SENIOR FIVE - HOMEOSTASIS

Topic: Homeostasis
Subtopic: Negative Feedback Mechanisms

Learning Outcome: Analyse the homeostatic control system, focusing on the role of negative feedback mechanisms in maintaining internal stability.

Knowledge / Understanding	Performance Indicators
Learners should demonstrate understanding of: 1. **Homeostasis:** definition and biological relevance 2. **Significance of maintaining a stable internal environment:** ✓ Maintains optimal conditions for enzyme activity ✓ Supports cell metabolism and survival ✓ Prevents health issues like hyperthermia, dehydration, acidosis, etc. 3. **Components of an efficient homeostatic system:** ✓ **Stimulus:** Change in internal/external environment ✓ **Receptor:** Detects the change (e.g., thermoreceptors) ✓ **Control Centre:** Processes input and sends instructions (e.g., hypothalamus) ✓ **Effector:** Carries out the corrective action (e.g., sweat glands, muscles) ✓ **Feedback:** Usually negative to reverse the change	☞ Correctly define and explain homeostasis and its significance ☞ Identify and describe the components of a homeostatic control system ☞ Analyse negative feedback mechanisms using examples like temperature ☞ Analyse diagrams showing body responses to changes in temperature or water levels. ☞ Construct or interpret flowcharts/ diagrams showing feedback control ☞ Predict physiological responses when internal conditions deviate from the norm. ☞ Compare adaptations in desert vs aquatic or temperate animals. ☞ Construct and interpret models of negative feedback involving ADH or temperature regulation.

4. Physiological and behavioural adaptations of endotherms to survive in varying temperature conditions. **5.** The role of the hypothalamus and skin in regulating temperature in endotherms **6.** How ADH works to maintain water balance in the body **7.** Animal adaptations to different water availability in their environment **8.** The concept of set points, normal ranges, and deviation correction in biological systems.	
Subject Skills (Biological Competencies)	**Generic Skills (Cross-cutting)**
• Interpretation and drawing of feedback loops using flow diagrams • Explanation of the mechanisms of hormone action (e.g., ADH) and thermoregulation. • Comparison of homeostatic strategies among organisms. • Analysis of experimental data on temperature, water balance, or hormonal control. • Identification of malfunctions of homeostatic processes (e.g., diabetes insipidus).	○ **Critical thinking:** Predicting outcomes if components of the system fail ○ **Communication:** Describing feedback systems clearly in oral or written form ○ **Problem-solving:** Suggesting corrective actions for disrupted homeostasis ○ **Collaboration:** Working in groups to build models or simulate body responses ○ **ICT skills:** Using animations or simulations to explore feedback mechanisms
Values / Attitudes	**Nature of Assessment**
♦ Appreciation of the body's ability to maintain balance ♦ Responsibility in making lifestyle choices that promote internal stability ♦ Empathy towards individuals with homeostatic disorders (e.g., diabetes)	**Formative Assessment:** ✍ Group discussions ✍ Presentations ✍ Simulating feedback systems ✍ Concept mapping of homeostatic pathways **Summative Assessment:** ✍ AOI & EOC exams

♦ Discipline in habits that promote health (e.g., hydration, proper nutrition)	✍ Structured exam questions with real-life scenarios

HOMEOSTASIS

Homeostasis is the relative constancy of the body's internal environment regardless of the conditions in the external environment.

Examples of homeostatic processes:

- Concentration of blood glucose at 90mg/100cm3
- Average core body temperature at 37^0C (98.6^0F)
- Blood PH (acid-base balance) at 7.4
- Blood pressure in brachial artery averages near 120/80
- Blood levels of ions such as Na+ , K+ , Cl- , Ca2+
- Concentration of carbon dioxide
- Osmotic pressure (quantity of water relative to salts)

Cybernetics: This is the science of control systems i.e. self-regulating systems which operate by means of feedback mechanisms.

Feedback system: This is a mechanism in which an input stimulus causes an output response that 'feeds back' to the initial input.

Negative feedback: This is a mechanism in which the effect of deviation from the normal condition triggers a response that eliminates its deviation in order to reduce further corrective action of the control system once the set point value has been reached.

Examples of negative feedback:

In negative feedback mechanism, a stimulus causes a sensory receptor to signal a regulatory centre in the brain. The regulatory centre then signals an effector to respond and the response cancels / reverses / negates the stimulus to restore the condition to the norm.

Positive feedback: This is a mechanism in which the effect of deviation from the normal condition intensifies the original response such that the change tends to proceed in the same direction as the initial stimulus.

Examples of positive feedback:

- A 10^0C in temperature doubles metabolic activity, releasing more heat that raises the activity even more.
- During blood clotting to stop bleeding to keep blood volume constant, one clotting factor activates another in a cascade that leads quickly to the formation of a clot.

- During childbirth, oxytocin released stimulates contraction of uterine muscles, which in turn stimulates further oxytocin release until the fetus is expelled.

Cascade effect: This is the way in which a small amount of say hormone can cause a target organ to produce a large amount of product.

Qn: Explain why positive feedback mechanisms are few in biological systems.

