$	$sYsy$	$sYSY$

- Do practise questions on these

Morgan and Sex Linkage

- Morgan found non-mendelian ratios in fruit flies
- F_1 were all red eyed except for 3 flies, F_2 had more white flies, all of which were male.
- Using Mendel's principles, he expected a 3 to one ratio, irrespective of gender
- Factor for eye colour found exclusively on X, hence it explains why these traits did not assort independently
- Sex linkages $\rightarrow$ when alleles are located on X chromosome (groups of genes located on the X chromosome)

Linked Genes

- genes are linked if they are found on the same chromosome
- Can be autosomal or sex linkage

Note: Recombination is the formation of DNA or chromosomes with a new combination of alleles

Variation

Discrete

- if we have distinct categories, e.g. blood types

Continuous

- Where we have a range of potential categories
- The phenotype of polygenic [a large number of genes coding] characteristics are an example of this mostly codominance
- More unlinked genes and co-dominant alleles involved, ∴ more phenotypes.
- Can be approximated to the normal distribution by Central Limit Theorem
- This approximation is proof that more than 1 gene involved

Environmental Factors and Polygenic traits

- Note that polygenic characteristics are continuous in terms of variation because of subtle differences in phenotypes
- Skin colour → sunlight stimulates melanin production, darkening the skin, which is also a polygenic trait

Chi-Squared

- find E by doing Punnett square
- $$\chi^2 = \sum \frac{(O - E)^2}{E}$$
- Write H_0 and H_a , α , Critical Region and Conclusion
- Degrees of freedom is Number of possible phenotypes - 1.

Tips for doing Questions

Sex Linkage → gene on X, varied inheritance between male + female, one X v 2X, females can be carriers, e.g. haemophilia, Red Green colour blindness, Y mutation/diseases, only males

If asked to predict dihybrid autosomal → do the $SsYy$ and $SsYy$ mix for 9:3:3:1 ratio

10.3: Gene Pools and Speciation

Gene pools and Allele frequency

- A gene pool consists of all genes and their different alleles within an interbreeding population
- Can have multiple gene pools for same species if two populations are reproductively isolated
- Genetic equilibrium exists when all members of a population have an equal chance of contributing to the future gene pool.
- Evolution requires a change in allele frequency over time in a population
- Selection pressure will favour the reproduction of individuals with certain alleles over others, allowing for a cumulative change in the heritable characteristics of a species (Evolution)
- A random change (e.g. mutation) can have a significant effect on allele frequency if n is small
- Read mechanism for Natural Selection

Selection

How Allele Frequency can change

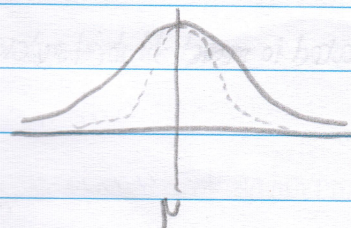
- 1) Mutation → random and permanent change to gene base sequence, producing new alleles, shifting allele frequencies
- 2) Gene Flow → movement of individuals and the genetic material they carry from one population to another, altering the gene pool and allele frequency
- 3) Gene drift → change in the composition of the gene pool as a result of random effects, if it occurs in smaller populations → more significant and faster effect. Larger populations are more stable, more stable allele frequencies
- 4) Selection - Natural Selection, disruptive, directional + stabilising

Selection

NS → change in the composition of a gene pool in relation to a differentially significant environmental

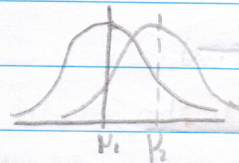
1) Stabilising

- An intermediate phenotype is favoured, resulting in the removal of extreme phenotypes
- This shifts reduces the σ of the normal distribution
- E.g. Human Birth Weight → low weight babies susceptible to more disease, ↑ mortality, ↓ frequency of low weight



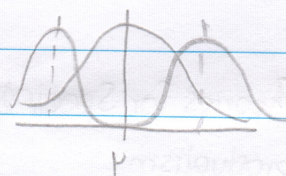
2) Directional

- where one ^{extreme} phenotype is more favoured than the others
- Shifts distribution to change μ
- Operates to gradual or ~~sharp~~ sustained changes in conditions
- E.g. Medium ground finch, in the dry season, less small seeds, only large seeds, hence finches' with larger beaks survived



3) Disruptive

- Both phenotype extremes favoured as opposed to the intermediate
- Results in bimodal spread
- Continued split of the 2 phenotypes potentially leads to speciation
- E.g. ~~black and white~~ ^{peppered} moths. Because of pollution, polluted areas favour black, non polluted favour ~~white~~ peppered (melanism)



Speciation

- formation of a new species by the splitting of a population
- Reproductive isolation: when barriers prevent 2 populations from interbreeding (separate gene pools)
- Allopatric Speciation [geographical isolation] → remember, selection pressures act differently on 2 populations of the same species
- speciation that occurs because of geographical isolation
- E.g. cichlids of East Africa, water levels rise, resulting in the duplication of population, where selection pressures have different effects → ∴ speciation occurs, cannot interbreed (pre-zygotic)
- ~~Post-zygotic~~

Sympatric Speciation

- isolation of gene pools within the same geographical area

Temporal

- different time periods for hibernation + fertilisation / mating result in a mechanical inability to interbreed
- E.g. flowering plants → ^{certain} orchids flower for a single day, another flower may only produce pollen at a certain temperature. When flowers of 1 species open, the other does not produce pollen ∴ isolated

Behavioral

Behavioural

- Difference in courtship behaviour, inability to attract variants of the species

Skill: Comparing allele frequencies between population

- Pan I is a gene coding for an integral membrane protein called pantophysin
- Pan I^A and Pan I^B available, differ by 4 amino acids
- Because of geographical isolation
- Distributed because of different allele frequencies [Discuss the 4 factors]

Theories for Speciation

1) Gradualism

- slow pace of evolutionary change
- predicted that evolution occurred by a long sequence of continuous intermediates [Chorose fossils] ↖ transitional fossil
- explained gaps in fossil records were imperfections

2) Punctuated Equilibrium

- states that species remain stable for periods of time but this stability is punctuated by rapid changes
- supported by the lack of intermediates in the fossil record → could be explained by specific fossilisation conditions too
- Rapid changes are very common for species with short lifespans, consider prokaryotes and unicellular eukaryotes.
- stronger evidence than for gradualism

Ploidy

- a condition in which an organism has 2 or more sets of chromosomes
- Allopolyploidy → polyploid offspring from 2 different parent species
- offspring produced sterile because the different species have different chromosome numbers ∴ uneven chromosome pairing

- speciation has occurred in allium as a result
- Many species reproduce asexually, allowing for their polyploidy nature to be an advantage
- polyploidy is sympatric ~~self~~ isolation, that results in >2 sets of homologous chromosomes, if asexual reproduction, a new species to form → ~~interbreed~~ potentially interbreed to produce fertile offspring

Antibody Production and Vaccination



Antigens

- a chemical that stimulates a specific immune response
- generally, foreign molecules that trigger immune responses
- Mostly proteins or very large polysaccharides
- e.g. influenza has hemagglutinin and neuraminidase as antigens on its surface
- We have our own antigens
- Antigens recognised as foreign (i.e. not on our cells) are responsible for triggering an immune response, so it is not a "self" marker (MHC)
- In the **BLOOD**, RBCs have distinctive antigens which limit the capacity for transfusions
- Mismatch can lead to immune response
- A → N-acetyl galactosamine added to basic antigen sequence H → forms antigen A
- B → galactose added to antigen H → forms antigen B
- AB → both added → both antigen A and B present
- ⁺present because of the Rhos factor, an additional glycoprotein, Absence = -ve

<u>A</u>	<u>B</u>	<u>AB</u> (too used to vectors)	<u>O</u>
→ antigen A	→ antigen B	→ antigen A and B	→ new antigen H only
→ anti-B antibodies	→ anti-A antibodies	→ no antibodies	→ anti A + anti B
→ cannot take A or B	→ cannot take A or B	→ can receive from all, <u>universal recipient</u>	→ cannot receive from A, B or AB
→ can have O or A	→ can have O or B		→ only get from O
			→ <u>universal donor</u>

- If wrong blood type transfused, agglutination occurs because of the antibodies, leading to haemolysis, destroying RBC and causing coagulation in vessels

Specific Immune Responses

- the antigen acts as the "challenge," and initiates a "response" from the body by lymphocytes
- Firstly, macrophages (large phagocytes) ingest pathogens and display the pathogen's antigens on the plasma membrane. These ones that display the pathogen's antigens are dendritic cells.
- Specific Helper-T lymphocytes bind to the antigens, because they have antibody-like receptors that bind to the antigens in the dendritic cell.

