Homeostasis

UNIT 4

Chapter 9: Homeostasis: A Fine Balance

Organisms must constantly maintain their internal conditions to survive in their environment. The enzymes that control metabolism work at an optimal temperature range that is controlled by both behaviour and physiology. When many endothermic organisms become too warm, they dilate blood vessels in their extremities, causing more thermal energy to be lost to the surroundings. When many ectothermic organisms become too cold, they bask in the sun to absorb thermal energy from the environment. Water balance must also be maintained. This is often accomplished by osmoregulation and excretion of solutes in liquid waste. Many animals have elaborate excretory functions to regulate the concentrations of water, solutes and waste in the extracellular fluid. Negative feedback loops, in which an abundant product acts as an inhibitor to the process that creates it, are used to control homeostatic mechanisms.

Chapter 10: The Endocrine System

Hormones are chemical messengers that control body processes. Most hormones are made in one part of the body and carried by the blood stream to control other parts of the body, either a specific organ or a generalized effect. Protein hormones consist of amino acid chains and exert their effect by binding to receptors on cell membranes. Steroid hormones are derived from cholesterol, and exert their effect by binding to receptors in the cytosol. Both types of hormones are controlled by negative feedback mechanisms.

Growth, reproduction, and the concentration levels of many substances are controlled by hormones. For example, insulin, a protein hormone, is synthesized by the pancreas and reduces blood sugar levels. Impaired insulin secretion results in diabetes. Synthetic steroids have been developed to mimic the functions of natural steroids for medical applications and for enhanced athletic performance.

Hormone imbalances are being addressed by biotechnology in several ways, for example, by producing synthetic hormones such as insulin or by genetic engineering, which is still in the research stage.

Chapter 11: The Nervous System

Nerves (neurons) are living cells that use rapid, precise electrochemical impulses to control body functions and maintain homeostasis. Sensory neurons collect input from the environment and pass these signals to interneurons in the central nervous system for processing. Response signals are then carried to the appropriate muscles and glands by efferent neurons. All neurons receive electrochemical impulses through dendrites, and transmit electrochemical impulses through an axon. These impulses move across electrical or chemical synapses from one neuron to another.

Nervous responses can be voluntary and controlled by the somatic system, for example, touching your toes. Reflex loops enable even faster responses, for example pulling your hand away from a hot stove. The autonomic nervous system controls the involuntary actions of digestive, circulatory and respiratory muscles to control metabolic functions automatically.

The main organs of the central nervous system are the spinal cord and the brain. The human brain has evolved several specialized areas to allow for fast, accurate processing of information.

BIG IDEAS

- Organisms have strict limits on the internal conditions that they can tolerate.
- Systems that maintain homeostasis rely on feedback mechanisms.
- Environmental factors can affect homeostasis.

9.1 Maintaining an Internal Balance

Textbook pp. 428–431

Vocabulary

homeostasis
internal environment
interstitial fluid
homeostatic mechanism

MAIN IDEA: Homeostasis is the process by which animals and plants maintain an internal environment that promotes proper cellular function. Homeostasis is an ongoing dynamic process that acts in response to both internal and external conditions.

1. Describe two changes that you experience in your external environment when you get up in the morning. Do you respond to these changes by altering your behaviour or do your internal systems make the adjustments? K/U T/I A

2. List two changes in your internal environment that you experience on a normal day. Do you respond to these changes by altering your behaviour or do your internal systems make the adjustments? K/U T/I

3. Why is it important for an organism to maintain homeostasis? T/I

4. Which of the following are responses to changing conditions that can help maintain homeostasis? Circle your answers. K/U
   (a) a cat curling up to sleep
   (b) a turtle sunning itself on a rock
   (c) a dog barking
   (d) the leaves of a plant releasing oxygen into the atmosphere
   (e) a girl putting on mittens
   (f) a family building a house

MAIN IDEA: The body's internal environment consists of the interstitial fluid that surrounds cells and tissues, and the plasma in the blood. Numerous organs and organ systems coordinate their activities to maintain homeostasis; however, the nervous and endocrine systems are the most important systems.