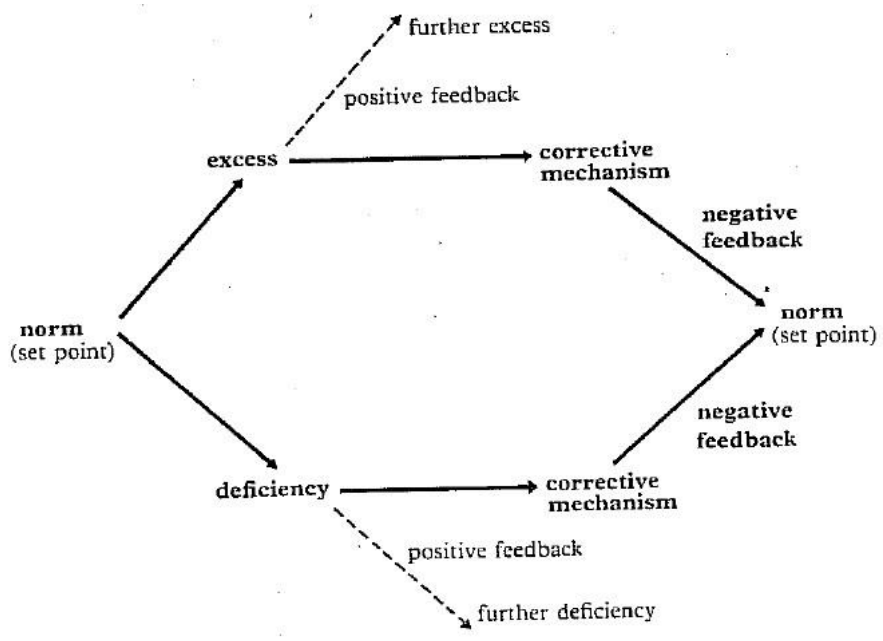
It is because positive feedback mechanisms cause larger deviations from the normal set point and may lead to unstable conditions and extreme states.

ESSENTIAL COMPONENTS OF A CONTROL SYSTEM

Each control system must have the following essential components:

1. **Receptors / detectors:** These are parts of the body that constantly monitor and detect changes from the reference point / norm in the internal environment and then signal the deviations; e.g. thermo-receptors that detect temperature changes.
2. **Control centre:** This is usually the brain that coordinates the information received from various receptors and sends out instructions which will correct the deviation; e.g. hypothalamus for temperature regulation.
3. **Effectors / responding organs:** These are parts of the body that bring about the necessary changes needed to return the system to the reference point / norm.
4. **Reference point / norm:** The set level at which the system operates; e.g body temperature of an endotherm being 37°C.
5. **Feedback loop:** Hormones and or nerve impulses that inform the receptor of any change in the system as a result of the action by the effectors.

General scheme summarizing any homeostatic control process



TEMPERATURE REGULATION

One of the most important homeostatic processes is thermoregulation. This is the maintenance of the body temperature of an organism at a relatively constant level. Environmental temperatures vary from about -60°C at the poles to about 55°C in the Sahara Desert. Living organisms possess several adaptations to survive such temperature variations.

Animals are categorized into two major groups regarding thermal regulation; i.e.

- Ectotherms (poikilotherms) &
- Endotherms (homiotherms)

Ectotherms

These are animals whose body temperature varies with temperature changes of the environment. Such animals get body heat from the surroundings. Most ectotherms can therefore not maintain the body at a constant level.

However, some ectotherms maintain their body temperature a few degrees higher than the environmental temperature through behavioral means; for example:

- They move to hot places to gain energy to raise their body temperature when its cols; or,
- They move to cool places to lose heat when it is hot. Such organisms include reptiles, amphibians, invertebrates, fish.

Temperature regulation in ectotherms

This depends on the environmental temperature. When the environmental temperature is high (hot), the rate of metabolism lowers and less heat is generated. On the other hand, when the environmental temperature is low (cold), body metabolism increases and hence more heat is generated.

<u>Ectotherms depend on behavioral methods for regulating their body temperature;</u>

- By basking in the sun i.e. changing body orientations with respect to the sun rays. It helps them gain heat into their bodies. E.g. in most insects, arachnids, amphibians and reptiles.
- By moving into the shade and wall cracks to cool the body when the body temperature is very high.
- In some large reptiles like crocodiles and alligators, they practice thermal gaping to allow loss of heat as water evaporates from lungs and mouth.
- Endotherms like lizards burrow to build a layer of warm air around themselves.

- Tortoises salivate over the neck and legs thus loosing heat as a result of evaporation of water from such surfaces.

Desert lizards tend to be more active in early morning and late evening when it is neither too cold nor too hot respectively.

Advantages of being ectothermic

- There is low food consumption since they do not generate heat from within the body for temperature regulation.
- In case of extremes in external temperature, the organisms change their behaviors; hence there is no need of special temperature regulatory organs. E.g. hibernation when it is very cold or hiding under the shade when it is very hot.

Disadvantages of being ectothermic

- Enzymatic activities are not maintained at optimum temperature and therefore metabolic processes do not proceed efficiently.
- Since the metabolism of such animals is significantly affected, they cannot respond to the external stimuli fast enough thus reducing their survival chances.
- Since their body temperature depends on the external environment, such organisms are restricted to specific environments.
- Reproductive potential is low since these organisms tend to be inactive most of the time.

Endotherms

These are animals that maintain a relatively high and constant body temperature. This aids the organisms to remain active even when the environmental temperature is low. Such animals generate most of their body heat internally as a result of metabolic processes in the liver and the body muscles. Therefore, they use physiological mechanisms to maintain body temperature. Such organisms include the birds and the mammals.

Advantages of being endothermic

- The metabolism of endothermic animals is always high, hence they can respond to stimuli fast and move faster, increasing their chances of survival
- It allows enzymes to work at optimum body temperature hence body reactions proceed efficiently.
- Since the external temperature does not affect the organism's body, such organisms can occupy a wide range of habitats.
- Organisms experience high productive potential since they are active most of the time.

