B I O L O G Y Hl

(Chapter 7 —> 11)

Chapter 7 —> Nucleic acids

7.1 DNA structure and replication

Hershey and Chase:

- Conducted a series of experiments to prove that DNA was the genetic material

1) Viruses (T2 bacteriophage) were grown in one of two isotopic mediums in order to radioactively label a specific viral component
2) Viruses grown in radioactive sulphur (^{35}S) had radio-labelled proteins (sulfur present in proteins but not DNA)
3) Viruses grown in radioactive phosphorus (^{32}P) had radio-labeled DNA (phosphorus present in DNA but not proteins)
4) Viruses were allowed to infect a bacterium (E. Coli)
5) the virus and bacteria were separated via centrifugation

- The bacterial pellet was found to be radioactive when infected by the ^{32}P–viruses (DNA) but not the ^{35}S–viruses (protein) —> pellet is the DNA

Structure of DNA:

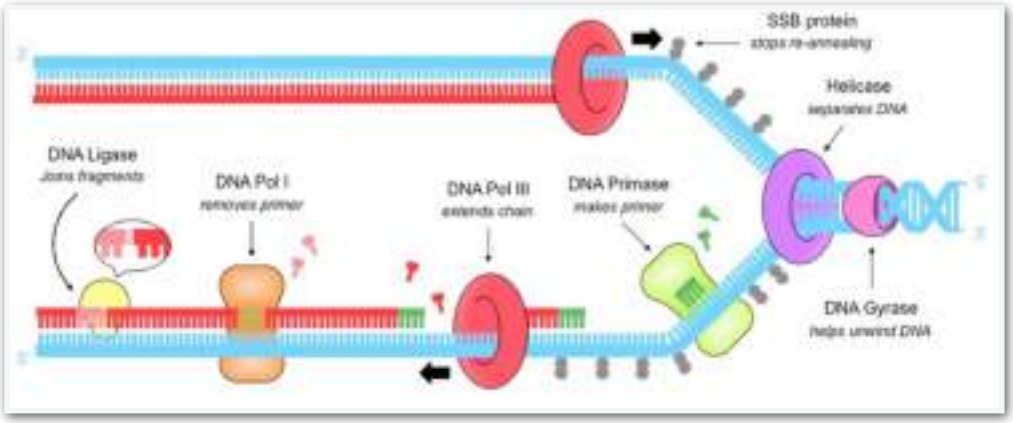
1) DNA was purified and then fibres were stretched in a thin glass tube
2) The DNA was targeted by a X-ray beam, which was diffracted when it contacted an atom
3) The scattering pattern was recorded on a film and used to see details of molecular structure

- Franklin —> Phosphates (and sugars) form an outer backbone and nitrogenous bases are packaged within the interior
- Chargaff —> nitrogenous bases are paired (purine + pyrimidine) within the double helix
  —> the two strands must run in antiparallel directions
- Watson and Crick —> Adenine and thymine (2 hydrogen bonds), guanine and cytosine (3Hy. b)

DNA replication:

- A semi-conservative process that is carried out by a complex system of enzymes
- Helicase —> Unwinds and separates the double-stranded DNA (breaks Hyd bonds of pairs)
  —> occurs at origins of replication
- DNA gyrase —> reduces the torsional strain created by the unwinding of DNA by helicase
  —> it relaxes positive supercoils that would form during the unwinding of DNA
- SSB proteins —> Single stranded. Binding proteins
  —> bind to the DNA strands after being separated and prevents re-annealing
  —> help to prevent the single stranded DNA from being digested by nucleases
  —> will be dislodged from the strand when a new complementary strand is added
- DNA primase —> generates a short RNA primer (10 / 15 nucleotides) on each templated strands
  —> provides an initiation point for DNA polymerase III
- DNA polymerase III —> can extend a nucleotide chain but not start one (5’ to 3’ direction)
  —> free nucleotides align opposite to their complementary base partners
  —> moves in opposite directions on the two strands
  —> leading strand —> moves towards the replication fork (synth. always)
  —> lagging strand —> moves away the replication fork (synth. in pieces)
- DNA polymerase I —> the lagging strand has multiple RNA primers along its length
  —> removes the RNA primers and replaces them with DNA nucleotides

- DNA ligase —> joins the Okazaki fragments together to form a continuous strand
  —> joins the sugar-phosphate backbones together with a phosphodiester bond



Okazaki fragments:

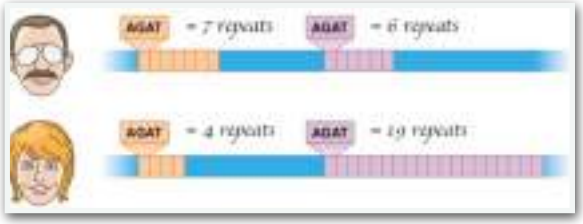
- Needed because DNA polymerase cannot initiate replication
- The lagging stand is copied as a series of short fragments (Okazaki), each preceded by a primer
- The primers are replaced with DNA bases and the fragments are joined together by a combination of DNA pol I and DNA ligase

DNA sequencing:

- The process by which the base order of a nucleotide sequence is elucidated
- Involves the use of chain-terminating dideoxynucleotides
- Dideoxynucleotides —> lack the 3'-hydroxyl group necessary for forming phosphodiester bond
  —> prevent further elongation of a nucleotide chain and terminate replicat.
  —> length will reflect the specific nucleotide position of the the ddNTP
  —> can be used to determine DNA sequence using the Sanger method
- Sanger method —> Four PCR mixes are set up —> (ddA, ddT, ddC, ddG)
  —> fragments are separated using gel electrophoresis
  —> the base sequence is determined by ordering fragments according to length
  —> if a fluorescently labelled primer is present in each mix, the sequence can be detected by using an automated sequencing machine

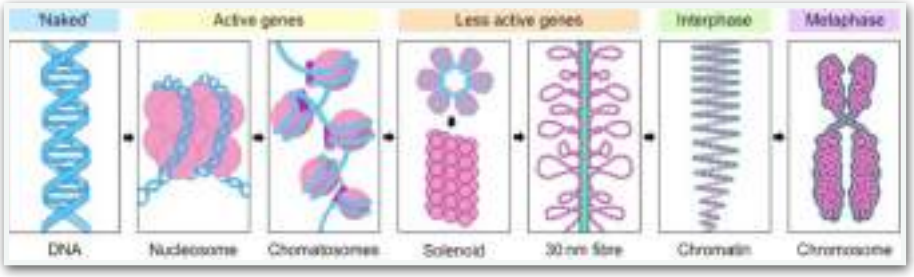
Non-coding DNA:

- Genes only account for 1.5% of the total sequence —> the rest is non-coded DNA
- DNA profiling —> a technique by which individuals can be identified and compared via their DNA profiles
- Individuals will likely have different numbers of repeats at a given satellite DNA locus, so will generate a unique DNA profile



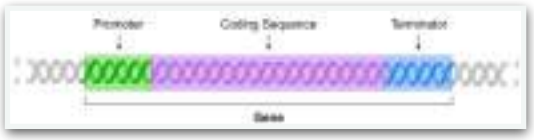
Nucleosomes:

- Help to supercoil the DNA —> better compacted structure that allows for efficient storage
- Helps protecting the DNA from damage and allows chromosomes to move during reproduction
- Eukaryotic DNA —> complexed with eight histone proteins (forms nucleosome)



- Nucleosomes —> a molecule of DNA wrapped around a core of eight histone proteins
  —> the negatively charged DNA associates with the positively charged amino acids on the surface of the histone proteins
  —> the histone proteins have N-terminal tails extruding outwards of nucleosome
  —> tails link up and draw the nucleosomes closer during chromosomal condens.

7.2 Transcription



Sections of a gene:

- Gene —> a sequence of DNA which is transcribed into RNA and contains three main parts
- Promoter —> the non-coding sequence responsible for the initiation of transcription
  —> typically located immediately upstream of the gene's coding sequence
  —> functions as a binding site for RNA polymerase (transcription RNA)
  —> binding is mediated and controlled by some transcription factors in eukaryotes
  —> transcription factors bind to the proximal control element or distal control elements
- Coding sequence —> the region of DNA that is transcribed by RNA polymerase
  —> after RNA polymerase has bound to the promoter
  —> it causes the DNA strands to unwind and separate
- Terminator —> RNA polymerase will continue to transcribe the DNA until a terminator sequence
  —> the mechanism differs between prokaryotes and eukaryotes

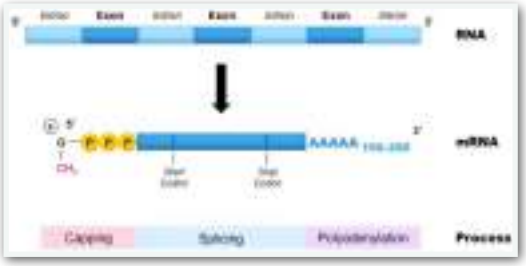
Antisense vs Sense:

- A gene consist of two polynucleotide strands (just one is transcribed into RNA)
- Antisense strand —> the strand transcribed into RNA (template strand)
  —> the DNA version of the tRNA anticodon sequence
- Sense strand —> the strand not transcribed into RNA
  —> the DNA version of the RNA sequence
  —> the coding strand

Transcription:

- The process by which a DNA sequence is copied into a complementary RNA sequence by RNA polymerase
- Nucleotides triphosphates —> free nucleotides inside a cell (NSPs)
- RNA polymerase covalently binds them together in a reaction involving two phosphate release
- The 5'-phosphate is linked to the 3'-end of the growing mRNA strand (5' to 3' direction)

Messenger RNA:



-In eukaryotes three post-transcriptional events must occur in order to form an mRNA

-Capping —> involves the addition of a methyl group to the 5'-end of the transcribed RNA

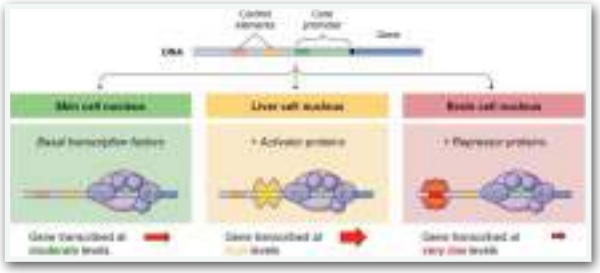
—> provide protection against degradation by exonuclease

—> it allows the transcript to be recognised by the cell's translation machinery

- Polydenylation —> the addition of a long chain of adenine nucleotides to the 3'end of transcript
  —> improves stability of the RNA transcript and facilitates export from nucleus
- Splicing —> introns —> non-coding sequences which must be removed prior to form mRNA
  —> exons —> coding regions that are fused together when introns are removed
  —> introns are intruding sequences while exons are expressing sequences
  —> can also result in the removal of exons —> alternative splicing —> will result in the formation of different polypeptides from a single gene sequence

Gene expression:

- Transcriptional activity is regulate by two groups of proteins
- Transcriptional factors form a complex with RNA polymerase at the promoter
- RNA polymerase cannot initiate transcription without these factors



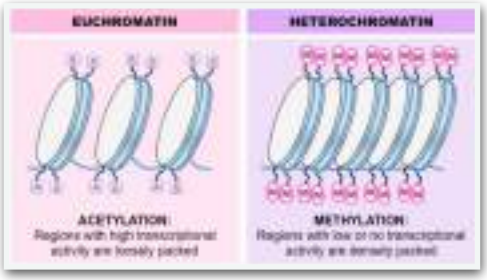
- Regulatory proteins bind to DNA sequences outside of the promoter and interact with factors
  —> activator proteins bind to enhancer sites and increase the rate of transcription
  —> repressor proteins bind to silencer sequences and decrease the rate of transcription
  —> the presence of certain transcription factors may be tissue-specific
  —> chemical signals can also moderate protein levels
- Control elements are the DNA sequences to which regulatory proteins bind to
  —> some are proximal elements (near to promoter) and others are distal elements
  —> regulatory proteins typically bind to distal control elements while transcription factors usually bind to proximal elements
  —> most genes have multiple control elements —> gene expression is tightly controlled
- Changes in the external or internal environment can trigger changes to gene expression patterns
  —> chemical signals within the cell can change the levels of regulatory proteins or factors in response to stimuli
  —> this allows gene expression to change in response to alterations in the environments
  —> ex. humans produce different amounts of melanin depending on light exposure

Modification of Histone tails:

- Histone tails have a positive charge and hence associate tightly with the negatively charged DNA
- By adding an acetyl group, the tail neutralises —> DNA il less tightly coiled and < transcription
- By adding a methyl group, the tail remains positive —> DNA more coiled and > transcription

Types of chromatin:

- Heterochromatin —> DNA is supercoiled/condensed and so is not accessible for transcription
- Euchromatin —> DNA is loosely packed and is accessible to the transcription machinery
- Different cell types will have varying segments of DNA packaged as hetero/euchromatin
- Some segments of DNA may be permanently supercoiled



DNA methylation:

- Can also affect gene expression patterns (prevents the binding of transcription factors)
- Increased methylation of DNA decreases gene expression —> genes that are not transcribed tend to exhibit more DNA methylation than genes that are actively transcribed
- Ex. Maternal diet, exposure to microbes, environmental, diet, lifestyle and age-related changes

Epigenetics:

- The study of changes in phenotype as a result of variations in gene expression levels
- Shows that DNA methylation patterns may change over the course of a lifetime
- It is influence by heritability but is not genetically pre-determined
- Different cell types in the same organism may have totally different DNA methylation patterns
- Environmental factors may influence the level of DNA methylation within cells

---

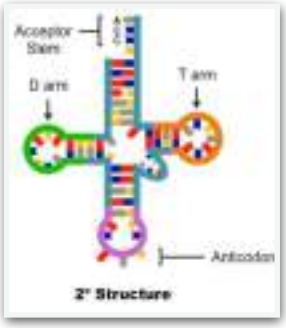
7.3 Translation

Ribosomes:

- are made of protein (for stability) and ribosomal RNA (for catalytic activity)
- Two subunits —> small subunit contains an mRNA binding site
  —> large subunit contains three tRNA binding sites (aminoacyl, peptidyl, exit)
- Can be found freely floating in the cytosol or bound to the rER for eukaryotes
- Prokaryotes —> 70s Eukaryotes —> 80s

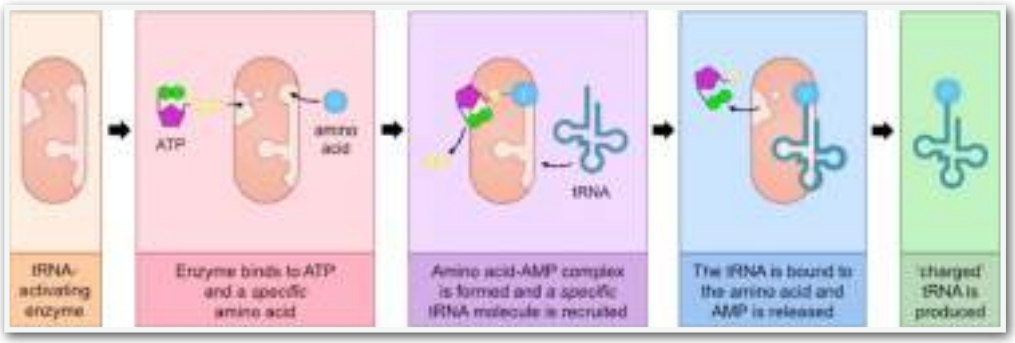
Transfer RNA:

- tRNA molecules fold into a cloverleaf structure with four key regions:
  —> the acceptor stem (3'-CCA) —> carries an amino acid
  —> the anticodon —> associates with the mRNA codon
  —> the T arm —> associates with the ribosome (E, P, A sites)
  —> the D arm —> associates with the tRNA activating enzyme



tRNA activation:

- Each tRNA molecule bind with a specific amino acid in the cytoplasm —> each amino acid is recognised by a specific enzyme
- The binding of an amino acid to the tRNA acceptor stem occurs as:
  —> enzyme binds ATP to the amino acid to form an amino acid —> AMP complex linked
  —> the amino acid is then coupled to tRNA and the AMP is released —> now charged
- The function of the ATP is to create a high energy bond that is transferred to the tRNA molecule
  —> this energy will provide the energy required for peptide bond formation in translation



Translation:

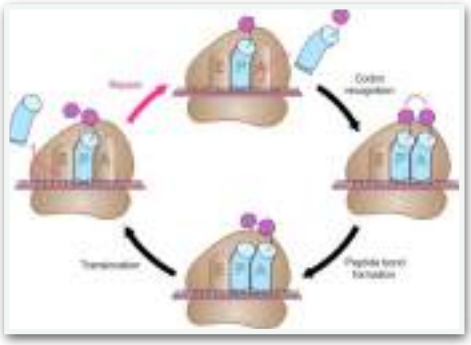
- Initiation —> the first stage and involves the assembly of the three components that carry out the process (mRNA, tRNA, ribosome)
- The small subunit binds to the 5'-end of the mRNA and moves along it until it reaches AUG
- Then the appropriate tRNA molecule binds to the codon via its anticodon (comp. base pairing)
- Lastly the large subunit aligns itself to the tRNA molecule at the P site and forms a complex

Elongation:

- A second tRNA molecule pairs with the next codon in the ribosomal A site
- The amino acid in the P site is covalently attached via a peptide bond to the amino acid in A
- The tRNA in the P site is deacylated (no amino acid)

Translocation:

- The ribosome moves along the mRNA strand by one codon position (5' to 3')
- The deacylated tRNA moves into the E site and is released while the tRNA on A goes to P
- Another tRNA molecule attaches to the now unoccupied A site
- The process is repeated until the stop codon



Termination:

- Final stage of translation —> involves the disassembly of the components and the release of the polypeptide chain
- Elongation and translocation continue until a stop codon is reached
- These codons do not recruit a tRNA molecule, but instead a release factor
- The polypeptide is released and the ribosome disassembles back in its two independent subunits

Polysomes:

- In eukaryotes, ribosomes are separated from the genetic material by the nucleus
- After transcription the mRNA must be transported from the nucleus (pores) prior to translation
- This transport requires modification to the RNA construct

- Prokaryotes lack a compartmentalised structure, so transcription and translation are not separated
- Ribosomes begin translating the mRNA molecule while it is still being transcribed from the DNA
- Possible because both transcription and translation occur in a 5' to 3' direction

- A polysome is a group of two or more ribosomes translating an mRNA sequence simultaneously
- Will appear as a bead (ribosomes) on a string (mRNA)
- Polysomes in prokaryotes may form while the mRNA is still being transcribed from the DNA

- Ribosomes located at the 3'-end of the polysome cluster will have a longer polypeptide chain

Protein destinations:

- If the protein is targeted for intracellular use within the cytosol —> ribosome free and unattached
- If protein is targeted for secretion, membrane fixation or lysosomes —> ribosome binds to ER

- Destination is determined by the presence or absence of an initial signal sequence on a chain
- The presence of a signal sequence results in recruitment of a signal recognition particle (SRP)

1) SRP halt translation in ribosomes
2) The SRP-ribosome complex is docked to a receptor located on the ER membrane
3) Translation is re-initiated and the polypeptide chain continues to grow into a transport channel to finish inside the ER lumen
4) The synthesised protein will then be transported via a vesicle to the Golgi complex or lysosome
5) Proteins targeted for membrane fixation get embedded into the ER membrane
6) The signal sequence is cleaved and the SRP recycled once the chain is fully synthesised

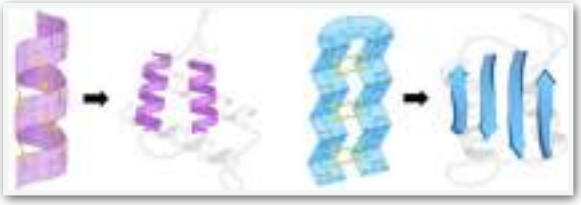
Protein structure:

Primary structure:

- The order of amino acids from which the polypeptide chain is comprised
- Formed by covalent peptide bonds between the amine and carboxyl groups of adjacent amino.
- It controls all subsequent levels of protein organisation —> determines the interactions between R groups of different amino acids

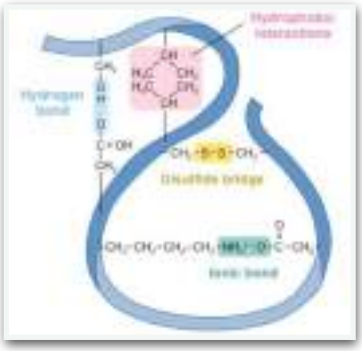
Secondary structure:

- Way a polypeptide folds in a repeating arrangement, forms Alpha helices or Beta-pleated sheets
- Results of hydrogen bonding between the amine and carboxyl groups of non-adjacent amino.
- Random coil —> sequences with neither alpha or beta arrangement
- Provides the polypeptide chain with a level of mechanical stability



