EXCRETION AND HOMEOSTASIS

Excretion is the removal of waste products of metabolism from the body. These waste products are toxic when allowed to accumulate in the body.

Homeostasis is the control and maintenance of a constant internal environment around the cells in the body despite fluctuations in the external environment.

The processes that contribute to excretion and homeostasis are egestion and secretion. **Egestion** is the removal of indigestible and undigested food substances that have not participated in the metabolic activities from the body. **Secretion** is the release of *useful substances* from cells into body fluids such as blood and tissue fluids, or to the outside of the body. Examples of secretions are hormones, enzymes, mucus, milk and wax.

Importance of excretion and homeostasis

- Excretion removes toxic waste products whose accumulation in the body poisons/harms the organism.
- Excretion remove excess materials in the body which when left to accumulate affects the body metabolism.
- Homeostasis maintains the internal environment within normal range whose deviation would affect body's metabolic reactions.

Examples of excretory products

1. Nitrogenous excretory products.

These are excretory products, which contain the element ***nitrogen***. They include ammonia, urea and uric acid.

Ammonia:

This is a ***highly toxic*** nitrogenous waste and it ***requires a lot of water for its elimination***. It is very soluble in water and due to this it requires less energy to be excreted. Ammonia is excreted by organisms which live in fresh water and therefore have a lot of water in their bodies. Such organisms include bony fish, protozoans and amphibians when in water.

Urea:

This is a ***less toxic*** nitrogenous waste. It ***requires less water for its excretion***. It however requires a lot of energy for its excretion because of its low solubility in water compared to ammonia. Urea is excreted by terrestrial organisms which have easy access to water and marine organisms. Such organisms include terrestrial mammals, amphibians when on land and cartilaginous fish.

Uric acid:

This is ***less toxic*** than urea and ***requires no water for its elimination*** from the body. It is ***insoluble in water***. The disadvantage of excreting uric acid is that it requires a lot of energy for its excretion. Uric acid is excreted by birds, reptiles and insects and also common in desert animals.

2. Non nitrogenous excretory products.

These are excretory substances that do not contain the element nitrogen. Such products include carbon dioxide, water, excess salts and excess water.

Excretion in Amoeba

Amoeba is a protozoan. They live in fresh water and therefore their body fluids are hypertonic to the surrounding medium. Water moves by osmosis through the cell membrane into the body of the amoeba. This leads to accumulation of excess water in the cytoplasm which is removed by the ***contractile vacuole***. Water containing dissolved ammonia, excess mineral salts and carbon dioxide is drawn into the contractile vacuole. The vacuole fills up and then moves towards the cell membrane which bursts to release its contents into the surrounding. Most of the carbon dioxide is excreted by simple diffusion.

Excretion in plants

Plants carry out metabolic processes such as photosynthesis and respiration. Carbon dioxide from respiration is used in photosynthesis, while oxygen from photosynthesis is used in respiration. Any waste products from metabolic processes that are not used need to be excreted. Metabolic processes in plants occur at a slower rate than in animals and hence plants do not need special excretory organs because:

- Some waste products produced in one process are used in another process yet animals rarely reuse their waste products.
- Most of the substances broken down in plants are carbohydrates in nature which are not harmful to plants.
- Animals are more active than plants because they move about in search for food, shelter and mates.
- Animals produce a variety of waste products in larger quantities than plants.
- Plants can store excess proteins unlike in mammals.
- Plants do not produce nitrogenous waste products. They produce non-nitrogenous wastes which are less toxic to their bodies.

- Some wastes accumulate in particular parts of the plant and they are eliminated when this part of the plant falls off.
- Plants do not locomote and they are less metabolically active than animals.

Plant waste products

Most of the excretory products of plants are useful to humans. These include:

i) **Carbon dioxide:** this is produced during respiration. It is released out of the plant at night. However, during day it is reused for photosynthesis.
ii) **Oxygen:** it is produced during photosynthesis. It is reused during respiration.
iii) **Resins:** It is a transparent hard or sometimes soft substance exuded by some trees and plants such as fir and pine. It is secreted by plants for protection in response to injury against insects and pathogens. They are used to make varnish and adhesives.
iv) **Tannins:** they are deposited in dead tissues of trees such as bark and wood. They are common in acacia, conifers and mangroves. Tannins are used in the treatment of leather and in the manufacture of ink. They are also used in cosmetics like *henna* used to colour the nails, feet and hair.
v) **Latex:** is a milky substance produced by some plants. Latex from the *rubber tree is used to make rubber.*
vi) **Anthocyanin:** these produce the red, purple and blue colours of petals. They are extracted to make dyes.
vii) **Alkaloids:** these are very poisonous nitrogenous compounds, some of which are used in small dozes as medicines such as quinine, cannabis, cocaine, caffeine and morphine.

Methods of excretion in plants

i) Diffusion: Waste products that are in gaseous form like carbon dioxide and oxygen are excreted through stomata and lenticels by diffusion.
ii) Transpiration: Water containing dissolved carbon dioxide and oxygen are excreted through transpiration.
iii) Guttation: This is the secretion of droplets of water from the pores of plants. Water and dissolved mineral salts are excreted through guttation.
iv) Deposition: Resins, tannins, caffeine, nicotine, etc. are deposited in the xylem, bark, seeds, fruits, flowers and leaves of plants so that the plant is able to carry out metabolic activities without the influence of the deposited substances. When these structures fall off or drop, any waste products they contain are got rid of incidentally.
v) Exudation: This is the release of a fluid from a plant at a slow rate. Such wastes include gums, resins, latex and rubber.

EXCRETION IN ANIMALS

Animals like human beings have specialized organs such as the kidneys, lungs, liver and skin for excretion. Waste products include carbon dioxide, water, mineral salts and nitrogenous wastes. These excretory organs ensure that ions, water and temperature are regulated in the body.

