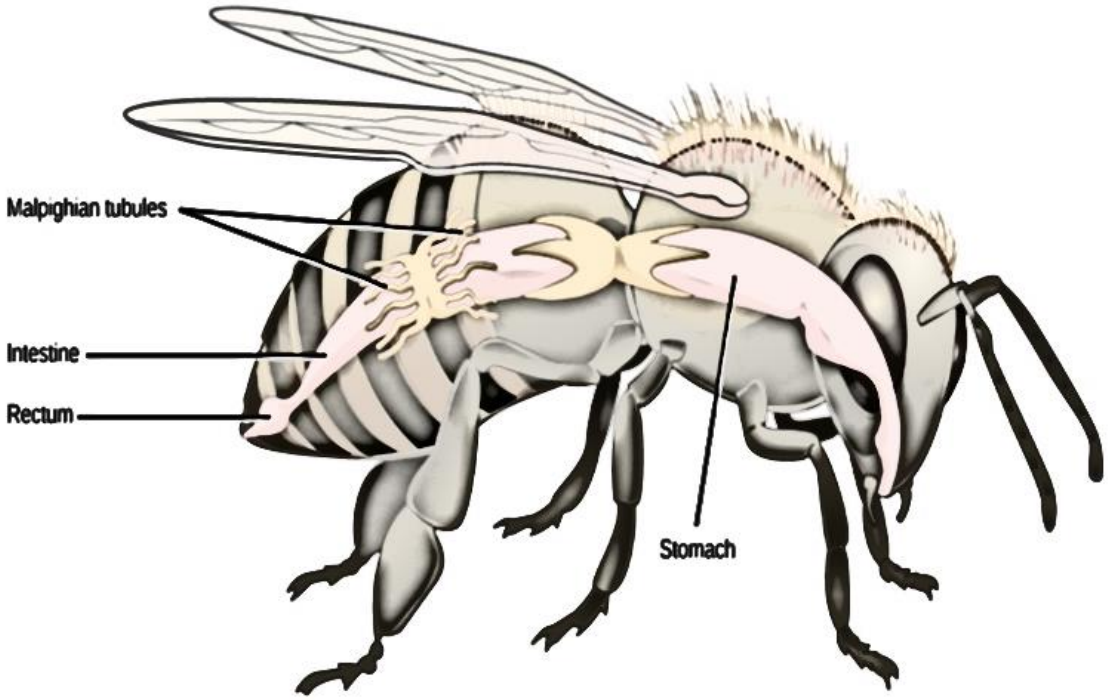
Atika School

Free Online Academy

PRESENTS KCSE BIOLOGY NOTES

TOPIC 9: EXCRETION AND HOMEOSTASIS

(42 LESSONS)



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SPECIFIC OBJECTIVES

By the end of the topic, the learner should be able to:

a) distinguish between excretion and egestion

b) explain the necessity for excretion in plants and animals

c) state the uses of excretory products of plants

d) describe the methods of excretion in a named unicellular organism

e) relate the structures of the human skin, lungs, liver and kidney to their functions name common kidney diseases

f) explain the concept of internal environment and homeostasis

g) compare responses to changes in temperature by behavioural and physiological methods in animals

h) relate heat loss to body size in

i) describe methods by which mammals gain and lose heat

j) explain how the functions of the following relate to homeostasis - skin, hypothalamus, liver and kidney

k) discuss the role of antidiuretic hormone, insulin and glucagons

l) describe simple symptoms of Diabetes mellitus and Diabetes insipidus.

TOPICS / SUB-TOPICS OUTLINE

Excretion in Plants

Methods of excretion in plants

Useful and harmful excretory products of plants and their economic importance e.g. caffeine in tea and coffee, quinine, tannins, colchicines, cocaine, rubber, gum, papain (from pawpaw) and products of cannabis sativa (bhang) and khat (miraa)

Excretion and homeostasis in Animals

Distinction between excretion, homeostasis and egestion

Excretion in a named uni-cellular organism (protozoa)

Structure and functions of skin and kidney

Neuro-endocrine system and homeostasis

- ✓ Water balance (blood osmotic pressure)
- ✓ Blood sugar level (control)
- ✓ Temperature regulation (mention the role of hypothalamus)

Common kidney diseases, their symptoms and possible methods of prevention and control

The role of the skin in thermoregulation, salt and water balance.

