Topic 1.1: Cell biology – Introductions to cells

The evolution of multicellular organisms allowed cell specialization and cell replacement.

• **Understanding: According to the cell theory, living organisms are composed of cells.**

- Three tenets of the cell theory:
  1. All living organisms are composed of one or more cells
  2. The cell is the basic unit of structure and organization in organisms
  3. Cells arise from pre-existing cells

• **Understanding: Organisms consisting of only one cell carry out all functions of life in that cell.**

- Unicellular organisms: organisms composed of a single cell that carry out all of their life processes within that cell
- Multicellular organisms: organisms composed of multiple cells that carry out functions of life by division of labour

- Most cells in multicellular organism are much less complex than unicellular organisms as the latter needs to carry all functions of life while the roles may be divided in the former.

- Essential functions of life:
  - Metabolism: chemical reaction inside the cell (often uses ATP for energy)
  - Response: ability to react to environmental stimuli (as it appropriately perceives)
  - Homeostasis: maintenance of condition inside the organism (through measures such as phospholipid bilayer)
  - Growth: getting to full size and repairing old cells (via cell division)
  - Reproduction: ability to produce offspring (sexual or asexual)
  - Excretion: removal of waste products
  - Nutrition: obtaining food for energy and growth

• **Understanding: Surface area to volume ratio is important in the limitation of cell size.**

- Surface area to volume ratio: ratio of surface area to volume (i.e. SA:V)
  - Ratio trend: ratio falls as cell size increases (as the cell size increases, volume increases faster than surface area)

- To function efficiently a cell needs a large surface area relative to its volume (high SA:V ratio)
  - If the ratio is too small: waste products accumulates, cells may overheat
  - If the ratio is too big: cells may not be able to contain all the necessary organelles

• **Understanding: Multicellular organisms have properties that emerge from the interaction of their cellular components.**

- Emergent properties: arise from the interaction of the component parts of a complex structure.
  - Alternatively expressed as: "the whole is greater than the sum of its parts"

• **Understanding: Specialized tissues can develop by cell differentiation in multicellular organisms.**

- Specialized cells: cells modified (undergo differentiation) to carry out a particular function more efficiently
- Division of labour: different cells perform different functions in multicellular organisms
  - Division of labour in human cells: humans have 220 distinctively different cell types

• **Understanding: Differentiation involves the expression of some genes and not others in a cell's genome.**

- Cell differentiation: process where a cell changes from one cell type to another to develop ideal structure for specific functions
  - Cause: different sequence of genes is expressed (used) while others are not for cells to differentiate
  - Result: differentiation give rise to different sets of genes being expressed despite identical genome
  - Advantage: epigenetic modifications to shut down the expression of irrelevant genes

  - Cells have genes required to specialize in every possible way, but all genes in a cell's genome are not always used
  - Control of gene expression is therefore important for development in multicellular organisms

• **Understanding: The capacity of stem cells to divide and differentiate along different pathways is necessary in embryonic development and also makes stem cells suitable for therapeutic uses.**

- Characteristics of stem cells:
  - Undifferentiated: have not yet specialized into a certain type of cells and therefore all genes can be expressed
  - Self-sustaining: can divide and replicate for a long time to produce copious quantities of new cells

- Cause of stem cell differentiation: stem cells are able to differentiate into a particular cell type when given a specific signal
- Therapeutic use: stem cells are therefore useful to produce regenerated tissues and provide a means of healing certain diseases

- Cell potency (stages and versatility of early stem cells):
  - Totipotent: can become any type of cells; constitutes in early zygotes
  - Pluripotent: can become almost any kind of cells; found and cultured in blastocysts
  - Multipotent: can become a limited number of particular cell types; found in umbilical cords or in bone marrow

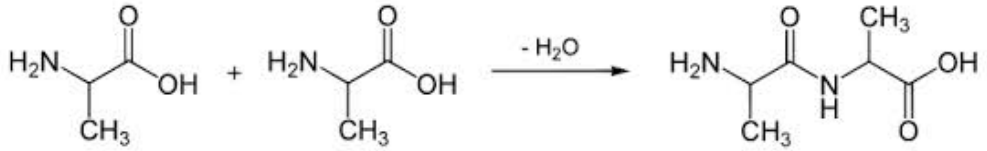
Topic 2.4: Molecular biology – Proteins

Proteins have a very wide range of functions in living organisms.