A table showing organisms and their excretory organs, products and habitat

Example of organism	Excretory product	Excretory organ	Habitat
Bony fish	Ammonia	Kidney	Flesh water
Cartilaginous fish	Urea	Kidney	Marine water
Reptiles	Uric acid	Kidney	Terrestrial
Birds	Uric acid	Kidney	Terrestrial
Tadpoles	Ammonia	Gills	Flesh water
Adult amphibians	Ammonia	Kidney	Flesh water
	Urea		Terrestrial
Mammals	Urea	Kidney	Terrestrial
Insects	Uric acid	Malphigian tubules	Terrestrial

In mammals the excretory organs are the kidneys, skin, liver and lungs. Their excretory waste products are as shown in the table below.

Organ	Excretory products
Skin	Urea, ammonia, carbon dioxide, lactic acid, excess mineral salts and excess water
Lungs	Carbon dioxide and excess water
Kidney	Urea, ammonia, uric acid, excess salts and excess water.
Liver	Bile, excess cholesterol, urea

Revision questions

The table below shows changes in the amount of ammonia excreted by a tadpole during development.

Age of tadpole or frog(days)	***50***	***55***	***65***	***75***	***90***	***95***	***100***	***110***
Ammonia as % of total excretory material	*92*	*88*	*84*	*83*	*68*	*20*	*13*	*12*

a) Plot a graph of the data above.
b) Describe the changes in percentage of ammonia excreted with time.
c) With a reason, identify the period when the animal leaves water.
d) Explain the importance of excretion by animals.
e) State two structural changes that accompany the change in excretory product.
f) From the data what is the importance of metamorphosis in the animal?

THE SKIN

The skin is a continuous protective layer over the body. It is the largest organ of the body.

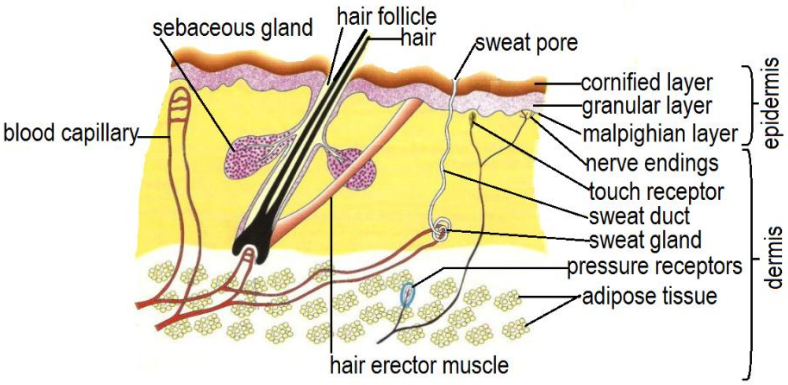
Functions of the skin

- Protection of the body from physical damage.
- Protection against entry of microorganisms such as bacterial and viral infections.
- Prevents loss of water from the body.
- It acts as a sense organ sensitive to pain, touch and heat. This helps the organism to be aware of its environment.
- Regulates body temperature.
- It synthesizes vitamin D in presence of sunlight.
- It excretes salts, excess water, lactic acid, carbon dioxide and traces of urea.
- Stores fats in the adipose tissue.
- Melanin pigment blocks ultraviolet rays from penetrating into the body tissues.

Structure of the skin

The skin consists of two main layers; the ***epidermis*** (outer layer) and the ***dermis*** (inner layer).

Transverse section through the mammalian skin



The epidermis:

This is made up of three sub layers.

i) The Malpighian layer

This is the inner most sub layer in the epidermis. It consists of dividing cells which give rise to cells of the granular layer. It secretes a pigment called melanin, which gives the skin its colour and protects the skin from ultraviolent rays. Albinos do not produce melanin in their skins.

ii) The granular layer

This contains living cells arising from the malphigian layer. It is the biggest layer of the epidermis. It gives rise to cells of the cornified layer.

iii) The cornified layer.

This is the outermost layer of the skin. It is made up of dead cells, which are keratinized. Cells of this layer continuously ware away and are replaced by cells from the granular layer. Its function is to protect the inner parts of the body from mechanical injury and entry of bacteria and other germs.

It also offers water proofing to the skin.

The dermis:

This is the inner layer of the skin. It is below the Malpighian layer. It is thicker than the epidermis.

It contains the sweat glands, nerve fibers, fat cells and blood capillaries.

Functions of other parts of the skin

i) **Hairs:** They protect the body and trap a layer of air on the skin which insulates the body against heat loss.

ii) **Sebaceous gland:** This secretes an oily substance called sebum. This oil softens the cornified layer and prevents it from cracking. The oil also provides water proofing to the skin.

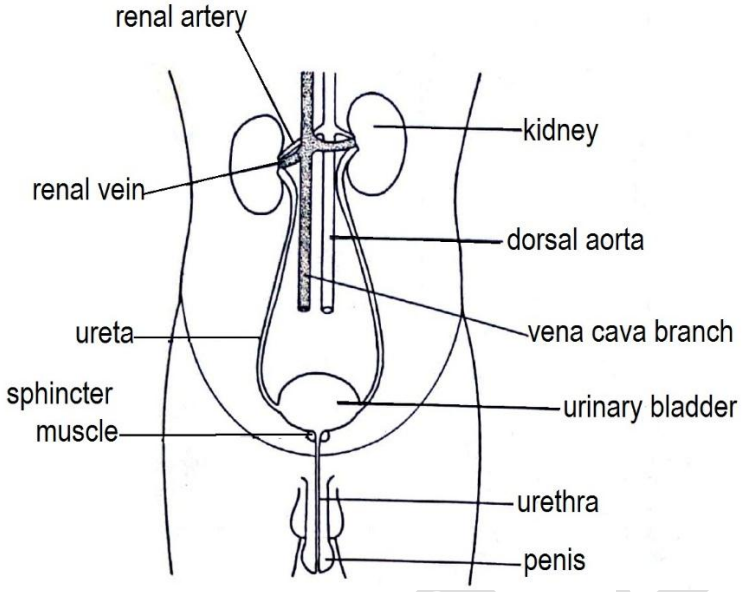
iii) **Nerve endings:** These perceive external stimuli and transfer impulses to the central nervous system.

iv) **Sweat glands**: They excrete sweat, which is released out of the skin through the sweat duct.

