EXCRETION and HOMEOSTASIS IN PLANTS AND ANIMALS

DEFINITION OF EXCRETION

This is the process by which living organisms removes metabolic waste products from its body. The waste products include urea, excess salts excess water and cardon dioxide.

Note:

1. egestion involves the removal of undigested food from the body through the anus.

ii) Secretion which involves the manufacture and release of substances/useful by-products of metabolism by living cells e.g. enzymes, mucus, hormones, nectar etc.

NECESSITY OF EXCRETION

1. To remove toxic waste products whose accumulation in the body would soon become harmful and poisonous to living cells?
2. Organisms cannot always exercise strict control over nutrients they ingest. Sometimes they ingest materials in excess of what they need. The excess must be eliminated and excretion is an important part here.
3. To regulate the PH of the body fluids which would affect enzyme activity.
4. To facilitate continued production of the required products which would be prevented by accumulation of waste products.

COMMON EXCRETORY PRODUCTS OF ORGANISMS

Excretory substance	**How formed**	**How & where excreted**
Oxygen	During photosynthesis in green plants	Leaves of green plants e.g. by diffusion through stomata
Carbon dioxide	In respiration of most living things	From gaseous exchange surfaces e.g. lungs or gills & by diffusion over cell surface. In flowering plants by diffusion through stomata
Water	In Aerobic respiration	By osmosis or evaporation at the cell surface
Ions	In synthesis of metabolites	Ions in excess, those that can't be stored, toxic ones may be excreted in sweat, or urine by kidney, or deposited in dead cells of woody plants
Nitrogenous wastes e.g. Ammonia, urea, uric acid	Metabolism of proteins & nucleic acids	Ammonia by diffusion in small aquatic organism, urea is excreted by excretory organs (kidney)
Organic acids e.g. oxalic acid	Synthesis of substances (harmful to herbivores & predator)	Deposited in cells of stem or leaves.
Bile pigments	In breakdown of haemoglobin	In bile stored in the gall bladder and egested in feaces out of body.

Excretory products fall into two categories namely;

A. Nitrogenous excretory products

These are waste products which contain nitrogen.

They include **urea**, **uric acid, ammonia and trimethylamine oxide**.

The nitrogenous excretory substances have disadvantages and advantages in the form they are eliminated.

i) Ammonia it is commonly excreted by aquatic animals (toads, fresh water fish) with problem of excess water in their body. However, it requires less energy to be removed since it's very soluble in water.

Advantages of excreting ammonia to animals are;

i) To remove excess water from the body in the process of diluting ammonia.

ii) Its removal requires less energy. The it leads to conservation of energy by the body.

Disadvantages of excreting ammonia to animals

It's highly toxic**/ poisonous** in body and **requires more water for removal**.

ii) Urea is less toxic in body, less soluble and thus it needs less water for removal. Its excreted by land animal.

Disadvantage: However much energy is needed for its removal.

iii) Uric acid it is insoluble in water, non-poisonous ,hence it requires little water for its excretion/removal.

Advantages of excreting uric acid is to conserve water .its commonly excreted by desert animals lizards and insects

Disadvantage:

However, **much energy** is required to eliminate it out.

B. Non nitrogenous excretory products

These are waste products which don't contain nitrogen in them.

They include ***excess water***, ***excess salts*** ,**CO_2** and **Bile pigments**

Nitrogenous excretory products and their organs in some organisms

Organism	**Habitat**	**Nitrogenous excretory products**	**Excretory organ**
Cartilaginous fish	Marine (aquatic)	Urea	Kidney
Bony fish	Marine (aquatic) Fresh H_2O (aquatic)	Trimethylamine oxide Ammonia	Kidney Kidney
Tadpoles	Aquatic (fresh water)	Ammonia	Gills
Adult amphibian	Aquatic and land	Urea on	Kidney

		land & ammonia in H_2O	
Insects	Terrestrial	Uric acid	Malpighian tubules
Reptiles	Terrestrial	Uric acid	Kidney
Birds	Terrestrial	Uric acid	Kidney
Mammals	Terrestrial	Urea	Kidney
Flat worms	Terrestrial		Flame cells
Annelids	Terrestrial		nephridia
Platyhelminthes	Terrestrial		Flame cells

EXCRETION IN MAN

In man and most other mammals the main excretory organs are: lungs, kidney, skin and liver. In the lungs, water and CO_2 are excreted in the process of breathing out.

The table below shows the organs, their products and excretory component.

Organ	**Products**	**Excretory products**
Kidney	Urine	Urea, excess water ,excess salts,
Skin	Sweat	excess water ,excess salts,
Lungs	Exhaled air	Water vapour, cardon dioxide

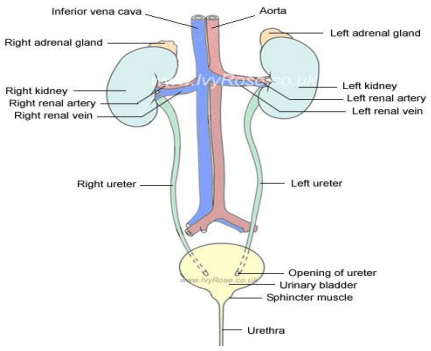
THE KIDNEYS AND URINARY SYSTEM

Position and structure of kidneys in human body

Kidneys are two in number, each one found on the side of the abdomen. They are red brown in colour, bean shaped and attached to the dorsal wall of abdominal cavity on either side of vertebral column, with the left one being slightly higher than the right.