5. The interstitial fluid and the blood plasma make up a body's extracellular fluid. What is the function of the extracellular fluid? K/U

6. Complete **Table 1** to summarize the role different organ systems play in maintaining homeostasis. K/U T/I C

Table 1 Organ Systems Involved in Homeostasis

Organ system	Role in maintaining homeostasis
nervous system	
excretory system	
endocrine system	
immune system	
digestive system	
integumentary system	
circulatory system	

STUDY TIP

Review Previous Work
Concepts you studied in biology in previous grades can help you understand homeostasis. Review the organs in each organ system and their primary functions to help you understand how the systems work together to maintain homeostasis.

7. Why are the nervous system and the endocrine system described as the most important organ systems in maintaining homeostasis? Give specific examples of processes that these two organ systems regulate. K/U T/I

8. Use homeostasis to explain why each of the following events might occur. K/U A

(a) We sweat when the temperature rises.

(b) We become very thirsty after we eat salty foods.

(c) Squirrels look fluffier in the winter.

9.2 Homeostasis and Feedback Mechanisms

Textbook pp. 432–435

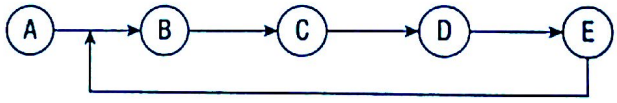
Vocabulary

negative feedback | integrator | effector
sensor | set point | positive feedback

MAIN IDEA: Negative feedback occurs when a system responds to change by attempting to compensate for this change. A negative feedback mechanism has three components: a sensor, which detects changes in the body's conditions; an integrator, which compares the sensory information to the desired set point; and an effector, which acts to re-establish homeostasis.

1. A negative feedback loop restores normal conditions. Explain why it is described as 'negative' and give an example of a negative feedback loop in humans. K/U T/I

2. Use the flow chart below to identify the five stages of a negative feedback loop. K/U C



STUDY TIP

Negative Feedback Loops
There are many examples of negative feedback loops that help maintain balance. Every one has a sensor, an integrator, and an effector. Think of some negative feedback loops that operate at home or at school.

3. For each of the following examples of a negative feedback loop, suggest a sensor, an integrator, and an effector. K/U
   (a) You feel cold, so the blood vessels in your skin constrict to minimize the loss of thermal energy.

   (b) A driver sees the car is moving over the speed limit, so takes her foot off the accelerator.

   (c) You get a cut in your leg and begin to bleed.

4. Use the flow chart from question 2 to illustrate a negative feedback loop using the following labels: sweat gland, thermoreceptors in skin, sweat, thermoreceptors in hypothalamus, skin blood capillaries, increase in thermal energy. K/U C

MAIN IDEA: All animals use many negative feedback mechanisms to maintain homeostasis, and responses can be physiological or behavioural.

5. Which of the following types of organisms use feedback loops to regulate internal processes? Circle your answers. K/U
   (a) mammals
   (b) fish
   (c) insects
   (d) reptiles
   (e) plants
6. List four examples of negative feedback mechanisms in animals. Indicate whether each response is physiological or behavioural. K/U T/I

MAIN IDEA: Positive feedback mechanisms enhance the effect of a change in the internal or external environment, but usually do not result in homeostasis.

7. A positive feedback loop usually does not restore normal conditions. Explain why it is described as "positive." K/U T/I

8. (a) Describe an example of a positive feedback loop in humans.

   (b) In what way is the result of the example you described in part (a) *not* an example of homeostasis?

   (c) Why is it advantageous for the body to *not* be in homeostatic balance at certain times? K/U T/I

9.3 Thermoregulation

Textbook pp. 436–441

Vocabulary

thermoregulation	endotherm	torpor
homeotherm	ectotherm	hibernation
poikilotherm	thermal acclimatization	estivation

Main idea: Thermal energy is transferred between animals and their environment by conduction, convection, radiation, and evaporation.