THE HUMAN URINARY SYSTEM

This is a collection of organs and tissues involved in the formation and removal of urine out of the body.

Diagram showing the human urinary system



Functions of parts of the urinary system

Aorta:
Supplies blood to renal artery.

Renal artery:
It brings blood containing excretory products to the kidney.

Renal vein:
It carries filtered blood from the kidney to the posterior vena cava.

Ureter:
Carries urine from the kidneys to the urinary bladder.

Urinary bladder:
It is a thick walled elastic sac-like structure which stores urine before it is removed from the body.

Sphincter muscles:
They relax to let urine out of the bladder into the urethra.

Urethra:
It's a passage for urine out of the body from the urinary bladder.

The human kidney

The kidneys are solid bean-shaped structures and they occur in pairs in mammals. They are reddish-brown in colour enclosed in a transparent membrane and attached to the back of the abdominal cavity. It plays a role in excretion, homeostasis and osmoregulation.

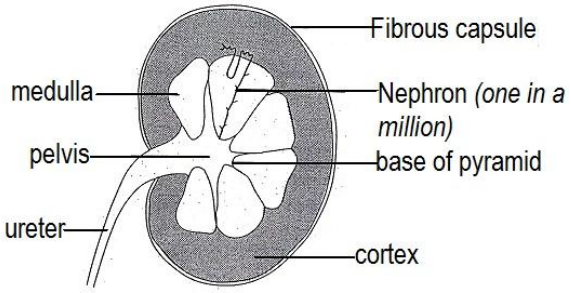
The kidney has two major parts:

1. The **cortex** which is a dark outer part. It consists of the Bowman's capsule which is responsible for ultra-filtration of blood passing across it.
2. The **medulla**, which is a lighter inner part. It is made up of many cone-shaped portions called pyramids.

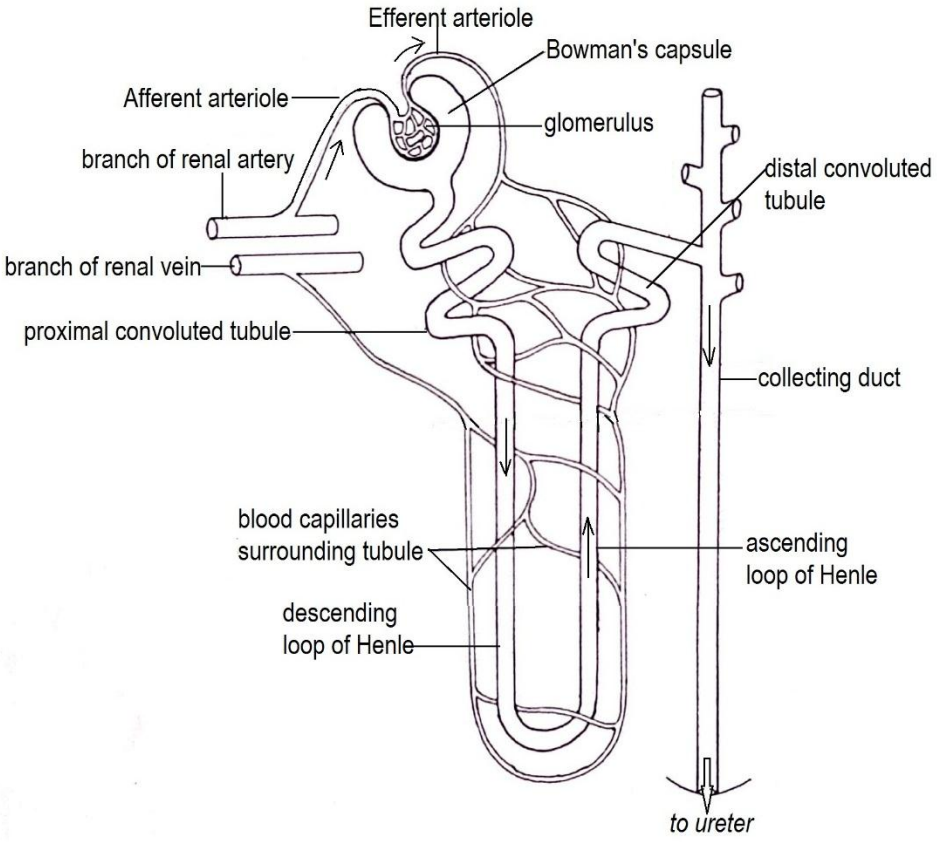
The pelvis is the area where the ureter leaves the kidney.

The kidney is made up of several microscopic structures (functional units) called **nephrons** where the actual excretion and osmoregulation takes place. The nephrons run from the cortex, thorough the medulla and back to the cortex.

Structure of the kidney



Structure of the nephron



Parts of the nephron and their functions

1. Bowman's capsule:

It is located in the cortex and contains a dense-network of capillaries called ***glomerulus*** formed from a wider afferent arteriole.

The Bowman's capsule filters small molecules from blood into the capsular space such as urea, glucose, etc. which forms the glomerular filtrate through a process called *ultra-filtration*.

