BIOLOGY NOTES FORM TWO K.C.S.E SYLLABUS

TRANSPORT IN PLANTS AND ANIMALS

Need for Transport

- carry required substances to body parts
- remove metabolic wastes from the body

- **Lower organisms and simple multicellular organisms** have small bodies that make them have a large surface area to volume ratio. Diffusion alone is enough to transport substances.

- **Higher organisms** have large bodies and thus **smaller surface area to volume ratio.** Hence, tissues and organs are far from the site of supply of materials. Therefore, they require an elaborate transport system.

TRANSPORT IN PLANTS

- **Simple plants** such as mosses and liverworts transport substances by **diffusion, osmosis, and active transport.**
- **Higher plants** have a specialized transport system known as the **vascular bundle.** It comprises of **xylem (**transports water and mineral salts) and **phloem (transports** dissolved food substances).

Root Structure and Function

The primary functions of roots are anchorage and absorption. Specialized roots store food and water, and allow gaseous exchange.

1. **Root cap:** protects the apical meristem.

2. **Root hairs**: microscopic outgrowths of epidermal cells. Are thin walled to shorten distance for absorption of water and mineral salts. Have an elongated cytoplasm at one side to increase surface area for absorption of water and mineral salts.

3. **Piliferous layer:** a special epidermis of young roots that gives rise to root hairs.

4. **Cortex:** loosely packed thin walled cells to allow passage of water molecules to reach the vascular bundles; and to store substances.

5. **Endodermis: a single layer** of cells surrounding the vascular bundles, characterized by possession of starch grains and a **casparian strip,** it controls the amount of water and mineral salts entering into the vascular bundles.

6. **Vascular bundles:** each vascular bundle consists of xylem and phloem. In **monocotyledonae, xylem alternate in the arrangement with phloem.** In **Dicotyledonae, the xylem is star-shaped and the phloem is located at the centre of the star.**

7. Epidermis: a single layer of cells covering all other inner tissues

Stem Structure and Function

The primary functions of stems are support, conduction of water and mineral salts and manufactured food. Other functions of specialized stems include storage of food and water, gaseous exchange and perennation.

1. **Epidermis**

2. **Cortex:** simple tissues found in the cortex are:

a) Collenchyma: walls thickened at the corners with cellulose and pectin deposits, and thus it is a **strengthening tissue;**

b) **Parenchyma:** irregular cells, thin walled and loosely packed, with intercellular air spaces, store water and food. Some parenchyma cells contain chloroplasts and are called **chlorenchyma.**

c) Sclerenchyma: walls thickened by **lignin,** serve as a strengthening tissue.

3. **Pith:** central region with parenchyma cells that store water and food substances.

4. **Vascular bundles**

Comparison between the Structure of Monocots and Dicots

Monocot root	**Dicot root**
Many vascular bundles alternately arranged	Usually 3-5 groups of phloem and xylem arranged alternately.
No cambium	Cambium present

Monocot stem	**Dicot stem**
Vascular bundles randomly scattered in the cortex	Vascular bundles arranged around the pith
No cambium tissue	Cambium present

Other differences between Monocots and Dicots

monocots	**Dicots**
Flower petals in multiples of three	**Multiples** of four or five
Leaves have **parallel** venation	**Reticulate** venation
Pollen with single pore or furrow	**Pollen** with three furrows
fibrous **root system**	**Tap root system**
No secondary growth	**Secondary growth occurs**
One cotyledon	**Two cotyledons**

Absorption of Water and Mineral Salts

a) Absorption of Water

1. **Water** is drawn into root hair cells by **osmosis**
2. Cell sap of root hairs contains dissolved substances that make its concentration to be greater than that of the soil solution
3. Therefore, there exists a concentration gradient between cell sap and soil water
4. This exerts a higher osmotic pressure thus drawing water molecules from soil across the cell wall and cell membrane of root hair cells
5. The osmotic forces exerted by the cells overcome the water retaining powers of the soil thus water enters the root hair cells
6. As more water is drawn into root hair cells, it dilutes the cell sap making it less concentrated than that in the adjacent cortex cell of the root
7. Due to osmotic gradient, water moves from the adjacent cells to the next by osmosis
8. Similarly, water passes through the successive cortex cells until it enters the xylem vessels located in the center of the root
9. The xylem vessels then conduct the water up into the xylem vessels of the stem and into the leaves

b) Uptake of Mineral Salts

1. Soil water contains dissolved mineral salts, which plants require for their growth and proper functioning
2. Generally, the concentration of the cell sap in the root hairs is greater than that in the soil
3. The mineral salts therefore enter the root hairs against the concentration gradient
4. This process requires the use of energy and is referred to as **active transport**
5. **Active transport** is believed to involve substances known as **carriers**
6. These carriers combine with the mineral ions and then carry them across the plasma membrane into the cell
7. Thus, the carriers move back and forth carrying the salt ions from the soil water to the root hair cells
8. After absorption, the mineral salts move through the root cells into the xylem vessels of the vascular tissue in the centre of the root
9. Then the salts and water are carried up the stem into the leaves by a combination of osmosis, diffusion, root pressure, transpiration pull, cohesive forces and capillary attraction

Forces involved in Transportation of Water and Mineral Salts

1. Transpiration pull

- A suction force pulls a stream of water from the xylem vessels in the stem and roots. It develops when water vaporizes from the spongy mesophyll cells, increasing the concentration of their cell sap, which in turn increases the osmotic pressure and causes water to flow from surrounding cells and xylem vessels.
- Transpiration pull creates a continuous stream of water flowing from the roots, up the stem to the evaporating surface referred to as **transpiration stream**

Q. a] Distinguish between the terms transpiration pull and transpiration stream [1]
b] How does transpiration pull arise? [3]

2. Cohesion and Adhesion forces

- **Cohesion force:** forces that keep water molecules together
- **Adhesive force:** attractive force between water molecules and the walls of xylem vessels

3. Capillarity

- Ability of a solution to rise up in a tube with a very small diameter because of surface tension
- Water rises up by capillary action in xylem vessels because they are *very narrow* and there is *a high attractive force* between the water molecules and the cell walls

4. Root pressure

- A force in the roots that pushes water up the stem
- Root pressure is caused by active pumping of water across the **endodermis** to the xylem vessels because the **casparian strip** present in endodermis is almost impermeable to water
- Energy is required in this process

TRANSPIRATION

Dfn: Process by which plants lose water in the form of **water vapour** into the atmosphere

- Sites of transpiration are **stomata (80-90%), cuticle (**up to 20%), and **lenticels** (negligible).
- Each stoma opens into the **sub-stomatal air spaces** that are lined with spongy mesophyll cells.

- Water **vaporizes** from the spongy mesophyll cells into the sub-stomatal air spaces, and then the water vapour **diffuses out** of the leaf through the stomata
- The cell sap of the spongy mesophyll cells becomes more concentrated than the adjacent cells
- Therefore, this increases the osmotic pressure of the cells
- As a result, water flows into the cell from other surrounding cells, which in turn take in water from xylem vessels within the leaf veins

Factors that Increase Transpiration Rate

1. **Thick** layer of cuticle: increases diffusion distance

2. **Broad** leaves: expose a large surface area

3. **More stomata** on upper leaf surface/ large stomatal apertures: exposed to sun light, wind and heat

4. **High temperature:** increases capacity of atmospheric air to hold **more** water vapour; increases internal temperature of leaf, which in turn increases LHV and therefore enhances evaporation from the leaf cells.

5. **Low relative humidity:** saturation deficit is high; more water vapour diffuses out of the leaf into the atmosphere

6. **Wind:** carries away water vapour around leaves, maintaining a high diffusion gradient between the inside and outside of the leaf

7. **High light intensity:** causes stomata to open fully, exposing sub-stomatal air into direct contact with the outside environment.

8. **Low atmospheric pressure/high intercellular air pressure:** more water vapour is lost to the atmosphere due to the pressure deficit in the atmosphere

9. **Adequate water supply from the soil:** walls of mesophyll cells are kept continuously wet

Factors that Decrease Transpiration Rate

1. Thin cuticle

2. Small leaves/ needle-like

3. Few stomata on upper leaf surface/sunken stomata

4. Midday closure: protects from wilting

5. Reversed stomatal rhythm: to conserve water in xerophytes

6. Leaf fall: reduced S/A

7. Hairy leaves/scales on leaves: trap still moist air.

8. Low temperature

9. High relative humidity

10. Still air

11. Low light intensity

12. High atmospheric pressure/low intercellular air pressure

13. Lack of enough water in soil

Guttation

- It is the loss of water in liquid form through **hydathodes**
- common in **hydrophytes** when the relative humidity is high
- caused by **root pressure**
- typically occurs during the night
- occurs **only** at the tip or along the edges of leaf
- The soil must have high amount of water than that in the roots
- When the water evaporates, sugars and minerals left behind

Significance of Transpiration

- Replaces lost water
- transports water and mineral salts
- cools plants
- removes excess water in aquatic plants
- maintains turgor

Structure and Function of Xylem Tissue

- Xylem tissue is made up two main cell types: **vessels** and **tracheids.**

a) **Xylem vessels**

- Long hollow tubes to allow flow of water and dissolved mineral salts.
- Non-living
- Walls strengthened by deposition of **lignin** to prevent collapsing.

- Have bordered pits along their walls to permit passage of water in and out of the lumen into the neighboring cells.
- Found in **angiosperms only (flowering plants)**

b) **Tracheids**

- Hollow cells
- Non-living
- Have lignin deposits on their walls.
- Have tapering / chisel-shaped ends
- Sloping end walls are perforated.
- Have pits on the sidewalls to allow lateral water movement to cells surrounding the xylem. This makes them less efficient than vessels in conducting water than the vessels.
- Tracheids perform two functions: **support** and **transport of water.**
- Found in Pteridophytes, gymnosperms and angiosperms

Comparison between Vessels and Tracheids

vessels	**Tracheids**
Found in angiosperms only	Found in all vascular plants
Formed by many cells joined in different arrangements	Single cells with openings on both ends
Cells are shorter	longer
More efficient in conducting water and mineral salts	Less efficient in conducting
Have perforations at the end plates	Lack end plates
Derived from a pile of cells	Derived from single individual cells
Wide	thin

Translocation of Organic Compounds

- **Translocation** is the transport of soluble organic products of photosynthesis within the plant.
- Occurs in **phloem tissue**

Phloem structure and Function

1. Cytoplasmic filaments are contractile in nature to push food material from one sieve tube to another
2. Sieve tubes are hollow to allow passage of food material
3. Companion cells are densely packed with mitochondria, which produce energy for active transport of food

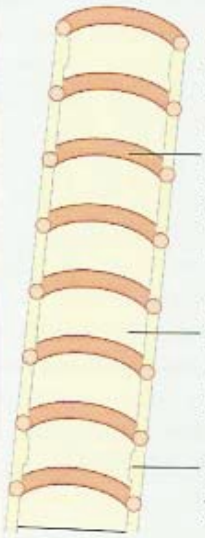
4. Presence of sieve pores allows the passage of food from one sieve tube to the next.
5. The plasmodesmata connect sieve cells with companion cells and allow for exchange of materials between the two cells

Q Describe the function of the endodermis in roots [3]

Q State two ways in which the **structure** of a phloem sieve tube is adapted for the transport of assimilates [2]

Xylem tissue contains long **xylem vessels** adapted for the rapid transport of water and **dissolved mineral ions.** Movement is always **up** the stem.