Major functions of the liver and their contributions to homeostasis

Common diseases of the liver, their symptoms and possible methods of prevention/control

Practical Activities

Examine and draw the mammalian kidney

Make vertical sections of the kidney to identify cortex and medulla

Observe permanent slides of mammalian skin

Investigate effect of catalase enzyme on hydrogen peroxide

Excretion and Homeostasis

Introduction

- ✓ Excretion is the process by which living organisms separate and eliminate waste products of metabolism from body cells.
- ✓ If these substances were left to accumulate, they would be toxic to the cells.
- ✓ Egestion is the removal of undigested materials from the alimentary canals of animals.
- ✓ Secretion is the production and release of certain useful substances such as hormones, sebum and mucus produced by glandular cells.
- ✓ Homeostasis is a self-adjusting mechanism to maintain a steady state in the internal environment

Excretion in Plants

- ✓ Plants have little accumulation of toxic waste especially nitrogenous wastes.
- ✓ This is because they synthesise proteins according to their requirements.
- ✓ In carbohydrate metabolism plants use carbon (IV) oxide released from respiration in photosynthesis while oxygen released from photosynthesis is used in respiration.
- ✓ Gases are removed from the plant by diffusion through stomata and lenticels.
- ✓ Certain organic products are stored in plant organs such as leaves, flowers, fruits and bark and are removed when these organs are shed.
- ✓ The products include tannins, resins, latex and oxalic acid crystals.
- ✓ Some of these substances are used illegally.
- ✓ Khat, cocaine and cannabis are used without a doctor's prescription and can be addictive.
- ✓ Use of these substances should be avoided.

Plant Excretory Products their source and uses

Plant	Product source	Use
Caffeine	Tea and coffee	Mild CNS stimulant
Quinine	Cinchona tree	Anti-malaria-drug
Tannins	Barks of Acacia, Wattle trees	Tanning hides and skins
Colchicine	Corms of crocus	Prevents spindle formation in cell division
Cocaine	Leaves of coca plant	Local anaesthesia
Rubber	Latex of rubber plant	Used in shoe industry
Gum	Exudate from acacia	Used in food processing and printing industry
Cannabis	Flowers, fruits and leaves of cannabis sativa	Used in manufacture of drugs
Nicotine	Leaves of tobacco plant	Manufacture of insecticides. Heart and CNS Stimulant
Papain	Pawpaw (fruits)	Meat tenderizer, Treats indigestion
Khat	Khatha edulis (miraa)	Mild stimulant
Morphine	Opium Poppy plant	Narcotic, Induces sleep / hallucinations
Strychnine	Seeds of strychnos	CNS stimulant

Excretory products in animals

Substance	Origin
Nitrogenous compounds: (i) Ammonia (ii) Urea (iii) Uric acid	Excess amino acids (proteins). Deamination of amino acids. Deamination of amino acids; then addition of carbon dioxide. Ammonia (from deamination of amino acids).
Carbon dioxide	Homeostasis and respiration.
Biliverdin and bilirubin	Breakdown of haemoglobin
Water	Osmoregulation
Cholesterol	Excess intake of fats.
Hormones	Excess production