Disadvantages of being endothermic

- When the external temperature is high, the organisms need efficient cooling mechanism to a void overheating.
- Organisms require better insulation and warming mechanisms to avoid over cooling when environmental temperatures become very low. Such requirements are not needed by ectodermic organism.
- Since heat must be generated for temperature regulation, there is a need for high food consumption

Temperature regulation in endotherms

Endothermic animals (birds and mammals) regulate their body temperature by a combination of 3 different means;

i) Structural means:

- This is done through use of structures on the body surface e.g. hair, feathers; or in the skin the subcutaneous fat which insulates the body ii) Behavioral means:

In cold conditions through;

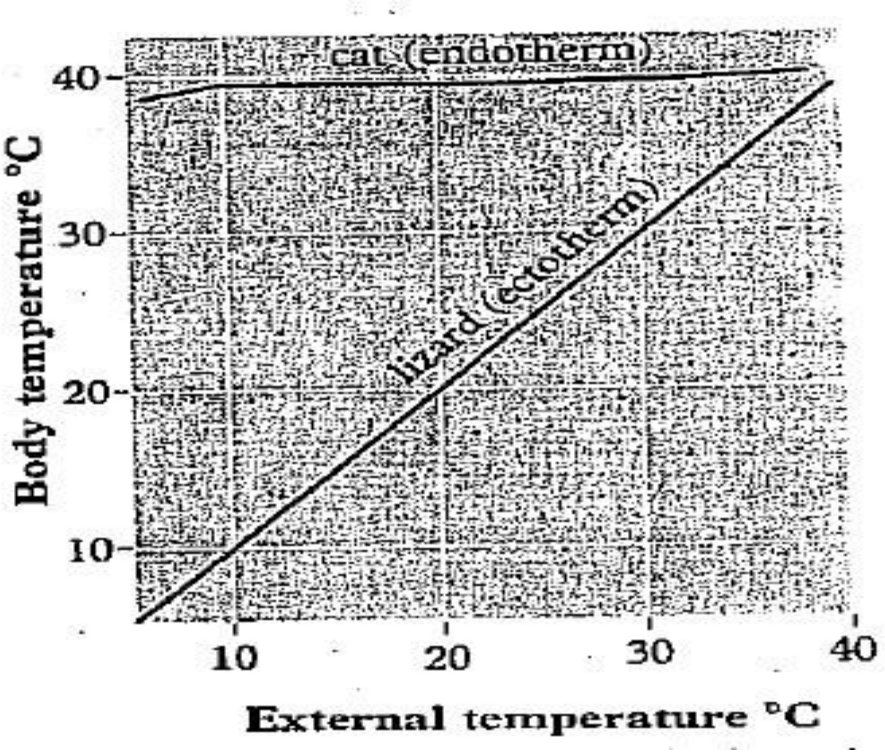
- Roosting in birds
- Taking drinks, wearing thick clothes, and undertaking exercise in man
- Small mammals hibernate under extreme cold

In hot conditions through;

- Moving under shade by most of the mammals ▪ Taking cold drinks and wearing light clothes in man iii) Physiological means (that lead to reduction in body metabolism):
- Small mammals undergo a state of aestivation.

Aestivation is a state where organisms go into burrows during the day to avoid hot conditions during the day, and only come out to feed at night. E.g. in hippos.

The graph below shows the effect of environmental temperature on the body temperature of various animals



HEAT LOSS AND HEAT GAIN

The main source of heat in the body of an organism is tissue respiration. 50% of the energy released in respiration is heat energy. Such heat is mainly produced by the skeletal muscles and the liver, deposited in blood, which distributes it throughout the body.

Heat production is proportional to the metabolic rate which normally increases during exercise.

Heat loss or heat gain occurs over the body surface in three major ways; these are:

- ✓ Conduction
- ✓ Convection
- ✓ Radiation

I. Radiation

This is the emission or absorption of heat depending on the surface temperatrure of the body. Heat is radiated to the surrounding air more rapidly than it is gained. A naked person in a room will lose 60% of the body heat by radiation.

II. Conduction

This is the passage of heat from the warm object to the cooler one in direct contact. Organisms lose about 20% of the body heat by conduction.

III. Convection

This is heat loss or gain by flow of air or water current over the body. Convection is an important heat loss or gain in ectotherms.

IV. Evaporation

Heat can be lost from the body due to evaporation of water from the body. The amount of heat lost from the body depends on the surface area to volume ratio of the body. Organisms with a large surface area to volume ratio like rats have a high rate of heat loss. This normally limits the size of terrestrial organisms.

Large animals like elephants have a problem of overheating while small animals have a problem of losing heat rapidly.

TEMPERATURE REGULATION IN MAMMALS

Regulation of body temperature in mammals like man involves balance in heat loss and heat gain. The human body temperature is maintained between 36 – 37.5^{o}C.