Longitudinal section of xylem vessels

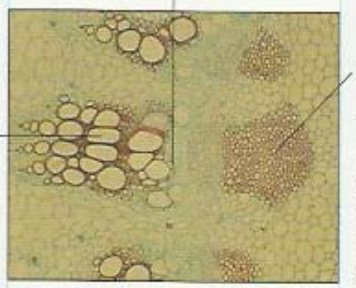


Walls are thickened with **lignin.** This is waterproof and strong enough to prevent the cells collapsing inwards. In the shoot, the xylem is on the **inside** of the vascular bundle, helping support the stem.

No cytoplasm or organelles – cells are dead. There is no obstruction to the flow of water and mineral ions.

End walls removed – cells join to form long tubes called **xylem vessels.**

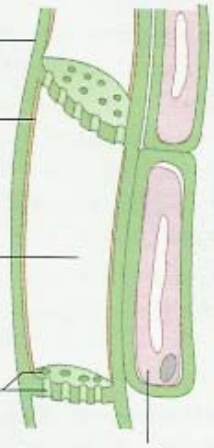
Cambium tissue (see page 204) contains cells which divide by mitosis to produce more phloem and xylem.



Vascular bundle (× 100).

Phloem tissue contains **sieve tubes** and **companion cells.** It is adapted for transport of the **organic products of photosynthesis** i.e. sugars (transported as **sucrose**) and amino acids. This transport is called **translocation.**

Longitudinal section of phloem sieve tubes



Sieve tube

Thin cytoplasm – cell must remain alive or sugar transport stops.

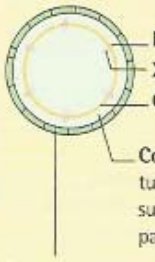
No nucleus or organelles, so sugar flow is not impeded.

Pores in **sieve plates** allow sugars to pass from one cell to the next.

Companion cell does not transport sugar but carries out some life processes of the sieve tubes.

Direction of transport varies with the seasons!
Sucrose is transported **from** stores in the root **to** leaves in spring, but **to** stores in the root **from** photosynthesising leaves in the summer and early autumn. Whatever the time of year the movement of sugars and amino acids (translocation) is from **source** to **sink.** In other words, sucrose and amino acids are translocated from the region where they are made or absorbed to the region where they are stored or used.

Stem – vascular bundles are arranged in a ring with soft cortex in the centre, helping to support the stem.



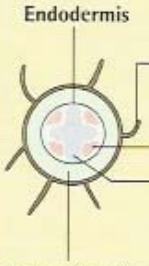
Phloem
Xylem
Cambium
Vascular bundle

Cortex – cells become turgid and help to support non-woody parts.

Epidermis – protects against infection by viruses and bacteria, and dehydration.



Root – root hairs are extended cells of the epidermis.



Endodermis

Epidermis – protects against infection by fungi.

Phloem
Xylem
Together form a strong central rod.

Cortex (pith) can act as a winter store for starch.

The transport tissues xylem and phloem are arranged in vascular bundles.

TRANSPORT IN ANIMALS

- **Open circulatory system:** transport fluid (haemocoel) is contained in the general body cavity or **coelom, ex arthropods**
- **Closed circulatory system:** transport fluid (blood) is conveyed in **blood vessels, ex vertebrates, annelids.**

Comparison between Open and Closed Circulatory System

closed	**open**
High pressure generated hence flows faster	low pressure, flows slowly
Tissues receive requirements faster	slowly
Metabolic wastes removed faster	Slowly
Organisms more active	Less active
pure blood does not mix with impure blood	Pure and impure haemocoel mix

Q Explain why the mammalian circulatory system is described as a closed double circulation.

Transport in a typical Insect (cockroach)

- Has open circulatory system where blood is contained in **coelom** and within a dorsal tubular heart.
- Blood contains suspended leucocytes and some pigments.
- Transport of gases occurs mainly by diffusion in the tracheal system.
- The heart has thirteen chambers, three in the thorax and ten in the abdominal segments.
- The anterior segment is joined to the aorta that empties the blood into sinuses of the head.
- Each chamber contains a pair of valves at the anterior part, which prevent back flow of the blood.
- Each chamber has a pair of lateral openings called ostia, which are closed by valves. The valves allow blood to flow into the heart through the ostia but not out of it.

The Mammalian Circulatory System

- organization of the transport system in mammals:
  Heart→arteries→arterioles→capillaries (**in tissues)**→venules→veins→heart
- Mammals have a double circulation: blood flows into the heart **twice** for every complete circulation. First, blood is pumped to the lungs for oxygenation and then back to the heart (**pulmonary circulation).** Then blood is pumped from the heart to the rest of the body organs (**systemic circulation).**

- Some animals like fish have **single circulation** in which blood flows only once through the heart for every complete circuit.

The Structure and Function of the Heart

1. Pericardium: membrane that encloses heart to prevent over stretching, secretes **pericardial fluid to** lubricate the heart wall when pumping blood
2. **Cardiac muscles** have interconnected fibres so that waves of contraction can travel throughout the muscle
3. Cardiac muscles have myogenic property to initiate contraction without external nerve supply; and to contract continuously without fatigue
4. S**ino-atrial node** on the right atrium initiates contractions/serves as the pacemaker
5. **Purkinje fibres** allow waves of contraction to reach ventricles
6. **Coronary artery** supplies the heart muscle with nutrients and oxygen
7. **Coronary vein** removes metabolic wastes
8. **Right auricle:** thin walled, receives deoxygenated blood from through vena cavae veins
9. **Left auricle:** thin walled, receives oxygenated blood from the lungs through the pulmonary vein
10. **Left ventricle:** has thicker muscles than right ventricle because it pumps blood to a longer distance to all the body parts which requires *higher* pressure
11. **Right ventricle** has thinner muscles because it pumps blood a shorter distance from heart to the lungs which requires *less* pressure
12. **Inter-ventricular septum** prevents mixing of oxygenated and deoxygenated blood
13. **Atrio-ventricular valves** prevent blood from flowing back into the auricles when ventricles contract. (left: bicuspid valves; right: tricuspid valves)
14. **Tendons** prevent valves from turning inside out when ventricles contract
15. **Semi-lunar valves** prevent back flow of blood when the ventricles relax

Q Explain how increased intensity of exercise leads to an increased heart rate. [4]

Pumping Mechanism of the Heart

Diastole (Relaxation)

1. **Ventricle** muscles relax
2. Volume of ventricle increases pressure decreases
3. **Cuspid** valves **open**
4. **Deoxygenated blood** from body tissues flows into the **right ventricle**

5. **Oxygenated blood** from lungs flows from the left atrium into the **left ventricle**
6. **Semi-lunar valves** close preventing blood from flowing back into the ventricles
7. The **slight contractions of the auricles** force the blood into the ventricles

Systole (Contraction)

1. Ventricle muscles contract
2. Volume of ventricles decreases while pressure increases
3. Blood is forced out of the heart to the lungs and to body tissues
4. Cuspid valves close preventing blood from flowing back into the auricles

Initiation of Heartbeat

1. Heartbeat is initiated by **sinoatrial node (SAN)** or the pacemaker found at the right atrium
2. SAN starts electrical waves that spread over the walls of the two atria making them contract
3. waves then pass through **atrioventricular node (AVN)**
4. There is a **short delay** of about 0.1 seconds before waves pass from atria to ventricles, to prevent them from contracting simultaneously (it would be disastrous if this happened)
5. AVN passes waves on to **Purkinje tissue** in the interventricular septum
6. to the **apex of the heart**
7. and then through the **ventricle walls**
8. causing ventricles to contract from the base upwards
9. forcing blood to flow out thro the vessels leaving the heart
10. **Vagus nerve** slows down heartbeat while **sympathetic nerve** speeds it up

Q Describe the initiation and control of heartbeat (8 marks)

Structure and Function of Blood vessels

1. Arteries

- Thick muscular wall to resist pressure
- smooth endothelium to reduce friction as blood flows
- Muscular layer to produce pulsating action to force blood forwards as heart beats

- Muscular wall controlled by nerves and hormones to alter lumen diameter so as to regulate blood flow to organs

2. Capillaries

- Numerous and very close to tissues to increase S/A for exchange of substances
- One cell-thick wall to reduce diffusion distance
- Very narrow lumen to bring substances very close to cells/tissues for fast diffusion/create very high pressure for ultra filtration
- Smooth endothelium to reduce friction to blood flow

3. **Veins**

- *Larger* lumen than arteries to offer minimum resistance to blood flow
- Valves to prevent back flow of blood (skeletal muscular contraction assists in blood flow)

Diseases and Defects of the Circulatory System

1. Thrombosis: formation of blood clot in vessels, commonly due to heavy fat intake e.g. coronary thrombosis
2. Arteriosclerosis: deposition of calcium in walls of blood vessels leading to hardening, associated with being overweight, lack of exercise and emotional stress
3. Varicose veins: swollen superficial veins at the back of legs due to failure of valves to function properly; results in the retention of tissue fluid
4. Hypertension or High Blood Pressure: pressure above upper limit of normal blood pressure (140/90)
    - associated with intake of too much salt in food, *sustained* stress and arteriosclerosis

Structure and Functions of Mammalian Blood

- consists of fluid called plasma and cells suspended in it
- plasma consists of dissolved substances and plasma proteins
- Serum is blood plasma without fibrinogen and cells
- Functions of plasma: Transport cells; dissolved food substances; metabolic wastes; hormones**;** some oxygen and CO_2**; r**egulate pH of body fluids**;** distribute heat

Red blood cells

- No nucleus when mature
- Short life span

- Made in bone marrow of **short bones** in adults, **liver and spleen** in the embryo
- Contain haemoglobin (Hb)
- Cytoplasm red/pink
- Number increases when living at higher altitudes
- Main function is transport