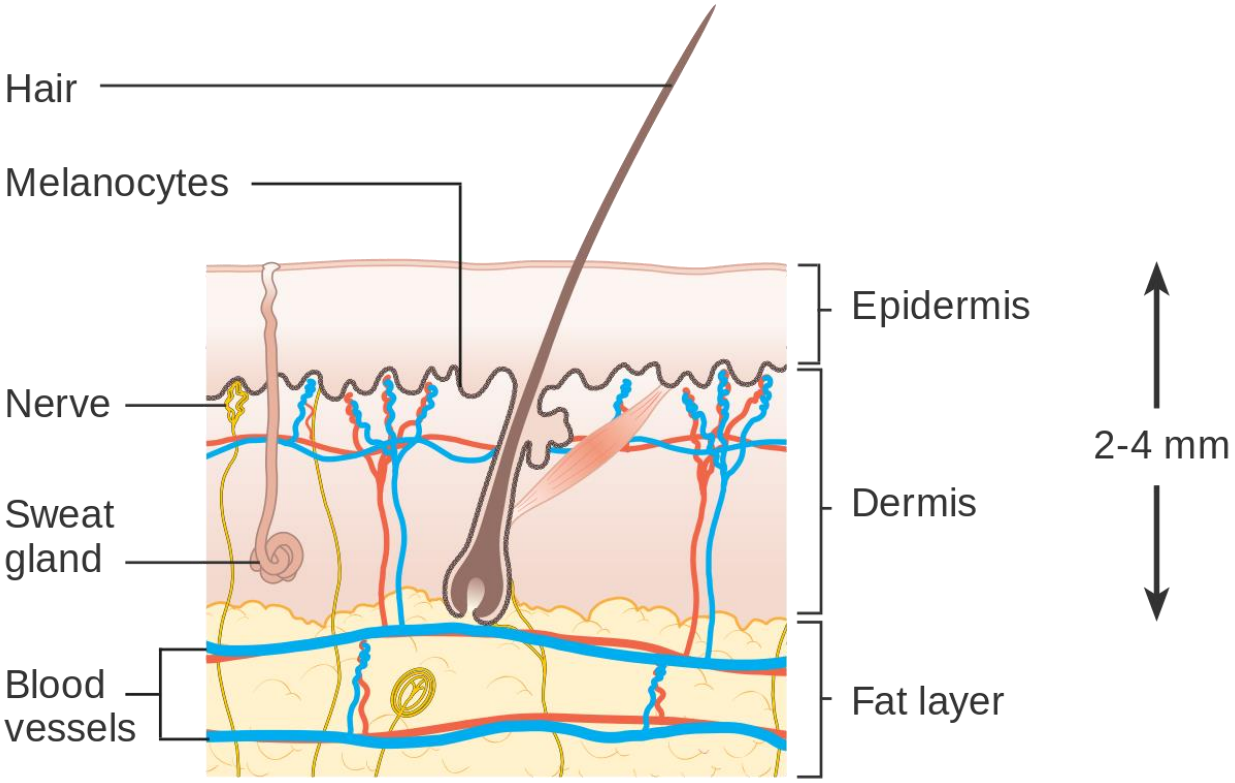
Excretion and Homeostasis in Unicellular Organisms

- ✓ Protozoa such as amoeba depend on diffusion as a means of excretion.
- ✓ They have a large surface area to volume ratio for efficient diffusion.
- ✓ Nitrogenous waste and carbon (IV) oxide are highly concentrated in the organism hence they diffuse out.
- ✓ In amoeba excess water and chemicals accumulation in the contractile vacuole.
- ✓ When it reaches maximum size the contractile vacuole moves to the cell membrane, bursts open releasing its contents to the surroundings.

Excretion in Human Beings

- ✓ Excretion in humans is carried out by an elaborate system of specialised organs.
- ✓ Their bodies are complex, so simple diffusion cannot suffice.
- ✓ Excretory products include nitrogenous wastes which originate from deamination of excess amino acids.
- ✓ The main excretory organs in mammals such as human beings include lungs, kidneys, skin and liver.

Structure and function of the human skin



Nerve Endings:

These are nerve cells which detect changes from the external environment thus making the body to be sensitive to touch, cold, heat and pressure.

Subcutaneous Fat:

- ✓ Is a layer beneath the dermis.
- ✓ It stores fat and acts as an insulator against heat loss.