Adaptations of the glomerulus to ultra-filtration

- The afferent arteriole is wider than the efferent arteriole which generates high blood pressure in the glomerulus that forces small molecules out of the glomerulus.
- Has many capillaries in the glomerulus that give it a large surface area for ultra-filtration.
- Has a semi permeable membrane that allow any small molecule to pass through.

2. Proximal convoluted tubule:

This is a site where re-absorption of useful materials such as glucose and some small amino acids and water from glomerular filtrate back to blood takes place.

3. Loop of Henle:

It's made up of a descending (going down) limb and an ascending (going up) limb. The *main function of the loop of Henle is to make the tissue fluid in the medulla more concentrated than the glomerular filtrate in the nephron so that water needed in the body is reabsorbed*. ***It's known to cause water retention in the body.*** *This is one way of conserving water in camel because of its extremely long loop of Henle.*

4. Distal convoluted tubule:

It mainly re-absorbs salts like chloride ions together with water, leaving a concentrated liquid now called urine which passes down to collecting ducts.

5. Collecting duct: This duct carries urine from the distal tubule to the pelvis. It is also permeable to water thus allows reabsorption of water back into blood.

Functions of the kidneys

- It contains endocrine glands, which secrete hormones.
- Excretion of metabolic waste products such as urea, excess water, uric acid, ammonia, etc.
- Regulation of water and solute content of blood (osmoregulation)
- Maintenance of PH of body fluids at 7.4.
- Regulation of blood levels of ions such as Na^+, K^+, Cl^-, Ca^{2+}
- Retention of important nutrients such as glucose and amino acids through reabsorption from glomerular filtrate into blood.

URINE FORMATION

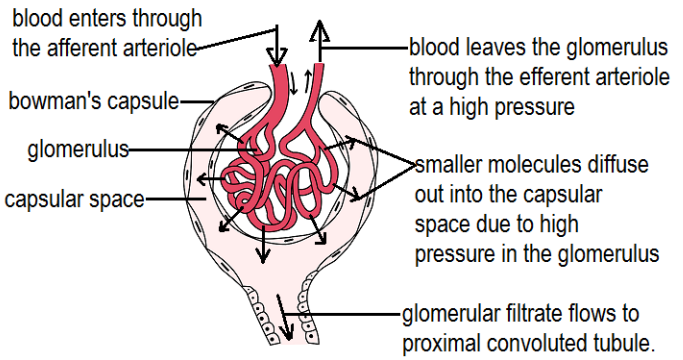
The process of urine formation takes place in the nephron. It occurs in two phases i.e. ***Ultra-filtration*** and ***Selective re-absorption***. Much blood comes from the afferent vessel into the glomerulus than that which leaves through efferent because the afferent vessel is wider than the efferent vessel. This creates high pressure in the glomeruli that leads to **ultrafiltration.**

The walls of the blood capillaries have very small pores which only allow small molecules to pass through into the Bowman's capsule to form the glomerular filtrate. *This filtrate contains glucose, amino acids, hormones, uric acid, urea, water, salts and vitamins.*

Plasma proteins and blood cells are retained in the blood capillaries because they are made up of large molecules which cannot pass through the capillary walls.

The glomerular filtrate flows into *proximal convoluted tubule* where useful substances are selectively reabsorbed back into the blood capillaries.

Diagrammatic illustration of ultrafiltration



Substances useful to the body are reabsorbed. This is referred to as **selective reabsorption**

In the proximal convoluted tubule:

All the glucose, amino acids, vitamins, hormones and a big percentage of sodium chloride and water are reabsorbed into the blood capillaries. The blood capillaries join and drain the substances into the renal vein and eventually into the general blood circulation. The glomerular filtrate flows into loop of Henle.

In the loop of Henle:

The loop of Henle is U-shaped with a descending and ascending limb. As the filtrate flows down the descending limb, water is re absorbed back into the capillaries by osmosis leading to increased concentration of the filtrate down the descending limb.

As the filtrate ascends the thick ascending limb, sodium chloride is reabsorbed by active transport. The glomerular filtrate flows to the distal convoluted tubule.

In the distal convoluted tubule:

Selective reabsorption of salts occurs. Also water is reabsorbed depending on the permeability of the tubules which is affected by hormones. The glomerular filtrate flows to the collecting ducts.

In the collecting duct:

More water is reabsorbed and the remaining highly concentrated filtrate is ***urine***. The urine drains into the pelvis. It then flows to the urinary bladder through the ureter.

Note: *Because of the high concentration, when urine is poured on grass or any plant, they get scotched because the cells lose water to the surrounding concentrated urine and the plant cells become flaccid. This brings about wilting and drying of the plant.*

Comparison of substances in blood and urine

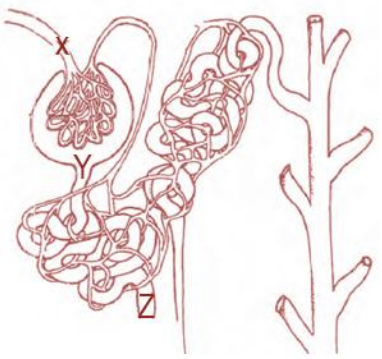
Nitrogenous waste	In blood	In urine
Urea	0.03	2.0
Proteins	7-9	0
Glucose	0.1	0
Chloride ions	0.37	0.6
Sodium ions	0.32	0.35
Water	93	95

- ✓ There are proteins in blood and there is none in urine because proteins are not filtered out of the blood vessels into the glomerulus due to the large size of their molecules.
- ✓ Urea is more in urine than in blood because it is filtered out of blood and it is not reabsorbed back in the blood.
- ✓ Water is more in urine than in blood because it is used to dissolve urea.
- ✓ However the relative amounts of water in urine and in blood varies depending on the amount of water in the body, amount of solutes in the body, temperature and body activity.