Adaptations

1. no nucleus when mature: create more space to pack more haemoglobin to carry more oxygen (unfortunately makes RBCs have short life span)
2. haemoglobin to transport oxygen and CO_2
3. numerous in number to increase S/A for transport
4. flexible plasma membrane to enable them squeeze through narrow capillaries
5. biconcave shape increases S/A over which gaseous exchange can take place
6. carbonic anhydrase speeds up the conversion of CO_2 to weak carbonic acid

Q Mature mammalian red blood cells have no nuclei. State **one** advantage and **one**
disadvantage of this [2]

White Blood Cells (leucocytes)

1. nucleated
2. very long life span
3. lack Hb
4. cytoplasm colorless
5. fewer in number than RBCs
6. formed in bone marrow of **long bones** and in **lymph nodes**
7. their number increases during infection
8. main function is defense

Q State five differences between red blood cells and white blood cells (5 marks)

Defense Function of Leucocytes

1. Phagocytosis
2. Antibody secretion: antitoxins neutralise toxins; agglutinins clump together microorganisms; lysins digest cell walls and membranes of microorganisms; opsonins coat microorganisms making them easier to phagocytose

Q State four ways antibodies function to fight pathogens [4]

Platelets (Thrombocytes)

- Fragments from large cells in the bone marrow
- No nucleus
- Take part in blood clotting

Transport of Oxygen and Carbon (IV) oxide

a) Oxygen

1. Haemoglobin in RBCs has high affinity for oxygen
2. In the lungs, there is high oxygen tension
3. haemoglobin picks up oxygen to form an unstable cpd called oxyhaemoglobin
4. Oxyhaemoglobin is transported to tissues where there is low oxygen tension
5. In tissues, oxyhaemoglobin readily dissociates into haemoglobin and oxygen
6. Oxygen diffuses out of RBCs and through the capillary walls into the tissues
7. Free haemoglobin is transported to lungs to pick up more oxygen molecules
8. Foetal Hb has higher affinity for oxygen than maternal Hb

b) Carbon (IV) oxide

1. RBCs transport about 95% of CO_2
2. carbonic anhydrase inside speeds up the reaction btn CO_2 and water to form weak carbonic acid
3. Carbonic acid dissociates into hydrogen carbonate and hydrogen ions
4. hydrogen carbonate ions diffuse out of RBCs into plasma and is transported to the lungs
5. to counterbalance charge, chloride ions diffuse into the RBCs cytoplasm **(chloride shift)**
6. Hydrogen ions are buffered by i) Hb forming weak haemoglobinic acid, and ii) plasma proteins forming proteinic acids
7. **Some** CO_2 that diffuses into RBCs combines with the amino acids of Hb to form **carbaminohaemoglobin cpd**
8. A small amount of CO_2 dissolves in plasma water to form carbonic acid
9. In lungs, there is low CO_2 tension which favours the release of CO_2 for exhalation

Q State three functions of haemoglobin [3]

Q State two advantages of transporting carbon (IV) oxide in red blood cells [2]

Q Explain the meaning of the term chloride shift [2]

Q Describe how respiratory gases are transported in the human body [12]

Q State the advantage of foetal haemoglobin having higher affinity for oxygen than maternal haemoglobin [2]

Q Red blood cells have no nucleus. Explain how this feature is an adaptation to the function of red blood cells [2]

Respiratory Poisoning by Carbon (II) Oxide (Carbon Monoxide)

1. CO has higher affinity for haemoglobin than oxygen
2. therefore it readily combines with Hb to form a cpd called **carboxyhaemoglobin**
3. which being stable reduces the capacity of Hb to transport oxygen to tissues
4. if a lot of CO is inhaled, the person will die of suffocation

Blood Clotting Process

1. when blood vessels are injured
2. the platelets exposed to air
3. and rupture to release **thromboplastin**
4. which neutralises **heparin**
5. and activates **prothrombin to thrombin**
6. a reaction which requires calcium ions
7. formation of prothrombin requires vitamin K
8. Thrombin converts **fibrinogen to fibrin**
9. which forms a meshwork of fibers across the cut surface and dries up to form a scab
10. that stops excessive bleeding
11. and protects the damaged tissues from infection by pathogens

Q Describe the process that leads to the formation of a blood clot on a wound [11]

Preventing blood clotting in undamaged blood vessels

1. blood contains prothrombin, but not thrombin
2. blood contains heparin, an anticlotting factor
3. platelets are not exposed to air

Human Blood Groups

- proteins called antigens are expressed on RBC membranes
- these are A and B and they determine type of blood gp
- some people lack A and B antigens on their RBCs and belong to blood group O
- antigens determine type of blood gp
- the plasma too has proteins called antibodies

- the antibodies do not correspond with the antigens so as to prevent **agglutination /clumping of RBCs**
- several other antigens expressed on RBCs have been discovered, the most important is called Rhesus factor
- people with Rhesus factor are Rh^{+}ve while those lacking are Rh-ve

Summary of Blood Groups, Antigens and Antibodies

Blood group	**Antigens on RBCs**	**Antibody in plasma**
A	A	b
B	B	a
AB	A and B	None
O	None	Both a and b

Q Explain why blood group B cannot be transfused to a recipient with blood group A

[4]

Suggested response

Recipient blood has antigen A and antibody b; donor blood has antigen B and antibody a; the recipient's antibody b would react with the donor's antigen B; this would cause agglutination of blood; blocking blood vessels which may result to death;

Blood Transfusion

- it is the transfer of blood from a **donor** to the circulatory system of the **recipient**
- gp A receives blood from gp A and gp O donors
- gp B receives blood from gp B and gp O donors
- gp AB receives blood from gp AB, gp A, gp B, and group O donors
- blood gp AB is referred to as a **universal recipient** while blood gp O is called **universal donor**
- donated blood is mixed with an anticoagulant and kept at very low temperature
- the blood is not used after one month because most of the RBCs will have died

- the blood gp of donor and recipient are determined to ensure they are compatible, this is called **blood group typing**
- donor's blood is tested for pathogens such as HIV, Hepatitis B and this is called **blood screening**
- **cross matching** is done to check if minor blood groups can cause serious agglutination of recipient's blood

Rhesus incompatibility and its significance in Pregnancy

1. if a Rh- mother bears a Rh+ baby, fragments of foetal RBCs can pass across the placenta into mother's blood stream
2. mother's immune system responds by producing rhesus antibodies
3. that in turn pass across the placenta into the blood of foetus
4. but the antibodies formed are too few to affect the first pregnancy
5. therefore the first baby is born without any serious reaction
6. but during subsequent pregnancies bearing Rh+ foetus, there occurs a severe antigen-antibody rxn
7. between rhesus antigens on foetal RBCs and maternal rhesus antibodies
8. foetal RBCs are destroyed
9. causing **haemolytic disease of the new-born** or erythroblastosis foetalis
10. the new born baby can be saved by replacing its blood with Rh- blood
11. or by transfusing blood to the foetus in-utero
12. the disease can be prevented by treating the mother with an anti-rhesus globulin
13. which coats the surfaces of her RBCs thus preventing the antigen-antibody reactions

Q Describe the cause, treatment and prevention of haemolytic disease of the newborn [10]

The Lymphatic System

Formation of lymph

1. lymph is formed by ultra-filtration of blood from blood capillaries in tissues
2. the pumping force of the heart together with the narrow lumens of the capillaries exert a high pressure
3. that forces the fluid part of blood to filter out of the capillary walls
4. into the surrounding tissues
5. This filtrate consists of all the constituents of blood plasma except the blood cells and the proteins because these are too large to filter out of capillary walls
6. The fluid is known as tissue fluid or intercellular fluid

7. And bathes the cells of tissues supplying them with oxygen, food and other useful substances
8. cells absorb these substances and pass out CO_2 and other waste products
9. Most of the tissue fluid then returns to the blood system through the venule end of the capillaries
10. due to the lower hydrostatic pressure of the blood at the venule end compared to that at the arteriole end of the capillary
11. The excess tissue fluid drains into the lymph vessels where it is known as lymph
12. Lymphatic vessels from various parts of the body join together to form thoracic duct which drains into the left subclavian vein near the neck
13. Flow of lymph is aided by movement of skeletal muscles around the lymph vessels which squeeze them; inspiration movements that suck lymph into the thoracic duct; exhalation movements that force lymph into the left subclavian vein; and presence of valves that prevent back flow of lymph
14. Along the lymphatic system are swellings called lymph nodes that produce lymphocytes

Q Describe the formation and transport of lymph [14]

Immune Responses

- These are reactions in the body that occur when **antigens are introduced**
- **Immune responses involve the production of** antibodies or leucocytes which combine with antigens
- An antibody is a chemical substance, usually a protein, which is formed in the blood when an antigen is introduced into the tissue of a human being or any other animal
- An antibody has a chemical composition which is complementary to the antigen against which it reacts
- Therefore, a particular antibody combines with or responds only to a particular antigen to make it harmless
- Antibodies are produced by leucocytes called lymphocytes
- When harmful organisms or proteins invade the body, some lymphocytes start producing antibodies which are complimentary to them
- The bone marrow also begins to produce more phagocytes while the thymus gland also begins to produce more lymphocytes

Types of Immunity

1. **Natural (innate) immunity**
   - inherited (transmitted from parent to offspring)
   - manifested as immunity against a particular disease in a family, race or breed
2. **Acquired immunity**

- develops after suffering from a disease or thro vaccination
- It is either **natural or artificial** and in both cases it can be **active or passive**
- active if antibodies are formed as a response to natural infection by a pathogen; and passive if antibodies are passed from mother to foetus through the placenta or to the new born through colostrum in maternal milk
- Artificial acquired immunity is either **active or passive**; it is active when antibodies are formed in response to **vaccination; and** is passive where serum containing antibodies is transferred from one animal to another, e.g. horse antiserum against snake bite confers immunity to snake bite victims
- Vaccination is the administration of dead or attenuated (weakened) pathogens or chemically treated toxins (toxoids)
- Following either a natural infection by a disease causing organism or vaccination, the antigens stimulate the immune system to produce corresponding antibodies which destroy the pathogens
- The body then retains the “memory” of the structure of specific antigens in a small number of cells called memory cells, we say the body has been immunized against the disease
- In case the same disease causing organism attacks the immunized body again these memory cells divide very rapidly into antibody secreting cells called plasma cells
- Therefore a large amount of specific antibody is produced within a relatively short time to eliminate the pathogens

NOTE:

Vaccination: refers to the act of giving a vaccine either by injection or swallowing

Immunization: refers to the process of both having the vaccine and becoming immune to the disease as a result of the vaccine