• **Understanding: Amino acids are linked together by condensation to form polypeptides.**

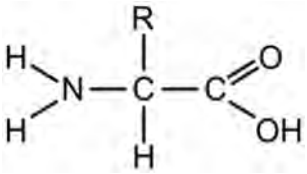
- Polypeptides: chains of amino acids that are made by linking together amino acids by peptide bonds in a condensation reaction
  - Polypeptides in protein: Polypeptides are the main component of proteins and are often the only components of protein

- Condensation reaction (formation of peptide bonds):



- Polypeptide bonds can be broken down by the enzyme protease

• **Understanding: There are 20 different amino acids in polypeptides synthesized on ribosomes.**



- Identical structural features of amino acids:
  - Carbon atom: in the centre bonded to a hydrogen atom
  - Amine group: gives amino acids its basic property
  - Carboxyl group: gives amino acid its acidic property
  - Additional R group: differentiates amino acids

- There are 20 different types of amino acids resulting from the variety of the R-group
- Some proteins contain amino acids that are not the basic 20; these are usually one of the twenty modified after synthesis

• **Understanding: Amino acids can be linked together in any sequence giving a huge range of possible polypeptides.**

- Although there are only 20 variants of different amino acids, these can combine into an almost infinite variety of proteins
- Ribosome can make peptide bonds between any pair of amino acids, so any sequence is possible

• **Understanding: The amino acid sequence of polypeptides is coded for by genes.**

- Most genes in cells store the amino acid sequence of a polypeptide

- Triplet: three bases of the gene is required to code for each amino acid in the polypeptide
- Degeneracy of the code: repeat in amino acid coding as 64 variants are possible with three bases

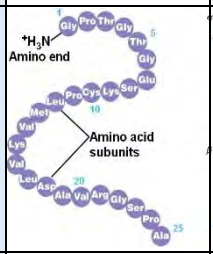
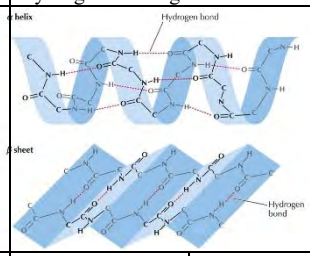
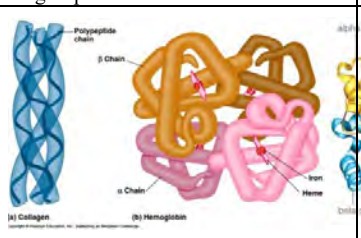
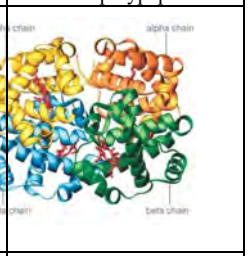
• **Understanding: A protein may consist of a single polypeptide or more than one polypeptide linked together.**

- Quaternary structure: association of polypeptide chains in a protein
  - A protein can consist of more than one polypeptide chains for different functions

No. of polypeptides	Example	Function
1	Lysozyme	Enzyme in secretions such as tears, nasal mucus
2	Integrin	Membrane protein used to make connections between structures inside and outside of a cell
3	Collagen	Structural proteins that provide high tensile strengths; the rope-like structure of collagen polypeptides ensure a greater tensile strength
4	Haemoglobin	Transports oxygen in red blood cells; the four parts of haemoglobin interact to transport oxygen more effectively to tissues that if they were separate

• **Understanding: The amino acid sequence determines the three-dimensional conformation of a protein.**

- The different R-group interactions between amino acids determine the three dimensional conformation
- R groups can be hydrophobic (nine, with three containing rings), hydrophilic (even, with seven that can be charged)

	Primary structure	Secondary structure		Tertiary structure		Quaternary structure
		Alpha helices	Beta sheets	Fibrous	Globular	
Description	Sequence of amino acids	Stabilized interaction through hydrogen bonding		Further and final interaction between R-group backbones		Interaction between different polypeptides
Diagram						
Note		Adjacent	Opposite	Insoluble	Soluble	

Topic 5.2: Evolution and biodiversity – Natural selection

The diversity of life has evolved and continues to evolve by natural selection.

• **Understanding: Natural selection can only occur if there is variation among members of the same species.**

- Individuals in species share the same genes but with different versions resulting in variation
- Natural selection depends on such variations; individuals with more favourable traits tend to survive

• **Understanding: Mutation, meiosis and sexual reproduction cause variation between individuals in a species.**

- Cause of variation between individuals in a species:
  - Mutation: original source of new alleles that enlarges the gene pool
  - Meiosis: produces new combinations of alleles through crossing over and independent orientation
  - Sexual reproduction: allows mutations that occurred in different individuals to be brought together

• **Understanding: Adaptations are characteristics that make an individual suited to its environment and way of life.**

- Adaptation: inherited characteristics evolved through natural selection that makes an individual suited to its environment
  - Non-directional nature of adaptation: adaptation through natural selection does not develop with a direct purpose

• **Understanding: Species tend to produce more offspring than the environment can support.**