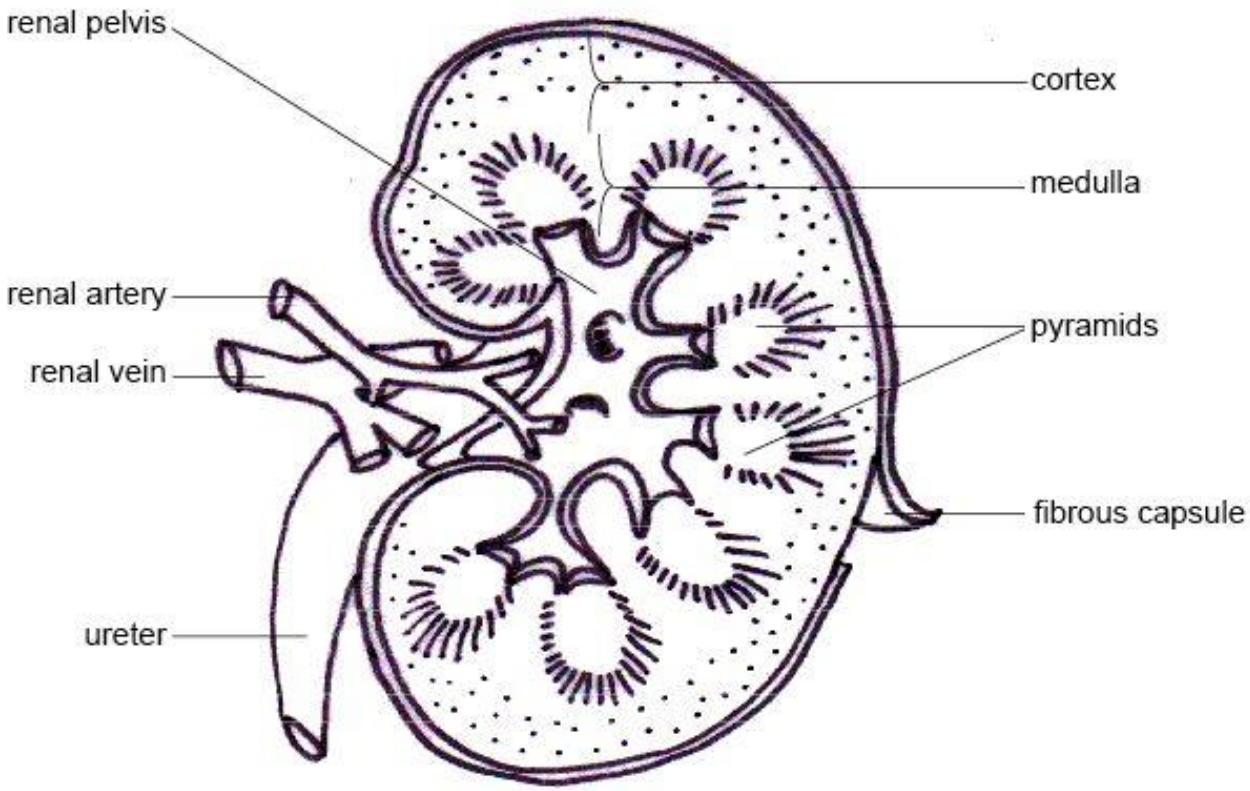
- ✓ The skin helps in elimination of urea, lactic acid and sodium chloride which are released in sweat.

The Lungs

- ✓ Carbon (IV) oxide formed during tissue respiration is removed from the body by the lungs.
- ✓ Mammalian lungs have many alveoli which are the sites of gaseous exchange.
- ✓ Alveoli are richly supplied with blood and have a thin epithelium.
- ✓ Blood capillaries around the alveoli have a high concentration of carbon (Iv) oxide than the alveoli lumen.
- ✓ The concentration gradient created causes carbon (IV) oxide to diffuse into the alveoli lumen.
- ✓ The carbon (IV) oxide is eliminated through expiration.

Structure and Functions of the Kidneys

- ✓ The kidneys are organs whose functions are excretion, osmoregulation and regulation of pH.
- ✓ Kidneys are located at the back of the abdominal cavity.
- ✓ Each kidney receives oxygenated blood from renal artery,
- ✓ While deoxygenated blood leaves through the renal vein.
- ✓ Urine is carried by the ureter from the kidney to the bladder, which temporarily stores it.
- ✓ From the bladder, the urine is released to the outside via the urethra.
- ✓ The opening from the urethra is controlled by a ring-like sphincter muscle.
- ✓ A longitudinal section of the kidney shows three distinct regions: a darker outer cortex, a lighter inner medulla and the pelvis.
- ✓ The pelvis is a collecting space leading to the ureter which takes the urine to the bladder from where it is eliminated through the urethra.



The Nephron

- ✓ A nephron is a coiled tubule at one end of which is a cup-shaped structure called the Bowman's capsule.
- ✓ The capsule encloses a bunch of capillaries called the glomerulus.
- ✓ The glomerulus receives blood from an afferent arteriole a branch of the renal artery.
- ✓ Blood is taken away from the glomerulus by efferent arteriole leading to the renal vein.
- ✓ The Bowman's capsule leads to the proximal convoluted tubule that is coiled and extends into a U-shaped part called loop of Henle.
- ✓ From the loop of Henle is the distal convoluted tubule that is also coiled.
- ✓ This leads to the collecting duct which receives contents of many nephrons.
- ✓ Collecting ducts lead to the pelvis of the kidney.