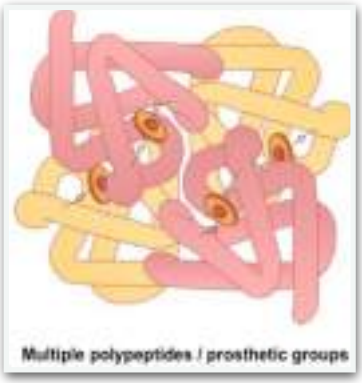
Tertiary structure:

- The way the polypeptide chain coils and turns to form a complex molecular shape
- Caused by interactions between R groups (disulphide bridges, ionic bonds, hydrophobic interactions)
- Relative amino acid positions are important
- It may be important for the function of the protein



Quaternary structure:

- Multiple polypeptides or prosthetic groups, interact to form a single, larger, biologically active protein
- Prosthetic group —> an inorganic compound involved in protein structure or function
- A protein containing a prosthetic group is called a conjugated protein (haemoglobin)
- May be held together by a variety of bonds



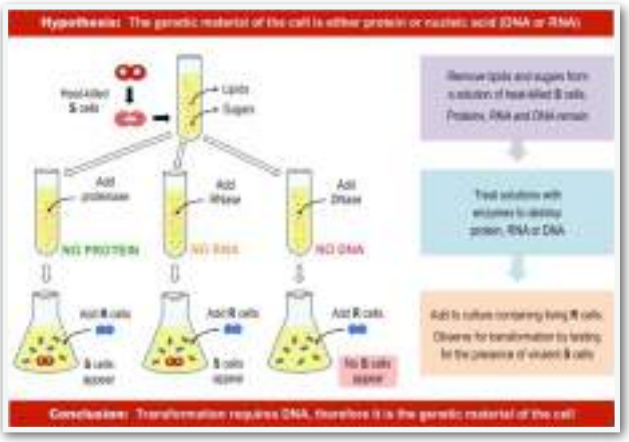
Extra:

DNA experiments:

Griffith's experiment:

- 1928, Frederick Griffith —> one of first experiments to show that cells posses genetic material
- Involved the use of two strains of pneumococcus (deadly virus strain and non-virulent strain)
- When Griffith infected mice with the non-virulent bacteria the mice survived
- When Griffith infected mice with the virulent bacteria the mice died
- When Griffith infected mice with a mix of heat-killed strain virulent bacteria and non-virulent living strain the mice were found dead —> there were some form of genetic material transfer

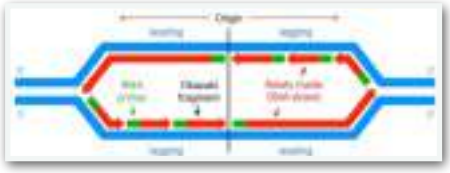
Avery-Maclord-McCarty experiment:



DNA structure elucidation:

- Rosalind Franklin and Maurice Wilkins used X-ray diffraction to identify key properties of DNA
- Wilkins shared this data with Watson and Crick
- W and C used this data to help construct an accurate model of DNA structure (double helix)
- Watson, Crick and Wilkins were awarded the Nobel prize, but not Franklin

Origins of replication:



- Sequences where DNA replication is initiated in a genome
- DNA synthesis may occur bi-directionally from an origin of replication —> greatly limits the time required for the process —> when it happens the two replication forks move in opposite directions to create a replication bubble
- Replication bubbles expand in both directions —> will fuse together as intervening regions copy

Supercoiling:

- Refers to the additional twisting of a DNA strand and is an expression of the strain on that strand
- Can be overwound —> positive supercoiling
- Can be underwound —> negative supercoiling —> most DNA is like this
- Supercoiling functions to reduce the space required for DNA packaging
- DNA will form positive supercoils when unwound by helicase and requires DNA gyrase to reduce the strain

Genes versus repetitive DNA:

	Simple copy Gene	Repetitive DNA
Proportion	Small (~1.5%)	High (5 – 45%)
Rate of mutation	Low	Higher
Occurrence	Once in genome	Occurs many times
Function	Makes protein	Not translated
Identification	Similar b/w individuals Not used for profiling	Varies greatly Used for profiling
Length	Long unique sequence	Short repeating sequence
Example	Exons	Introns

Telomerase:

-Regions of repetitive DNA located at each end of chromatid (prevent chromosomal deterioration)
-The extreme end of the telomere cannot be copied —> gets marginally shorter —> the terminal RNA primer on the lagging strand cannot be replaced
-The progressive shortening of telomeres is ageing
-Cells have limited capacity for cellular division (Hayflick limit —> 40/60x)
-Telomeres can be lengthened by enzyme telomerase
-Permanent activation of telomerase can cause cells to become immortal and leads to cancer

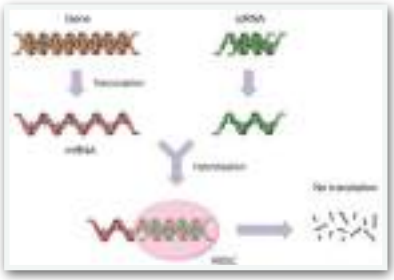
Types of RNA:

- RNA functions to transfer genetic instructions from the nucleus to the cytoplasm
- Messenger RNA (mRNA) —> a transcript copy of a gene which encodes a specific polypeptide
- Transfer RNA (tRNA) —> carries the polypeptide subunits (amino acids) to the organelle responsible for synthesis (ribosome)
- Ribosomal RNA (rRNA) —> primary component of the ribosome —> responsible for catalysis
- Cells may produce other variants of non-coding RNA to support and regulate gene expression:
    —> small nuclear RNA —> component of the spliceosome (involved in intron splicing)
    —> short interfering RNA —> moderates gene expression levels via RNA interference

Operons:

- A sequence of DNA containing a cluster of genes under the control of a single promoter
- Genes within an operon will always be expressed together or not at all
- Three basic components to an operon:
    —> Promoter —> upstream sequence to which RNA polymerase binds
    —> Operator —> Segment of DNA to which a repressor protein binds
    —> Structural genes —> genes that are collectively regulated by the operon
- Operons are related to stimulons —> set of genes under regulation from a single cell stimulus while a regulon is a set of genes under regulation from a single regulatory protein

RNA interference:



- Short interference RNA is a double-stranded RNA molecule that is roughly 20-25 base pairs
- SiRNA interferes with expression of genes —> mRNA transcripts to be broken prior translation
- RISC —> RNA induced silencing complex

Protein modification:

- Post-translational modif. —> all change in the chemical composition of proteins after translation
- These modifications may be vital to the formation of a mature functional protein
- Addition of new functional groups —> enzymes modify protein structure via the introduction of a new chemical group to specific amino acids in the molecule (phosphorylation, acetylation, …)
  —> can alter the properties of the chain and induce conformational change affecting activity
- Proteolytic cleavage of existing elements —> proteins may also be modified via the removal of specific amino acid segments from a propeptide
  —> occurs in zymogens —> active site is occluded and inactive untile proteolytic … occurs
  —> insulin requires the separation of a middle segment to form two polypeptides linked by disulphide bridges
- Racemization —> amino acids can exist as chiral enantiomers (mirror image)
  —> involves converting proteins from one enantiomeric arrangement to another
  —> different enantiomers may have distinct chemical properties

Protein expression:

1) Transcription control —> by controlling the amount of transcription (less mRNA = less protein)
   —> achieved primarily through the effects of transcription factors and regulatory proteins
2) RNA processing con. —> involves regulation the formation of mature mRNA in eukaryotes
   —> necessary to help direct the mRNA to the ribosome and prevent premature degradation
3) RNA transport con. —> RNA must be transported out of the nucleus to associate with ribosome
   —> preventing transport, the related protein cannot be synthesised
4) Translation con. —> protein expression can be regulated by controlling amount of translation
   —> may involve inhibiting ribosomal subunit or actively targeting mRNA for degradation
5) Protein activity con. —> protein expr. patterns may be affected by the rate of prot. degradation
   —> post-translational modification may target proteins for destruction (ex. phosphorylation)

Visualising proteins:

- Haemoglobin —> a globular protein responsible for oxygen transport within red blood cells
  —> it has a quaternary structure made up of four polypeptide subunits
  —> each polypeptide chain is associated with a prosthetic heme group
- Aquaporins —> are integral membrane proteins that form channels that allow water passage
  —> form tetramers in the cell membrane with each monomer allowing water move
  —> are impermeable to charged species —> prevent passage of ions or solutes
- Keratin —> is a fibrous protein that functions as a key structural material in hair, skin and nails
  —> form long twisted stands that may interconnect via disulphide bridges
- Green fluorescent protein —> is a fluorophore produced by jellyfish
  —> the fluorescing chromophore is attached to a central alpha helix surrounded by 11 beta
  —> the tightly packed beta barrel excludes solvent molecules

Chapter 8 —> Metabolisms, Cell respiration & photosynthesis

8.1 Metabolism

Metabolic pathways:

- Metabolism —> the sum of all reactions that occur within an organism
- Allow fro a greater level of regulation of the chemical changes
- Organised in chains (Glycolysis, …) or in cycles (Krebs, Calvin, …)

Activation energy:

- Every chemical reaction requires a certain amount of energy in order to proceed
- Enzymes binding to substrates stresses and destabilises the bonds in the substrate —> reduces the overall energy level needed to convert it into a product —> reaction is also faster
- Exergonic —> if the reactants contain more energy than the products (energy released around)
- Endergonic —> if reactants contain less energy than the products (energy taken from around)

Enzyme inhibition:

- A molecule that disrupts the normal reaction pathway between an enzyme and a substrate —> prevent the formation of an enzyme-substrate complex —> prevent formation of a product
- Can be either competitive or non-competitive

Competitive inhibition:

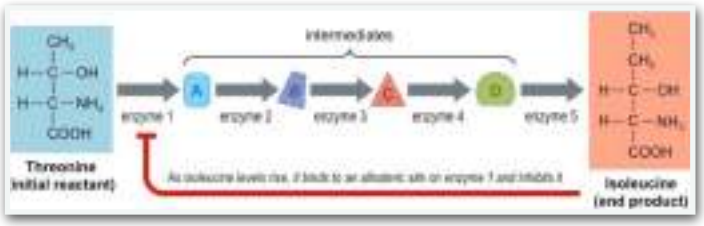
- Involves a molecule (not the substrate), binding to the enzyme's active site
- The molecule is both structurally and chemically similar to the substrate
- As the active site is occupied the substrate can't binds to it
- Effects of inhibitor can be reduced by increasing substrate concentration
- Relenza —> synthetic drug to treat individuals infected by influenza virus
  —> competitively binds to the neuraminidase (virus) active site and prevents binding

Non-competitive inhibition:

- Involves a molecule binding to a site other than the active site —> allosteric site
- The binding causes a conformational change to the enzyme's active site —> does not match any more with the substrate, so can't bind
- Increasing substrate levels cannot mitigate the inhibitor's effect
- Cyanide —> a poison which prevents ATP production via aerobic respiration —> death
  —> it binds to an allosteric site on cytochrome oxidase —> the electron transport chain cannot continue to function anymore

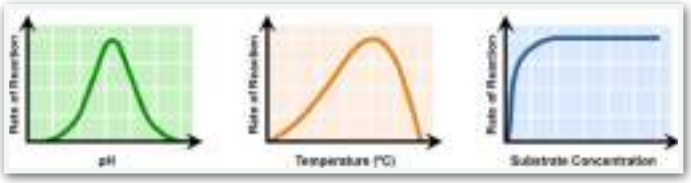
Feedback inhibition:

- A form of negative feedback by which metabolic pathways can be controlled
- The final product in a series of reactions inhibits an enzyme from an earlier step (non-comp)
- The enzyme cannot function —> the reaction sequence is stopped —> lower production rate
- Needed to ensure levels of an essential product are always tightly regulated
- Isoleucine —> an essential amino acid (not synthesised by humans) (eggs, fish, cheese, …)
  —> plants and bacteria use threonine to synthesise it (5 steps)

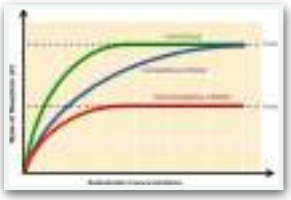


—> firstly threonine is converted into an intermediate compound by an enzyme
—> then isoleucine can bind to an allosteric site on this enzyme and be a non-comp
—> ensures that isoleucine production does not cannibalise stocks of threonine

Enzyme kinetics:



- Rate of reaction (s^{-1}) = 1 / time taken (s)
- Factors affecting enzyme activity include:
- Competitive inhibitors —> exist in direct competition with the substrate —> maximum rate can still be achieved but with a higher substrate concentration
- Non-competitive inhibitors —> are not in direct competition with the substrate so increasing substrate concentrations won't change anything so max. rate is reduced



Rational drug design and malaria:

- Malaria —> a disease caused by parasitic protozoans of the genus plasmodium
- The parasite requires both a human and mosquito host —> hence mosquito bites needed
- Anti-malarian drugs target the specific enzymes malaria uses and inhibits them
- Computer modelling techniques can be used to invent compounds that will function as inhibitors

---

8.2 Cell respiration

ATP:

- A high energy molecule that functions as an immediate power source for cells
- The three covalently bonded phosphate groups store potential energy in their bonds
- When ATP is hydrolyse (forms ADP+Pi) —> energy is released for use by the cell
- Two functions —> the energy currency of the cell
  —> the released phosphate group may be given to other molecules
- ATP is synthesised from ADP by:
  —> solar energy —> photosynthesis converts light energy into chemical
  —> oxidative processes —> cell respiration breaks down molecules to release ATP

Cell respiration:

- The controlled release of energy from organic compounds to produce ATP
- Anaerobic respiration —> the incomplete breakdown of molecules for few ATP (no oxygen use)
- Aerobic respiration —> the complete breakdown of molecules for a lot of ATP (oxygen needed)
- The breakdown occurs via a number of linked processes —> less energy required

	Oxidation	Reduction
Electrons	Loss	Gain
Hydrogen	Loss	Gain
Oxygen	Gain	Loss

Reduction and Oxidation:

-Energy stored in the molecules is transferred with the protons and electrons to carrier molecules
-$NAD^+ + 2H^+ + 2e^-$ —> $NADH + H^+$
-$FAD + 2H^+ + 2e^-$ —> $FADH_2$

Glycolysis —> Link reaction —> Krebs Cycle —> Electron transport chain —> Chemiosmosis
$C_6 H_4 O_6 + 6 O_2$ ——> $6 CO_2 + 6 H_2O$

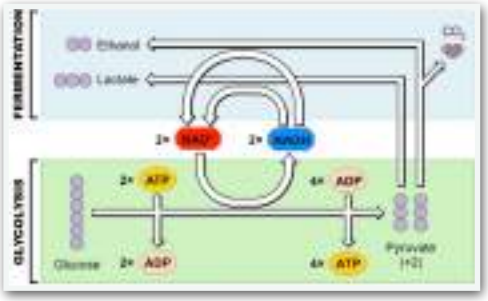
Glycolysis:

- Occurs in the cytosol of the cell —> a hexose sugar (6C) is broken down in two pyruvate (3C)
- It is an anaerobic process
- Glucose —> main organic compound used in cell respiration (lipids and proteins can be used)
- Lipids —> not preferentially used as they are harder to transport and digest
- Proteins —> not preferentially used as they release potentially toxic nitrogenous compounds

1) Phosphorylation —> hexose sugar is phosphorylated by two ATP (forms hexose biphosphate)
   —> makes the molecule less stable and more reactive + no diffusion out of cell
2) Lysis —> the hexose biphosphate (6C sugar) is split into two triode phosphates (3C sugars)
3) Oxidation —> hydrogen atoms are removed from the 3C sugars to reduce NAD^+ to $NADH + H^+$
   —> two molecules of NADH are produced in total
4) ATP formation —> some energy released from the sugars is used to directly synthesise ATP
   —> called substate level phosphorylation
   —> 4 molecules of ATP are generated during glycolysis (2ATP per 3C sugar)

Aerobic respiration:
- If oxygen is present the pyruvate is transported to the mitochondria for further breakdown
- The further oxidation generates large numbers of reduced hydrogen carriers (NAD e FAD)
- In the presence of oxygen, the reduced hydrogen carriers can release their stored energy to synthesise more ATP
- Link reaction, Krebs cycle and electron transport chain are the next processes

Anaerobic respiration (fermentation):
- If oxygen is not present the pyruvate is not broken down further and no more ATP is produced
- The pyruvate remains in the cytosol and becomes lactic acid (animal) or ethanol and CO_2 (plants)
- This conversion is reversible



Link reaction:

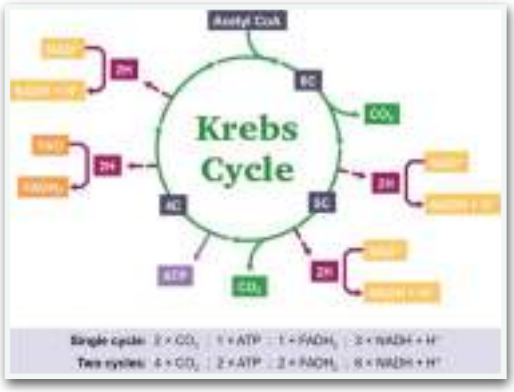
- It links the products of glycolysis with the aerobic processes of the mitochondria

1) pyruvate is moved from the cytosol to the mitochondrial matrix by carrier proteins
2) The pyruvate loses a carbon atom (decarboxylation) —> it forms a CO_2 molecule
3) The 2C compound forms an acetyl group when it loses hydrogen atoms via oxidation
4) The acetyl compound combines with coenzyme A to form acetyl CoA

- The link reaction occurs twice per molecule of glucose (2 pyruvate received)

Krebs cycle:

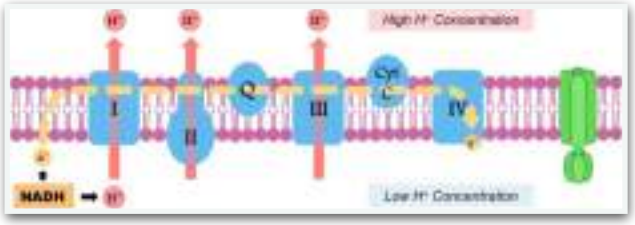
- Occurs in the matrix of the mitochondria
- Acetyl CoA transfers its acetyl group to a 4C compound to make a 6C compound —> then it is released and returns to the link reaction
- Two carbon atoms are released via decarboxylation to form 2 CO_2 molecules
- Multiple oxidation reactions —> reduction of hydrogen carriers
- One molecule of ATP is produced directly via substrate level phosphorylation
- Krebs cycle occurs twice (one per each acetyl CoA)



Oxidative phosphorylation:

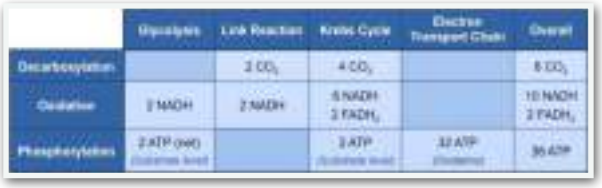
Electron transport chain:

1) hydrogen carriers are oxidised and release high energy electrons and protons
2) The electrons are transferred to the electron transport chain
3) As electrons pass the chain they lose energy —> used to pump protons (H^+) from the matrix
4) The accumulation of H^+ ions in the inter membrane space created an electrochemical gradient

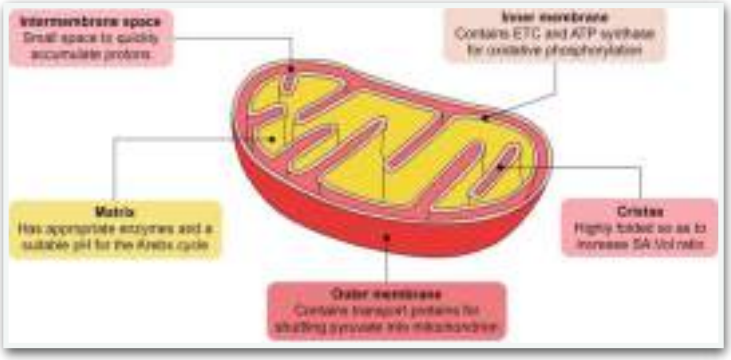


Chemiosmosis:

1) the electrochemical gradient will cause H^+ ions to diffuse back into the matrix
2) This diffusion is facilitated by the transmembrane enzyme ATP synthase
3) H^+ ions move through ATP synthase —> cause molecular rotation of the enzyme, synth. ATP
4) Oxygen acts as the final electron acceptor —> removes the de-energised electrons to prevent the chain from becoming blocked —> it also binds to H^+ ions to form H_2O



Mitochondria:



8.3 Photosynthesis

- The process by which cells synthesis organic molecules from inorganic molecules using light
- It can only occur in certain organisms and requires photosynthetic pigments
- Two step process —> Light independent rxn —> convert light energy into chemical (ATP)
  —> Light independent rxn —> use chemical energy to synthesise compounds

$6\ CO_2 + 12\ H_2O \longrightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O$

Light dependent reactions:

- Use photosynthetic pigments to convert light energy into chemical energy (ATP and NADPH)
- These reactions occur in the thylakoids
- Photophosphorylation —> light provided is the initial energy source for ATP production