- ✓ There is glucose in blood and no glucose in urine because glucose is reabsorbed from the glomerular filtrate back into the blood.
- ✓ Salts like chlorides and sodium ions are more in urine than in blood. This is because they are in excess and they are not reabsorbed back into the blood. Because of this they tend to concentrate in urine.

Revision questions

1. *Distinguish between **excretion** and **osmoregulation**.*
2. *Describe the contribution of the following parts to urine formation in mammals:*
   i) Bowman's capsule
   ii) Proximal convoluted tubule
   iii) Loop of Henle
   iv) Collecting duct
3. *The diagram below represents a single kidney nephron:*



Two experiments were carried out to analyze fluid from different regions of the kidney.
*In experiment one, samples were taken using a micropipette from the three regions, **X, Y** and **Z**.*
These were then tested using Benedict's (for reducing sugars) and Biuret reagents (for protein).

The results are shown in the table below:

Sample	***Benedict's***	***Biuret***
Experiment one		
X (blood plasma)	*Brown ppt*	*Intense purple*
Y (glomerular filtrate)	*Brown ppt*	*Pale purple*
Z (start of loop of Henle)	*Blue solution*	*Blue (unchanged)*
Experiment two – chilled kidney		
Z	*Green solution*	*Very pale purple*

a) Explain the difference in the Biuret result between samples X and Y (in experiment one).
b) Account for the difference between the Benedict's result between samples Y and Z (in experiment one).
*c) In experiment two, the kidney was **chilled (placed in freezing temperature)** and a sample was taken from region Z using a micropipette. Explain the results of the Benedict's and Biuret tests shown above.*

The lungs as an excretory organ

Lungs play a role in excretion of heat, water and carbon dioxide in the following ways:

1) **Heat:** when the liver carries out metabolic reactions, a lot of heat is generated which leaves the liver by blood. When the blood reaches the lungs, the heat leaves the blood and dissolves into the moisture in the alveoli and warms up the air in the alveoli. The warm air is then removed out of the lungs into the atmosphere.
2) **Water:** some water is lost through exhalation of moist air from the lungs.
3) **Carbon dioxide:** carbon dioxide from respiration in tissues is brought by blood to the lungs where it diffuses into the alveoli and then removed from the body through exhalation.

HOMEOSTASIS

Homeostasis is the maintenance of a constant internal environment of the body. The internal environment of the body is composed of tissue fluids which surround cells. Homeostasis therefore involves maintenance and control of blood sugar level, blood salt level, blood water level, body temperature and carbon dioxide concentration in tissues. This is done by the kidney, liver and lungs.

Role of the kidney in homeostasis

The kidney is involved in water and salt balance regulation. These two influence the concentration of blood.

1) Role of the kidney in osmoregulation:

Osmoregulation is the control of the amount of water in the body.

The water level is kept neither high nor low but within a limit according to the demands of the body. The level is maintained by loss of excess and gain if more is required.

Water is lost from the body through urine, sweat, expiration, and faeces during egestion and it can be gained through; drinking, eating and water from metabolism.

The loss and gain of water brings about changes in blood concentration. These changes are detected in the brain by the hypothalamus.

If the blood passing through the brain is too concentrated, the hypothalamus stimulates the anterior lobe of the pituitary gland to secrete a hormone called ***antidiuretic hormone (ADH)*** into the blood stream. When the hormone reaches the kidneys, it increases the permeability of the nephron tubules (distal convoluted tubules and collecting ducts) to water. More water is reabsorbed from the glomerular filtrate back into the blood. Less urine that is concentrated and yellowish in colour is produced. This restores the optimum concentration of the blood.

If blood passing through the hypothalamus is too dilute, the hypothalamus signals the posterior pituitary gland to reduce the production of ADH. Less ADH decreases the permeability of the nephrons to water. Less water is therefore reabsorbed from the glomerular filtrate resulting into production of colourless urine in big volumes. This mostly happens during cold conditions where water loss through sweating is minimal.

When conditions are hot, sweating increases lowering the water level in blood. This causes more re-absorption of water in the nephrons resulting in production of concentrated pale yellow urine.

When the level of water in blood is too low, the hormone causes a feeling of thirst which makes one to drink water in order to bring back the normal water level in blood.

Failure of the kidney to regulate the volume of water in urine due to inefficient production of ADH leads to frequent urination of large amounts of dilute urine thus increases the blood concentration. This condition is known as ***diabetes insipidus.*** *Diabetes insipidus is treated by administering natural or synthetic ADH.*

2) Role of the kidney in ionic/salt balance (control of salt levels) in blood:

The ions/salts involved are the sodium, potassium and chloride ions. The hormone involved is ***aldosterone.*** Aldosterone is secreted by the adrenal gland found close to the kidney.

Aldosterone stimulates reabsorption of sodium ions into the blood from the glomerular filtrate along with chloride ions.

When the concentration of sodium ions in the blood is very high, aldosterone secretion is inhibited. This causes more ions to be lost through urine.

Revision question

The bar chart shows the amount of water lost from the body of a student on two different days. The student ate the same amount of food and drank the same amount of liquid on the two days. The temperature of the surroundings was similar on the two days.

a) The total volume of water lost on day 1 was 3250 cm^3. How much water was lost on day 2? Show your working.