- Overpopulation: production of offspring than the environment can support; general trend in most species

• **Understanding: Individuals that are better adapted tend to survive and produce more offspring while the less well adapted tend to die or produce fewer offspring.**

- Darwin and Wallace's theory of evolution: "Theory of Natural selection"
  - Variation: chance variations between individuals occur within species
  - Heritability: organisms beget like organisms, and so some of the variation among individuals is passed down
  - Overpopulation: more offspring are produced each generation than can be supported by the habitat
  - Selective pressure: some individuals with certain traits have a higher chance of surviving and reproducing (competition)

• **Understanding: Individuals that reproduce pass on characteristics to their offspring.**

- Inherited characteristics: characteristics an individual is born with; passed on to offspring
- Acquired characteristics: characteristics acquired during the lifetime of an individual; not passed on to offspring

• **Understanding: Natural selection increases the frequency of characteristics that make individuals better adapted and decreases the frequency of other characteristics leading to changes within the species.**

- Gene pool: combination of all genes in a population and frequency of alleles for each gene
  - The favourable alleles increase in frequency in the gene pool due to natural selection
  - Ratio of alleles and genotype will gradually change (evolve) with time

• **Application: Changes in beaks of finches on Daphne Major**.

- On Daphne Major island, species of bird (Geospiza fortis) feed on large and small seeds
- Their beak length correlated with their size and availability of diet over years

- Event of natural selection:
  - 1977 – drought caused shortage of small seeds; highest mortality amount short beaked individuals
  - 1982-1983 – increased supply of small seeds; increased population among short beaked individuals
  - 1987 – weather back to normal, less small seeds; decreased population among short beaked individuals

• **Application: Evolution of antibiotic resistance in bacteria.**

- Process of antibiotic resistance development in bacteria:
  - Exposure to antibiotic: population is exposed to antibiotics
  - Mutation of bacteria: in a population with no resistance, a bacterium with antibiotic resistance form with mutation
  - Natural selection: survival becomes more advantageous for bacteria with resistance, so this strain becomes prevalent in
  - Resistance propagation: most individuals in the population becomes antibiotic resistant with transformation

- Reason for prevalence of antibiotic resistance:
  - Hospital use: uncontrolled use in hospital that allows for resistance development
  - Livestock feed: antibiotic use in animals to increase yield
  - High chance of mutation in bacteria: high chance for bacteria to mutate and survive
  - Transformation ability of bacteria: ability of bacteria to pass genes onto other bacteria through plasmids

• **Nature of science: Use theories to explain natural phenomena—the theory of evolution by natural selection can explain the development of antibiotic resistance in bacteria.**

• **Guidance:** Students should be clear that characteristics acquired during the lifetime of an individual are not heritable.
• **Guidance:** The term Lamarckism is not required.

• **Understanding: The rate of ventilation is controlled by the respiratory control centre in the medulla oblongata.**

- Controlling rate of ventilation
  - Respiratory control centre receives signal: receives signals from chemoreceptors in aorta and carotid artery
  - Control centre sends impulse to lungs: medulla oblongata send impulse to lungs by two nerves
    - Intercostal nerves: stimulate intercostal muscles in the lung
    - Phrenic nerves: stimulates diaphragm in the lung

  - Lung expands: impulse send to intercostal muscles and diaphragm stimulates lung to expand
  - Stretch receptors send signal: stretch receptors in the lung to respiratory centre triggers cessation of signal
  - Lung collapses: cessation of signal cause exhalation as lung collapses
  - New signal is sent: stretch receptors stops sending signals, causing continuity of signals from medulla

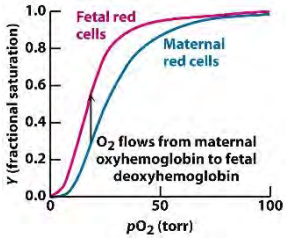
  - Cycle repeats: rate in which the following cycle undergoes depends on rate of impulse transmitted
  - Negative feedback loop: rate of ventilation in response to pH acts as a negative feedback

• **Understanding: During exercise the rate of ventilation changes in response to the amount of CO_2 in the blood.**

- Consequences of exercise
  - Increased CO_2 levels: increased metabolism lead to greater cellular respiration that results in high CO_2 waste level
  - Lower pH: increased CO_2 means more CO_2 dissolve in water to dissociate into H^+ and bicarbonate ions

- Hyperventilation: rapid breathing; faster ventilation rate
  - Reason: high level of CO_2 trigger increase in ventilation rate in order to remove excess CO_2
  - Chemoreceptors detect change in blood carbon dioxide and send impulses to quicken ventilation