Mechanism of Excretion

- ✓ Excretion takes place in three steps:
- ✓ Filtration, reabsorption and removal.

Filtration

- ✓ The kidneys receive blood from renal artery a branch of the aorta.
- ✓ This blood is rich in nitrogenous waste e.g. urea.
- ✓ It contains dissolved food substances, plasma proteins, hormones and oxygen.
- ✓ Blood flow in capillaries is under pressure due to the narrowness of the capillaries.
- ✓ The afferent arteriole entering the glomerulus is wider than the efferent arteriole leaving it.
- ✓ This creates pressure in the glomerulus.
- ✓ Due to this pressure, dissolved substances such as urea, uric acid, glucose, mineral salts and amino acids are forced out of the glomerulus into the Bowman's capsule.
- ✓ Large sized molecules in the plasma such as proteins and red blood cells are not filtered out because they are too large.
- ✓ This process of filtration is called ultra-filtration or pressure filtration and the filtrate is called glomerular filtrate.

Selective Reabsorption

- ✓ As the filtrate flows through the renal tubules the useful substances are selectively reabsorbed back into the blood.
- ✓ In the proximal convoluted tube all the glucose, all amino acids and some mineral salts are actively reabsorbed by active transport.
- ✓ The cells lining this tubule have numerous mitochondria which provide the energy needed.
- ✓ Cells of the tubule have microvilli which increases the surface area for re-absorption.
- ✓ The tubule is coiled, which reduces the speed of flow of the filtrate e.g. giving more time for efficient re-absorption.
- ✓ The tubule is well supplied with blood capillaries for transportation of reabsorbed substances.
- ✓ The ascending loop has thick wall and is impermeable to water.
- ✓ Sodium is actively pumped out of it towards the descending loop.

- ✓ As glomerular filtrate moves down the descending loop, water is reabsorbed into the blood by osmosis in the distal convoluted tubule and in the collecting duct.
- ✓ Permeability of the collecting duct and proximal convoluted tubule is increased by anti-diuretic hormone (ADH) whose secretion is influenced by the osmotic pressure of the blood.
- ✓ The remaining fluid consisting of water, urea, uric acid and some mineral salts is called urine.
- ✓ The urine is discharged into the collecting duct and carried to the pelvis.
- ✓ The loop of Henle is short in semi¬-aquatic mammals, and long in some mammals like the desert rat.

Removal

The urine is conveyed from the pelvis to the ureter.

The ureter carries the urine to the bladder where it is stored temporarily and discharged to the outside through the urethra at intervals.

Common Kidney Diseases

Uraemia

This is a condition in which concentration of urea in the blood.

It may be due to formation of cysts in tubules or reduction in blood supply to the glomeruli as a result of contraction of renal artery.

Symptoms

- ✓ Symptoms include yellow colouration of skin, smell of urine in breath, nausea and vomiting.
- ✓ Treatment includes dialysis to remove excess urea and a diet low in proteins and salts especially sodium and potassium.

Kidney Stones

- ✓ Kidney stones are solid deposits of calcium and other salts.
- ✓ They are usually formed in the pelvis of the kidney where they may obstruct the flow of urine.

- ✓ **Causes:** the stones are formed due to crystallisation of salts around pus, blood or dead tissue.
- ✓ **Symptoms:** include blood in urine, frequent urination, pain, chills and fever. Severe pain when urinating.

Treatment

- ✓ Use of laser beams to disintegrate the stones.
- ✓ Pain killing drugs like morphine.
- ✓ Stones can be removed by surgery.
- ✓ Taking hot baths and massage.

Nephritis

- ✓ Nephritis is the inflation of glomerulus of the kidney.
- ✓ Causes: Bacterial infection, sore throat or tonsillitis, blockage of glomeruli by antibody-antigen complex.
- ✓ Signs and Symptoms: include headaches, fever, vomiting, and oedema.
- ✓ Control includes dietary restrictions especially salt and proteins.
- ✓ Prompt treatment of bacterial infections.

Role of Liver in Excretion

- ✓ The liver lies below the diaphragm and it receives blood from hepatic artery and hepatic portal vein.
- ✓ Blood flows out of the liver through hepatic vein.
- ✓ Excretion of Nitrogenous Wastes
- ✓ Excess amino acids cannot be stored in the body, they are deaminated in the liver.
- ✓ Hydrogen is added to amino group to form ammonia which combines with carbon (IV) oxide to form urea.
- ✓ The urea is carried in the blood stream to the kidneys.

