BIOLOGY NOTES. YEAR 3 RAFFLES PROGRAMME

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TOPIC 1: BIOTECHNOLOGY

Not tested for Y3 EOY, tested for Y4 FYE

1.1: **What are enzymes?**

- Protein catalysts
- Functions independently of the cell provided certain conditions are maintained.
- Commercial enzymes obtained from:
    - Plants
    - Animals
    - Microbes
- Many commercially produced enzymes are hydrolases.

1.2: **Production of enzymes**

- Mutant strains selected to maximise enzyme production.
- Genetic engineering aids in tailoring of producer organisms.
- More than 2000 enzymes isolated, small number used at a large scale.

1.3: **Procedures**

- Selected strains taken for the culture.
- Inoculated in large sterilised vessels containing sterilised and cooled nutrient medium.
- Sterile air is pumped through and the bioreactor is cooled with circulating water.
    - Optimum temperature between 18 degrees Celsius to 37 deg Celsius

1.4: **Extraction**

- Nutrient liquor separated
    - Liquid with dissolved contents
    - Insoluble cells and other substances
- If enzymes are intracellular:
    - Separated from growth contents of the growth medium through centrifuge or filtration
    - Cells disrupted by ultrasound/liquidising and the contents are separated from the membranes/walls again through filtration.
- If enzymes are extracellular
    - Separation are to be done via centrifuge/filtration

1.5: **Concentration and Packaging**

- Enzyme is now concentrated by removing most of the water through:
    - Low temperature vacuum evaporation
    - Reverse osmosis
- Preservatives are then added and the enzyme is then packaged for distribution to industrial users
- If pure enzymes are needed then other procedures are involved before packaging, e.g. fractional distillation

1.6: **Enzyme Immobilisation**

- Widespread usage of enzymes brought one question: HOW TO RECOVER ENZYMES FOR REUSE?
    - Expensive to produce and extract
- Cell and enzyme immobilisation
    - Conversion of enzymes from water soluble to water insoluble
    - Maintains its catalytic activity
- 4 ways to immobilise enzymes
    - Adsorption onto insoluble surfaces
    - Covalent attachment
    - Entrap the enzymes in the fibres of gels
        - Substrate or product may not be small enough to enter or leave the gel
    - Direct cross-linking (often gluteraldehyde) between enzyme molecules to form a polymerised enzyme.

1.7: **Advantages of Immobilised Enzymes**

- Easy recovery for enzymes for reuse
- Easy harvesting of products (no enzyme contamination)
- Greater enzyme stability
- Extends the life of proteolytic enzymes by preventing them from digesting each other.

1.8: **Increased Demand for Cell-Free Enzymes**

- When whole cells are used, some of the substrate is used in the cell metabolism
- The optimum condition for individual enzymes is often different to that of a whole cells
- No wasteful side reactions

1.9: **Production of Lactose-Free Milk**

- Large percentage of the human population are lactose intolerant.
    - Missing an enzyme (lactase) that converts lactose to glucose and galactose
    - When lactose is consumed it is undigested and passes into the colon where bacteria may convert it to:
        - Ethanoic acid
        - Butanoic acid
        - Carbon dioxide
        - Methane
    - Causes a variety of symptoms, e.g. cramps, distension, acid diarrhoea
- Immobilised lactase is used to convert lactose to glucose and galactose
- Heat-treated milk is passed through a column containing immobilised lactase
- Lactose-free milk emerge from the bottom to be packaged.

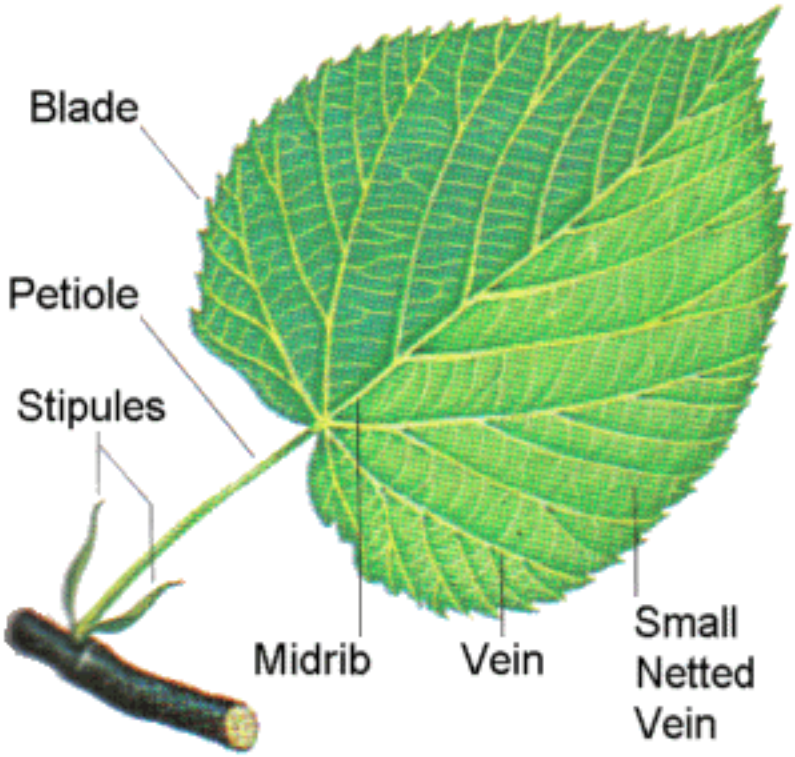
1.10: **Clarification of Fruit Juices**

- Fruit juices contain pectins, a complex group of carbohydrates that cement adjacent cells together
    - Occurs in the middle lamella
    - Forms gels with calcium ions
    - Possess a viscosity problem for fruit juice manufacturers
    - Also form colloids with proteins
- Immobilised pectinase is used to remove pectins from the juices.

TOPIC 2a: PLANT NUTRITION

Tested for Y3 EOY and Y4 FYE

2a.1: **Structure of a Typical Leaf**



- Lamina
  - Large, flat surface for maximum exposure to sunlight
  - Thin for facilitation of transport of gases
- Petiole
  - Holds the lamina away from the stem
  - Continues into the midrib of the leaves
- Veins
  - Carry water and mineral salts to the cells in the leaf blade
  - Carry manufactured food from the leaf blade to the other parts of the plants
  - In dicotyledonous plants, there is a midrib (the main vein) with a network of side veins
  - In monocotyledonous plants, veins run parallel to each other

2a.2: **Internal Structure**

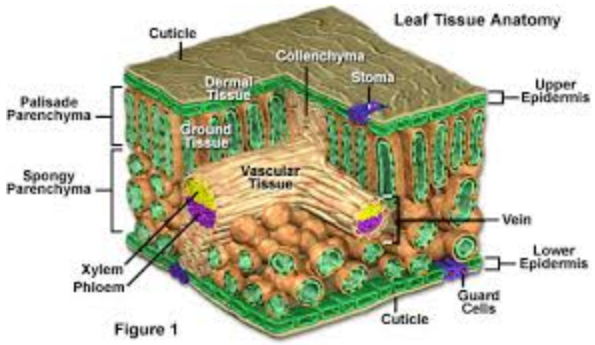
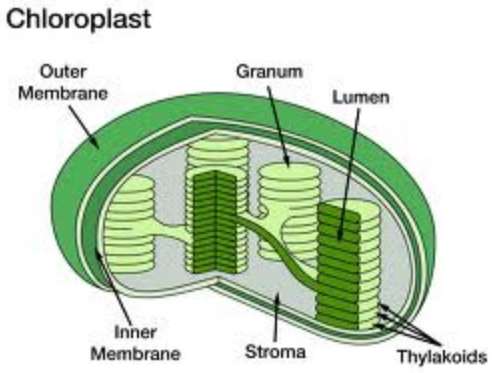


Figure 1

- Epidermis
    - Single layer of closely packed cells
    - Both upper and lower surface of the leaf
    - Helps to keep the leaf's shape
    - Reduce evaporation from the leaf, prevent bacteria and fungi from getting in
    - Focuses the light on mesophyll layers
    - Thin waxy layer called cuticle to reduce water loss
- Mesophyll
    - Lies below epidermis
    - Site of photosynthesis
    - Two regions:
        - Palisade mesophyll
        - Spongy tissue
    - Palisade cells are long and contain chloroplasts
    - Chloroplasts absorb sunlight and the energy is used to make carbohydrate from carbon dioxide and water
    - Spongy mesophyll cells are irregularly shaped
    - Loosely arranged so that numerous intercellular air spaces occur among them
    - Also contains chloroplasts

2a.3: **Chloroplasts**



- Stroma
    - Enzymes for light-independent stage found here
- Grana
    - Stacks of membranes or thylakoids
    - Chlorophyll molecules and enzymes for light-dependent reactions located here
    - On average, a chloroplast contains 60 grana
        - Each granum has 50 thylakoids
    - Surface area for photosynthesis is substantial
- Each mesophyll cell has 30-40 chloroplasts
- 2-4 micrometres by 4-7 micrometres

2a.4: **Stomata**

- Found in the leaf epidermis
- More abundant in the lower epidermis in most dicotyledonous plants
- Consists of a pair of guard cells surrounding an opening or stomatal pore
- Guard cells bean-shaped in surface view
- Guard cells contain chloroplasts, epidermal cells do not

2a.5: **Stomata Regulation by Guard Cells**

- During sunlight hours…
    - Photosynthesis takes place in guard cells
    - Sugar produced causes water potential in guard cells to drop
    - Water enters the guard cells through osmosis
    - Guard cells become swollen and turgid
    - Guard cells have a thicker cellulose wall on the side of the stomata pore
    - As such, that part of the wall is less able to stretch
    - Causes the guard cells to curve in such a way the pore is opened

- During night time…
    - Sugar is used up
    - Water potential in guard cells increase
    - Water leaves the guard cells
    - Guard cells become flaccid, straighten up and the stomatal pore closes

2a.6: **Entry of Carbon Dioxide into the Leaf**

- Carbon dioxide is used in photosynthesis
- Carbon dioxide concentration in the leaf becomes lower than in the atmospheric air
- Diffusion gradient exists
- Carbon dioxide diffuses through the stomata into the system of air spaces in the leaf
- Carbon dioxide dissolves in thin film of water on the mesophyll layer of cells
- Dissolved carbon dioxide then diffuses into the cells

2a.7: **Entry of Water and Mineral Salts into the Leaf**

- Water and mineral salts enter the plant via the notes
- Xylem tissue brings water and dissolved mineral salts to the leaf from the roots
- Veins contain xylem and phloem tissue
- Once out of the veins, water and dissolved mineral salts diffuse from cell to cell to the mesophyll cells of the leaf

2a.8: **Why is Photosynthesis Important?**

- Converts light energy from the sun to chemical energy. Stored in carbohydrates.
- Carbohydrates, proteins, fats and other organic compounds are formed. Directly or indirectly fills our dietary requirements
- Energy in coal, petroleum and natural gas, all come from the sun via photosynthesis
- Helps to “purify” the air by removing carbon dioxide and releasing oxygen.

2a.9: **Autotrophs**

- Organisms that make their own organic matter from inorganic matter.
- Photoautotrophs use energy from light for this process

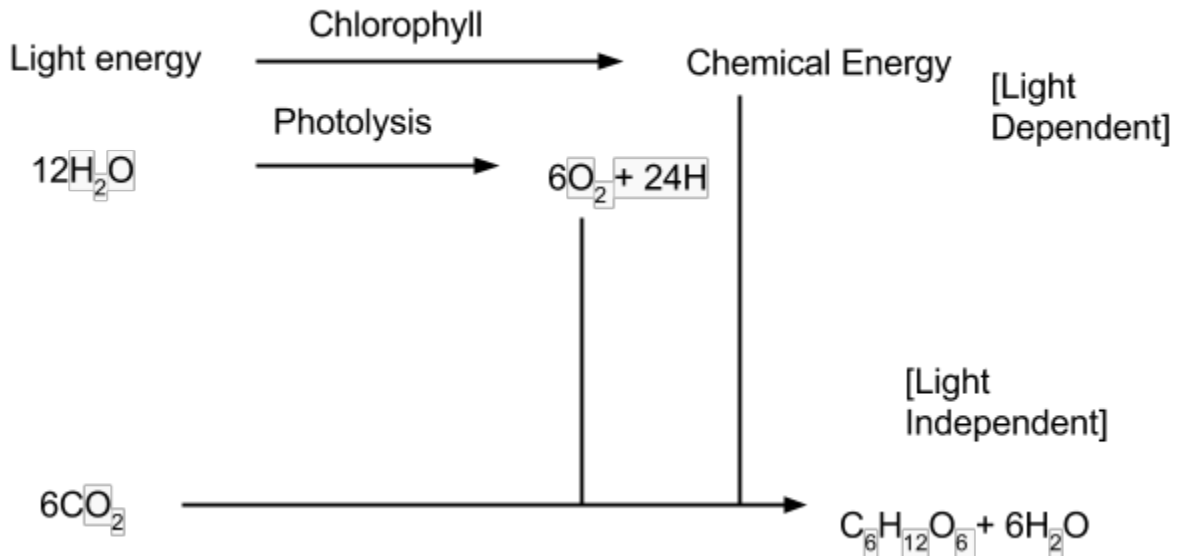
2a.10: **Heterotrophs**

- Organisms that depends on compounds produced by other organisms
- Heterotrophs either:
    - Consume the remains of dead organisms and organic litter through decomposition
    - Dependent highly on photoautotrophs for food and oxygen

2a.11: **Definition of Photosynthesis**

- Photosynthesis is light energy absorbed by chlorophyll and transformed into chemical energy used in the synthesis of carbohydrates from water and carbon dioxide. Oxygen is liberated in the process

2a.12: **Photosynthesis: The 2 Stages**



A significant result of the shuffling of atoms during photosynthesis is the extraction of hydrogen from water and its incorporation into sugar. The waste product of photosynthesis, oxygen, is released into the atmosphere.

2a.13: **Absorption and Action Spectrum of Chlorophyll**

- Absorption spectrum
  - A graph of relative absorbance of different wavelengths of light by a photosynthetic pigment
- Action spectrum
  - A graph of relative photosynthetic rates at different wavelengths of light

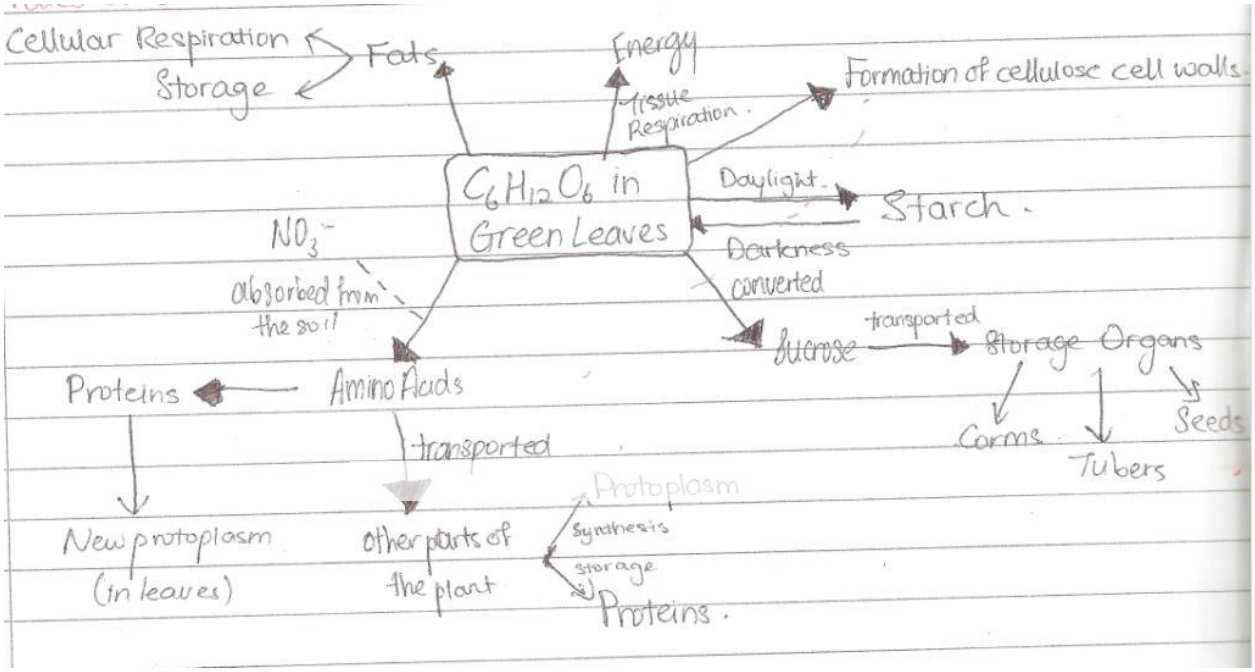
2a.14: **Limiting Factors for Photosynthesis**

- Any factor that directly affects a process if its quantity is changed
- In this case:
  - Concentration of carbon dioxide
  - Light intensity
  - Temperature

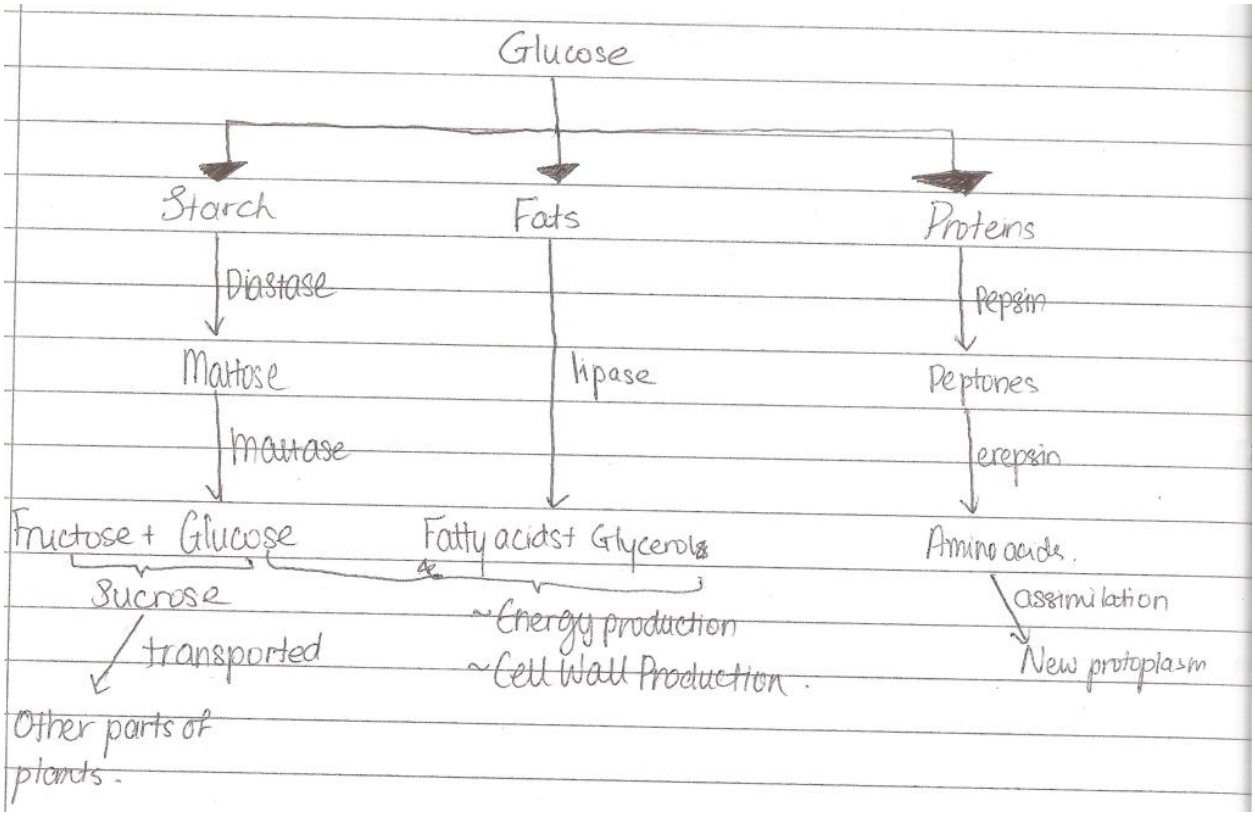
2a.15: **Adaptations of Leaf to Photosynthesis**