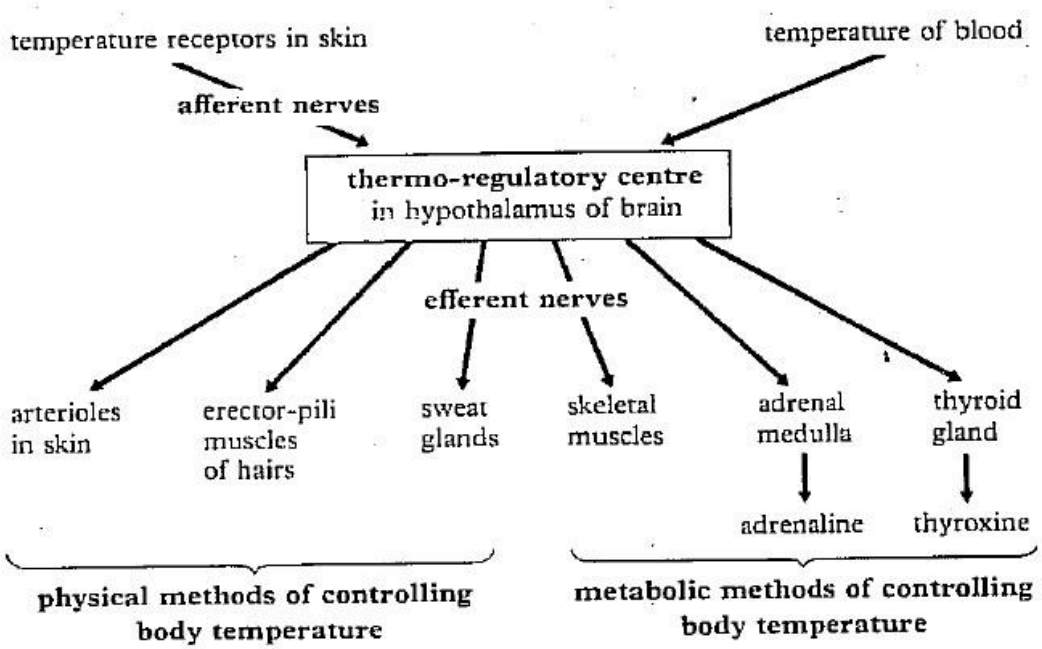
A high body temperature of above 43^{o}C may result in death due to **hyperthermia** (heat exhaustion). Low body temperature of about 26^{o}C may lead to death due to inactivity of body enzymes; a process called **hypothermia**.

Body temperature is monitored by thermo-receptors in the hypothalamus, that normally detect internal body temperature changes; and thermo-receptors in the skin can normally detect internal and external body temperature changes.

Within the hypothalamus, there is thermal regulatory centre, which responds to temperature changes in the body. The thermo-regulatory centre consists of two parts;

- The hot centre &
- The cold centre

Thermo-receptors in the thermo-regulatory centre monitor the blood temperature flowing through the hypothalamus.



The cold centre

The cold centre responds to blood with a temperature less than the normal. It initiates processes which increase heat gain and decrease heat loss. Once initiated by the thermoreceptors, the cold centre will set off processes like;

- Increased metabolism
- Vasoconstriction
- Hairs to raise/ stand
- Shivering

Such processes will increase the temperature and the temperature will return back to normal.

The cold centre also receives impulses from the skin which are sensitive to environmental changes. Apart from activities of the cold centre, the body normally secretes hormones which can increase body temperature; e.g

- Thyroxine which increases the body metabolic rate
- Adrenaline
- Noradrenaline

The heat centre

This responds to blood with a temperature higher than the normal body temperature. It initiates processes which result in heat loss in order to return body temperature to normal. Such processes include:

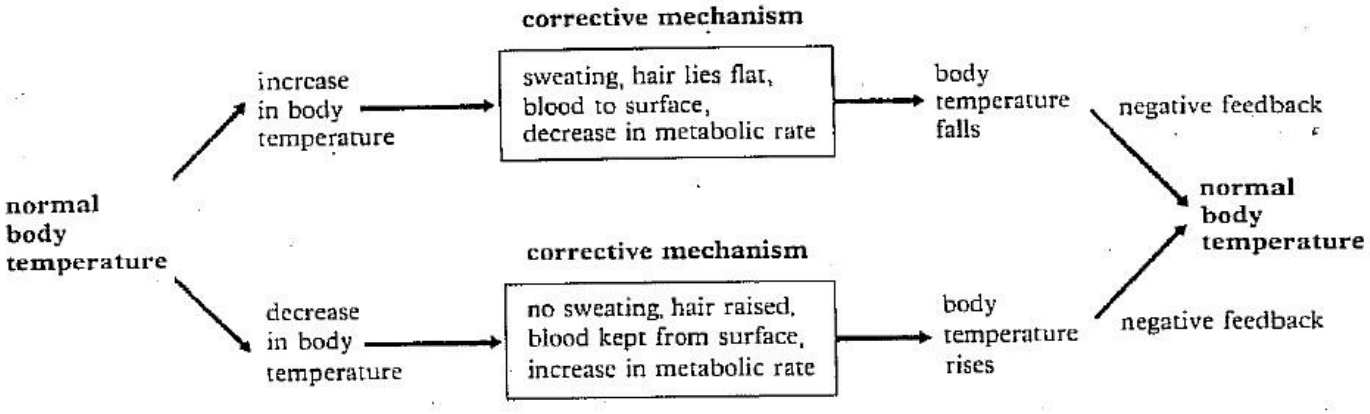
- Reduced metabolism

- Vasodilation

- Sweating
- Hair fall

The heat centre inhibit the activities of the cold centre.

The homeostatic control of body temperature in a mammal (negative feedback control of body temperature)