- ✓ The remaining carboxyl group, after removal of amino group, is either oxidised to provide energy in respiration.
- ✓ Or built up into carbohydrate reserve and stored as glycogen or converted into fat and stored.

Breakdown and Elimination of Haemoglobin

- ✓ Haemoglobin is released from dead or old red blood cells which are broken down in the liver and spleen.
- ✓ Haemoglobin is broken down in the liver and a green pigment biliverdin results which is converted to yellow bilirubin.
- ✓ This is taken to the gall bladder and eliminated as bile.

Elimination of Sex Hormones

Once they have completed their functions, sex hormones are chemically altered by the liver and then taken to the kidney for excretion.

Common Liver Diseases

Cirrhosis

Cirrhosis is a condition in which liver cells degenerate and are replaced by scar tissue .

This causes the liver to shrink, harden, become fibrous and fail to carry out its functions.

Causes

Chronic alcohol abuse, schistosomiasis infection, obstruction of gall-bladder.

Symptoms

Headache, nausea, vomiting of blood and lack of appetite, weight loss, indigestion and jaundice.

Control and Treatment

- ✓ Avoid alcohol consumption and fatty diet.
- ✓ Use drugs to kill the schistosomes if that is the cause.

Jaundice

This is a yellow colouration of the skin and eyes.

Cause:

- ✓ Presence of excess bile pigments.
- ✓ This happens due to blockage of bile duct or destruction of liver.

Symptoms:

Yellow pigmentation of skin and eyes, nausea, vomiting and lack of appetite. Itching of skin.

Treatment

- ✓ Removal of stones from the gall bladder by surgery.
- ✓ Give patient fat-free diet, reduced amount of proteins.
- ✓ Give antihistamines to reduce itching.

Homeostasis

Homeostasis is the maintenance of a constant internal environment.

The internal environment consists of intercellular or tissue fluid.

This fluid is the medium in the space surrounding cells.

Tissue fluid is made by ultra-filtration in the capillaries.

Dissolved substances in the blood are forced out of the capillaries and into intercellular spaces.

Cells obtain their requirements from tissue fluid while waste products from cells diffuse out into the tissue fluid.

Some of the fluid gets back into the blood capillaries while excess fluid is drained into the lymph vessels.

Cells function efficiently if there is little or no fluctuation in the internal environment.

The factors that need to be regulated include temperature, osmotic pressure and pH.

The body works as a self-regulating system and can detect changes in its working conditions bringing about corrective responses.

This requires a negative feedback mechanism e.g. when body temperature falls below normal, mechanisms are set in place that bring about increase in temperature.

And when the increase is above normal, mechanisms that lower the temperature are set in place.

This is called a negative feedback and it restores the conditions to normal.

Neuro-Endocrine System and Homeostasis

Homeostatic mechanisms are brought about by an interaction between nervous and endocrine systems.

Nerve endings detect changes in the internal and external environment and relay the information to the brain.

The hypothalamus and pituitary are endocrine glands situated in the brain.

The hypothalamus detect changes in the blood.

The pituitary secretes a number of hormones involved in homeostasis e.g. anti-duretic hormone (ADH).

The discussion below shows the nature of these interactions.

The Skin and Temperature Regulation

The optimum human body temperature is 36.8°C.

A constant body temperature favours efficient enzyme reaction.

Temperatures above optimum denature enzymes, while temperature below the optimum range inactivate enzymes.

The skin is involved in regulation of body temperature as follows:

The skin has receptors that detect changes in the temperature of the external environment.

When the body temperature is above optimum the following takes place:

Sweat:

Sweat glands secrete sweat onto the skin surface.

As sweat evaporates it takes latent heat from the body, thus lowering the temperature.

Vasodilation of Arterioles:

The arterioles near the surface become wider in diameter.

More blood flows near the surface and more heat is lost to the surrounding by convection and radiation.

Relaxation of hair erector muscle:

When hair erector muscles relax, the hair lies flat thus allowing heat to escape from the skin surface.

When body temperature is below optimum the following takes place:

Vasoconstriction of Arterioles:

The arterioles near the surface of the skin become narrower.

Blood supply to the skin is reduced and less heat is lost to the surroundings.

Contraction of hair erector muscles.

When hair erector muscles contract, the hair is raised.