- Veins contain xylem and phloem
    - Xylem transports water and mineral salts to mesophyll cells
    - Phloem transports food away from the leaf to the rest of the plant
- Petiole present
    - Holds leaf in position to absorb maximum light energy
- Large flat surface
    - Absorbs maximum light energy
- Thin lamina
    - Allows carbon dioxide to reach inner cells rapidly
    - Enables light energy to reach inner cells rapidly
- Chloroplasts contain chlorophyll. All mesophyll cells have chloroplasts
    - Chlorophyll required for photosynthesis
    - Absorbs and transform light energy into chemical energy during photosynthesis
- More chloroplasts can be found in upper palisade tissue
    - More light energy can be absorbed near the leaf surface
- Interconnecting system of air spaces in mesophyll
    - Allows rapid diffusion of carbon dioxide to mesophyll cells
- Stomata present in epidermal cells
    - Allows carbon dioxide to diffuse in and oxygen to diffuse out of the leaf

2a.16: **Fates of Glucose in Green Leaves**



2a.17: **Digestion and Use of Glucose**



TOPIC 2b: CHEMICALS OF LIFE

Tested for Y3 EOY and Y4 FYE

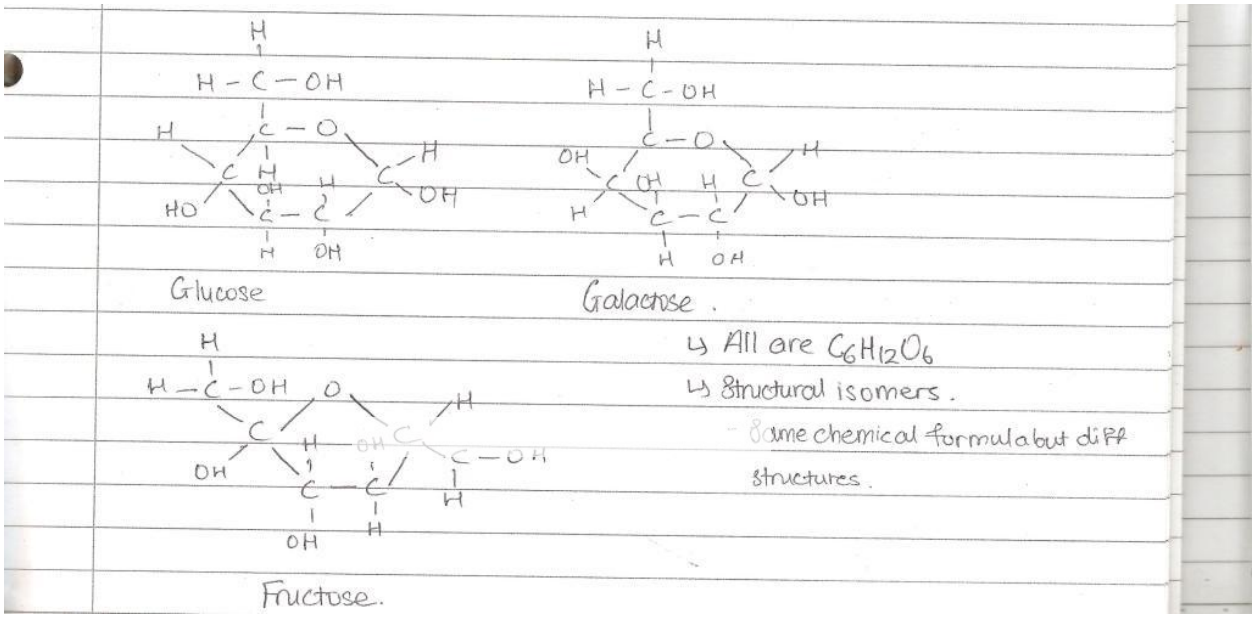
2b.1: **Biological Molecules**

- Large, complex molecules produced by living organisms
- Categories:
    - Carbohydrates
    - Lipids
    - Proteins
    - Nucleic acids
- Water is a major component of the cell

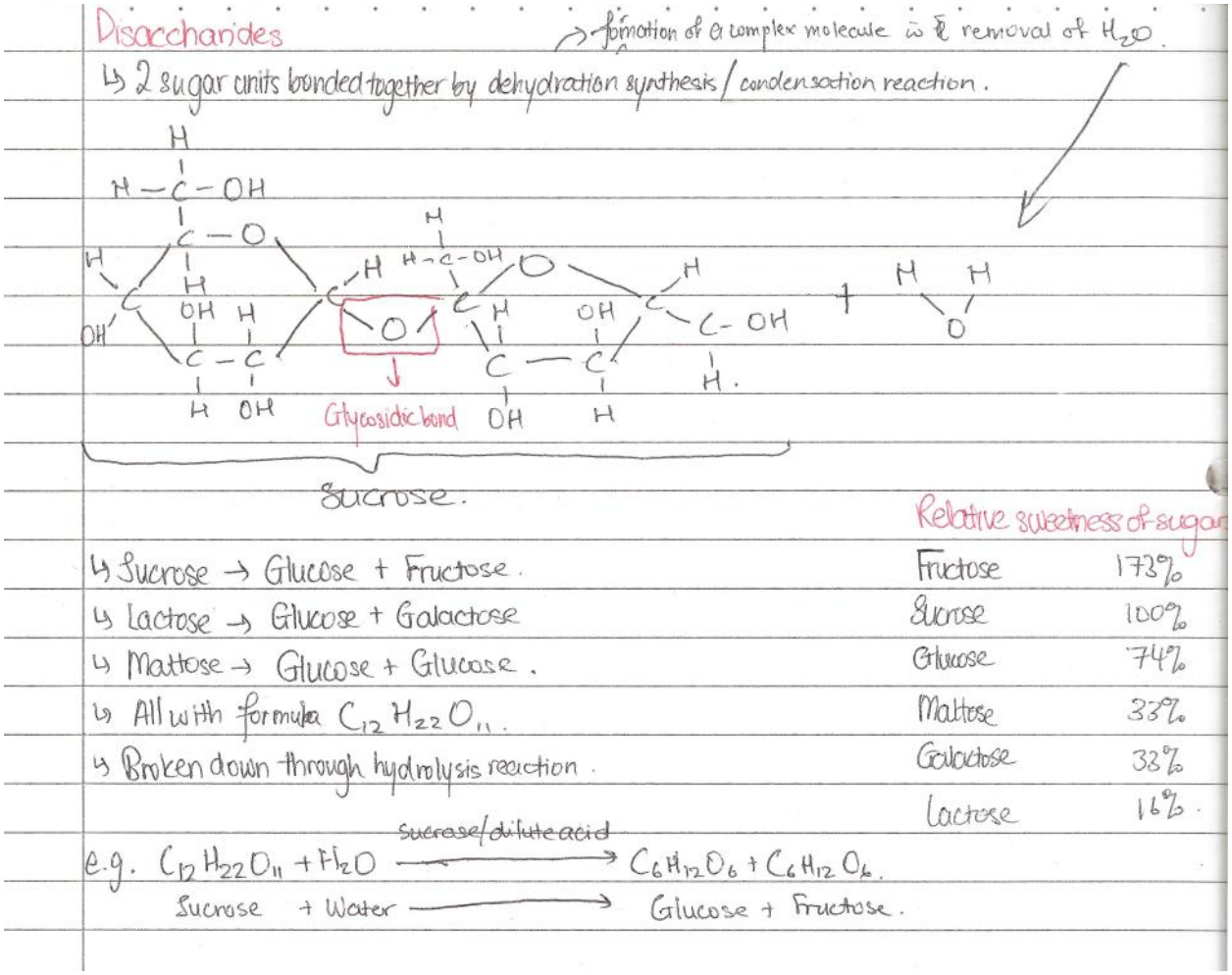
2b.2: **Carbohydrates**

- Made up of the elements C, H, O
    - General formula: $C_x(H_2O)_y$
    - 3 types of carbohydrates
        - Monosaccharides
        - Disaccharides
        - Polysaccharides
- 1 g of carbohydrates = 16kJ of energy

2b.3: **Monosaccharides**



2b.4: **Disaccharides**



2b.5: **Polysaccharides**

- Macromolecules that are polymers of a few hundred or thousand monosaccharides
- Formed by linking monomers in enzyme-mediated dehydration synthesis
- 2 important biological functions:
    - Energy storage (starch for plants, glycogen for animals)
    - Structural support (cellulose and chitin)
- Also called glycans
- Differ in the
    - Nature of recurring monosaccharides
    - Length of their chains
    - Degree of branching/No branching

2b.6: **Storage Polysaccharides**

- An ideal storage material would be:
    - Reasonably compact and inert
    - Mobilised quickly when food materials are unavailable from the environment
- Starch (plants) and glycogen (animals) are convenient storage molecules because:
    - Large size makes them more or less insoluble in water, so they exert no osmotic or chemical influence in the cell
    - They fold into compact shapes
    - They are easily converted to sugars by hydrolysis when required

2b.7: **Functions of Carbohydrates**

- Source of energy
- To form supporting structures
- Formation of nucleic acids
- Synthesise lubricants
- Produce nectar in sunflowers to attract insects for pollination

2b.8: **Test for Reducing Sugars (Benedict's Test)**

- Reduces Cu^{2+} ions to Cu^{+} ions in Benedict's solution, forming a brick-red precipitate of CuO

1. To test a sample of an unknown solution, add an equal volume of Benedict's solution. Shake
2. Heat in a boiling water bath
3. Positive test: A coloured precipitate is seen. Different colours indicate different concentration
    a. Green --> Yellow --> Orange --> Red --> Brick-red
4. Negative test: Solution remains blue (colour of Benedict's solution)

- All monosaccharides except for glucose are reducing sugars

2b.9: **Test for Starch (Iodine Test)**

1. Add a few drops of iodine solution to unknown solution
2. Positive test: Blue-black mixture is seen
3. Negative test: Solution remains brown

2b.10: **Lipids**

- Made up of the elements C, H, O
- No fixed molecular ratio
- Contains much more H than O
- 1 g of fat = 38 kJ of energy

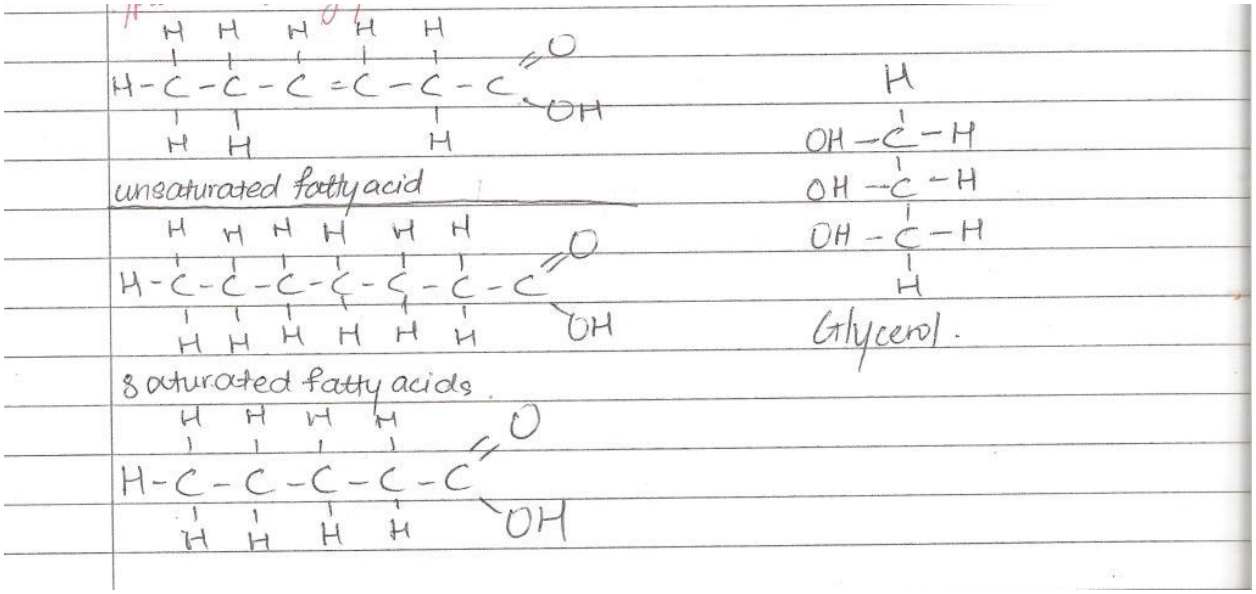
2b.11: **Sources and Types of Lipids**

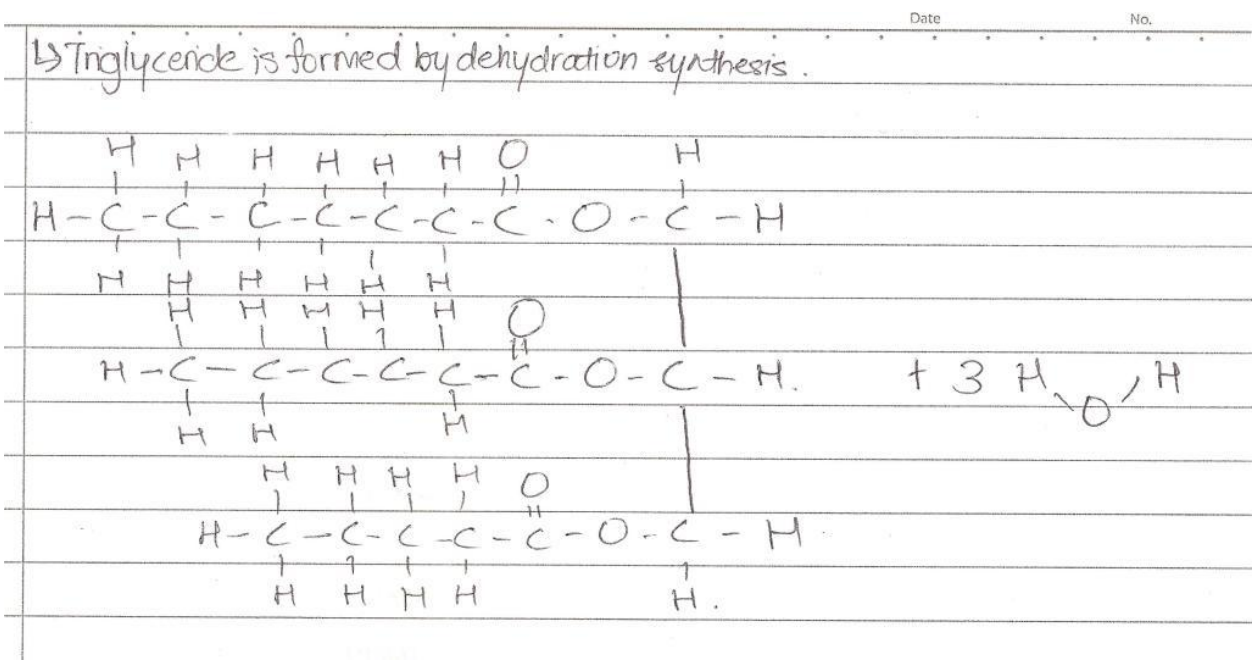
- Saturated fats
    - No double bond formed in fatty acid chain
    - Found in animals
- Monounsaturated fats
    - 1 double bond formed in fatty acid chain
    - Found in oils, avocado, cold-water fish
- Polyunsaturated fats
    - 2 or more double bonds in fatty acid chain
    - Found in vegetable oils, many nuts and seeds

2b.12: **Functions of Lipids**

- Source of and store for energy
- Insulating material, especially beneath the skin, to prevent excessive heat loss
- Solvent for fat-soluble vitamins (Vitamins A, D, E, K) and hormones
- Constituent of cell membranes
- Layer of oil on skin surface helps in restricting water loss from skin surface
- Production of sex hormones and growth hormones from cholesterol

2b.13: **Types of Fat and Triglyceride Molecule**





2b.14: **Overconsumption of Fats**

- Increase of blood cholesterol levels
- Excess cholesterol deposits on inner walls of arteries leading to hardening and narrowing of arteries (atherosclerosis)
- High blood pressure and blood clot formations
- Blood clot swept into coronary arteries can lead to blockage and therefore cause a heart attack

2b.15: **Tests for Lipids (Ethanol Emulsion Test)**

1. Add $2cm^3$ of ethanol to a drop of oil in a test tube
2. Shake mixture thoroughly (oil will be seen to dissolve to form a clear solution)
3. Add $2cm^3$ to the mixture and shake
    a. Positive test: A white emulsion is formed and heat is evolved
    b. Negative test: No white emulsion is formed on shaking with water

- Oil is insoluble in water, and is less dense. Usually floats on water
- Oil is first dissolved in ethanol, which is miscible in water
- When water is added, the ethanol is laden with oil and mixes with water
    - Oil does not mix, but is dispersed in water as minute droplets
- Light passing through the test tube is scattered in all directions and gives the suspension a milky white suspension

2b.16: **Proteins**

- Made up of the elements C, H, O, N (may include S, P)
- Basic unit of proteins: Amino acids
- Amino acids joined together through dehydration synthesis to form dipeptides, oligopeptides and polypeptides
- Can be broken down via hydrolysis

2b.17: **Essential vs. Non-essential Amino Acids**

- Essential amino acids must be taken in through the diet as it cannot be manufactured in the body
    - Histidine
    - Isoleucine
    - Leucine
    - Lysine
    - Methionine
    - Phenylalanine
    - Threonine
    - Tryptophan
    - Valine
- The rest of the 11 amino acids are non-essential and can be synthesised by the body from other substances

2b.18: **Functions of Proteins**

- Synthesis of protoplasm (nucleus, cytoplasm, cell membranes), hence it is needed for growth and repair of worn out/damaged body cells
- Synthesis of enzymes and hormones
- Formation of antibodies to combat diseases
- Source of energy

2b.19: **Types of Proteins**

- Globular proteins
    - Transport proteins
        - Haemoglobin
            - Transport of oxygen to other parts of the body
        - Membrane pumps
            - Transport molecules across cell membranes
    - Enzymes
        - Catalyse chemical reactions in the body
    - Antibodies
        - Immunity
- Structural proteins
    - Collagen
        - Component of bone, tendon, teeth, skin
    - Keratin
        - Hair and nails

2b.21: **Tests for Proteins (Biuret Test)**

1. Add $1cm^3$ of NaOH solution to $2cm^3$ of unknown solution
2. Shake thoroughly
3. Add $CuSO_4$ solution to the mixture, shaking after each drop
    a. Positive test: A violet/purple colouration is seen
    b. Negative test: Solution remains blue (Colour of $CuSO_4$)

2b.22: **Importance of Water**

- 70-80% of cell contents made up of water
- Universal solvent, medium in which many chemical reactions of an organism occur
- Transporting agent for digested food substances, hormones and excretory products from one part of the body to another
- Essential component of lubricant found in the joints, blood and digestive juices
- Raw material for photosynthesis
- Temperature regulation
    - Excess body heat removed by evaporation of sweat from skin surface

TOPIC 3: CELLULAR RESPIRATION

Tested for Y3 EOY and Y4 FYE

3.1: **What is Respiration?**

- Oxidation of food substances
- With the release of energy
- Occurs in all living cells
- Energy released is stored in Adenosine Triphosphate:
    - Short-term energy store of all cells

3.2: **Uses of Energy**

- Synthesis
    - Formation of new substances for growth, development and repair
- Transport
    - Transport of material by active transport
    - Movement of materials across cell membranes
- Movement
    - Contraction of muscles
- Electrochemical activity
    - Generation of impulses
- Heat production
    - Maintain a constant body temperature in warm-blooded temperature

