UNIT 3 BIOLOGY

SUMMARY NOTES FOR THE VCAA EXAMS

WRITTEN BY A STUDENT WHO OBTAINED A NEAR PERFECT STUDY SCORE

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UNIT 3

GLOSSARY

Organic: Containing hydrogen and carbon

Denatured: Permanent destruction of the characteristic properties of a biological macromolecule by disrupting its molecular conformation by heat, acidity, or other

Endosymbiotic theory:

- Cells are engulfed by phagocytosis but not digested
- Cells live together is a mutually benefiting relationship, or symbiosis
    - Survival advantage
- Mitochondria and chloroplasts have intriguing similarities in structure, reproduction, biochemistry, and genetic makeup to certain prokaryotes.
    - Has its own singular circular DNA not bound within a nucleus
    - Has its own ribosomes
    - Double membrane bound
    - Reproduces by binary fission
    - Similar size

Hydrolysis: The chemical breakdown of a compound due to a reaction with water. Opposite to condensation polymerisation

Hydrophilic: Attracted to polar substances

Hydrophobic: Attracted to nonpolar substances

EXPERIMENTAL METHOD

- ❑ What biological concepts are relevant to this experiment?
- ❑ What were the dependent, independent variables and controlled variables?
- ❑ What calculations have been performed? What values need to be measured in order to perform these calculations and how were they measured?
- ❑ How many trials were carried out?
- ❑ Based on the procedure, what outcome is expected?

Hypothesis

- A statement that can be tested
- Cannot be proved → Must be supported or not supported by the data

Independent variable

- What you change
- x-axis

Dependent variable

- Must be measurable (how will it be measured?)
- y-axis

Controlled variables

- Must state " the same"
- To attribute the change in DV to change in IV

Control group

Repeat

- The experiment

Large sample

- Eg. 100 mice

Expected outcomes

- Reference IV and DV

Trend

- Suggests there is some kind of relationship between the independent and dependent variables
- Must be described fully and accurately
- Rapidly, smoothly, reached a peak, became constant, fluctuated

Accuracy

- Obtaining the correct (true) measurement
- Not a quantity
- Increased by changing the way the experiment was conducted

Precision

- Obtaining the same measurement over and over again
- Little spread about their mean
- Gives no indication of how close the results are to the true value
- Increased by having a larger sample size and averaging and removing outliers

Reliability/Repeatability

- Obtaining same measurement if experiment is repeated again or by someone else

- Reliability of results can be evaluated by repeating the investigation and determining the degree to which the results vary.

- The purposes of reproducing experiments include checking of claimed precision and uncovering of any systematic errors from one or other experiments/groups that may affect accuracy. Experiments that use subjective human judgment or that involve small sample sizes or insufficient trials may also yield results that may not be repeatable and/or reproducible.

- Can be increase by repeating the experiment many times to reduce the effects of random errors in order to make the results more likely to be obtained if someone else repeats the experiment

Validity

- Whether the results are due to change in IV affecting DV
- Increased by controlled variables

Systematic error

- Consistent error that occurs every time a measurement is taken
- Caused by the design of the experiment and the way it was conducted
- Cannot be eliminated by averaging
- Affects accuracy

Random error

- Unpredictable variations in measurements over which you have little to no control (cause high variation in results)
- Errors equally likely to be high or low
- A high sample size and averaging and removing outliers can reduce their effects
- Affects precision

Personal errors

- Personal errors include mistakes or miscalculations
- Personal errors can be eliminated by performing the experiment again correctly the next time, and do not form part of an analysis of uncertainties.

Uncertainties

- Uncertainty is a quantification of the doubt associated with the measurement result.
- Inherent in the measurement process and cannot be eliminated simply by repeating the experiment no matter how carefully it is done.
- There are two sources of experimental uncertainties: systematic effects and random effects.

PLASMA MEMBRANE

- To separate the extracellular fluid from the intracellular fluid
- Cholesterol maintains the fluidity of membranes when exposed to a variety of temperatures.
- Phospholipids are not bonded to each other
- The proteins are held within the cell membrane and are able to move along the membrane rather than being held in a fixed position.
- One saturated and unsaturated fatty acid makes up the hydrophobic tails of the phospholipid. The unsaturated one has a kink, preventing adjacent phospholipids from packing too closely together. This helps with fluidity and allows molecules to easily diffuse into/out of the cell.
- Impermeable to most water soluble compounds
- Transport across membranes may be by diffusion, osmosis or active transport
- Temperature affects permeability
- Glycolipids → identify self-cells

MEMBRANE TRANSPORT

- Take about direction of water or solute, NOT solution

GLOSSARY

- **Solute:** dissolved
- **Solvent:** liquid

TYPES OF MEMBRANE TRANSPORT

SIMPLE DIFFUSION

The net passive movement of molecules from an area of high concentration to an area of low concentration. If relating to cells, it would be from one side of the cell membrane to the other through the phospholipid bilayer

- Movement is based on kinetic energy of molecules related to the temperatures of the environment.
- Equilibrium is reached when there is an even distribution of solute molecules and there is no net diffusion.

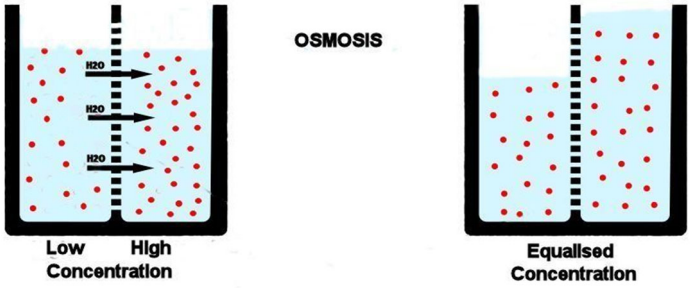
FACILITATED DIFFUSION

The net passive movement of large molecules down the concentration gradient facilitated by either:

- **Carrier proteins**
  - That bind to a specific molecule to be transported across the membrane
- **Protein channel**
  - That provide a passage for water-soluble (polar) molecules and ions across the phospholipid bilayer.
  - The channel proteins are specific for a substance
  - Integral (span across whole membrane)
  - Hydrophilic internally, hydrophobic externally

OSMOSIS

The net passive movement of free water molecules from a region of high concentration of free water to a region of low concentration of free water molecules across a selectively permeable membrane (region of lower solute concentration to a region of higher solute concentration). Free water moves so it is in equal concentration on both sides of the selective permeable membrane.



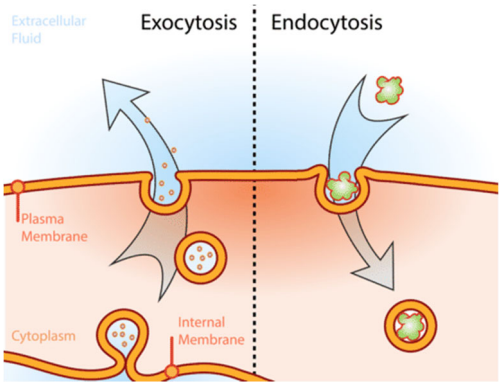
Key terms	Meaning
Free water	Water molecules NOT attached/bound to a solute (something dissolved in water like ions, aminos acids, etc.)
Hypotonic	Less solute → more free water
Hypertonic	More solute → less free water
Isotonic	Equal concentration of solution → equilibrium No net movement
Lysis	Animal cell placed in hypotonic solution swells and bursts and cease to function properly
Crenation	Animal cell placed in a hypertonic solution shrinks and shrivels and cease to function properly
Turgid	Plant cell placed in hypotonic solution → large vacuole fills with water and expands. The pressure builds up on the cell wall the cell will and cease to function properly
Plasmolysis	Plant cell placed in hypertonic solution → large vacuole shrinks and the cytoplasm pulls away from the cell wall and the cell will and cease to function properly

ACTIVE TRANSPORT

The net movement of molecules from across the membrane against the concentration gradient. This transport requires energy (ATP). Active transport has the same properties of selectivity, saturation and competitive inhibition as facilitated diffusion, because it also and only occurs through transport proteins.

VESICLE MEDIATED TRANSPORT

Vesicles or vacuoles transport larger molecules, such as proteins, polysaccharides, or large particles (e.g. bacteria). The membrane bound vesicles may fuse with the cell membrane, releasing their contents into or out of the cell. The membrane increases and decreases in size with every vesicle that enters or leaves the cell. Requires energy.



Exocytosis

The movement of materials out the cell (e.g. contractile vacuole in amoeba, release of enzymes from the cell) via vesicles.

Endocytosis

The movement of materials into the cell (e.g. white blood cell engulfing a bacterium, paramecium engulfing food) via vesicles.

There are two types of endocytosis:

- **Phagocytosis** (“cell eating”) - large particles brought into cell
- **Pinocytosis** (“cell drinking”) - extracellular fluid brought into cell

FACTORS AFFECTING RATE OF DIFFUSION

1. **Temperature**
    - The higher the temperature, the greater the kinetic energy (energy required to move), therefore greater rate of diffusion
2. **Concentration gradient (difference in concentration between two areas)**
    - The greater difference in concentration, the faster the rate of diffusion
    - Leads to a greater probability of molecular collisions over the region
3. **Size of the molecule**
    - The smaller the molecule, the faster the rate of diffusion
4. **SA:V**
    - The larger SA:V, the faster the rate of diffusion

SUBSTANCES THAT CROSS THE MEMBRANE

- **Small nonpolar molecules (hydrophobic)**
    - Simple diffusion
        - Carbon dioxide
        - Oxygen
        - Urea
        - Alcohol
- **Small polar molecule (hydrophilic)**
    - Facilitated diffusion
        - Potassium ion
        - Sodium ion
    - Water → simple diffusion
- **Large polar molecule (hydrophilic)**
    - Facilitated diffusion
        - Amino acid
        - Glucose

What is the difference between passive and active transport?

Passive transport requires no energy as it follows the concentration gradient. Active transport in comparison requires energy as it goes against the concentration gradient. Active transport has to use proteins whilst passive transport does not have to (eg. simple diffusion).

What are the similarities between diffusion and facilitated transport?

The similarities between diffusion and facilitated transport include:

- No energy is required for both
- Both transport molecules across the membrane
- Both follow the concentration gradient

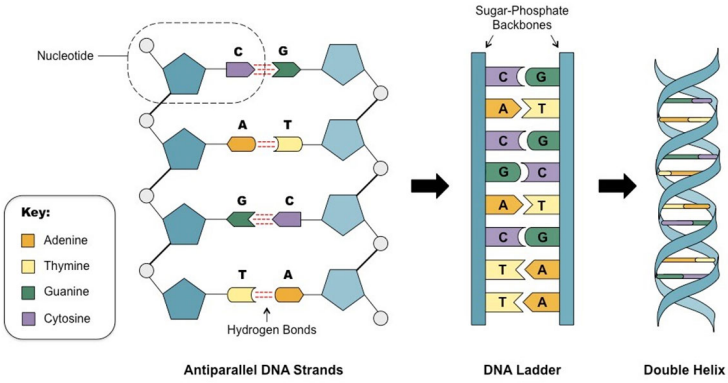
Compare active transport and facilitated diffusion:

- Active transport requires energy whilst facilitated diffusion does not.
- Active transport moves against the concentration gradient, whilst facilitated diffusion follows the concentration gradient.
- Both require proteins

NUCLEIC ACIDS

- Are acidic
- CHONP

DNA contains the information that will be decoded for the production of proteins.