- receptor-antigen specificity
- activates the Helper-T cell (T_H), releases cytokines that ~~bind to~~ act as a signalling protein, ~~act~~ stimulating a specific B-lymphocyte that produces antibodies to divide and form clones [clonal selection]
- Otherwise, antigens on the T_H receptor binds to a receptor on a B-lymphocyte activating it.

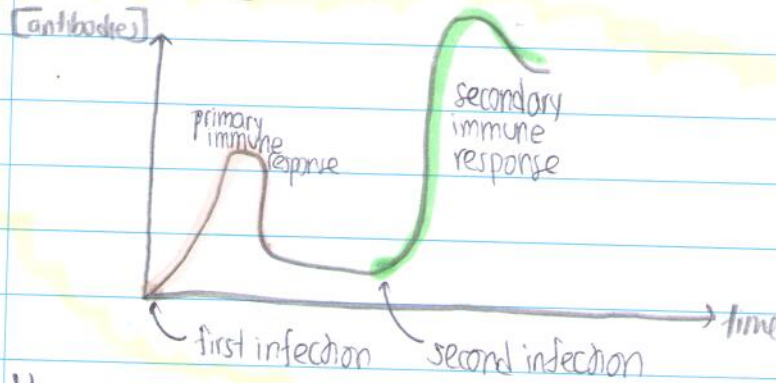
Clonal Selection and Plasma Cells

- The activated B cells divide by mitosis repeatedly following cytokine signalling
- form genetically identical clones
- Most develop into plasma cells, mature B-lymphocytes that produce and secrete a large number of antibodies during an immune response + transport
- have extensive network of r. ERs, to enable greater synthesis of protein based antibodies per unit time
- Lot of same protein produced, hence lower number of genes expressed in plasma cells.
- Clonal Selection: the generation of a large number of plasma cells that produce a specific antibody type
- antibodies help to destroy pathogen but only persist for a few weeks or months
- Plasma cells gradually lost
- It is likely to have polyclonal selection - both T and B lymphocytes, of different types, activated because of multiple antigens presents on pathogen.

Immunity

- depends upon the persistence of memory cells
- either due to presence of antibodies that can bind to the antigen or memory cells.
- Immunity develops when the immune system is challenged by a specific antigen and produces antibodies and memory cells in response
- Small proportion of activated B lymphocytes form memory cells
- long living → produce low levels of circulating antibodies
- Same infection: more vigorous response by memory cells, greater antibody

- faster production begets limited pathogen reproduction
- limited reproduction → smaller numbers → does not ^{cause} ~~show~~ symptoms of the disease
- hence as pathogen exposure does not cause the disease to occur, immune



Vaccines

- contain antigens that trigger immunity but do not cause the disease.
- weak (attenuated) version of the pathogen or a derivative that has the same antigens
- Stimulates a ^{primary} immune response that results in the development of memory cells by monoclonal selection
- Hence, when the actual disease-causing pathogen strikes, a secondary immune response is initiated, as explained earlier, lower number of cells do not cause disease symptoms
- done for Tuberculosis
- Booster shots maintain immunity

Case Study: Smallpox

- example of internationalism → worked together under WHO
- officially eradicated 1980
- no animal vectors, only humans catch + transmit
- Fast emergence of symptoms
- Long lasting immunity

Vaccines and Epidemiology

- study of statistics of a disease
- monitor spread to minimise danger of outbreaks
- plan and evaluate vaccination plans
- Epidemiologists investigate distribution + identify reasons and do stuff
- can determine effectiveness of campaign, determine origins

Antibodies

- 1) Opsonization → make pathogen more recognisable by coating antigen with some of the antibody. Enhances phagocytosis
- 2) Agglutination → cause sticking together, prevent entry into cells, easier for phagocytes to ingest, easily filtered by lymphatic system and phagocytised. Occur in incorrect blood transfusions
- 3) Neutralising the viruses/bacteria - prevent ~~bacteria~~ viruses from docking to host cells
- 4) Neutralising secreted toxins → bind to toxins, prevent them from affecting susceptible
- 5) Activation of complement → complement system is a collection of proteins that lead to membrane perforation in membranes of pathogens. Antibodies bind to receptors on the pathogen membrane, activating a complement cascade that forms a membrane attack complex. This forms pores in the membrane, allowing for the entry of water or ions, causing the cell to lyse (death by bursting)

Zoonosis

- a pathogen which can cross a species barrier
- some pathogens are specific to humans → smallpox, polio, measles
- ~~Variants~~ Variants with pathogen's ability to survive in different internal environments
- Examples of zoonoses include bubonic plague ^(rats), bird flu and Lyme disease ^(ticks)

Histamines

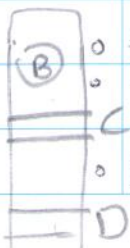
- released by leucocytes in response to allergens
- Mast cells in connective tissue secrete histamines, as do basophils
- dilation of small blood vessels in infected area to ~~make them~~ increase permeability to tissue fluid and lymph fluid
- Increases flow of fluid with the immune components to the infected side and allows some to leave the blood.
- cause allergic symptoms → cells have several different ~~histo~~ membrane bound histamine receptors.
- causes itching, sneezing, mucus secretion, inflammation
- can cause anaphylaxis (swelling that is severe)

Hybridoma Cells and Monoclonal antibodies

- fusion of a tumour cell with ~~a plasma~~ an antibody producing plasma cell produces a hybridoma cell
- antigen specific to a disease or cell injected into a mouse
- initiates immune response, plasma cells extracted (provided they produce the correct antibody)
- removed from spleen
- fused with myeloma cells
- These cells produce monoclonal antibodies: highly specific, purified antibodies that are produced by a clone of cells.
- The desired hybridoma cell is allowed to divide and form a clone
- cultured in fermenter to produce a large number of genetically identical cells
- each secretes the antibody produced by the original ~~type~~ B lymphocyte
- used in treatment and diagnosis: test for malaria, HIV or to treat rabies

Pregnancy Tests

- use monoclonal antibodies that respond to ^{an} antigen on human chorionic gonadotrophin (HCG)
- uniquely produced during pregnancy, present in urine
- free dye stained monoclonal antibodies at B, moved down by urine flow + bind to HCG
- The ~~two~~ antibodies bound to HCG bind to antibodies (HCG) that are immobilised at C
- D simply contains antibodies that ~~can~~ bind to dye holding antibodies



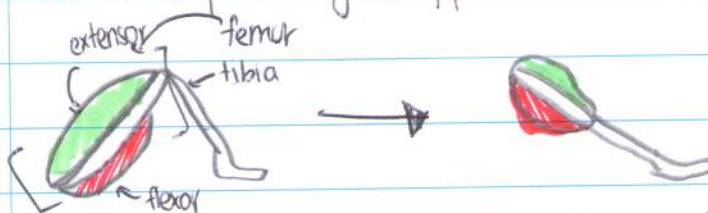
882: Movement

Bones and exoskeletons

- exoskeletons are external skeletons that surround and protect the body surface of an organism
- bones and exoskeletons facilitate movement by acting as anchoring points for muscles and acting as levers
- bones are connected to bones by the ligaments and to muscles by tendons

Antagonistic Muscles

- movement requires muscles to work in opposite directions
- single muscle = single direction
- antagonistic pairs can produce opposite movement at a joint
- e.g. biceps curl forearm and triceps extend forearm
- Take the example of a grasshopper