• **Understanding: Fetal haemoglobin is different from adult haemoglobin allowing the transfer of oxygen in the placenta onto the fetal haemoglobin.**



- Fetal haemoglobin has a higher affinity for oxygen compared to adult haemoglobin
  - Comparison: dissociation curve on the left; higher affinity for oxygen
  - Adaptive feature: gas exchange in fetus does not occur in the lungs with high partial pressure; but rather with maternal blood in placenta (which has relatively low PO_2 compared to atmospheric air)

• **Application: Consequences of high altitude for gas exchange.**

- Effect of altitude on atmospheric pO_2
  - Low atmospheric pO_2: there is relatively low pO_2 in the air
  - Low supply of tissues with oxygen: haemoglobin may not be adequately saturated with oxygen

- Physiological response to high altitude
  - Increased number of red blood cells: red blood production increase in increase total circulating haemoglobin
  - Increased ventilation rate: increases rate of gas exchange and oxygen available in body
  - Myoglobin production: muscles produce more myoglobin to ensure deliver of oxygen to tissues
  - Greater lung surface area: increase area available for gas exchange for more oxygen

• **Application: pH of blood is regulated to stay within the narrow range of 7.35 to 7.45.**

- Normal range of human blood pH: 7.35 to 7.45
  - pH and pCO_2: higher pCO_2 result in lower pH

- Regulation of blood pH
  - Increased rate of ventilation
    - Signalling of chemoreceptors: in low pH, chemoreceptors send impulse to respiratory centres in medulla
    - Increased ventilation rate: medulla sends impulse via phrenic and intercostal nerves to increase ventilation
    - Withdrawing of CO_2 from blood: CO_2 dissolved is withdrawn, reversing carbonic acid reaction
    - Reduce acidity: H^+ ions and bicarbonate ions form more CO_2 and water; hence reduced pH

  - Secretion/reabsorption of ions in kidney
    - Secretion of H^+ ions: protons can be secreted into the urine bound to buffers
    - Absorption of bicarbonates: bicarbonates can be reabsorbed to neutralize the acid
    - Secretion of bicarbonates: bicarbonates can be secreted if the blood becomes to basic

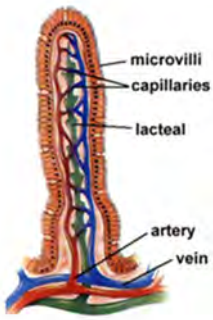
• **Application: Causes and treatments of emphysema.**

- Emphysema: lung condition in which the walls between individual alveoli break down leading to reduction in surface area
  - Inefficient gas exchange: gas exchange becomes less effective due to less surface area in alveoli
  - Low oxygen uptake: oxygen uptake to blood is restricted with low gas exchange

- Symptoms of emphysema
  - Barrelled chest: physical increase in chest cavity due to lungs being trapped in inspiration position
  - Shortness of breath: breaths are often short due to inability to inspire and expire properly

• **Understanding: The structure of cells of the epithelium of the villi is adapted to the absorption of food.**

Characteristics	Role
Microvilli	Increases surface area for absorption
Abundance of mitochondria	Provide energy to drive active transport process
Pinocytic vesicles	Enables absorption by endocytosis
Proteins imbedded of surface	Involved in both passive and active material transport across
Tight junction	Ensures most material pass into the blood vessel through epithelial cells



• **Understanding: Materials not absorbed are egested.**

- Egestion: discharge or expulsion of undigested materials
  - Undigested food: food such as cellulose and lignin
  - Secretion by digestive organs: secretion such as saliva, intestinal and pancreatic juice
  - Excretory products: materials such as bilirubin in breakdown of red blood cells

• **Understanding: The rate of transit of materials through the large intestine is positively correlated with their fibre content.**

- Dietary fibres: edible parts of plants that are resistant to digestion and are not absorbed (e.g. cellulose and lignin)
  - Source: foods of plant origin, foods made from cultured fungi

- Advantages of dietary fibres in diet
  - Quicker rate of transit of materials in large intestine: rate of transit is positively correlated with fibre content
    - Increased water in intestine: increased bulk of material passing through the intestine draws water in
    - Faster movement of faecal matter: there is a positive correlation between water and intestinal movement

  - Lower risk of diseases: risk of diseases such as bowel cancer, haemorrhoids and appendicitis is reduced
  - Reduced risk of obesity: presence of bulky material increases feelings of satiety
  - Prevents development of diabetes: absorption of sugar may be slowed down

• **Application: The reduction of stomach acid secretion by proton pump inhibitor drugs.**

- Production of an acidic stomach
  - H+, K+ -ATPase protein pump: protein pump that uses one ATP molecule to exchange protons for potassium
    - From the lumen: two potassium ions are exchanged for two protons
    - From the cytoplasm: two protons are exchanged for two potassium ions