DNA

- Found in the nucleus, wrapped around histones, in chromatin to make chromosomes
- Double helix molecule
    - Strands run antiparallel
- Monomers: nucleotides
    - Nitrogenous base
    - 5 carbon sugar → deoxyribose sugar
        - Numbered clockwise by where the nitrogenous base is
        - Attached to the 1st carbon
    - Phosphate group
        - Attached to 5th carbon
        - Phosphodiester bond between sugar and phosphate group
    - 5 prime end and 3 prime end
        - Orientation of the 5 carbon sugar
        - 5 prime end and 3 prime end
            - Flips when joined with another nucleotide
            - 5 prime up on the left, 3 prime down
            - 3 prime up on the right, 5 prime down
            - Antiparallel

        - 4 different nucleotides in DNA
        - Adenine → two hydrogen bonds → two rings
        - Thymine → two hydrogen bonds → one ring
        - Guanine → three hydrogen bonds → two rings
        - Cytosine → three hydrogen bonds → one ring
        - Purines → two rings
        - Pyrimidines → one ring

    - 5th base in RNA

        - Uracil → two hydrogen bonds → one ring

- Nitrogenous base and deoxyribose sugar makes a nucleoside

mRNA

- Messenger RNA
- Carries the information that codes for proteins outside the nucleus
- **More in protein synthesis**

tRNA

- Transfer RNA
- Brings specific amino acids to the ribosome to synthesise a polypeptide by peptide bonds formed by condensation reactions
- Anticodon on one end
    - Pairs with three bases in mRNA to code for an amino acid → a codon
    - Genetic code is degenerate/redundant as some amino acids can be coded by several different codons.
    - Genetic code is unambiguous as some amino acids can be coded by only one specific codon
    - Genetic code is universal → applies to all cells in all species
    - START
        - AUG
        - Always starts the process
    - STOP
        - no tRNA that has the anticodon.
        - Doesn't fit
        - Polypeptide is terminated at that point
- Corresponding amino acid on the other side

rRNA

- Ribosomal RNA
- Found in ribosomes
- Structural protein
- Reads codons on mRNA

DIFFERENCES BETWEEN DNA AND RNA

- DNA is double stranded whereas RNA is single stranded
- Deoxyribose and ribose sugar → difference is deoxyribose sugar has lost an oxygen (second carbon on 3 prime end)
- Thymine and Uracil
    - Both pairs with Adenine
    - Extra carbons and hydrogens in thymine
- 3 different kinds of RNA
    - All copied from the DNA
    - All converge at the ribosome to produce a protein molecule
        - Amino acids pair with mRNA
    - mRNA (messenger RNA) → threads through the ribosome
    - tRNA (transfer RNA) → brings amino acids to the mRNA and ribosome → folds upon itself (complementary part) making a triangular structure
    - rRNA (ribosomal RNA) → makes up the ribosome

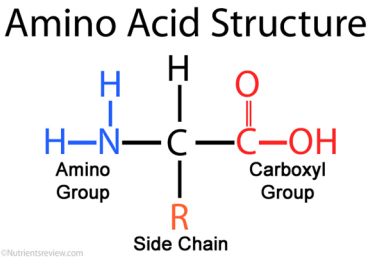
NUCLEOTIDE (CONDENSATION) POLYMERISATION

- DNA polymerase catalyse the synthesis of DNA from a DNA template (pre existing strand)
- New nucleotides can only be added to the 3 prime end by DNA
- New nucleotides have a nucleoside with 3 phosphates → deoxynucleoside triphosphate
    - dATP
    - dGTP
    - dTTP
    - dCTP
- Two phosphates break off the triphosphate when the 3 prime end of the existing DNA strand reacts with the 5 prime end of the deoxynucleoside triphosphate, forming a nucleotide
    - Hydrogen breaks of 3 prime end's hydroxyl group and joins to the two phosphates
        - Forms molecule with two phosphates
    - Nucleotide joins onto where the hydrogen broke off
- 3 prime end moves down
- https://www.youtube.com/watch?v=xGDDfY1wQtc

POLYPEPTIDE SYNTHESIS

How amino acids are joined together to make a polypeptide chain.

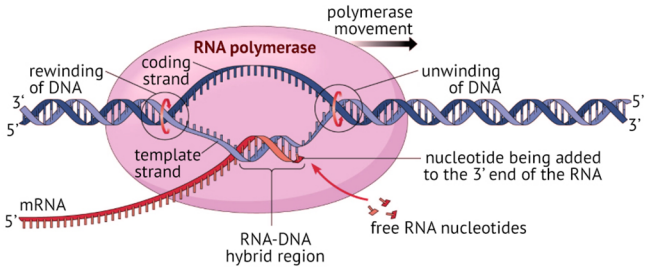
AMINO ACIDS



- Made up of:
    - Amino (amine) group → nitrogen, two hydrogen (negative charge)
    - Carboxyl group → carbon, two oxygens, hydrogen (negative charge)
    - R group (functional group) → only thing that changes between amino acids
- Joins together via condensation polymerisation
    - Hydrogen from amino group and hydrogen and oxygen from carboxyl group
    - Energy is an input
    - Water is an output
- 20 types
- Have charges: hydrophilic/hydrophobic
    - Polar → uneven distribution of hydrogens around oxygens
    - Electrical properties → oxygens are negative, hydrogens are positive.
        - Opposites are attracted to each other → chain will bend
- Can be acidic, basic or neutral

PROTEIN SYNTHESIS

1. Transcription



Initiation: DNA molecule unwinds, separates and RNA polymerase binds to the promoter of the template strand

Elongation: RNA polymerase moves along the template strand, synthesising an mRNA molecule

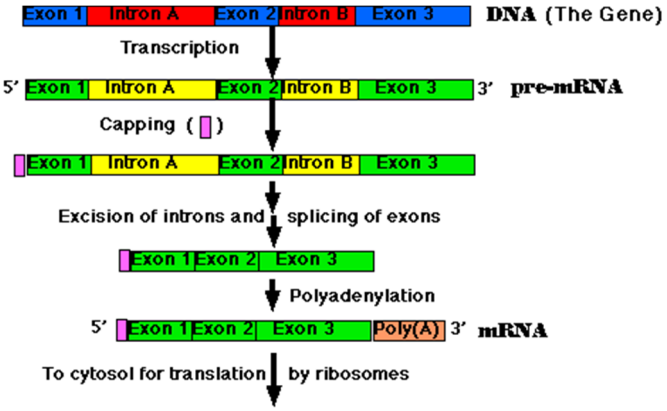
Termination: The completed mRNA strand detaches from the template strand and a poly A tail is added at the 3' end. A methylated cap is added on the 5' end of the mRNA

Processing: Intronic RNA are removed and exonic RNA are spliced together to form a mature mRNA molecule

- DNA is unwound.
- RNA polymerase binds to the promoter region.
- RNA polymerase reads the DNA template strand
- RNA polymerase joins nucleotides (condensation polymerisation) that are complementary to the template DNA strand to produce a pre-mRNA strand that runs 5' to 3' that is a copy of the template strand. Occurs in the nucleus.
    - Promoter
        - Upstream of the coding region and controls activity of the gene
        - Binding site for RNA polymerase
    - RNA polymerase adds on complementary bases (free nucleotides) on the three prime end on the template strand
    - New strand (pre-mRNA) is a copy of the complementary strand running 5' to 3'
        - With DNA and RNA differences
            - Ribose sugar
            - Uracil in place of thymine
    - Terminator region
        - Stopping site for RNA polymerase (downstream of the coding region)
    - Complementary strand
        - Joins back to the template strand

2. Post transcriptional modification (in nucleus)

- Pre-mRNA peels away from the template
- Exons
  - Coded instructions for adding amino acids to a protein
- Introns get cut out
  - Do not contain the coded instructions for adding amino acids to a protein
- No RNA processing in prokaryotic cells
- mRNA
  - Introns removed
  - Methyl cap is added to the 5 prime end
    - Feeds into the ribosome
    - Protects it
  - Poly A tail is added to the 3 prime end
    - Adenine is lost every time it is run through a ribosome
    - Protects it
    - Translation stops when all adenines are gone
      - Not translated into proteins forever
  - Limited lifetime determined by the poly A tail
  - Methyl cap and Poly A tail helps with movement



mRNA Codon/Amino Acid Chart

First Base	Second Base: U	Second Base: C	Second Base: A	Second Base: G	Third Base
U	UUU, UUC – Phenylalanine (Phe)	UCU, UCC, UCA, UCG – Serine (Ser)	UAU, UAC – Tyrosine (Tyr)	UGU, UGC – Cysteine (Cys)	U
	UUA, UUG – Leucine (Leu)		UAA, UAG – Stop	UGA – Stop; UGG – Tryptophan (Trp)	C, A, G
C	CUU, CUC, CUA, CUG – Leucine (Leu)	CCU, CCC, CCA, CCG – Proline (Pro)	CAU, CAC – Histidine (His); CAA, CAG – Glutamine (Glu)	CGU, CGC, CGA, CGG – Arginine (Arg)	U, C, A, G
A	AUU, AUC, AUA – Isoleucine (Ile)	ACU, ACC, ACA, ACG – Threonine (Thr)	AAU, AAC – Asparagine (Asn); AAA, AAG – Lysine (Lys)	AGU, AGC – Serine (Ser); AGA, AGG – Arginine (Arg)	U, C, A, G
	AUG – Start Methionine (Met)				
G	GUU, GUC, GUA, GUG – Valine (Val)	GCU, GCC, GCA, GCG – Alanine (Ala)	GAU, GAC – Aspartic Acid (Asp); GAA, GAG – Glutamic Acid (Glu)	GGU, GGC, GGA, GGG – Glycine (Gly)	U, C, A, G

3. mRNA leaves the nucleus through nuclear pores into the cytoplasm

- Finds a ribosome on the Rough ER
- Locks itself into the ribosome (methyl cap first)

4. Translation (cytoplasm)

- 1. mRNA locks itself into a ribosome.
- 2. rRNA reads the codons and starts (start codon is read) matching complementary tRNA anticodon sequences, carrying a **specific** amino acid, to the mRNA codon sequence.
- 3. Each time a new tRNA comes into the ribosome, the amino acid that it was carrying gets added to the elongating polypeptide chain via condensation polymerisation.
- 4. The ribosome continues until it hits a stop sequence, then it releases the polypeptide and the mRNA.
- 5. The polypeptide forms into its native shape and starts acting as a functional protein in the cell or goes through further modification and export.

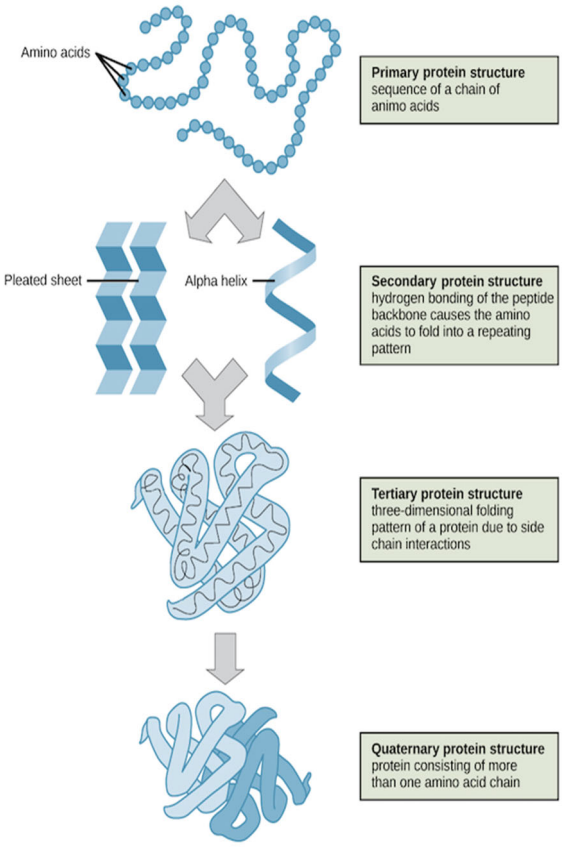
5. Post translational modification (cytoplasm)

- Polypeptide folds into a 3D shape or joins to other polypeptides
- Becomes a functional protein

PROTEIN STRUCTURE

1. Primary structure

- The specific linear sequence of amino acids that form a polypeptide chain. Amino acids are bonded by a peptide bond, formed by a condensation reaction. Determined by DNA and produced by the process of transcription and translation
- Occurs in ribosomes



2. Secondary structure

- The specific folding of the polypeptide chain into alpha helices and beta pleated sheets due to hydrogen bonding
- Alpha helix
- Beta pleated sheet
- Random coils
- Hydrogen bonds causes these shapes
- Occurs in ribosomes

3. Tertiary structure

- The specific 3D folding of one polypeptide chain due to hydrogen bonding
- Overall specific outside shape of the protein determines its specific function
- Can be a final protein.