The functional unit of the kidney is the blood filtration unit called ***NEPHRON***.

DIAGRAM OF THE URINARY SYSTEM OF MAN



PARTS OF URINARY SYSTEM

1 KIDNEY

Functions of kidneys

I) **EXCRETION**:-They remove unwanted nitrogenous substances such as urea, ammonium compounds and dissolved CO_2 from blood in form of urine.

ii) **OSMOREGULATION**:-this is the control of the water content and salt concentration in the body of an organism. They also get rid of excess H_2O and salts thereby keeping the osmotic concentration and volume of blood constant i.e. carries out osmoregulation.

iii) **REGULATION OF PH :-helps** in maintaining the pH of blood.

iv) **IONIC BALANCE (salts)**

Lying above each kidney is a conical gland called **adrenal gland**. These secrete **adrenalin** from

their medulla.

2. Renal artery

This arises from dorsal aorta. It carries **0xygenated bl**ood with excretory waste products and all food materials like glucose, proteins, fatty, and glycerol water and salts to the kidney. i.e there blood contains less CO_2, more O_2, much excretory wastes, much food nutrients.

3. Renal vein

This is a blood vessel, which carries **deoxygenated filtered blood** with very little urea and normal amounts of salts and water from the kidney to the posterior venacava. i.e Blood contains much CO_2, less O_2, very little excretory wastes/urea, no food nutrients

4. Aorta. It carries oxygenated blood with all food nutrients to all body capillaries

5. Ureters

These are narrow tubes, which arise from kidney and they connect the kidney to the urinary bladder.

They **carry urine from the kidney to the urinary bladder**

6. Urinary bladder

It is thick walled and elastic sac like structure which stores urine temporarily.

7. Sphincter muscles

These muscles are elastic and thus contract and expand to control the urine flow through urethra to the outside.

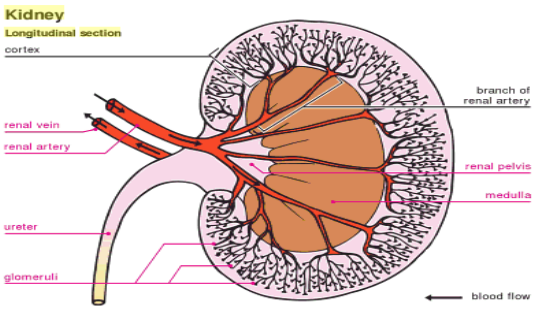
8. Urethra

This is a narrow muscular tube that allows passage of urine.

The urethra of males is longer than that of females because it runs throughout the erectile organ, the penis. The urethra is the exit of urine from body.

KIDNEY

Longitudinal section of kidney



The **kidney** consists of two distinct regions namely:

i) Outer dark coloured region called **cortex**

ii) Inner paler coloured region called **medulla**

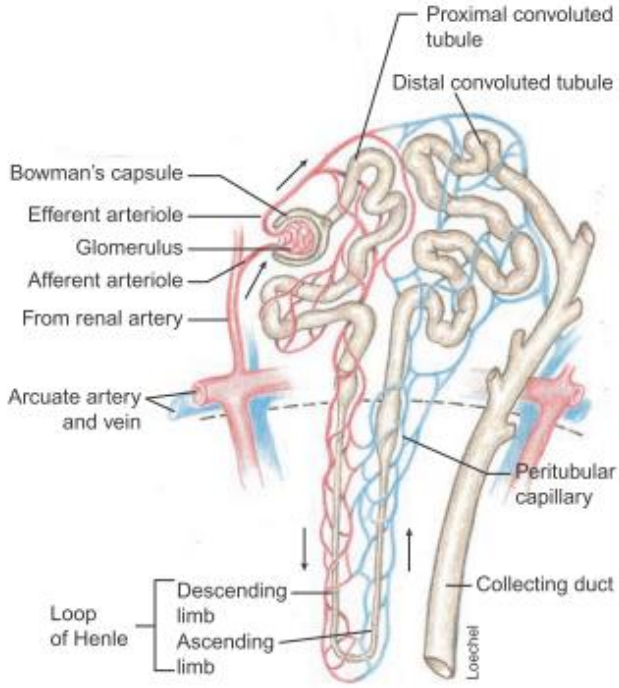
The cortex consists of **Bowman's** capsule which is responsible for ultrafiltration of blood passing through it.

The medulla is made up of many cone-shaped portions called **pyramids**. It also contains many tubules w play a role of collecting the excretory fluid. The pyramids open into a funnel-shaped cavity near the he called **pelvis.** The pelvis is continuous to the ureter and plays a role of conveying the excretory fluid to the bladder.

Each kidney contains over a million functional units called **nephrons**. Each nephron has a

rich supply blood. **Nephrons** are responsible for purification and regulation of blood composition at a steady level. This is achieved by removing the constituents/components of urine.