Allergic Reactions

1. an allergy is a hypersensitive reaction to an antigen by the body
2. it occurs when antibody-antigen combination produces a violent reaction in the body
3. allergic pple are hypersensitive to usually harmless materials like dust, pollen grains, some foods, some drugs and certain air pollutants
4. allergy manifests itself as skin rashes, vomiting, difficulties in breathing or sneezing
5. the body reacts by over-producing antibodies against harmless antigen**s**
6. the antibody –antigen rxn takes place on the surface of mast cells that burst open
7. releasing histamine

8. histamine increases the permeability of epithelial cells thus making them take in fluid
9. the intercellular spaces also become filled with fluid and swell up
10. histamine causes inflammation and pain
11. sometimes **anaphylaxis** occurs in which blood vessels lowering BP too much causing death
12. bee stings can cause death by anaphylaxis
13. avoiding the allergen or administration of **antihistamine drugs** can control allergic reactions

Q People may be immunised against diseases using vaccines. Which part of the vaccine stimulates the body's defence system? [1]

Q Explain why a person has who been vaccinated against measles does **not** catch measles even when he comes into contact with it [3]

Q a) What is an allergen? [1]

b) Describe how histamine is produced in response to an allergen [3]

End of topic

GASEOUS EXCHANGE

Gaseous Exchange in Plants

- Gaseous exchange: process by which respiratory gases, O_2 and CO_2, are passed across the respiratory surface
- Concentration gradient existing btn the respiratory surface and the surrounding medium facilitates gaseous exchange

- The mechanism of exchange involves simple diffusion.
- Gaseous exchange is important because it promotes uptake of O_2 for respiration and removal of CO_2 as a waste product
- In plants, the respiratory surface is **spongy mesophyll tissue**: its cells are **loosely packed,** with large intercellular air spaces where gases can collect and mix; the **cell walls are thin to allow quick diffusion**; and are **moist** to allow gases to dissolve before diffusing;
- The sites across which gases diffuse into and out of plants are *stomata* and *lenticels.*

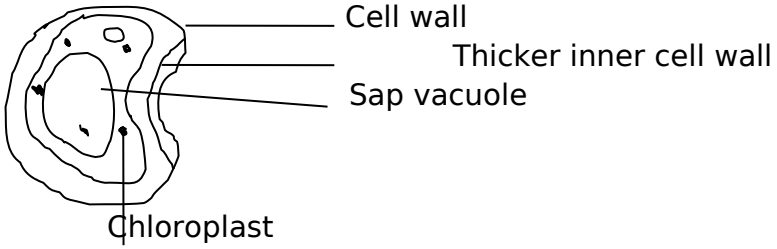
Q State two adaptations of spongy mesophyll cells to their function [2]

The Stomata

- Stomata are NOT cells, but tiny openings found on leaf surface
- Bordered by bean shaped guard cells.
- Allow gaseous exchange to take place.
- Guard cells control the size of stomata by osmotic changes that open more or close the stomatal pores.

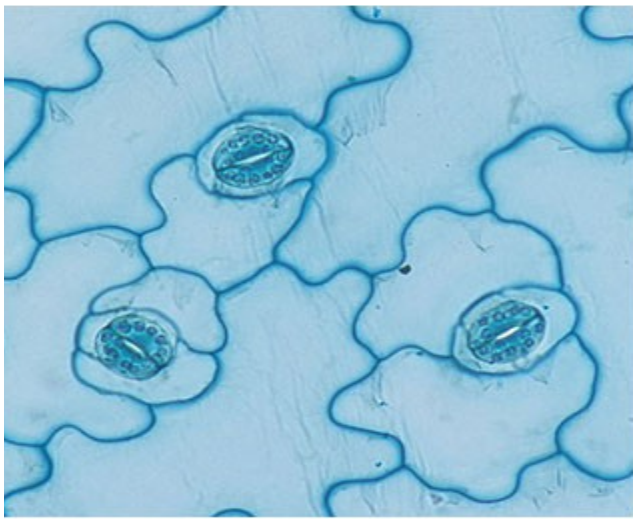
The Guard Cells

- Have thicker inner cell walls and thinner outer cell walls
- Have a few chloroplasts to allow some photosynthesis to occur



A guard cell

Q State how guard cells are suited to carry out their role [2]



Surface view of lower epidermis of leaf of *Kalanchoe* sp.showing stomata and guard cells

Mechanism of Opening and Closing of Stomata

1. According to *photosynthetic theory*, guard cells produce sugar through photosynthesis and this causes osmotic pressure of the sap vacuoles to increase.
2. According to the *starch-sugar interconversion theory*, during daylight photosynthesis takes place in guard cells using CO_2. This makes $_P$H in the guard cells to rise, favouring the conversion of starch into glucose. This increases the osmotic pressure of sap vacuoles.
3. As a result, guard cells absorb water by osmosis from adjacent cells and become turgid.
4. Since the inner cell walls are thicker than the outer cell walls, the guard cells bulge outwards making the stomata to open.
5. At night, sugar is converted to starch in guard cells.
6. At night, CO_2 accumulates in the guard cells resulting in lowering of $_P$H.
7. This favours the conversion of glucose to starch.
8. Starch is osmotically inactive therefore, the osmotic pressure of guard cells falls
9. The cells lose turgidity due to water loss to adjacent epidermal cells by osmosis
10. Guard cells become flaccid and draw towards one another thereby closing the stomata.

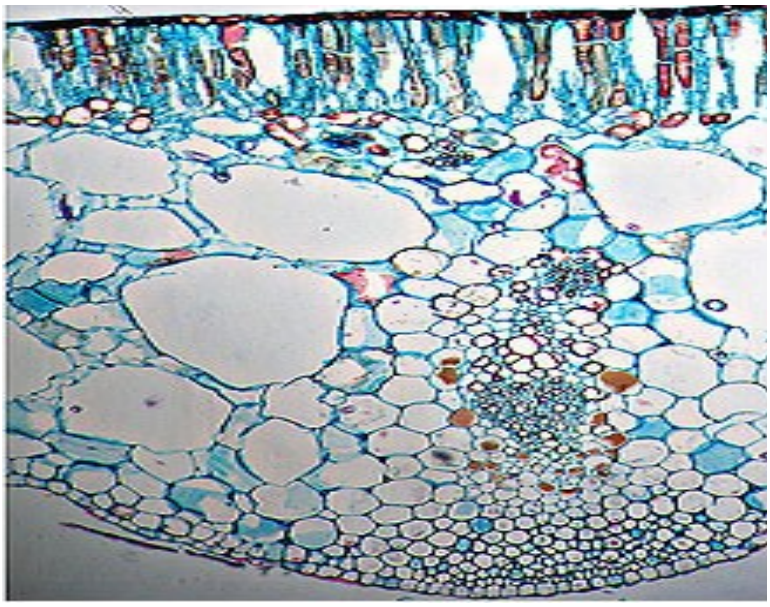
Q Describe the mechanism of stomatal opening [5]

Q Describe the mechanism of stomatal closure [5]

Mechanism of Gaseous exchange in Plants

1. Gaseous exchange takes place in aerial roots, stems and leaves
2. There exists a concentration gradient btn atmospheric air and air inside the roots, stems or leaves
3. O_2 diffuses from the atmosphere where its concentration is high into the plant where its concentration is kept low due to respiration
4. CO_2 diffuses out of the plant as a metabolic waste product along a concentration gradient
5. Stomata are modified according to habitat. In **Xerophytes** (plants adapted to living in desert conditions), stomata are *small*, *few in number* and are *found mainly on the lower leaf surface*. In some xerophytes, stomata are found in *sunken pits*. In others, stomata remain closed at day light, only opening partially at intervals to allow for gaseous exchange and open only at night. This reduces water loss by transpiration
6. In **hydrophytes** (plants adapted to growing in water or swamps e.g. water lilies), stomata are *large*, and are *more stomata on upper leaf surface* than lower leaf surface. This allows the plants to release excess water by transpiration. Hydrophytes also have aerenchyma tissue with large air spaces to store air for gaseous exchange
7. **Mesophytes** are plants that grow in areas with adequate water supply. They have *fairly large number of stomata*, of *medium size* and *almost equal in number on both surfaces* of leaves.
8. Gaseous exchange also occurs through *lenticels*. These are openings on stems and roots formed by loosely packed corky cells. Gaseous exchange takes place on the moist surfaces of cells under the lenticels. Gaseous exchange takes place btn the interior of the plant and the outside by diffusion.
9. In **halophytes** (plants that grow in muddy salty waters e.g. mangroves), gaseous exchange takes place in lenticels found in specialised aerial breathing roots called *pneumatophores*

The image below shows a transverse section of leaf of a Water Lily (*Nymphaea* sp.) Plants that are adapted for living in water are known as hydrophytes. The image shows a layer of tissue known as aerenchyma underneath the palisade layer. Aerenchyma contains large air spaces, which gives the leaves buoyancy, allowing them to float on the surface of the water. Stomata occur in the upper leaf epidermis of plants with floating leaves, allowing gas exchange with the air above. The cuticle is usually thin or absent from the leaves of hydrophytes. The high density of water gives support to the submerged leaves and stems, and there is a lack of the supporting tissues found more widely in mesophytes, such as collenchyma or sclerenchyma.