1. How is having a constant body temperature useful to an organism? K/U

2. Describe four ways an animal can lose thermal energy. K/U

3. Describe two ways an animal can gain thermal energy. K/U

Main idea: Homeotherms are animals that maintain a fairly constant internal temperature regardless of the external temperature. The internal body temperature of poikilotherms varies in response to the temperature of the external environment. Ectotherms are animals that regulate their body temperature by absorbing thermal energy from the environment. Endotherms are animals that regulate their body temperature with the internal mechanisms of thermal energy generation, conservation, and dissipation. Both endotherms and ectotherms have behavioural mechanisms that they can use to regulate their body temperature.

4. Describe similarities and differences between homeotherms and endotherms. K/U T/I

5. Describe similarities and differences between poikilotherms and ectotherms. K/U T/I

6. Describe advantages and disadvantages of controlling body temperature by behaviour.

7. Describe advantages and disadvantages of controlling body temperature by physiology.

8. Use **Table 1** to describe how endotherms and ectotherms respond to environmental temperature changes on a diurnal and seasonal scale.

Table 1 Response to Temperature Change

	Endotherms	Ectotherms
Diurnal		
Seasonal		

9. Many animals are either endothermic homeotherms or ectothermic poikilotherms. List two examples of each group.

10. A hummingbird is an endotherm, and can also be considered a poikilotherm. Why?

STUDY TIP

Prefixes and Suffixes
Examine suffixes and prefixes carefully to learn the meanings of words. *Ecto* means "outside", *endo* means "inside", and *homeo* means "the same as". How can knowing this help you understand endotherm, ectotherm, and homeotherm?

Main idea: Thermal acclimatization is the gradual adjustment to seasonal variations in temperature.

11. If the temperature is 15 °C in August, you feel cold and put on extra clothing but if the temperature is 15 °C in April, you feel hot and put on shorts. Why do you think the same temperature can have opposite effects on the body?

12. Describe an example of an ectotherm using thermal acclimatization adaptations.

9.4 Water Balance

Textbook pp. 442–445

Vocabulary

osmotic pressure
hyperosmotic
hypoosmotic
isoosmotic
osmoregulation

MAIN IDEA: Osmoregulation ensures that the intracellular and extracellular fluids are isoosmotic, and it keeps the internal concentrations of water and ions different from the concentrations in the external environment.

LEARNING TIP

The Behaviour of Water
Water diffuses in the same manner as all other molecules, from areas where it has a high concentration to areas where it has a low concentration. It is important to remember that a solution with low concentration is a solution where water is at a high concentration.

1. Why would an animal that lives in an aqueous environment, such as a salmon, have to regulate water uptake and expulsion? K/U

2. Complete **Table 1** to compare the characteristics of hyperosmotic, hypoosmotic and isoosmotic solutions. K/U T/I C

Table 1 Characteristics of Solutions

	Hyperosmotic	Hypoosmotic	Isoosmotic
Concentration of water			
Concentration of solutes			
Direction of water diffusion			
Direction of solute diffusion			

3. (a) Discuss the pressures in the cell that cause water to enter the cell.

(b) Discuss the pressures in the cell that cause water to leave the cell. K/U

4. Why do plants sometimes wilt on a hot dry day? K/U A

MAIN IDEA: Osmoregulation is closely linked to the process of excretion, in which animals expel waste products of metabolism to the external environment. The excretory system removes nitrogenous waste, excess water, and toxic compounds from the body. The main organs in the excretory system are the liver and the kidney.

5. Distinguish between the terms excretion and secretion. Include an example of each. K/U

6. How do diffusion, osmosis, and excretion work together to maintain homeostasis in an organism? K/U T/I

7. Do all animals have bladders? Explain. K/U T/I

8. In addition to water concentrations, what other two factors does excretion help animals keep in balance? K/U

9. One of the main waste products we produce is ammonia. Where does this type of waste come from and why is it important for our bodies to eliminate it? K/U

10. What challenge does elimination pose for many terrestrial animals? K/U

11. Draw a flow chart to show how nitrogenous waste is created and then excreted in mammals. K/U C

9.5 The Excretory System

Textbook pp. 446–454

Vocabulary

contractile vacuole
metanephridium
Malpighian tubule
nephron
Bowman's capsule
glomerulus
afferent arteriole
efferent arteriole
peritubular capillaries
proximal convoluted tubule
loop of Henle
distal convoluted tubule
filtration
reabsorption
aquaporin
secretion

MAIN IDEA: Single-celled organisms excrete waste directly to the environment. Most invertebrates have specialized structures to process and excrete waste.