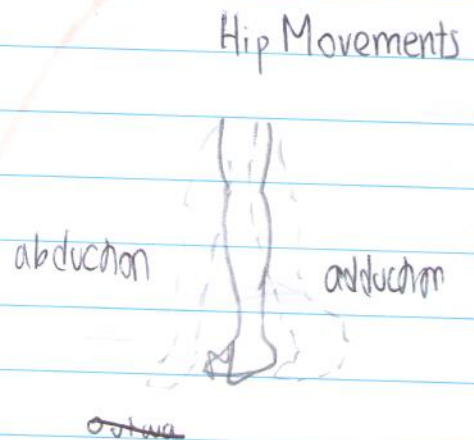
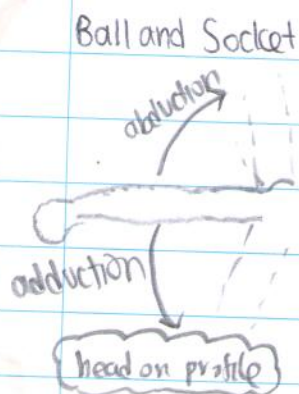


- First, the flexor muscle contracts, pulling the tibia inwards towards the femur. This is flexing [extensor relaxes]
- This buildup of potential energy is exploited when the ^{flexor} ~~extensor~~ muscles relax [extensor contracts] extending the tibia and producing a propelling force

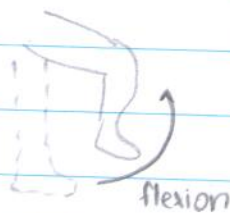
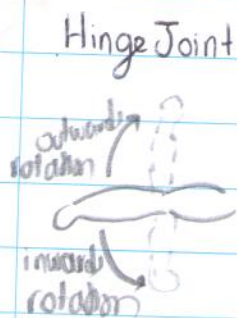
Joints

- point where bones meet
- allows bones to move in relation to one another [articulation]
- structure determines possible movement
- ~~the~~ Hinge joints, ball and sockets
- Hinge allows flexion (bending) or extension (straightening) e.g. knee

- hyperextension extension
- Ball and socket can ~~under~~ facilitate flexion ~~extension~~, adduction and abduction.



Outwards and inwards rotation of knee

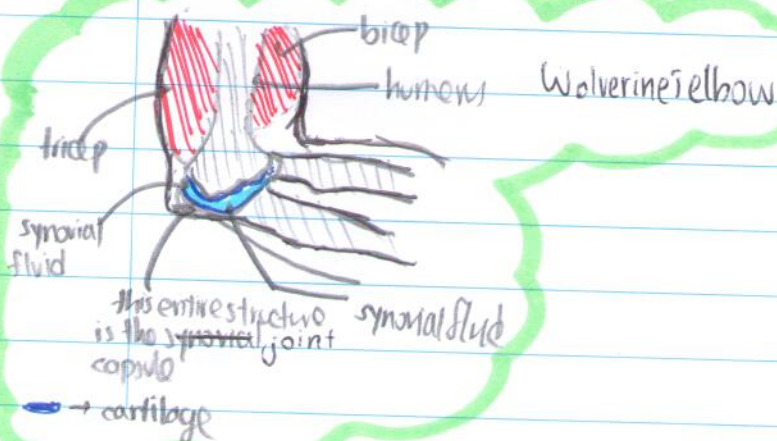


* adduction brings you closer to body

Muscle fibres

Synovial joint

- an example is the hinge joint in the elbow
- capable ~~more~~ of unidirectional angular movement
- ~~excess~~ multi-axial movement may cause damage



Humerus - anchors triceps and biceps

Radius - anchors bicep

Ulna - anchors tricep

Tricep - extension

Bicep - flexion

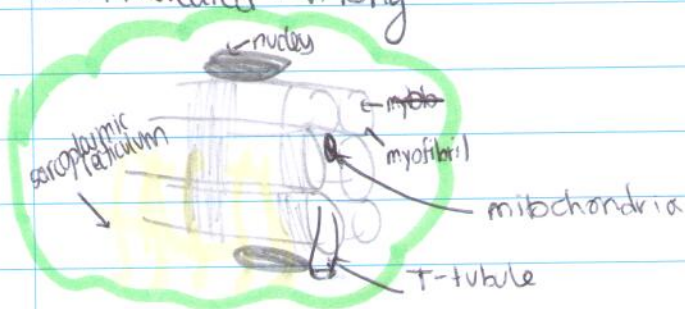
Synovial fluid - lubrication + provides nutrients + O₂ to cartilage

Cartilage → reduces friction, absorbs shock, covers bones

Joint capsule → seals joint space + limits range of motion → ↑ stability

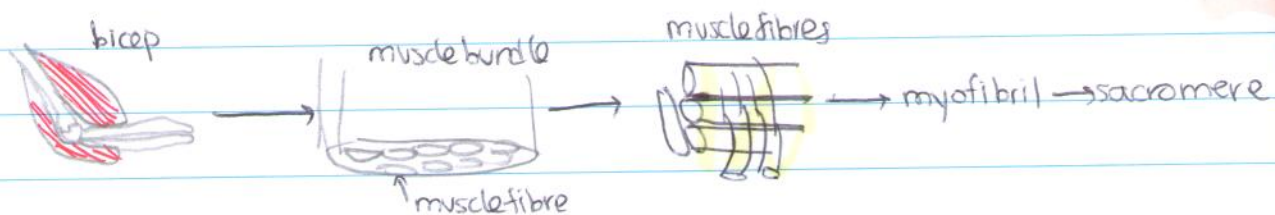
Muscle Fibres

- muscles involved in movement are dubbed striated muscle due to the presence of bands when viewed under a microscope
- Striated muscle has bundles of muscle cells called muscle fibres
- embryonic muscle cells fuse together to form muscle fibres
- a single plasma membrane called a sarcolemma is present, has invaginations called T-tubules
- multinucleated + v. long



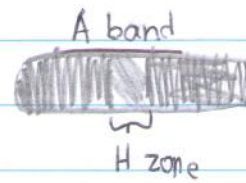
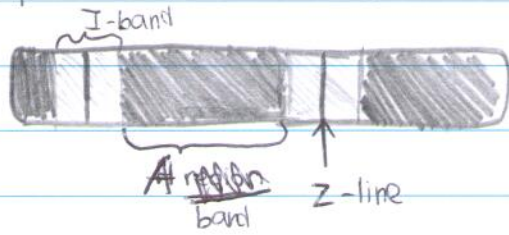
- the sarcoplasmic reticulum wraps around every myofibril to and conveys the signal to contract to all parts of the muscle fibres at once.
- between myofibrils are mitochondria, which provide the large amounts of ATP needed for muscle contraction

Breakdown of Muscle Structure



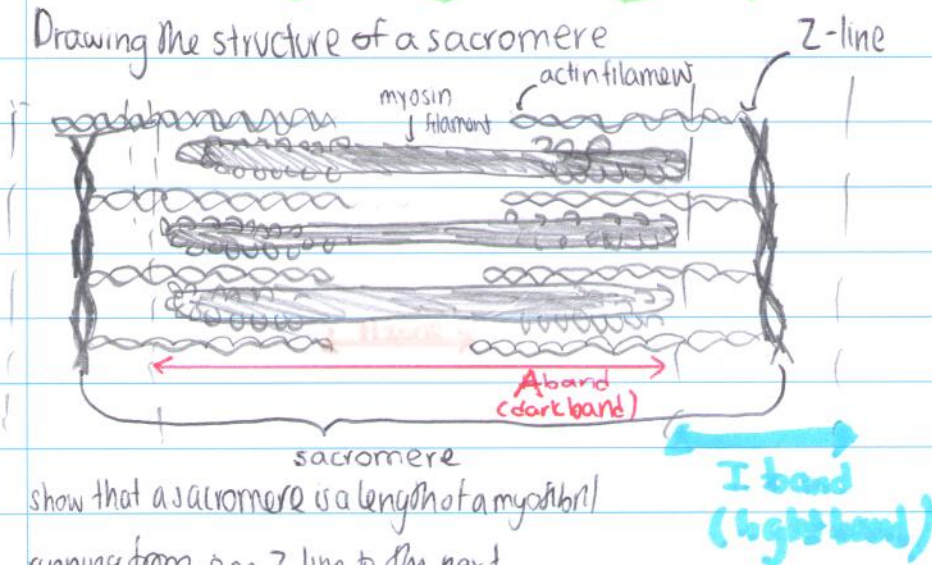
- skeletal muscles consist of tightly packed muscular bundles, surrounded by connective tissue
- Each bundle is comprised of muscle fibres
- Each muscle fibres have tubular myofibrils that run the length of the fibre + cause contraction
- Myofibrils have repeating contractile units called sarcomeres

Myofibrils and Sacromeres



- The part of a myofibril between 2 Z-lines is a sarcomere, the functional unit of the myofibril
- Made of thick myosin and thin actin filaments
- Actin filaments attached to a Z line at one end
- myosin occupies centre and are interdigitated with actin filaments at both ends
- actin filaments radiate out of the Z line and anchor the myosins in place

Drawing the structure of a sarcomere



- show that a sarcomere is a length of a myofibril running from one Z line to the next
- show banding
- Draw heads on myosin

General Mechanism of Skeletal Muscle Contraction

- achieved by sliding of actin and myosin filaments
- actin pulled towards the centre of the sarcomere, shortening each sarcomere and shortening muscle fibres, resulting in contraction
- heads on myosin filaments enable cross bridge formation with actin to exert a power stroke
- many heads + binding sites, many cross bridges formed per unit time.