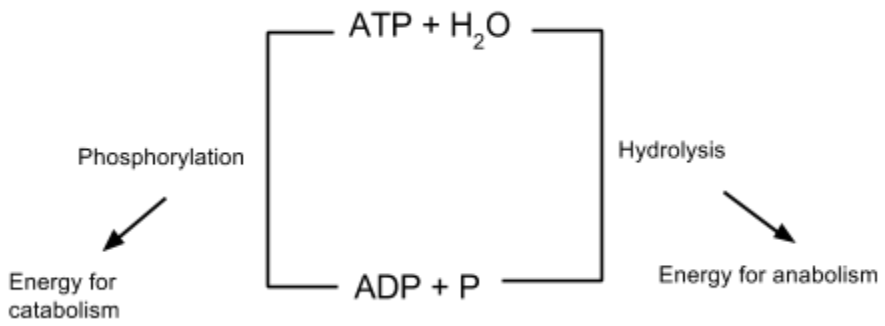
3.3: **Aerobic Respiration**

- Breakdown of food substances
- In the presence of oxygen
- One glucose molecule can produce about 38 ATP worth of energy
- Takes place in the mitochondria of cells
- Overall Equation: $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + Lots of energy

3.4: **ATP, The Universal Energy Currency**

- Constantly recycled with Adenosine Diphosphate
- A reservoir of energy
- Takes part in many metabolic reactions
- Delivers energy in small amounts to drive individual reactions
- Involved in both exergonic and endergonic reactions

3.5: **ADP → ATP Cycle**



3.6: **Anaerobic Respiration**

- Breakdown of food substances in the absence of oxygen
- Produces 2 ATP worth of energy

3.7: **Anaerobic Respiration: Yeast**

- Yeast cells can respire both anaerobically and aerobically
- Ethanol and carbon dioxide produced
- Process known as fermentation
- Overall equation: $C_6H_{12}O_6 \rightarrow 2CO_2 + 2C_2H_5OH$ + small amount of energy

3.8: **Anaerobic Respiration: Muscles**

- Normally respire aerobically to produce large amounts of energy, carbon dioxide and water
- During muscular activity, insufficient oxygen is transported to the muscles
- Muscles will therefore undergo anaerobic respiration
    - Respiration is incomplete
    - Lactic acid builds up
- Overall Equation: $C_6H_{12}O_6 \rightarrow 2CH_3CHOHCOOH$ + small amount of energy
- Only the first stage of respiration occurs
    - Glycolysis in the cell cytosol
- Muscles fatigued due to accumulation of lactic acid
- After period of rest:
    - Lactic acid transported to liver
    - Some oxidised produce energy
        - Oxygen debt
            - Amount of oxygen required to oxidise lactic acid produced
    - Energy used to convert remaining lactic acid to glucose
    - Glucose and energy transported to muscles for usage or storage

3.9: **Aerobic vs. Anaerobic Respiration**

- Small amount of ATP produced in anaerobic respiration
- Waste products lactic acid and ethanol contain a lot of unused energy
- Lactic acid and ethanol harmful if accumulated
- Lactic acid can be converted back to sugar to be used for respiration
- Yeast cannot metabolise ethanol

3.10: **Differences between Respiration and Photosynthesis**

RESPIRATION	*Process*	**Photosynthesis**
Energy is liberated	*Energy*	**Energy is stored in carbohydrate molecules**
Used: O_2 **Given Out: CO_2 and H_2O**	*Materials used*	**Used: CO_2 and H_2O** **Given out: O_2**
Catabolic process (Breakdown of glucose)	*Process*	**Anabolic process (Glucose is formed)**
Occurs all the time	*Frequency*	**Occurs only in:** ● **Cells with chlorophyll** ● **In the presence of sunlight**
Loss of dry mass	*Mass*	**Gain of dry mass**

TOPIC 4: EXTERNAL RESPIRATION

Tested for Y3 EOY and Y4 FYE

4.1: **Inspiration and Expiration**

- Inspiration
    - Air is taken into the body
- Expiration
    - Process in which air is given out

4.2: **Respiratory System**

(Organs are in chronological order, in accordance to the path air goes along)

- Nose
    - Hair and mucus trap dust
    - Receptor smell: Dust
- Nasal cavity
- Pharynx
- Larynx
- Trachea
    - C-shaped cartilage keeps trachea open and enable food to pass through oesophagus easily
    - Mucus: Trap dust and micro-organisms
    - Cilia: Move mucus upwards towards pharynx where mucus is swallowed
- Lungs
    - Bronchi
    - Bronchioles
    - Alveolus
        - Small, rounded air sacs
        - Wall is one-celled thick
        - Thin film of moisture
        - Closely bound to capillaries
            - One-cell thick endothelium
        - Breathing movement brings in oxygen, while blood circulation brings oxygen away, maintaining concentration gradient for gas exchange
        - Oxygen dissolves in layer of moisture before diffusing
        - Maximum surface area

4.3: **Input and Output**

Input	Material	**Output**
21%	O_2	**16%**
0.03%	CO_2	**4%**
78%	N_2	**78%**
Variable	H_2O	**Saturated**
Variable	Temperature	**37°C**
Present	Dust Particles	**Lacking**

4.4: **Movement of Lungs**

	Ribs	**Diaphragm**	**Thoracic Volume**	**Thoracic Air Pressure**	**Internal Intercostal Muscles**
Breathe In	Move out and up	Move down	Increase	Decrease	Relax
Breathe Out	Move down and in	Move up	Decrease	Increase	Contracts

4.5: **Gaseous Exchange**

- Air entering the lungs will have a higher oxygen concentration and a lower carbon dioxide concentration
- Air leaving the lungs will have a lower oxygen concentration and a higher carbon dioxide concentration
- Diffusion gradient maintained through:
    - Continuous flow of blood through the capillaries
    - Continuous flow of air in alveoli
- Membrane separating blood vessels (capillaries) from alveolar air permeable to both O_2 and CO_2
- During short pause between inspiration and expiration:
    - Oxygen dissolves in moisture lining alveolar walls
    - Dissolved oxygen diffuses into blood
    - Combines with haemoglobin to form oxyhaemoglobin
    - Carbon dioxide diffuses into the alveolar space
- Carbon dioxide is transported in 3 forms:
    - Dissolved into the plasma (5-7%)
    - Bound to the amino groups of haemoglobin (15-20%)
    - Bicarbonate ions in the plasma (70-80%)
- When carbon dioxide concentration is low, carbonic anhydrase (CA) catalyses reaction in which hydrogen carbonates converted to carbon dioxide and water
    - $H_2O + CO_2 \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$
- Carbon dioxide diffuses out of the blood into alveolar cavities
- Water evaporates from the walls of alveoli
- Heat also escapes from blood into alveolar air

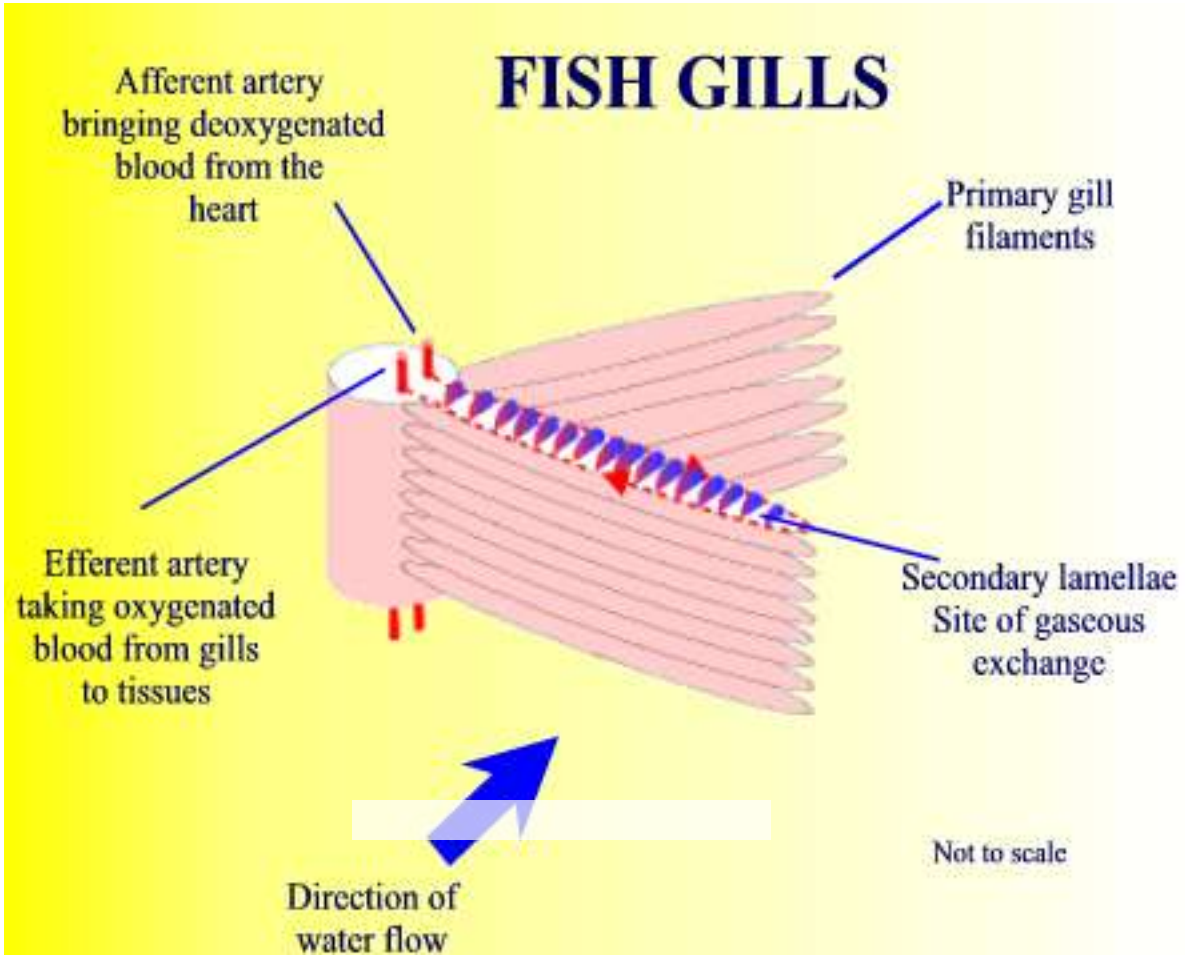
4.6: **Health and Breathing Hazards/Ailments**

- Cigarette smoking can cause:
    - Head/Neck Cancer
    - Lung cancer
    - Stomach cancer
    - Kidney cancer
    - Pancreatic cancer
    - Colon cancer
    - Bladder cancer
    - Cervical cancer
    - Stroke
    - Blindness
    - Gum infection
    - Aortic rupture
    - Heart disease
    - Pneumonia
    - Hardening of arteries
    - Chronic lung diseases and asthma
    - Reduced fertility
    - Hip fracture
    - Carbon monoxide poisoning
        - Carbon monoxide is a colourless and odourless gas
        - It binds irreversibly to form carbaminohaemoglobin
        - Oxygen transport is reduced
        - Can result in fetal deformity if smoking during pregnancy

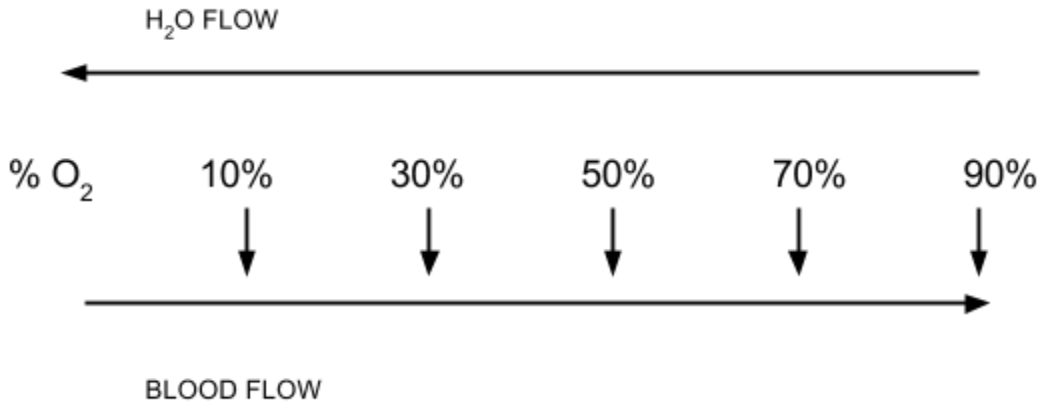
Disease	**BRONCHITIS**	**EMPHYSEMA**	**ASTHMA**	**SARS**
Cause/Spread	● Influenza A & B ● Inhalation of irritating fumes or dust	● Cigarette smoking ● Deficiency of alpha-1-antitrypsin ● Air pollution ● Airway reactivity	● Inherited tendencies ● Allergens	● Person-to-person contact ● Transmission through droplets in air
Part of resp. system affected	● Air passages	● Alveoli	● Trachea ● Lungs	● Lungs
Symptoms	● Fever with chills ● Muscle ache ● Nasal congestion ● Sore throat ● Significant phlegm ● Coughing ● Wheezing	● Loss of elasticity in lung tissue ● Difficulty in breathing ● Mucus secretions not cleared ● Alveoli broken down	● Shortness of breath ● Wheezing ● Coughing ● Chest tightness	● High fever ● Headache ● Fatigue ● Muscle ache ● Malaise ● Decreased appetite ● Diarrhoea ● Dry Cough ● Shortness of breath ● Runny nose ● Sore throat ● Pneumonia
Treatment	● Cough suppressants ● Broncholidator inhalers ● Antibiotics	● Broncholidating medicine	● Inhalants ● Long-term medicine that relieves airway and lung inflammation	● NIL

Prevention	• Don't/Stop smoking • Avoid exposure to irritants • Avoid second-hand smoke or long exposure to air pollution	• Don't smoke	• Avoid allergens	• Stay at home until 10 days after recovery • Wear protective suit when in contact with patient • Maintain hygiene

4.7: **Structure and Function of Fish Gills**



4.8: **Countercurrent Exchange**



Equilibrium not reached, diffusion is constantly taking place.

EXAM ANS:
The opposing directions and different concentration gradients of oxygen and carbon dioxide in the blood vessels and the water flow allows a maintained diffusion gradient as equilibrium will not be reached from opposing directions of flow of water and blood. Water will have a higher concentration of oxygen as compared to the blood vessels throughout the length of the gill filament.

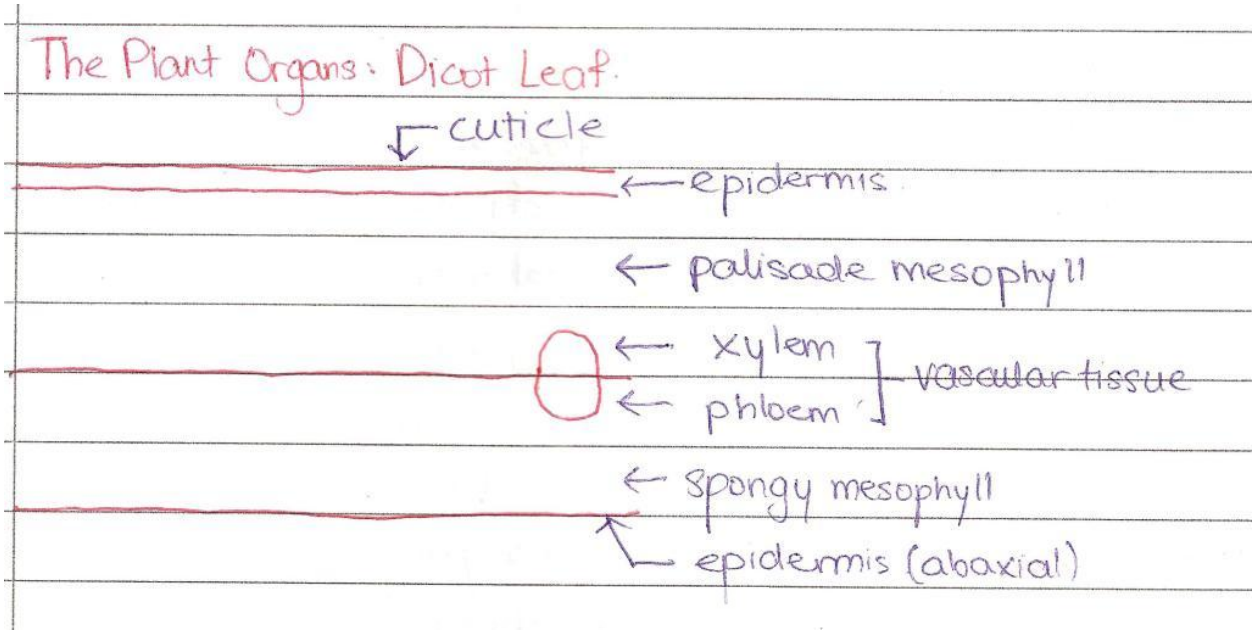
TOPIC 5: TRANSPORT IN PLANTS

Tested for Y3 EOY and Y4 FYE

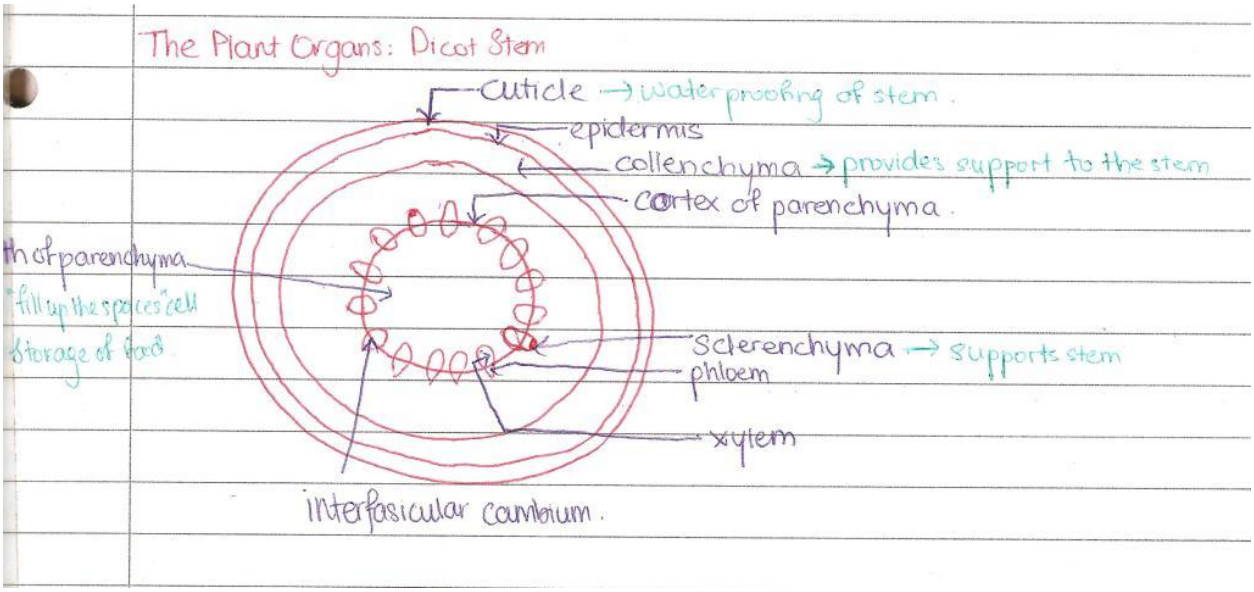
5.1: **The Difference**

Monocotyledonous Plant	Properties	**Dicotyledonous Plant**
1	No. of Cotyledons	**2**
In 3s	Floral Parts	**In 4s or 5s**
Parallel	Leaf Veins	**Network**
One pore/Furrow	Pollen grain	**3 pores/furrows**
Throughout stem's ground tissue	Vascular Bundle	**Arranged in a ring**