4. Quaternary structure

- The specific 3D arrangement of two or more polypeptide chains bonded by hydrogen bonds

- The specific functioning of the protein is determinant on its specific 3D shape which is determined by its primary structure as amino acids have different properties (R group) → if changed, hydrogen bonding is affected

Rate of transcription can be decreased if the DNA is tightly wrapped around histones with methyl groups.

How can the expression of a single gene lead to the production of different proteins?

- Alternate gene splicing of exons
- Different post-transcriptional modifications code for different proteins
- Different nucleotide sequences/mRNA sequences of the same gene code for different proteins
- Different post-translational changes to the protein. For example, alternative folding

GENETIC CODE

GLOSSARY

Genome: All the genetic information found in one set of an organism's chromosomes.

Gene: A sequence of DNA that has a function (expressed as a protein). Number of genes reflects complexity

Proteome: The entire set of proteins expressed at any given time in the cell

Functional diversity:

- Structural
- Transport (Channel proteins)
- Enzymes
- Immune response (antibodies)
- Receptors
- Hormones
- Ribosomes
- Antigens

Proteomics: The study of all proteins in an organism

Inducible gene: Is always off but can be turned on

Repressible gene: Is always on but can be turned off

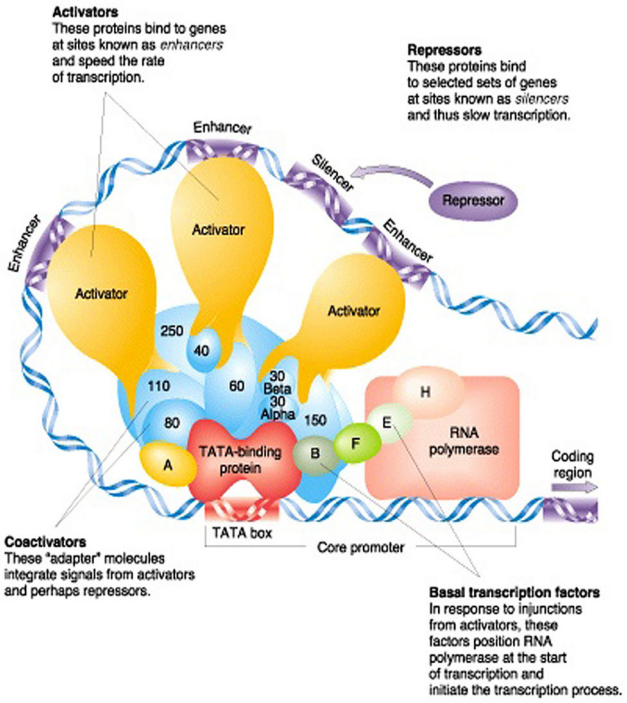
Regulatory genes: Produces transcription factors (eg. repressor proteins, RNA polymerase)

Structural gene: Produce proteins that become part of the structure and functioning of an organism

Gene expression: The transcription and translation of genes to form a protein.

Gene regulation: The switching on and off of genes to ensure that particular proteins are only produced when they're needed.

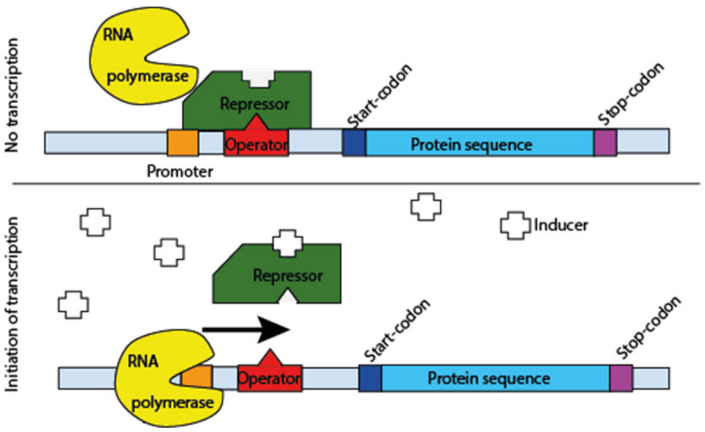
GENE STRUCTURE



- Open Reading Frame (ORF)
    - Contains the coded instructions for the production of proteins
    - Both introns and exons
- Untranslated regions (5 prime and 3 prime end)
    - Are transcribed
    - Used to add the methyl and poly A tail
    - Not translated
- Promoter
    - RNA polymerase assembles here
    - Upstream of the ORF
- Operator
    - Gene regulation
    - Repressor protein joins here
        - If binded, it blocks the promoter
        - Not an enzyme
- Enhancers and silencers
    - Transcription factors
    - Increasing or decreasing the rate of transcription
    - Proteins will bind to them
        - Activators or repressors
    - Interacts with the promoter
    - Way upstream
- Insulators
    - Prevent the RNA polymerase from transcribing the next gene
    - Up and downstream

GENE REGULATION (metabolism)

- Can be regulated by alternate gene splicing → of exons in pre-mRNA
- **Lac operon**
    - In prokaryotic cells
    - Operon: Section of genes that all have a related function and in a little cluster.
        - Transcribed together
    - Digestion of lactose
    - 3 different genes (LacZ, LacY and LacA) to produce 3 different enzymes



- An operator **downstream** of the promoter regulates the RNA polymerase to transcribe the lac operon
    - Repressor protein can be bound to switch the gene off so that energy is not wasted in building proteins that have no purpose
- If there is lactose (**inducer**):
    - Turns the gene on
    - It binds to the operator, changing its shape (like a non-competitive inhibitor)
    - Repressor no longer fits into the operator and jumps off the operator
    - RNA polymerase is **unblocked** and now can transcribe the genes
    - Enzymes made digest the lactose
    - Not a waste of energy as there is lactose to be digested
- When all the lactose is gone, the repressor returns to its original shape and binds back to the operator to turn the gene off.

Advantages of gene regulation:

- Prevents toxicity from build up of enzymes
- Conserve energy otherwise used in protein synthesis and resources such as amino acids and nucleotides.

PROTEIN EXPORT

Rough Endoplasmic Reticulum

- Synthesises proteins for export
- Proteins are then secreted into the RER for transport
- Made of protein and rRNA (ribosomal RNA)
- ATP required (comes from the mitochondria in animal cells)
- System of membrane bound channels and studded with proteins

Smooth Endoplasmic Reticulum

- Further modification

Secretory vesicles

- Vesicles bud off SER/RER and transport protein to golgi apparatus
    - Membrane is liquid and naturally rejoins

Golgi Apparatus

- Modifies and packages proteins in budding vesicles for export from the cell
- Stack of flattened membrane stacks

Secretory vesicles

- Vesicles bud off the golgi and transport protein to plasma membrane
    - Membrane is liquid and naturally rejoins

Exocytosis

- Membrane **fuses** with the plasma membrane to **eject** material
- Energy is required (from mitochondria)

ENZYMES

- Lower activation energy
    - Increase the reaction rate of chemical reactions (catalysed reactions)
    - Controls the rate of chemical reactions by weakening bonds thus lowering the amount of activation energy needed for the reaction
- Are protein catalysts
- Globular proteins
- **Specific** shape of active site (tertiary structure of protein) which binds to specific substrates → **complementary** shapes to form enzyme substrate complex (substrate bonding site and enzyme active site bonded)
- Enzymes are reusable
    - Unchanged by the chemical reaction
    - Increases the rate of naturally occurring chemical reactions
        - The reaction will still occur but so slowly that the cell will be unable to function efficiently
- Have optimal conditions

GLOSSARY

Chemical energy: The form of energy that cells use, store and convert to other forms of energy as required

Metabolism: The sum of all reactions occurring within an organism. Can be classified into anabolic or catabolic

Anabolic reaction: The addition of substrates to form a single molecule that gains energy. Eg. protein synthesis

- Endergonic reactions
- Larger activation energy needed to start the reaction
    - Energy becomes stored in the products

Catabolic reaction: The substrate bonds are broken into products and releases energy. Eg. digestion

- Exergonic reactions
- Lesser activation energy needed to start the reaction
    - Greater energy is released

TYPES

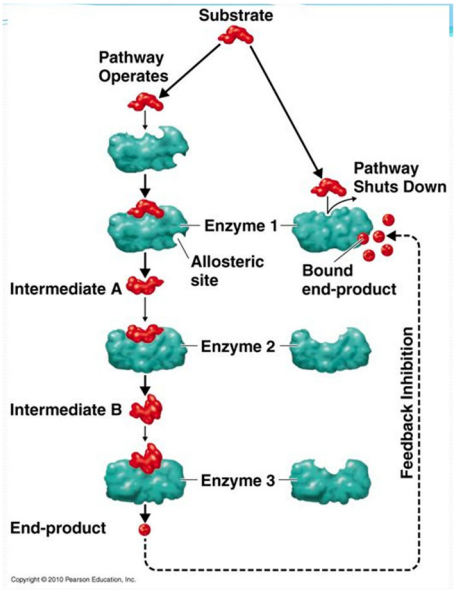
- **Lock and key**
- **Induced fit** → enzyme incloses the substrate
    - Substrate almost fits exactly
    - Enzyme changes shape to fit perfectly
    - A handshake
    - Substrate changes shape and in the process is broken (catabolic)

FACTORS THAT AFFECT ENZYME RATE

- **Temperature (movement of molecules)**
    - Increase with increasing temperature
        - Enzymes and substrates move faster and meet faster. Kinetic energy is increased and therefore increase the frequency of successful collisions between enzyme and substrate
    - Enzymes **denature** at high temperature
        - Heat energy breaks hydrogen bonds that hold the protein in its 3D shape
            - 3D shape is put together by other proteins
            - Not the natural shape
        - Destroys hydrogens and therefore the 3D functional shape of the protein, permanently changing its active site so it cannot bind to the substrate
        - Broken down by the body
    - Optimal temperature changes with different cells
        - The temperature at which the enzyme works the best without some of the enzyme being denatured
    - Critical temperature
        - Enzyme is denatured
        - Reaction stops altogether

- **pH**
    - Optimal pH
        - Enzyme works the fastest
    - Enzyme doesn't permanently denature under natural circumstances
        - If the pH goes back to the optimal pH, the rate of reaction will increase
    - At extreme pH, the enzyme **denatures**
        - Extreme pHs can denature proteins as they alter the bonds within the protein, therefore changing the shape of the active site so the substrate can no longer bind to the enzyme's active site. This will slow down the rate of reaction
- **Enzyme concentration (limiting factor)**
    - As the enzyme concentration increases, the rate of reaction increases because there are more active sites for the enzymes to bind to.
    - Reaches a plateau
        - Substrate becomes the **limiting factor**
        - Enzyme is working at a maximum rate
- **Substrate concentration (limiting factor)**
    - As the concentration increases, the rate of reaction increases because the distance between substrate and enzymes decrease.
    - Reaches a plateau
        - Enzyme becomes the **limiting factor**
        - Enzyme is working at a maximum rate
- **Inhibitors**
    - Competes **(competitive inhibitor)** with the substrate to get into the active site
        - Rate of reaction can be increased by increasing substrate concentration
    - **Non-competitive inhibitor** does not bind to the active site
        - Binds to an allosteric site and changes the shape of the enzyme
            - Substrate can't bind to the active site as it has changed
        - Rate of reaction cannot be increased by increasing substrate concentration