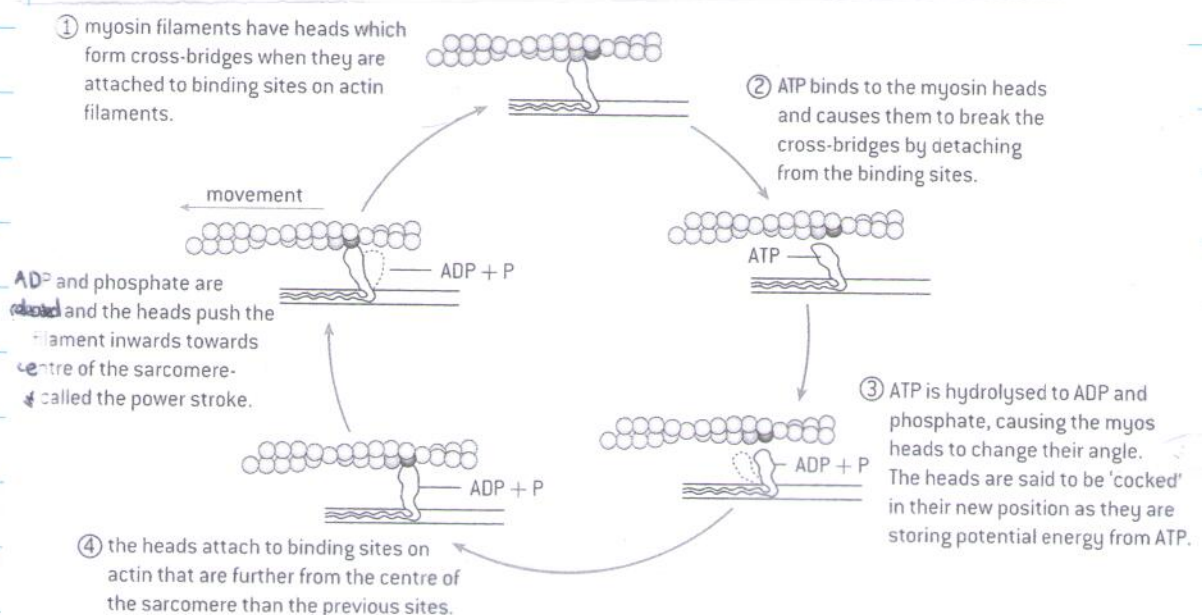
- same length of A band
- I band decreases due to actin movement
- Z moved in as it is connected to actin filaments
- shorter sarcomere

Muscle Contraction

- initiated + controlled by tropomyosin, troponin and Ca^{2+}
- When a nerve impulse reaches the effector, the sarcoplasmic reticulum releases Ca^{2+} and bind to troponin and cause tropomyosin, a regulatory protein that covers the ~~actin~~ binding sites on actin, to move. The movement of Ca^{2+} occurs because of depolarisation
- Myosin heads then bind to the binding sites on the actin filaments,
- ATP binds to the myosin heads, breaking the crossbridges by facilitating detachment from actin filament binding sites
- ATP is ~~then~~ then hydrolysed to $\text{ADP} + \text{PO}_4^{3-}$. The energy from this exergonic reaction used for the "cocking" of the myosin heads, they swivel out away from the center of the sarcomere, adjacent now to an actin binding site one further from the centre of sarcomere
- ~~Energy stored by~~ Myosin heads form crossbridges with the new actin binding sites
- Energy stored in "cocked" form used in a power stroke, swivelling the myosin heads towards the centre of the sarcomere
- This ^{slides} ~~pushes~~ the actin filament closer to the centre of the sarcomere
- continues until nerve impulses stop; when Ca^{2+} no longer releases, no crossbridges, normal state restored

See textbook for on flow

Diagram



11.3: The Kidneys and Osmoregulation

Osmoregulators

RECALL → osmolarity is the concentration of all osmotically active solutes

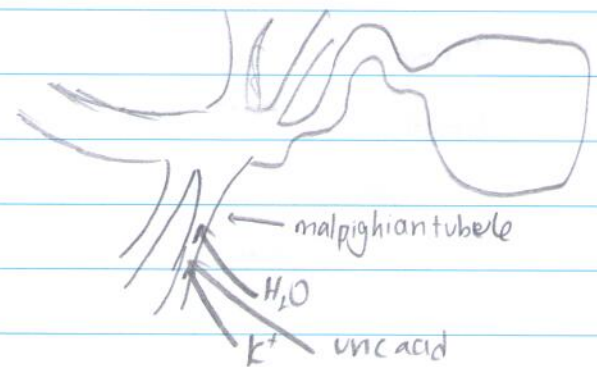
- organisms that maintain a constant internal solute concentration irrespective of their environment's osmolarity
- all terrestrial organisms and freshwater organisms

Osmoconformers

- organisms whose internal osmolarity tends to be the same as that of their surroundings.

Malpighian Tubule System

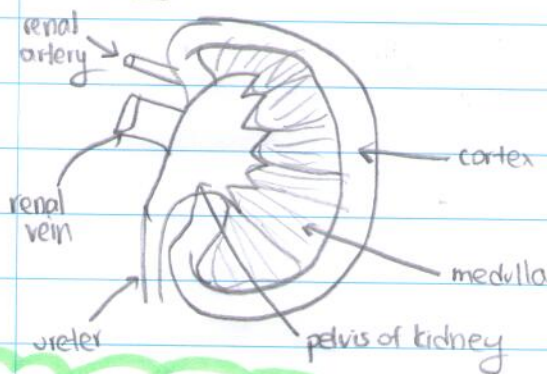
- found in insects
- tubules that branch off from intestinal tract
- Cells in the tubule walls actively transport ions and uric acid from the haemolymph into the lumen of the tubules
- This draws water by osmosis into the tubules, increasing hydrostatic pressure, enabling the contents to flow to the gut
- in the hindgut, most water and salts are reabsorbed
- nitrogenous waste excreted with faeces



Forms of Nitrogenous Waste

- correlated with evolutionary history and habitat
- ammonia initially produced, toxic + can shift pH
- only certain marine animals release NH_3
- Terrestrial animals convert it to less toxic urea (mammals) or uric acid (birds + insects)
- E needed for $NH_3 \rightarrow CO(NH_2)_2 \rightarrow$ uric acid
- Uric acid not water soluble, no need to release with water, save weight for birds, easier to fly (save E)
- Crystallises as it builds up in embryos, does not dissolve, hence low $[]$, limited toxicity.