DIAGRAM SHOWING A KIDNEY NEPHRON



Bowman's capsule

This is a cup-shaped funnel structure of nephron. It contains a dense-network of capillaries called **glomerulus**

The glomerulus is formed from the wider arteriole of renal artery called **afferent arteriole**

The Bowman's capsule serves the function of filtering small molecules in blood such as urea glucose etc, process called **ultrafiltration**. Bowman's capsule is found in the cortex of kidney

Afferent arteriole

It carried blood for filtration to the Bowman's capsule. It's wider than efferent arteriole rising pressure. **Efferent arteriole**

This blood vessel carries filtered blood containing mainly red blood cells, white blood cells, platelets, plasma proteins and some H_2O leaving the to convoluted tubules to renal vein.

Proximal convoluted tubule

This is a highly coiled tubule that runs from the Bowman's capsule to the U-shaped structure called **loop of Henle.** This is a site where re-absorption of useful materials such as ions like Na+, glucose and some small amino acids and water from glomerular filtrate back to blood takes place.

Loop of Henle

This is a U-shaped part of nephron connecting the proximal and distal convoluted tubules. It's embedded in both medulla and cortex region. It's made up of a descending (going down) limb and an ascending (going up) limb. Salt (Na^+, Cl^-) diffuses out passively in lower part of ascending limb and actively in upper portion. These are sites where selective reabsorption of water and salts takes place. It's known to cause the retention of water. This is one way of conserving water in camel because of its extremely long loop of Henle.

Distal convoluted tubule

This lies in cortex region. It chiefly re-absorbs salts like chloride ions together with water, leaving a

concentrated liquid now called **urine** which passes down to collecting ducts.

Collecting duct

This is a channel through which urine formed is carried to the pelvis of kidney. It also allows outward movement of H_20 from it hence conserving the water, a process called **osmotic return**.

THE EXCRETORY FUNCTION OF KIDNEY (i.e urine formation)

There are three steps that are involved in urine formation. These are:

i) Ultra filtration of blood in glomerulus.
ii) Selective reabsorption along the length of nephron.
iii) Tubular secretion along the distal convoluted tubule.

Ultra filtration

Blood which enters the glomerulus is under higher pressure due to pumping action of heart. Higher pressure is created further due to the afferent arteriole being wider than efferent arteriole. Because of the permeability of capillary walls of blood vessels together with higher pressure in glomerulus, small molecules such as glucose, water, vitamins, urea, amino acids, mineral, salts, ammonia pass from blood into **capsular space of Bowman's capsule** forming the glomerular filtrate.

This process leading to formation of glomerular filtrate is called ultra filtration. Blood proteins and blood cells do not filter trough since their molecules are too large to pass across the capillary wall. The glomerular filtrate formed flows into the proximal convoluted tubule.

Selective reabsorption As the glomerular filtrate flows along **the proximal convoluted tubule**, useful materials such as glucose, amino acids are actively re-absorbed into blood. This process occurs by active transport since energy is involved in pumping of these substances across the tubular capillaries, other substances such as urea, ammonia and other nitrogenous wastes are completely retained, mineral salts are reabsorbed by active transport and H_2O is re-absorbed by the process of osmosis,

In the loop of Henle, more osmotic reabsorption of H_2O takes place in the thin descending limb leading to the increasing concentration of the filtrate down descending limb.

All the glucose and large percentage of the salts are reabsorbed. As the filtrate ascends the thick ascending limbs of the Henle salts like Na and K are **actively** lost to the medulla tissues of the kidney leading to the decreasing concentration of the filtrate up the ascending limb.

As the medulla tissues receive the salts from the ascending limb they become highly concentrated. This selective re-absorption ensures that useful materials are not lost from the body.

The remaining liquid passes to the **distal convoluted tubule** where salts are reabsorbed by ***diffusion process.*** It then moves down to collecting duct where more H_2O is reabsorbed into the capillaries regulating the concentration of blood.

The end product now is called **urine**, which contains excess water, excess salts, and urea which is carried by collecting ducts to the renal pelvis then through the ureters to **the bladder** where it's stored. Urea is formed in liver according to equation

Ammonia + Carbon dioxide $\longrightarrow$ Urea + Water

$NH_3 + CO_2 \longrightarrow CO(NH_2)_2$ (Less poisonous)

SUMMARY OF STEPS INVOLVED IN URINE FORMATION IN KIDNEY.

Name	Process	Examples of molecules
Ultra filtration (Pressure filtration)	Blood pressure forces small molecules from the glomerulus into bowman's capsule	Water, glucose, amino acids, salts, urea, uric acid, creatinine

Substance	Blood plasma entering glomerulus	Glomerular filtrate	Urine	Approx. degree of concentration.

Selective reabsorption	Diffusion and active transport return molecules to blood at the proximal convoluted tubule.	Glucose, water, salts and amino acids.
Tubular secretion	Active transport moves molecules from blood into the distal convoluted tubule.	Uric acid, creatinine, ammonia and hydrogen ions.
Reabsorption of water	Along the length of the nephron and notably at loop of Henle and collecting duct, water returns by osmosis following active reabsorption of salts.	Salts and water.
Excretion	Urine formation rids body of metabolic wastes	Water, salts, urea, uric acid,

Adaptations of the tubules to the reabsorption function.