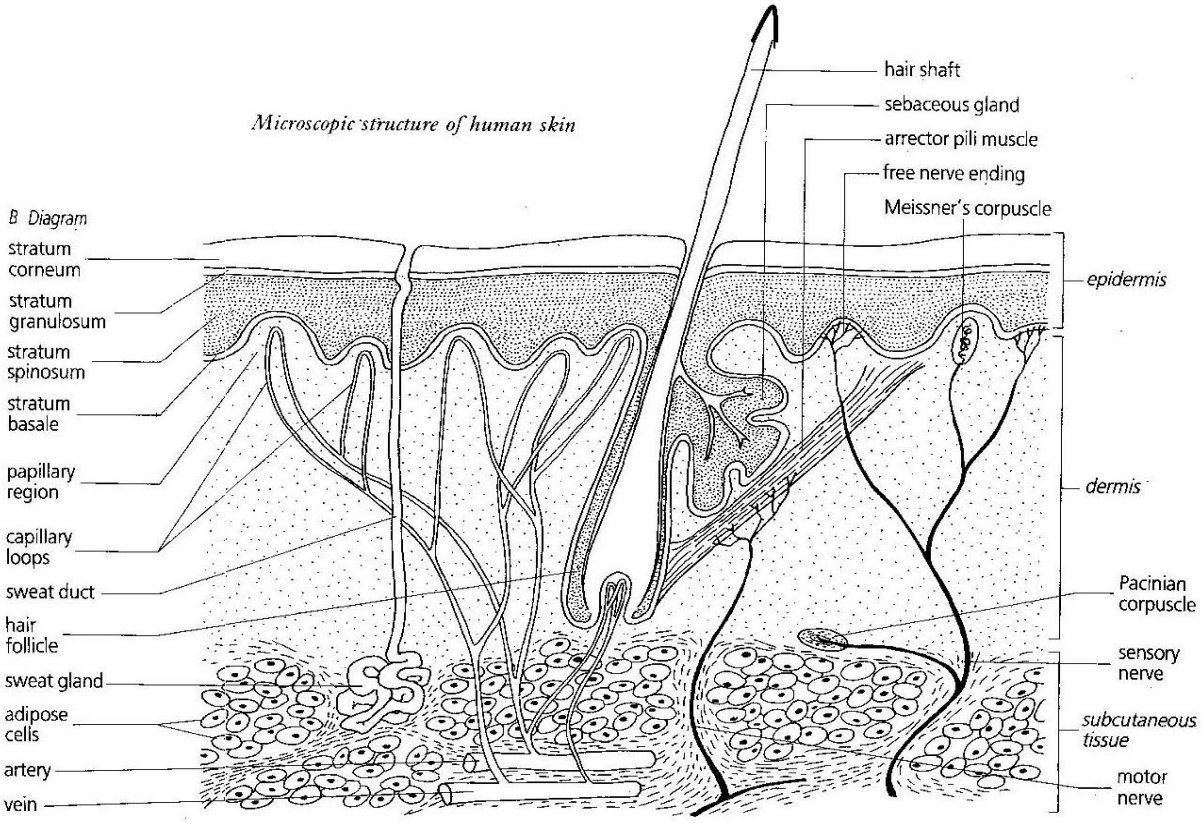
The human skin and temperature regulation

The mammalian skin is an important organ. It is a tough flexible barrier that prevent excessive heat loss and entry of pathogens in the body.

Functions of the mammalian skin

1. It manufactures vitamin D.
2. It screens the body from ultraviolet light which may cause cancer
3. It is a sensory organ with several nerve cells
4. It is an excretory organ with sweat glands that remove waste products of metabolism from the body.

Structure of the mammalian skin



The skin consists of three main layers;

- Epidermis
- Dermis
- Fat layer

The epidermis: this is the top most layer

and consists of;

I. Cornified layer

This is the top layer consisting of dead cells. It forms a tough outer coat which offers resistance to damage and entry of bacteria and prevents water loss from the body (dessication)

II. Glandular layer

This contains living cells but gradually forms a cornified layer towards the top. It is continually being shed off to replace the cornified layer.

III. Malphigian layer

It is a continuous layer consisting of dividing cells which produce new epidermal cells. This layer has a pigment called melanin. Melanin has two functions;

- Acts as a shield against ultra-violet rays from the sun
- Determines the skin color

The Dermis

This is a thicker layer of connective tissue containing hair follicles, sweat glands, lymphatics, blood capillaries and nerve endings.

I. Sweat glands

This consists of coiled tubes. It secretes sweat. The sweat moves up the sweat ducts and gets out via pore from where it evaporates. Evaporation of the sweat is accompanied by loss of heat from the body, hence its cooling.

II. Hair

- This grows from the base of the hair follicle with hair papilla providing food nutrients and pigments for growth from the capillary network.
- When the erector muscle contracts, the hair stands upright on the surface of the skin. It then traps a layer of air close to the skin surface thus minimizing heat loss because air is a bad conductor of heat.

III. Sebaceous glands

This is an opening into each hair follicle near the top. It secrets an oily substance called sebum. Sebum has 3 main functions;

- It lubricates the skin
- It acts as an antibacterial chemical
- It water proofs the skin

IV. Blood capillaries

These supply the necessary food and oxygen to the skin.

They also help to remove waste products

Fat layer (sub-cutaneous fat)

This consists of many fat cells which form a continuous tissue known as adipose tissue.

It insulates the body minimizing heat loss.

How the skin controls body temperature

The mammalian skin is an important organ used for temperature regulation. An endothermic organism like a mammal uses both physical and physiological mechanisms to control body temperature. Most of the physical mechanisms are carried out by the skin throughout the activities of the thermo-regulatory centre. The hypothalamus sends impulses to the skin in order to reduce the increasing body temperature and return it to the norm. Such activities include the following:

1. Vasodilation

This is the enlargement of skin blood vessels and their movement near the skin surface. This increases the blood volume flowing over the skin surface which increases the amount of heat lost from the body.

2. Sweating

As more sweat is produced, energy is used to evaporate the swat. This energy is lost from the body and therefore the body cools.

3. Hairs flattening

Impulses are sent to the erector pilli muscle, which relaxes. This causes the hairs to fall over the skin. Heat will easily be lost from the body.

Through the above activities, the skin is able to detect heat loss and return body temperature to normal.