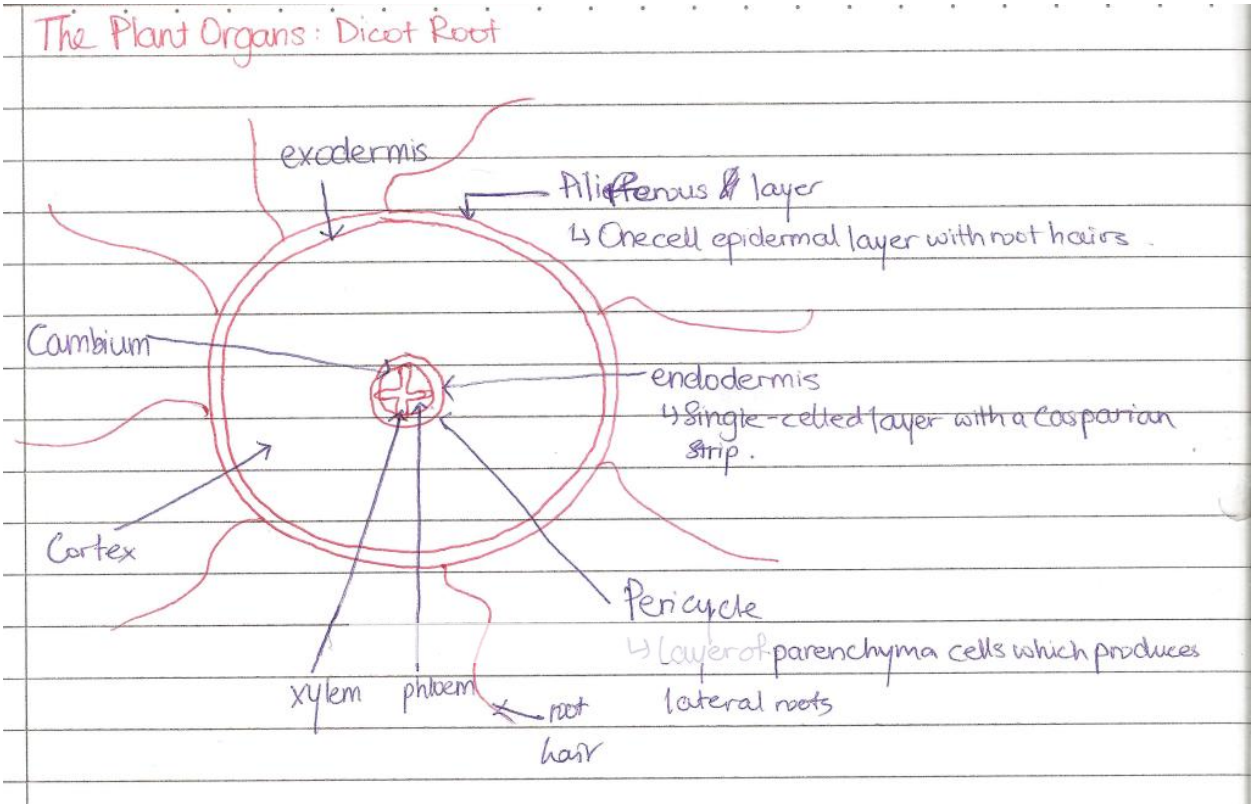
5.2: **The Plant Organs: Dicot Leaf**



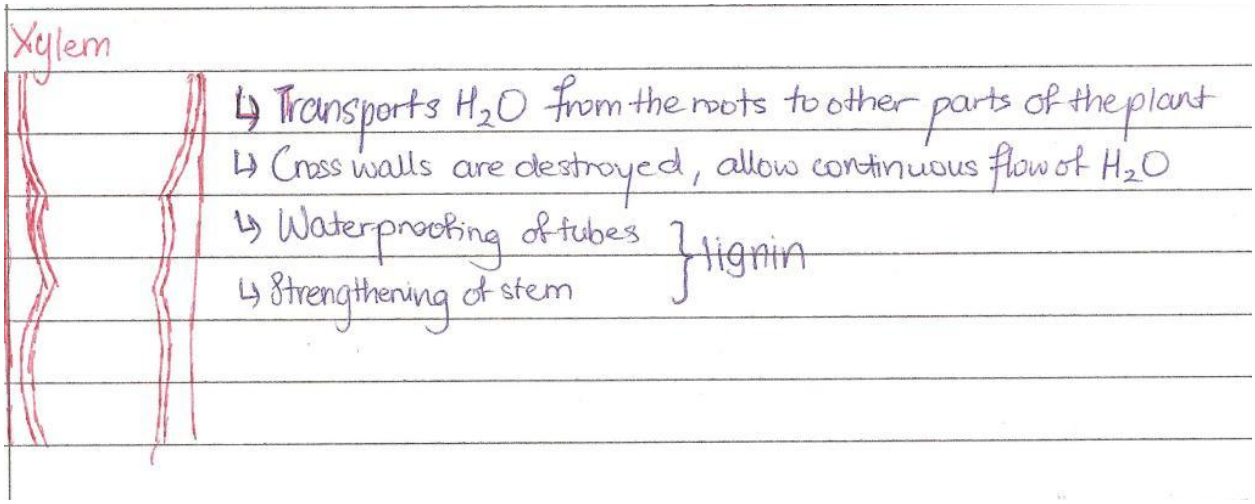
5.3: **The Plant Organs: Dicot Stem**



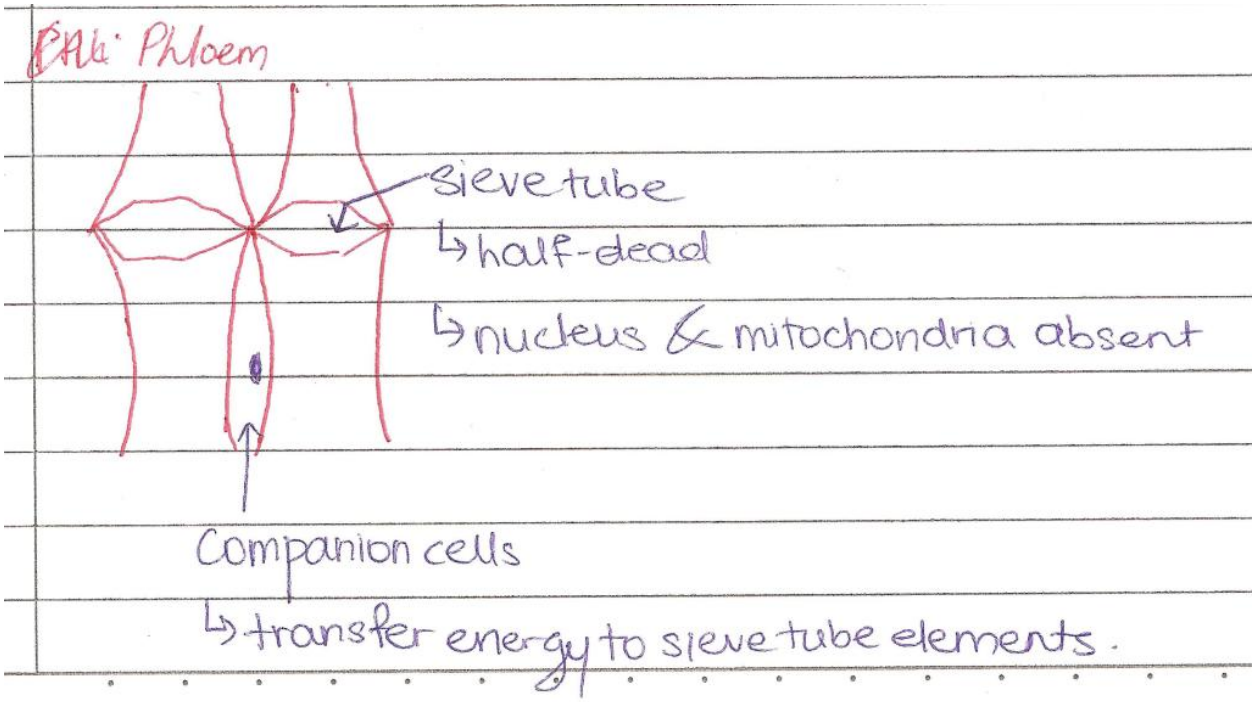
5.4: **The Plant Organs: Dicot Root**



5.5: **Xylem**



5.6: **Phloem**



5.7: **Transport in Plants: 7-step Process**

1. Root absorb water and dissolved minerals from the soil
    a. Water and salts absorbed in root tips in the region of root hairs
    b. Water potential of cell sap in root hair cells lower than soil water
    c. Entry to root hair cells through partially permeable membrane (osmosis)
    d. Movement from
        i. Cell wall to cell wall (apoplast pathway)
        ii. Cytoplasm to cytoplasm (symplast pathway)
        iii. Vacuole to vacuole (vacuolar pathway)
2. Water and minerals are transported upwards from roots to shoots as xylem sap
3. Transpiration creates a force within the leaves to push xylem sap up
    a. Water in xylem enter mesophyll cells and travel from cell to cell via osmosis
    b. Water evaporates from water layer on surface mesophyll cells
    c. Diffusion through intracellular air spaces and out of stomata
4. Through stomata, leaves take in carbon dioxide for photosynthesis and expel oxygen (some of which taken in respiration in plants)
5. Sugars are produced by photosynthesis in the leaves
6. Sugars are transported as phloem sap to roots and other parts of the plant
    a. Translocation
7. Roots exchange gases with gases in the soil, taking in oxygen and discharging carbon dioxide. Oxygen supports sugar breakdown.

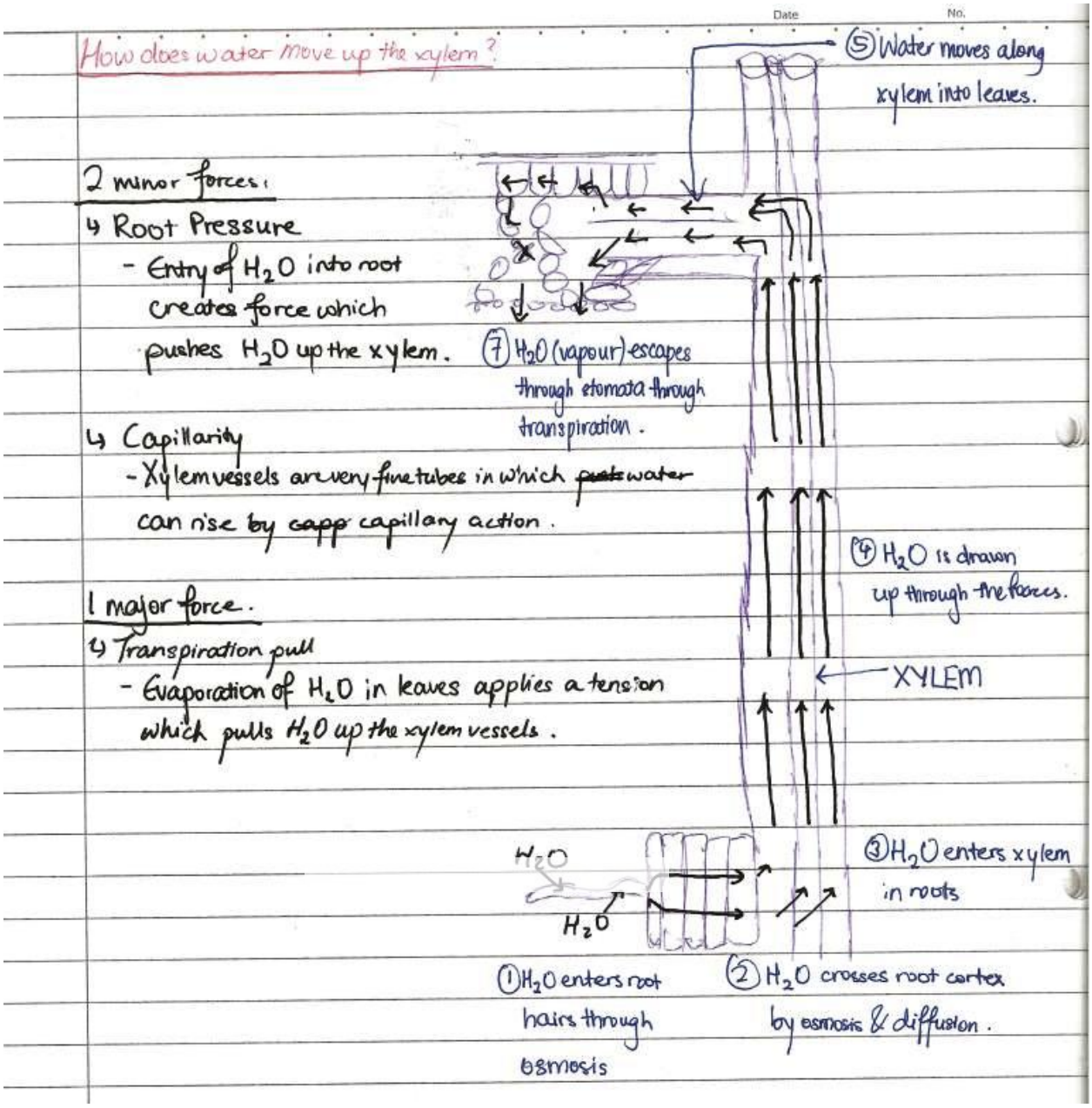
5.8: **What is Transpiration**

- Loss of water vapour from stomata of leaf
- Rate affected by:
    - Environmental factors
        - Humidity
            - High humidity **lowers the concentration gradient** of water **between inside and outside of leaf, lowering the rate of transpiration**
            - Low humidity **increases the concentration gradient** of water **between inside and outside of leaf, increasing the rate of transpiration**

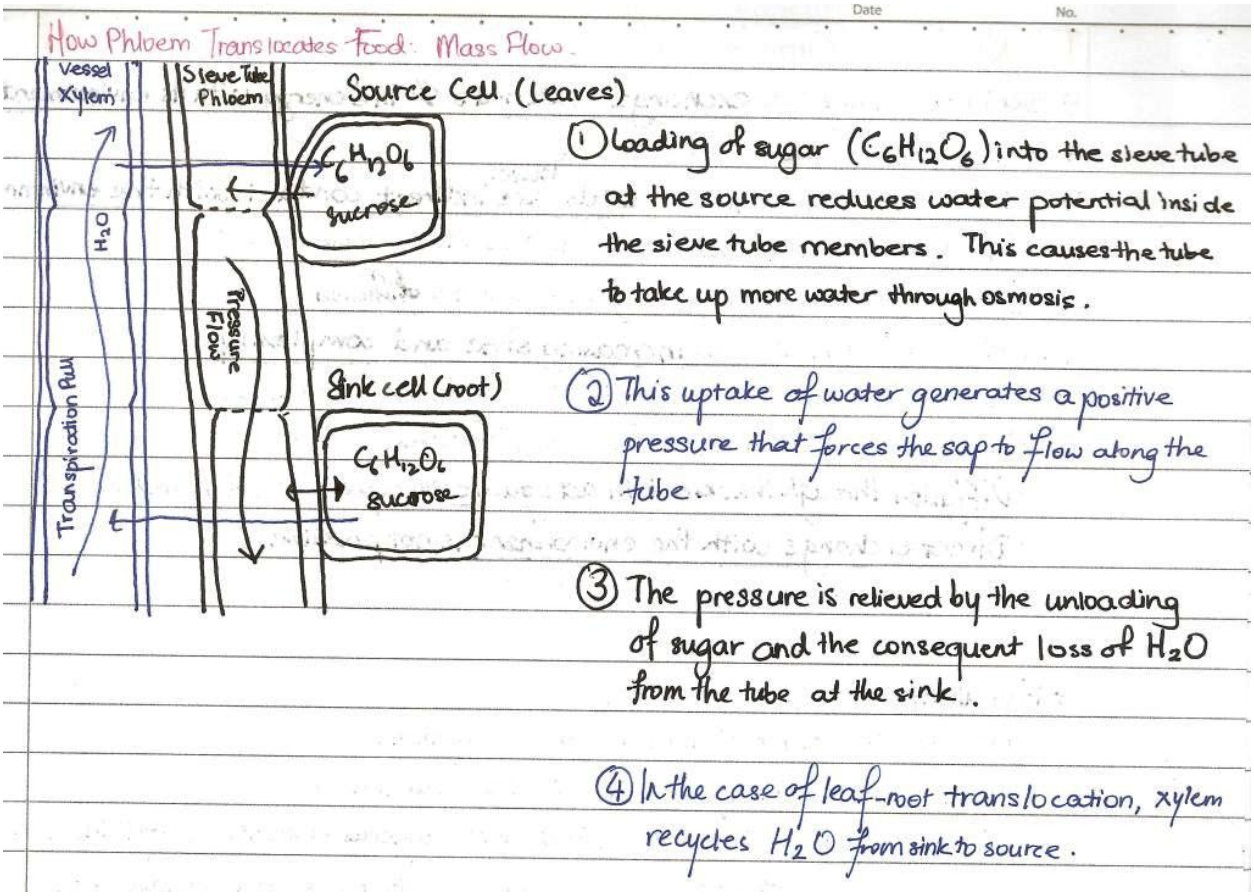
        - Temperature
            - At low temperatures:
                - Water evaporates slower
                - Ability of the atmosphere to hold water vapour is lesser causing humidity levels to reach saturation levels faster
                - Lowers transpiration rates
            - At high temperatures:
                - Water evaporates faster
                - Ability of the atmosphere to hold water vapour is more, causing humidity to reach saturation levels at slower rates
                - Rate of transpiration faster
        - Light
            - Low intensity/Dark
                - Stomata closed as there is a lack of photosynthesis
                - Rate of transpiration greatly reduced
            - High intensity
                - Stomata open due to photosynthesis
                - Rate of transpiration increases
        - Wind
            - Weak
                - Cannot move the boundary on the leaf surface created by water vapour
                - More water vapour outside the stomata = decrease in concentration gradient
                - Lowers the rate of transpiration
            - Strong
                - Can move the boundary/layer on the leaf surface created by water vapour
                - Less water vapour outside stomata = increase in concentration gradient
                - Increases the rate of transpiration
    - Plant parameters
        - Cuticle thickness
            - Thick
                - The thicker the cuticle layer, the harder it is for water to pass through
                - Transpiration rate decreases
            - Thin
                - The thinner the cuticle layer, the easier it is for water to pass through
                - Transpiration rate increases

- Stomata
  - Closed
    - Water vapour cannot leave the plant
    - Rate of transpiration drops
  - Open
    - Water vapour can leave the plant
    - Rate of transpiration increases

5.9: **How Does Water Move Up The System?**



5.10: **How Phloem Translocates Food: Mass Flow**



TOPIC 6: TRANSPORT IN MAN

A HUGE TOPIC tested in Y3 EOY and Y4 FYE

6.1: **The Need for a Circulatory System**

- Every organism needs to exchange materials and the energy with its environment
    - Exchange occurs at cellular levels
- In simple organisms, almost all cells have indirect contact with the environment
    - Unicellular organisms exchange materials with the environment
- Exchange of nutrients, gases and wastes occur via diffusion
- Multicellular organisms with increasing size and complexity
    - Amount of materials moving in and out of the body increases
    - Distance the materials have to travel increases
    - Diffusion through the skin is inadequate to cope with the demand
    - Direct exchange with the environment is not possible

6.2: **The Circulatory System in Man**

- Functions:
    - Provides an efficient internal transport system
    - Connects the organs of exchange with the body cells
    - Circulating fluid provides a bridge between the aqueous environment of living cells and the exchange organs that exchange chemicals with the outside environment
- Diffusion occurs at the capillary beds
- Materials (nutrients and oxygen) diffuse into the cells through the plasma membrane
- Metabolic wastes diffuse out of cells through the plasma membrane for disposal

Arteries → Arterioles → Capillaries → Venules → Veins

6.3: **Components of a Circulatory System**

- 3 main components
    - Central muscular pump (Heart)
    - Vascular system (Blood Vessels)
    - Circulating fluid
- Unidirectional flow of blood