*b) The student did much more exercise on one of the days than on the other. On which day did he do more exercise? Give **two** reasons for your answer.*

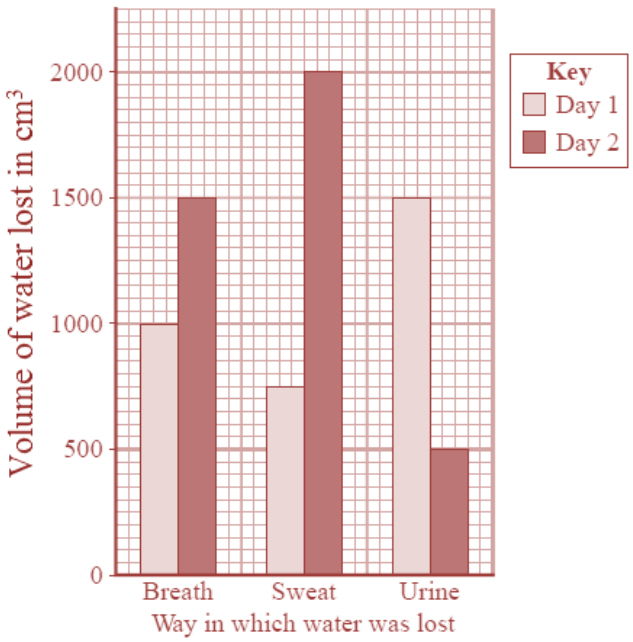
*c) State **one** chemical reaction that produces water in the body.*

d) Briefly explain how sweating is important to the body

e) If the body loses more water than it gains, it becomes dehydrated and the concentration of the solution surrounding the body cells increases.

f) Briefly explain how this affects body cells.

g) Describe the effect of ADH on the functioning of the kidney nephron.



Role of the liver in homeostasis

The liver regulates blood sugar levels. Blood sugar is called glucose. The regulation is done by the hormones secreted by the islets of Langerhans in the pancreas.

Importance of blood sugar regulation

- It prevents cells running short of glucose in case its level drops. Blood sugar (glucose) is the main source of energy.
- Any slight increase in glucose level alters the concentration of blood's concentration which results in alteration of the rate at which water moves in and out of the body cells by osmosis.

Regulation of blood glucose

The normal amount of glucose in blood is about 90 mg per 100 cm^3. After a meal, carbohydrates are digested in the alimentary canal to glucose and absorbed from the gut into the blood stream and taken to the liver through the ***hepatic portal vein.*** Any increase in blood glucose level above the normal level is detected by the brain which sends impulses to the pancreas to secrete insulin. Insulin moves to the liver and sets up mechanisms that reduce the amount of glucose back to the normal range.

Insulin causes glucose;

- To be converted into glycogen and stored in the liver and muscles.
- To be converted into fats and later stored under the skin and around internal organs.
- To be broken down faster into carbon dioxide, water and energy. This energy is stored in form of ATP.

When there is decreased glucose concentration in the blood, for example during fasting or starvation, the pancreas is stimulated to release glucagon hormone. Glucagon is transported to the liver where it raises and restores glucose concentration in the blood back to the normal range.

Glucagon causes;

- Conversion of stored glycogen to glucose.
- Conversion of fats to glucose.
- A reduction in the rate of respiration to reduce the rate at which glucose is broken down.

Failure to produce insulin causes the presence of much glucose in urine a condition known as ***diabetes mellitus.***

Other functions of the liver

1) ***Deamination.*** Excess amino acids are not stored in the body but are deaminated. Deamination is the removal of the amino group from an amino acid. The amino group undergoes some reactions to from urea which is excreted through the kidney.
2) ***Production of heat.*** Many metabolic reactions occur in the liver leading to heat generation. This heat is distributed by the blood to other body parts.
3) ***Manufacture of plasma proteins.*** The liver is responsible for the manufacture of proteins found in the blood like Albumin, Globulin and fibrinogen which are important in body process like clotting of blood (stopping bleeding).
4) ***Production of bile.*** The liver produces bile which is important in the process of digestion i.e. in the emulsification of lipids.
5) ***Storage of minerals.*** The liver stores minerals like iron, potassium, copper and zinc.
6) ***Storage of vitamins.*** The liver stores vitamins A, B, D, E and K which can later be released if deficient in the diet.
7) ***Formation and breakdown of red blood cells***. Red blood cells in the fetus are produced by the liver but in adults, they are made in the bone marrow. The adult liver however continuous to break down the expired red blood cells at the end of their 120-day life span.
8) ***Storage of blood.*** Blood vessels in the liver can expand and contract such that the amount of blood in the liver can vary from 300cm^3 – 1500cm^3, an increase of five times thus the liver can be a blood reservoir.
9) ***Detoxification.*** The liver convert toxic substances to harmless substances by altering their chemical structure and later sends them to the excretory organs for expulsion e.g. it converts Ammonia to urea which is then expelled by the kidneys. It also contains ***catalase enzyme*** which catalyzes the breakdown of hydrogen peroxide to water and oxygen. Hydrogen peroxide is a toxic waste product produced when the water from metabolism combines with oxygen.
10) ***Break down of hormones.*** The liver break down all hormones like testosterone and insulin.

Revision questions

The table below shows the effect of exercise on the secretion of insulin and glucagon hormones in a human being. The exercise lasted 6 minutes.

Time (Minutes)		*0*	*1*	*2*	*3*	*4*	*5*	*6*
Concentration of hormone in blood in arbitrary units	*Glucagon*	*3*	*4*	*6*	*9*	*15*	*20*	*26*
	Insulin	*18*	*14*	*11*	*10*	*9*	*8*	*7*

a) Draw an appropriate graph to represent the information in the table.
b) Explain the variations in insulin and glucagon during the exercise.
c) Explain how the concentration of the two hormones would vary if the individual swallowed much glucose after the exercise.

THERMOREGULATION

This is the regulation and maintenance of body temperature of an organism within a narrow constant range that is optimum for their body activities.

To maintain the body temperature constant, there must be a balance between heat loss and heat gain.

The body loses heat by;

- Radiation: Heat diffuses from the warm body to the cold environment.
- Conduction: The body loses heat to the cold object in contact with it.
- Convection: Where cold air or wind carries heat from the warm body.
- Evaporation: Heat is lost during sweating.