The kidneys



note the following

- concave shape needed
- medulla fibres needed
- renal vein width and size > renal artery
- pelvis drains into ureter

Differences between blood in the renal artery and renal vein

Present in higher [] in artery

- Toxic substances ingested and absorbed but not fully metabolised, e.g. drugs
- Nitrogenous waste, mainly $\text{CO(NH}_2)_2$
- Higher water, excess produced by cell respiration or taken in
- Higher salt → excess in diet

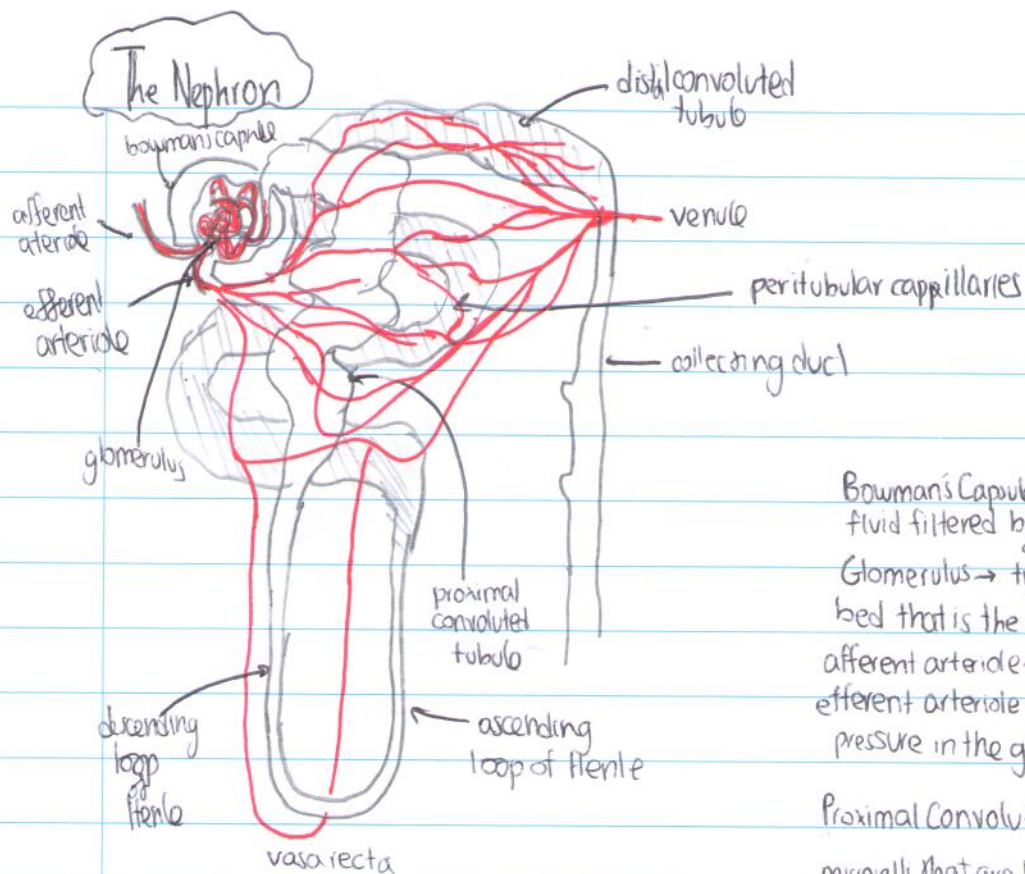
} excretory product

Others

- higher $[\text{O}_2]$ in artery than vein, used in kidney metabolism, e.g. ATP for active transport in a loop of Henle or in the glomerulus
- Higher CO_2 partial pressure → excretory waste product from respiration
- Lower $\text{C}_6\text{H}_{12}\text{O}_6$ → used in respiration (relative to artery)

Similarities

- Same concentration of plasma proteins



Bowman's Capsule → highly porous inner wall that collects fluid filtered by the glomerulus

Glomerulus → tight knot high pressure capillary bed that is the site of filtration

afferent arteriole → carries blood from renal artery

efferent arteriole → narrow, restrict flow, gen high pressure in the glomerulus

Proximal Convoluted Tubule → many mitochondria + microvilli that are long

Loop of Henle → goes deep into medulla

Distal convoluted tubule → fewer mito and fewer microvilli (that are of smaller length)

Peritubular capillaries → low pressure capillary bed that runs along c. tubules to absorb fluid

Vasa recta → carries blood deep into medulla

Collecting Duct → carry fluid to ureter

The Glomerulus

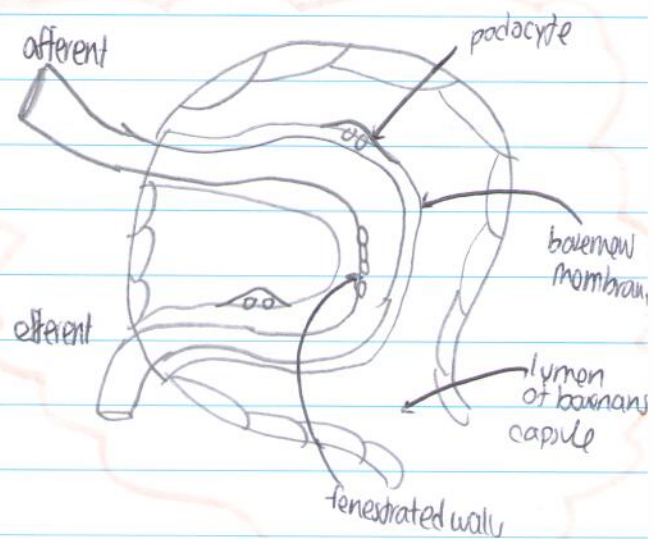
- high pressure + v. permeable capillary walls
- 100x volume fluid filtered than other tissues

- Separates particles differing by size by only a few nanometers - ultrafiltration

- no ~~charged~~ or large particles e.g. plasma proteins can pass through

- Composed of 3 major parts

- 1) Fenestrations: gaps in cells in capillary walls, increase permeability, allow fluid (but not RBC) escape
 - 2) Basement Membranes → covers and supports bed of capillaries. Made of negatively charged glycoproteins. Prevent entry of large plasma proteins, especially charged ones
 - 3) Podocytes: cells that have finger like projections which wrap around capillaries and have branches called foot processes. Prevent small molecules from being filtered out.
- If stuff passes through, it becomes part of the glomerular filtrate



The Proximal Convoluted Tubule

- selectively reabsorbs using active transport
- all glucose + a. acids + ~~sodium and minerals~~
- 80% of H_2O , Na^+ and other mineral ions
- ① Na^+ → active transport pumped out from filtrate into space outside the tubule, then pass to peritubular capillaries
- ② Cl^- or anions → attracted to Na^+ in the area outside tubule
- ③ Glucose + a. acids → Na^+ from outside tubule move down their concentration gradient from outside tubule into fluid, releases energy, which is used by a cotransport protein to ~~transport~~ reabsorb $C_6H_{12}O_6$ and amino acids [symport]
- ④ Water - high solute [] outside the tubule results in osmosis, allowing water reabsorption

Loop of Henle

- maintains hypertonic conditions in the medulla
- energy comes from ascending cells
- active transport → Na^+ pumped out of filtrate into fluid between cells in the medulla - interstitial fluid
- wall of the ascending LoH is impermeable to water, water retained in filtrate
- ∴ interstitial fluid hypertonic relative to the fluid
- walls of descending permeable to water but impermeable to Na^+
- The hypertonic nature of the medulla steepens the water potential gradient between the ~~medulla~~ ^{interstitial fluid} and fluid in the descending LoH, causes water to be ~~quick~~ drawn out of the filtrate and eventually, solute concs in both would equalise
- However, continued a.t of Na^+ into interstitial in ascending causes constantly rising (until a plateau) osmolality in the interstitial fluid
- countercurrent multiplier system → countercurrent because of the flow of fluids in opposite directions, multiplier because steeper gradients than standard ~~current~~ countercurrent system
- Peritubular vasa recta - prevent transport into interstitial tissue but allow reabsorption of H_2O and some Na^+
- Longer loops of Henle in animals in water deficient environments → greater opp for water reabsorption → deeper into medulla, which must become thicker

Note: osmoregulation is the control of the water and solute balance at appropriate levels

ADH (antidiuretic hormone)

- ~~norma~~ controls reabsorption of water in the collecting duct
- usually, distal CT and the collecting duct have low permeability to water
- $\therefore$ as it is already hypotonic, large volume of urine produced
- If solute conc of blood is too high, hypothalamus ~~detects~~ detects it and signals the pituitary gland to produce ADH, which increases permeability of DCT and collecting duct to water
- more water from filtrate is absorbed $\rightarrow$ hence high [] urine produced, [solute] in blood $\downarrow$
- part of osmoregulation

Dehydration and Hydration

- loss of water from body such that body fluids become hypertonic
- ~~is~~ caused by diarrhoea, insufficient water or exercise
- causes RBCs to become crenated
- darkened urine [more conc]
- lethargic, lower b.p, higher pulse
- Inability to sweat $\therefore$ cannot regulate body T

Overhydration

- ~~over intake~~ consumption - hypotonicity
- swelling of cells
- nerve function disruption and headaches