Q Explain the mechanism of gaseous exchange in plants [12]

Q State how the following structures are adapted to their function
- a) Aerenchyma [1]
- b) Lenticels [1]
- c) Pneumatophores [2]

Gaseous Exchange in Animals

Types of Respiratory Surfaces

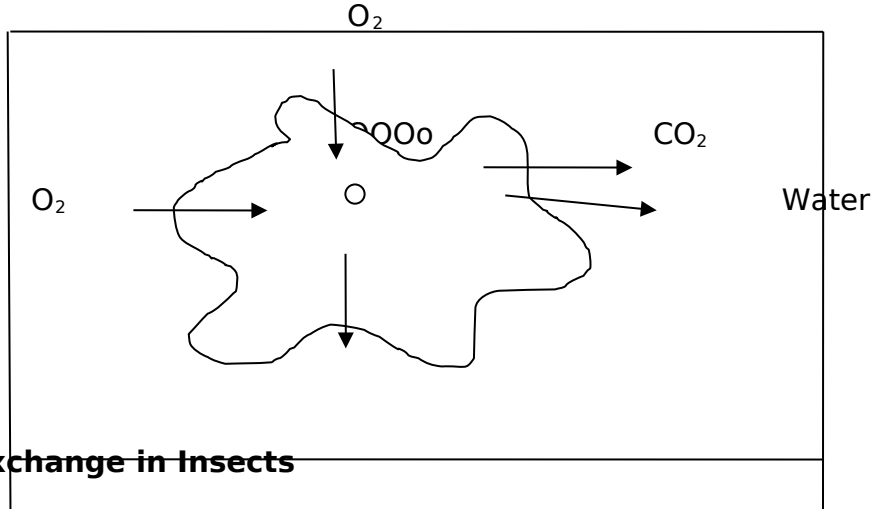
1. Cell membrane e.g. protozoa
2. Gill filaments e.g. fish
3. Tracheoles e.g. insects
4. Alveoli/lungs e.g. mammals, birds, frogs, reptiles
5. Skin e.g. frog, earthworm
6. Buccal cavity e.g. frog

Characteristics of Respiratory Surfaces

1. Large S/A
2. Moist surface
3. Rich capillary network
4. Thin membrane

Gaseous Exchange in Protozoa e.g. *Amoeba*

1. Amoeba are single-celled organisms that live under fresh water
2. They have a large SA/V ratio exposed to water
3. Thus, gaseous exchange takes place by diffusion alone very fast across the cell membrane
4. O_2 dissolved in water diffuses across the cell membrane into the cytoplasm
5. CO_2 and other soluble wastes diffuse out through the membrane into the water along a concentration gradient



Gaseous Exchange in Insects

Structure and Function of the Tracheal System

1. Spiracles are openings on either side of the abdomen and thorax thro which air enters and leaves the body

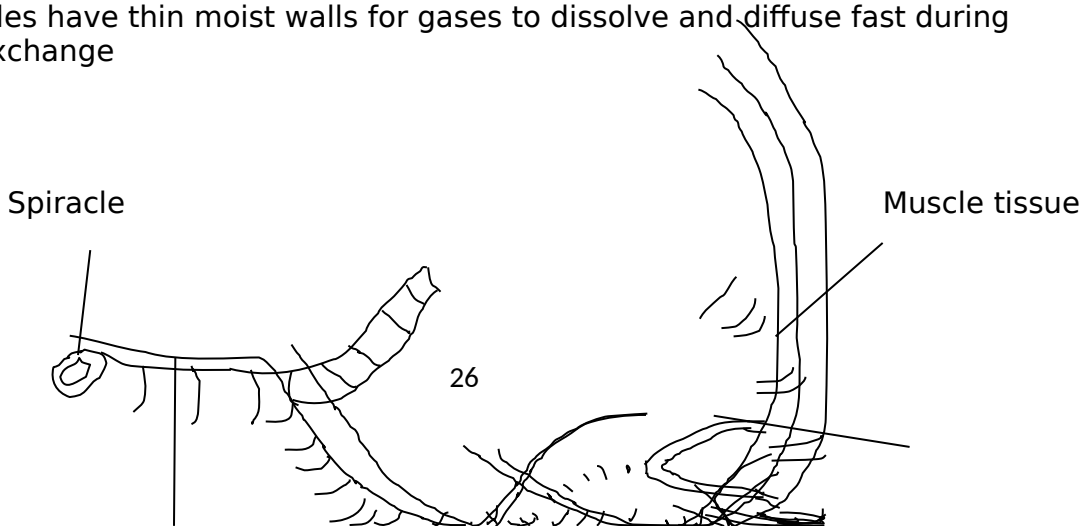
2. Each spiracle has a muscular valve to control its opening and closing

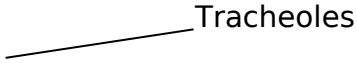
3. and hairs to prevent excessive loss of water from the body by evaporation

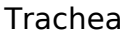
4. Spiracles open into tubes called trachea that are in turn branched into tracheoles to increase S/A for gaseous exchange

5. Bands of chitin support the air tubes to keep them open

6. Tracheoles have thin moist walls for gases to dissolve and diffuse fast during gaseous exchange







Q State four structural adaptive features of the insect tracheal system [4]

Mechanism of Gaseous Exchange in the Tracheal System of Insects

1. Air is drawn into and out of the tracheal system by movement of muscles of abdominal wall
2. When spiracle valves open, air is drawn into the tracheal system
3. The valves then close and air is forced along the tracheal system by muscle movements
4. O_2 diffuses into the tissue fluid and into the cells due to higher O_2 diffusion gradient
5. CO_2 diffuses out of tissue cells and into the tissue fluid and then into the tracheal system due to a CO_2 diffusion gradient
6. The thoracic spiracle valves close as the abdominal spiracle valves open
7. CO_2 is released through the spiracle openings in the abdomen

Q. Explain how gaseous exchange occurs in terrestrial insects [7]

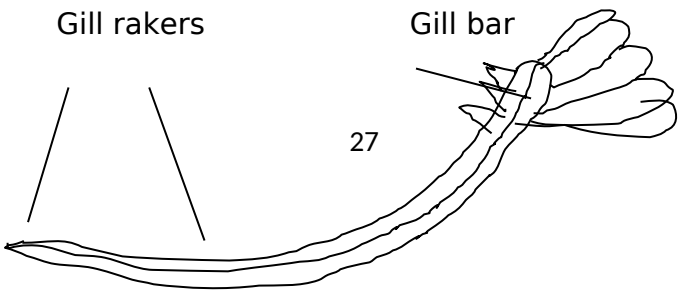
Gaseous Exchange in Fish

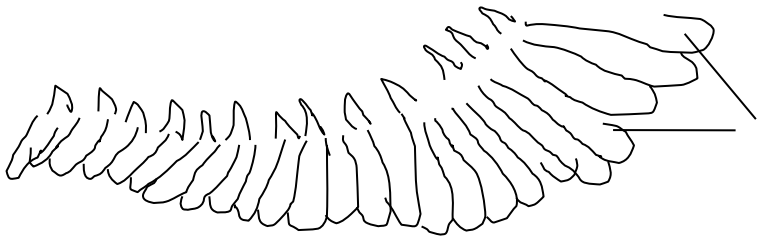
Structure and Function of Gills
1. Numerous gill filaments provide large surface area for gaseous exchange

2. Gill rakers prevent solids in water from reaching the delicate gill filaments

3. Gills have blood capillaries to deliver oxygen and remove CO_2

4. Operculum is a bony plate that protects the gills



filaments  Gill

Mechanism of Gaseous Exchange in Bony Fish

1. Gaseous exchange in fish occurs through gills
2. During inhalation, muscular contractions lower the floor of the mouth cavity
3. This increases volume of mouth cavity but reduces pressure
4. As a result, water flows into the mouth through the open mouth cavity
5. Each operculum bulges outwards to reduce pressure in the gill cavity
6. This causes water containing dissolved O_2 to flow from the mouth cavity to the gill chamber over the gills
7. The mouth then closes and muscles raise the floor of the mouth cavity, this causes remaining water in the mouth to flow towards the gill chamber
8. Water entering the mouth has a higher O_2 concentration than in the gill filaments
9. Therefore, O_2 diffuses from water into the blood through the thin walls of capillaries
10. O_2 combines with haemoglobin and is transported to all parts of the body
11. CO_2 concentration in capillaries of gill filaments is higher than that in water
12. This causes CO_2 to diffuse out of the blood into the water through the walls of blood capillaries
13. To facilitate maximum gaseous exchange, a steep concentration gradient is maintained by the water and blood in gill filaments flowing in opposite directions. This is the counter-current flow system.

Q Explain how gaseous exchange takes place in bony fish [13]

Gaseous Exchange in Mammals

Adaptive Features of the Breathing System in Mammals

Nose

1. Has two openings to let in air into air passages
2. Warms and moistens air to facilitate quick diffusion across alveoli
3. Lining has hair shafts to trap dust/spores present in air
4. lining has sense organs for smell to detect smell of air

Trachea
1. A tube made up of rings of cartilage to prevent collapse
2. Lumen with ciliated epithelium to move mucus and foreign particles upwards

Lungs
1. Enclosed by pleural membrane for support onto thoracic cavity
2. Pleural cavity filled with pleural fluid to reduce friction during breathing
3. Numerous alveoli to increase SA for gaseous exchange
4. Alveoli covered by dense network of capillaries to maintain steep diffusion gradient
5. Thin epithelial wall to provide short distance for diffusion of gases
6. Walls of alveoli are moist to allow gases to dissolve then diffuse across
7. Detergent like fluid/ surfactant in alveoli lowers surface tension to prevent them from collapsing
8. Lungs are spongy and elastic to allow expansion and relaxation during breathing
9. Pleural membrane is airtight to allow pressure changes inside lungs without external influence

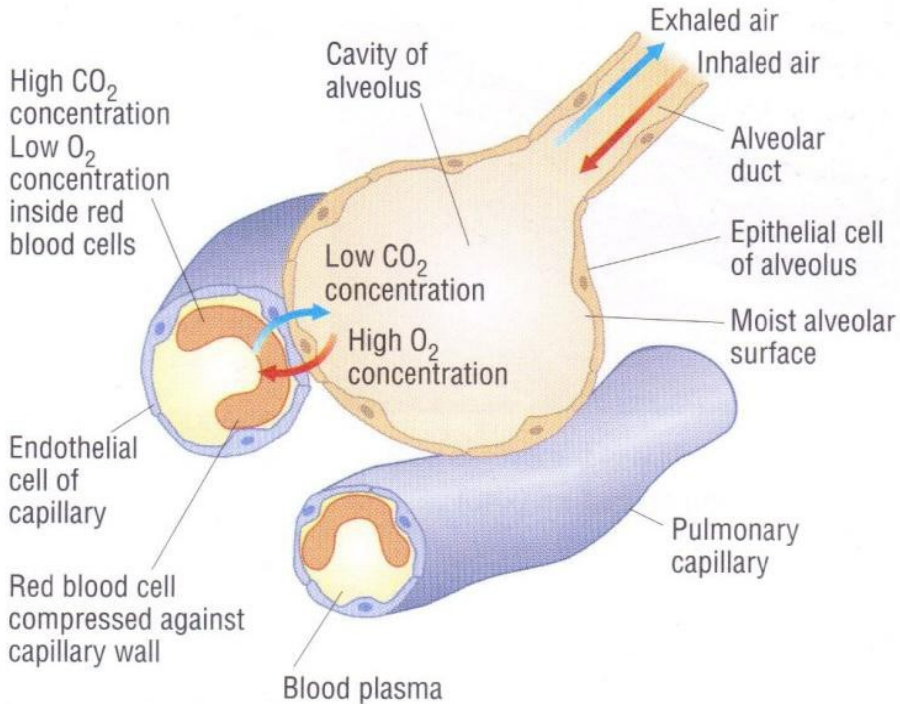
The Mechanism of Breathing

a) Inspiration
1. External intercostal muscles contract while internal intercostals muscles relax
2. This pulls rib cage upwards and outwards
3. Diaphragm muscles contract making diaphragm to flatten
4. Volume of thoracic cavity increases while pressure inside decreases
5. Atmospheric pressure being higher than pressure inside thoracic cavity
6. forces air to rush into the lungs through the nose and trachea hence inflating them

b) Expiration
1. External intercostal muscles relax while internal intercostal muscles contract
2. This brings rib cage down and inwards
3. Diaphragm muscles relax and diaphragm regains its original dome shape
4. Volume of thoracic cavity decrease and pressure inside it increases
5. This forces air out of the lungs through the air passages into the atmosphere

Mechanism of Gaseous Exchange in the Alveolus

Plan diagram summarising gaseous exchange in the alveolus



1. Oxygen in inhaled air dissolves in film of moisture present in the wall of alveolus
2. O_2 concentration in RBCs inside blood capillaries surrounding the alveoli is lower than in the alveoli lumens
3. Therefore, it diffuses through the alveolar epithelium, across the capillary wall, into the plasma and finally into the RBCs inside capillaries where it combines with haemoglobin
4. CO_2 in the RBCs inside the capillaries surrounding the alveoli is at a higher concentration than inside the alveoli lumens
5. Hence, it diffuses out of the RBCs, into the blood plasma, across the capillary wall, across the alveolar wall into the alveolar lumen where it is exhaled

Q Describe how oxygen in air in the alveoli enters the blood in capillaries.