- **Feedback inhibition**



  - Feedback inhibition is when a reaction product is used to regulate its own further production.
  - Metabolic reactions, such as anabolic and catabolic processes, must proceed according to the demands of the cell. In order to maintain chemical equilibrium and meet the needs of the cell, some metabolic products inhibit the enzymes in the chemical pathway while some reactants activate them.
  - Enzymes bind to molecules with active sites that are specifically designed to fit with the molecule undergoing the reaction. These enzymes have a second active site for the reaction product to bind to.
    - This causes the enzyme to spatially re-arrange so it can no longer bind to the initial reagent and the reaction stops (non-competitive inhibitor)
      - Rate of reaction cannot be increased by increasing substrate concentration
  - Prevents toxicity of product
  - Conserves energy and resources

COENZYMES

- A non-protein compound that is necessary for the functioning of an enzyme.
- Coenzymes are not considered part of an enzyme's structure. They are sometimes referred to as cosubstrates.
- They cannot by themselves catalyze a reaction but they can help enzymes to do so.
- Coenzymes do not become integral parts of the enzymatic reaction. Instead, the covalent bonds are broken at the end of the reaction, and the coenzyme returns back to free circulation within the cell until it is used again.
- Without coenzymes or cofactors, enzymes cannot catalyze reactions effectively. In fact, the enzyme may not function at all. If reactions cannot occur at the normal catalyzed rate, then an organism will have difficulty sustaining life.
- When an enzyme is denatured by extreme temperature or pH, the coenzyme can no longer attach to the active site.
- **ATP**
    - When a enzyme needs to join two substrate molecules to make one product that requires energy, an ATP molecule binds (covalently) to a portion of the active site of the enzyme.
    - Phosphate breaks off (ADP)
    - Energy is released
- **NADH (Nicotinomide Adenine Dinucleotide)**
    - Two nucleotides joined together
    - Hydrogen breaks off (NAD+)
    - Energy is released
- **NADPH (Nicotinomide Adenine Dinucleotide Phosphate)**
    - Phosphate group attached to the bottom of NADH (three phosphates)
    - Hydrogen breaks off (NADP+)
    - Energy is released
    - Chloroplasts

PHOTOSYNTHESIS

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

LIGHT AND CHLOROPHYLL

- Production of glucose → synthesises glucose to use in cellular respiration
- Anabolic reaction as energy is required to build a larger product from smaller reactants (endergonic)
- Oxygen is a waste product
- Chloroplasts are the site of photosynthesis

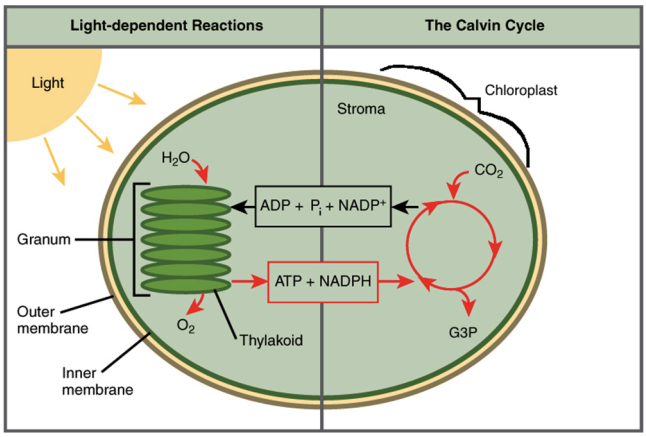
CHLOROPLASTS

- Derived from prokaryotic bacteria (endosymbiotic theory)
    - Same size and shape
    - Its own circular DNA not held in a nucleus
    - Double membrane
    - Ribosomes
- Stroma
    - Fluid
    - Light independent stage (calvin cycle)
- Thylakoids
    - Disk
    - Thylakoid membrane
    - Light dependent stage
        - Large surface area for light absorption
- Granum (grana pl.)
    - Stack of thylakoids
- Ribosomes
- Double membrane

STAGES OF PHOTOSYNTHESIS

Light dependent stage:

- Depends on light
- This stage takes place in the thylakoid membranes of chloroplasts (grana).
- **To produce ATP and NADPH for the light independent cycle**



1) Light is absorbed by chlorophyll

2) Photolysis occurs: water is split to form H+ ions and oxygen gas using sunlight

3) NADPH and ATP is formed from NADP and ADP + Pi from the splitting of water into H+ ions and oxygen gas

4) Oxygen is released via simple diffusion through plasma membrane as a by-product

- INPUTS
  - 12H2O
  - Light energy
  - NADP
  - ADP + Pi
- OUTPUTS
  - NADPH
  - ATP
  - 6O2

Light independent stage (calvin cycle):

- **Relies on light dependent stage's outputs**
- **To produce glucose**
- This stage takes place in the stroma of chloroplasts.

1) Carbon dioxide reacts with H+ ions (provided by NADPH from light dependent) to produce 2 PGAL (glucose in cytosol).

2) ATP from light dependent provides the energy for the synthesis of glucose.

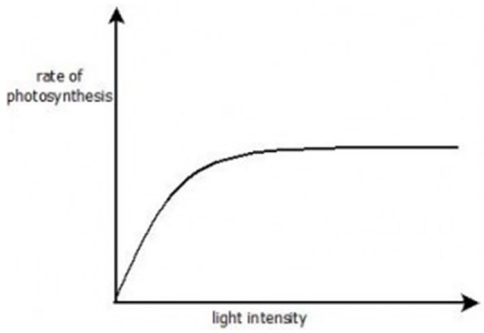
3) Excess H+ ions react with O2- ions to produce water (a by-product).

4) ADP + Pi and NADP is cycled back to light dependent stage

- INPUTS
  - 6CO2
  - ATP
  - NADPH
- OUTPUTS
  - 2 PGAL (glucose)
  - 6H2O
  - NADP (cycled back to light dependent stage)
  - ADP + Pi (cycled back to light dependent stage)

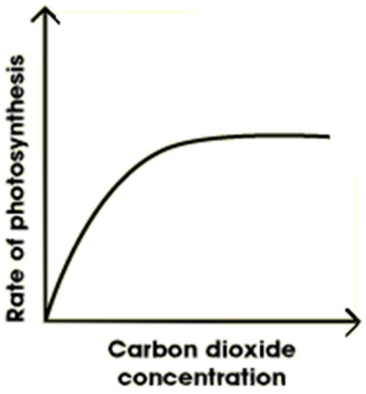
FACTORS THAT AFFECT THE RATE OF PHOTOSYNTHESIS

1. **Light intensity**
   - Plateau (constant)
     - Chlorophyll cannot trap anymore light
     - Not enough CO_2 or H_2O → **limiting factor**
   - Light dependent stage
     - grana



2. Carbon dioxide concentration

- Plateau (constant)
  - Not enough light or H_2O → **limiting factor**
- Higher carbon dioxide concentration means that there is a higher concentration difference therefore diffusion will occur faster and there is more input, meaning the rate of photosynthesis will increase.
- Light independent stage
  - stroma



3. Chlorophyll

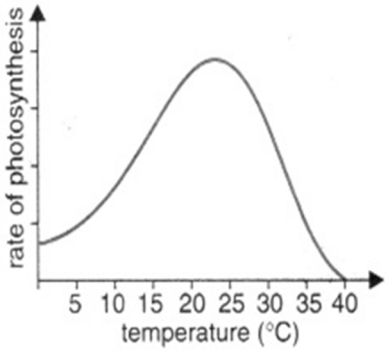
- The greater the amount of chlorophyll, the more light trapping pigment so more light may be harnessed, therefore increasing the rate of photosynthesis

4. Water

- Water is a substrate/reactant for photosynthesis

5. Temperature

- Optimum temperature
  - At high temperatures, enzymes **denature**
  - At low temperature, kinetic energy is reduced in enzymes and substrate
  - As temperature increases, the rate of cellular respiration increases as kinetic energy between substrate and enzyme increases, increasing the frequency of successful collisions until a point where temperature gets too high and then the enzymes involved in photosynthesis reactions denature

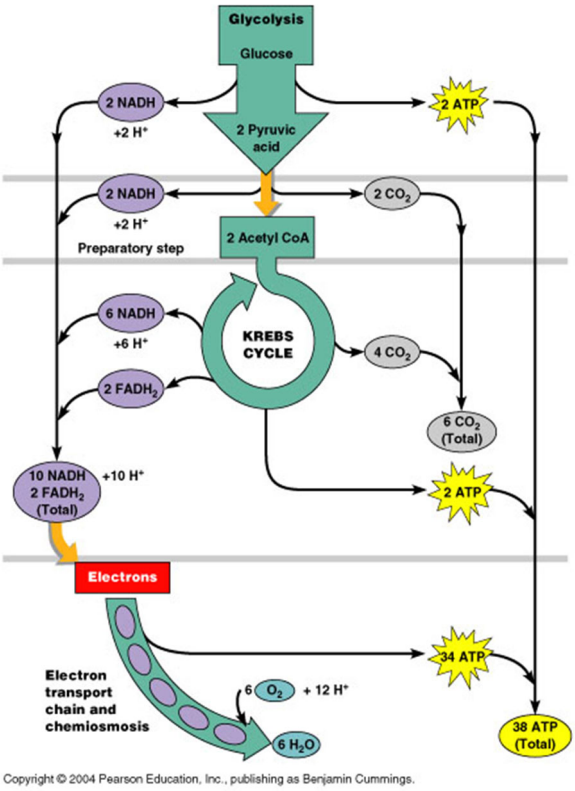


Availability or concentration of these can limit the rate of reactions. For each factor, there is an optimum amount for reactions to proceed at the fastest rate.

CELLULAR RESPIRATION

The purpose of cellular respiration is to take glucose, take the energy out of glucose and use that energy to build ATP for metabolic processes

ATP carries energy to drive all cellular metabolic activities and is the immediate energy supply of the cell



AEROBIC RESPIRATION

High efficiency but slower than anaerobic respiration.