- Reduction of stomach acid secretion
  - Proton pump inhibitor (PPI) drugs: drugs that bind irreversibly to a single pump to reduce acid secretion

  - Ingestion of drug: inactive form of PPI drug is consumed
  - Activation of drug: acidity of stomach acid activates inactive form of the drug to active form
  - Inhibits functioning of pump: PPI drugs bind irreversibly to H+, K+ -ATPase protein pump
  - Non-permanent nature: drug is not permanent as inhibited pumps are replaced with new pumps

- Conditions of stomach made worse by release of acid
  - Stomach ulcer: where protective mucus barrier in stomach is lining broken down, allowing acid to damage the lining
  - Acid reflux (heartburn): where circular muscle at the top which prevents fluid from escaping malfunctions

• **Application: Dehydration due to cholera toxin.**

- Cause of cholera infection: infection by the bacterium *Vibrio cholera* that releases toxin that binds to receptor on intestinal cells
- Consequences of cholera infection: constant watery diarrhoea; death due to severe dehydration

- Impact of cholera toxin on intestinal cells
  - Bacterium release of toxin: bacterium that enters the body releases a toxin
  - Toxin enters cell: toxin is brought into the cell by endocytosis
  - Efflux of ions: toxin triggers a response that ultimately leads to efflux of Cl- and HCO_3- from cells into intestine
  - Osmosis: water follows the ions by osmosis leading to diarrhoea
  - Loss of fluid in cells: water is drawn from blood into the cells to replace fluid loss from intestinal cells

• **Application: Helicobacter pylori infection as a cause of stomach ulcers.**

- Stomach ulcer: open sores caused by partial digestion of the stomach lining by the enzyme pepsin and hydrochloric acid
  - Helicobacter pylori: colonies *H. pylori* bacteria is found on the surface of the human gut suffering from ulcer

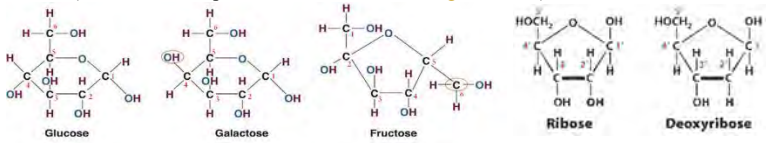
  - Infection by Helicobacter pylori: bacterium digs into the mucus layer of the stomach
  - Destruction of mucus layer: bacteria destroys mucus lining by bacterial mucinase
  - Mucosal cell death: toxic ammonia and exposure to acid condition and pepsin destroys mucus layer
  - Formation of ulcer: cell death result in partial digestion of stomach lining

Topic 2.3: Molecular biology – carbohydrates and lipids

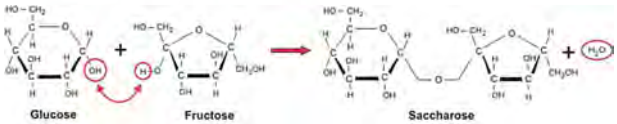
Compounds of carbon, hydrogen and oxygen are used to supply and store energy.

• **Understanding: Monosaccharide monomers are linked together by condensation reactions to form disaccharides and polysaccharide polymers.**

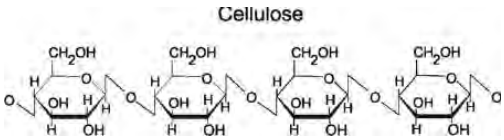
- Monosaccharide: simple sugar consisting of only one unit (often has an empirical formula of CH_2O; e.g. $C_6H_{12}O_6$)
  - Glucose ($C_6H_{12}O_6$)
  - Fructose ($C_6H_{12}O_6$)
  - Galactose ($C_6H_{12}O_6$)
  - Ribose ($C_5H_{10}O_5$)
  - Deoxyribose ($C_5H_{10}O_4$)



- Disaccharides: consists of two monosaccharides linked together by glycosidic bonds in a condensation reaction
  - Maltose: α glucose + α glucose (1-4 glycosidic bond)
  - Lactose: β glucose + galactose (1-4 glycosidic bond)
  - Sucrose: α glucose + fructose (1-2 glycosidic bond)