Other activities that may be done by the mammal to reduce body temperature include the following:

- Physiological processes
  - The organism reduces metabolic rate so that less heat is generated from the liver and skeletal muscles.
- Behavioral activities may include: -

  Taking cold drinks
  - Moving to cold places
  - Taking cold bath
  - Putting on light clothes
  - Thermogapping
  - Panting

When the body temperature reduces to a point less than the normal body temperature, the hypothalamus initiates processes that increase body temperature. It sends impulses to various parts of the skin, which respond through processes including the following:

1. Vasoconstriction

Blood vessels in the skin narrow and move more deeper into the skin. This reduces the volume of blood flowing near the skin surface. Therefore, the amount of heat that would have been lost is retained in the body and used to maintain body temperature.

2. Sweat glands stop producing sweat

Energy which would have been used in sweat production is used to raise body temperature.

3. Hairs raise

Impulses are sent to erector pilli muscle, causing them to contract. The hairs raise and trap a layer of air which acts as an insulator that prevents heat loss from the body.

Other processes carried out by the organism to increase body temperature include the following:

- Physiological processes:
  - The liver increases the metabolic rate. A lot of heat is generated in the body, deposited in blood and distributed to all body parts to raise body temperature.
  - Shivering occurs. This is the rapid contraction of the skeletal muscles to generate heat, that increases body temperature.
- Behavioral mechanisms:
  - Moving to warm places to gain heat.
  - Taking warm drinks
  - Putting on warm clothes.

Such activities will return body temperature back to norm.

ADAPTATIONS TO EXTREME ENVIRONMENTS

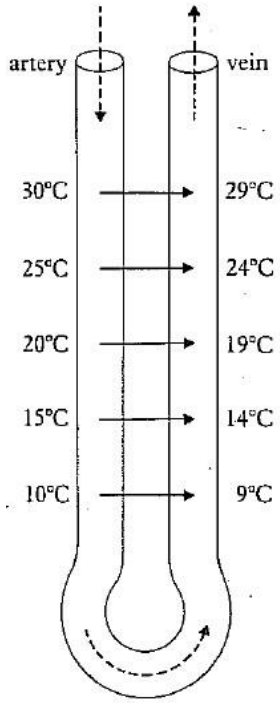
Animals in cold climatic conditions

Animals in extreme cold conditions tend to be larger than animals of the same species living in hot regions. This is referred to as Bergman's rule.

In order to survive cold conditions, animals in cold conditions have adapted to the following ways:

- They have a high metabolic rate in order to maintain the high body temperature.
- They have small extremities to reduce the surface area over which heat loss can occur, e.g the ear size.
- Heat loss from such extremities like the ears can be prevented by the arrangement of blood vessels in such structures, whereby arteries carrying blood to appendages are surrounded by veins carrying blood back to the body. This enables heat from arteries to be passed on to veins such that blood returning to the body is at a relatively high temperature. This is referred to as **counter current heat exchanger mechanism**.

Counter current heat exchanger



- Organisms may hibernate. Hibernation is where an endothermic organism becomes inactive in cold weather and it enters a prolonged sleep. During hibernation, all body activities reduce to the minimum to maintain life. E.g the heart rate and breathing rate slow/ lower, low body temperature, low oxygen consumption rate, and the organism is inactive.
  During hibernation, urination, defecation stop. Mammals which hibernate include rodents, bats, hedges, hogs, bears, etc. Some large mammals may not hibernate but may undergo the **winter sleep**.
  The organisms mainly hibernate because of lack of food to support their metabolic rate during these extreme cold conditions. Some organisms e.g the humming birds are too small and cannot maintain their body temperatures at a constant level overnight. At night, the metabolic rate of the humming birds falls to the minimum, and the body temperature drops to that of the environment, i.e. the organism goes into a state of hibernation. Such condition occurs once every 24 hours and it is called diurnal hibernation.

Animals in very hot environments

Animals in hot environments have a problem of high temperature and therefore show adaptations to increase heat loss. Such adaptations include:

- They possess large extremities. These increase the surface area over which heat can be lost from the body e.g large ear flaps on an elephant.
- Some organisms show temperature tolerance e.g the camel. It has tissues that function at a wide range of temperatures. It saves water during the day by not sweating. This results in the gradual increase in the body temperature to about 40^{o}C.

Its body temperature falls at night to about 34°C. This prevents the body temperature from reaching less values.

- The animal may aestivate. Aestivation is where an organism becomes inactive in hot weather and it enters a prolonged sleep. During this period, all the body activities fall to the minimum. Aestivation is common in the African long fish, which forms a cacoon as the rivers dry up during the dry seasons.