1) Excitation of photosystems by light energy

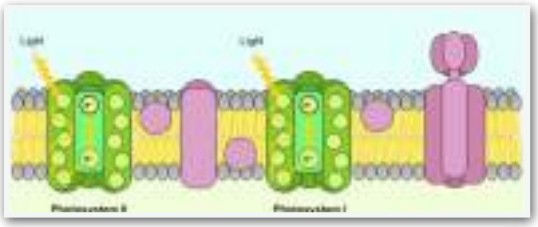
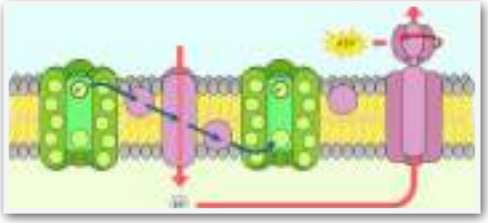
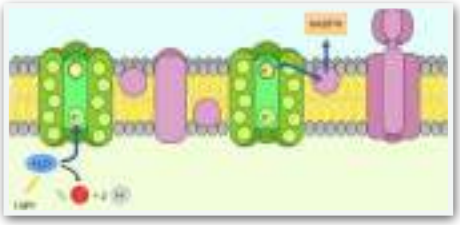
—> photosystems —> groups of photosynthetic pigments in the thylakoid membrane
—> PS I (700 nm) is before PS II (680 nm)
—> when a photosystem absorbs light energy, it energises delocalised electrons
—> the exited electrons are transferred to carrier molecules within the thylakoid membrane
—> the electrons lost are replaced by electrons released from water via photolysis

2) Production of ATP via electron transport chain

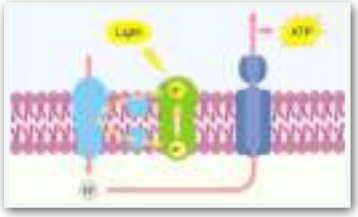
—> electrons from PS II are transferred to an electron transport chain
—> electrons lose energy in the process —> used to translocate H^+ ions into the thylakoid creating an electrochemical gradient
—> The H^+ ions return to the Stroma via ATP synthase (chemiosmosis) —> used to catalyse the synthesis of ATP from ADP + Pi
—> the de-energised electrons are taken up by PS I

3) Reduction of $NADP^+$ and the photolysis of water

—> PS I energises the electrons again
—> electrons transferred to carrier molecule and reduce $NADP^+$ to form NADPH (by ferrodoxin)
—> water is split by light energy into H^+ ions (for chemiosmosis) and oxygen

Photophosphorylation:



Cyclic photophosphorylation:

- Only uses the PS I and there is no reduction of $NADP^+$
- The de-energised electron returns to the photosystem after having entered the electron transport chain to produce ATP
- $NADP^+$ is not reduced + water is not needed to replenish electron supply

Non-Cyclic photophosphorylation:

- Involves both photosystems and reduces $NADP^+$
- The process explained in Light dependent reactions

Light independent reactions:

- Use the chemical energy from LD reactions to form organic molecules
- Occur in Stroma, the fluid-filled space of the chloroplast
- Calvin cycle —> light independent reactions

1) **Carbon fixation**
   —> The Calvin cycle beings with a 5C compound (Ribulose biphosphate)
   —> enzyme rubisco catalyses the attachment of a CO_2 molecule to RuBP —> 6C
   —> the 6C are unstable so break down into two 3C compounds (Glycerate-3-phosphate)
   —> one cycle takes three molecules of RuBP with three CO_2 to make six G3P

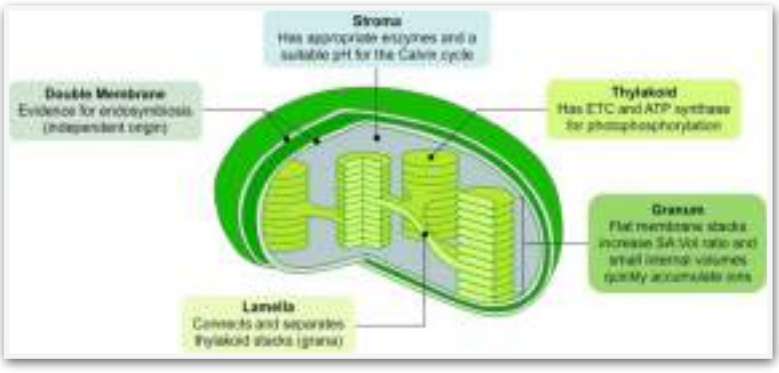
2) **Reduction of Glycerate-3-phosphate**
   —> G3P is converted into triode phosphate using NADPH and ATP
   —> the reduction by NADPH transfers H atoms to the compound
   —> the hydrolysis of ATP provides the necessary energy

3) **Regeneration of RuBP**
   —> out of 6, just one triose phosphate molecule can be used to form half a sugar molecule
   —> other five TP molecules are recombined to regenerate stock of RuBP (5 x 3C = 3 x 5C)
   —> the energy to regenerate RuBP is derived from the hydrolysis of ATP

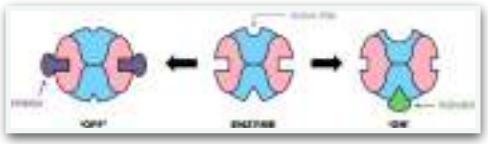
Lollipop Experiment:

1) Radioactive carbon-14 is added to a lollipop apparatus containing Chlorella algae
2) Light is given to the plant to induce photosynthesis
3) After different periods of time the algae is killed with heated alcohol (stops cell metabolism)
4) Dead algal samples are analysed using 2D chromatography —> to see different carbon comp.
5) Radioactive carbon compounds on the chromatogram were identified by autoradiography
6) By comparing different periods of light exposure, the order in which carbon comp. generate was determined —> Calvin cycle

Chloroplasts:



Extra:

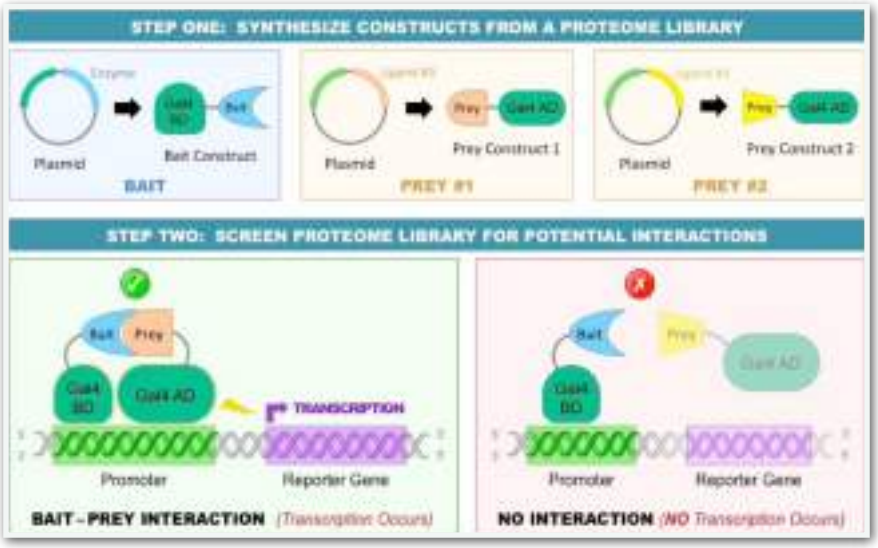


Allosterism:

- Is the modulation of an enzyme's activity via the binding of an effector molecule (ligand) to a site other than the enzyme's active site (allosteric site)
- Positive al. —> the binding of oxygen molecules to haemoglobin
  —> haemoglobin can bind to four oxygen molecules (HbO_8)
  —> as each molecule binds it changes conformation of Hb and increases capability
  —> this ensures that Hb will transport the max amount of oxygen
- Negative al. —> any example of non-competitive inhibition

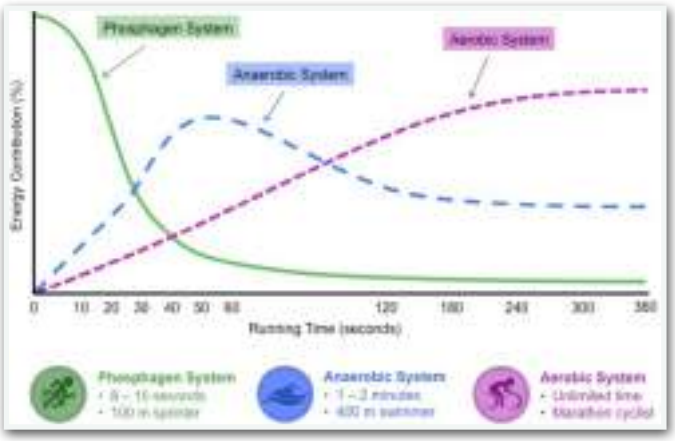
Yeast-2-Hybrid system:

- A simple scientific technique used to screen a library of proteins for potential interactions
- Bait —> eg. enzymes
- Prey —> eg. different ligands
- Simple technique —> has a relatively high rate of false positives (partial interactions)



Phosphagen system:

- Phosphagens —> energy storing compounds that are chiefly found in muscle and nervous tissue
- They function as an immediate access reserve of high energy phosphates that can make ATP
- Are found in tissues that experience rapidly changing energy needs
- Phosphocreatine —> common example used by animals
  —> at rest, ATP hydrolysed to ADP and phosph. used to make phosphocreatine
  —> this occurs in the mitochondria where ATP levels are high
  —> during exercise phosphocreatine is hydrolysed and the phosphate released to make ATP from ADP
  —> this occurs in the muscles, where ADP levels will be high
- Phosphocreatine synthesises a pool of ATP more rapidly than cell resp. but reserves don't last
- The phosphagen system will be used for the first 10-12 seconds of intense exercise
- Anaerobic respiration provides a more sustained pool of ATP but produces lactic acid
- Anaerobic respiration will be used for the first 1-2 minutes of exercise
- Aerobic respiration requires a constant supply of oxygen but can produce a large yield of ATP
- Will be used for long-distance and less intense exercise activities



Photosynthesis vs Respiration:

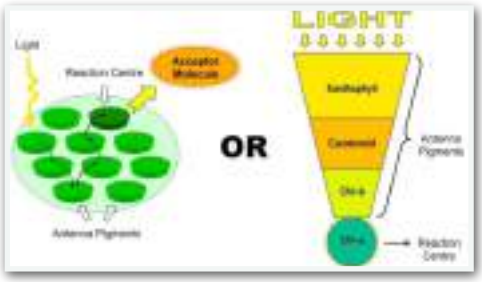
Similarities:

- Both involve the production of chemical energy (ATP)
- In photosynthesis ATP is produced via light energy (photophosphorylation)
- Cell respiration ATP produced by breaking down organic molecules (oxidative phosphorylation)
- In both cases the production of ATP involves an electron transport chain and chemiosmosis
  —> photosynthesis —> electrons are donated by chlorophyll and protons accumulate within the lumen of the thylakoid
  —> cell respiration —> electrons are donated by hydrogen carriers and protons accumulate in the intermembrane space

Differences:

- Photosynthesis is an anabolic process while cell respiration is a catabolic process
- Photosynthesis —> water is broken down to oxygen to release electrons for ETC
  —> electrons from the ETC are taken up by hydrogen carriers (NADPH)
  —> uses the Calvin cycle to synthesise glucose (requires CO_2 and H carriers)
- Cell respiration —> uses the Krebs cycle to break down glucose (releases H carriers and CO_2)
  —> H carriers release electrons for the ETC (NADH and $FADH_2$ specifically)
  —> electrons from the ETC are taken up by oxygen to form water

Accessory pigments:



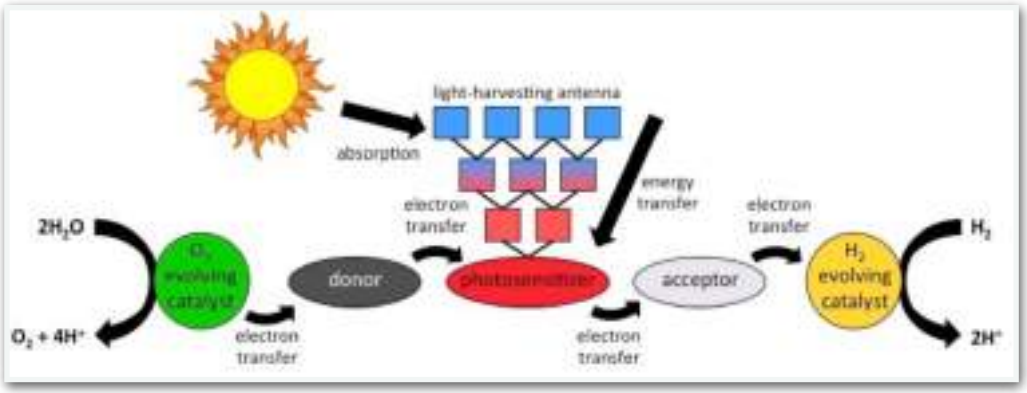
- Photosynthetic organisms do not rely on a single pigment to absorb light, but instead on a combined action of many
- These photosynthetic pigments are grouped into photosystems (absorb and funnel light energy)
- In this way the cell maximises its light absorption
- When a pigment is energised by light it releases high energy electrons (ionisation)
- Antenna pigments —> transfer energised electrons to a central reaction centre —> than electrons are passed on to an acceptor molecule in an ETC to synthesise ATP
- Accessory pigments presence explains why not all leaves are green
  —> other pigments may produce different colours than green
  —> deciduous trees change colour when leaves stop producing chlorophyll in winter

C3, C4 and CAM plants

- C3 plants —> plants that fix carbon dioxide directly from the air
- Rubisco can also use oxygen as an alternative substrate —> photorespiration
- Photorespiration reduces levels of photosynthesis by up to 25% in C3 plants
- Oxygen act as a competitive inhibitor for rubisco
- In hot and arid conditions plants have evolved to limit exposure of rubisco to oxygen
- C4 and CAM plants use the enzyme PEP carboxylase to combine CO_2 to a 3C compound
- PEP carboxylase has a higher affinity for CO_2 than rubisco and doesn't bind to oxygen
- C4 pathway —> CO_2 is physically separated from oxygen to improve the binding to Rubisco
  —> it is brought to a deeper tissue layer and is released (less oxygen present)
- CAM pathway —> CO_2 reserves are created to improve binding to Rubisco
  —> the CO_2 reserves created during the night are used during the day when stomata must remain closed to avoid water loss

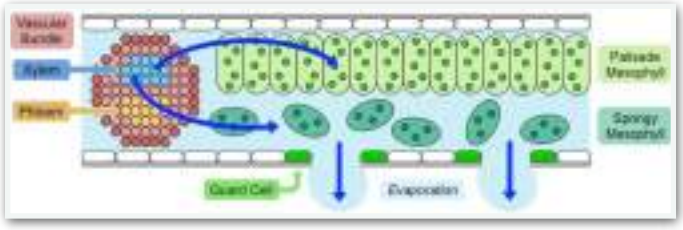
GAP project:

- Global Artificial Photosynthesis Project —> an international venture aimed at copying the natural process of photosynthesis in order to develop more efficient solar energy harvesting tech.
- Artificial photosynthesis —> aimed to produce clean energy with heat the only product released
    —> involves constructing systems that will undertake three key steps:
        —> harvest light energy
        —> transduce this energy to electrons
        —> use redox reaction to generate chemical fuel resources



Chapter 9 —> Plant biology

8.1 Xylem transport



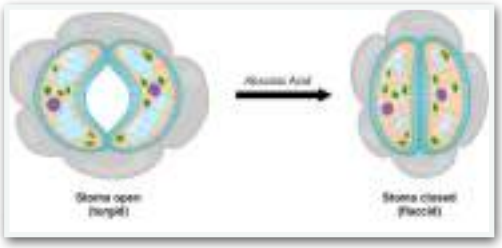
Transpiration:

- The loss of water vapour from the semi and leaves of plants
- An inevitable consequence of gas exchange in the leaf

1) light energy converts water in the leaves in vapour —> evaporates within the spongy mesophyll via the stomata —> creates a negative pressure gradient within the leaf
2) The negative pressure creates a tension force in leaf cell walls —> draws water from the xylem —> water is pulled from the xylem under tension due to the adhesive attraction water has
3) New water is absorbed from the soil by the roots —> difference in pressure created
4) Water flows via the xylem along the pressure gradient (transpiration stream and pull)

- The cohesive property of water molecules causes it to be dragged up in a continuous stream
- Adhesion makes water move up via capillary action —> pull inward on the xylem walls

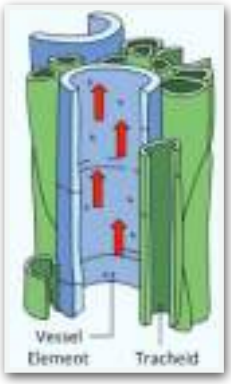
Stomata:

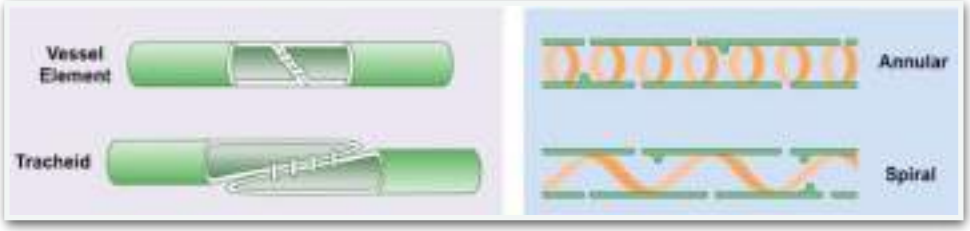


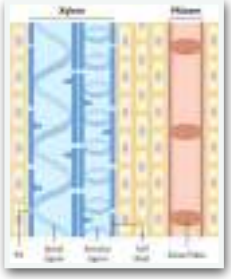
-Pores on the underside of the leaf which facilitate gas exchange
-The amount of water lost from the leaves is regulated by the opening and closing of the stomata
-Abscisic acid —> triggers the efflux of potassium from guard cells —> decreases turgor —> makes the stomatal pore close as the guard cells become flaccid and block the opening
-Affected by photosynthesis, humidity, temperature, light intensity and wind

Structure of they xylem:

- Specialised structure that facilitates the movement of water throughout the plant
- Composed of a tube made of dead cells that are hollow —> free water movement
- Because cells are dead —> water movement is all passive and in one direction
- Pits —> pores in the cell wall that enable water to be transferred between cells
- Lignin —> gives support to the structure (spiral or anular)
- Xylem composition —> Tracheids and vessel elements
- Tracheids —> tapered cells that exchange water solely via pits —> slower water transfer
- Vessel elements —> end walls fused to form a continuous tube —> faster rate







Root Uptake:

- Plants take up water and mineral ions from the soil via their roots (large SA needed)
- Fibrous roots —> highly branching root system
- Tap roots —> with lateral branches —> can penetrate the soil more
- Root hairs —> cellular extensions which further increase the SA for absorption
- Materials are absorbed by the root epidermis —> they diffuse across the cortex towards a central stele —> the stele is surrounded by an endodermis layer (casparian strip) —> water and minerals are pumped across this barrier by specialised cells (allow for controlled rate of uptake)

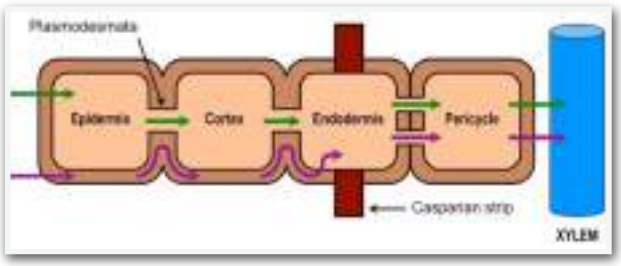
Mineral uptake:

- Fertile soil contains negatively charged clay particles —> positively charged mineral ions attach
- Minerals needed are Mg^{2+}, nitrates, Na^{+}, K^{+}, and PO_4^{3-}
- Minerals can passively diffuse into roots but mostly actively uploaded by indirect active transport

1) Root cells actively expel H^{+} ions in the soil with proton pumps
2) Ions displace the positively charge mineral ions from the clay —> diffuse into root via gradient
3) Negatively charged mineral ions bind to the H^{+} ions and are reabsorbed with the proton

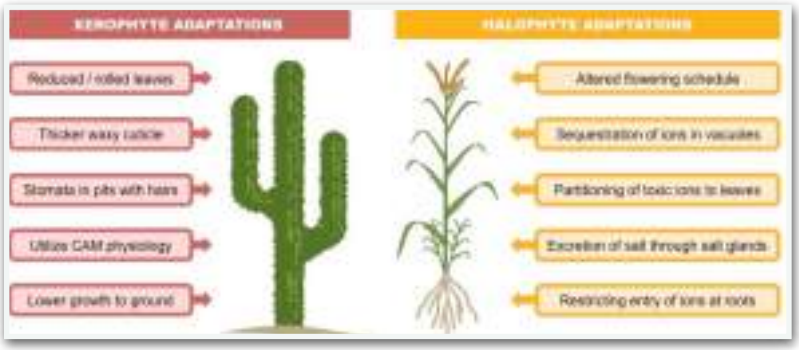
Water uptake:

- Water follows the mineral ions into the root via osmosis —> move towards higher solute conc.
- Aquaporins —> specialised water channels on the root which regulate water uptake
- Symplastic pathway —> water moves continuously through the cytoplasm of cells (plasmodesmata)
- Apoplastic pathway —> water cannot cross the casparian strip —> enters cytoplasm at endodermis



Water conservation:

- Xerophytes —> plants that grow in high salinity
- Halophytes —> possess various adaptations for water conservation



Plant experiments:

Capillary tubing:

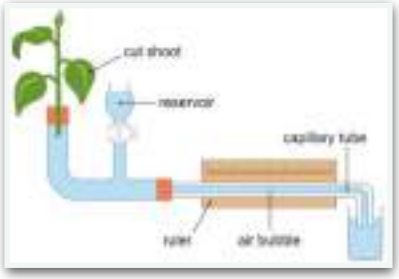
- Water has the capacity to flow along narrow spaces in opposition to external forces
- Due to combination of surface tension and adhesion with the tube walls
- The thinner the tube / less dense the fluid —> the higher the liquid will rise

Filter paper:

- Will absorb water due to both adhesive and cohesive properties
- The paper is composed of cellulose

Porous Pots:

- Semi-permeable container that allow for free passage of certain small materials through pores
- The water loss creates a negative pressure that draws more liquid upwards



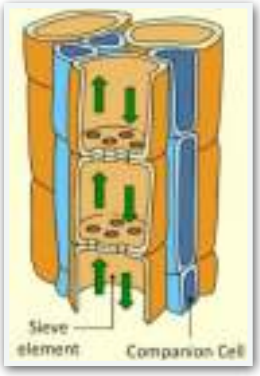
Potometer:

-Can be used to test a number of variables that may affect the rate of transpiration in plants

-Variable : Temperature, humidity, light intensity and wind exposure

---

9.2 Phloem transport



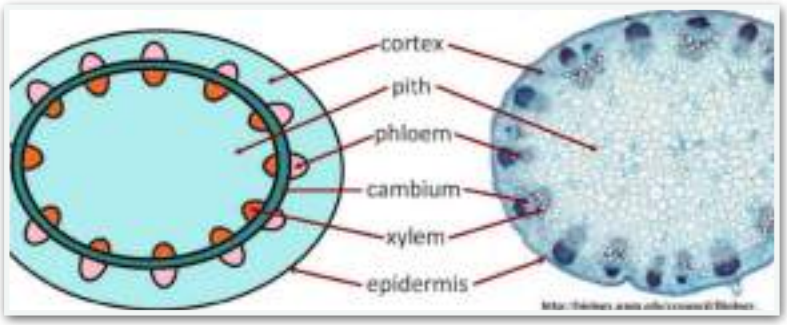
Active translocation:

- Translocation —> the movement of organic compounds from sources to sinks
- Sources —> where the compounds are synthesised (leaves)
- Sinks —> where the compounds are delivered to for use or storage (roots, fruits and seeds)
- Phloem —> vascular tube that transports the compounds from sources to sinks
- Sugars are principally transported as sucrose (soluble and metabolically inert)
- Plant sap —> nutrient-rich viscous fluid in the phloem

Phloem structure:

- Phloem sieve tubes —> mostly composed of sieve element cells and companion cells
- Sieve element cells —> long and narrow cells that are connected together to form the sieve tube
  —> connected by sieve plates which are porous
  —> have no nuclei and reduced numbers of organelles (to maximise space)
  —> have thick and rigid cell walls to withstand the hydrostatic pressure
  —> unable to sustain independent metabolic activity without companion cell
- Companion cells —> provide metabolic support for SEC and facilitate load and unload of comp.
  —> possess an infolding plasma membrane (increased SA:V ration)
  —> many mitochondria to fuel the active t. of materials at sources and sinks
  —> contain appropriate transport proteins in the plasma membrane to move materials into or out of the sieve tube
- Plasmodesmata —> large quantity between sieve elements and companion cells
  —> connects cytoplasm of 2 cells + mediate symplastic exchange of metabolites

Phloem loading:



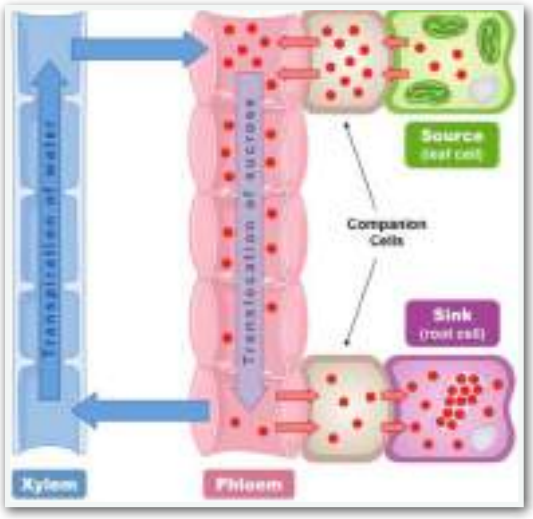
-Organic compound produced at the source are actively loaded into the phloem by companion cells

-Symplastic or apoplastic loading

-H^+ ions are actively transported out of phloem cells by proton pumps

-H^+ ions passively diffuse back into the phloem cell via a co-transport protein which requires sucrose movement

Mass flow:



At the source:

- The active transport of solutes such as sucrose makes the sap solution hypertonic —> causes water to be drawn from the xylem via osmosis (high solute concentration)
- Hydrostatic pressure increases —> due to the incompressibility of water
- The increase of hydrostatic pressure forces the phloem sap to move towards areas of lower pressure (mass flow down)

At the sink:

- The solutes are unloaded by companion cells and transported into sinks —> causes sap solution at sink to be hypotonic
- Water is drawn out of the phloem and back to the xylem by osmosis for this reason
- This ensures the hydrostatic pressure at the sink is lower than at the source
- Organic molecules at sinks are either metabolised or stored in vacuoles

Aphids:

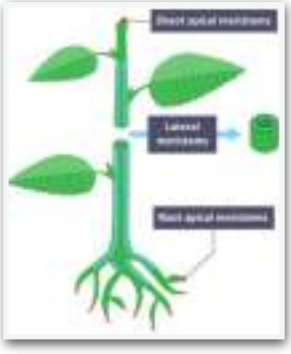
- A group of insects which feed primarily on sap extracted from the phloem
- Possess a protruding mouthpiece (stylet) —> pierces the plant's sieve tube for sap extraction
- If the stylet is severed —> sap will continue flow from the plant because of hydrostatic pressure
- Can be used to collect sap at various sites along a plant's length

1) plant given radioactively-labelled carbon dioxide
2) The leaves will convert the CO_2 into radioactively-labelled sugars
3) Aphids are positioned along the plant's length and their stylet is severed
4) The sap is analysed in search of radioactively-labelled sugars
5) The rate of phloem transport can be calculated based on the time taken for the radioisotope to be detected at different positions along the plant

---

8.3 Plant growth

Meristems:



- Tissues in a plant consisting of undifferentiated cells capable of indeterminate growth
- Are analogous to totipotent stem cells in animals
- Meristematic tissue can allow plants to regrow structures or even new plants
- Can be either apical or lateral
- Apical meristems —> occur at shoot and root tips and are responsible for primary growth
- Lateral meristems —> occur at cambium and are responsible for secondary growth

Apical growth:

- Growth is due to a combination of cell enlargement and repeated cell division
- Differentiation of the dividing meristem gives rise to a variety of stem tissues and structures
- Nodes —> were growth occurs in the stem
- Axillary buds —> have the potential to form new branching shoots with leaves and flowers

Auxins:

- Group of hormones produced by the tip of a shoot or root and regulate plant growth
- Auxin's influence cell growth rates by changing the pattern of gene expression in cells
- Auxin's mechanism of action is different in shoots and roots as different gene pathways are activated in each tissue
- Auxin efflux pumps —> can set up concentration gradients within tissues
  —> control the direction of plant growth by determining which regions of plant tissue have high auxin levels
- In the shoots auxin stimulates cell elongation, so high concentrations of auxin promote growth
- In the roots auxin inhibit cell elongation, so high concentrations of auxin limit growth

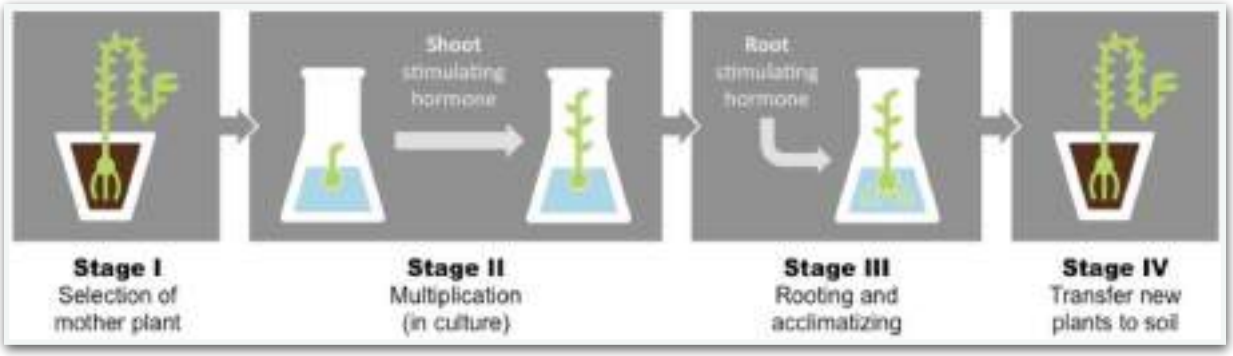
Tropisms:

- Describe the growth of a plant in response to a directional external stimulus
- Phototropism —> growth movement in response to an unidirectional light source
- Geotropism —> growth movement in response to gravitational forces
- Are both controlled by the distribution of auxin within the plant cells

Micropropagation:

- Technique used to produce large numbers of identical plants from a selected stock plant
- Vegetative propagation —> plant cutting used to reproduce asexually in the native environment
- Micropropagation —> plant tissues are cultured in the laboratory in order to reproduce asexually

1) specific plant tissue is selected from a stock plant and sterilised
2) The tissue sample is grown on a sterile nutrient agar gel with many auxins
3) The growing shoots can be continuously divided and separated to form new samples
4) Once the root and shoot are developed, the cloned part can be transferred to soil



- Rapid Bulking —> desirable stock plants can be cloned to conserve fidelity to selected charact.
  —> more reliable than selective breeding as new plants are genetically identical
- Virus-free strains —> viruses spread in infected plants via the vascular tissue (no in meristems)
  —> allows for rapid reproduction of virus-free strains
- Rare species —> used to increase numbers of rare or endangered plant species
  —> also used to increase numbers of species difficult to breed sexually (orchids, …)

9.4 Plant reproduction

- Types of reproduction for plants are —> Vegetative propagation, Spore formation, Pollen transfer

Pollen transfer:

Pollination:
- The transfer of pollen grains from an anther to a stigma
- Many plants possess both parts —> can self-pollinate or cross-pollinate (more genetic diversity)

Fertilisation:
- The fusion of a male gamete nuclei with a female gamete nuclei to form a zygote
- The male gamete is stored in the pollen grain and the female gamete is found in the ovule

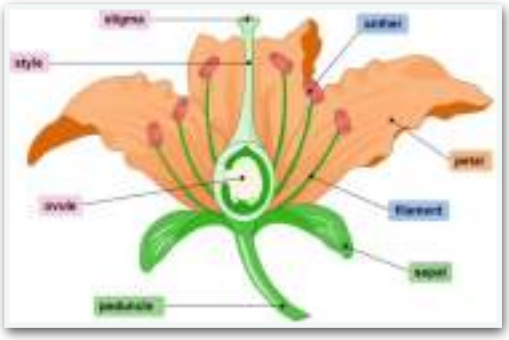
Seed dispersal:
- Fertilisation results in the formation of a seed —> moves away from the parental plant
- Seed dispersal reduces competition for resources between the seed and the parental plant
- Can be done throughout wind, water, fruits and animals

Cross-pollination:
- Transferring pollen grains from one plant to the ovule of a different plant
- Can be done by wind or water but animals are more common
- Mutualistic relationship —> both species benefit from the interaction (bees and plants)

Flowering:

- Flowers are the reproductive organs of angiospermophytes (flowering plants) —> develop from shoot apex
- Changes in gene expression trigger the enlargement of the shoot apical meristem —> the tissue differentiates to form the different flower structures (spells, petals, stamen and pistil)
- The activation of genes responsible for flowering are influence by abiotic factors
  —> amount of pollinator levels
  —> photoperiodism

Flower structure:



-Male part of the flower —> stamen and is composed by the anther and the filament
-Female part of the flower —> pistil and is composed by the ovule, the stigma and the style

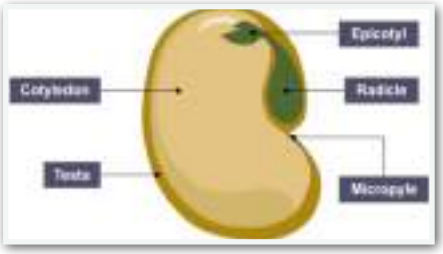
Photoperiodism:

- Phytochromes —> leaf pigments which are used by plants to detect periods of light and darkness
- Critical factor responsible for flowering are the length of light and dark periods
- Photoperiodism —> the response by the plant to the relative lengths of light and darkness

- Only Phytochrome far red is capable of causing flowering
- Plants can be classed as short-day or long-day plants, but night length is the critical factor

- Short-day plants —> flower when the days are short —> night period to exceeds critical factor —> P_{fr} inhibits flowering —> flowering requires low levels of P_{fr}
- Long-day plants —> flower when the days are long —> night period is less than critical factor —> P_{fr} activates flowering —> flowering requires high levels of P_{fr}
- Horticulturalists —> manipulate the flowering of short and long-day plants by controlling light

Seed structure:



-Testa —> outer seed coat —> protects the embryo
-Micropyle —> small pore for water passage
-Cotyledon —> contains food stores and form embryonic leaves
-Plumule (epicotyl)—> the embryonic shoot
-Radicale —> the embryonic root

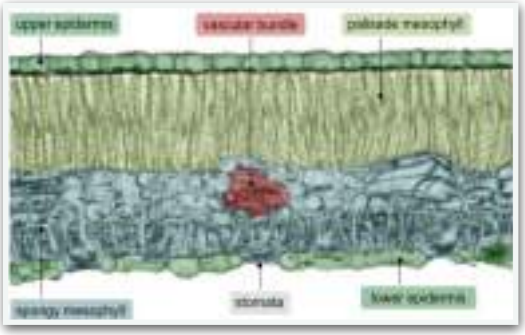
Germination:

- The process by which a seed emerges from a period of dormancy and begins to sprout
- Oxygen, Water, Adeguate temperature, Adeguate pH are required for germination to occur
- Additional conditions are: Fire, Freezing, Digestion, Watching, Scarification

---

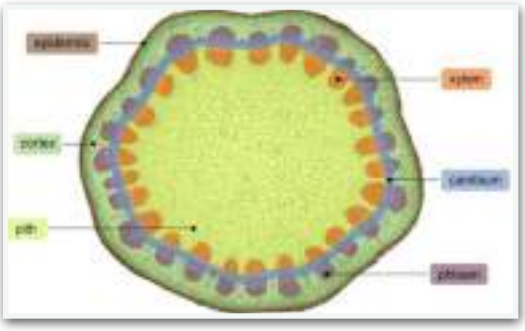
Leaf tissue:

- Palisade mesophyll —> the site of photosynthesis —> located on the upper surface of the leaf
- Spongy mesophyll —> the main site of gas exchange —> located on the lower surface of the leaf
- Stomata —> are on the underside of the leaf —> keeps open channel for gas exchange
- Waxy cuticle —> prevents water absorption (would affect transp.)—> top thick surface of leaf
- Vascular bundles —> (xylem and phloem) —> located centrally for optimal access by leaf cells



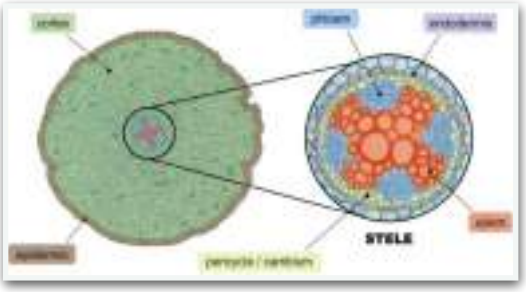
Stem tissue:

- Epidermis —> covers the outer surface and functions to waterproof, protect the stem and control gas exchange
- Cortex and pith —> found internally and assist in the transport and storage of materials within the stem
- Cambium —> circular layer of undifferentiated cells responsible for lateral growth of the stem
- Vascular bundles —> arranged in bundles near the outer edge of the stem to resist compression and bending

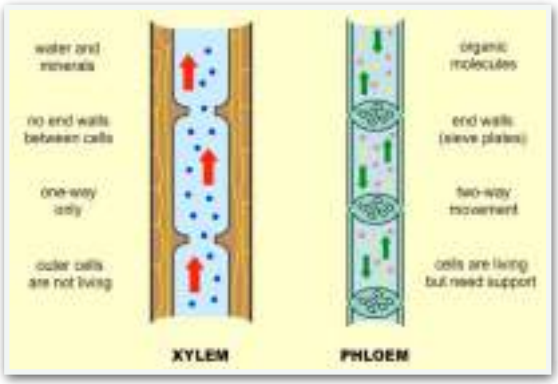


Root tissue:

- Epidermis —> may have protrusions called root hairs to increase available surface area for material exchange
- Stele —> central region surrounded by an endodermis with a Casparian strip (controls water transport)
- Pericycle / cambium —> provides strength to the root and is responsible for the development of lateral roots
- Vascular bundle —> located centrally to withstand stretching forces and allow for material transport control



Xylem vs Phloem:



Storage organs:

-A part of a plant specifically modified to store energy (e.g. carbohydrates) or water
-Usually found underground (for protection from herbivores) (due to changes to roots, leaves or stems)
-Bulbs, storage roots and tubers are common examples

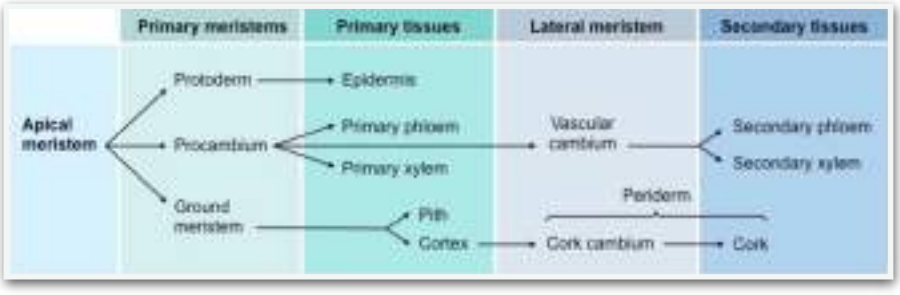
Fungal hyphae:

- Hyphae are tubular projections of multicellular fungi that form a filamentous network: mycelium
- Fungal hyphae release digestive enzymes in order to absorb nutrients from food sources

1) The hyphae penetrate into the plant's root tissue in response to chemical exudates produced by both plants and fungus
2) Within the cortical cells of the root, the hyphae forms arbuscular projections which absorb nutrients from the plant cells
3) In return, the fungus transfers minerals absorbed from the soil into the plant, so both species benefit from the interaction

Apical growth:

- Apical meristems give rise to the primary tissues needed to increase a plant's length and grow new leaves and fruits



Lateral secondary growth:

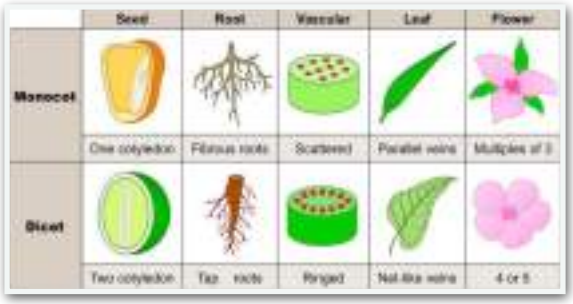
- Lateral meristems give rise to the secondary tissues needed to support an increase in the plant's width (e.g. bark)
- The thickening of a plant's stem (secondary growth) is controlled by the cambium (where lateral meristems are found)
- Growth rings can be counted to estimate the age of the plant (dendrochronology)

Plant hormones:

- Plant growth and development are controlled by plant hormones (phytohormones)
- Auxins —> promotes primary growth, cell elongation and increases rates of cell division
  —> promotes apical dominance —> tip of a plant grows while the lateral buds do not
  —> concentrations may change in response to directional stimuli
- Cytokinins —> promote cell division (cytokinesis) and ensure roots and shoots grow at same rate
  —> promotes secondary growth (thickening) and help control branching rate of plant
  —> are also involved in stimulating the growth of fruit
- Gibbellerins —> trigger germination in dormant seeds (initiates plant growth)
  —> causes stem elongation by promoting cell elongation and cell division
- Ethylene —> gas —> acts as plant hormone and stimulates maturation and ageing (senescence)
  —> responsible for the ripening of certain fruit —> opposite of gibb. and auxins
  —> contributes to the loss of leaves (abscission) and the death of flowers
- Abscisic acid —> principally functions to inhibit plant growth and development
  —> promotes the death of leaves (abscission) and is responsible for seed dormancy
  —> generally initiates stress responses in plants (ex. winter dormancy)
  —> controls the closing of stomata and hence regulates water loss in plants

	Germination	Growth to Maturity	Flowering	Fruit Development	Abscission	Seed Dormancy
Gibberellin	✓	✓	✓	✓	✗	✗
Auxin	✗	✓	✓	✓	✗	✗
Cytokinins	✗	✓	✓	✓	✗	✗
Ethylene	✗	✗	✓	✓	✓	✗
Abscisic Acid	✗	✗	✗	✗	✓	✓

Monocotyledons vs Dicotyledons:



Germination stages:

1) Metabolic activation of a dormant seed
- Germination begins with the absorption of water, which causes gibberellin to be produced
- Gibberellin triggers the synthesis of amylase, which breaks down starch into maltose
- Maltose is either hydrolysed (to glucose) for energy, or polymerised (to cellulose) for cell wall—> used to promote cell division and the growth of a nascent shoot

2) Once the seed is metabolically activated, germination proceeds according to the following stages:
- The seed coat (testa) ruptures and the embryonic root (radicle) grows into the ground to extract key nutrients and minerals
- The cotyledon emerges and produces the growing shoot's first leaves
- The growing plant can be divided into the epicotyl (embryonic shoot), hypocotyl (embryonic stem) and developing roots

Chapter 10 —> Genetics

11.1 Meiosis

Interphase:

- Period preceding meiosis and involves events needed to prepare the cell for successful division
- DNA replicated in S phase —> results in chromosomes that contain two identical DNA strands
  —> sister chromatids —> the genetically identical strands —> centromere holds them
  —> separate during meiosis II —> become independent chromosomes
- If DNA replication did not occur there would be no need for 2 meiotic divisions —> benefit is that increases genetic recombination that occurs
- Interkinesis —> may occur between meiosis I and II, but no DNA replication occurs

Stages of meiosis:

Meiosis I:

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

Meiosis II:

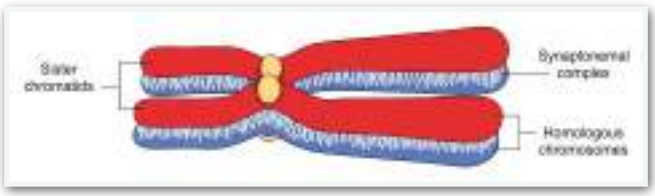
- P II —> chromosomes condense, nuclear membrane dissolves, centrosomes move to opposites
- M II —> spindle fibres from opposing centrosomes attach to chrom. and align at the equator
- A II —> spindle fibres contract and separate the sis chromatids bringing them to opposites
- T II —> chromosomes decondense,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

Random assortment:

- Independent assortment describes how pairs of alleles separate independently from one another during gamete formation —> gene inheritance is independent from other genes
- Due to the random orientation of homologous chromosomes in meiosis I —> metaphase I
- Independent assortment won't occur if two genes are on the same chromosome (linked genes)

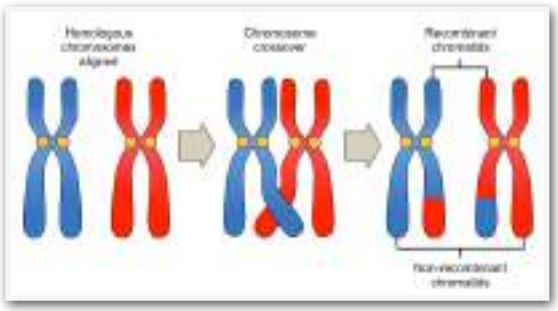
Chiasmata:

- Synapsis —> when homologous chromosomes become connected —> during prophase I
  —> bivalent —> two chromosomes or tetrad —> four chromatids



- Synaptonemal complex —> protein-RNA complex that connects chromosomes
- Chiasmata —> where non-sister chromatids remain physically connected at —> hold hom. chromosomes together as a bivalent until anaphase I
  —> forms as a result of crossing over and non-sister chromatids can show an exchange of genetic material

Crossing over:



- DNA can be exchanged between non-sister homologous chromatids —> if it happens the chromosomes become recombinant chromosomes
- Produces new allele combinations on the chromosomes
- Increases the genetic diversity of potential offsprings

10.2 Inheritance

Dihybrid crosses:

- Determines the genotypic and phenotypic combinations of offspring for two unlinked genes
  —> four different gamete combinations
- The independent segregation of unlinked genes results in a greater number of potential gamete combinations, as well as a greater variety of possible phenotypes
- Dihybrid cross formation:
  1) Designate characters to represent the alleles
  2) Write down the genotype and phenotype of the parents (P generation)
  3) Write down all potential gamete combinations for both parents
  4) Use a Punnett square to work out potential genotypes of offspring
  5) Write out the phenotype ratios of potential offspring

Linked genes:

- A linkage group is a group of genes whose loci are on the same chromosome and hence don't independently assort —> tend to be inherited together
  —> phenotypic ratio similar to a monohybrid cross
  —> may become separated via recombination —> due to crossing over
- Thomas Hunt Morgan —> proved that linked genes were not independently assorted
- Sex linkage —> clear bias in phenotypic distribution —> may be X-linked
- Gene linkage —> certain phenotypic combinations occurred in much lower frequencies than was to be expected —> due to —> alleles for these traits were located on a shared chromosome
  —> linked alleles could be uncoupled via recombination
- The amount of crossing over between linked genes differed depending on traits combination
  - Crossover frequency may be a product of the distance between two genes on a chromosome
  - The further apart, the higher the crossover frequency
  - Used to show the relative positions of genes on a chromosome

Recombinations:

- Results in combinations of genes not found in the parents
- The frequency of recombinant phenotypes within a population will be lower than that of non-recombinant phenotypes —> because crossing over is random and chiasmata do not form at the same locations with every meiotic division

- The relative frequency of recombinant phenotypes will be dependent on the distance between linked genes —> more possible locations where a chiasma could form between the genes when they are more apart
- Recombinant phenotypes can be identified by performing a test cross (crossing with a homozygous recessive for both traits)

Chi Squared Test:

- Offspring with unlinked genes have an equal possibility of inheriting any potential phenotypic combination
- Offspring with linked genes will only express the phenotypic combinations present in either parent unless crossing over occurs —> 'unlinked' recombinant phenotypes occur less frequently
- Are a statistical measure that are used to determine whether the difference between an observed and expected frequency distribution is statistically significant
- If observed frequencies are not as expected for unlinked dihybrid cross:
  —> genes are linked —> do not independently assort
  —> inheritance of traits not random —> affected by natural selection

1) Identify hypotheses (null versus alternative)
2) Construct a table of frequencies (observed versus expected)
3) Apply the chi-squared formula —> $\chi^2 = \sum \frac{(O-E)^2}{E}$
4) Determine the degree of freedom (df) —> df = (m - 1)(n - 1) —> m = n. rows , n = n. columns
5) Identify the p value (should be <0.05)

Polygenic traits:

- Variation in phenotypes for a particular characteristic can be either discrete or continuous
- Monogenic traits —> (characteristics controlled by a single gene loci) tend to exhibit discrete variation —> individuals express one of a number of distinct phenotypes
- Polygenic traits —> (characteristics controlled by more than two gene loci) tend to exhibit continuous variation —> individual's phenotype is on of a spectrum of potential phenotypes
  —> More number of loci responsible for trait more possible phenotypes
  —> follow Gaussian distribution —> bell shape
- Maize grain colour —> example of polygenic trait —> controlled by three gene loci
  —> each gene has two possible alleles

- Phenotypic characteristics aren't only determined by genotype, but also environmental factors
- Human height is controlled by multiple genes —> Environmental factors such as diet and health (disease) can further influence an individual human's height
- Skin colour is controlled by multiple melanin producing genes, but is also affected by factors such as sun exposure

---

10.3 Speciation

Evolution:

- Gene pools —> the sum total of alleles for all genes present in a sex reproducing population
  —> if large, high genetic diversity and chances of biological fitness and survival
  —> if small, low genetic diversity, reducing biological fitness, more chances of extinction

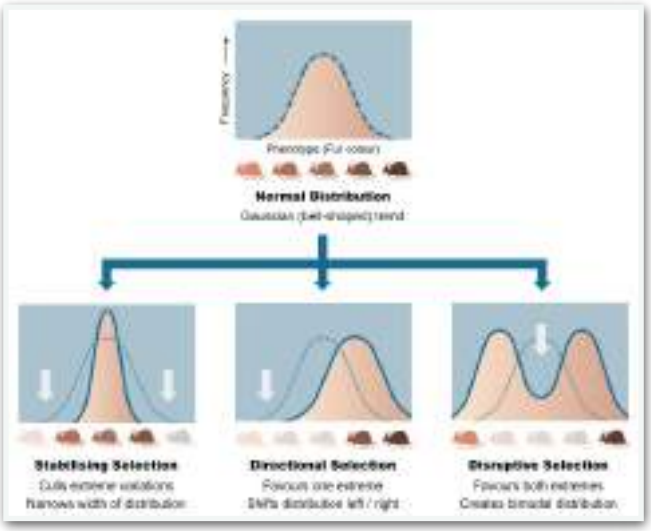
- Can be used to determine allele frequency within a population
- Evolution —> the cumulative change in the heritable characteristics of a population across successive generations —> allele frequencies change
- Mechanisms of change —> mutation —> random change in the genetic composition
  —> gene flow —> immigration or emigration affecting alleles
  —> sexual reproduction —> new gene combinations
  —> genetic drift —> change in gene pool composition —> random event
  —> natural selection —> as a result of different environmental pressures

Allele distribution:

- Genetic drift —> change in composition of a gene pool as a result of chance or random events
  —> smaller populations will be more affected by event
- Allele frequencies change significantly when a large population is reduced to a small population
  —> occurs due to two mechanisms —> population bottlenecks and founder effect

Population bottlenecks:
- Occur when an event reduces population size by an order of magnitude (~ >50%)
- May result from natural occurrence (fires, …) or be human induced (overhunting, …)
- Results in a higher level of genetic drift and newly developing gene pool will be different from the original

Founder effect:
- Occurs when a small group breaks away from a larger population to colonise a new territory
- Subject to more genetic drift as smaller population —> gene pool will change accordingly
- Original population remains largely intact —> differently from population bottlenecks



Types of selection:

-Natural selection —> the change in the composition of a gene pool in response to a differentially selective environmental pressure

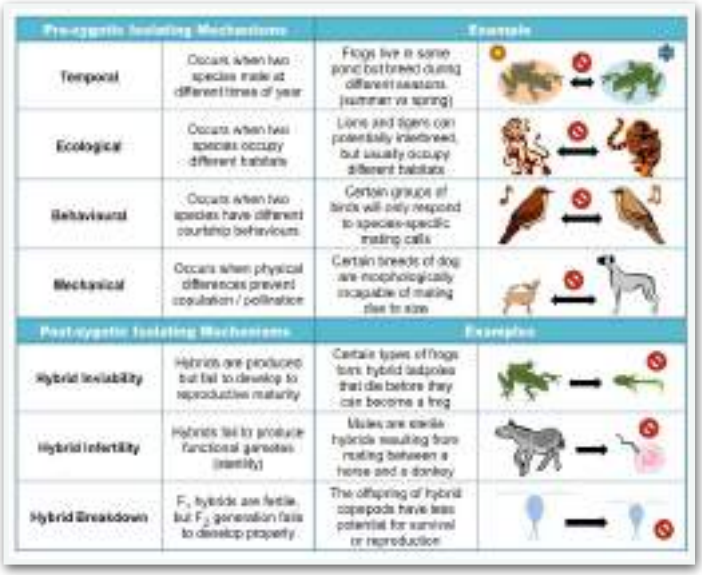
-**Stabilising selection —>** an intermediate phenotype is favoured at the expense of both phenotypic extremes
  —> results in the removal of extreme phenotypes
  —> env. conditions are stable + low competition

-**Directional selection —>** one phenotypic extreme is selected at the cost of the other phenotypic extreme
  —> phenotypic distribution shifts in one direction
  —> in response to changes in env. conditions
  —> typically followed by stabilising selection

- **Disruptive selection —>** phenotypic extremes favoured at expense of intermediate phenotypes
  —> results in a bimodal spread
  —> occurs when fluctuating env. conditions (e.g. seasons) favour two different phenotypes
  —> separation may eventually split the population into two distinct species —> speciation

Isolation barriers:

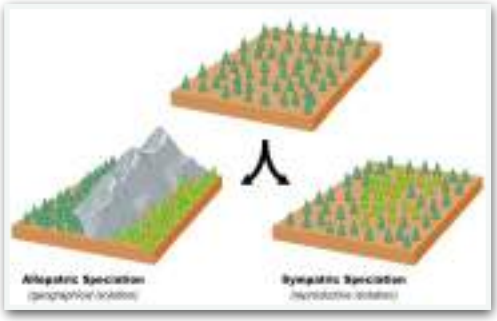
- Reproductive isolation —> when barriers prevent two populations from interbreeding
  —> pre zygotic isolation —> before fertilisation —> no offspring
  —> post zygotic isolation —> after fertilisation —> offspring infertile



Pre zygotic isolation:

- Temporal —> when two populations differ in their periods of activity or reproductive cycles
- Behavioural —> when two populations exhibit different specific courtship patterns
- Geographical —> when two populations occupy different habitats within a common region

Speciation:



- Evolutionary process that results in the formation of a new species from a pre-existing species
- Occurs when reproductive isolating mechanisms prevent two breeding organisms from producing fertile, viable offspring —> can be allopatric or sympatric

Allopatric speciation:

- Occurs when a geographical barrier physically isolates populations of an ancestral species
- Populations begin to evolve separately due to cumulative mutation, genetic drift and natural sel.
- Eventually populations won't be able to interbreed no more

Sympatric speciation:

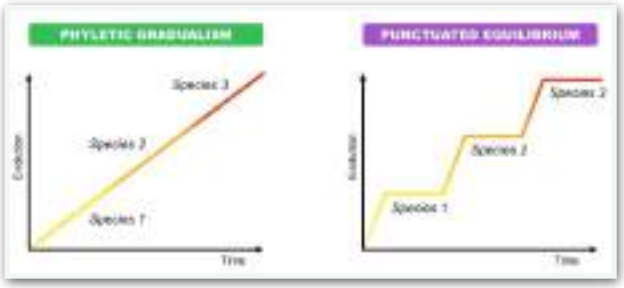
- The divergence of species within the same geographical location (i.e. without a physical barrier)
- May result from the reproductive isolation of two populations as a result of genetic abnormalities
- Chromosomal error may arise + prevent successful reproduction with organisms lacking the error
- Most commonly caused by meiotic failure during gamete formation —> can cause polyploidy

- Polyploidy —> meiotic cells fail to do cytokinesis, chromosomal number doubles in gamete
- Fertile polyploid offspring will typically require two polyploid parents —> if not it will result in an uneven number when forming gametes
- More common in plants as they lack separate sexes, can reproduce asexually and self fertilise
  —> polyploid crops —> allow for the production of seedless fruits
  —> typically grow larger, live longer and are disease resistant
- Gene allium —> monocotyledonous flowering plants and includes onions
  —> many of these species are polyploid —> resulted in distinct phenotypes

Pace of speciation:

- Evolution occurs both within a species (microevolution) and across the species barrier (macroevolution = speciation)
- Via speciation may occur by two models: phyletic gradualism or punctuated equilibrium

Phyletic gradualism:
- Generally occurs uniformly, via the steady and gradual transformation of whole lineages
- Speciation is seen as a smooth and continuous process —> fossil record of the horse is a proof



Punctuate equilibrium:
- Species remain stable for long periods before undergoing abrupt and rapid change (speciation)
- Speciation seen as periodic process —> supported by lack of transitional fossils for most species

---

Extra:

Meiosis vs Mitosis:

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

Stages of prophase:

- **Leptotene** —> chromosomes condense and attached to the nuclear membrane by telomeres
- **Zygotene** —> synapsis form with a synaptonemal complex between homologous chromosomes
- **Pachytene** —> crossing over of genetic material occurs between non-sister chromatids
- **Diplotene** —> synapsis ends with disappearance of synaptonemal complex; homologous pairs remain attached at chiasmata
- **Diakinesis** —> chrom. fully condensed + nuclear membrane disintegrates prior metaphase I

Mendel and meiosis:

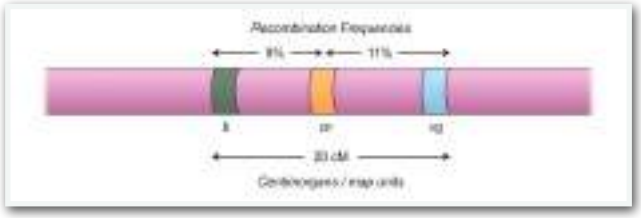
- **Law of Segregation:** Each hereditary characteristic is controlled by two alleles which separate into different gametes

- **Law of Independent Assortment:** The separation of alleles for one gene is independent to allele separation for another gene
- **Principle of Dominance:** In pairs of alleles that are different, one allele will mask the effect of the other allele
- Exceptions —> linked genes will not undergo independent assortment
  —> not all genes display a dominance hierarchy —> codominance, …

Test cross:

- Involves mating an unknown genotypic individual with a known homozygous recessive
  —> as recessive alleles are masked by dominant alleles
  —> phenotype of any offspring will reflect genotype of unknown parent
- Also used to determine if two genes are linked or unlinked —> mate with known heterozygote
  —> if equal ratio of the four potential phenotypes —> two genes are likely unlinked
  —> if two phenotypes in high amounts and two phenotypes in low amounts (recombinants), the two genes are likely linked

Centimorgan:



- Unit of measure used to approximate the distance between genes —> 1 map unit = 1% recombination *f*
- No longer used to measure distance —> Genome mapping allowed scientists to determine specific distances between genes in kilo bases (kb)
- Thomas Morgan demonstrated that genes that were further apart on a chromosome were more likely to recombine —> more potential sites for crossing over to occur between distant genes

Species caveats:

- Members of a species are unable to produce fertile, viable offspring different species
- Certain organisms do not reproduce sexually but can transfer genetic material via plasmids
- Breeding capacity unestablished —> no contact between populations
  —> no living representatives
- May be physically impossible for certain members of the same species to interbreed
- Ring species —> species spread around an area to form interlinked populations, but population ‘ends’ cannot interbreed

Allopolyploidy:

- Autopolyploidy occurs when a polyploid offspring is derived from a single parental species
- Allopolyploidy occurs when a polyploid offspring is derived from two distinct parental species
- Allopolyploids are more prevalent than autopolyploids as they do not show polysomic inheritance and have better fertility rates

Extinction:

- The total cessation of a species or higher taxon level —> reduces biodiversity
- Phyletic extinction —> results gradually —> organisms progressively evolve into something else
- Abrupt extinction —> species may not leave any identifiable descendants and cease to exist

- Caused by —> habitat degradation, predation, disease, natural disaster, …
  —> over 99% of species that have ever existed on Earth are now extinct
- Mass extinction events —> categorised by an unusually high number of species dying out in a relatively short period —> 5 to this moment

Polymorphisms:

- The occurrence of two or more clearly different phenotypes within same population of a species
- Are the individual components of a trait —> involve more than one allele for any given gene
- Transient poly. —> when there are two alleles in the gene pool, and one is replacing the other
  —> due to a strong environmental pressure causing directional selection
- Balance poly. —> when two alleles in the gene pool have non-changing frequencies of the alleles
  —> due to selective pressures promoting the coexistence of two alleles

Hardy-Weinberg principle:

- To predict the frequency of two alternate alleles within a population
- For two alleles —> possible genotypes are AA, Aa, aa —> A with frequency p and a with q
- Total frequency of both alleles will be 100 % —> $p + q = 1$
- Equation must be squared as genotypes have two alleles each —> $(p + q)^2$
- Population must be large and with random mating
- No mutation or gene flow must be present
- No natural selection or allele-specific mortality

Chapter 11 —> Animal physiology

11.1 Self versus Non-self

- The immune system can distinguish between body cells (self) and foreign materials (non-self)
- It will react to the presence of non-self —> immune response eliminates material from the body
- All nucleated cells of the body have unique + distinctive surface molecules that identify it as self
  —> self makers are called Major histocompatibility complex molecules (MHS class 1)
  —> they act as identification tags —> the immune system will not react to those cells
  —> they are genetically determined markers
- Antigen —> any substance that is recognised as foreign + triggers a immune response (non-self)
  —> are recognised by lymphocytes which bind to and detect the epitope
  —> lymphocytes trigger antibody production (adaptive immunity) —> antibodies specifically bind to epitopes via complementary paratopes
- Epitope —> characteristic shape of an expose portion

Antigenic determinants:

- Surface markers present on foreign bodies in the blood and tissue – including bacterial, fungal, viral and parasitic markers
- Self markers of cells from a different organism (transplantation often results in graft rejection)
- Proteins in food may be rejected if not first broken down into component parts by the dig. Syst.
- Transplantation of tissues is easier when there is a very close genetic match

Red blood cells:
- Not nucleated —> do not possess the same distinctive and unique self markers as all other cells
- They possess basic antigenic markers which limit the capacity for transfusion (ABO blood syst.)