I. Cells lining tubules have many mitochondria to provide energy for active reabsorption of materials.
II. The tubules are lining has microvilli to increase the surface area for reabsorption of materials
III. Tubules are long and highly coiled to increase the surface area for reabsorption of materials
IV. Coiling of the proximal and distal convoluted tubules slows down movement of the filtrate to allow more time for efficient reabsorption.
V. Tubules are well supplied with blood capillaries for efficient transport of reabsorbed materials.
VI. The loop of Henle has a counter-current flow system of blood and the glomerular filtrate, for maximum re-absorption.
VII. They have thin membranes for easy diffusion of materials.

Adaptations of the Bowman's capsule

I. possession of a cup shape enables collection of filtrate.
ii).having porous membranes that easily allow filtrate to pass through.
iii) Having large volume to accommodate more filtrate.

TABLE: COMPOSITION OF FLUID IN KIDNEY

Water	90-93	90.0	95.0	1.06
Proteins	07-09	0,0	0.0	0.00
Glucose	0.1	0.1	0.0	0.00
Urea	0.03	0.03	2.0	66.67
Sodium ions	0.32	0.32	0.35	1.09
Chloride ions	0.37	0.37	0.60	1.62
PH	7.35-7.46		4.7-6.0	

From the table the following observations are made;-

i) the %age composition of water in urine increases because some materials are fully reabsorbed back into the blood capillaries.e.g.glucose

ii) Percentage composition of protein is zero in the glomerular filtrate because it is filtered due to their large size.

iii) Urea % composition shoots up in the urine because it is not reabsorbed all yet other substance like glucose is all reabsorbed. urea increases in urine by the **concentration factor** of; 2 / 0.03= **66.7**

Note. Animals living in arid areas have longer loops of Henle to allow more H_2O re-absorption. They also produce less glomerular filtrate because they have reduced number and size of glomeruli.

EXCRETION IN PLANTS

Excretory products of plants. These are

i. **Water** - produced during tissue respiration

ii.**$C0_2$** - produced during tissue respiration

iii. **Oxygen** produced during photosynthesis

Plants do not require special excretory organs as animals because of the following.

i. They are less metabolically active compared to animals e.g. they don't locomote like animals.

ii. Plants produce waste products very slowly due to low metabolic rate, hence low accumulation of metabolic wastes

Iii. Plants synthesize all their organic requirements according to demand hence no excess is always produced

Iv. Some wastes such as organic acids which may happen to be harmful are always neutralized by many salts, precipitated and stored safely in plants.

V. Some substances are eliminated in different parts of plants e.g. leaves through falling when mature.

Vi. The main excretory products i.e. CO_2, H_2O and O_2 are always used as raw materials for other metabolic processes which are vital to a plant.e.g.CO_2 IS used for photosynthesis while O_2 produced by photosynthesis is used in respiration.

Vii. They are even able to store waste products within their dead permanent tissues such as leaves, barks of stem. Some of these products include: tannins and alkaloids.

TANNINS

These are bitter tasting substances usually in bark of trees, under ripe fruits and certain seeds. Tannin is useful in making ink and tanning leather.

Alkaloids

These are poisonous nitrogenous compounds insoluble in water and stored in various parts. They include:
Quinine- This is used as anti-malarial drug extracted from cinchona tree.
Morphine- extracted from opium used for easing severe pain
Caffeine- found in coffee and tea used as stimulants in small quantities, increases mental activity and reduces fatigue. Addiction may cause heart and kidney damage.
Nicotine - found in the leaves of tobacco. It can be used as an insecticide.
Cocaine - Used as local anaesthetic and an intoxicant extracted from cocoa leaves

OSMOREGULATION IN ORGANISMS

Osmoregulation is the process by which water and dissolved solutes in the body are regulated at relative constant level.
Contents, which are osmoregulated in organisms, include sugars, amino acids, and inorganic ions such as K^+, Na^+, H^+, Cl^-, NO_3^-, HCO_3^-, as well as water content.
Hence, **osmoregulation** is a mechanism of keeping an organism's water content constant.

When blood concentration lowers/high water potential, the cells absorb water by osmosis, expand and rupture/**burst** leading to leaking of blood into the vessels a process called **haemolysis/hemorrhage.**

When the blood concentration increases/high salt content, compared to the cells, the cells lose water by osmosis and **shrink**. Shrinking and haemolysis of the cells leads to impaired functioning of the blood.e.g.reduced transportation of respiratory gases and internal bleeding respectively.

The blood concentration lowers when organism
I. takes a lot of water.e.g dilute alcohol
Ii.does not take salts
And decreases when organism,
I. does not take water
Ii.takes a lot of salts
Iii.sweat a lot.
To maintain blood concentration constant, one has to balance water and salt lose and gain

PROCESS OF OSMOREGULATION IN MAN

a. Organisms gain H_2O in body by:
I. Direct drinking of H_2O and other H_2O containing substances
Ii.Eating food/ juicy fruits
Iii.Metabolism of food i.e. metabolic H_2O produced during respiration
b.organisms loses water from the body in the following ways:
1. Exhaled air during breathing out/exhalation.
2. Defecation through faeces
3. Sweating through sweat
4. Urinating through urine
5. Evaporation from mouth parts

Salts in the body are gained from ingesting salty foods and lost through sweating through sweat and urinating through urine.