The body gains heat by;

- Radiation: e.g. from the sun's heat and reflection from the ground.
- Conduction: e.g. from the ground via the feet.
- Convection: e.g. from the wind bringing hot air to the body.
- Metabolism: e.g. since many of the body's chemical reactions release heat during respiration.

The rate of heat loss and gain depends on the following;

- Surface area to volume ratio: Small organisms having a large surface area to volume ratio tend to lose more heat than the large ones with small surface area to volume ratio.
- Temperature of surrounding environment: Organisms tend to lose more heat in cold environment and gain more in hot environment.
- Rate of respiration: The higher the rate of respiration, the more heat energy gained by the body.
- Humidity of the environment: Heat loss increases in humid conditions because high humidity makes the environment colder.

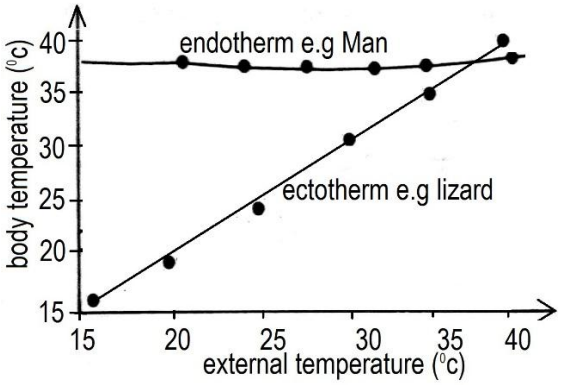
Animals are either endothermic or ectothermic.

Endothermic animals (Homeotherms) are those that are able to maintain a constant body temperature irrespective of the temperature of the external environment. They depend mainly on heat generated within their bodies. They are warm blooded animals e.g. all mammals and birds.

Ectothermic animals (Poikilotherms) have a body temperature that changes with that of the external environment. They are cold blooded animals e.g. all invertebrates, fish, reptiles and amphibians.

The graph on the *right* shows how body temperature changes with increase in external temperature. The body temperature of endotherms remains constant despite increase in the surrounding external temperature. The body temperature of ectotherms changes with the external environment temperature.

A graph showing how body temperature varies with environmental temperature



Thermoregulation in endotherms

The body uses physiological and behavioral means to regulate the temperature.

Physiological means are the automatic responses.

Behavioral means are the conscious responses. The organism consciously decides what to do when external and internal temperatures change.

In cold conditions, the body loses heat to the environment. However, the body uses physiological and behavioral means to regulate the temperature.

Physiological means:

- The erector pill muscles of the hair contract to make the hairs stand upright on the skin to trap a layer of air. The layer of air insulates the body against heat loss.
- The rate of sweating reduces. This leads to less water lost through latent heat of vaporization.
- The metabolic activity of the liver increases to produce heat to raise body temperature.
- Blood vessels near the skin constrict in the process called vasoconstriction to reduce on the blood reaching the skin thus less heat is brought close to the skin surface and this reduces heat loss.
- Shivering which involves the rapid contraction of skeletal muscles to generate heat.

Behavioral means:

- Sitting near hot bodies to raise their body temperature by conduction or radiation.
- Humans take hot drinks.
- Increased muscular activity such as rubbing hands and stamping feet.
- Taking a warm water shower.
- Dressing in warm heavy clothing which enables the body to conserve heat.
- Small animals like the mouse undergo hibernation where they dig holes and live deep in them to reduce heat loss

In hot conditions, the body gains heat from the environment. The body can also generate its own heat for example during sickness. However, the body also uses physiological and behavioral means to regulate the temperature.

Physiological means:

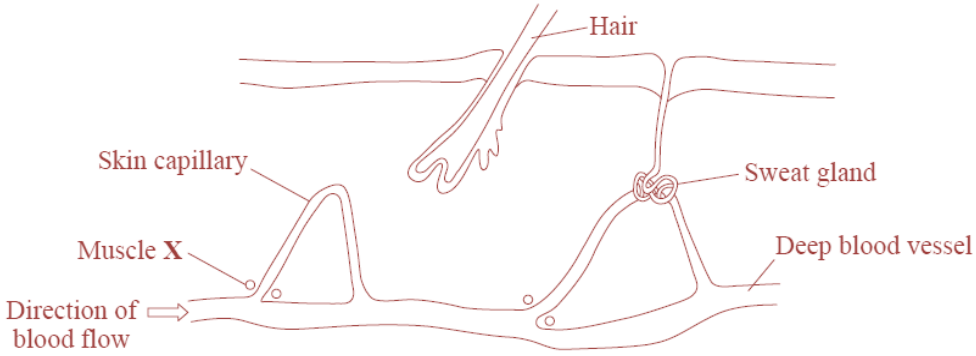
- The erecter pili muscles of the skin relaxes making the hairs lie flat on the skin. Air is not trapped beneath the hair which allows heat loss by radiation, conduction and convection.
- The metabolic rate of the body reduces to reduce on the amount of heat produced.
- Increase in sweat production leads to heat loss through latent heat of vaporization.
- Vasodilatation. Arterioles beneath the skin dilate and allow more blood to reach the skin surface in order to lose heat to the atmosphere by radiation.

Behavioral means:

- Resting on cold bodies like rocks to lose heat by conduction.
- Drinking cold drinks.
- Dressing in light clothes which do not retain much heat.
- Swimming.
- Moving to a shade to avoid exposure to direct sunshine.
- Panting in some animals like dogs and lions. This involves hanging the tongue out so that evaporation can occur from the mouth resulting into loss of heat from the body which eventually cools the animal.
- Some animals like elephants have large ears which are flapped vigorously to create air currents which take the heat away from the body.
- Some animals ***aestivate***. Aestivation is a state of inactivity by some animals that occur during prolonged period of heat that may accompany drought.