Pathogenesis:

- Disease —> any condition that disturbs the normal functioning of the body (homeostasis)
- Illness —> deterioration in the normal state of health of an organism (can be due to a disease)
- Pathogen —> an agent that causes disease —> either a microorganism, virus or prion
  —> are generally species-specific —> cause disease to particular species
  —> polio, syphilis, measles and gonorrhoea —> specifically affect human hosts
- Zoonoses —> diseases from animals that can be transmitted to humans (zoonotic diseases)
  —> rabies (dogs), certain strains of influenza (bird flu), and the bubonic plague (rats)

Disease transmission:

- Direct contact —> via physical association or the exchange of body fluids
- Contamination —> ingestion of pathogens
- Airborne —> via coughing and sneezing
- Vectors —> intermediary organisms that transfer pathogens without dev. disease symptoms

Clonal selection:

- When the body is challenged by a foreign pathogen it will respond with both a non-specific (macrophages) and a specific immune reaction
- Macrophages engulf pathogens non-selectively and break them down internally —> some of them (dendritic cells) will show the antigenic fragments of the pathogen to specific lymphocytes
- The body contains millions of different T lymphocytes and B lymphocytes —> each recognise a single specific antigen
- Polyclonal activation —> pathogens typically contain multiple distinct antigenic fragments on their surface —> likely stimulates several different T and B lymphocytes

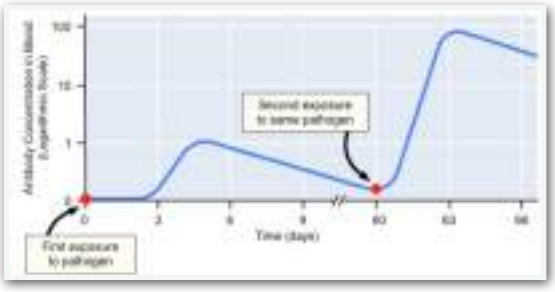
1) the antigenic fragments are presented to specific helper T lymphocytes which when activated release cytokines
2) cytokines stimulate a specific B cell that produces antibodies to the antigen to divide + clone
3) most clones are short-lived plasma cells that produce large quantities of specific antibody
4) a small proportion will differentiate into long-lived memory cells —> long-term immunity

Antibodies:

- When a specific B lymphocytes is activated, it decides into plasma cells and memory cells
- Plasma cells —> short-lived and secrete many antibodies specific to a particular antigen
  —> will secrete 2000 antibody molecules per second into blood for 4/5 days
- Antibodies aid in the destruction of pathogen by:
  —> precipitation —> soluble pathogens become insoluble and precipitate
  —> agglutination —> cellular pathogens become clumped for easier removal
  —> neutralisation —> antibodies may occlude pathogenic regions
  —> inflammation —> may trigger an inflammatory response within the body
  —> complement activation —> complement proteins perforate membranes (cell lysis)
- Antibodies enhance the immune system by aiding the detection and removal of pathogens by the phagocytic leukocytes of the innate immune system —> the constant region of antibodies can be recognised by macrophages, improving opsonisation (pathogen identification)

Immunity:

- The adaptive immune system relies on clonal expansion of plasma cell to produce antibodies
- There is a delay between the initial exposure to a pathogen and the production of antibodies —> if pathogens can reproduce rapidly during this delay period, they can impede normal body functioning —> can cause a disease
- Memory cells are produced to prevent this delay in subsequent exposures and hence prevent disease symptoms



Allergens:

- An environmental substance that triggers an immune response despite not being intrinsically harmful —> response tends to be localised to the region of exposure
- Anaphylaxis —> severe allergic reaction which can be fatal if left untreated

- An allergic reaction requires a pre-sensitised immune state
- When a specific B cell first encounters the allergen, it differentiates into plasma cells and makes large quantities of antibody (IgE) —> the IgE attach to mast cells —> upon re-exposure, the IgE-primed mast cells release large amounts of histamine which causes inflammation
- The inflammatory response results in allergic symptoms —> redness, heat, swelling and localised pain

Vaccination:

- Vaccinations induce long-term immunity to specific pathogenic infections by stimulating the production of memory cells
- Vaccine —> a weakened form of the pathogen containing antigens (does not result in a disease)
- The antigenic determinants in a vaccine may be conjugated to an adjuvant —> functions to boost the immune response
- The body responds to an injected vaccine by initiating a primary immune response —> results in memory cells being made —> when exposed to the actual pathogen they will trigger a stronger secondary immune response —> disease symptoms do not develop
- Memory cells may not survive a lifetime and individuals may require a booster shot

- Herd immunity —> vaccination confers immunity to vaccinated individuals but also indirectly protects non-vaccinated individuals
- Vaccinations programmes are implemented to reduce the outbreak of particular infectious diseases within population
- Epidemic —> substantially increased occurrence of a particular infection within a given region
- Pandemic —> an epidemic that has spread across a large geographical area

- Smallpox —> first infectious disease of humans to have been eradicated via vaccination (1967)
- Eradication was successful because —> smallpox was easily identifiable due to overt symptoms
  —> transmission only occurred via direct contact and there were no animal vectors
  —> the infection period was short lived (3/4 weeks) and the virus didn't mutate
  —> there was global cooperation and immunity was long-term
- Epidemiology —> the study of the patterns, causes and effects of health and disease condition
  —> it can be used to compare the incidence of a disease over time
  —> it can be used to compare the incidence of a disease in different regions

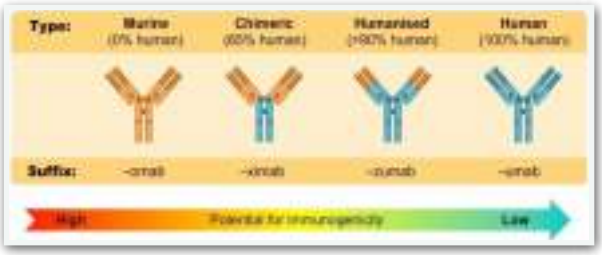
Monoclonal antibodies:

- Antibodies artificially derived from a single B cell clone
- Can be used for both therapeutic treatment (treatment of rabies) and clinical detection of disease (detection of pregnancy)

1) An animal is injected with an antigen and produces antigen-specific plasma cells
2) Plasma cells are removed and fuse (hybridised) with tumour cells capable of endless divisions
3) The resulting hybridoma cell is capable of synthesising large quantities of monoclonal antibody

Treatment use:

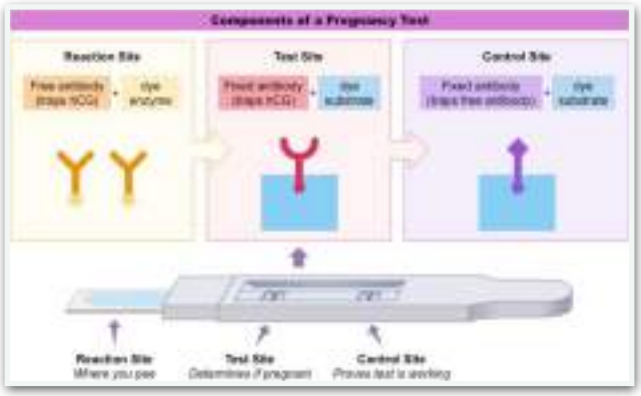
- Monoclonal antibodies are commonly used to provide immune protection for individuals who contract harmful diseases —> the rabies virus can potentially be fatal —> injecting purified antibodies functions as an effective emergency treatment



-Can be used to target cancer cells that the body's own immune cells fail to recognise as harmful
-Therapeutic monoclonal antibodies are named according to the source organism

Diagnostic use:

- Can be used to test for pregnancy via the presence of human chorionic gonadotrophin (hCG)
- hCG —> hormone produced during foetal develop.
- ELISA —> enzyme-linked immunosorbent assay —> used by test to identify a substance via a colour change —> free monoclonal antibodies specific to hCG are conjugated to an enzyme that changes the colour of a dye



11.2 Movement

Skeletal framework:

- The ability to move is controlled by a number of interacting body systems:
  —> skeletal system —> bones that act as levers + provide a structure for the muscle to pull
  —> muscular system —> muscles deliver the force required to move one bone
  —> nervous system —> delivers signals to the muscles which cause them to contract
- Skeletons are a rigid framework that function to provide support and protection for body organs
  —> internal (endoskeletons) or external (exoskeletons) —> depends on the organism
  —> endoskeletons are usually numerous bones while exoskeletons are connected segments
- Skeletons provide a surface for muscle attachment and facilitate the movement of an organism
- Ligaments —> how bones are connected to other bones
- Tendons —> how bones are connected to muscles

Joints:

- Joints —> function to maintain structural stability by allowing certain movements but not others
- Synovial joints —> capsules that surround the articulating surfaces of two bones —> 3 parts

—> joint capsule —> seals joint space and provides stability by restricting possible movement
—> cartilage —> lines the bone surface to facilitate smoother movement + absorbs shocks and distributes load
—> synovial fluid —> provides oxygen and nutrition to cartilage + acts as lubricant

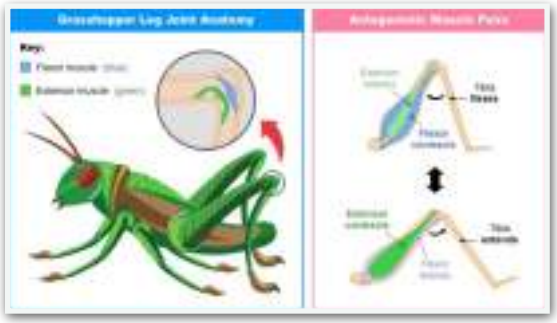
Human elbow joint:

- Hinge joint located between the humerus and radius
- Capable of angular movement in one direction

Structure	Function
Bones	
Humerus	Anchors muscle (muscle origin)
Radius	Acts as forearm lever for biceps
Ulna	Acts as forearm lever for triceps
Muscles	
Biceps	Bends the forearm (flexion)
Triceps	Straightens the forearm (extension)
Joint	
Joint capsule	Seals joint space and limits range of movement to promote stability
Synovial fluid	Provides food, oxygen and lubrication to the cartilage
Cartilage	Allows smooth movement (reduces friction), absorbs shock and distributes load

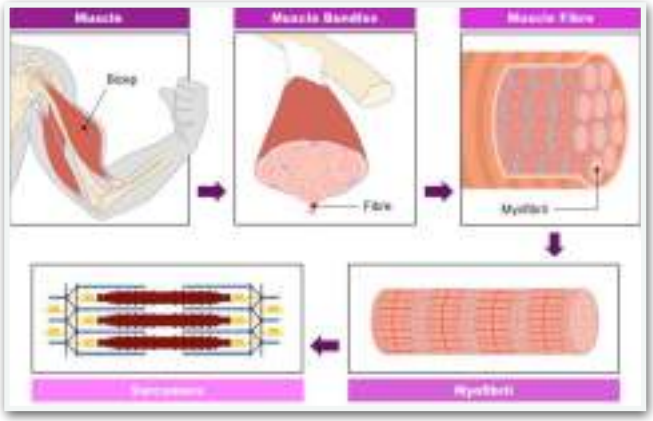
Muscles:

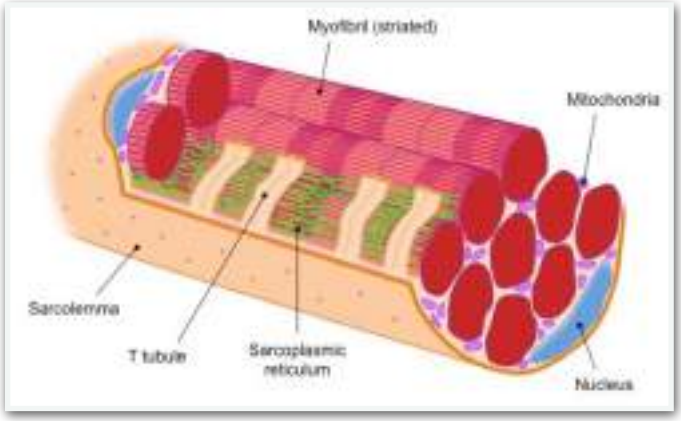
- Muscles connect bones and contract to provide the force required to produce movement
- Static bone —> where the muscle connects —> point of origin
- Moving bone —> point of insertion
- Skeletal muscles exist in antagonistic pairs (one contracts and the other relaxes)



- Many types of insects have hind legs that are specialised for jumping (grasshoppers, …)
- The jointed exoskeleton of the hind leg is divide into —> femur, tibia and tarsus

Muscle fibres:



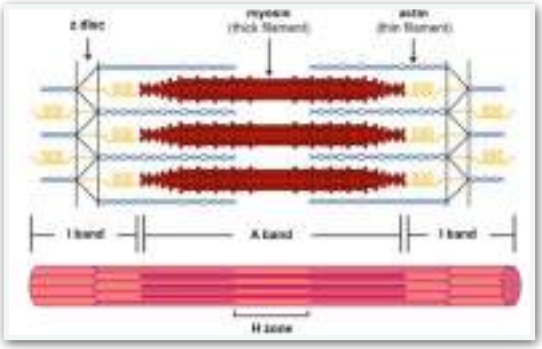


- Muscular bundles (fascicles) are surrounded by connective tissue (perimysium)
- Each individual muscle fibre has the following specialised features:
  - —> multicucleanted —> fibres form from the fusion of individual muscle cells
  - —> they have a large number of mitochondria —> for more energy
  - —> specialised endoplasmic reticulum (sarcoplasmic reticulum) —> stores calcium ions
  - —> contain tubular myofibrils made up by two myofilaments (thin actin and thick myosin)
  - —> sarcolemma —> continuous membrane surrounding the muscle fibre
  - —> T tubules —> invaginations in the sarcolemma

Sarcomeres:

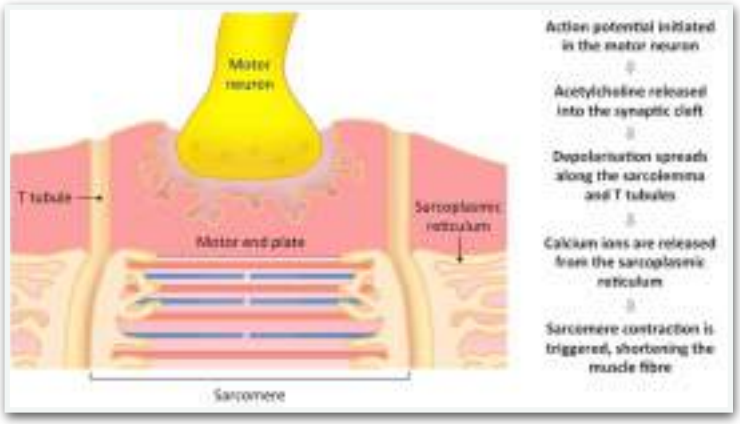
- Myofibrils consist of repeating contractile units called sarcomeres
- Are made of two protein myofilaments
- Myosin is thick and contains small protruding heads which bind to regions of the thin actin
- Movement of these two filaments relative to one another causes the lengthening and shortening of the sarcomere

- Z lines —> dense protein disc which holds the myofilaments in place
- The actin filaments radiate out from the Z discs and help to anchor the central myosin filaments in place
- The recurring sarcomeres produce a striated pattern along the length of the skeletal muscle fibres
- The I bands appear lighter than the A band



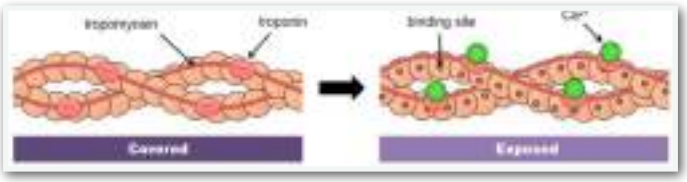
Muscle contraction:

1) Depolarisation and calcium ion release:

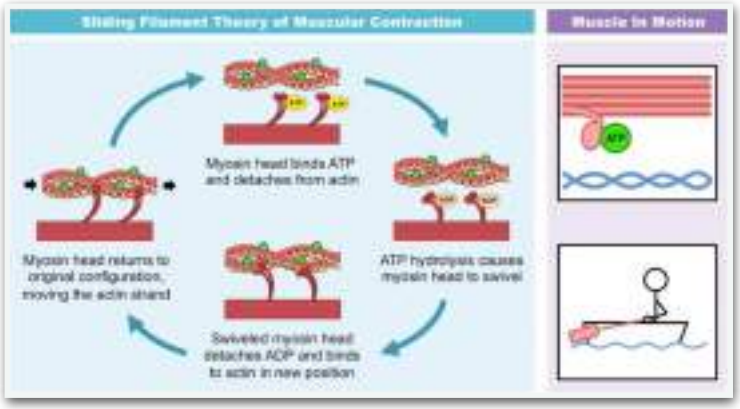


2) Actin and Myosin cross-bridge formation

- On actin, the binding sites for the myosin heads are covered by a blocking complex (troponin and tropomyosin) —> calcium ions bind to troponin and reconfigure the complex —> exposes binding sites for myosin heads
- The myosin heads then can form a cross-bridge with the actin filaments

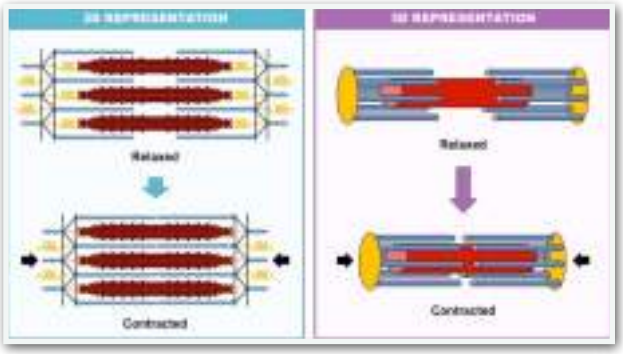


3) Sliding mechanism of actin and myosin



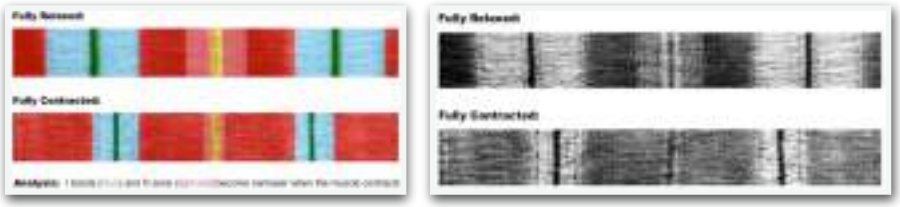
4) Sarcomere shortening

-The repeated reorientation of the myosin heads drags the actin filaments along the length of the myosin —> dragging pulls Z lines closer
- As the individual sarcomeres become shorter, the muscle fibres as a whole contract



State of contraction:

- The arrangement of myofilaments within a sarcomere give a skeletal muscle fibre a striated appearance



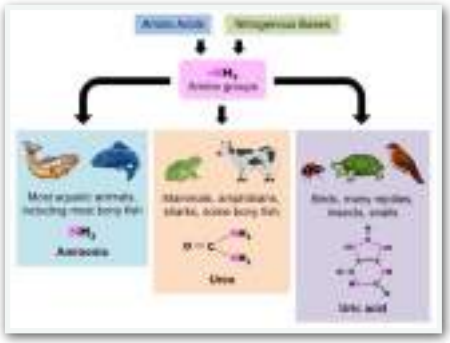
11.3 The kidney

Excretory systems:

- Excretion is the removal from the body of the waste products of metabolic activity
- Defecation is not considered part of excretion as faeces are undigested food remnants and not metabolic waste products
- Excretory system performs:
  —> removes nitrogenous wastes that may be toxic to the body if too many
  —> removes excess water to maintain a suitable osmolarity within the tissues and cells

Removing nitrogenous waste:

- Are produced from the breakdown of nitrogen-containing compounds (amino acids and nucleotides, …)
- Ammonia —> aquatic animals use it —> is highly toxic but also very water soluble
- Urea (mammals) and uric acid (reptiles and birds) —> are less toxic