WATER BALANCE IN MAN

The balance of water is maintained by the kidney and neuro-endocrine systems.

When the **osmotic pressure of blood rises** due to the increase in amount of dissolved solutes/as a result of dehydration, the hypothalamus(has osmoreceptors) located in the brain is stimulated to send nerve impulses to the posterior lobe of pituitary gland to release a hormone called **Antidiuretic hormone** (ADH) also called Vasopressin.
This hormone causes the kidney tubules (DCT and collecting duct) to become more permeable to water during urination formation;
They osmotically reabsorb more water into the blood **thus** making the urine more concentrated (hypertonic).hence the osmotic pressure falls to normal level.

If the **blood osmotic pressure is low/falls below normal** (i.e when there is more water and low solute content), the pituitary gland is less stimulated and less or no **antidiuretic hormone is** produced and as a result less water is re-absorbed from the tubules of nephrons resulting in production of large quantities of dilute urine. Hence osmotic pressure rises to normal.

Note . If an individual **does not drink** much water on a certain day, posterior lobe of pituitary gland releases ADH, more water is reabsorbed, blood volume is maintained at normal, and consequently there's less urine.
On the other hand, if an individual drinks a large volume of water and does not sweat much, the posterior lobe of pituitary gland does not release ADH, more water is excreted, blood volume is maintained at a normal level and a greater amount of urine is formed.

EFFECT OF ADH IN BODY

Increase in ADH	Increased reabsorption of water in kidney tubules	Less urine produced (antidiuresis)	Urine becomes concentrated
Decrease in ADH	Decreased reabsorption of water in kidney tubules	More urine (diuresis)	Urine becomes dilute

Diuresis means increased amount of dilute urine
Antidiuresis means decreased amount of urine/concentrated urine
ADH is secreted according to whether blood volume needs to be increased or decreased and when water is reabsorbed at the collecting duct blood volume increases.

NB.on cold days animals don't sweat leading to dilute blood due to accumulation of water .this limits ADH secretion and hence lowers water reabsorption by the kidney leading to production of large quantities of dilute urine causing frequent urination.When the pituitary gland fails to produce enough **Antidiuretic hormone** (ADH). Large amounts of dilute urine are produced (diuresis). This results in serious **thirst /** the patient is dehydrated and individual drinks a large amount of H_2O.this condition is called **diabetes insipidus.**

PROCESS OF OSMOREGULATION IN AMOEBA

An amoeba lives in fresh water which enters it by osmosis. If a lot of water enters it without being eliminate the cell bursts. However, the amoeba does not burst because it has a contractile vacuole. The contractile vacuole gets rid of excess water inside the body and releases it outside. The contractile vacuole eliminates excess water from the body without losing salts.

Similarly, vertebrates living in fresh water face such a problem e.g. tilapia in L. Victoria. These have kidneys as organs of osmoregulation. Their kidneys have numerous glomeruli resulting in the production of a large volume of glomerular filtrate. Hence these organisms produce a Large volume of dilute urine which they pass out.

Vertebrates living in marine (sea) water e.g. sharks have difficulties in obtaining water since they even lose water to the surrounding by osmosis. Such organisms have kidneys with less glomeruli that results in the production of little urine, so as to conserve water.

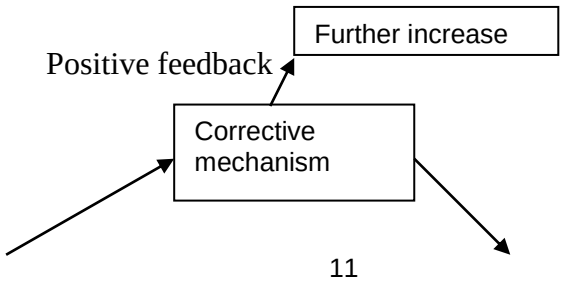
HOMEOSTASIS (Homoio = same, stasis = standing)

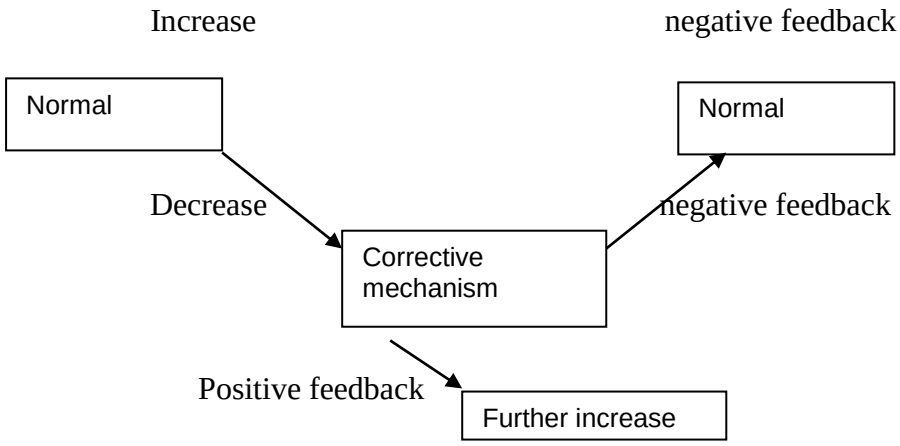
Homeostasis is the process or mechanism by which the internal environment of organisms is kept constant in living organisms. Internal environment is the immediate surroundings of the body cells. it is the tissue fluid.