THE EFFECT OF CHANGING ENVIRONMENTAL TEMPERATURE ON BODY TEMPERATURE OF AN ENDOTHERM

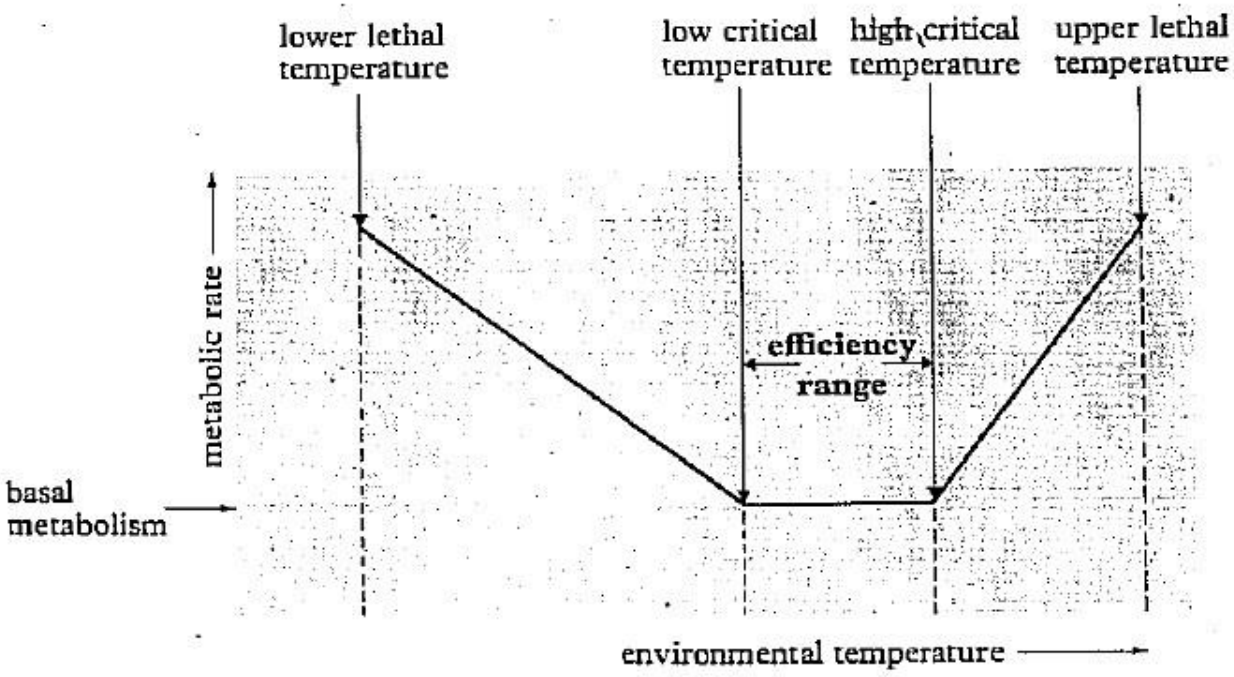
Body temperature is regulated by the physical and chemical mechanisms. Physical mechanisms regulate the temperature between a high and a low critical temperature. This is called the **efficiency range.**

If a naked person is faced with a gradually decreasing temperature, at first he/she relies on purely physical mechanisms to maintain the body temperature while the metabolic rate remains constant. At about 27°C, the physical mechanisms are no longer capable of maintaining the constant body temperature. This is called **low critical temperature (L.C.T)**. thus the lowest temperature at which physical methods can no longer regulate body temperature.

As the environmental temperature further decreases, the metabolic rate starts to increase and it will increase until eventually the mechanisms breakdown. This is called the **lower lethal temperature (L.L.T**) and at this point the person dies.

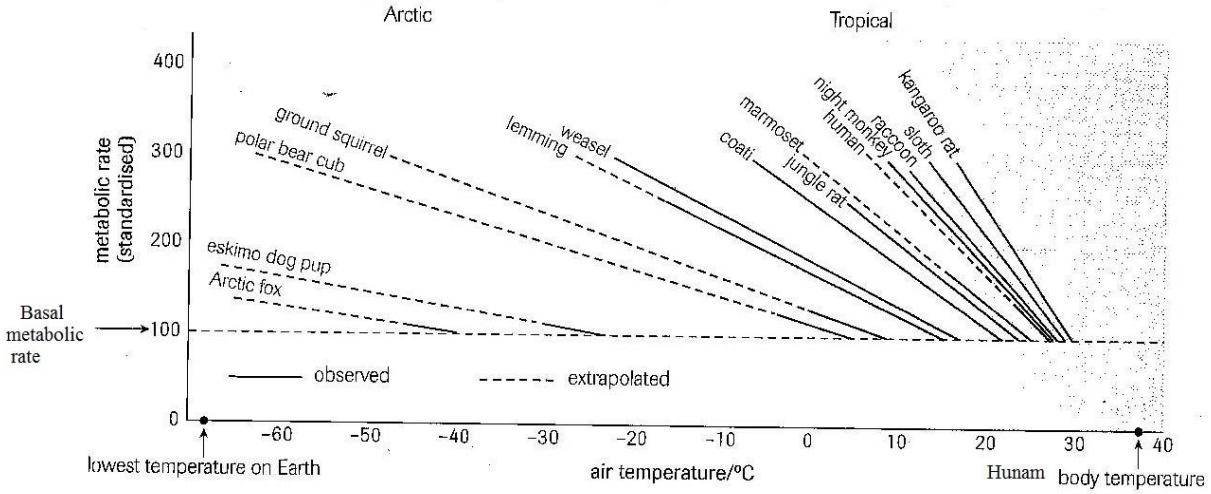
As the temperature increases, the ability of the body to regulate its temperature breakdown, a point called **high critical temperature (H.C.T).** The metabolic rate would double for every 10oC increase. As body temperature increases, heat exhaustion occurs; this is characterized by muscle crumps and dizziness. This is called the **upper lethal temperature (U.L.T)** accompanied by death.

Graph showing metabolic rate as a function of the external air temperature in a generalized mammal



Efficiency range varies according to the environmental temperature in which the animal inhabits. This is because animals have the ability to acclimatize. If the environmental temperature is high, acclimatization is by raising the upper critical temperature and if low, acclimatization is by lowering lower critical temperature.

Graph showing metabolic rate of various mammals as a function of the external air temperature



Observations from the graph:

a) The low critical temperature for animals living in cold places is much lower than for those, which live in warm places. E.g. the desert kangaroo rat Dipodomys has a low critical temperature just below 30^0C, whereas the Arctic fox's is about -40^0C.

b) The lower lethal temperature is much lower for cold-dwellers than for warm-dwellers.

c) Below the low critical temperature, the metabolic rate of warm-dwellers rises more sharply than in cold-dwellers.

d) The metabolic rate starts to rise at a much lower critical temperature for cold-dwellers that for warm-dwellers.