Q Give **two** ways in which capillaries are adapted for exchanging oxygen with the tissues

RESPIRATION

Definition: process by which food substances are chemically broken down in all living cells to release energy, carbon (IV) oxide and water or alcohol

- Tissue respiration takes place in mitochondria. These organelles occur in large numbers in cells of organs that require a lot of energy e.g. kidney cells, muscle cells, sperm cells

- Adaptations: mitochondria have folded inner membrane forming cristae to provide a large S/A for respiratory activities; have a fluid filled cavity called matrix in which respiratory reactions take place; have their own genetic material DNA that enables them to self replicate independently of the cell

The Process of Respiration

- If the energy produced during respiration were to be released at once, the heat would burn the body cells (some energy is always released as heat)
- To prevent this, energy is released in small quantities and in stages
- During respiration, energy produced is used to cause reaction between *adenosine diphosphate* (ADP) and an inorganic *phosphate molecule*, to form another compound called *adenosine triphosphate* (ATP)

$$ADP + PO_4^{3-} + Energy \longrightarrow ATP$$

- The overall equation for respiration:

$$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{respiratory enzymes}} 6CO_2 + 6H2O + \text{energy (ATP)}$$

- ATP molecules store energy released in respiration
- ATP readily breaks down into ADP and phosphate, releasing energy locked in its bonds
- The **first phase** of respiration takes place *without using oxygen*
- It involves the breakdown of glucose to pyruvic acid
- it takes place in the *cytoplasm of cells*
- glucose is broken down (glycolysis) into a three carbon compound called **pyruvic acid**
- Glycolysis produces *two molecules of ATP per molecule of glucose.*
- The fate of pyruvic acid depends on whether oxygen is available or not
- Normally pyruvic acid proceeds onto the **second phase** of respiration in which it is completely oxidised into carbon (IV) oxide, water and energy (ATP).
- *Oxygen is needed* in the second phase
- It takes place in the *matrix of mitochondria*
- It produces *38 molecules of ATP per molecule of glucose.*
- If there is no oxygen, pyruvic acid is converted to lactic acid (in animals) or ethanol (in plants, fungi, and in most bacteria)
- Lactic acid stores a lot of energy, and when oxygen is available, it is converted back to pyruvic acid, which is then used in the aerobic phase of respiration
- The process of anaerobic respiration is summarised as:

a) In plants: $C_6H_{12}O_6 \longrightarrow 2C_2H_5OH + CO_2 + Energy$
b) In animals: $C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3 + Energy$

Q Write a simple equation to show how ATP is synthesised from ADP[1]

Q Give **two** ways in which the properties of ATP make it a suitable source of energy in
biological processes [2]

Oxygen Debt

- It is the oxygen required to get rid of lactic acid that accumulates in the body when the supply of oxygen is less than the demand e.g. during a race

- Lactic acid is toxic, and causes fatigue and muscle cramps. However, it also locks up a lot of energy in its bonds, which should be availed to the body.
- Oxygen debt is paid back after the race when the person breaths in quickly and more deeply so as to increase the supply of oxygen
- During the process of paying back the oxygen debt, lactic acid is converted to pyruvic acid, which is then oxidised to carbon (IV) oxide, water and energy.
- Lactic acid can also be taken to the liver and converted into glycogen for storage

Application of Anaerobic Respiration

1. Production of ethanol, wine, cider, beer and spirits by fermentation of sugars
2. Biogas production
3. Making of compost manure
4. Production of vinegar, citric acid, oxalic acid and some drugs

Comparison

First phase of respiration	Second phase of respiration
Takes place without using oxygen	Reactions require oxygen
Occurs in cell cytoplasm	Occurs in matrix of mitochondria
Glucose is the substrate	Pyruvic acid is the substrate
One molecule of glucose yields two molecules of ATP	One molecule of glucose yields 38 ATP molecules

Aerobic respiration	Anaerobic respiration
Oxygen is necessary	Oxygen not required
More energy released, 2880kJ/38 ATPs	Less energy released, 210kJ/2ATPs
End products are water, CO_2 and ATP	End products are ethanol (plants, fungi, most bacteria) or lactic acid (animals) and ATP

Respiratory Quotient (RQ) And its Significance

- RQ is a ratio of the amount of CO_2 produced against the amount of O_2 consumed during respiration i.e.

$$RQ = \frac{\text{volume of } CO_2 \text{ produced}}{}$$

$$\text{RQ} = \frac{\text{Volume of } CO_2 \text{ produced}}{\text{Volume of } O_2 \text{ consumed}}$$

- RQ for carbohydrates = 1.0; fats/lipids = about 0.7; proteins = about 0.9
- Significance of RQ values
    1. Indicates type of substrate
    2. Indicates conditions under which substrates are respired, whether aerobic, anaerobic or both
    3. RQ depends on age, state of health and temperature

Factors Affecting Rate of Respiration

1. Oxygen concentration
2. Substrate concentration
3. Hormones: adrenaline and thyroxine increase respiration rate
4. Body size/SA:V ratio

Practice Questions

1. Some sterile seeds were soaked in water for 4 hours before being left in moist air to germinate. The respiratory quotient (RQ) values of these seeds are shown in the table below.

Time	RQ
Immediately after soaking	6.34
After 12 hours in air	2.22
After 36 hours in air, radicles appearing	1.02

Account for the changes in RQ values of the germinating seeds:

i) Immediately after soaking [3]

ii) After 12 hours in air [2]

iii) After 36 hours in air [3]

Q Desert iguanas are lizards that live in hot, dry conditions. Scientists measured the rate of oxygen consumption of desert iguanas at different body temperatures. Some of their results are shown in the table.

Body temperature /^{0}c	Mean rate of oxygen consumption at rest/cm^{3} g $^{-1}$hr^{-1}
25	0.4
30	0.7
35	1.2
40	1.5

Explain how an increase in the iguana's body temperature affects its oxygen consumption when it is at rest.

Q a)Name the organism that causes tuberculosis (TB).

b) Explain how TB is transmitted from an infected person to an uninfected person.

Q Explain why carbohydrates release half as much energy per unit mass as fats and oils.[2]

EXCRETION AND HOMEOSTASIS

PART I: EXCRETION

- Excretion is a process by which living organisms separate and eliminate waste products of metabolism from their bodies
- Metabolic wastes are toxic to cells if allowed to accumulate, and could also alter the normal conditions for cell function, killing the cells
- Secretion is the release of certain *useful substances* produced by cells, such as enzymes and hormones
- Egestion is the removal of indigestible and undigested materials from food vacuoles or alimentary canal

EXCRETION IN PLANTS

- Plants lack complex excretory organs because:

    1. Their wastes accumulate very slowly
    2. The main wastes originate from carbohydrate metabolism and are often reused by the plant e.g carbon (IV) oxide, oxygen and water
    3. Wastes in form of gases are removed by simple diffusion thro stomata and lenticels
    4. Some wastes are stored in non toxic forms in certain tissues or organs which later drop off with age e.g resins, alkaloids

Economic Importance of Plant Excretory Products

- Tannins in barks of Acacia are used in leather tanning
- Caffeine in coffee berries and tea leaves are used to prepare stimulant drinks

- Quinine from the bark of cinchona tree and *Aloe* leaves is an antimalarial agent
- Papain from raw pawpaw fruit skins is a proteolytic substance used in food industry to soften beef
- Colchicine is an alkaloid used to induce non-disjunction in genetic breeding expts and to treat cancer
- Rubber is made from latex of rubber plant, used in making tyres and shoes

Excretion and Homeostasis in Unicellular Organisms

- Protozoans like Amoeba, Paramecium, remove CO_2 and nitrogenous wastes by simple diffusion across their bodies. This is possible because these organisms have *large surface area to volume ratio,* which allows diffusion rate to be very fast. Wastes diffuse along a diffusion gradient from the cytoplasm across the cell membranes into the surrounding water medium
- Protozoans remove excess water and dissolved solutes from their bodies by using their contractile vacuole. These substances accumulate in the contractile vacuole, which swells and moves towards the cell membrane then bursts releasing the contents to the outside

EXCRETION IN ANIMALS

- Animals need an elaborate system of excretion because they have more complex bodies and have numerous cells and thus diffusion alone is not enough to remove wastes
- Excretory tissues and organs include flame cells in flat worms, nephridia in round worms, malpighian tubules in insects, gills, lungs , liver, kidneys and skin in vertebrates

The Mammalian Skin

- The main functions of the skin are:

    1. Defence: protective barrier against entry of microorganisms, mechanical damage, and UV from the sun
    2. Regulation of body temperature

3. Excretion: salts, excess water, some urea
4. Reception of stimuli: heat, cold, pain, touch, pressure
5. Vitamin D synthesis on exposure to sunlight
6. Fat storage in adipose tissue

Structure-Function Relationship of the Mammalian Skin

1. Cornified layer: outermost layer of the skin is made of flattened dead cells filled with tough flexible substance called keratin, protects against mechanical damage and entry of bacteria, and reduces loss of water by evaporation
2. Granular layer is the middle layer of skin made of living cells with granules, it gives rise to the cornified layer
3. Malpighian layer is the innermost layer of the skin, made up of actively dividing cells that give rise to new epidermis, the cells have pigment granules called **melanin** that gives colour to skin, and also absorbs UV rays that are harmful to skin
4. Blood vessels supply nutrients and oxygen to skin tissues and remove waste products, blood also regulates body temperature
5. Lymphatic vessels drain excess tissue fluid
6. Nerve endings detect external stimuli, creating awareness within the body to initiate appropriate responses
7. Sweat glands consist of coiled secretory cells extending into long tubules that open to the surface of the skin as sweat pores. The cells absorb excess water, mineral salts, some urea, lactic acid and CO_2 from the surrounding cells and tissues, and secreted to form sweat. This flows through the sweat duct into the skin surface. Sweat glands are involved in temperature regulation thro loss of water by evaporation from skin surface
8. Hair shafts originate from hair follicles located in the Malpighian layer. Erector pili muscles attached to the follicle at one end and to the epidermis on the other end contract and relax to alter the angle btn the hair shaft and the skin. This varies the amount of air trapped btn the hair and the skin, which is important in temperature regulation
9. Sebaceous glands are closely associated with hair follicles; they secrete **sebum** to keep hair and epidermis flexible and waterproof. Sebum contains antiseptic substances to protect against bacteria.