FACTORS WHICH MUST BE KEPT CONSTANT
These include:
-Glucose
-blood PH
-Carbon dioxide
-Osmotic pressure determined by relative amounts of water and dissolved solutes.
-Temperature

COMPONENTS OF HOMEOSTATIC PROCESS
-**Set point** e.g. the set point for normal body temperature of man is 37°C
-**Sense organ** (receptors) which detects any deviation from set point
-**Control center** normally in brain which sends out instruction to correct deviation
-**Responding organs** (effectors) which implements the instruction to put back the deviation to set point
-**Feedback** which sends information to sense organ from responding organs of any corrective measure.
If the corrective action is taken to bring a given factor back to normal. Such a response is called **negative feed back.**
If the change below or above the normal is not corrected but instead there is further deviation, this is called **positive feed back.**

Homeostatic mechanism/scheme





THE LIVER AND REGULATION OF BLOOD SUGAR

The liver's main homeostatic function is to regulate the amount of food which reaches the blood and tissue fluid. It does so by mainly absorbing and storing the food, which it receives and then, releasing it into the circulatory system at a rate which depends on the body's current needs.

REGULATION OF BLOOD SUGAR

Importance of blood sugar regulation

Blood sugar (glucose) is the main source of energy and in case it's in very low amounts, less energy will be yielded thus affecting various parts of body which need that energy.
Any slight increase in glucose level alters the concentration of blood's osmotic pressure, which results in the alteration of the rate at which water moves in and out of body cells by osmosis.
]
The normal glucose level in blood of man is 90mg/100cm^3 of blood. It normally rises after heavy meal carbohydrates but does not exceed 150mg/100cc of blood. This is regulated by the liver together with a set of glands in the pancreas.

BLOOD SUGAR CONTROL

The level of sugar (glucose) in blood is regulated and controlled by two hormones namely:

i. **Insulin** - produced by **β**- cells of islets of langerhans of pancreas

Ii. Glucagon produced by **α**- cells of islets of langerhans of pancreas

When there is **an increase in glucose** level of blood, this level stimulates the **β**- cells of islets of langerhans of pancreas to release more insulin. This insulin secreted stimulates the liver cells to either:
-Convert the excess glucose to glycogen for storage in liver
-Convert the excess glucose into fat which is stored in adipose tissue or

-The excess glucose is used in tissue respiration to release energy. This energy is stored in a form of high energy compound called Adenosine triphosphate (ATP).

A drop/fall in the level of glucose inhibits the secretion of insulin and stimulates the **α**- cells of islets of langerhans of pancreas to release **glucagon**. Glucagon stimulates the liver cells to:
-Convert glycogen to glucose
-Convert fats and protein to glucose
-reduce the oxidative breakdown of glucose to carbondioxide and water.

When glucose is lost in urine, this abnormality is called **diabetes mellitus** and it's caused by the failure of the Pancreas to produce enough **insulin hormone.**

Symptoms
-glucose in urine
-frequent passing of urine
-feeling thirst due to excess loss of water
-loss of body weight
-chronic starvation.

Treatment and control
-Administration of insulin injection
-avoid foods rich in sugar and alcohol
-general control of the diet

THE MAMMALIAN SKIN
This is the most extensively distributed tissue found all over the body.
FUNCTIONS OF SKIN
I.It protects the underlying tissues from physical injury and prevents entry of bacteria
ii.It is a sense organ which enables the organism detect the changes in external environment
iii.It synthesizes vitamin D when exposed to sunlight
iv.It is an excretory organ. It excretes excess water and salts (sweat).
iv.It is used in the regulation of body temperature i.e. thermoregulation.

STRUCTURE OF SKIN

The skin is made up of two main layers namely:
1. Epidermis: It is made up of three layers which are:
I.Cornified layer (outer layer)
Ii.Granular layer
Iii.Malpighian layer (inner layer)

1. Cornified layer
This consists of flattened dead cells with keratin which offers protection to the inner tissues and reduces loss of water by evaporation.

FUNCTIONS

It provides a water proof layer for preventing the loss of body fluids
It provides protection against blows injurious chemicals and entry of bacteria and other foreign bodies

2. Granular layer

This contains living cells and lies next to the cornified layer. Its cells are pushed up to form the cornified layer. The cells here form a protein called keratin.

FUNCTIONS

It gives rise to new cornified layer.

3. Malpighian layer

It is made up of actively dividing cells by mitosis to give rise to new epidermis.

FUNCTION

-Produce new cells forming the epidermis thus maintaining the surface of skin and healing wounds

-It produces a pigment called melanin which determines the skin colour. It also protects the skin from ultra-violet light rays from the sunlight.

NB: Albinos do not produce melanin in their skin.

4. Hairs

These are found as protrusions through epidermis. They grow from pockets located in epidermis as invaginations of Malpighian layer called **hair follicle**. These are embedded in dermis. They are made up of a protein called **Keratin**.