HOW ADH WORKS TO MAINTAIN WATER BALANCE IN THE BODY

- The human body must maintain a constant water balance for cells to function properly.
- The kidneys are the main osmoregulatory organs, and ADH (vasopressin) is a key hormone that regulates water reabsorption.
- Produced by the hypothalamus and released by the posterior pituitary gland.
- The kidneys control the water content and ion balance of the body. This is called osmoregulation.
- The water and salt reabsorption in the distal convoluted tubule (DCT) and the collecting ducts depends on the body's blood osmotic pressure **(Op)** and the permeability of the tubules determined by hormones.

How ADH works (Control of water content):

- Osmoreceptors in the hypothalamus detect changes in blood concentration.
- The body contains osmo-receptors in the hypothalamus that detect changes in blood concentration (change in the **Op** of blood).

*Once the **Op** of blood is high,*

- Osmo-receptors send information to the **hypothalamus**, which stimulates the **pituitary gland** to release **anti-diuretic hormone (ADH)**.
- ADH flows through blood to the DCT and the collecting ducts to increase the permeability of their walls to water.
- This encourages the reabsorption of more water into blood.
- As more water is reabsorbed to the body, a concentrated urine is produced.

*When the concentration of blood is low (i.e. low **Op**),*

- It means that the amount of water in blood plasma is high.
- Osmo-receptors stop stimulating the hypothalamus, and ADH is not produced.
- This causes the walls of DCT and CDs to become impermeable to water, and therefore more water is not reabsorbed into the body.
- This leads into production of dilute urine.

NOTE: failure of the body to produce ADH means that the amount of water in the body cannot be controlled automatically. Such an individual would need to take in water to control the amount of water in the body, a condition called **diabetes insipidus**.

Action of ADH on Kidneys:

- ADH travels in the blood to the kidneys, targeting the collecting ducts and distal convoluted tubules.
- It binds to specific membrane receptors on cells in the collecting duct and distal convoluted tubules.
- It then causes vesicles with aquaporins (water channel proteins) to fuse with membranes/ it stimulates the insertion of aquaporins (water channels) into cell membranes.
- This increases water reabsorption from filtrate back into the blood.

Negative Feedback Loop:

- Increased ADH restores water balance; osmoreceptors detect normal levels; reduce ADH release.
- Decreased ADH restores dilute blood; feedback reduces suppression; ADH levels normalize.

Animal Adaptations to Different Water Availability

OSMOREGULATION IN PLANTS

Topic: Homeostasis
Subtopic: Osmoregulation in Plants

Learning Outcome: Examine the adaptations and management of different plant Categories (xerophytes, mesophytes, and hydrophytes) based on their osmoregulatory abilities and the application of excretory plant products in everyday life. (u, s, gs, v/a).

Knowledge / Understanding	Performance Indicators
Learners should demonstrate understanding of: **1.** Processes in which plants minimize overheating: e.g. transpiration cooling, sunken stomata, reduced leaf surface, thick cuticle. **2. Plant adaptations to water availability:** ✓ Xerophytes; water conservation (thick cuticle, spines, CAM metabolism). ✓ Mesophytes; balanced water use (broad leaves, moderate stomata, flexible roots). ✓ Hydrophytes; excess water handling (aerenchyma, stomata on upper surface, thin cuticle). ✓ Halophytes **3. Human management techniques:** irrigation, mulching, drainage, use of drought-resistant varieties, greenhouse farming. **4.** Excretory products in plants: e.g. resins, tannins, latex, gums, essential oils – and their applications (medicine, industry, perfumes).	**Learners should be able to:** ☞ Correctly differentiate xerophytes, mesophytes, and hydrophytes by structure and adaptation. ☞ Explain how plants minimize overheating and regulate water. ☞ Describe human techniques for managing plant growth in different habitats. ☞ Give examples of plant excretory products and their uses in everyday life. ☞ Apply knowledge to real-life agricultural or conservation practices.

Subject Skills (Biological Competencies)	Generic Skills (Cross-cutting)
• **Analytical skills:** Comparing adaptations of xerophytes, mesophytes, hydrophytes, halophytes. • **Observation skills:** Examining plant structures using specimens, diagrams, or real plants. • **Application skills:** Relating adaptations to osmoregulation and human practices. • **Scientific drawing:** labeling structures correctly.	○ **Critical thinking:** Evaluating how adaptations aid survival. ○ **Communication skills:** Presenting findings orally in discussions or written reports. ○ **Problem-solving:** Suggesting ways to manage plants in different environments. ○ **Collaboration:** group discussions, teamwork in field studies or lab practical. ○ **ICT skills:** Using animations, simulations or power point slides to present their responses.
Values / Attitudes	**Nature of Assessment**
• Environmental stewardship, through promoting sustainable use of water and land. • Health & wellness orientation, through recognizing uses of plant excretory products (herbal medicine, cosmetics, food preservation). • Appreciation of how plants survive under different conditions. • Scientific curiosity, through valuing plant diversity and ecological balance.	**Formative Assessment:** ✍ Class discussions ✍ Oral questioning ✍ Quizzes ✍ Short presentations ✍ Diagrams **Summative Assessment:** ✍ AOI ✍ EOC exams **Competence-based assessment**: ✍ Project-based Learning/ tasks

Senior Five – Holiday Package

Research and discuss the following. Prepare a power point presentation. (you can do it either in groups or individually)

1. Analyze and discuss animal adaptations to different water availability in their environment.
2. Describe the different processes in which plants minimize overheating.
3. Discuss the plant adaptations to varying water availability in their habitats (xerophytes, mesophytes, and hydrophytes).
4. Explore the techniques employed by humans to manage plants that survive in different environments.

PBL (Tob be done after my guidance)

- ☞ Investigate excretory products in plants (latex, anthocyanins, oils, quinine, and saponins) to discover their uses in everyday life.