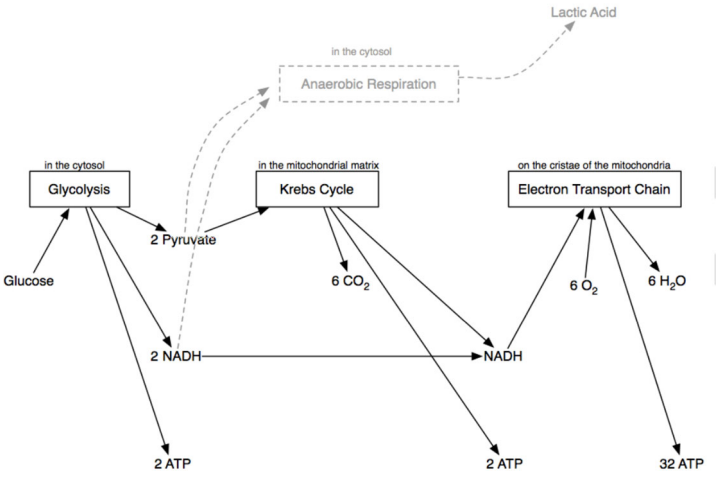
$6O_2 + C_6H_{12}O_6 \rightarrow 6CO_2 + 6H_2O + 36\text{-}38\ ATP$

STAGES

1. **Glycolysis**
    - The breaking of glucose
    - Occurs in the cytosol of the cell
    - Doesn't require oxygen
    - Inputs:
        - Glucose
        - 2 ADP + Pi
        - 2 NAD
    - Outputs:
        - 2 ATP
        - 2 pyruvate
        - 2 NADH
    - ADH is used in electron transport chain or in anaerobic respiration

2. Krebs Cycle/Citric acid cycle

- Occurs in the matrix of the mitochondria
  - Strips off the carbons from the pyruvate (acetyl coenzyme A)
    - Here it is further broken down. Overall, this stage produces six CO 2 as a by-product, energy is released (2 ATP) and energy is also used to form loaded acceptor molecules (NAD → NADH and FAD → $FADH_2$)



- Inputs:
  - 2 pyruvate
  - 2 ADP + Pi
  - NAD
  - FAD
- Outputs:
  - 6 CO_2
  - 2 ATP
  - NADH
  - $FADH_2$

3. Electron Transport Chain

- Occurs on the cristae as it has a high surface area (more efficient)
  - Electrons from loaded acceptor molecules (NADH and $FADH_2$) enter cytochromes in the cristae of mitochondria
  - Energy is produced (32-34 ATP) from ADP + Pi
  - The hydrogen ions then react with oxygen to produce water.
- Inputs:
  - NADH
  - ADP + Pi
  - FADH2
  - $6O_2$

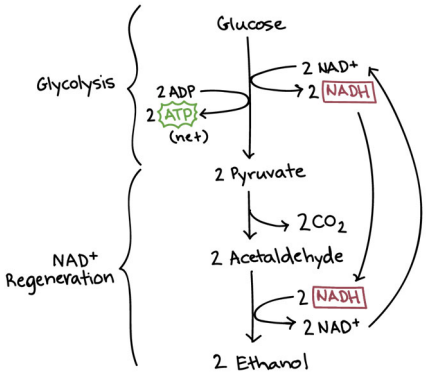
- Outputs:
  - 32 or 34 ATP (high yield) → depends on the cell
    - Energy can be used to transport NADH from glycolysis into the electron transport chain
  - $6H_2O$
  - NAD
  - FAD

ANAEROBIC CELLULAR RESPIRATION (fermentation)

Faster than aerobic respiration as it is less efficient

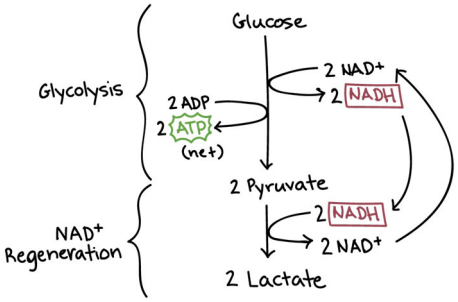
STAGES

1. **Glycolysis**
   - The breaking of glucose
   - Occurs in the cytosol of the cell
   - Doesn't require oxygen
   - Inputs:
     - Glucose
     - 2 ADP + Pi
     - 2 NAD
   - Outputs:
     - 2 ATP
     - 2 pyruvate
     - 2 NADH
2. **Plant Cells:**
   - NADH needs to be recycled for glycolysis therefore it needs to be turned into NAD and hydrogen.
   - Energy from NADH molecules are used to ferment 2 pyruvate to produce 2 ethanol and 2 carbon dioxide molecules.
   - 1 glucose → 2 ethanol + 2 carbon dioxide + 2 ATP



3. Animal Cells:

- NADH needs to be recycled for glycolysis therefore it needs to be turned into NAD and hydrogen.
- Energy from NADH molecules are used to ferment 2 pyruvate to produce 2 lactic acid.
- 1 glucose → 2 lactate + 2 ATP



DIFFERENCES

	Aerobic respiration	Anaerobic respiration
Where it takes place	Cytosol and mitochondria	Cytosol
Oxygen required	Yes	No
Inputs (reactants)	Glucose and oxygen	Glucose
Output (products)	Carbon dioxide, water and ATP	Plants and yeast: ethanol, carbon dioxide and ATP Animals: lactic acid and ATP
ATP produced	36 approx ATP	2 ATP
Efficient/not efficient	More efficient	Less efficient
Fast/slow	Slow	Fast

FACTORS THAT AFFECT THE RATE OF CELLULAR RESPIRATION

- **Temperature**
    - As temperature increases, the rate of cellular respiration increases as kinetic energy between substrate and enzyme increases, increasing the frequency of successful collisions until a point where temperature gets too high and then the enzymes involved in cellular respiration reactions denature
- **Glucose availability**
    - Input of the process
    - If there is not enough glucose, all stages of cellular respiration will slow down as it is the source of energy of cellular respiration
- **Oxygen concentration**
    - Input of the process
    - If there is not enough oxygen, the cell will have to do anaerobic respiration and the rate will increase → aerobic will slow down (may be switching back and forth)
- **Concentration of wastes**
    - As the concentration of wastes increases, the rate of respiration decreases
    - The rate decreases due to the reduced number of successful collisions of reactants as the wastes block the collisions.
    - Wastes can become toxic to the cell, causing the cell the denature.

ADVANTAGES OF AEROBIC OVER ANAEROBIC:

- Aerobic respiration is more efficient as it has a **higher yield of ATP per glucose molecule**, 36-38, compared to aerobic respiration which produces 2 ATP

SIGNALLING MOLECULES

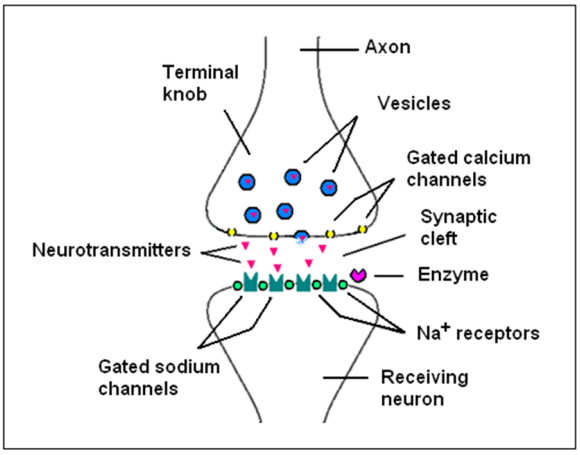
1. **AUTOCRINE:** Work on the **same cell**
2. **PARACRINE:** **Diffusion through tissue fluid**, action on nearby cells/tissues
    a. Specific receptor complementary to the hormone
3. **ENDOCRINE:** Secreted directly into the **bloodstream**, transported through bloodstream, action on distant cells

- Receptors for hydrophilic substances are on the outside of the plasma membrane as it cannot pass through the phospholipid bilayer. Protein based hormones leave the cell via exocytosis.
    - Transduction must occur through a G protein
- Receptors for hydrophobic substances are in the inside of the plasma membrane (cytosol) because it can pass through the phospholipid bilayer. Lipid based hormones leave the cell via diffusion.
    - Can enter the nucleus (hormone-receptor complex)
- Homeostasis
    - Maintenance of a relatively stable internal environment in response to changes in the external environment and the demands of the body at a particular time.
    - Involves
        - Regulation
        - Coordination
        - Integration
        - Adaption

NEUROTRANSMITTERS (NERVE CELLS)

Neurotransmitters relay chemical messages (action potential) from one neuron to another to stimulate a response by crossing the synaptic gap to bind to a **specific complementary receptor** on the postsynaptic neuron.

- **PARACRINE:** Diffusion of neurotransmitters across the synapse to bind to the receptor, stimulating action potential on nearby cells/tissues (it is hydrophilic → peptide based)
    - Specific receptor complementary to the hormone
- Calcium ions enter through ion pumps via active transport → allows exocytosis of neurotransmitters through vesicles fusing with membrane
- Vesicles containing neurotransmitter move to the cell membrane
- Vesicles fuse with cell membrane, neurotransmitter released via exocytosis
- Neurotransmitters diffuse through synapse



- Rapidly broken down by enzymes in the synaptic gap, ensuring the signal is brief and the neurotransmitters are unable to travel to other nearby neurons or effectors
- Neurotransmitters bind to a specific complementary receptor that surrounding cells may not possess
- Hydrophilic

ANIMAL HORMONES

- **ENDOCRINE:** Secreted directly into the bloodstream, transported through bloodstream, action on distant cells
- Produced in endocrine glands
- Slow and prolonged responses
- Protein or lipid based
    - Steroid hormones → hydrophobic
    - Peptide hormones (less than 200 amino acids) → hydrophilic
    - Protein hormones (more than 200 amino acids) → hydrophilic
    - Amino acid derivatives
- Target cell must have **complementary receptors**
- Insulin: reduces the blood glucose concentration
- Glucagon: increases the blood glucose concentration

PLANT HORMONES/PLANT GROWTH REGULATORS

- **PARACRINE:** Diffusion through tissue fluid, action on nearby cells/tissues
    - Specific receptor complementary to the hormone
- Are not produced in endocrine glands as plants don't have endocrine glands. Instead, each cell is able to produce hormones.
    - Therefore don't travel in general circulation
- Slow and prolonged responses
- Are not biomacromolecules → very small
- Target cell must have **complementary receptors**
- Auxin is a stimulus which causes phototropisms (growth towards light)
    - Accumulates in regions opposite to the light
    - Promotes cell growth in these regions by increasing plasticity of cell walls and allowing cells to elongate
- Abscisic acid is a stimulus which promotes stomatal closure
- Ethylene is a stimulus that causes fruit ripening

CYTOKINES

- Non-specific but act in both non-specific and specific immunity
- Small proteins that act as signalling molecules in the immune response.
- Interact with cells via cell surface molecule receptors in signal transduction.
- **Signalling molecule** that acts as a messenger between cells of the immune system
- Produced by virtually all cells of immune system, but mainly by certain T cells
- A cell can only respond to a message from cytokine if it has the **specific complementary external receptor** as they are hydrophilic
- Produced by immune cells
- **AUTOCRINE:** Work on the same cell
- **PARACRINE:** Diffusion through tissue fluid, action on nearby cells/tissues
    - Specific receptor complementary to the hormone

PHEROMONES

- Secreted by one organism of a species to stimulate another organism of the same/other species
    - **Specific receptors** in the same species
- Act outside of the body of the animal or insect secreting it.
- Communication

STIMULUS RESPONSE MODEL IN CELLS

1. Stimulus (occurrence of **signal picked up** by the receptor)
2. Receptor (specialised molecules capable of **receiving** particular stimuli changes shape)
3. Transduction (**cascade of events is triggered**)
4. Effector (**what** part of the body/cell the cascade of events stimulate.)
5. Response (occurrence of an **action** undertaken by the cell)
    a. In multicellular animals, two systems are used to transmit information, the nervous system and the endocrine system
        i. Endocrine system sends transmissions through hormones which have an effect on a specific target effector organ(s). It consists of a number of glands.