FUNCTION

They trap air thus providing an insulating layer of air against heat loss by the body. They also offer protection to the body surface.

2. Dermis

It is a thick layer with blood vessels, nerve endings, sweat glands, hair and a subcutaneous layer of fat.

Sebaceous glands

They open into the hair follicles. They secrete an oily substance called sebum which makes the skin proof and smooth.

FUNCTIONS OF SEBUM

-It helps to keep the hairs smooth and water proof and also prevents the cornified layer surface from cracking in dry conditions.

-It acts as a mild anti-septic thus fighting and destroying certain bacteria

Erector muscle of hair

This controls the contraction of hair in response to fluctuations in body temperature

Sweat glands

It forms sweat by absorbing materials from the blood capillaries. They continue as **sweat ducts** that conveys sweat to the surface of the skin via sweat pores. They contain secretory cells

Each sweat gland is surrounded by a **network of capillaries** which supplies nutrients to the

skin and drain wastes products from the skin.

FUNCTION
-They excrete sweat on to the skin surface which helps to control the body temperature and also eliminate waste products from blood e.g. sodium chloride, water.

Nerve endings

There are several types of nerve endings scattered in the dermis

The nerve endings include:

Free nerve ending - for pain

Meissner's corpuscle - for touch
Pacinian corpuscle - for pressure
Hair plexus - for both touch and pain

FUNCTION
-They perceive various stimuli and convey it to nerve fibres which carry the messege in form of impulses to central nervous system.
Subcutaneous fat; these are fat deposit beneath the skin that insulates the body against heat loss because fats are bad conductor of the heat.

FUNCTION
-It is used for the storage of excessive body fat
-They provide insulation against heat loss
-they act as energy reserves

REGULATION OF BODY TEMPERATURE

Temperature regulation is the process of maintaining body temperature within a narrow range that favours optimum enzyme activity.
This is important for normal functioning of bodily processes which are controlled by enzymes not to get affected by changes in temperatures. to maintain body temperature constant, there must be a balance between heat loss and gain.

Ways by which organisms gain heat

- -**Metabolism** of food
- -**Absorption** of solar energy. This may be absorbed directly or indirectly through
- -**radiation** from hot objects
- -**convection** from the warming ground
- -**conduction** from hot object

Ways by which organisms lose heat
-**Evaporation** of water e.g during sweating
Conduction from the body to cold objects in contact.
Convection from the body to cold air or water
-Radiation heat diffuses from the warm body to

cold environment.

The rate of heat lose and gain depends on;

1. **Surface area to volume ratio** i.e. small organisms have a large surface area to volume ratio hence lose more heat fast than the large ones with a small surface area to volume ratio.

2. **The rate of respiration.** the higher the rate of respiration the more heat energy gained by the body

3. **The surrounding temperature,** organisms tend to lose more heat in cold environment and gains more in hot environment.

4. **air current ,**organisms lose heat in windy environment than in still air.

5. **Humidity.** Heat loss increases with increase in humidity because high humidity makes the environment colder.

Relationship of body temperature and environmental (ambient) temperature in organisms

Animals fall into two broad categories with respect to their body temperatures namely:

Poikilotherms (poi kilos = various, thermo = heat)
These are organisms whose body temperature varies with environmental temperature.
They are also called ectotherms (ecto = outside) because they rely on heat derived from the external environment. They include: fish, reptiles, and amphibian.

Homoiotherms (homoios = like)
These are organisms that regulate their body temperature constant by physiological processes independent of environment. They are also termed as endotherms (endos = inside) because they rely on internal sources of heat.

Graph showing relationship between body temperature & environmental temperature of ectotherm & endotherm

ADVANTAGES OF ENDOTHERMY

-It allows those animals to live in a wide range of environment irrespective of the prevailing temperature
-It promotes the functioning of enzymes efficiently at optimum body temperature
- It enables animals to have higher rates of metabolism thus yielding more energy which is necessary for quick response to stimuli. This is important for survival of organisms especially those living on land.

- It allows terrestrial animals to maintain a constant body temperature.

DISADVANTAGES OF ENDOTHERMY

-It is energetically expensive especially in the cold environment due to high heat loss.
-Much food must be consumed so as to generate heat internally.

ADVANTAGES OF ECTOTHERMY

-Low food consumption since heat is derived mainly from external surrounding
- Ability to modify behavioural patterns hence regulating the body temperature

DISADVANTAGES OF ECTOTHERMY

-Slow responses to stimuli due to low metabolic when the temperature is low
-Restrictions in animal's activities in case of extremes of environmental temperature

TEMPERATURE REGULATION IN ECTOTHERMS Response to cold or low temperature

-Basking in the sun to gain heat. This is common in lizards, crocodiles e.t.c
-Hibernation. This is a state of long rest by burrowing. During hibernation, the body temperature falls close to environmental temperature hence reducing heat loss. Here the animal uses stored food reserves.

-Burrowing into cracks, crevices in walls during cold
-Some reptiles orientate themselves towards heat sources to increase heat uptake and expanding the body surface exposed to heat source.