10. Subcutaneous layer is a layer of fat beneath the dermis; it binds the skin to muscles and other organs deep in the body, stores fats and insulates against heat loss.

The Mammalian Kidneys

Structure and Function of the Kidneys

- The functions of kidneys are *excretion, osmoregulation, ionic balance* and *regulation of pH*
- Mammals have 2 kidneys located at the dorsal part of the abdominal cavity in the lumbar region
- Above each kidney are the **adrenal glands** that secrete hormones
- A kidney is convex on one side and concave on the other side. The concave side has a depression called **hilum** where renal *artery* enters to supply blood and *renal vein* leaves to remove blood
- From the hilum also leaves a large thick walled tube called **ureter** that links the kidney to the **urinary bladder.** The ureter transports urine from the kidney to the bladder, which stores urine for a short time. When the bladder is full, **sphincter muscles** located at the base of the bladder relax and urine is released via the **urethra**
- In males the urethra is long and joined to the reproduction system unlike in females
- LS of kidney show **cortex, medulla** and **pelvis** starting from the convex side towards the concave side. In the cortex are *glomeruli and Bowman's capsules,* while in the medulla are *Loops of Henle and collecting tubules*, and in the pelvis are *collecting ducts.*
- The basic functional unit of the kidney is called the **nephron**

Fine Structure of the Nephron

- Each nephron is made up of two main parts namely a renal tubule and glomerulus
- A renal tubule has 5 main parts: **Bowman's capsule, proximal convoluted tubule, Loop of Henle, distal convoluted tubule** and **collecting tubule**
- The glomerulus is a fine network of blood capillaries enclosed by the Bowman's capsule. It is formed from the afferent blood vessel, a branch from the renal artery
- The efferent arteriole collects blood from the glomerulus and extends to renal tubule where it divides into capillaries that form a meshwork over the entire

tubule. This blood is then collected by the venules that join into the venous system

The Role of Nephron in Excretion

1. Kidneys receive blood from the renal artery

2. This blood is rich in nitrogenous wastes e.g urea; and contains dissolved food substances, plasma proteins, mineral ions, hormones and oxygen

3. The afferent arteriole entering the glomerulus is wider than the efferent arteriole leaving it, this creates resistance to blood flow and very high pressure in the glomerulus

4. Furthermore, the renal artery branches directly from the aorta whose blood flow is at high pressure, contributing to the high pressure within the glomerulus

5. This high pressure forces the liquid part of blood and dissolved substances of low molecular sizes (e.g urea, glucose, salts, hormones, amino acids) to pass out of the glomerulus into the cavity of the Bowman's capsule

6. Large sized molecules in the plasma such as proteins and blood cells are not filtered out This process is known as **ultrafiltration** and the filtrate formed is called glomerular filtrate

7. This filtrate flows into the proximal convoluted tubule (PCT)

8. All glucose, amino acids, some water and mineral salts are actively reabsorbed against a concentration gradient. Active reabsorption requires energy.

9. Some urea is reabsorbed to the blood down its concentration gradient until its concentrations in the filtrate and blood are equal, so in each pass through the kidneys half the urea is removed from the blood and half remains in the blood
10. The filtrate then flows into the loop of Henle where salts especially sodium chloride are reabsorbed into the blood by active transport

11. At the distal convoluted tubule, a controlled amount of water is reabsorbed into the blood by osmosis

12. Water reabsorption is enhanced by the high osmotic pressure of the blood due to salt reabsorption at the loop of Henle, and secondly by a hormone known as antidiuretic hormone

13. The filtrate in the collecting tubule becomes urine and flows down into the collecting duct. Urine flows into the urinary bladder through the ureter

14. As urine accumulates, the urge to urinate is initiated and the sphincter muscles relax to pass out urine

NB: when the bladder is full, stretch receptors in the elastic walls send impulses to the medulla oblongata of the brain, which causes the sphincter muscles to relax, causing urination (or micturition). This is an *involuntary reflex response* that we can learn to control to a certain extent when we are young.

Large urine volume → stretch receptors in bladder → A → Brain B bladder sphincter → Urination

Stimulus **Receptor** **Coordinator** **Effector** **Response**

A = Sensory neurone, B= Motor neurone

Q. Describe how urine is formed in the mammalian kidney (14 marks)

Diabetes Insipidus

- Cause: pituitary gland not producing ADH or producing insufficient ADH
- Effect: kidney tubules unable to reabsorb water from GF; diuresis; dehydration of body; frequent thirst
- Treatment: replacing ADH/vasopressin, with a synthetic form of the natural hormone

Structure-Function Relationship of the Nephron

I: Glomerulus

1. Afferent arteriole is wider than efferent arteriole to generate high pressure for the process of ultrafiltration
2. Capillary walls have very small pores to prevent filtration of large sized molecules and to allow only filtration of small sized molecules
3. Dense network of capillaries to increase surface area for ultrafiltration

II PCT

1. Cells lining PCT have numerous mitochondria to generate energy for active transport
2. Cells lining PCT have microvilli to increase surface area
3. Long and highly coiled to increase area
4. Highly coiled to reduce the speed of flow of filtrate to give more time for efficient reabsorption

5. Well supplied with blood capillaries to deliver nutrients and oxygen

6. One cell thick wall for fast movement of substances

III Loop of Henle

1. U-shaped loop to create a counter-current flow between the filtrate and blood in vessels

2. Descending limb is impermeable to ions but permeable to water to allow some water to move out by osmosis into the blood stream so as to make the glomerular filtrate more concentrated as it descends the loop

3. Ascending limb is impermeable to water but permeable to ions and contains Na^+ and Cl^- ions pumps to actively transport these ions into the blood stream to make it highly hypertonic relative to glomerular filtrate

IV DCT

1. Well supplied with blood capillaries to supply nutrients and oxygen

2. One cell thick wall for fast movement of substances

3. Cells lining DCT have numerous mitochondria to generate energy for active transport

4. Cells lining DCT have microvilli to increase surface area

5. Long and highly coiled to increase area for reabsorption

6. Highly coiled to reduce the speed of flow of filtrate to give more time for efficient reabsorption

7. numerous membrane pumps for active transport

The Liver

Functions of the liver

1. Deamination

   - Excess amino acids are broken down to form ammonia, and the residue is fed into carbohydrate metabolism

   - Ammonia is highly toxic; it is converted into the less toxic urea through a series of reactions called Ornithine cycle

   - Urea is released into the blood stream and finally removed by kidneys

2. Detoxification

   - Processes by which the liver convert toxic substances into harmless or less harmful substances
   - Substances in drugs, foods or drinks are detoxified in the liver
   - Enzyme catalase produced by all cells is broken down into harmless products i.e water and oxygen

3. Thermoregulation

   - If body temperature tends to fall below norm, the hypothalamus stimulates the liver to increase its exothermic metabolic reactions to produce more heat
   - If body temperature tends to rise above norm, the hypothalamus stimulates the liver to increase its endothermic metabolic reactions to consume more heat thereby lowering body temperature

4. Haemoglobin elimination

   - Haemoglobin from worn out RBCs is broken down in the liver into urochrome and bilirubin
   - Urochrome is eliminated by the kidneys, it gives urine a light yellow colour
   - Bilirubin is excreted together with bile juice into the alimentary canal

5. Regulation of plasma proteins

   - Plasma proteins namely albumin, fibrinogen, prothrombin and globulins/antibodies are mainly synthesised from amino acids in the liver
   - Deamination and haemoglobin elimination also regulate the amounts of proteins
   - Hb is broken down into haem and globin
   - Globin is digested into amino acids
   - Haem group is converted into biliverdin and bilirubin, transported to gall bladder and mix with bile juice. Later excreted through faeces giving it a brown colour

6. Manufacture of red blood cells during foetal stage

7. Formation and elimination of excess cholesterol

8. Regulation of fat metabolism
9. Storage of blood
10. Storage of vitamins B,C,E,K and minerals
11. Blood sugar regulation

PART II: HOMEOSTASIS

Definition: maintenance of a steady state of internal environment within the body, despite wide fluctuations in the external environment

- Internal environment: immediate surroundings of body cells, which is the tissue fluid
- External environment: immediate surroundings of the organism, which may be aquatic or terrestrial
- Internal envt factors that should be kept at steady state: osmotic pressure, $_{p}$H, temperature, ionic level

Principles of Homeostasis

- Homeostasis works on a feedback mechanism: positive and negative
- Negative feedback: body responses that restore a condition which is in excess or in deficiency to *norm*
- homeostasis relies mainly on negative feedback mechanisms
- Positive feedback: body responses that lead to further deviation of a condition from norm either causing further deficiency or further excess
- Most positive feedback mechanisms are abnormal and result from a failure of negative feedback mechanisms. They often lead to disease states e.g diabetes
- Very few positive feedback mechanisms are beneficial e.g milk let down, uterine contractions during birth
- Norm or set point, a genetically predetermined level of a parameter that must be kept steady for proper functioning of cells e.g temperature, blood pressure, $_{p}$H
- For an homeostatic mechanism to work normally, there must be **receptors** capable of detecting the change; a **control mechanism** capable of initiating the appropriate corrective measures; and **effectors** that can carry out these corrective measures

Q Explain the role of negative feedback in homeostasis in mammals. [4]