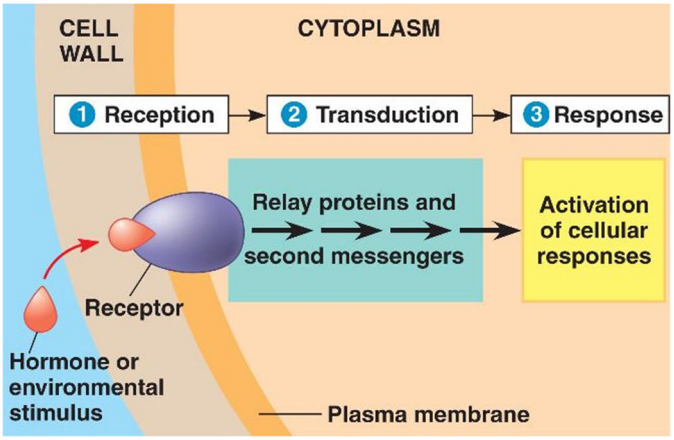
Comparison of nervous and endocrine systems

- Messages of the nervous system are electrical along the axon, chemical at the synapse whereas messages of the endocrine system are chemical through the use of hormones
- Messages of the nervous system are faster than that of the endocrine system
- Messages of the nervous system affects cells which are on direct pathways whereas endocrine messages only affect cells that have the specific receptor
- Messages of the nervous system are short whereas messages of the endocrine system are prolonged until the hormone is destroyed.

SIGNAL TRANSDUCTION

Allows for a singular molecule to cause a response in response to change

state what the signal is in relation to the question, where the receptor is what what specific response is produced



1. **RECEPTION:** The signal is received by the **specific complementary receptor molecule**, either on surface of cell membrane or in cytoplasm

2. **TRANSDUCTION:** **Secondary messengers are activated and triggers a cascade of relay molecules** (cascade of events is triggered).

    a. **Secondary messengers:** A molecule that relays messages in a cell from a receptor on a cell membrane to the final destination where an action within the cell is to take place

    b. Hydrophilic substances

        i. Unable to bind inside the cell → must bind to an external receptor
        ii. Causes a cascade of events.

    c. Hydrophobic substances

        i. Able to cross the plasma membrane and bind to a receptor inside the cell (intracellular receptor)

        ii. Receptor changes shape as the ligand binds to it.

        iii. Complex moves into nucleus

        iv. No secondary messengers

3. **CELLULAR RESPONSE:** The cellular response is **amplified** and **elicits a response** → receptor cell changes in a particular way

The same hormone can have different responses in different target cells because:

- The target cells have **different receptors** which **initiate different responses**
- **Different/same secondary molecules** are activated which results in **different cellular responses**

Types of responses to signals include:

- Activation/suppression of genes
- Production of another hormone
- Activation/inhibition of enzyme action
- Open/close of protein channels
- Transport vesicles to be moved to plasma membrane to secrete cellular products

APOPTOSIS

Programmed cell death, the cell responds to certain signals to release **caspase enzymes** in a highly regulated way.

Caspases are involved in an amplified and regulated signal transduction pathway inside a cell during apoptosis. They enter the nucleus and break down proteins and DNA inside

When does it occur?

- When cells are no longer required (eg. cells between fingers and toes in developing foetus).
- Cells that haven't fully developed (eg. embryonic brain cells).
- Damaged or old cells

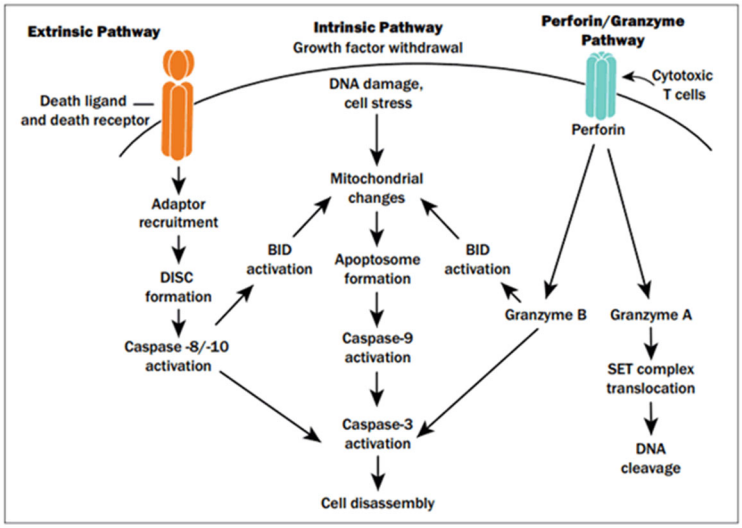
Steps

1. A specific death signal is received by the binding of the death ligand to a complementary death receptor, internally or externally
2. Activates a series of caspase enzymes, **amplifying the response**
3. Cell sends a signal to attract phagocytes to the area
4. Caspases enter nucleus and break down the DNA (nuclear fragmentation) and dismantles the cytoskeleton (cleaves intracellular proteins)
5. Cytochrome C is released from the mitochondria to amplify the response that are generated by the pathways
6. Cell starts to shrink and **blebs**
7. **Phagocytes** digest the apoptotic bodies via phagocytosis

https://www.wehi.edu.au/wehi-tv/apoptosis-and-signal-transduction

Intrinsic (Mitochondrial pathway)

- Signal from inside the cell
    - Triggered by stress or damage to the cell.
- Mitochondria release cytochrome C



Extrinsic (Death receptor pathway)

- Signal from outside the cell
    - This may occur if the cell is no longer needed, or if it is diseased.
    - Ligand binds to a complementary death receptor
- Mitochondria release cytochrome C and break down cell fragments doesn't always happen

Malfunctions

- When apoptosis occurs when it shouldn't be happening or doesn't happen when it should it causes health issues
    - Cancer
        - Uncontrollable division of infected/abnormal self cells that have failed to kill themselves via apoptosis
        - When normal cells turn into cancer cells, some of the antigens on their surface changes so that they are different to the healthy cells surrounding it

Why is it beneficial?

It is beneficial as it removes cells that are no longer necessary therefore saves energy and resources for the organism. It also removes cells that are damaged and/or dangerous therefore maintaining health of organism. It is also essential for development and shaping of organs and tissues.

THE LYMPHATIC SYSTEM

Lymphatic system: The lymphatic system is a network of tissues and organs that help rid the body of toxins, waste and other unwanted materials.

- To transport lymph, a fluid containing white blood cells, throughout the body.
- To collect some of the tissue fluid from the region of the cells that may contain antigens
- In vessels (run alongside blood vessels): Dendritic cells, Macrophages
- In lymph node: spaces where immune cells congregate
    - Antigen presentation occurs here
    - Where large amounts of B memory and B plasma cells are found
- Lymphocytes are produced in bone marrow of long bones
- Unidirectional due to valves

Primary lymphoid organs produce new lymphocytes

1. Thymus gland
    a. T cells mature
2. Bone marrow

Secondary lymphoid organs are where immune responses occur

1. Spleen
2. Tonsils
3. Lymph nodes
    - Lymphocytes hang out here in large numbers
    - Spongy swelling
    - Site of antigen presentation

THE IMMUNE SYSTEM

GLOSSARY

Self markers (don't cause immune responses)

- MHC (Major Histocompatibility Complex) 1
    - A group of proteins which are important for the compatibility of self
    - Specific to the individual
    - Only red blood cells do not have MHC 1 markers
        - Has different self antigens resulting in different blood type
- MHC 2
    - Found in cells in the immune system
    - Antigen presentation
- In order to prevent the body from incorrectly identifying its own cells as pathogenic and destroy its own tissues
- If inactive or suppressed, it leads to the destruction of self cells, causing an autoimmune disease

Antigens: Structures that activate the immune system.

Antibodies: Can specifically bind to antigens

- Adaptive immunity only
    - **Agglutinate**
    - **Block**
    - **Lyse**
- Made up of 4 polypeptides (quaternary structure)
    - 2 long (heavy chains)
    - 2 short (light chains)
    - Bound by disulfide bonds
- Most of the antibody is made up of a constant region (same across all antibodies)
- Antigen-Binding site is part of the variable region (different across all antibodies)

Immune system: Protects our body against all foreign substances.

- Immune cells are produced in bone marrow
    - They move rapidly through the body in the blood to get to sites of infection, where they pass into tissues and then move between individual cells. They return to the blood by travelling via the lymphatic system. Lymph nodes are special sites where they collaborate to fight infection.

TYPES OF IMMUNITY

	Natural/Innate - No medical intervention	**Artificial/induced/aquired** - Medical intervention
Active - Antibodies produced by your immune system	Response to an infection such as influenza	Vaccinations
Passive - Antibodies not produced by your immune system	Breast feeding	● Anti-venom ● Injections that contain antibodies ○ Produced by injecting dead/attenuated pathogens into an animal to stimulate the production of antibodies ○ Antibodies made by the animal are extracted

MALFUNCTIONS OF THE IMMUNE SYSTEM

- **Autoimmune disease**
    - The body incorrectly identifies self cells as non-self and are killed via apoptosis
        - Cells of the immune system fail to recognise other body cells as 'self'
        - The body begins to manufacture antibodies (autoantibodies) and T cells directed against the body's own cells and organs.
        - These autoantibodies attach to the self-antigens and signal attack by white blood cells.
        - Antibodies and T cytotoxic cells may bind to the body's own cells as the infection may antigenically resemble self cells
    - **Multiple Sclerosis**
        - Axons are surrounded by schwann cells and produce myelin (myelin sheath)
            - Prevents electrical signals from escaping from the axon
            - Speeds up action potential
        - Schwann cells are identified as non self, destroying the myelin sheath
        - Neuron can no longer transmit nerve impulses properly, resulting in breakdown of the axon
        - Inflammatory response is also produced, which has other damaging effects.
        - Symptoms include:
            - Loss of movement
            - Speech difficulties
            - Tremors or hand shaking
            - Extreme tiredness
            - Dizziness and feeling of weakness
            - Loss of feeling and control of bodily functions
    - Are not transmitted

- **Allergies**
    - Occurs when immune response is damaging (overreaction to previously encountered antigen) rather than helpful to host
    - Caused by an unwanted inflammatory response
    - Initial exposure:
        - Antigen is engulfed by antigen presenting cell which then travels to the lymph nodes
        - Allergen is presented to T helper cell
        - T-helper cell releases cytokines to attract immature B cell
        - Immature B cell undergoes clonal expansion producing B memory and B plasma cells
        - **Malfunction in B cells cause the overproduction of IgE antibodies** in lymphoid tissue
        - IgE antibodies travel in bloodstream and attach to mast cells, causing them to become hypersensitive
            - For large parasites/bacteria
            - Parasite must bind to two IgE to stimulate an immune response
    - Reinfection:
        - Upon reinfection, a small antigen is able to bind to two IgE, which **triggers mast cells to release histamines that cause an inflammatory response**
            - During anaphylactic shock:
                - Circulating histamines and other released mediators cause airways (smooth muscle) to constrict making it difficult to breathe
        - Allergic responses become worse because each subsequent reaction produces more IgE antibodies against it, which causes more mast cells to become hypersensitive and produce a larger reaction at next exposure.
    - Antihistamines
        - Block receptors for histamine
    - Adrenaline

- Persistent Inflammation
    - When inflammation persists, surrounding healthy tissues can also become damaged
    - Anti-inflammatory drugs inhibit inflammation but in doing so reduces one of our defences (inflammation itself)
- Hypersensitivity reactions should be avoided in order to not increase the response against the antigen

- **Immune deficiency disease**
    - Poorly functioning immune system (line of defence is compromised in some way)
    - Primary Immunodeficiency
        - Child born with deficiency due to a genetic defect
        - Thymus fails to develop – no T cell produced
        - Bone marrow not able to produce specialised immune cells – no B and T cells (Bubble Babies)
    - Secondary Immunodeficiency
        - Occurs as a result of severe stress or another disease
        - HIV
            - Transmitted through direct exchange of bodily fluids
            - A retrovirus (nucleic acid composed of RNA instead of DNA)
            - **Targets Helper T cells** (host cells)
            - **Third line of defence is compromised**
                - People with HIV are more susceptible to other viruses, bacterial and fungal infections as T helper cells cannot coordinate immune response