Response to high temperature

-Aestivation i.e form of hibernation during hot environment by sheltering under rocks, or burrowing beneath the surface.
-Salivation over neck and legs e.g. in tortoise

-Moving into shades to cool Body temperature i.e. seeking favourable microclimate in environment.
-Thermal gaping as in crocodiles i.e opening the mouth to allow evaporation of H_2O which carries away excess heat.

TEMPERATURE REGULATION IN ENDOTHERMS.
The hypothalamus in the brain is the thermoregulatory centre. It has temperature receptor cells which detect the slightest changes in body temperature.

Response to high temperature i.e control of over heating.

When the body temperature rises above the normal, it is detected by the hypothalamus which sends impulses to the effector organs which bring it back to normal as follows
Physiological means

1. Sweating
Sweat glands in the skin are activated, they increase the rate of sweat production, and latent heat of evaporation lost from the body as sweat evaporates causes a cooling effect.

2. Relaxation of hair erector-pili muscle
Hair erector –pili muscles relax making hairs lie flat on the body. this traps less air on the skin encouraging loss of heat from the body by radiation and convection.

3. Vasodilation
This is the expansion and increase in diameter of superficial blood vessel that lead blood to skin surface thus allowing more blood to flow through them.
This increased blood flow to the skin carries more heat to the surface which is then lost to the environment either by convention, conduction or radiation.

4. Decreased metabolic rate
Metabolic activities of the body are reduced, decreasing the heat energy being liberated.
5. Reduced or **no shivering occurs**

Behavioural activities
5. Panting and licking
This occurs in animals having a few or no sweat glands. Panting involves hanging out the tongue e.g in dogs; this causes evaporation from mouth and lungs thus cooling the body. Licking involves the animal moving its tongue across the body surface to wet it. This helps to reduce the heat.

6. **Change in behaviour**

In most endotherms, this involves resting under shelters to avoid the sun. In man, this involves wearing light clothes, swimming e.t.c

Response to low temperature i.e. control over-cooling

When the body temperature decreases below normal, it is detected by the hypothalamus which sends impulses to the efffector organs bringing temperature back to normal as follows.;

1. Sweat production decreases. Sweat glands are made inactive hence reducing the amount of sweat produced minimizing heat loss by evaporation

2. Vasoconstriction of l blood vessels near the skin surface, diverting blood away and reducing blood flow near the skin surface so that less blood reaches skin surface, hence less heat is lost from blood by convection and radiation. More blood is stored in the spleen

3. Contraction of hair erector-pili muscles making hairs erect/stand upright on the body. More warm air is trapped in the spaces between the hair thereby acting as an insulator and preventing the loss of heat from the body.

4. The metabolic rate increases which results into the production of more heat from the body.

5. Shivering occurs. This is the spasmodium contraction and relaxation of muscles which produce heat.

Behavioural activities include

1. **Hibernation (deep sleep in cold conditions)** by some mammals like squirrels
2. Becoming active during day i.e diurnal
3. Huddling (gather tightly together) i.e. individuals coming closely to one another in a group e.g. chicks huddle under their mother.
4. Man normally changes behaviour by putting on thick clothes e.g. sweaters.

Animals which live in cold environments/temperates posses some of the following features to enable them live in such environments

1. Thick layer of subcutaneous fatty layer which insulates the body against heat loss.
2. Thick layer of fur to minimize heat loss by trapping more air.
3. having a very small surface area for heat loss by having compacted bodies.e.g very small pinna and feet
4. Counter current flow of blood in the extremities e.g. the legs to reduce heat loss.
5. Having very short loop of Henle to reduce water reabsorption leading to elimination of excess water in urine.
6. Small animals like rats hide from cold and become dormant during winter to reduce heat loss. this behavioral process is called **hibernation.**

Animals living in deserts show some of the following features to avoid overheating.

I.they have the ability to produce a highly concentrated urine thus conserving water e.g. camels ad kangaroo rat.

Ii.having long loop of Henle to increase area for reabsorption of water this conserves water and leads to urination of highly concentrated urine.e.g. kangaroo rat
Iii.having a large surface area for more heat loss .e.g. having expanded pinna like for the elephant. Or having certain body parts which are extremely large e.g ears compared to corresponding species in cold environment and have rich blood supply to allow more heat being lost
Iv.respiring a lot of fats that generates more metabolic water to avoid dehydration/desiccation.
V.having tissues more tolerant to high temperatures so that they stand high temperature without much sweating.
.**vi.**having a thin layer of fur to trap less air leading to excessive heat loss.
Vii.Possess a thin layer of subcutaneous fats to minimize insulation and hence allow more heat loss.
-**Bein**g unable to sweat because they lack sweat glands thereby conserving water.eg camel
-**they** have the ability to keep nosal passages and mouth dry most of the time to reduce water loss.
-**some organisms like insects have exoskeleton** /cuticle to prevent excessive water loss.
Viii.Some become more active at night i.e. are nocturnals mainly.
-Have fur which is usually light in colour to help reflect the sun's radiations

Relationship between body size and heat loss
Small organisms have a large surface area than large animals. Therefore small organisms lose heat rapidly than larger ones. In order to maintain a high body temperature, they must have a high metabolic rate to produce the necessary heat. Therefore they need to feed more frequently than large animals.