6.4: **Open Circulatory System**

- Circulating fluid is pumped through open-ended vessels
- Flows out into the cells
- Circulating fluid bathes the cells directly
- System used in most invertebrates

6.5: **Closed Circulatory System**

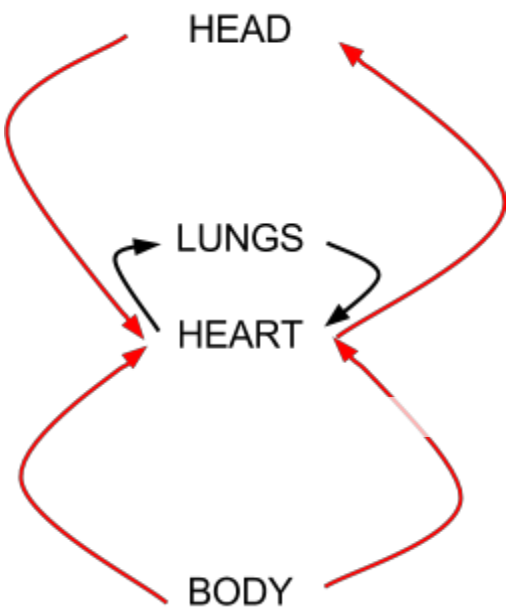
- Consists of transport vessels and a pump
- Circulating fluid is confined to the transport vessels
- Circulating fluid distinct from interstitial fluids
- Exchange occurs between cells and interstitial fluids
- More efficient at transporting circulatory fluids to tissues and cells
- Used in most vertebrates

6.5.1: **Closed Circulatory System In Man**

- Blood flows in a closed cardiovascular system
    - Consisting of blood vessels and a 4-chambered heart
- Arteries carry blood to capillaries from the heart
- Capillaries: Site of chemical exchange between the blood and interstitial fluid
- Veins return blood from capillaries to the heart

6.6: **Double Circulation System**

- Blood passes through the heart twice in complete circulation



Red: Systemic Circulation
Black: Pulmonary Circulation

Left and Right separated to prevent oxygenated and deoxygenated blood from mixing with each other

6.7: **Pulmonary Circulation**

- Transports blood between the heart and the lungs
- Pulmonary arteries
    - Exits the heart
    - Carry deoxygenated blood to the lungs
        - Blood loads oxygen and unloads carbon dioxide
- Pulmonary veins
    - Enters the heart
    - Carry oxygenated blood to the heart

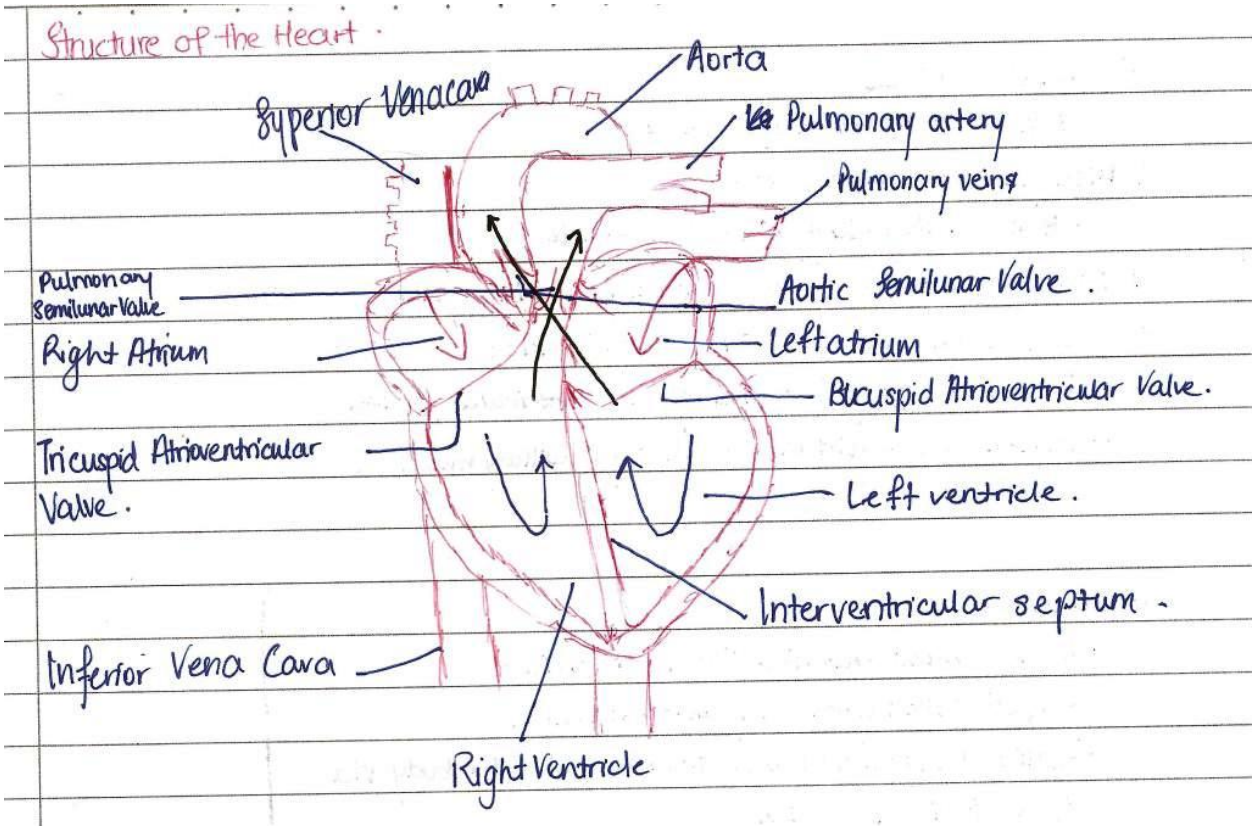
6.8: **Systemic Circulation**

- Transports blood between the heart and the rest of the body tissue
- Supplies blood rich in oxygen and nutrients to body cells, tissues and organs
- Removes carbon dioxide and other metabolic wastes from cells, tissues and organs
- Difference between arterial and venous transport

6.9: **The Heart**

- Muscular organ
- Pumps blood through blood vessels
    - Repeated rhythmic contractions
- Approximately the size of a clenched fist
- Located within the thorax (protection and structural support)
    - Behind the sternum
    - Surrounded by the lungs
- Enclosed within a sac known as a pericardium

6.10: **Structure of the Heart**



6.10.1: **Atria (Atrium)**

- Upper chambers
- Thin-walled as compared to ventricular walls
- Receive blood returning to the heart
- Pump blood into the ventricles

6.10.2: **Ventricles**

- Lower chambers
- Thick-walled as compared to the atria
- Able to generate high pressure
    - Dumps oxygenated blood to the rest of the body
- Left ventricular wall 3x thicker than right ventricular wall
    - Pumps blood to the rest of the body requires more pressure
- Right ventricle pumps blood to the lungs

6.10.3: **Atrioventricular Valves**

- Tricuspid valve
    - Between the chambers on the right side
- Bicuspid valve (mitral valve)
    - Between the chambers on the left side
- Prevent backflow of blood into the atria during systole
- Chordae tendineae to hold the valves in place
    - Prevent prolapsing/inverting of atrioventricular valves
    - Fastened to ventricular walls by papillary muscles

6.10.4: **Vessels Associated with the Heart**

- Vena cavae (RIGHT SIDE)
    - Major veins entering the right atrium
        - Superior vena cava and inferior
    - Return deoxygenated blood from the rest of the body via the systemic circulation
- Pulmonary artery (RIGHT SIDE)
    - Blood vessel leaving the right ventricle
    - Transports deoxygenated blood from the heart to the lungs via the pulmonary circulation
- Pulmonary Vein (LEFT SIDE)
    - Blood vessel entering left atrium
    - Transports oxygenated blood from the lungs to the heart via the pulmonary circulation
- Aorta (LEFT SIDE)
    - Major artery leaving the left ventricle
    - Transports oxygenated blood to all parts of the body via the systemic circulation

6.10.5: **Semilunar Valves**

- Present in the arteries leaving the heart
    - Pulmonary (Semilunar) Valve
    - Aortic (Semilunar) Valve
- Prevent backflow of blood into the ventricles

6.11: **Cardiac Cycle**

STAGE (Duration)	Diastole (0.4s)	Atrial Systole (0.1s)	Ventricular Systole (0.3s)
Heart muscles	Relaxed	Atria contract	Ventricles contract
Blood flow	Atria → Ventricles	Ventricles	Forced into arteries
Semilunar Valves	Closed	Closed	Open
Tricuspid Valves	Open	Open	Closed
Bicuspid Valves	Open	Open	Closed

6.12: **Pacemaker**

- Some cardiac muscle cells (myocytes) are self-excitable/auto-rhythmic
- These cells generate rhythmic impulses and directly control the heart rate\
- Region of the heart called the sinoatrial node
- Impulses from the sinoatrial node travel to the atrioventricular node
- Impulses are delayed at the atrioventricular node before travelling to the Bundle of His and the Purkinje Fibres
- Can be recorded through an electrocardiogram

6.13: **Blood Vessels**

- Transport blood to all parts of the body
- Blood delivers nutrients and removes wastes
- 3 major types of blood vessels
    - Arteries
    - Capillaries
    - Veins

6.13.1: **Arteries**

- Carry blood away from the heart
- Branch and narrow into arterioles
- Arterioles branch and narrow further into capillaries
- Thicker muscular and elastic walls than veins
    - Endothelium
        - Made of endothelial cells, smooth
    - Smooth muscles
        - Constricts and dilates blood flow
    - Elastic fibres
        - Stretches and recoils for blood pressure
    - Connective tissues
- Accommodate and maintain high pressure of blood pumped from the heart
- High pressure helps move the blood along
- No valves

6.13.2: **Veins**

- Carry blood to the heart
- Thinner-walled vessels
    - Endothelium
    - Smooth muscles and elastic fibres
    - Connective tissue
- Extremely low blood pressure
    - Skeletal-muscle pump helps move the blood along
        - Skeletal muscles contract
        - Pressure exerted on veins by the surrounding contracting muscles
        - Pushes blood through one-way valves
            - Keep blood moving only towards the heart
        - Muscular contractions help to move blood along
- Valves present
    - Prevent backflow of blood

6.13.3: **Capillaries**

- One cell thick
    - No smooth muscles
    - Endothelial cells
- Allows rapid diffusion
- Branches repeatedly
    - Large surface area for exchange of materials between blood and tissue cells
    - Exchange driven by osmotic and hydrostatic gradients

6.14: **Blood Flow Velocity**

- Varies in the circulatory system
- Fastest in the arteries (high pressure)
- Slowest in the capillary beds (low pressure)
- Volume of flow per second must be constant (law of continuity)
- Total cross-sectional area increases → Flow velocity decreases
    - Blood travels slower in capillaries: vast surface area
- Total cross -sectional area decreases → Flow velocity increases
    - Blood travels in veins and arteries

6.15: **Blood Pressure**

- Blood pressure
    - Hydrostatic pressure that blood exerts against the walls of a vessel
- Systolic Pressure
    - Pressure in the arteries during ventricular systole
    - Highest pressure in the arteries
- Diastolic Pressure
    - Pressure in the arteries during diastole
    - Lower than systolic pressure
- Determined by:
    - Cardiac output
        - Volume of blood pumped by each ventricle per minute
    - Peripheral resistance
        - Variable constriction of the arteries

6.16: **Capillary Function**

- Capillaries in major organs are usually filled to capacity
- In many other sites, blood supply varies over time

6.17: **Exchange of Materials**

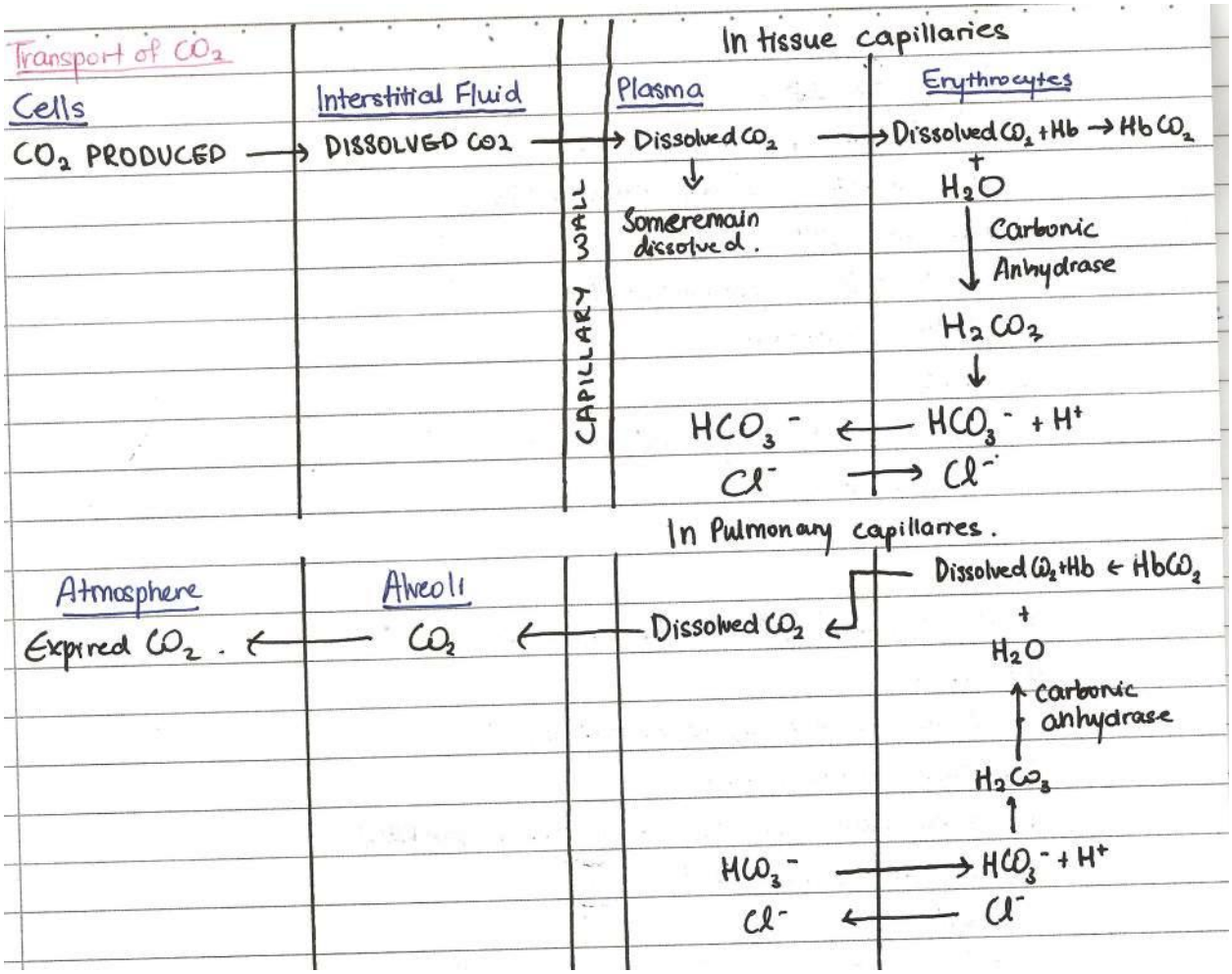
- Critical exchange of substances between the blood and interstitial fluid
    - Takes place across the thin endothelial walls of the capillaries
- Difference between hydrostatic pressure and osmotic pressure due to blood proteins (e.g. fibrogen)
    - Drives fluids out of capillaries at the arteriole end
    - Draws fluids into the capillaries at the venule end
- Fluid reenters the circulation
    - Directly at the venule end of the capillary bed
    - Indirectly via the lymphatic system
- The lymphatic system
    - Returns fluid to the body from the capillary beds
    - Acids in body defense

- At the arteriole end, plasma is forced out of the capillaries
    - Plasma proteins too bulky to pass through capillary walls
- White blood cells changes shape and squeeze through capillary walls
- These make up the interstitial fluid, which
    - Bathes all living cells in the body
    - Contains dissolved food and oxygen from blood
        - Supply to cells
    - Receives waste products of cells
        - Returned to blood in capillaries to be removed

6.18.1: **Plasma**

- About 55% of the blood
- Pale yellowish liquid
- Made of many different materials
    - Water
        - Solvent for carrying other substances
        - 90% of the plasma content
    - Ions (blood electrolytes)
        - Osmotic balance
        - pH buffering
        - Regulation of membrane permeability
            - Sodium
            - Potassium
            - Calcium
            - Magnesium
            - Chloride
            - Bicarbonate
    - Fibrinogen
    - Albumin
    - Immunoglobulins
    - Substances transported by blood
        - Nutrients
        - Metabolic wastes
        - Respiratory gases
        - Hormones
- Transports dissolved nutrients and removes waste products

6.18.2: **Transport of Carbon Dioxide**



- 3 ways of transport
    - Dissolved into the plasma
        - 5%
    - Reversible bind to haemoglobin to form carbaminohaemoglobin
        - Carbon dioxide does not bind to the haem group, unlike oxygen
        - Binds with amino groups on polypeptide chains of haemoglobin
    - Majority travel as HCO_3^-
        - Enter RBCs and combines with H_2O to form carbonic acid, H_2CO_3
        - Reaction catalysed by carbonic anhydrase
        - Dissociates to form bicarbonate ions and hydrogen ions

6.18.3: **Red Blood Cells (Erythrocytes)**

- 5 000 000 to 6 000 000 per mm^3 of blood
- Transports oxygen and helps to transport carbon dioxide
- Circular, flattened, flexible biconcave discs
- No nuclei
    - More space to transport materials
- Less than 0.01 mm in diameter
- Contains haemoglobin
    - 250 000 000 molecules per RBC
- Elastic
    - Can squeeze through capillaries smaller than themselves
- Produced in bone marrow
- Destroyed in the spleen and the liver
- Life span of 3-4 months

6.18.4: **Haemoglobin**

- Made up of four globular protein subunits
- Each subunit comprises
    - A protein chain
    - An iron-containing haem group
- Each haem group is capable of binding to an oxygen molecule, forming oxyhaemoglobin
- Oxygen requires haemoglobin as a transport molecule as it is poorly soluble in water
- Deoxyhaemoglobin is the form of haemoglobin without the bound oxygen

6.18.5: **Transport of Oxygen in the Blood**

- Majority of the dissolved oxygen molecules binds with haemoglobin
- Less than 1% remain dissolved in either plasma or erythrocytes

6.18.6: **White Blood Cells (Leukocytes)**

- 5 000 to 10 000 per mm^3 of blood
- Defense and immunity
- Irregular in shape
    - Ability to squeeze through walls of blood capillaries through a change in shape
- Colourless
    - No haemoglobin

- Two main type of leukocytes
    - Lymphocytes
        - Produced in bone marrow
        - Large rounded nucleus
        - Small amount of cytoplasm
        - Produce antibodies
            - Antitoxins to kill bacteria
            - Clumping of foreign particles
    - Phagocytes
        - Lobed nucleus
        - Ingests foreign particles, bacterias and dead/dying cells
            - Phagocytosis

6.18.7: **Platelets (Thrombocytes)**

- Platelets are not true cells
- Fragments of cytoplasm from bone marrow cells
- Play a role in blood clotting
    - Reduce blood loss
    - Prevent entry of micro-organisms at a wound
- When endothelium of a blood vessel is damaged
    - Clotting cascade begins

6.19: **Summary: Functions of Blood**

- Acts as a transport medium
    - Carries various substances from one part of the body to another
        - Blood plasma
        - Erythrocytes
- Protects the body against disease-causing organisms
    - Leukocytes
        - Lymphocytes produce antibodies
        - Phagocytes that engulf foreign particles
    - Platelets
        - Help in blood clotting
        - Prevent entry of micro-organisms