Dialysis (haemodialysis) and Kidney Transplants

- failure by chronic HBP or diabetes
- pass blood over semipermeable dialysis membrane, allowing waste to exit, several hours exit but preventing loss of RBCs or proteins
- Transplant involves replacement from living or ~~N~~ non living

D

vs

Kidney T

Pros $\rightarrow$ limited complications

Cons $\rightarrow$ infection, $\downarrow$ mobility

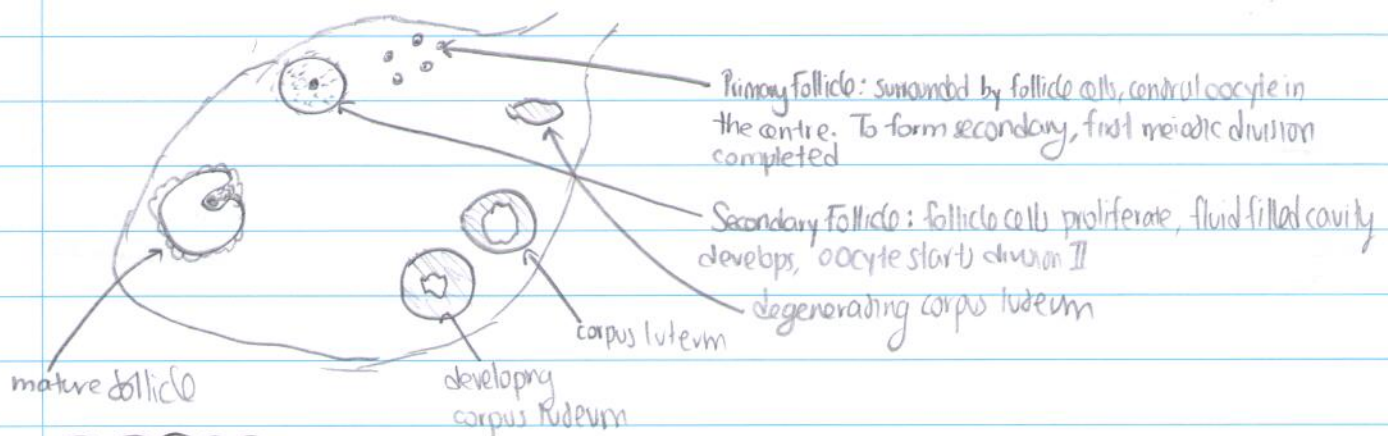
Pros $\rightarrow$ ~~limited~~ mobility
greater independence

Cons $\rightarrow$ possible rejection

11.4: Sexual Reproduction

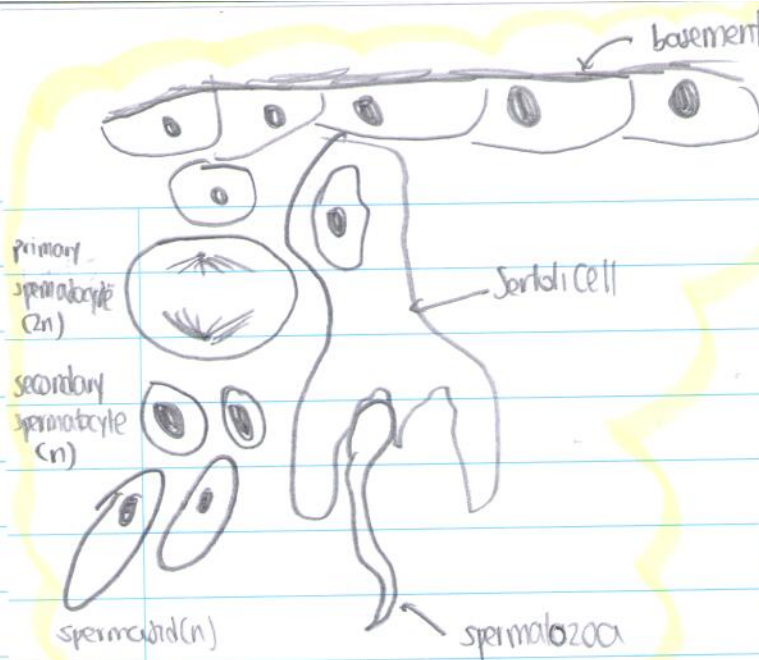
Oogenesis

- production of egg cells in the ovaries
- starts in the ovaries of female fetuses
- Germ cells in the fetal ovary distribute themselves across the cortex of the ovary
- At the 4/5 month mark, these cells begin to divide by mitosis
- 7th month - still first ^{division} stage of mitosis, and a layer of cells (follicle cells) form around them
- Nothing further until start of puberty
- The cell that has started dividing by meiosis, and its surrounding follicle cells are a primary follicle
- $\approx 400,000$ primary follicles
- At the start of each cycle, ~~each~~ p follicles stimulated to develop into a mature follicle
- The first meiotic division produces one large cell and one small cell, the small cell is the ^{second} first polar body and eventually degenerates. Cell 2 goes on to the second stage of meiosis
- One egg/ovum per cycle produced
- a few hundred female gametes produced across lifespan.



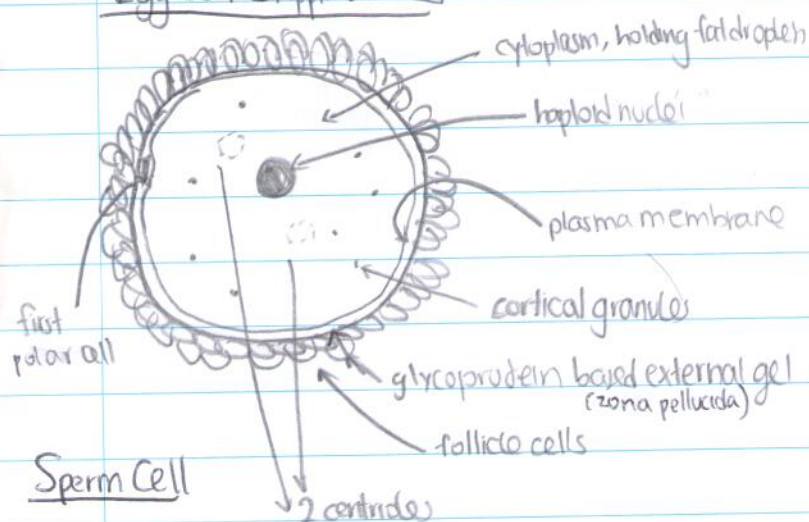
Spermatogenesis

- production of sperm
- testes are comprised of a mass of narrow tubes called ~~seminiferous~~ seminiferous tubules
- Small groups fill up gaps between tubules (interstitial spaces), called Leydig cells
- Outer tube layer called germinal epithelium

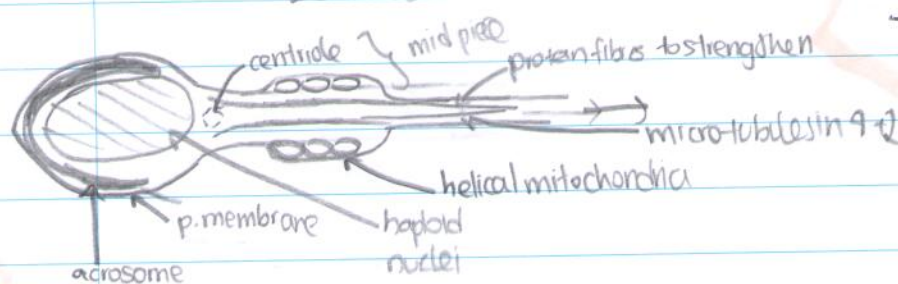


- ① Germinal epithelial cells divide to produce diploid
- ② The larger diploid cells are primary spermatocytes
- ③ Each p. spermatocyte undergoes Meiosis to form 4 haploid s. spermatocytes (n)
- ④ Each s. spermatocyte carries out DII to produce spermatozoa (n)
- ⑤ Spermatozoa become associated with Sertoli cells (nurse cells) that help encourage differentiation into spermatozoa
- ⑥ Sperm detach from Sertoli cells and are carried out from testes via fluid in the centre of the seminiferous tubule.