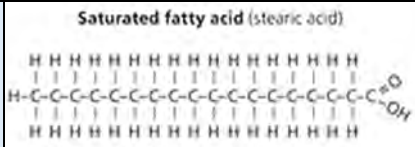
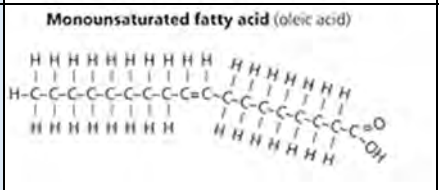
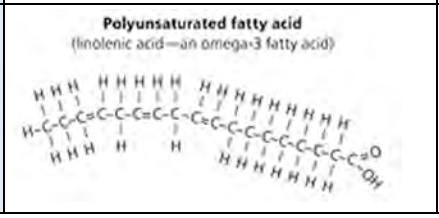
- Polysaccharides: consists of many monosaccharides linked together by glycosidic bonds in a condensation reaction
  - Starch: chains of α glucose monomers (1-4 glycosidic bond)
  - Cellulose: chains of β glucose monomers (1-4 glycosidic bond)
  - Glycogen: chains of α glucose monomers (1-2 glycosidic bond)
  - Chitin: chains of β glucose monomers (1-4 glycosidic bond)



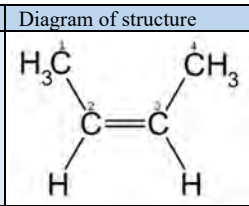
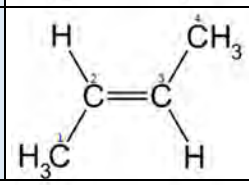
- Disaccharides and polysaccharides can be broken down by the enzyme amylase

• **Understanding: Fatty acids can be saturated, monounsaturated or polyunsaturated.**

- Fatty acid: a chain of carbon atoms with hydrogen atoms linked by a single covalent bond, beginning with a carboxyl group
  - Low-density lipoprotein (LDL); contributes plaque formation
  - High-density lipoprotein (HDL); remove LDL from arteries, decrease risks of heart diseases

Name	Diagram of structure	Description	Health implications	Found in
Saturated fatty acid		Composed of single bonds between all carbon atoms	Increases overall LDL	Meat Dairy products Eggs Poultry
Mono-unsaturated fatty acid		Composed of mostly single bonds between all carbon atoms with one double bond between two carbon atoms	Increase overall HDL Decrease overall LDL	Nuts Seeds Avocados Plant oil
Poly-unsaturated fatty acid		Composed of mostly single bonds between carbon atoms with multiple double bonds between two carbon atoms	Decrease overall LDL	Fish Corn Sunflower Safflower Plant oils

• **Understanding: Unsaturated fatty acids can be cis or trans isomers.**

Name	Diagram of structure	Description	Characteristics	Health implication
Cis isomer		Hydrogen atoms are on the same side of the two carbon atoms that are double bonded	The bend makes the cis-unsaturated fatty acids containing triglyceride less good at packing together	Increase overall HDL Decrease overall LDL
		There is a bend in the hydrocarbon chain	Liquid at room temperature (are oil)	
Trans isomer		Hydrogen atoms are on the opposite side of the two carbon atoms that are double bonded	The bend makes the trans-unsaturated fatty acids containing triglyceride better at packing together	Increases overall LDL
		There is no bend in the hydrocarbon chain	High melting point; solid at room temp.	

Topic 4.1: Ecology – Species, communities and ecosystem

The continued survival of living organisms including humans depends on sustainable communities.

• **Understanding: Species are groups of organisms that can potentially interbreed to produce fertile offspring.**

- Species: groups of organisms that can potentially interbreed to produce fertile off-springs
- Crossbreeding: interbreeding between different species with off-springs almost always infertile

• **Understanding: Members of a species may be reproductively isolated in separate populations.**

- Speciation: process in which one species is reproductively isolated into different populations they develop into different species where they are unable to produce viable off-springs

Type of mechanism	Description	Example
Geographical isolation	Population is separated as the environment imposes a geographical barrier	Natural disasters, continental shift
Ecological isolation	Population is separated by occupying different habitats (disruptive evolution)	Tree and mud lizards
Temporal isolation	Population is separated through reproducing at a different season/time	Winter and summer plants
Behavioural isolation	Population is separated through differing in their respective mating rituals	Birds of paradise

• **Understanding: Species have either an autotrophic or heterotrophic method of nutrition (a few species have both methods).**

- Autotrophs: organisms that synthesize their won organic molecules from simple inorganic substances
- Heterotrophs: organisms that obtain organic molecules from other organic organisms
- Mixotrophs: organisms that has both autotrophic and heterotrophic means of nutrition (e.g. Chlamodomonas or Euglena)

• **Understanding: Consumers are heterotrophs that feed on living organisms by ingestion.**

- Consumers: heterotrophic organisms that feed on living organisms by ingestion

• **Understanding: Detritivores are heterotrophs that obtain organic nutrients from detritus by internal digestion.**

- Detritivores: heterotrophic organisms that feed on organic nutrients from detritus (dead organic matter) by internal digestion