6.20: **Cardiovascular Diseases**

- Atherosclerosis
    - Caused by the buildup of cholesterol within the arteries
    - Exarcerbated by consumption of excessive amounts of trans fat and saturated fat in the diet
- Hypertension
    - Promotes atherosclerosis and increases the risk of heart attack and stroke
- Heart Attack
    - Death of a cardiac muscle tissue resulting from blockage of one or more coronary arteries
- Stroke
    - Death of a nervous tissue in the brain, usually due to a rupture or blockage of arteries in the head

TOPIC 7a: NERVOUS SYSTEM

Tested for Y3 EOY and Y4 FYE

7a.1: **The Nervous System**

- Central Nervous System
    - Brain
    - Spinal Cord
- Peripheral Nervous System
    - Cranial nerves from brain
    - Spinal nerves from spinal cord
        - Receptors
    - Somatic (Voluntary) Nervous System
    - Autonomic (Involuntary) Nervous System
        - Sympathetic Division
        - Parasympathetic Division
        - Enteric Division

7a.2: **Stimulus/Response**

- Stimulus
    - A change that is detected by the receptors
- Receptors
    - Nerve endings and specialised cells in sense organs
        - Receive stimuli from environment
- Response
    - A reaction of the body towards the stimulus
- Effectors
    - Muscles or glands that bring about the response

7a.3: **The 2 Different Responses**

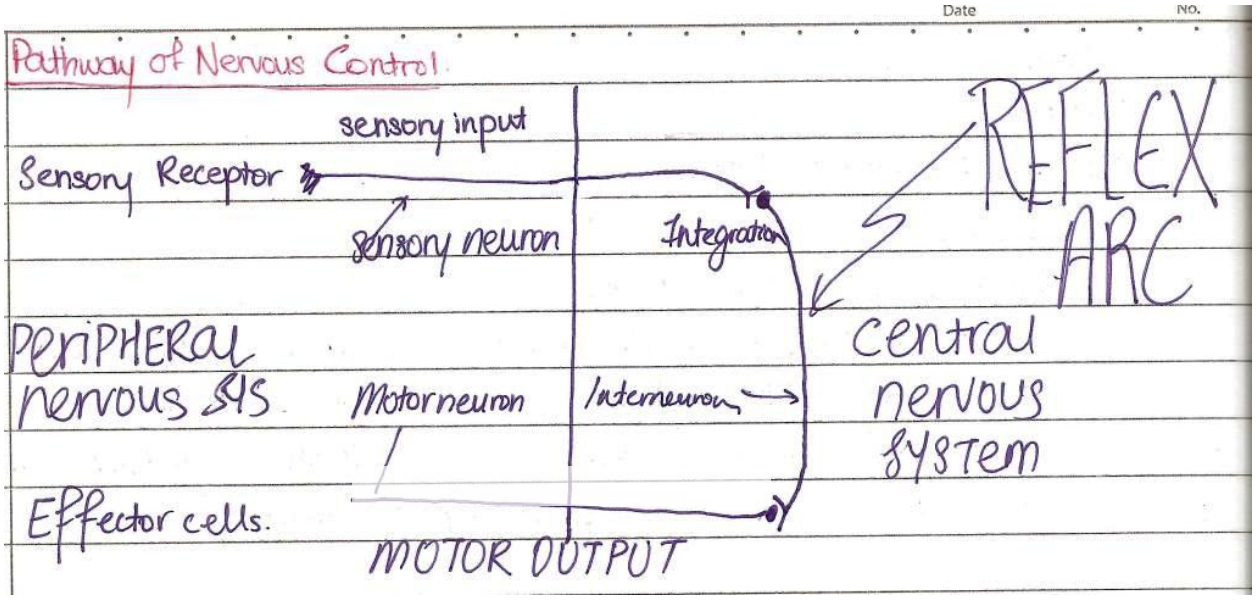
PARASYMPATHETIC (Rest or Digest)	*Organ*	**SYMPATHETIC (Fight of Flight)**
Constricted	*Pupil*	**Dilated**
Stimulated (for salivation)	*Salivary Glands*	**Inhibited**
Heartbeat inhibited	*Heart*	**Heartbeat Accelerated**
Constricted	*Bronchi*	**Relaxed**
Stimulated	*Digestive System*	**Inhibited**
Gall Bladder stimulated	*Liver/Kidney*	**Liver stimulated for glucose release** **Secretion of epinephrine and norepinephrine from kidney**
Contracted	*Bladder*	**Relaxed**
Relaxed	*Rectum*	**Contracted**

7a.4: **Receptors**

- Nociceptors
    - Pain
    - Commonly located at the
        - Superficial parts of the skin
        - Joint capsules
        - Periostea of bones
        - Walls of blood vessels
        - Deep tissues/Most visceral organs

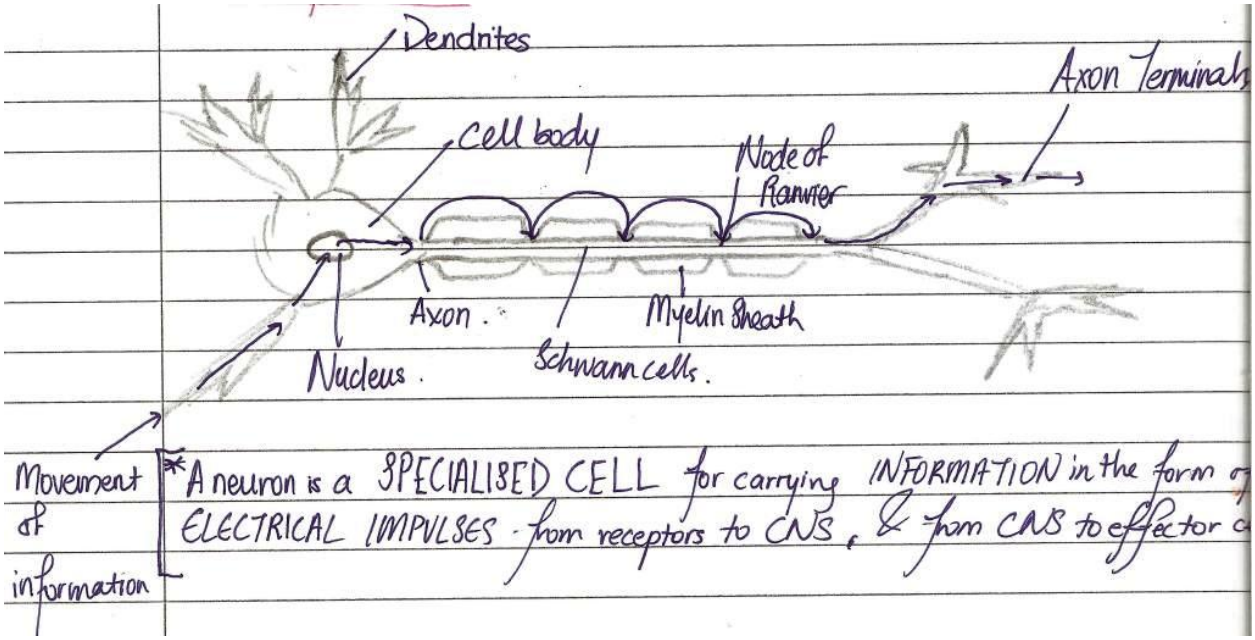
- Thermoreceptors
    - Temperature, heat or cold
    - Commonly located at the:
        - Immediately beneath the skin surface
        - Skeletal muscles
        - Liver
        - Hypothalamus
    - Cold receptors are 3-4 times more numerous than heat receptors
    - Free nerve endings
- Chemoreceptors
    - Chemical stimuli
    - Respond to water-soluble or lipid-soluble substances
    - No well-defined chemosensory pathways in the brain/spinal cord
        - Except for taste and smell
    - Neurons within the respiratory centres of the brain respond to concentrations of H^+ ions and carbon dioxide in the cerebrospinal fluid
    - Receptors in the periphery monitor the oxygen concentrations of the arterial blood
- Mechanoreceptors
    - Touch/pressure/position
    - Sensitive to stimuli that distort their cell membranes

7a.5: **Pathway of Nervous Control**



- Stimulus detected by receptors
- Information sent via the sensory nerve to the Central Nervous System
- CNS receives the information and processes the information
- The brain decides the response
- Response sent via motor nerves to effector cells

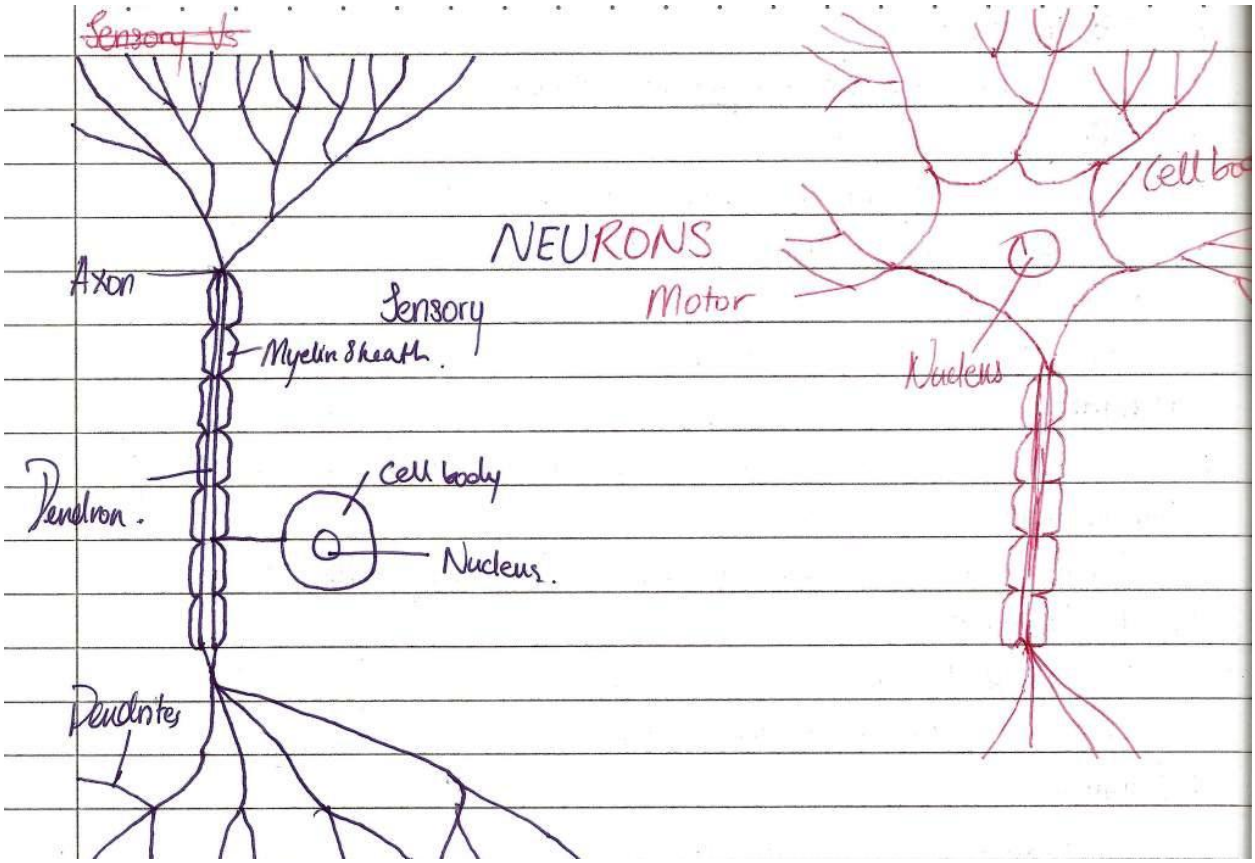
7a.6: **Structure of a Neuron**



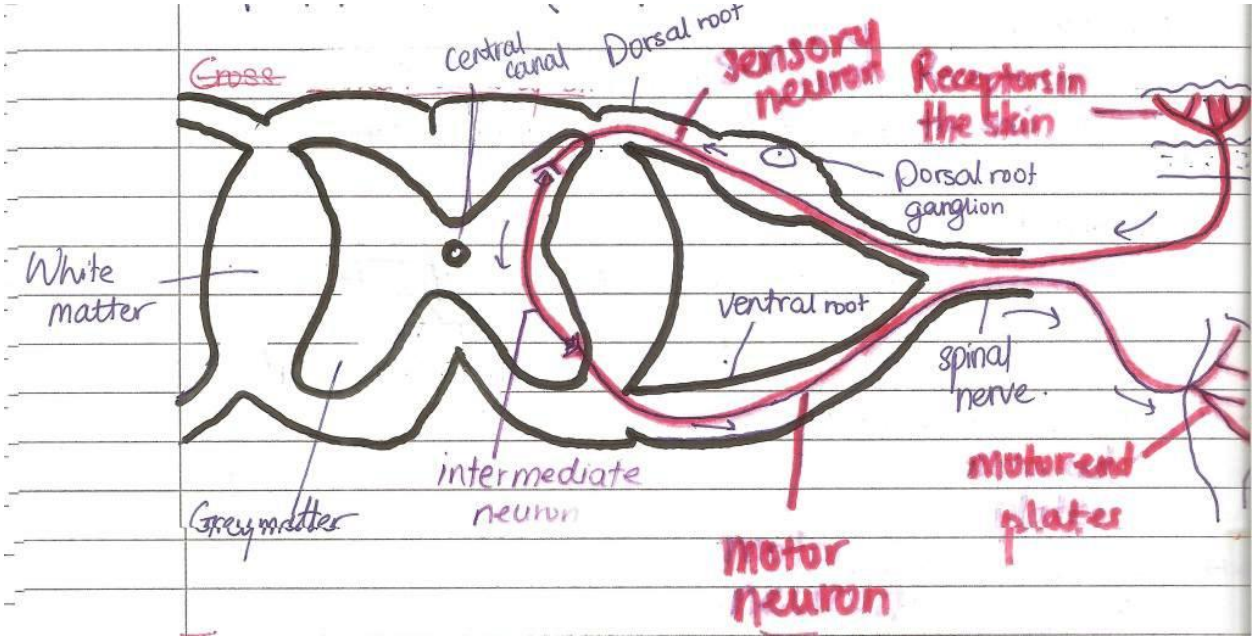
- Cell body/Soma
    - With nucleus, cytoplasm and plasma membrane
- Axon
    - Covered with myelin sheath (made of lipids)
    - Transmits impulses away from cell body
- Dendron
    - Conducts impulses to cell body
- Dendrites
    - Conduct impulses from other cells to dendron and cell body
- Myelin Sheath
    - Thin membrane (neurilemma), provides nourishment for the cell
- Node of Ranvier
    - Unmyelinated part of axon/dendron
    - Speeds up transmission of impulses
- Synapse
    - Junction between 2 neurons
- Neurotransmitter
    - Chemical substance that is released at the synapse
    - Aids in the transmission of the impulses across the synapse
- Schwann cells
    - Forms the myelin sheaths around the axons of neurons

7a.7: **Types of Neurons and Their Functions**

- Sensory/Afferent/Receptor Neuron
    - Carry impulses from receptors or sense organs to central nervous system
- Intermediate/Relay neuron
    - Carry impulses from sensory to motor neuron
    - Found in the central nervous system (brain and spinal cord)
- Effector/Efferent/Motor neuron
    - Carry impulses from the central nervous system to the effector neuron



7a.8: **Central Nervous System**



- The brain and the spinal cord consists of 2 distinct regions
    - White matter
        - Consists mainly of nerve fibres (axons and myelins)
    - Grey matter
        - Consists mainly of cell bodies of motor and relay neurons
- The Spinal Cord
    - Passes through the vertebral column
    - 31 pairs of spinal nerves that emerge at regular intervals along the length of the spinal cord
- Central Canal
    - Narrow canal that runs through the middle of the spinal cord
    - Carries cerebrospinal fluid
    - Cerebrospinal fluid carries nutrients to the spinal cord
    - Cushions the Central Nervous System
- Spinal Nerve
    - Bifurcates into two: Dorsal and Ventral Roots
        - Ventral roots contains motor neurons
        - Cell bodies of these found in grey matter of spinal cord
        - Dorsal roots only contain sensory neurons
- Dorsal Root Ganglion
    - Cell bodies of the sensory neurons in the dorsal root aggregate in a small swelling called the Dorsal Root Ganglion

7a.9: **Reflex Action**

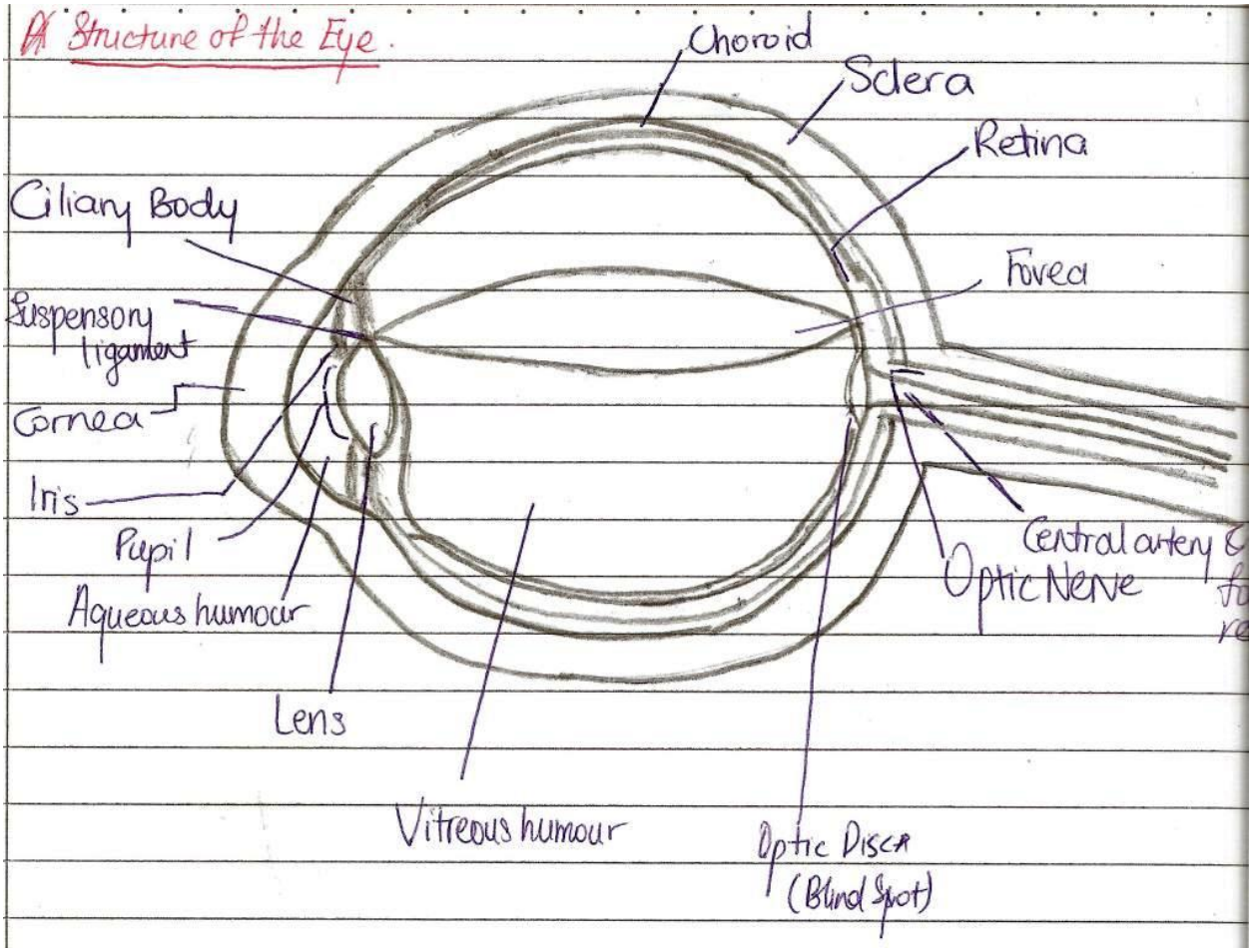
- Spontaneous/Immediate/Rapid response to a certain stimulus without conscious control
- Most basic form of response to protect oneself from harm/injury
- The reflex arc:

1. Stimulation of nerve endings/receptors
2. Nervous impulses are initiated by receptors
3. Travel along the dendron of sensory neuron to spinal cord
4. Impulses transmitted across synapse to relay neuron
5. Impulses transmitted across another synapse to motor neuron
6. Impulses leave the spinal cord
7. Travel along the axon of the motor neuron to the effector
8. Effector muscles bring appropriate

- Axon of sensory neuron has many branches in spinal cord
    - One branch forms a synapse with a relay neuron transmitting impulses to the brain
    - Another branch forms a synapse with a motor neuron to the larynx (for a cry)
- Spinal cord acts as a coordinator for simple refelx action

TOPIC 7b: A SENSE ORGAN - THE EYE

Tested for the Y3 EOY and Y4 FYE



7b.1: **Structure of the Eye**

- Sclera
  - White, tough protective outer coat
- Choroid
  - Pigmented, contains blood vessels
- Retina
  - Inner layer, contains photosensitive neurons that join to form the optic nerve
- Cornea
  - Refracts and converges light onto the retina
- Iris
  - Controls the amount of light entered through the radial and circular involuntary muscles
- Ciliary body
  - Helps to hold the lens in place by suspensory ligaments
  -

7b.2: **How Do We See?**

- The cornea allows light into the eye, while the pupil controls the amount of light that can enter
- The cornea and lens focuses light onto the retina
- Impulses from the photoreceptors travel along neurons to the optic nerve fibres
- The two optic nerves carry impulses to the visual centre in the back of the brain where the image is seen

7b.3: **Photoreceptors**

- Two kinds are found in the retina
    - Rods
        - Very sensitive to light and enables us to see in dim light
        - Contributes more to night vision
        - Contains a pigment derived from Vitamin A
        - Vitamin A deficiency can cause night blindness
    - Cones
        - Less sensitive to light and stimulated by bright light
        - Also used to distinguish colour

7b.4: **Focusing of the Eye**

- Clear vision depends primarily on the ability of the lens to focus the light on the retina
- As light rays pass through the eye, they are refracted by the different densities of the cornea and the lens so their point of convergence falls on the retina
- Accommodation of the eye for near vision:
    - Ciliary muscles contract
    - Suspensory ligaments slacken
    - Lens thicker, more convex
    - Less pull on lens
- Accommodation of the eye for far vision
    - Ciliary muscles relax
    - Suspensory ligaments tighten
    - Lens thinner, less convex
    - More pull on lens

7b.5: **Action of Iris - Pupil Reflex**

- Changes in light intensity stimulates the photoreceptors in the retina
- Nervous impulses are sent to the brain via the optic nerve
- Brain interprets these impulses and send impulses via a motor neuron to the circular and radial muscles in the iris
- The muscles contract and relax accordingly to ensure the correct amount of light entering the eye
- Without conscious control
- Pupil reflex for bright light:
    - Circular muscles contract
    - Radial muscles relax
    - Less light enters the retina to protect it
- Pupil reflex for dim light
    - Circular muscles relax
    - Radial muscles contract
    - More light enters the retina to stimulate it

7b.6: **Binocular Vision**

- Humans and most predators have two eyes, one located on each side of the face
- The image that each sees is slightly different because each eye views the object from a different angle
- This slight displacement of the images permits binocular vision, the ability to perceive 3D images and sense depth

TOPIC 7c: MUSCLES AND MOVEMENT

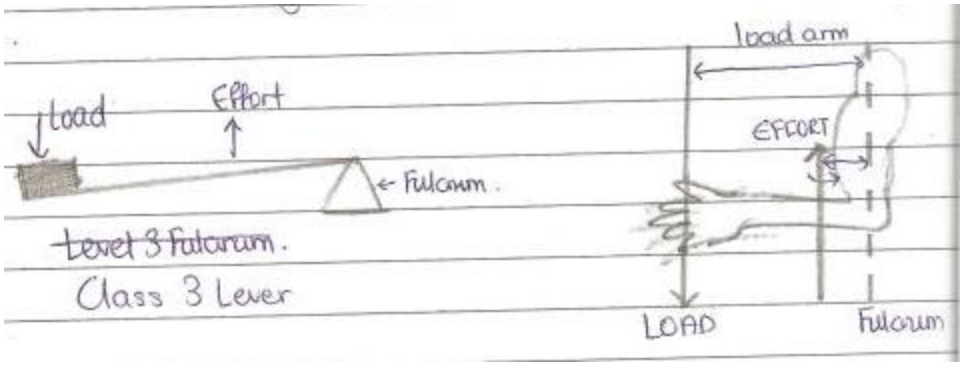
Tested for Y3 EOY and Y4 FYE

7c.1: **Functions of the Skeleton**

- Support
  - Provides a rigid internal framework, maintaining the shape of the body
- Protection
  - Skull protects the brain from injury
  - Ribcage protects the heart, lungs and liver
  - Spinal cord is enclosed in the vertebral column
- Movement
  - Provides points of attachment for skeletal muscles
  - When muscles contract, they pull on these bones, producing movement
- Production of Blood Cells
  - Bone marrow produces RBCs and WBCs

7c.2: **Joints: What are They?**

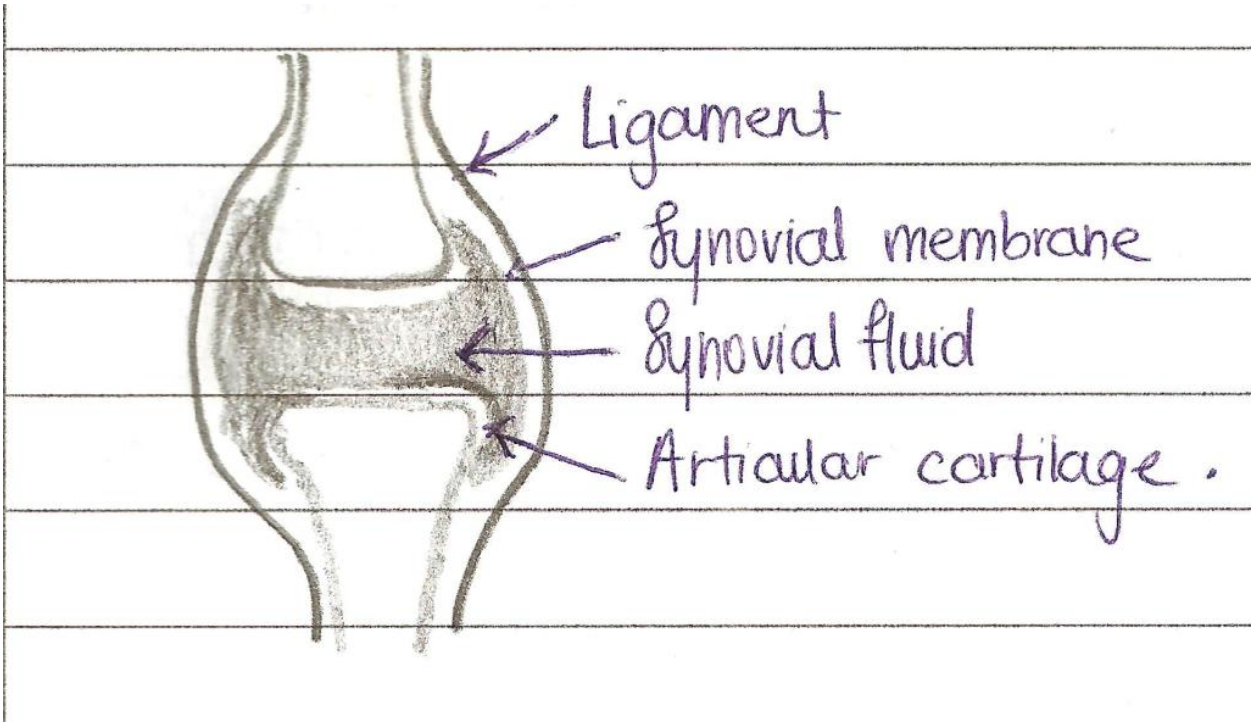
- The skeleton of an animal together with the muscles attached act as a system of levers



7c.4: **Types of Joints**

- 3 types
  - Immovable
    - Cranial bones: fused together at sutures
  - Partially movable
    - Gliding joints between bones of vertebral column
  - Freely movable/synovial
    - Ball-and-socket joint: Hip and shoulder
    - Hinge: Elbow and knee

7c.5: **Synovial Joints**



- Ligament
    - Fibrous covering, orientated to cope effectively with particular stresses on the joint
    - Joins 2 bones together
    - Made of collagen, which is elastic and flexible
- Synovial membrane
    - Secretes the synovial fluid
- Synovial fluid
    - Provides nutrients for the cartilage at the ends of the bones
    - Reduces friction when bones move against each other
- Articular cartilage
    - Prevents damage to the articulating surfaces of bones result of friction between them

7c.6: **Skeletal Muscles**

- Usually voluntary
    - Involuntary during reflex actions
- Attached to a bone in at least 2 places
    - Origin
        - Firm, non-movable part of the skeleton
    - Insertion
        - Freely movable part of the skin
- Antagonistic Action
    - One muscle group contracts, another one relaxes (Biceps-triceps)

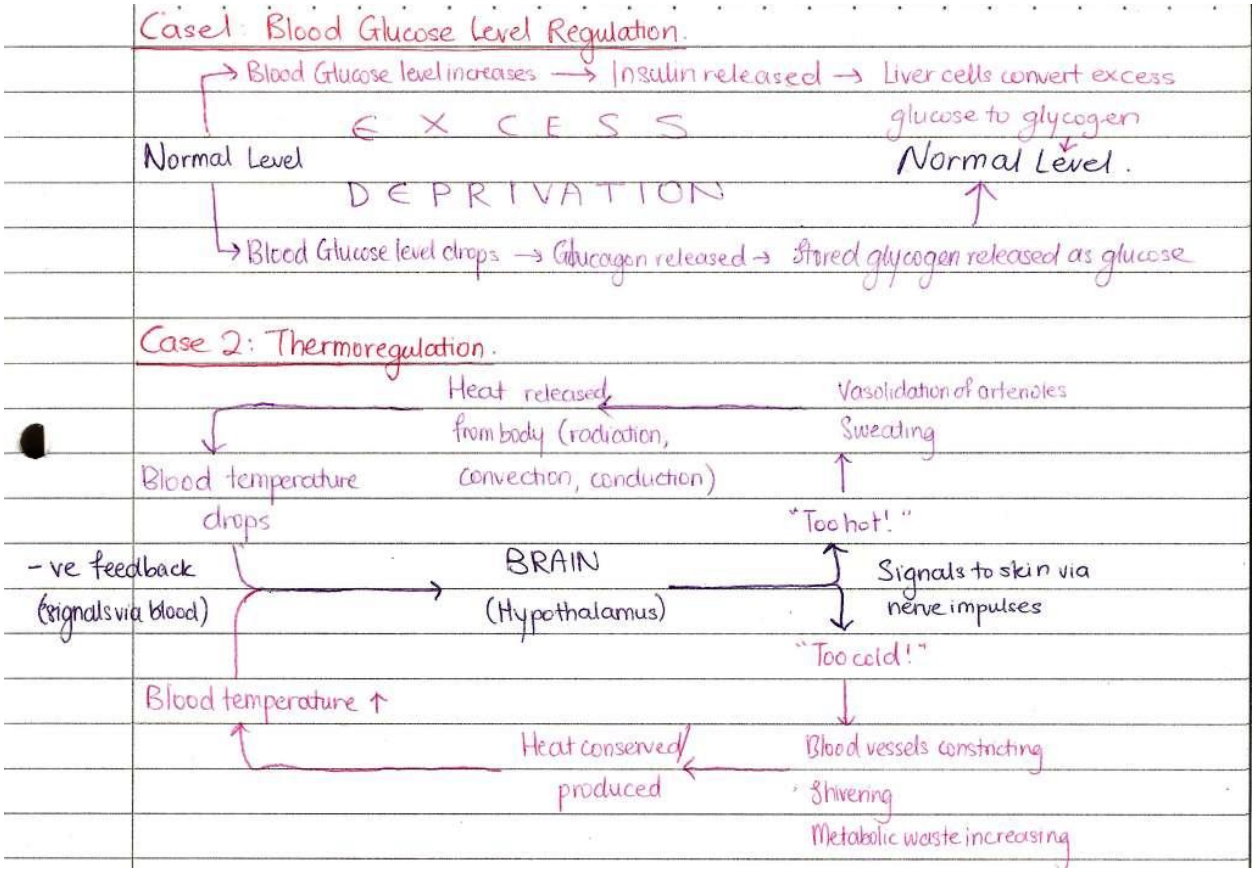
TOPIC 8: HOMEOSTASIS

Tested for Y3 EOY and Y4 FYE

8.1: **Homeostasis**

- The maintenance of a constant internal environment despite changes in the external environment
    - Animals manage their internal environment by regulating or conforming to the external environment
    - A regulator control its internal coordination in the face of fluctuating external conditions
    - A conformer allows its internal condition to vary with external change
- Involves 3 factors
    - Receptors → Detects stimulus
    - Messengers → Coordinate a corrective mechanism via negative feedback
    - Effectors → Carries our response
- Regulatory responses may be effected through
    - Nervous system
    - Endocrine system
- 4 kinds of regulatory processes to study
    - Blood glucose level regulation
    - Thermoregulation
    - Osmoregulation
    - Water potential
- What is a negative feedback
    - A response to a change by reserving the direction of the change so as to maintain a constant internal environment

8.2: **Negative Feedback**



- When blood temperature rises
    - Rise in blood temperature
    - Thermoreceptors in the hypothalamus in the brain detects this increase
    - Hypothalamus sends nerve impulses to bring about the following changes
        - Stimulation of sweat glands
            - As more sweat is produced is evaporated, more latent heat is removed from the body
        - Vasodilation of arterioles in skin
            - Allows more blood to flow through the skin
            - More heat lost through radiation, convection and conduction
        - Hair erector muscle relax
        - Metabolic rate decreases

- When body temperature falls
    - Fall in blood temperature
    - Thermoreceptors in hypothalamus in the brain detects this change
    - Hypothalamus sends nervous impulses to bring about the following changes
        - Sweat glands are not submitted
            - Less production of sweat
            - As less sweat evaporates from surface of skin, less latent heat is removed from the body
        - Vasoconstriction, or constriction of arterioles in skin
            - Allows less blood to flow through the skin
            - Less heat lost through radiation, convection or conduction
        - Hair erector muscles contract
            - Hair stand on ends, forms insulating layer of air between hair
        - Involuntary successive contraction and relaxation of muscles → Shivering
        - Metabolic rate increases

8.3: **Exchanges with the External Environment**

- Organisms must continuously exchange chemicals and energy with their surroundings
- All living cells must be bathed in a watery solution so that exchange of materials can occur
- Complex animals have extensively folded or branched internal surfaces to maximise surface area for exchange
- Osmoconformers are organisms whose:
    - Internal and external environments have similar solute concentrations
    - Include most marine vertebrates
- Osmoregulators are organisms who:
    - Actively regulate their water loss or gain
    - Include freshwater animals, as well as most marine invertebrates as well as land animals

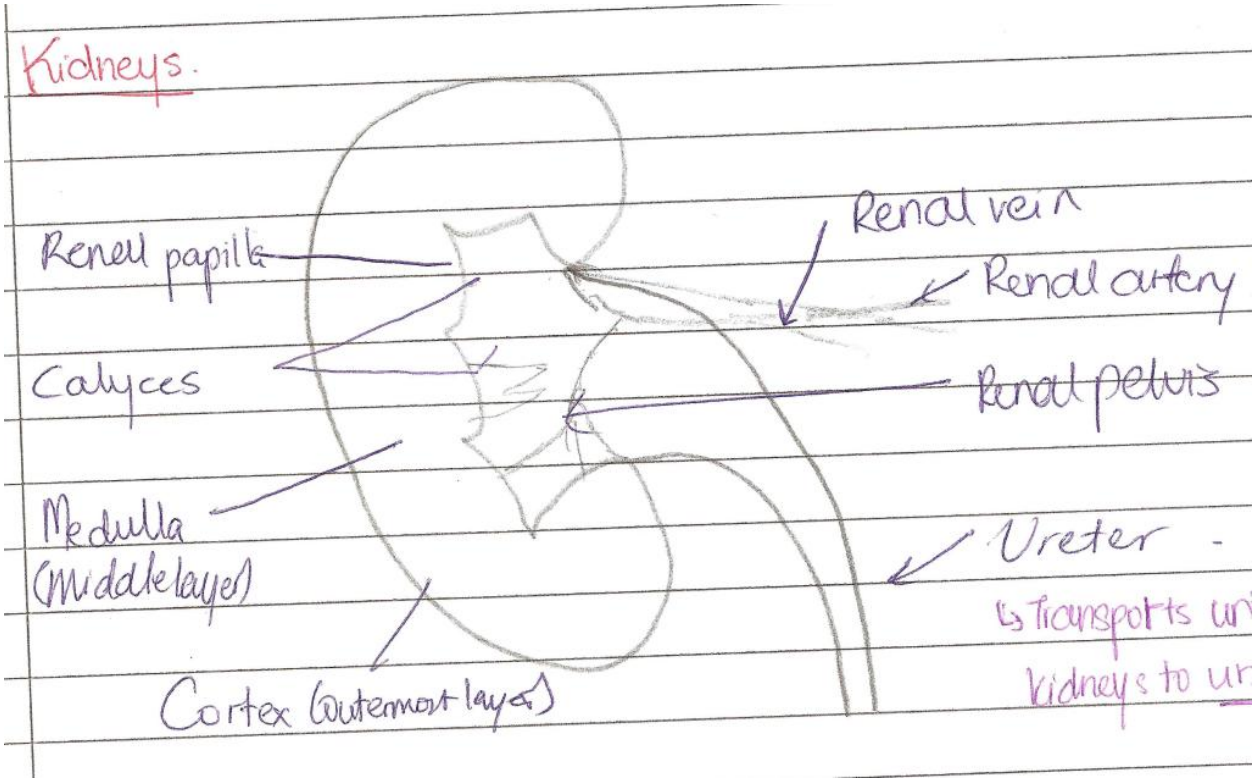
8.4: **Excretion**

- Removal of metabolic wastes from the body
- Products:
    - Carbon dioxide
        - Excreted by lungs as a gas in expired air
    - Excess water
        - Excreted by kidney, skin and lungs
        - A constituent of urine, sweat and expired air
    - Urea
        - Excreted by kidney and skin
        - A constituent of urine and sweat
        - Formed during deamination of proteins at the liver
    - Uric acid
        - Excreted by kidney and skin
        - A constituent of urine and sweat
        - Formed by the breakdown of nuclear materials
    - Bile pigments
        - Excreted by liver via the intestines
        - Formed by the breakdown of haemoglobin
            - Iron released is recycled
    - Mineral salts
        - Excreted by kidney and skin
        - Constituent of urine and sweat

8.5: **Lungs as Excretory Organs**

- Cellular respiration produces carbon dioxide and water
- Carbon dioxide from cells diffuse into blood
- Carried as hydrogen carbonate ($H^+ + HCO_3^-$) in RBC and blood plasma
- Carried to the lungs
- HCO_3^- changed back to CO_2 in the capillaries of lungs
- CO_2 diffuses into the alveoli
- O_2 diffuses into blood from alveoli
- CO_2 expelled during exhalation
- H_2O evaporates from walls of alveoli