1. Discuss the osmotic pressures on a protozoan and a mechanism that regulates these pressures. KU TI

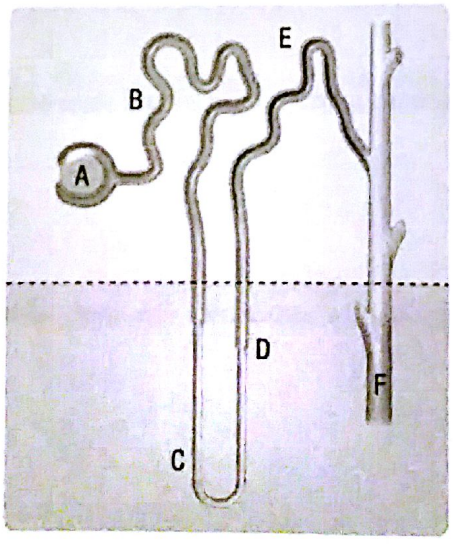
2. Discuss the role of the metanephridia and the Malpighian tubules, and their importance in storing waste in the organism's body. KU

MAIN IDEA: The Bowman's capsule and the glomerulus filter the blood. The fluid then moves through the proximal convoluted tubule, which actively reabsorbs ions and nutrients. Additional water is removed passively. The filtered blood reabsorbs water, ions, and other molecules, which are then absorbed in the peritubular capillaries. In the descending portion of the loop of Henle, water is reabsorbed by osmosis. In the ascending portion of the loop, ions are removed via active transport. In the distal convoluted tubule, the salt concentrations of the filtrate and the interstitial fluid are balanced. In the collecting duct additional water is reabsorbed. The urine is collected in the renal pelvis. From there, it flows into the bladder, where it is stored until it is excreted.

STUDY TIP

Using Diagrams and Descriptions
As you follow the path of waste through the kidney diagram at right, desribe what happens in each part of the kidney.

3. Label the parts of the kidney nephron shown in **Figure 1** below.



A. _____
B. _____
C. _____
D. _____
E. _____
F. _____

Figure 1

4. Complete **Table 1** to compare the relative concentrations of plasma, filtrate, and urine in the kidney. Use these terms: low, medium, high, variable, none. KU TI

Table 1 Fluids in the Kidney

	Glomerulus	Bowman's capsule	Collecting tubule
Water concentration			
Glucose concentration			
Amino acid concentration			
Sodium chloride concentration			
Urea concentration			
Oxygen concentration			
Carbon dioxide concentration			
Plasma proteins			
Cells			

5. Use **Table 2** to summarize the main points of the three stages of urine formation. KU TI

Table 2 Urine Formation

	Filtration	Reabsorption	Secretion
Location(s)			
Materials moving into blood and body			
Materials moving out of blood and body			
Active transport involved?			
Passive transport involved?			