Air is trapped between the hairs forming an insulating layer.

Animals in cold areas have a thick layer of subcutaneous fat, which helps to insulate the body.

Besides the role of the skin in thermoregulation as discussed above, the rate of metabolism is lowered when temperature is above optimum and increased when temperature is below optimum.

The latter increases the temperature to the optimum.

When this fails, shivering occurs.

Shivering is involuntary contraction of muscles which helps to generate heat thus raising the body temperature.

Homeostatic Control of Body Temperature in Humans

Body size and Heat Loss

The amount of heat produced by metabolic reactions in an animal body is proportional to its mass.

Large animals produce more heat but they lose less due to small surface area to volume ratio.

Small animals produce less heat and lose a lot, due to large surface area to volume ratio.

Small animals eat a lot of food in relation .to their size in order to raise their metabolic rate.

Behavioural and Physiological Responses to Temperature Changes

Animals gain or lose heat to the environment by conduction, radiation and convection.

Birds and mammals maintain a constant body temperature regardless of the changes in the environment.

They do this mainly by internally installed physiological mechanisms hence they are endotherms, also known as homoiotherms.

At the same time behavioural activities like moving to shaded areas when it is too hot assist in regulating their body temperature.

Other animals do not maintain a constant body temperature e.g. lizards.

They are poikilotherms (ectotherms) as their temperature varies according to that of surroundings.

They only regulate body temperature through behavioural means.

Lizards bask on the rocks to gain heat and hide under rocks when it is too hot.

Some animals have adaptive features e.g. animals in extreme cold climates have fur and a thick layer of subcutaneous fat like polar bear.

Those in extremely hot areas have tissue that tolerate high temperatures e.g. camels.

Some animals avoid cold conditions by hibernating e.g. the frog while others avoid dry hot conditions by aestivation e.g. kangaroo rat.

This involves decreasing their metabolic activities.

Skin and Osmoregulation

Osmoregulation is the control of salt and water balance in the body to maintain the appropriate osmotic pressure for proper cell functioning.

Sweat glands produce sweat and thus eliminate water and salt from the body.

The Kidney and Osmoregulation

The kidney is the main organ that regulates the salt and water balance in the body.

The amount of salt or water reabsorbed into the bloodstream is dependent on the osmotic pressure of the blood.

When the osmotic pressure of the blood rises above normal due to dehydration or excessive consumption of salt, the osmo-receptors in the hypothalamus are stimulated.

These cells relay impulses to the pituitary gland which produces a hormone called anti-diuretic hormone - ADH (vasopressin) which is taken by the blood to the kidneys.

The hormone (ADH) makes the distal convoluted tubule and collecting duct more permeable to water hence more water is reabsorbed into the body by the kidney tubules lowering the osmotic pressure in the blood.

When the osmotic pressure of the blood falls below normal due to intake of a large quantity of water, osmoreceptors in the hypothalamus are less stimulated.

Less antidiuretic hormone is produced, and the kidney tubules reabsorb less water hence large quantities of water is lost producing dilute urine (diuressis).

The osmotic pressure of the blood is raised to normal.

If little or no ADH is produced, the body may become dehydrated unless large quantities of water are consumed regularly.

Diabetes insipidus is a disease that results from the failure of the pituitary gland to produce ADH and the body gets dehydrated.

A hormone called Aldosterone produced by the adrenal cortex regulates the level of sodium ions.

When the level of sodium ions in the blood is low, adrenal cortex releases aldosterone into the blood.

This stimulates the loop of Henle to reabsorb sodium ions into the blood.

Chloride ions flow to neutralise the charge on sodium ions.

Aldosterone also stimulates the colon to absorb more sodium ions into the blood.

If the sodium ion concentration rises above optimum level, adrenal cortex

The liver

Formation of Red Blood Cells.

In the embryo, red blood cells are formed in the liver.

Breakdown and elimination of old and dead blood cells.

Dead red blood cells are broken down in the liver and the pigments eliminated in bile.

Manufacture of Plasma Proteins.

Plasma proteins like albumen, fibrinogen and globulin are manufactured in the liver.

Storage of blood, vitamins A, K, BI2 and D and mineral salts such as iron' and potassium ions.

Detoxification. Toxic substances ingested e.g. drugs or produced from metabolic reactions in the body are converted to harmless substances in a process called detoxification.