8.6: **Kidneys**

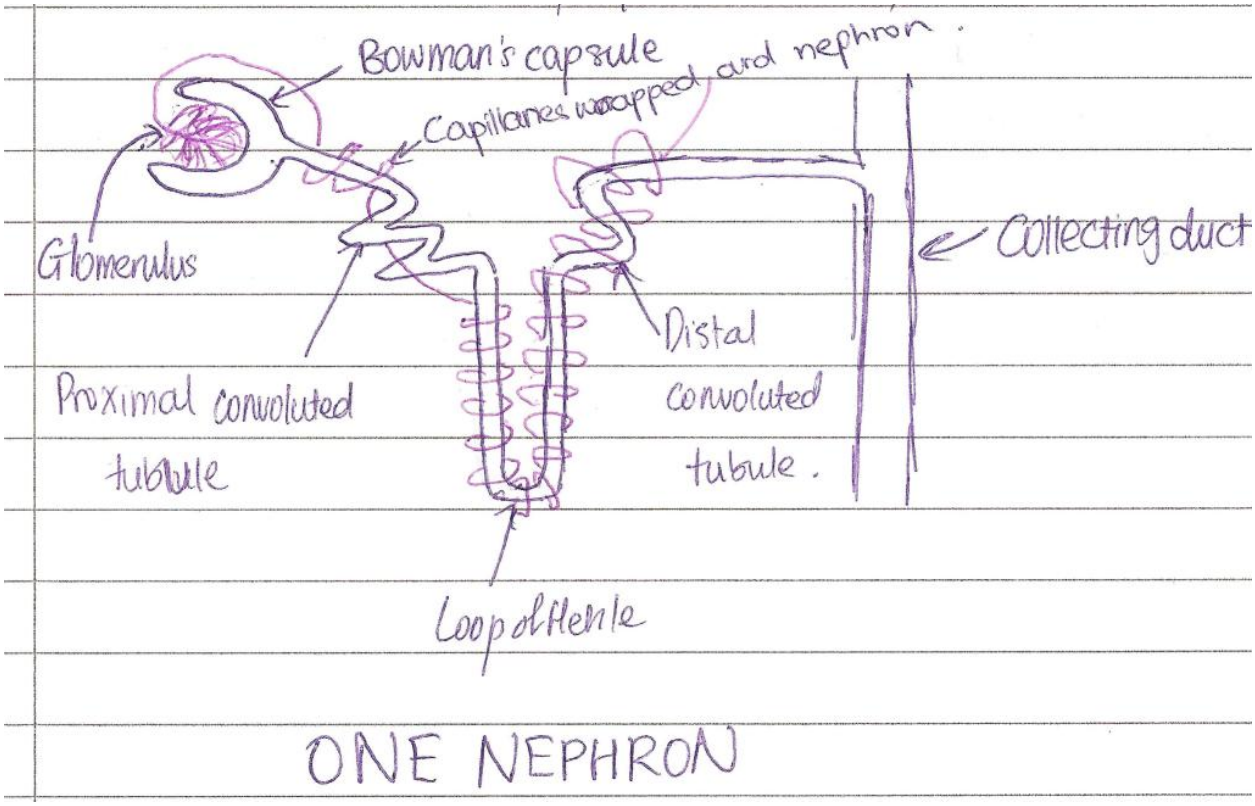


8.7: **Functions of Kidneys**

- Elimination of waste substance
- Salvage of essential ions such as Na^+, K^+, Cl^-
- Regulation of blood pH by removing/reabsorbing H^+ and HCO_3
- Regulation of plasma volume/blood pressure
- Regulation of blood osmotic concentration
- Production of hormones - erythropoietin and renin
- Removal of toxic substances

8.8: **Excretion by the Kidneys: Urine**

- A very large volume of extracellular fluid is separated from the plasma per day
    - 99% reabsorbed back into the plasma
        - Excess water, salts and urea left
- Working unit of kidney: NEPHRON
- Blood enters the kidney by renal artery



8.9: **Ultrafiltration**

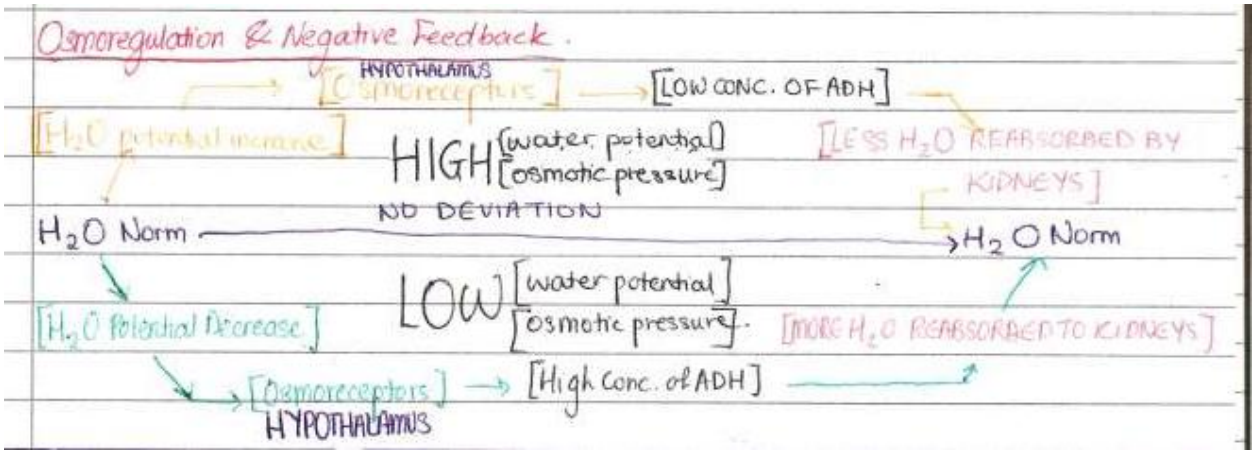
- Diameter of afferent arteriole is larger than diameter of efferent arterioles
- Hydrostatic pressure created forces fluid out from artery to Bowman's capsule
- Small particles are filtered into the Bowman's capsule
    - Plasma containing: Glucose materials, amino acid molecules, urea
- Large molecules (RBC, WBC, proteins) remain in the renal artery
- Resultant fluid is known as glomerular filtrate

8.10: **Selective Reabsorption**

- Occurs in proximal convoluted tubule
- Filtrate passes through tubule, selective reabsorption of molecules would occur
- Most of the water is reabsorbed
- Glucose, amino acids and some minerals are reabsorbed through tubule walls into surrounding capillaries
- By active/passive transport
- Excess water, mineral salts and nitrogenous waste allowed to pass through tubule and out to the ureter and urinary bladder as urine
    - 96% water
    - 1.8% mineral salts
    - 2.0% urea
    - 0.2% other nitrogenous wastes

8.11: **Osmoregulation**

- Osmoregulation is the regulation of blood osmolarity
- Controls the amount of water available for cells to absorb
- Osmoreceptors:
    - Capable of detecting osmotic pressure changes
    - Situated at the hypothalamus
    - Sends chemical messages to the pituitary gland next to it
    - Pituitary gland secretes anti-diuretic hormone (ADH), which targets the kidney responsible for maintaining water concentration levels
- Osmoregulatory effectors
    - When ADH reaches the kidneys, it alters the tubules of the kidney to be more or less permeable to water
    - If more water is required in the blood stream (Low osmotic pressure, concentrated blood)
        - High amounts of ADH produced
        - Tubules are more permeable to water
        - More water reabsorbed by the kidneys
        - Less urine is produced
    - If less water is required in the blood stream (High osmotic pressure, diluted blood)
        - Low amounts of ADH produced
        - Tubules are less permeable to water
        - Less water reabsorbed by the kidneys
        - More urine is produced



8.12: **Haemodialysis**

- When both kidneys fail, the patient will be treated with a dialysis machine
- Blood is drawn from a radial artery in the patient's arm
    - Requires an enlarged vein
- Flows through a tubing in the machine, bathed in a specially controlled dialysis fluid which is an isotonic solution
- Walls of tubing are partially permeable
    - Urea and other waste products diffuse through
    - Proteins and blood cells stay in the tubing
- Fluid contains essential salts for the body
- Therefore such salts do not diffuse out of the body
- Tubing is coiled
    - Increases surface area and speeds up exchange of substances
- Filtered blood then returns to the enlarged vein
- Process repeated 3 times a week, few hours each session

TOPIC 9: HORMONES

Tested for Y3 EOY and Y4 FYE

9.1: **Human Endocrine System**

- A system made up of small endocrine glands, which secrete chemical messengers known as hormones

9.2: **Endocrine vs. Exocrine Glands**

- Endocrine glands are ductless glands
    - Secretions directly enter and are carried at the bloodstream
- Exocrine glands have glands to carry their secretions
    - A duct distributes the secretions

9.3: **Hormones**

- Chemical messengers
- Carried by the blood
- Their effect on target cells is slow due to the time taken to travel through the bloodstream
    - As compared to the nervous systems
- Produced in minute amounts
- Alters the activities of one or more specific target organs
- Destroyed by the liver and/or excreted in the urine by the kidney

9.4: **How Hormones Work**

- 1-messenger model
    - Hormones are lipid-soluble
        - Can pass through membranes
    - Protein receptors recognise hormones and binds with it to form a complex
    - Complex recognises and binds to segments in the DNA to activate gene expression for certain protein
- 2-messenger model
    - Hormones are protein-based
        - Cannot pass through membranes
    - Specific receptors on cell surface recognise them, allowing hormones to bind
    - Binding release a secondary messenger into the cell, causing the hormonal response

9.5: **3 Major Tasks of Hormones**

- Control growth, metabolism
- Homeostasis: maintain a constant internal environment
- Regulate activities of different systems so that they are coordinated

9.6: **Pituitary Gland**

- Consists of 2 distinct parts
    - Anterior lobe
    - Posterior lobe
- The anterior lobe secretes and synthesises:
    - Growth Hormones which stimulates growth (duh)
        - Dwarfism occurs when too little GH is secreted
        - Gigantism occurs when too much of GH is secreted in childhood. The result is called acromegaly
    - Other hormones that control thyroid glands, adrenal glands and gonads
- The posterior lobe stores and secreted hormones that are synthesised by the hypyothalamus:
    - ADH which controls the volume of urine produced at the kidney
    - Oxytocin which regulates milk release during nursing and child birth

9.7: **Thyroid Glands**

- Located in the neck, just under the larynx
- Produces the hormones thyroxine and triiodothyronine
    - Regulates metabolic growth
    - Ensure normal growth and mental development
- Undersecretion causes:
    - Weight gain
    - Lethargy
    - Simple goitre
    - Mental development at a slower pace
- Oversecretion causes:
    - High body temperature
    - Profuse sweating
    - Irritability
    - Protruding eyes
    - Excitability
    - Trembling hands
    - Sensitivity to heat
    - High blood pressure

9.8: **Gonadal Sex Hormones**

- Gonads produce hormones that control development of male or female sexual characteristics
    - Testes of males
        - Testosterone
    - Ovaries of females
        - Oestrogen
        - Progesterone

9.9: **Adrenal Glands**

- Sits atop both kidneys
- Each adrenal gland has 2 portions
    - Adrenal cortex
    - Adrenal medulla
- Adrenal medulla produces the hormone adrenaline
    - Produced after nerve impulses by the brain under stress conditions
- Adrenal cortex produces the hormone cortisol
    - Produced after hormonal secretion by the pituitary gland

9.9.1: **Cortisol**

- Responds to stress or threat
- Effects of cortisol:
    - Blood clotting
        - On-the-spot injury repairs
    - Production of more amino acids
        - Repair of blood vessels and muscles
    - Dampening of pain
    - Faster healing

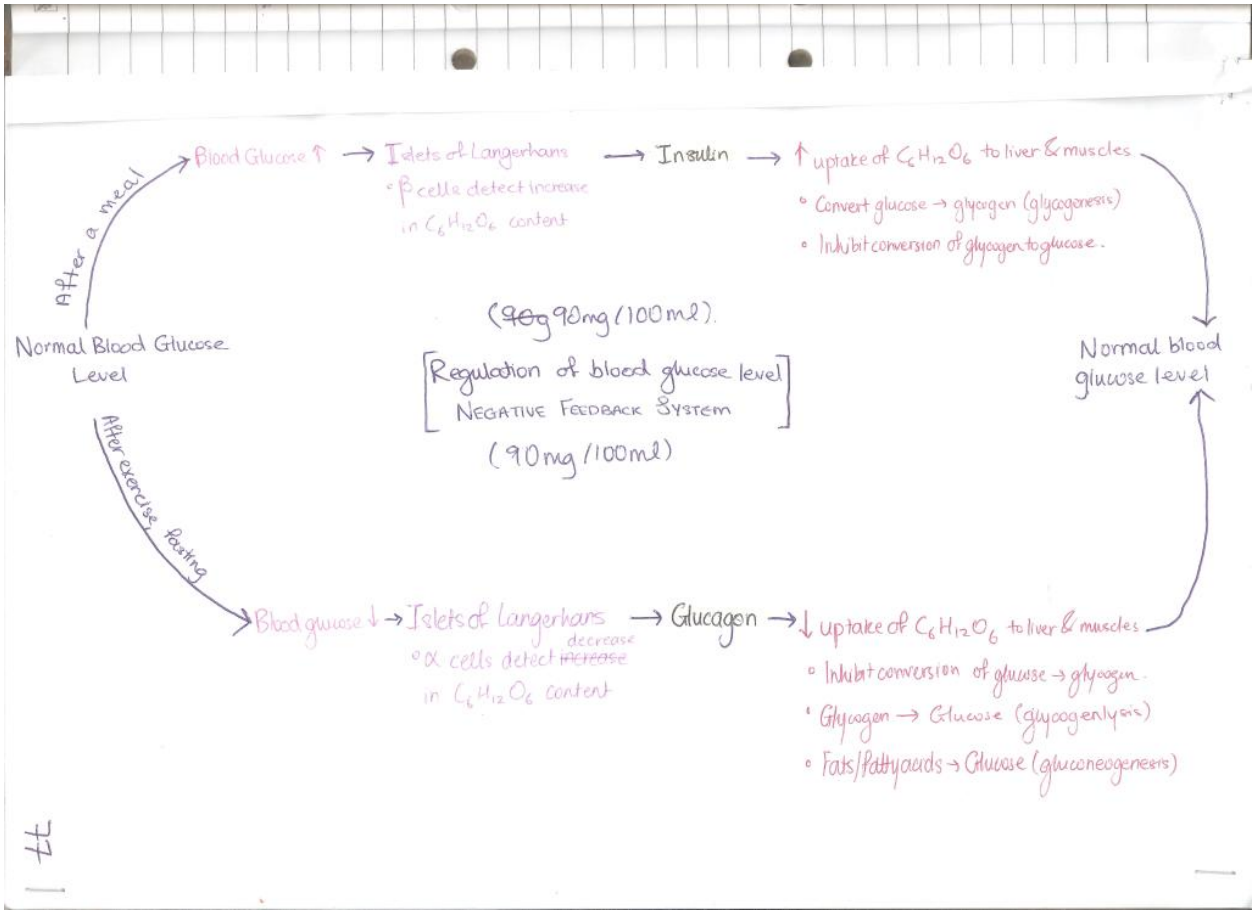
9.9.2: **Adrenaline**

- Causes the sympathetic/fight-or-flight response
- Effects of adrenaline:
    - Increased heart rate
        - Greater contraction of heart
        - Pumps more oxygen-concentrated blood to muscles and brain
    - Increased breathing rate
        - Higher intake of oxygen for energy supply
    - Air passages relax
        - More surface area for oxygen to pass through to the lungs
    - Dilation of blood vessels to muscles and brain
        - Receive more oxygen-concentrated blood from the heart for energy
    - Constriction of blood vessels to the skin and digestive system
        - Allow more oxygen-concentrated blood to be sent to the muscles and the brain
        - Slows digestion down
    - Dilation of pupils
        - Allows a person to see better through the entry of more light
    - Hair stand on ends
        - For a person to look bigger and fiercer (useless)
    - Lower urine production
    - Conversion of
        - Fat/fatty acids → Energy
        - Glycogen → Glucose
        - Increased energy supply

9.10: **Pancreas and the Islets of Langerhans**

- Endocrine glands are found in specialised regions called the islets of Langerhans
- Produces 2 antagonistic hormones to regulate blood glucose concentration
    - Glucagon in the α cells
    - Insulin in the β cells

9.11: **Blood Glucose Concentration Regulation: Negative Feedback**



9.12: **Effects of Insulin**

- Binds to receptors on liver/muscle/adipose tissue cell surface which modulates various enzymes to:
    - Increase uptake of glucose into the muscle and adipose tissue cells
    - Converts glucose → glycogen (glycogenesis)
    - Inhibit the breakdown of glycogen → glucose in skeletal muscle and liver cells
- Overall effect: Blood glucose concentration drops

9.13: **Effects of Glucagon**

- Binds to receptors on liver/muscle/adipose tissue cell surface which modulates various enzymes to:
    - Stimulate the hydrolysis of glycogen → glucose in the liver (glycogenlysis)
    - Converts fatty acids/amino acids to glucose (gluconeogenesis)
    - Inhibit the synthesis of glucose → glycogen in skeletal muscle and liver cells
- Overall effect: Blood glucose concentration increases

9.14: **Diabetes Mellitus**

- A hormonal disease caused by a deficiency of insulin (Type 1) or a decreased response to insulin in target tissues (Type 2)
    - 11% of Singaporeans aged 18-69 are affected in 2010
- Characterised by persistent hyperglycaemia where the blood glucose concentration is higher than the norm

9.14.1: **Type 1 Diabetes**

- Usually detected in childhood
- Autoimmune disease
    - 90% of the β cells are destroyed by the immune system
    - Unable to produce insulin
- Control of the disease:
    - Insulin injection
    - Diet regulation
    - Regular exercise

9.14.2: **Type 2 Diabetes**

- Appears normally after age 40
    - Young people who are overweight and/or sedentary can also develop this disease
- Pancreas produces insulin normally
- Body cells gradually become unresponsive to insulin
- Lowered rate of conversion of glucose to glycogen, causing high blood glucose levels
- Control of the disease:
    - Diet regulation
    - Regular exercise
    - Insulin injection (if need arises)

9.14.3: **Symptoms of Diabetes Mellitus**

- Weakness
    - Glycogen not readily converted to glucose
- Frequent urination (polyuria)
    - A lot of glucose = A lot of water reabsorbed from the kidney to regulate osmolarity
- Frequent thirst
    - A lot of glucose = A lot of water reabsorbed from the kidney to regulate osmolarity
    - Need for more water
- Frequent hunger (polyphagia)
    - Need for more glucose

9.14.4: **Long-Term Complications of Diabetes Mellitus**

- Damage to blood vessels affecting the eye, kidney and the cardiovascular system
    - Hardening of blood vessels from fatty and sugary deposits
- Kidney diseases
- Foot/leg amputation as a result from infections
    - Nerve desensitised

9.15: **Genetic Engineering of Hormones**

- Animal-derived insulin (porcine and/or bovine) was widely used to treat diabetes mellitus
- Synthetic insulin introduced in the 1980s
- Growth hormones, adrenaline, glucagon, gonadal sex hormones can also be produced synthetically to treat various conditions

9.16: **How Much Insulin Should Be Used?**

- Amount of insulin to be injected into the patient needs to be properly calibrated
- Depends on
    - Severity of condition
    - Carbohydrate intake
    - Lifestyle (sedentary/active?)
    - Type of insulin used

9.17: **Abuse of Hormones**

- Growth Hormone abuse
    - Some athletes have reportedly injected themselves with GH to increase performance
    - Can cause symptoms that mirror acromegaly
- Anabolic steroid abuse
    - Some athletes use it to gain muscle mass and lose body fat
    - Can cause baldness, severe acne, liver abnormalities and heart diseases
    - Can cause a change in behaviour

9.18: **Difference between Nervous and Endocrine Systems**

NERVOUS SYSTEM	*Criteria*	**ENDOCRINE SYSTEM**
Nerve impulses	*Involves…?*	**Hormones**
Impulses transmitted through neurons	*Transport*	**Transported by the blood**
Quick	*Response*	**Slow**
Short-lived	*How Long the Response?*	**Either short-lived or long**
Either voluntary or involuntary	*Type of response?*	**Involuntary**
Localised	*Location*	**Can be at more than one target cell**