- **Membrane Receptors and Transplant Rejection**
    - MHC molecules themselves are the antigens that play the major role in transplant rejection
    - If MHC molecules on transplanted tissue are recognised as non-self, immune system is triggered to reject foreign tissue
    - Always have to take immunosuppressive drugs for rest of life to prevent rejection by Tc cells

- **Evasion**
    - Pathogen hides within body's host calls and therefore are protected by the cell's self markers and as a result, the body is unable to detect it

PATHOGENS

A disease causing agent that **impairs the normal functioning of an organism**

- Cellular or noncellular
- Pathogens may be undetectable by the immune system if they hide in self cells or have no detectable foreign antigens on its surface.
- **ANTIGENS CAN MUTATE, RESULTING IN A NEW DISEASE**

GLOSSARY

Contagious: Spread by contact

Infectious: Spread by bodily fluids

Disease: Any condition that does not allow an organism to function normally

Parasite: An organism reliant on its host for survival

CELLULAR

Bacteria

- Prokaryotic
    - Cytoplasm, cell membrane, DNA and cell wall
    - Capsules, flagella and slime layers
- Many shapes, groupings and stainings in which they are classified
    - Rod or bacillus
    - Spherical or cocci
    - Long spiralling or spirochaete
- Binary fission
    - Exponential growth
- Releases toxins (exotoxins)
- Increase in virulence can be due to:
    - Fast reproductive rate
    - Fast mutation rate to allow antibiotic resistance
    - Flagella and pili to move around more quickly
- Normally heterotrophic
- **Treatment:** Antibiotics

Protozoa

- Unicellular eukaryotes
- Cell membrane but not all have a cell wall. Flagella or cilia may be present
- Binary fission and spores
- Heterotrophic
- **Treatment:** Break life cycle

Fungus

- Multicellular eukaryotes
    - Cell wall is composed of chitin
    - Yeast is unicellular
- More common in plants
- Heterotrophs
    - Cannot manufacture their own food
    - Obtain nutrients from the decomposition of organic matter
- Fungal spores everywhere and will grow on any organic matter with suitable moisture and temperature
    - Can also reproduce via binary fission
- **Treatment:** Fungicides

NON-CELLULAR

- Require host cells to produce
- No cytoplasm or ribosomes

Virus

- Non-cellular
- Only active in living cells
    - Cannot reproduce themselves--uses host cell
- Infectious particles
- Smaller than bacteria
- Antigens on the surface
    - Host cell has receptors for other purposes. Antigens bind to these receptors, taking advantage of them, and enters the cell
    - Host specific

- Made of a protein coat with nucleic acid inside
    - DNA – Adenoviruses
    - RNA – Retroviruses
    - Becomes incorporated into the genome of the host
    - Host produces new virus particles
- Lack own protein making machinery hence need for a **host cell** to reproduce
- Protein layer
- Lipid layer
- Can mutate to become resistant to drugs
    - Mutation rates in viruses can differ
    - Mutations cause a change in the surface antigens, therefore antibodies and memory cells produced previously may be ineffective
- Leaves viral footprints when the virus enters the cell
- **Treatment:** Antiviral drugs

Prions

- Protein that occurs mainly in nerve cells (function unknown)
- If we become infected with a defective protein it converts normal protein into abnormal protein
- Eventually cause cell to burst and are then free to infect other cells
- Self replicating
- **Treatment:** None

FIRST LINE OF DEFENCE → BARRIERS TO THEIR ENTRY

- Non specific

ANIMALS

- **Intact skin surface**
    - If a cell is dead, the virus can't infect it
    - A cut or abrasion will allow entry of bacteria or viruses
    - Glands in the skin secrete fatty acids and sweat contains salt – both inhibit bacteria
- **Ciliated mucous membranes**
    - Secreted by cells lining respiratory tract traps bacteria which are swept up to back of throat by action of cilia
        - Some are removed when you blow your nose or removed from respiratory tract when you cough or sneeze
        - Mucus lines digestive tract making it difficult for microorganisms to penetrate cells beneath
- **Stomach acid**
    - Low pH
    - Bacteria is destroyed in the acid
- **Lysozyme in tears**
    - Digests the proteins in bacterial cell walls
- **Expulsion reflexes**
    - Vomiting
    - Diarrhea
    - Sneezing
    - Coughing
    - Itching

- **Natural Flora**
    - Microbiological barriers would include ones that have some kind of organism that reduces infection.
    - Many different bacteria are normally found in skin and in the gut which are non-pathogenic in those areas
    - Presence inhibits the growth of pathogenic bacteria in those places because they compete more successfully for the space and nutrients that are available and needed for bacterial replication
    - Natural flora can be disturbed when a person takes antibiotics
- **Blood Clotting**
    - Blocking the wound with a mass of blood cells
        - Platelets come into contact with damaged blood vessels
        - Blood vessels release enzyme that converts fibrinogen into insoluble fibre and a clot forms
- **Sebum**
    - Produced by the skin and acts like a mild antiseptic

PLANTS

Physical

- A waxy cuticle over the epidermis → prevents entry of many pathogens
- Abnormal swelling of stomata (galls), helping limit distribution of pathogen in plant
- Thick bark creates a barrier to pathogens

Chemical

- Produce toxins
- Thickened cell wall → slows/prevents entry of viruses
- Some plants produce chemicals that protect against some fungi and bacteria produce enzymes which digest fungus cell walls
- Antibiotic secretion in cells
- Contain high levels of toxins in their leaves
- Some trees, eg lemon and mint, produce oils that repel some insect pests
- Oils and sap can seal breaches

How can the first line be compromised?

- Skin is no longer intact, which is the first line of defence, allowing the pathogen to gain entry into the body, compromising the first line of defence.

SECOND LINE OF DEFENCE → INNATE IMMUNE DEFENCE

- Non-specific inbuilt defences that defend against all types of pathogens
- No memory of the interaction
- Quicker than adaptive immune response

GLOSSARY

Vasodilation: Dilation of blood vessels

Erythrocyte: Red blood cell

Leukocyte: White blood cell

Platelets: Contain proteins for blood clotting.

Phagocytosis

1. Phagocyte recognizes bacterium as non-self
2. Phagocyte envelopes bacterium with its cell membrane
3. Vacuole forms around bacterium
4. Lysosomes fuse with vacuole
5. Powerful enzymes digest bacteria

MACROPHAGE

- Phagocytes engulf anything foreign
    - Endocytosis
        - Lysosomes digest
- Antigen presenting cells → MHC 2 markers that are used to present foreign antigens → sets up the adaptive immune response
- These cells ingest and clean up messes that include disabled cells or viruses that have been flagged with antibodies and dead cells.
- Can also secrete cytokines to activate tissue repair and attract other phagocytes
- Found all over the body in tissues
- Pseudopods to absorb things
- Longer life span that neutrophils

DENDRITIC CELL

- Phagocytes engulf anything foreign
    - Endocytosis
        - Lysosomes digest
- Antigen presenting cells → MHC 2 markers that are used to present foreign antigens to T helper cells and T cytotoxic cells→ sets up the adaptive immune response
- If they detect pathogens within the body, they incorporate antigenic material to present on its surface. Move to lymph nodes where they present to T helper cells, acting as communication between specific and non-specific (adaptive and innate) immune mechanisms.
- Found on the surface of the body, tissues and in lymphatic vessels
- Large folded cell membrane increasing surface area

NEUTROPHIL

- Phagocytes engulf anything foreign
    - Endocytosis
        - Lysosomes digest
- Most common → Found circulating in the bloodstream
- Neutrophils release cytokines that trigger other cells and amplify the inflammatory response.
- Destroy pathogens by release of toxins.
    - Can kill healthy cells
- When they sense signals that an infection is present, they are the first cells to migrate to the site of the infection to begin killing the invading pathogen.
- Weird nucleus

MAST CELLS

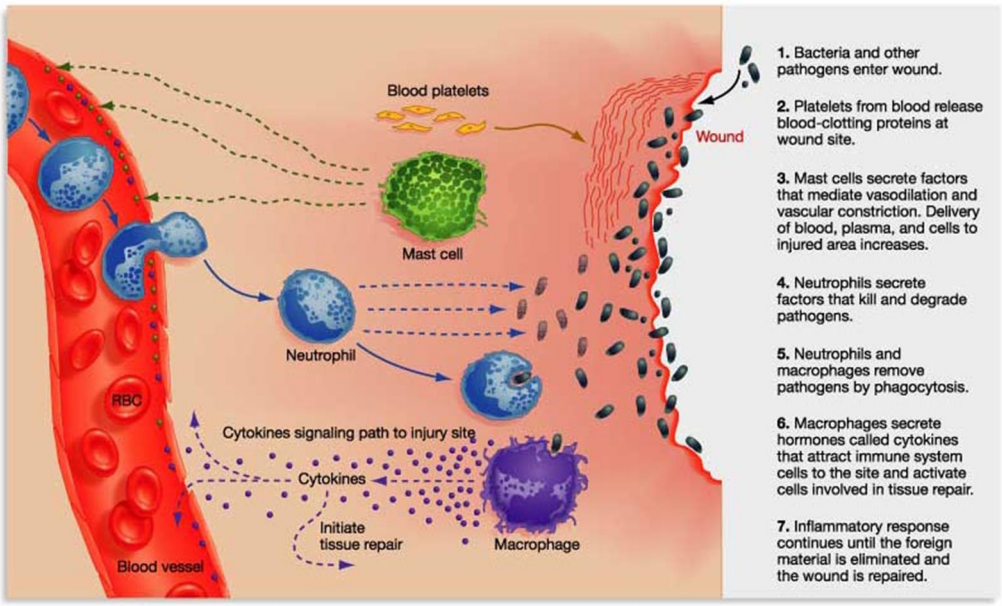
- Involved in the inflammatory response
- **Secrete histamine when foreign substances/damage is detected**
- Granular appearance due to vesicles filled with histamines which are released in allergic reactions or response to injury
- Embedded in connective tissues
- Mast cells circulate in an immature form, only maturing once in a tissue site.