Egg Cell [Application]



Sperm Cell



Similarities

- mitotic cell proliferation before meiosis
- meiosis, diploid → haploid
- stimulated by

Preventing polyspermy

- Fertilisation is the fusion union of sperm and egg to form a zygote
- sperm membranes have receptors that detect chemicals released by the egg
- Chemotaxis occurs, move towards by directional swimming
- cortical vesicles' contents released by exocytosis, digest membrane proteins so no more sperm binds (enzymes)
- The enzymes also result in a hardening of the zona pellucida

	<u>Spermatogenesis</u>	<u>Oogenesis</u>
Location	entirely testes	mostly ovaries
Meiosis	equal cytoplasmic division	unequal cyto division
Germ epithelium	involved	not involved
Number of cells	Sperm < 4	0 + 2/3 polar bodies
Size	sperm < spermatocyte	egg > oocyte
Duration	continuous	arrested stages
Onset	puberty	pre natal
Release	continuous	once a month
End	end of life	menopause

Fertilisation

① Acrosome Reaction

- ~~zona pellucida~~ sperm binds to the zona pellucida and the contents of the acrosome are released. The acrosome ~~cont~~ is a membrane bound sac of enzymes ~~that~~, the latter digest the zona pellucida, exposing an area of membrane

② Penetration of membrane

- sperm's membrane proteins bind to the membrane, leading to the fusion of the sperm and egg membrane
- leads to sperm nucleus entering the cytoplasm of the cell

③ Cortical Reaction

- activation of the egg caused by entry of the sperm's nucleus. Cortical granules (vesicles) undergo exocytosis. Enzymes released digesting membrane bound binding proteins on egg membranes.
- cause hardening of zona pellucida.

Internal

- fertilisation within the female's body
- sperm and ovum in prolonged close proximity
- mammals.
- Developing embryo protected in female's body

External

- ~~fertat~~ fertilisation outside female
- bring eggs into proximity with sperm
- predation + susceptible to environment
e.g. pollution, pH, T

Implantation

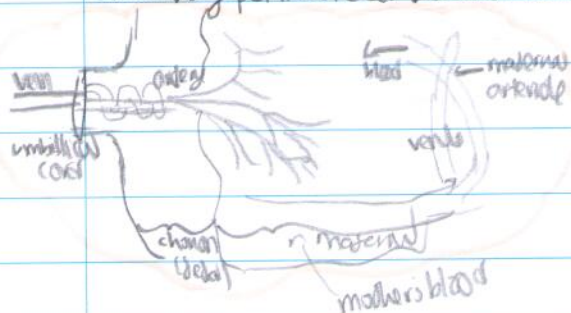
- zygote divides to form 2 diploid cells. Mitosis again to form 4 cells total, a four cell embryo
- $\approx$ 48 hours at this point
- Further cell divisions occur, some are unequal and some cells fragment, creating a hollow-ball shaped embryo. This is the blastocyst
- At 7 days, $\approx$ 125 cells and located in uterus, moved down oviduct by cilia cells
- zona pellucida breaks down, blastocyst has depleted egg's nutrient reserves
- Uses finger like projections to penetrate the endometrium via implantation
- Exchange materials with mother's blood, e.g. nutrients and O_2 .
- rapid development ensues, bone tissue by week 8 $\rightarrow$ fetus at this point and visibly male or female.

HCG (human chorionic gonadotropin)

- stimulates the ovary to secrete progesterone during early pregnancy, used to maintain endometrium as it prevents its degradation
- **RECALL**: Endometrium responsible for supporting developing fetus
- stimulates corpus luteum to continue secreting progesterone and estrogen → continued dev of endometrium

Placenta

- facilitates exchange of materials between mother and embryo
- humans are placental, marsupials give birth to underdeveloped offspring that develops in a pouch.
- monotremes lay eggs.
- Placenta needed due to ↑ S.A : V ratio, as fetus becomes larger, ~~harder~~ reduced capacity for transport
- made of fetal tissue, in contact with maternal tissue in uterus wall. Has finger like fetal tissue known as placental villi that are abundant and ~~are~~ have maternal blood flowing around them (unusual, no b. vet)
- Fetal blood circulates in capillaries, the cells making up capillary walls ~~are~~ form the placental barrier
- Selectively permeable. Does not allow blood to mix, could stimulate immune responses.



Movement

CO₂ out by diffusion, urea out by facilitated diffusion, water in and out by osmosis, O₂ in by diffusion, antibodies by endocytosis

- by week 9, placenta secretes estrogen + progesterone in sufficient quantities, switch from C. luteum, risk of miscarriage if placenta does not do so.

Parturition (childbirth)

- mediated by positive feedback
- progesterone inhibits oxytocin secretion and inhibits ~~the~~ the outer, muscular uterine wall (myometrium) from contracting. At the end, progesterone no longer produced, oxytocin produced, contractions ensue
- detected by stretch receptors which signal the pituitary to ↑ oxytocin secretion
- more frequent and vigorous contractions. Positive feedback OED
- gradual ↑ in myometrial contractions, baby born with minimum contraction intensity
- Cervix muscles relax → dilate. Uterine contractions burst the amniotic sac. Release amniotic fluid
- Further uterine (myometrial) contractions over hours push the baby out of cervix and vagina
- Umbilical cord broken

Gestation

- duration varies between species
- ↑ mass, ↑ size, ↑ gestation time
- Development at birth, if high; higher duration
- Altricial mammals give birth to underdeveloped, helpless offspring (e.g. mice) (↓ G)
- Reverse are precocial, which give birth to developed, mobile, independent offspring (↑ G)



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Name Ardon Pillay () Class 12VJ
Subject Biology / Geography Date 18 August 2016

Option C Notes

Definitions

Limiting factor: a factor that is most scarce in relation to an organism's needs

Niche: mode of existence, role within ecosystem, specific location in habitat

Competitive Exclusion Principle: states that 2 species cannot occupy the same niche indefinitely

Keystone Species: a species that has a disproportionate effect on the structure of an ecological community

Trophic Level: feeding position of an organism

Gross Production: total amount of organic matter produced per unit time per unit area by a t.l

Net production: Gross production remaining after subtraction of that which is used for respiration

Biomass: total dry mass of organisms in a given area

Endemic Species: a species native to an area

Alien Species: a species brought into a foreign ecosystem by unnatural means

Invasive Species: An alien species that increases in numbers and spreads rapidly

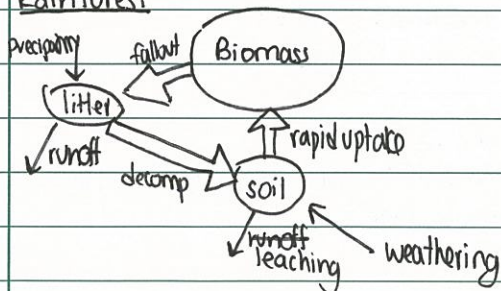
Biomagnification: The process by which toxins or chemical substances become more concentrated as you ascend trophic levels.

Indicator Species: a species/organism used to assess a specific environmental condition