The Role of the Kidneys in Osmoregulation

- Osmoregulation refers to the maintenance of correct amounts of water and salts in the body, hence osmotic pressure
- Low osmotic pressure (OP) of tissue fluids will cause cells absorb water by osmosis, swell and possibly burst
- High OP will cause cells to lose water by osmosis and shrink
- Osmoregulation is mainly carried out by the kidneys and neuro-endocrine system (the hypothalamus and pituitary gland)

a] Water Balance

- **If OP rises due to dehydration:** *hypothalamus is stimulated* and sends impulses to the (anterior) *pituitary gland* which releases *more* **antidiuretic hormone**, ADH, (or vasopressin) into the blood. On reaching kidneys, ADH causes DCTs and CTs to become *more permeable* to water. Thus, more *water is reabsorbed* into the blood stream, thereby lowering OP and producing concentrated urine.
- **If OP drops due to excessive rehydration,** *hypothalamus is stimulated* and sends impulses to the (anterior) pituitary gland. The gland is *less stimulated*, thus *less ADH* is released into bloodstream. The kidney tubules become *less permeable to water.* Thus *less water is reabsorbed* into the blood stream and this raises the OP of blood and dilute urine is produced

b] Ionic Balance

- Ion levels (Na^+, Cl^-, K^+, Mg^{2+}, Ca^{2+}, PO_4^{3-})must be regulated within narrow ranges for efficient functioning of body processes like protein synthesis, respiration, nervous co-ordination and muscle contraction
- When the level of sodium ions in the blood is low, adrenal glands produce more aldosterone into the blood. This hormone then stimulates the Loop of Henle and the gut to reabsorb more sodium ions into the blood, thereby raising their amount to norm. When sodium ions are reabsorbed into the blood, chloride ions follow in order to neutralise the charge on the sodium ions.
- When the level of sodium ions in the blood rises above optimum level, adrenal glands produce less aldosterone into the blood, which then stimulates the Loop of Henle and the gut to reabsorb fewer amounts of sodium ions into the blood, thereby raising their amount to norm

c] Regulation of $_{p}H$

- Kidneys get rid of hydrogen ions by combining them with ammonia at the DCT to form ammonium ions. (Cells lining the DCT have an enzyme that enables them to produce ammonia from the amino acid glutamine when the conditions allow)

d] Regulation of Blood Sugar

- adrenal glands produce adrenaline during emergencies which is transported in the bloodstream to the liver where it stimulates the liver to increase the breakdown of glycogen into glucose

- This will increase available glucose for respiration, and thereby releasing more energy for the emergency

The Role of Liver in Homeostasis

1. Blood Sugar Regulation

- If the sugar level in blood is above the norm or set-point i.e. 90mg per $100cm^3$ of blood, this stimulates the *beta* cells in islets of Langerhans of the pancreas to produce more insulin (glucose level is the **stimulus**)

- Insulin stimulates liver to convert glucose to glycogen and fat for storage;

- increase the oxidative breakdown of glucose into CO_2, water and energy;

- inhibit the formation of glucose from glycogen/inhibit glycogenolysis;

- and to inhibit the formation of glucose from non-carbohydrate sources/ inhibit gluconeogenesis;

- Thus, glucose level is lowered back to the normal range

- On the other hand, when glucose level drops below norm, this stimulates the *alpha* cells in islets of Langerhans in pancreas to secrete more glucagon

- Which stimulates the liver to: increase glycogenolysis to form glucose;

- convert fats, proteins and amino acids into sugar (gluconeogenesis);

- and reduce oxidative breakdown of glucose;

- Thus, glucose level is raised to the normal range

- Adrenaline is produced by adrenal glands during emergencies

- It is transported in the bloodstream to the liver where it stimulates the liver to increase the breakdown of glycogen into glucose thereby releasing more energy for the emergency

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Diabetes Mellitus (DM)

- Diabetes mellitus is characterized by elevated blood glucose levels (hyperglycemia) and glucose in urine (glycosuria)
- It results from inadequate insulin secretion, or inability to respond to insulin, or both.

Type 1 Diabetes

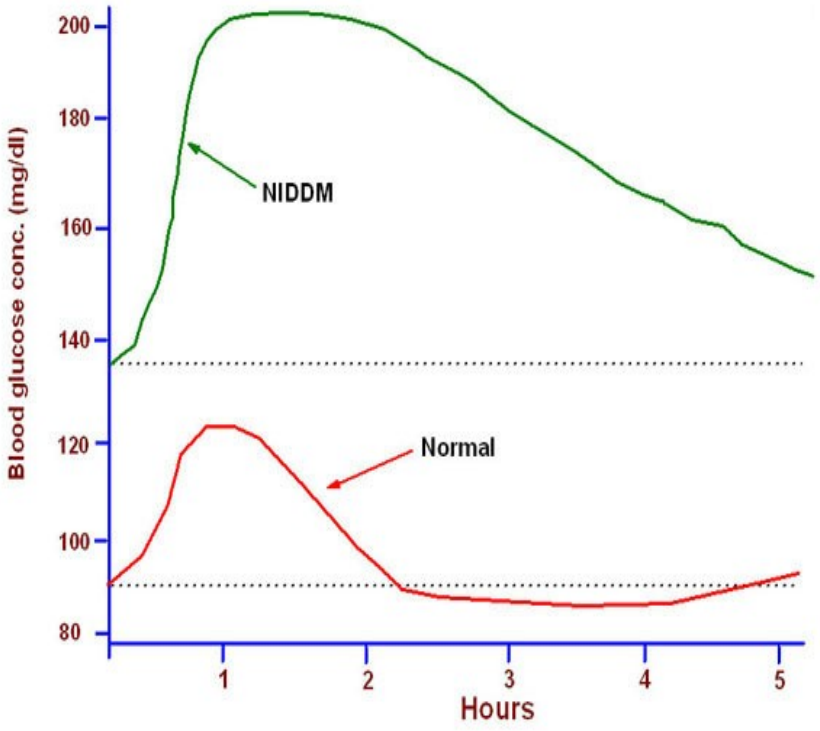
- immune destruction of the beta cells of the pancreas
- Insulin secretion gradually diminishes
- May present at any age, but most common in childhood and adolescence
- Insulin by **injection** is necessary for survival
- Contributing factors: Genetic predisposition; environmental triggers (infection or other stress)

Type 2 Diabetes

- Caused by insulin resistance in the liver, increased glucose production in the liver, over production of free fatty acids by fat cells
- insulin secretion decreases with gradual beta cell failure
- Oral medication and/or insulin injections are eventually required.
- Contributing factors: Obesity, age (onset of puberty is associated with increased insulin resistance), lack of physical activity, genetic predisposition

Early Warning Signs for Type 1 and Type 2 Diabetes

- Increased urination
- Increased thirst
- Increased appetite
- Unexplained weight loss



Acid-Base Balance

- Blood and tissue fluids are kept at a $_{p}H$ of about 7.4
- This constancy depends on controlling the relative concentrations of acid and base
- This is achieved in 3 main ways:
  1. Lungs expel CO_2
  2. Buffering mechanisms in the blood suppress the H^+ ion concentration e.g. haemoglobin buffer, sodium hydrogen-phosphate buffer, sodium hydrogen carbonate buffer, plasma proteins buffer
  3. Kidneys get rid of hydrogen ions by combining them with ammonia at the DCT to form ammonium ions. (Cells lining the DCT have an enzyme that enables them to produce ammonia from the amino acid glutamine when the conditions allow)

Thermo-Regulation in Mammals

- Mammals are **homoiotherms/endotherms**: they maintain a constant body temperature despite wide fluctuations in temperature of external environment

- Internal body temperature is detected by a small region in the brain called hypothalamus as blood flows in the brain

- External environmental temperature is received by thermo-receptors in the skin, these relay the nerve impulse through sensory nerves to the hypothalamus

- The hypothalamus has numerous thermo-receptor cells to detect body temperature and initiate appropriate responses

- When body temperature tends **to drop below norm:**

1. The hypothalamus sends impulses to the liver to increase exothermic reactions. More heat is produced and is distributed throughout the body by blood

2. Blood vessels in the skin constrict (vasoconstriction occurs) to divert blood to a shunt system. This reduces blood flow to near the skin surface, which in turn decreases heat loss by radiation and convection

3. Erector pili muscles are stimulated to contract, making hair to stand erect on the skin surface; trapping more air, which insulates the body against heat loss by radiation and convection

4. Sweat glands reduce the rate of secretion of sweat, body heat is not used up to cause evaporation of water in sweat hence this conserves body heat

5. In prolonged cold environmental temperatures, the skin stores more subcutaneous fat in the adipose tissue. Thick layer of fat offers more insulation against heat loss from the body

6. Hypothalamus also initiates skeletal muscles start shivering which is involuntary contraction of muscles to generate heat during coldness

7. Mammals also use behavioral activities to regulate body temperature during coldness.

8. Some mammals hibernate i.e. go into deep sleep due to cold conditions. Others migrate to warmer habitats to avoid extreme cold weather

9. Human beings put on heavy clothes and bask in the sun

- When body temperature **rises above norm**:

1. Hypothalamus stimulates the blood vessels in the skin to dilate (vasodilation); increasing blood flow to near the skin surface; encouraging more heat loss by radiation and convection

2. Sweat glands increase the rate of sweat production. Heat from the body is absorbed to cause evaporation of water in the sweat (latent heat of vaporisation) cooling the body

3. Erector pili muscles relax making hair to lie flat on the skin surface; less air is trapped; reducing insulation; thereby encouraging more heat loss from the body surface by radiation and convection;

4. Hypothalamus stimulates the liver to increase endothermic reactions; which consume body heat thus lowering body temperature

5. Mammals living in persistently hot habitats have a thin layer of subcutaneous fat; reducing insulation; thus encourages more heat loss from the body

6. Behavioural methods of lowering body temperature include migration to colder habitats, aestivation (going into deep sleep due to dry and hot conditions), moving into shade, and putting on light clothes

Thermoregulation in Plants

1. Plants have the ability to tolerate wide changes in temperature

2. Plants will increase transpiration rate when it is hot so as to cool down

3. Shiny cuticle reflects heat

4. A small leaf area reduces the uptake of heat

5. Wilting during hot days reduces leaf surface area which is exposed to direct rays of the sun

NB: Wilting is caused by more water being transpired than can be replaced through the roots, resulting into the parenchyma cells losing turgidity, and the plant droops

Questions

1. Describe the processes that prevent glucose being excreted in the urine [4]
2. Describe the role of insulin in the regulation of blood glucose concentration [7]

3. Describe how nitrogenous waste products are formed and explain why they need to be removed from the body.
   [6]

4. Describe how the kidney removes metabolic wastes from the body.
   [9]

5. Describe the part played by the proximal convoluted tubules in the functioning of the kidneys. [8]

6. Explain how the collecting ducts in the kidneys may reduce the loss of water from the
body.
[7]