• **Understanding: Saprotrophs are heterotrophs that obtain organic nutrients from dead organisms by external digestion.**

- Saprotrophs: heterotrophic organisms that feed on organic nutrients from detritus (dead organic matter) by external digestion

• **Understanding: A community is formed by populations of different species living together and interacting with each other.**

- Community: populations of different species living and interaction with each other
  - Examples of community interactions: symbiosis (mutualism, parasitism), predation, disease agents

• **Understanding: A community forms an ecosystem by its interactions with the abiotic environment.**

- Ecosystem: interaction of the community with the abiotic environment
  - Abiotic factors: non-living, physical components of an ecosystem (e.g. light, wind, pH, salinity, temperature)
  - Biotic factors: living components of an ecosystem (e.g. symbiosis, mutualism, predation)

• **Understanding: Autotrophs obtain inorganic nutrients from the abiotic environment.**

- Autotrophs: obtain all nutrients from the abiotic environment (e.g. carbon, nitrogen, sodium etc.)
- Heterotrophs: obtain most nutrients from food, but they obtain many inorganic nutrients from the abiotic environment (e.g. sodium)

• **Understanding: The supply of inorganic nutrients is maintained by nutrient cycling.**

- Nutrient cycles: cycle process in which organisms absorb, use and return elements from and to the abiotic environment (e.g. carbon)
  - Nutrients and energy: energy is able to enter and leave ecosystems while nutrients can only be cycled

• **Understanding: Ecosystems have the potential to be sustainable over long periods of time.**

- <u>Requirements for ecosystem sustainability:</u>
  - Nutrient availability: enough nutrients should be present to be cycled
  - Detoxification: waste products must not cumulate and needs to be cycled again
  - Energy availability: energy cannot be cycled like nutrients and hence ecosystems must have a stable source

• **Application: External and internal intercostal muscles, and diaphragm and abdominal muscles as examples of antagonistic muscle action.**

	Inspiration (breathing in)	Expiration (breathing out)
Diaphragm	Contracts (lowered)	Relaxes (raised)
Abdominal muscle	Relaxes	Contracts
External intercostal muscle	Contracts	Relaxes
Internal intercostal muscle	Relaxes	Contracts
Rib cage	Raised	Lowered
Chest volume	Increases	Decreases
Pressure	Decreases	Increases

• **Application: Causes and consequences of lung cancer.**

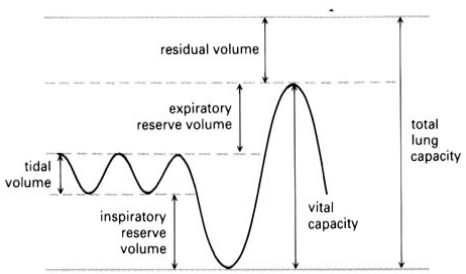
- Lung cancer: the most common cancer in the world (both in death by disease and number of cases)
- Main causes of lung cancer:
  - Smoking (direct and passive): chemicals in cigarettes contain many mutagenic chemicals
  - Air pollution: mostly from fumes from organic matter that contain mutagenic properties
- Consequences of lung cancer:
  - Difficulty with breathing
  - Persistent coughing (esp. blood)
  - Chest pain

• **Application: Causes and consequences of emphysema.**

- Emphysema: lung disease that results in the damage to the elasticity of alveoli and breakdown of lung tissue
  - Reason why gas exchange becomes less efficient: lower surface area for gas exchange (destruction of alveoli or merging of alveoli), over inflating alveoli that fail to recoil
- Causes of emphysema:
  - In smokers, the number of phagocytes in the lungs increase and they produce elastase
  - Digestion of proteins by elastase is not prevented as not enough enzyme inhibitors are present
  - Alveolus walls are weakened and destroyed
- Consequences of emphysema:
  - Shortness of breath
  - Dizziness and fatigue, poor concentration

• **Skill: Monitoring of ventilation in humans at rest and after mild and vigorous exercise.**

- Process of monitoring ventilation rate:
  - Simple observation: counting the number of times air is exhaled or inhaled at a natural rate in a minute
  - Data logging: inflatable chest belt can be placed around the thorax, and a pressure sensor is used to measure pressure variation in chest expansions
- Process of monitoring tidal volume:
  - Simple apparatus: inverted measuring cylinder can be held by a clamp placed in a water trough. One normal breath can be exhaled through the delivery tube into the cylinder to measure volume
  - Spirometers: air is exhaled into spirometers that measures flow rate into and out of lungs



- Tidal volume: volume of air expired in each breath
- Ventilation rate: number of breath an individual takes during a specific timeframe (rate of breathing)

• **Nature of science: Obtain evidence for theories—epidemiological studies have contributed to our understanding of the causes of lung cancer.**

• **Guidance:** Ventilation can either be monitored by simple observation and simple apparatus or by data logging with a spirometer or chest belt and pressure meter. Ventilation rate and tidal volume should be measured, but the terms vital capacity and residual volume are not expected.
• **Guidance:** Students should be able to draw a diagram to show the structure of an alveolus and an adjacent capillary.