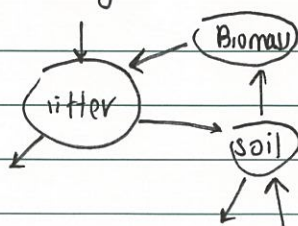
Diagrams

(1) Gersmehl Cycles

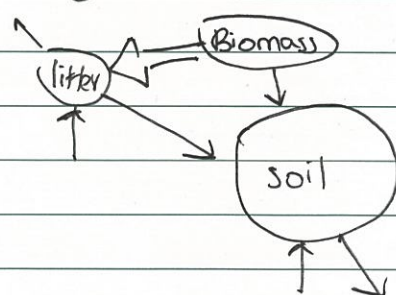
Rainforest



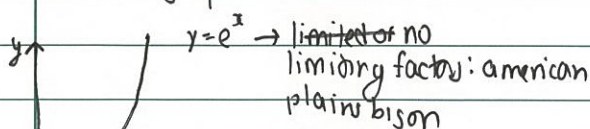
Taiga



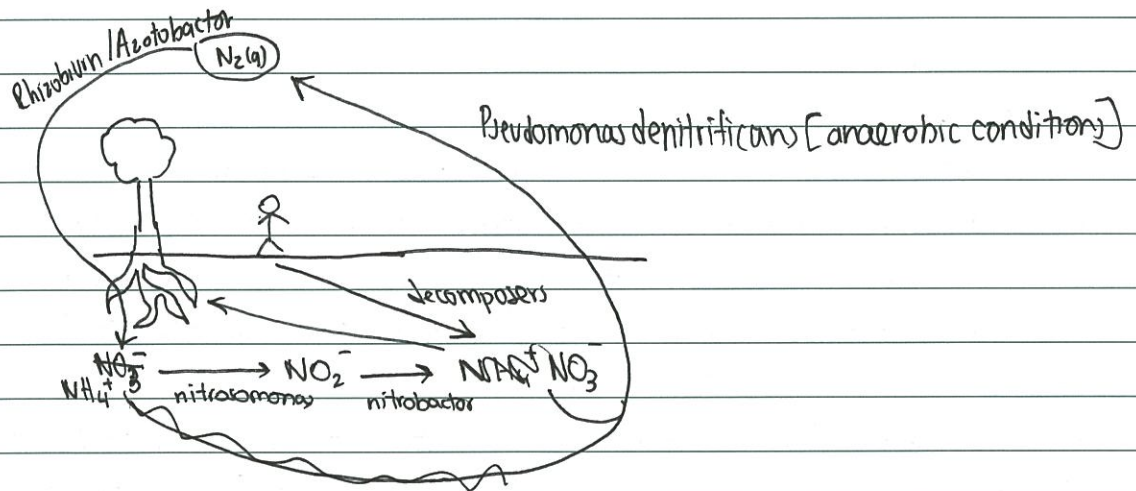
Desert



(2) S and J graphs



③ Nitrogen Cycle



Statistics

- ① FCR → $\frac{\text{intake}}{\text{mass increase}}$ ⇒ if low, high diet sustainability and vice versa
- ② Biotic index
- ③ Simpson's Diversity Index → $\frac{N(N-1)}{\sum n(n-1)}$ → species richness and heterogeneity → ↑, ↑ species diversity
- ④ Lincoln's Index
 $\frac{N_1 \times N_2}{N_3}$, N_1 = first capture
 N_2 = 2nd capture
 N_3 = marked individuals captured the 2nd time

Methods

- ① Controlling Invasive Species
 - Biological Control
 - Mechanical culling
 - Chemical Warfare
 - Entrapment
 - interfere with reproduction
 - controlled fire
 - use as food source
- ② Indicator Species
 - +
 - simple, specific
 - no disruption to ecosystem
 - - hard to discern between species
 - not a reflection of pollution
 - cash money



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③ In Situ (Nature Reserves)

+ve

- natural evolution
- niche + ecosystem + food chain maintained
- cheap + convenient

-ve

- active management (e.g. rewetting wetlands, culling invasive)
- space

④ Ex Situ → (Peregrine Falcon because of Ca-deficient shell)

+ve

- disease free + optimized environment
- botanic gardens
- seed banks
- zoos (breeding)

-ve

- no natural evolution
- does not maintain niche, ecosystem or food chain
- no defence mechanism for disease
- human involvement

Concepts + Arguments

① LF (Plants) → F, pH, salinity, water, mineral ions, light

② LF (Animals) → T, water, food supply, breeding sites, territory

③ Interactions - Herbivory
Predation

Mutualism

Commensalism

Parasitism

④ Keystone Species - e.g. Pisaster led to interspecific competition, ↓ biodiversity, sea otter and elephants

⑤ Food chain + Web → feeding habit position (trophic level) varies, web like nature of feeding patterns

⑥ Succession → P: on previously barren land
→ S: on previously colonised land that was cleared

→ change in conditions = loss of pre-existing climax community

→ pioneer species, e.g. lichens (moderates to ↑ [nutrients]), reduce toxicity of environment

→ ↑ availability of niches ∴ biodiversity ↑

→ stable climax community reached

⑦ Biomagnification → large quantities of prey consumed in lifetime → bioaccumulate toxins

→ varies with how lipid soluble it is + availability in abiotic environment

⑧ Bio Control / Invasive Species → Cane Toad, slow LF, spread and ↑ no rapidly - invasive → poisonous

→ Zebra Mussel → ballast water from black sea to USA → block pipes

⑨ PPT → insecticide approved by WHO but ↓ fertility, cancer, metabolite blocks male hormones
→ bioaccumulates + magnifies → lipid soluble

(10) Biodiversity (biogeographic factors)

- ↑ Area
- corridor effect → corridor between nature reserves → fragmented habitats ↑ biodiversity
- ↑ Area while minimizing perimeter

(11) Why Protect Rainforests

Economic

- ecotourism
- pharmaceutical products

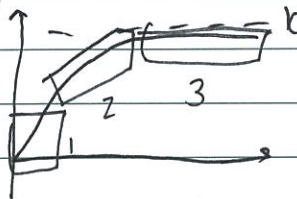
Ecological

- deforestation ↑ CO_2
- change pattern of light reflection } enhanced G-effect
- take in CO_2 and ↑ O_2
- transpiration - rainfall

Ethical

- role as stewards of Earth
- protect home of indigenous people
- preserve for future generations

(12) Sigmoid Growth



① → rapid period of growth as $N > M$, hence + abundant resource, low pop. ∴ competition is low

② → slow down due to higher comp, fewer resource, ∴ $M \uparrow, N \downarrow, \downarrow I, \uparrow E$

③ → When it approaches K, slows down because $I = E$ and $N = M$, limiting factors keep it at K, oscillates around K

(13) TD and BU limiting factors

- TD → pressure applied by higher trophic level → e.g. parrotfish on algae
- BU → lower trophic level → NO_3^- availability for algae

(14) Lincoln Index Considerations

- small markings → so as to not make the prey obvious to predators
- only for small populations
- assumes no reproduction, immigration or emigration, mortality or natality



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(15) Fish + Sustainability

- 1 billion dependent
- lots of young $\rightarrow$ high rate of pop growth, ideal time to fish
- If fisheries collapse $\rightarrow$ loss of revenue, recession, loss of food source
- harvest at high rate of growth = maximum sustainable yield
- How?

(1) ban on trawlers

(2) Closed fishing seasons

(3) larger net gaps to let young escape / restriction on catch size

(4) ban on fishing endangered fish

(16) Population Estimation

- for lakes, $\frac{N_1 \times N_2}{N_3}$
- sonar - shoal size
- check otolith and count rings to determine ages $\rightarrow$ how young population is
- Mathematical Model

(17) Nitrogen Fixation [$N_2(g) \rightarrow NH_4^+(aq)$]

- $\rightarrow$ by nitrogen fixing bacteria, e.g. Azotobacter and Rhizobium
- $\rightarrow$ Rhizobium has a mutualistic relationship with legumes, who supply them with shelter and rec (carbohydrate)
- $\rightarrow$ Azotobacter is free living

(18) Nitrification [$NH_4^+(aq) \xrightarrow{(i)} NO_2^-(aq) \xrightarrow{(ii)} NO_3^-(aq)$]

- $\rightarrow$ i $\rightarrow$ by nitrosomonas
 - $\rightarrow$ ii $\rightarrow$ by nitrobacter
 - $\rightarrow$ these are oxidations
- } chemoautotrophs

(19) Lightning strikes fix $N_2(g) \rightarrow NO_3^-(aq)$

(20) Aminification converts N compound in dead organic matter into NH_4^+ by saprotrophy

(21) Denitrification [$NH_4^+ + NO_3^- \rightarrow N_2$]

- $\rightarrow$ P. denitrifiers usually ~~oxidise~~ ^{reduce} O_2 , but in anaerobic conditions use NO_3^- , $\downarrow$ [N] in soil
- $\rightarrow$ hence, carnivorous plants (e.g. Venus flytrap) $\rightarrow$ gain N from other species / organisms

(22) Phosphorus Cycle

- Phosphorite has high P levels
- weathering + erosion release P into soil
- low turnover (low rate of recycling), due to slow erosion and weathering
- add by NPK fertilisers + harvesting (move from fields)
- but being mined faster than being regenerated
- no synthetic way to produce P

(23) Eutrophication ^[from soil]

- Caused by leaching/run off [litter] etc.
- nutrient availability is a BULF for algae, ↑ [nutrients], ↑ S.A of algal growth
- block sunlight, photosynthetic aquatic plants die
- decomposers act on them ↓ CO₂
- ↑ BOD BCOD
- death of biota → emigration + mortality ↑, ↓ Biod