Revision questions

The diagram shows a section through part of the skin.



*The muscle labelled **X** controls the flow of blood into the skin capillary. When muscle **X** contracts, the flow of blood into the skin capillary is reduced.*
Explain the role of the following parts in the control of mammalian body temperature:
*i) Muscle **X** **ii)** Sweat gland*
iii) Hair

Adaptations of mammals to cold conditions

- They have long and much hairs over their bodies to trap a layer of air.
- They have a thick fat layer to act as an insulator.
- Some are big and thus have a small surface area to volume ratio. This reduces the rate of heat loss.
- They have few sweat glands to reduce of the heat lost during sweating.
- They have fewer blood vessels on the skin surface to avoid heat loss through radiation.

Adaptations to hot conditions

- Having short or few hairs on the body to allow easy loss of heat.
- Having less fat to reduce on the insulation effect of fats.
- Having a large surface area to volume ratio to allow a faster rate of heat loss.
- Having a lot of sweat glands to increase heat loss through sweating.
- Having many blood vessels near the skin for easy loss of heat by radiation.

Thermoregulation in ectotherms

Examples of ectotherms are fish, reptiles and amphibians. Their body temperature is controlled by only behavioral means.

During hot conditions, they lose heat by:

- Resting on cold rocks to lose heat by conduction.
- Moving to a shade to avoid exposure to direct sunshine to reduce heat gain.
- Burrowing in cracks and lose heat by radiation.
- Thermal gaping. Reptiles open their mouths and pant. Panting lead to heat loss through evaporation of water from the mouth.
- Aquatic reptiles remain in water to reduce heat gain.

During cold conditions, they gain heat by;

- Resting on warm rocks to gain heat by conduction.
- Basking on rocks to gain heat by conduction.
- Burrowing in hot sand to gain heat by conduction.
- Basking in the sun to gain heat by radiation.

Advantages of being endothermic

- They are always active because their temperature is maintained at an optimum temperature for enzyme activity.
- They can live in a wide range of environments i.e. both hot and cold.
- Their metabolic rate is maintained at a high rate due to the ability to maintain a constant body temperature.

Disadvantages of being endothermic

- Having a high rate of food consumption due to high rate of metabolism.
- Maintaining the body temperature constant requires much energy.

Advantages of being ectothermic

- Low food consumption due to low metabolic rate.
- Easy to control body temperature by only behavioral means.

Disadvantages of being ectothermic

- They have limited body activity in cold environments.
- Show response to stimuli due to low metabolic rate.

Relationship between size of animal and heat loss

Small animals such as rats have a large surface area to volume ratio. Such animals tend to lose heat at a faster rate than large animals. Large animals like elephants have a small surface area to volume ratio, thus they retain most of their body heat.
Therefore small animals eat a lot of food to increase their metabolism. This produces heat which replaces the lost heat.

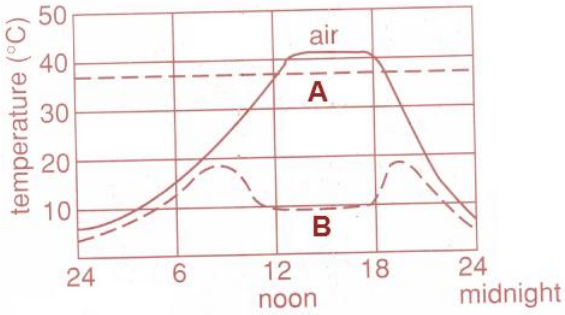
Temperature regulation in plants

Plants of different regions are adapted to different temperature ranges. More so, plants have tissues that can tolerate wide changes in temperature. However, at extreme conditions, plants regulate their temperature through the following ways:

- Plants keep cool through transpiration.
- Some plants may undergo conditions of dormancy when too hot or cold.
- The shiny cuticle reflects heat.
- Plants can wilt hence removing leaves from direct rays of the sun.

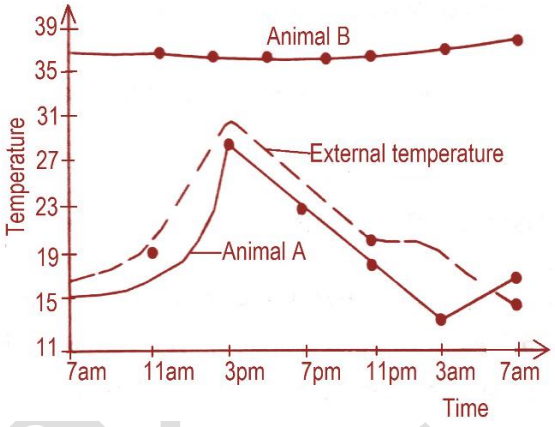
Revision questions

1. *The figure below shows the variation in atmospheric temperature and the body temperature of two animals **A** and **B** during the course of the day in the desert.*



   a) *Describe the observed patterns in temperature of animals **A** and **B** through the different hours of the day.*
   b) *What behavioral and physiological mechanisms explain the observed temperature of animals **A** and **B** through the different hours of the day?*
   c) *Suggest the classes of animals to which animals **A** and **B** belong*

2. *The graph below shows the body temperature of animal A, B, measured over a 24 hour period*



   a) *What happens to the body temperature of animal A as the external temperature increases?*
   b) *What happens to the body temperature of animal B as the external temperature increases?*
   c) *From the graph what can you deduce about the activity of A and B at night time?*
   d) *What advantages does this give one animal over the other in respect of night activities?*
   e) *How is temperature controlled in humans*
      i) *By behavior,* ii) *physiologically?*
   f) *How does this differ from temperature control in plants?*
   g) *What are the functions of the skin of man?*

"As iron rusts from disuse, water loses its purity from stagnation, even so does the inaction sap the vigor of the mind".