THE COMPLEMENT SYSTEM

- When infection occurs they are activated
- A group of 30 blood proteins that act on each other to produce four responses:
    - **Opsonize pathogens**
        - Stick on the surface of the pathogen and make the pathogen more easily recognisable as foreign for other cells
        - Stimulates phagocytes to become more active
        - Makes the innate immune system more effective
        - From cutaway proteins
    - **Attract phagocytes (chemoattractants)**
        - Phagocytes are attracted to the source of the complementary proteins
        - From cutaway proteins
    - **Cell lysis**
        - Form a membrane attack complex, a ring of proteins, (**MAC**)
        - **Creates pores to rupture and kill the bacteria**
        - Formed after many proteins are cut
- Second line: because it's in the blood
- Three pathways:
    - Classical
        - Starts when two antibodies join to a bacteria
        - Cascade of events
    - Lectin
        - Starts by a mannose binding lectin binding to mannose (common in the cell wall of bacteria) and turning it into an enzyme
        - Cascade of events
    - Alternative
        - Factor D will take the protein B and break it up and join up with C3b to form an enzyme
        - Cascade of events

INFLAMMATION RESPONSE

- Caused by a release of histamine
- Mast cells start in the blood stream and settle in connective tissue
- If they detect damage in nearby tissues (ie. too much UV or wound), they response by releasing histamines
    - Histamines can cause:
        - **Vasodilation of blood vessels** → **increases blood flow to bring in more phagocytes to infection site**
            - Redness – due to increased blood flow to region
            - Heat – due to increased blood flow to region. **Can kill some pathogens.**
            - Fever – reduces growth rate of bacteria and allows for other defences to intervene and increasing body enzymes activity
        - **Increases the permeability of capillaries** (leukocytes and phagocytes)
            - To allow phagocytes to pass easily from blood to infected tissue
            - Swelling – due to increased permeability allowing fluid to leave circulation and enter tissues. **Also limits movement of pathogens, preventing its spread.**
            - Pain – caused by swelling and substances released by injured tissue
        - **Constriction of airways (allergies)**
        - **Attract phagocytes**
    - Pus is dead phagocytes and bacteria
- **Steps**
    1. Pathogens enter wound
    2. Platelets from blood release blood clotting proteins at wound site
    3. Mast cells secrete histamines that increase blood flow and attract phagocytes
    4. Neutrophils secrete toxins to kill pathogens. Both neutrophils and macrophages remove pathogens via phagocytosis
    5. Macrophages secrete cytokines that activate tissue repair
    6. Inflammatory response continues until the foreign material is eliminated and the wound is repaired

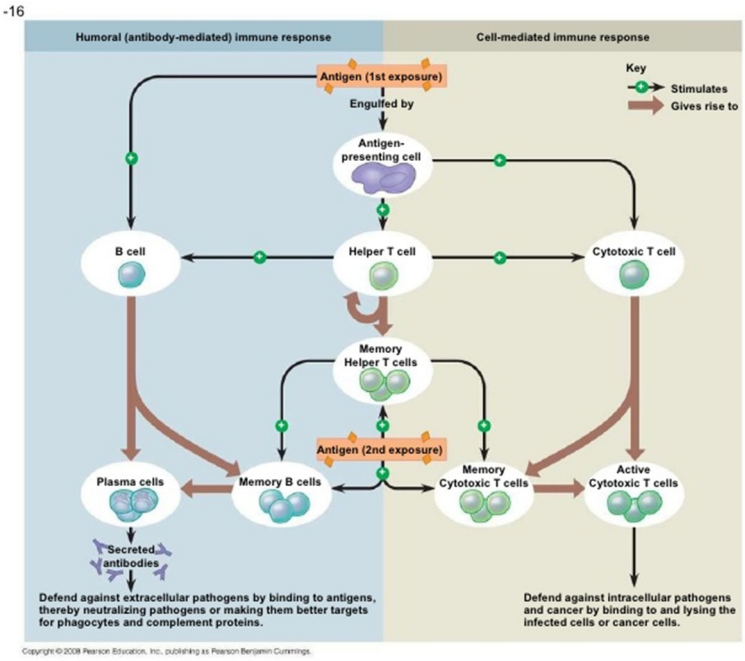


CYTOKINES

- Non-specific but act in both non-specific and specific immunity
- Small proteins that act as signalling molecules in the immune response.
- **Signalling molecule** that acts as a messenger between cells of the immune system
- Produced by virtually all cells of immune system, but mainly by certain T cells
- A cell can only respond to a message from cytokine if it has the **specific complementary external receptor** as they are hydrophilic
- Produced by immune cells
- **AUTOCRINE:** Work on the same cell
- **PARACRINE:** Diffusion through tissue fluid, action on nearby cells/tissues
    - Specific receptor complementary to the hormone

THIRD LINE OF DEFENCE → ADAPTIVE IMMUNE RESPONSE

- **Specific defences** that recognise and act against a specific antigen of a pathogen
- **Retains memory** of the interaction for **more rapid and larger response upon subsequent infection**
- T and B cells are lymphocytes.
- Occurs in the lymph



Humoural Immune Response

- Using the blood and lymph eg. Antibodies
- When the infection is in the body's fluids
- Involves B cells to produce specific circulatory antibodies to block or agglutinate pathogens

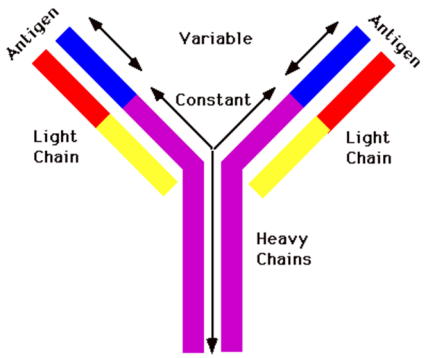
Antigen presenting cells present antigen on its surface to T Helper cell that has a surface receptor complementary to antigen. T Helper cell stimulates, via cytokines, clonal selection of B cell that has come into contact with antigen and has surface receptors complementary to the antigen to undergo clonal expansion into B plasma cells and B memory cells via secretion of cytokines. B plasma produce the specific circulatory antibody against the pathogen. B memory retains the specific antibody like receptor in case of reinfection.

Cell Mediated Immune Response

- Using cells eg. T Cytotoxic Cells
- Involves T Cytotoxic cells perforating toxins to kill infected self cells
- When infection is in the cells

Antigen presenting cells present antigen on its surface to T Helper cell that has a surface receptor complementary to antigen. T Helper cell stimulates naive T cytotoxic cell to undergo clonal expansion and become active via secretion of cytokines. When a T cytotoxic cells finds a self cell with the specific antigen presented on the MHC 1 marker that binds to its complementary receptor, the T Cytotoxic cell releases perforin to lyse the cell

ANTIBODIES



- Antibodies can specifically bind to antigens (reaction is not visible)
    - **Adaptive immunity only**
        - **Agglutinate** for phagocytes or complement system
            - Activities of foreign organisms are inhibited
        - **Block**
        - **Lyse**
    - Made up of 4 polypeptides (quaternary structure)
        - 2 long (heavy chains)
        - 2 short (light chains)
        - Bound by disulfide bonds
    - Most of the antibody is made up of a constant region (same across all antibodies)
    - Antigen-Binding site is the variable region (different across all antibodies)
        - Produced by **alternate gene splicing**
            - No set introns or exons
            - Some rearrangement configurations can accidentally mimic a person's self molecules and proteins
- 5 different classes of antibodies determined by its heavy chain (Ig = Immunoglobulin)
    - B Plasma cell can only produce one type of antibody
    - Different concentrations
    - Has an order of release
        - Ig M → found in mucus secretion
        - Ig G → found in milk (only one that crosses the placenta and is the most common)
        - Ig A → found in secretions mucus, cut, tears, saliva, milk etc
        - Ig E → least common and involved in allergic responses. Parasite must bind to two IgE to stimulate an immune response
        - Ig D

- **Monoclonal antibodies**
    - Antibodies that have been mass produced and designed artificially to bind to one specific part (epitope) of one specific antigen
    - Monoclonal means the antibodies are one type produced by one cell line, containing cells that are clones of one original antibody producing cell
    - Can use the antibodies to **carry material for more precise treatment**
        - Radiation
            - More precise radiation treatment
        - Toxins
            - More precise chemotherapy treatment
            - Chemotherapy uses a cytotoxin to kill cells while they are dividing
                - Not precise
        - Antigens
            - Antibody sticks to a specific protein on cancer cell
            - Attract phagocytes to the area
            - Cancer cell can be recognised as non-self
            - Phagocytes to engulf the cancer cells
    - Can **stimulate the complement system**
        - MAC to stick to cancer cells to destroy the cell
    - Designing antibodies **to bind to death receptors** (FasR) on cancer cells to stimulate apoptosis
    - To **damage the blood vessels leading to the tumor**
        - Tumors can produce their own vessels to get nutrients to fuel their rapid expansion
        - Cuts of nutrients so the tumor will not be able to grow as fast (reproduce)

T HELPER CELLS (Th)

- **Stimulates** responses in B and T cells with the use of **cytokines**
- T helper cells are responsible for **activating other immune cells** in the adaptive immune system via cytokines.
- Involved in both humoral and cell mediated responses
- Each T helper cell has **one specific T cell receptor** for an antigen (one antigen binding site)
- Antigen presenting cells present antigens to T helper cells
- Once the antigen binds to its specific T cell receptor, the T Helper cell is stimulated and undergoes clonal expansion (stimulated by antigen presenting cells)
- MHC 2 markers
- Identify non self MHC markers → Transplants
- If damaged/infected by virus, would be unable to activate B cells or cytotoxic T cells and without these a person is at risk from not being able to fight other infections

T CYTOTOXIC CELLS

- Kills infected self cells by **perforation** of toxins
- Specific T cell receptor
- **Once T Helper cell with the same specific antigen secretes cytokines (paracrine), it stimulates T cytotoxic cells to undergo clonal expansion**
- When a T Cytotoxic cells finds a self cell with the specific antigen presenting on the MHC 1 marker that binds to its receptor, the T Cytotoxic cell releases a chemical, perforin (a death ligand), to **stimulate the cell to undergo cell death**
    - Different to apoptosis in that Tc releases toxins (perforin) to perforate/lyse cells whereas apoptosis is initiated through the production and release of caspase enzymes

T MEMORY CELLS

- **Retains** the specific antibody-like receptors for the pathogen (retains informations on immune response)
    - Can act like a T Helper Cell
- Long life span
- **Rapid and large response**
- Used for reinfection
- Basis for vaccination

B CELLS

- Surface antibody
- Immature
- Once the antigen binds to its specific antibody-like receptor (selected), the B Cell cannot do anything until a T Helper cell with the same specific antigen secretes cytokines (paracrine) to stimulate a B cell to undergo **clonal selection (selecting correct B cell) expansion (into B Plasma or B Memory)**
    - When naive B cells encounter an antigen, it starts the maturation process for the B cell.
    - B cell modifies antigen and presents it on the cell membrane to be recognised by receptors on T Helper cells
    - Clonal selection expansion allows for more specific antibodies to fight infection to be produced as all cells are genetically identical so they respond to the same antigen
- MHC 2 markers to act like antigen presenting cells

B PLASMA

- Produces **specific circulatory antibodies** to fight against pathogens
- Sheds their antibodies and releases them into lymph to be pumped around the body
- Requires large amount of protein synthesising and exporting organelles

B MEMORY

- **Retains** the antibody-like receptors for the pathogen for reinfection
- Rapid and large response of clonal selection expansion for subsequent reinfection
    - More rapid response due to the existing presence of B memory cells from primary response
    - Larger response due to the rapid division of B memory cells after reinfection and as a result, produce more specific circulatory antibodies
- Long life span
- Lasting immunity
- Used in reinfection
- More surface antibodies

VACCINATIONS

- Treatment to produce specific B memory cells against a disease in case of reinfection
- To provide herd immunity
- Contains antigens but is not disease causing
    - Inactivated → Inactivated virus
    - Attenuated → Active virus but reduced in virulence (higher immunity)
    - Toxoid → Changing the toxin
    - VLP → Virus Like Particle (has the antigens but no DNA or RNA)
- Should **activate** the adaptive immune system
    - **Causes the production of specific B memory cells specific antibodies**
- Injected or taken orally
- After the first vaccine there are many memory B cells remaining in the vaccinated body. Each subsequent vaccine leaves an increasing number of memory B cells because once the antigen is administered, the chance of contact between the antigen and many of the B memory cells is high. Each interaction will lead to a similar response as the initial response. This makes the response faster and greater (more antibodies).
- Booster vaccinations exist to replace/increase number of B memory cells → to produce more B plasma and B memory cells
- B memory cells take time to mature → taking time between vaccinations allows the B memory cells to be activated effectively
- To limit the spread and occurrence of the virus through herd immunity

HERD IMMUNITY

- When there is a sufficiently high proportion of people who are vaccinated/immune (95%), it reduces the likelihood of non-immune individuals from contracting disease as they are unlikely to encounter pathogen.
- If not enough people (less than 95%) are vaccinated and an outbreak occurs, the people that are not vaccinated are more likely to contract the disease as there is no herd immunity
- 95% of the population
- People who depend on herd immunity
    - People without a fully-working immune system
    - Newborn babies who are too young to be vaccinated
    - Pregnant women
    - Elderly people
    - Many of those who are very ill in hospital