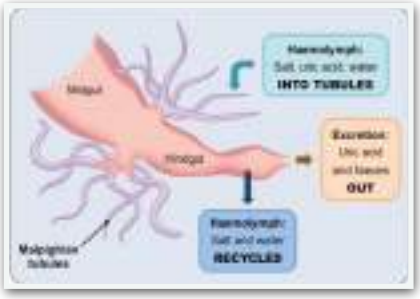


Removing excess water:

- Water levels within an organism are constantly changing as a result of metabolic activity
- Osmolarity (concentration of water within cells) will impact tissue viability
- Osmoconformers —> maintain internal conditions that are equal to the osmolarity of the environ.
  —> minimise water movement in and out of cells
  —> less energy is used to maintain internal osmotic conditions
- Osmoregulators —> keep their body's osmolarity constant regardless of conditions
  —> more energy-intensive process but optimal internal conditions

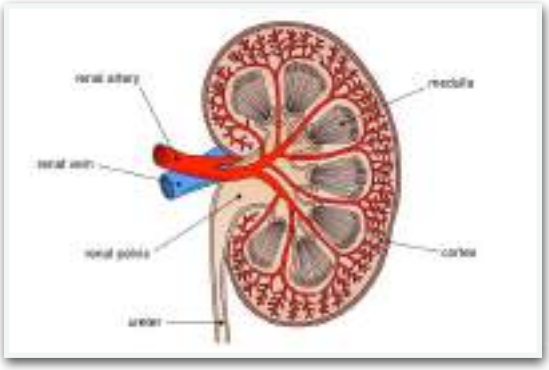
Malpighian tubules:

- All animals possess a specialised excretory system for osmoregulation and removal of nitrogen
- Malpighian tubules —> in insects —> connects to the digestive system of the animal

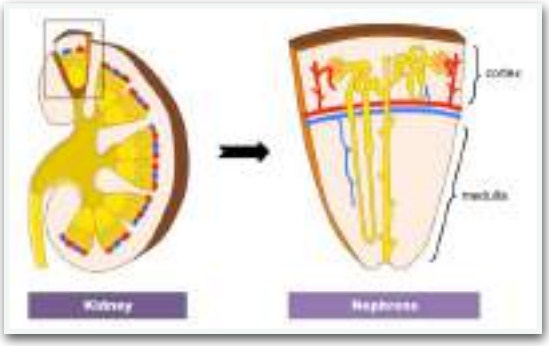


-Hemolymph —> circulating fluid in insects (as blood in mammals)
-Tubules branch off from the intestinal tract and actively uptake nitrogenous wastes and water from the hemolymph
-Tubules pass material into gut to combine with digested food products
-Solutes, water and salts —> reabsorbed into hemolymph at the hindgut, while nit. wastes and undigested food materials are excreted via the anus

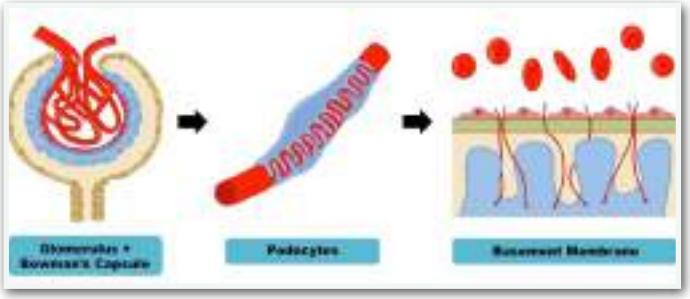
Kidneys:



- Kidneys —> in mammals —> are separate from the digestive system of the animal
- Function as blood filtration and water balancing system —> it removes metabolic wastes for excretion
- Blood enters kidneys via the renal artery and exits via the vein
- Blood is filtered by specialised structure called nephrons —> produce urine —> urine then transported away via the ureter to the bladder



- Nephrons —> specialised structures in the kidneys —> filter blood and eliminate wastes
- Blood in the renal vein will have —> less urea
  —> less water and solutes / ions
  —> less glucose and oxygen —> not eliminated but used by kidney for energy
  —> more CO_2 —> produced metabolic reactions

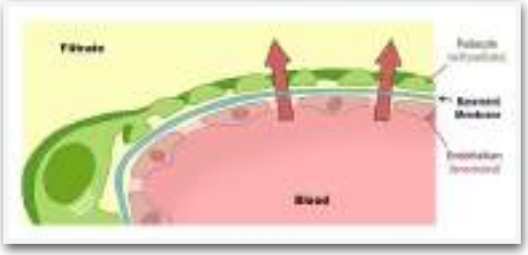


Ultrafiltration:

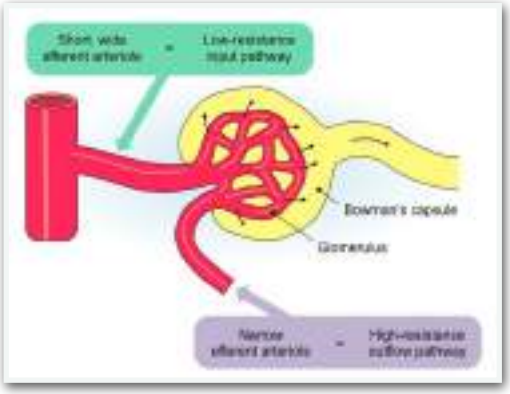
-The first of 3 processes by which metabolic wasted are separated from the blood to form urine
-Non-specific filtration of blood at high pressure —> occurs in Bowman's capsule of the nephron
-Glomerulus —> knot-like capillary tuft after the arterioles in the kidney
—> encapsulated by Bowman's capsule

- Podocytes —> inner surface of cells in the Bowman's capsule

Basement membranes:



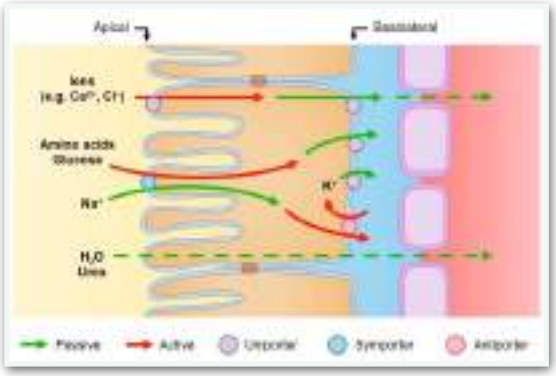
- Glycoprotein matrix between podocytes and glomerulus (filters blood)
- Glomerular blood vessels are fenestrated —> blood can exit
- The podocytes of the bowman's capsule have gaps between their pedicels —> allow fluid to move freely into the nephron
- Size-selective + restricts passage of blood cells + large proteins



Hydrostatic pressure:

-Ultrafiltration involves blood being forced at high pressure against the basement membrane
-Pressure is created in the glomerulus by having a wide afferent arteriole and a narrow efferent arteriole —> blood can easily enter the glomerulus, but difficultly exits —> increases pressure
-Extensive narrow branches in the glomerulus —> increases SA available for filtration

Selective reabsorption:



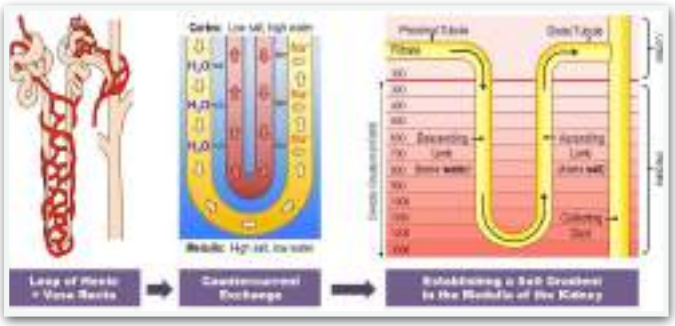
- The second of the 3 process by which blood is filtered and urine is formed
- The retake of useful substances from the filtrate and occurs in the convoluted tubules (proximal and distal) —> the majority will happen in the proximal tubule because it extends from the Bowman's capsule
- The proximal tubule has a microvilli cell lining —> to increase SA for material absorption from the filtrate
    —> tubule is a single cell thick and is connected by tight junctions —> no gaps
- Reabsorption involves active transport —> large number of mitochondria within tubules cells
- Substances are actively transported across the apical membrane, to then passively diffuse across the basolateral membrane (membrane of tubule cells facing the blood)
- The tubules reabsorb all glucose, amino acids, vitamins, hormones and water + 80% of minerals
    —> minerals ions and vitamins —> actively transported by carrier and proteins pumps
    —> glucose and amino acids —> co-transported across the apical membrane with sodium
    —> water follow the movement of the mineral ions passively via osmosis

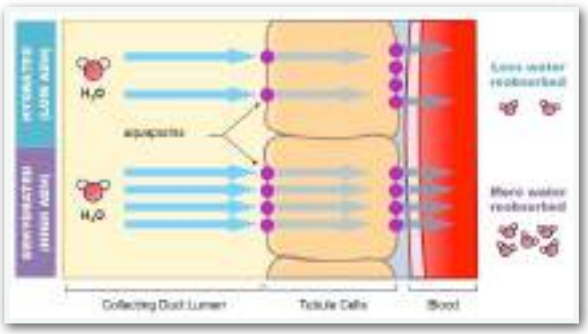
Osmoregulation:

- The third of the 3 processes by which blood is filtered and urine is formed
- The control of the water balance of the bloods, tissue or cytoplasm of a living organism
- Occurs in the medulla of the kidney and involves
    —> the loop of Henle establishes a salt gradient (hypertonicity) in the medulla
    —> anti-diuretic hormone (ADH) regulates level of water reabsorption in the collecting duct

Establishing a salt gradient:

- Loop of Henle —> creates hypertonicity in the tissue fluid of the medulla
- Descending limb of the loop —> permeable to water but not salts
- Ascending limb of the loop —> permeable to salts but not water
- As loop descends into medulla —> interstitial fluid becomes more slaty and hypertonic
- The vasa recta blood network flows oppositely





Water Reabsorption:

-The medulla will draw water out by osmosis due to the hypertonic conditions

-ADH controls the amount of water released from the collecting ducts to be retained by the body

—> is released from the posterior pituitary in response to dehydration (detected by osmoreceptors in hypothalamus)

—> increases the permeability of the collecting duct to water by up regulating production of aquaporins

—> less water in the filtrate —> urine + concentrated

Water balance:

- Maintaining an appropriate water balance within the body's tissues and cells is critical to the survival of an organism —> homeostasis cannot be maintained if water levels drop (dehydration), or are raised (overhydration) without regulation
- Water conservation can be improved by having a longer loop of Henle —> increases salt gradient in the medulla —> more water is reabsorbed by the collecting ducts and urine is concentrated
- Cortical nephrons —> short loops of Henle that don't descend deeply into medulla (moist env.)
- Juxtamedullary nephrons —> long loops of Henle (descend deeply into medulla) (arid environ.)

Dehydration:
- Loss of water from the body such that body fluids become hypertonic
- Effects —> thirst and excrete small quantities of heavily concentrated urine
  —> blood pressure will drop (less water in plasma) —> higher bpm
  —> individual becomes lethargic + inability to lower body temperature (no sweat)
  —> seizures, brain damage and death in severe cases

Overhydration:
- Less common occurrence —> over-consumption of water makes body fluids hypotonic
- Effects —> production of excessive quantities of clear urine —> to try and remove water
  —> cells will swell —> can lead to cell lysis and tissue damage
  —> can lead to headaches and disrupted nerve functions in mild cases
  —> blurred vision, delirium, seizures, coma and death in severe cases

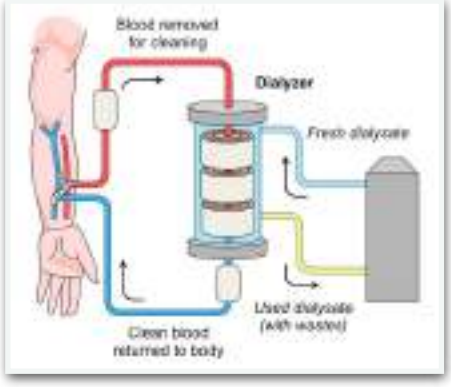
Kidney disease:

- Conditions which incapacitate the kidney's ability to filter waste products from the blood
- Result into reduced glomerular filtration rate (GFR)
- If untreated can lead to kidney failure —> is life threatening

Urinary analysis:

- Kidneys prevent excretion of blood cells, proteins and glucose —> present of them in urine indicated a disease
- Glucose —> indicates diabetes
- Proteins —> hormonal conditions (hCG) or diseases
- Blood cells —> variety of diseases + infections + cancer
- Drugs/toxins —> can be detected in urine

Hemodialysis:



- Kidney dialysis involves external filtering of blood —> to remove metabolic wastes in patients with kidney failure
- Blood removed and pumped through a dialysed —> contains a porous membrane that is semi-permeable and it introduces fresh dialysis fluid and removes wasted to maintain an appropriate concentration gradient
- Lasts about 4 hours for 3 times a week —> effective for years

Kidney transplant:

- Hemodialysis ensures continued blood filtering —> does not address the underlying issue affecting kidney function
- Kidney transplant —> best long-term treatment
  —> transplanted kidney is grafted into the abdomen (arteries, vein and ureter connected)
  —> donors must typically be a close genetic match in order to minimise graft rejection
  —> donors can survive with one kidney —> can donate the second to relatives suffering

---

11.4 Sexual reproduction

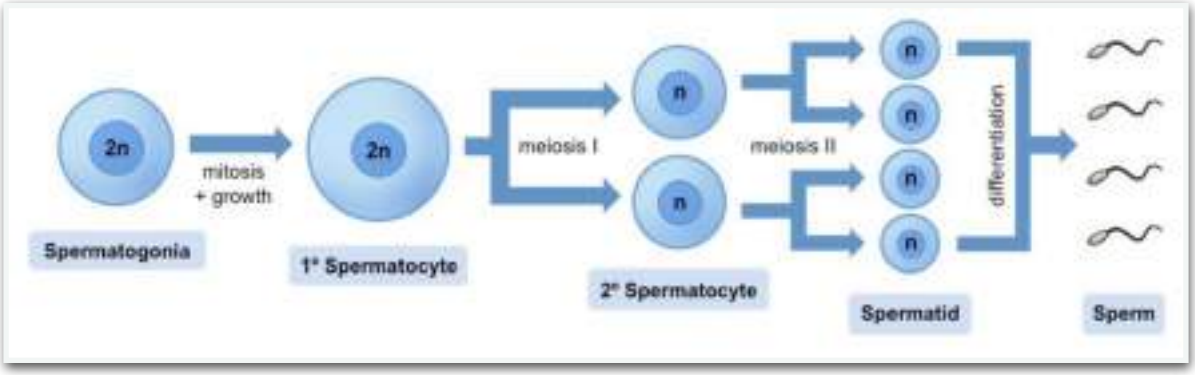
Gametogenesis:

- The process by which diploid precursor cells undergo meiotic division to become sex cells
  —> spermatogenesis in males —> produces a spermatozoa
  —> oogenesis in females —> produces an ova
- Occurs in the gonads and involves:
  —> multiple mitotic divisions and cell growth of precursor germ cells
  —> two meiotic divisions to produce haploid daughter cells
  —> differentiation of the haploid daughter cells to produce functional gametes

Spermatogenesis:

- Describes the production of spermatozoa in the seminiferous tubules of the testes

1) Begins at puberty when the germline epithelium of the seminiferous tubules divide by mitosis
2) Spermatocytes —> cells (spermatogonia) undergo a period of cell growth
3) Spermatids —> spermatocytes cells have two meiotic division —> 4 haploid daughter cells
4) Spermatozoa —> spermatids then differentiate in order to become functional sperm cells

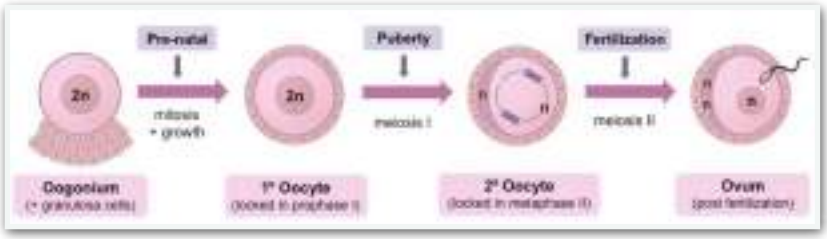


Oogenesis:

- Describes the production of female gametes (ova) within the ovaries

1) Begins during foetal development —> a large number of primordial cells (oogonias) are formed by mitosis (40.000)
2) Oogonias undergo cell growth until they are large enough for meiosis (now primary oocytes)
3) Primary oocytes begin meiosis but are arrested in prophase I —> granulosa cells surround them to form follicles —> remain arrested until puberty
4) FSH will trigger each month the. Continued division of some of the primary oocytes

5) These cells will complete the first meiotic division to for two cells of unequal size —> one cell has all cytoplasm to form secondary oocytes, the other cell forms a polar body
6) The polar body remains trapped into the follicle —> degenerates later
7) Secondary oocytes begins the second meiotic division —> arrested in metaphase II
8) Secondary oocyte is released from ovary (ovulation) and enters into the fallopian tube/oviduct
9) The follicular cells surrounding the oocyte form a corona radiate —> nourish the oocyte
10) If the oocyte is fertilised by a sperm —> chemical changes will trigger meiosis II completion and the formation of another polar body
11) Ovum formation —> once meiosis II is complete —> before fusing its nucleus with the sperm

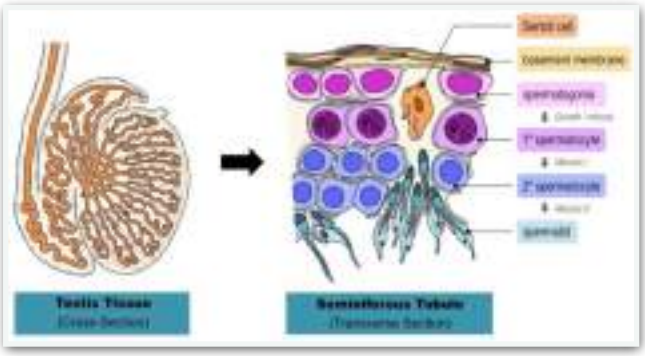


	Spermatogenesis	Oogenesis
Process		
Location	Occurs entirely in testes	Occurs mostly in ovaries
Meiotic divisions	Equal division of cells	Unequal division of cytoplasm
Germ line epithelium	Is involved in gamete production	Is not involved in gamete production
Gametes		
Number produced	Four	One (plus 2 – 3 polar bodies)
Size of gametes	Sperm smaller than spermatocytes	One larger than oocytes
Timing		
Duration	Uninterrupted process	In arrested stages
Onset	Begins at puberty	Begins in foetus (pre-natal)
Release	Continuous	Monthly from puberty (menstrual cycle)
End	Lifelong (but reduces with age)	Terminates with menopause

Reproductive tissue:

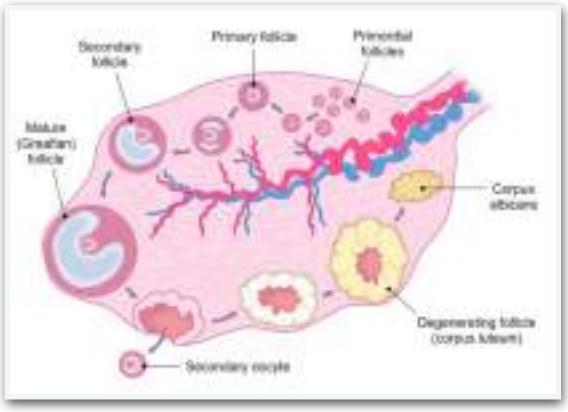
Seminiferous Tubule:

- Produce sperm
- Each tubule is surrounded by a basement membrane lined by germline epithelium
- The germline epithelium will divide by mitosis to make spermatogonia, which then make spermatids
- When spermatids differentiate into spermatozoa, they are released into the lime of the tubule and are nourished by Sertoli cells residing in the tubule lining
- Blood capillaries and interstitial cells (Leydig cells) are outside of the tubules —> produce testosterone



Ovary:

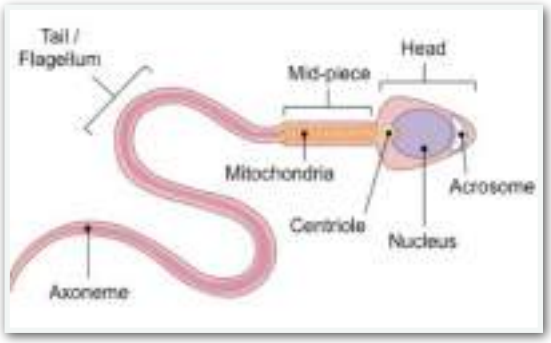
- Contains follicles in various stages of development
- Follicles will develop over the course of a menstrual cycle
- Primordial follicles —> contain egg cells that have been arrested in prophase I (primary oocytes) —> will become secondary follicles and then dominant Graafian follicles —> rupture to release the secondary oocyte
- Ruptured follicle will develop into a short-lived corpus luteum —> secretes key ovarian hormones —> then will become a corpus albicans



Sperm:

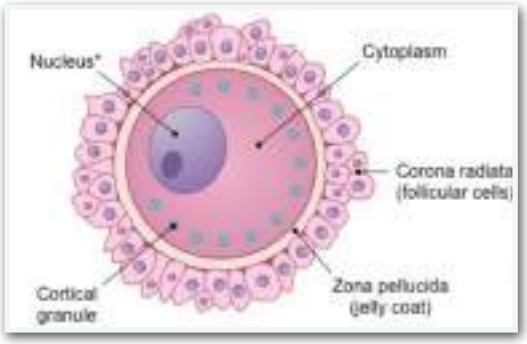
- A typical human spermatozoa can be divided into three sections

1) Head region —> has three structures —> haploid nucleus, acrosome cap and paired centrioles
—> haploid nucleus —> contains the paternal DNA
—> acrosome cap with hydrolytic enzymes —> help penetrating jelly coat of egg
—> centrioles —> needed by a zygote in order to divide (egg cells expel them)



2) Mid-piece —> contains high numbers of mitochondria —> provides energy needed for the tail
3)Tail —> flagellum —> composed of a microtubule structure Calle axoneme —> bends to move

Egg:



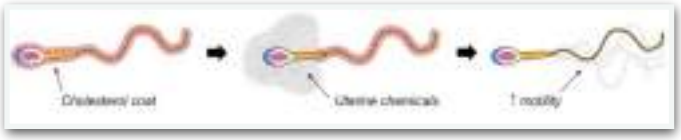
-A typical egg cell is surrounded by two distinct layers
1) Zona pellucida —> glycoprotein matrix which acts as a barrier to sperm entry
2) Corona radiata —> external layer of follicular cells —> provide support and nourishment to the egg cell
- Numerous cortical granules are in the egg cell —> release their contents upon fertilisation to prevent polyspermy
- The egg cells have no nucleus until after fertilisation

Animal fertilisation:

- External fertilisation —> involves the fusion of gametes outside of the body of a parent
—> most common in aquatic animals —> spawning
—> susceptible to environmental influences (pH changes, predators, …)
—> species that reproduces this way usually relate large quantities of gametes to compensate for losses
- Internal fertilisation —> involves the fusion of gametes inside of the body of a parent
—> requires copulation —> the gamete of one parent inside the other
—> common in terrestrial animals —> prevents exposure and desiccation
—> offers more protection to gametes, but is endangering to parent

Human fertilisation:

1) **Capacitation** —> occurs after ejaculation, when chemicals released by the uterus dissolve the sperm's cholesterol coat
—> improves sperm motility
—> destabilises the acrosome cap —> necessary for the acrosome reaction to occur upon egg and sperm contact



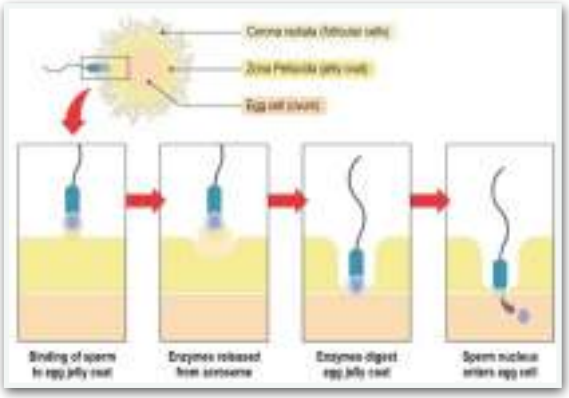
2) **Acrosome reaction** —> allows the sperm to break through the surrounding jelly coat

—> sperm pushes through the follicular cells of the corona radiata and binds to the zona pellucida

—> Acrosome vesicle fuses with jelly coat and releases digestive enzymes —> soften glycoprotein matrix

—> Sperm then pushes through softened jelly coat and binds to exposed docking proteins on the egg membrane

—> The membrane of the egg and sperm then fuse and the sperm nucleus (and centriole) enters the egg

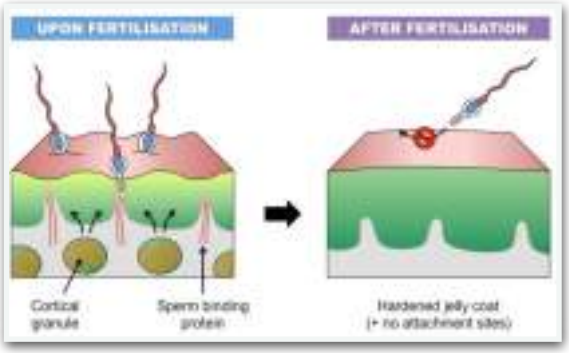


3) **Cortical reaction** —> occurs once a sperm has successfully penetrated an egg —> prevents polyspermy

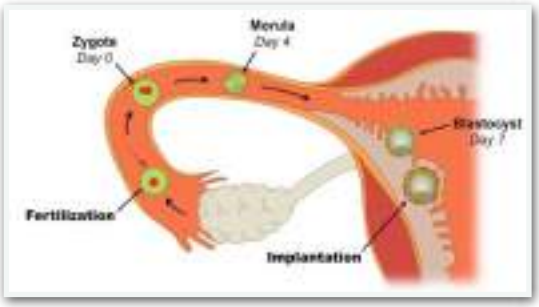
—> Cortical granules in the egg's cytoplasm release enzymes (via exocytosis) into the zona pellucida (jelly coat)

—> These enzymes destroy sperm binding sites + thicken and harden the glycoprotein matrix of the jelly coat

—> prevents other sperm from being able to penetrate the egg (polyspermy), ensuring zygote is diploid



Blastocyst formation:



-Following fertilisation, an influx of CA2+ into the ova prompts the completion of meiosis II —> zygote has formed

-Morula —> solid ball resulting from zygote undergoing several mitotic divisions —> forms a blastocyst as it differentiates and cavitates (forms a cavity)

-Blastocysts —> three distinct sections:

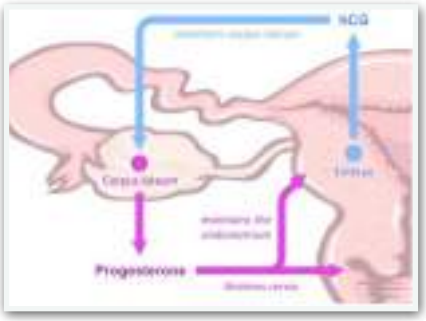
—> inner cell mass —> will develop into the embryo

—> trophoblast —> surrounding outer layer —> will develop into the placenta

—> blastocoele —> fluid filled cavity

- Blastocyst implantation into the endometrial lining —> final stage of early embryo development
  - —> blastocyst breaches the jelly coat surrounding it and preventing attachment to endometrium
  - —> digestive enzymes are released —> degrade the endometrial lining
  - —> autocrine hormones are released —> trigger its implantation into the uterine wall
- From fertilisation to implantation takes roughly 6 / 8 days

Human Chorionic Gonadotropin:



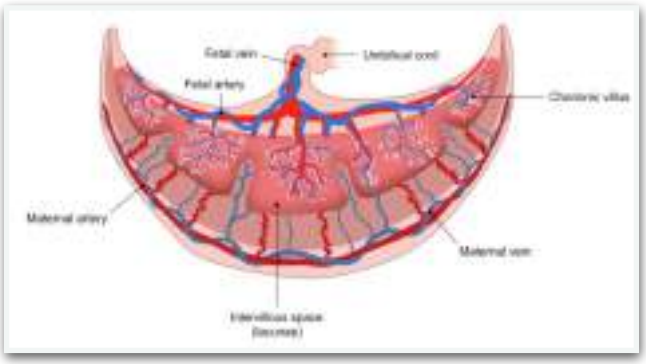
- Secreted by a blastocyst when implanted in the endometrial lining —> promotes the maintenance of the corpus luteum within the ovary + prevents its degeneration
- Corpus luteum will continue to produce both oestrogen and progesterone
- Levels of hCG are maintained for 8 - 10 weeks while the placenta develops —> when placenta becomes responsible for progesterone secretion + nourishing the embryo, corpus luteum no longer required + degenerates as hCG drops

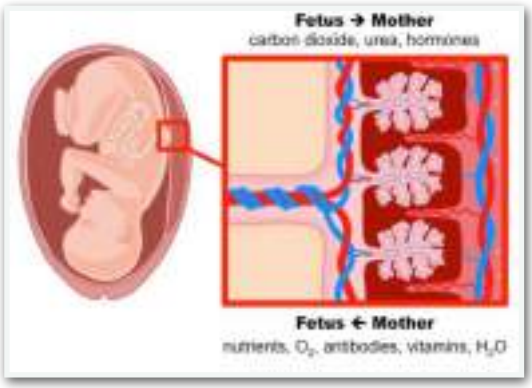
Placenta:

- Functions as the life support system for the foetus and has two key functions
  —> facilitates the exchange of materials between the mother and foetus
  —> secretes hormones to maintain the pregnancy after the corpus luteum has degenerated

Structure:

- Disc-shaped structure that nourishes developing foetus
- Formed from the development of the trophoblast upon implantation and invades the uterine wall
- Maternal bloods pools via open ended arterioles into intervillous spaces (lacunae)
- Chorionic villi extend into these pools of blood and mediate the exchange of materials between mom and foetus —> exchange material is transported from the villi via and umbilical cord —> connects foetus to placenta
- Upon birth, placenta is expelled from uterus with infant



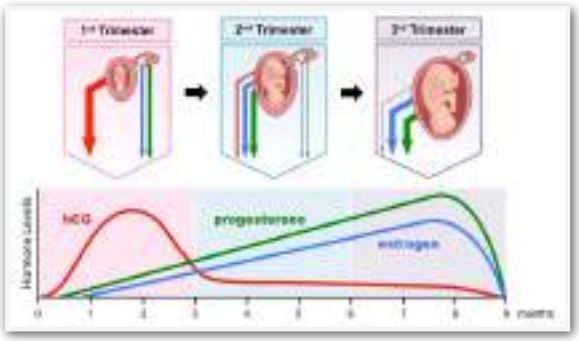


Material exchange:

- Chorionic villi extend into the intervillous space (lacuna) and exchange materials between the mother and foetus
- Chorionic villi are lined by microvilli to increase SA
- Foetal capillaries within the chorionic villi lie close to the surface to minimise diffusion distance from blood in the lacunae
- Materials such as oxygen, nutrients, vitamins, antibodies and water will diffuse from the lacunae into foetal capillaries
- Foetal waste (such as carbon dioxide, urea and hormones) will diffuse from the lacunae into the maternal blood vessels

Hormonal role:

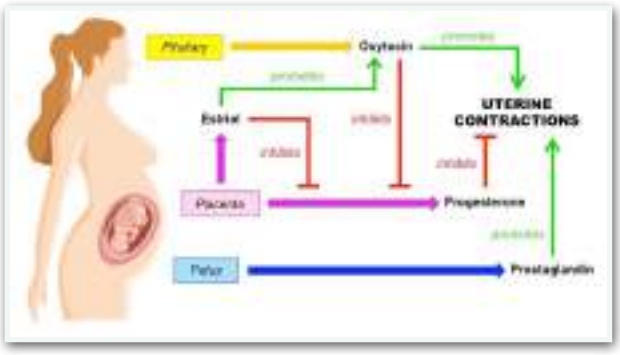
- Placenta takes over the hormonal role of the ovaries at ~12 weeks and begins producing estrogen and progesterone
- Estrogen stimulates the growth of uterine muscles (myometrium) and the development of the mammary glands
- Progesterone maintains the endometrium, as well as reducing uterine contractions and potential maternal immune responses
- Both estrogen and progesterone levels drop near birth



Birth process:

- Parturition —> process of childbirth —> occurs via positive feedback under hormonal control
- Fetal growth causes stretching of the uterine walls (detected by stretch receptors) —> will trigger the release of hormone oxytocin that induces uterine muscles to contract —> cycle will continue until the foetus is removed by giving birth

Hormonal control:



- After 9 months, the stress by the baby induces the release of chemicals which trigger a rise in the levels of estrogen (estriol in particular)
- Estriol prepares the smooth muscle of the uterus for hormonal stimulation by increasing sensitivity to oxytocin + inhibits progesterone (was preventing uterine contractions from occurring while the foetus developed)
- When uterus is primed for childbirth, the brain triggers the release of oxytocin from the posterior pituitary gland
- Oxytocin stimulates uterine muscles to contract, initiating birth + inhibits progesterone secretion
- The foetus responds to this uterine contraction by releasing prostaglandins, which triggers further uterine contractions —> positive feedback loop
- Contractions will stop when labour is complete and the baby is birthed (no more stretching of the uterine wall)

Gestation periods:

- The time taken for a foetus to develop — from fertilisation to birth
- Duration will differ between different species of animal
- Two main determining factors —> animal size and mass
  —> the level of development at birth

Level of development:

- Altricial mammals —> give birth to relatively helpless, undeveloped offspring
  —> need extended rearing
- Precocial mammals —> give birth to more developed offspring that are mobile and independent
  —> require minimal rearing

Extra:

Lymphatic system:

- Secondary transport system —> protects and maintains body by producing and filtering lymph
  —> also absorbs fats from the gut and extra fluid from all over the body
- Lymph —> clear fluid that contains white blood cells and arises from the drainage of fluid from the blood and surrounding tissues
  —> filtered at points called lymph nodes —> pathogens are removed before the fluid is returned to venous circulation

Types of immunity:

- Active —> involves the production of antibodies by the body itself —> later memory cells
- Passive —> from the acquisition of antibodies from another source —> no memory cells
- Both immunities can be induced by either natural (infection or vaccination) or artificial (maternal or monoclonal) mechanisms

Immune pathways:

- Humoral immunity —> describes the pathway by which antibodies are produced by B lympho.
  —> macrophages engulf exogenous pathogens and digest them within lysosomes to release antigenic fragments
  —> fragments are presented on MHC class II receptors and to helper T cells
  —> T cells secrete cytokines to activate the appropriate B lymphocytes
- Cell-mediated immunity —> describes a pathway that targets endogenous antigens
  —> cancerous + virus-infected cells are the body's own cells and are not recognised foreign
  —> present antigenic fragments as a complex with their own self markers (MHC class I)
  —> When helper T cells identify these cells, they stimulate a second type of T lymphocyte – cytotoxic T cells —> show specificity to particular antigens and will bind to the presented antigen and release perforating enzymes
  —> cause the infected / cancerous cell to by lysed, preventing the further spread of infection

Immune disorders:

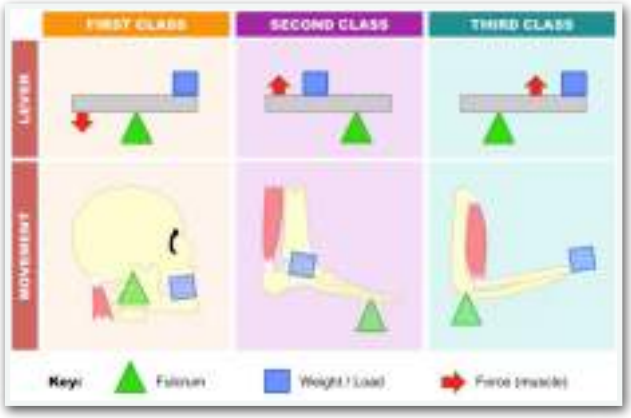
Hypersensitivity disorders:
- Excessively immune response to a substance that is not inherently harmful (allergen)
- Require a pre-sensitised immune state (prior exposure) —> excessive reaction at re-exposure

Autoimmune disorders:
- Immune system fails to recognise body cells as self and begins targeting them
- Pathogens can evade immune detection by producing antigens that closely resemble host markers
  —> detection of these pathogens leads to antibodies that will recognise body cells as targets
  —> diabetes type I, rheumatoid arthritis and multiple sclerosis

Immunodeficiency disorders:
- The immune system's capacity to fight infection is compromised or absent entirely
- Can be inherited, pathogenic (AIDS) or caused by drug treatments
- Cytotoxic drugs —> cause immunosuppression and are used during transplant operations

Types of levers:

- Muscles and bones act together to achieve a variety of movement by forming different types of levers
- 4 parts —> Bones —> lever arm
  —> Joints —> fulcrum
  —> Muscles —> provide the force
  —> Load —> weight of the body part moved
- Different classes based upon where the fulcrum is



Types of Muscles:

- Skeletal —> found attached to the skeleton —> responsible for the voluntary movement of bones
  —> its fibres run in parallel tracts and are multinucleate and heavily striated
- Smooth —> found in the lining of internal organs —> involuntary constriction of regions
  —> not striated and have a spindle shape —> each fibre has a single central nucleus
- Cardiac —> found in the heart and is responsible for the rhythmic contraction of the heart
  —> fibres are branching, intercalated, lightly striated and have a single nucleus per fibre

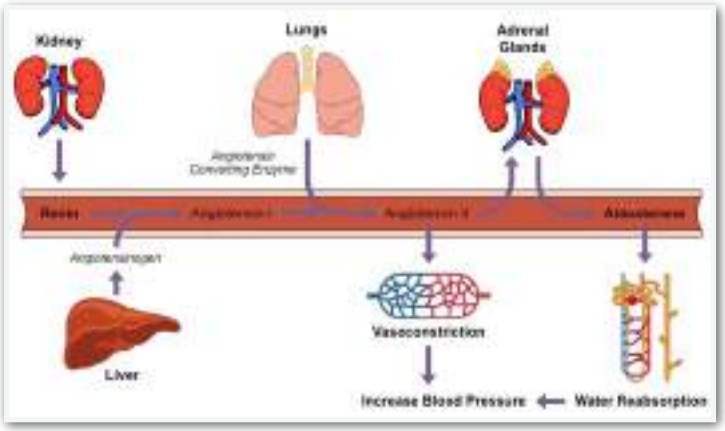
Slow vs Fast twitch:

- Slow twitch fibres —> used for muscular endurance —> contract slowly but do not fatigue easily —> oxygen for aerobic respiration —> many mitochondria and blood vessels —> typically red in colour due to dense supply of capillaries
- Fast twitch fibres —> used for muscular strength —> contract rapidly but fatigue easily —> respire anaerobically —> possess less mitochondria and blood vessels —> typically lighter in colour

Kidney stones:

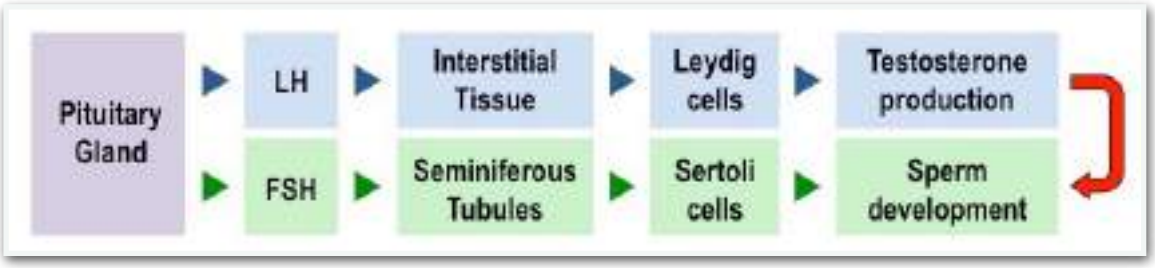
- Kidney stone or renal calculus —> solid piece of material formed in the kidneys from the minerals in urine —> may block the ureter —> decreases kidney function + painful urination
- Dehydration is a common contributing factor, but no known reason exists
- May be prevented by limiting the dietary intake of minerals which form the stones (calcium)
- Shock wave lithotripsy —> ultrasounds to shatter the stones into smaller fragments and urinated

Renin:



- Hormone produced by the kidneys that regulates blood pressure in response to changes in blood volume
- Renin is released from the juxtaglomerular apparatus (JGA) when the kidneys detect a drop in blood pressure
- When an individual is dehydrated, water levels in the blood plasma decrease – leading to lower blood pressure —> Renin is released from the kidney in response to low blood pressure and increases water reabsorption to raise blood volume
- Renin converts angiotensinogen (released from the liver) into angiotensin I
- In the lungs, angiotensin converting enzyme (ACE) converts angiotensin I into angiotensin II
- Angiotensin II causes vasoconstriction, which functions to increase blood pressure by reducing the diameter of blood vessels
- Angiotensin II also triggers the adrenal glands to release the hormone aldosterone
- Aldosterone stimulates sodium uptake in the distal convoluted tubules
- With more sodium reabsorbed into the bloodstream, more water is reabsorbed from the collecting ducts via osmosis
- This functions to raise blood volume and hence increases blood pressure

Hormonal control of male reproduction:



Amniotic sac:

- The foetus develops in a fluid-filled space that is encased by an amniotic sac —> separates the foetus from the mother and hence functions as a barrier against infection
- Protective fluid —> largely incompressible and good at absorbing pressure —> protects the foetus from impacts to the uterus
  —> creates buoyancy so that the foetus does not have to support its own weight while a skeletal system develops
  —> finally, amniotic fluid prevents the dehydration of foetal tissues
- Water breaking —> when amniotic sac ruptures while a women comes to term during labour

---