Topic 8.3: Metabolism, cell respiration and photosynthesis – Photosynthesis

Light energy is converted into chemical energy.

• **Understanding: Light-dependent reactions take place in the intermembrane space of the thylakoids.**

- Light dependent reaction: part of photosynthesis that uses light energy directly
  - Location: intermembrane space of the thylakoids (compartment inside the chloroplast)

• **Understanding: Light-independent reactions take place in the stroma.**

- Light independent reaction: part of photosynthesis that does not use light energy directly
  - Location: in the stroma (compartment inside the chloroplast)

• **Understanding: Reduced NADP and ATP are produced in the light-dependent reactions.**

- Light dependent reaction produces energy sources use in the light independent reaction
  - Conversion of energy: light energy is converted into chemical energy
  - Product of light dependent reaction: NADPH (reduced NADP) and ATP

• **Understanding: Absorption of light by photosystems generates excited electrons.**

- Photosystem: groups of chlorophyll and accessory pigments inside thylakoid that harvests lights
- Reaction centre: two special chlorophyll molecules that can donate excited electrons to electron acceptors
- Photoactivated electrons: electrons that becomes activated with light absorption

- Process of light dependent reaction from photosystem II to plastoquinone:
  - Light harvesting: chlorophyll molecules in PSII absorb light and pass it to the chlorophyll in the reaction centre
  - Donation of electrons: reaction centre in PSII donate excited electrons to a plastoquinone
  - Reduction of plastoquinone: two excited electrons cause one reduced plastoquinone

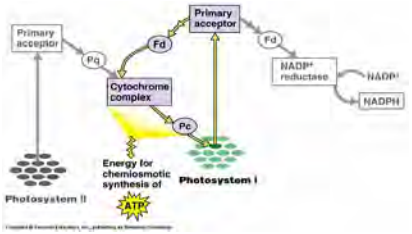
• **Understanding: Photolysis of water generates electrons for use in the light-dependent reactions.**

- Chlorophyll in reaction centre causes water molecules to split (photolysis) to replace lost electrons
- Oxygen molecules are generated in this process and are excreted as waster; hydrogen ions also assist build-up of proton gradient

- Photolysis: splitting of water molecules under the influence of light
  - Process of photolysis: $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

• **Understanding: Transfer of excited electrons occurs between carriers in thylakoid membranes.**

- Electron carriers in thylakoid membrane:
  - Plastoquinone (Pq): transfer electrons from photosystem II to start of electron carrier chain
  - Chain of electron carrier: generates a hydrogen gradient inside thylakoid using energy from electrons
  - Plastocyanin (Pc): transfer electrons from end of electron carrier chain to photosystem I
  - Ferredoxin (Fd): transfer electrons from photosystem I to $NADP^+$ reductase or back to electron carrier chain



• **Understanding: Excited electrons from Photosystem II are used to contribute to generate a proton gradient.**

- Process of light dependent reaction from plastoquinone to plastocyanin:
  - Addition of excited electrons: plastoquinone transports electrons from photosystem II to electron transport chain
  - Electron transport across chain: excited electrons are carried across to provide energy for proton pumps
  - Activation of proton pumps: protons are pumped across the thylakoid membrane to store potential energy
  - Formation of concentration gradient: concentration of proton develops inside thylakoid
  - Reduction of plastocyanin: electrons reduce plastocyanin when the end of transport chain is reached

• **Understanding: ATP synthase in thylakoids generates ATP using the proton gradient.**

- Chemiosmosis: process in which the proton transport is coupled with the phosphorylation of ADP to form ATP
  - Chemiosmosis in plants: enzyme ATP synthase in thylakoid generates ATP through the proton gradient

• **Understanding: Excited electrons from Photosystem I are used to reduce NADP.**

- Process of light dependent reaction from plastocyanin to $NADP^+$ reductase:
  - Electron transport by plastocyanin: electrons are transported to photosystem I
  - Photoactivation of electrons: light is absorbed by chlorophylls and reaction centre electrons becomes photoactivated
  - Reduction of ferredoxin: excited electrons are then passed onto ferredoxin

  - Cyclic phosphorylation: ferredoxin returns excited electrons to the electron transport chain
  - Non-cyclic phosphorylation: ferredoxin reduces $NADP^+$ in $NADP^+$ reductase