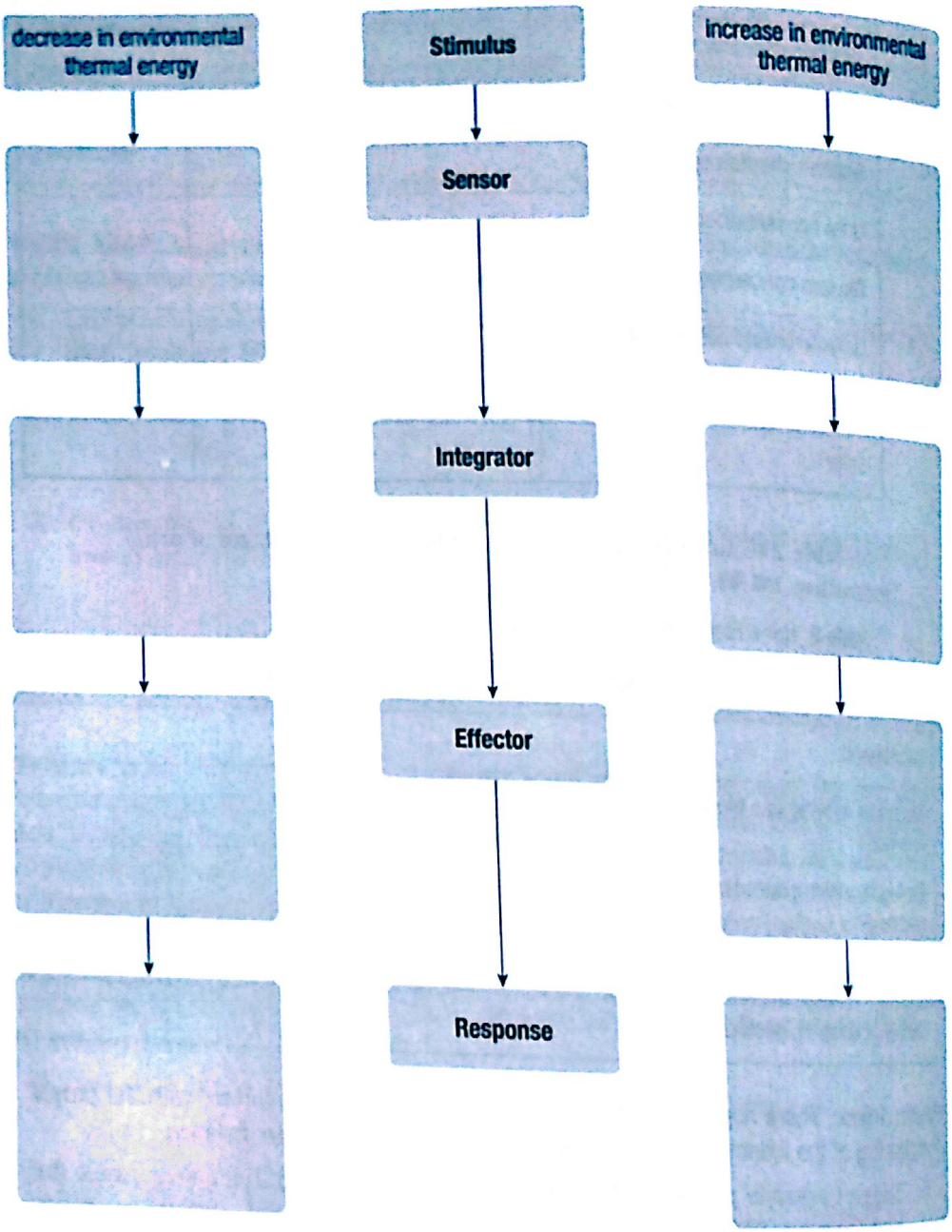
Main Idea: There are many diseases and disorders that can interfere with the proper functioning of the kidneys in excreting wastes and maintaining water balance.

6. Suggest possible problems that could develop in an organ that concentrates the body's wastes. KU TI

7. Suggest possible problems that could develop in an organ that contains large numbers of blood capillaries, some under pressure. KU TI

Homeostasis: A Fine Balance

Complete the flow chart that illustrates two examples of homeostatic control mechanisms using a negative feedback loop.



CHAPTER 9 QUESTIONS

K/U Knowledge/Understanding
T/I Thinking/Investigation
C Communication
A Application

1. When the ambient (room) temperature is very high, such as 32 °C, the body will lose thermal energy through which mechanism? (9.3) K/U
   (a) radiation
   (b) conduction
   (c) evaporation
   (d) increased metabolism

Table 1 shows a patient's test results. Use Table 1 to answer questions 2 and 3.

Table 1 Composition of fluids in kidney (g/100 mL)

Substance	Component	Plasma	Filtrate	Urine
U	urea	0.030	0.030	2.00
V	uric acid	0.004	0.004	0.05
W	glucose	0.100	0.100	0.00
X	amino acids	0.050	0.050	0.00
Y	salts	0.720	0.720	1.50
Z	proteins	8.000	0.036	0.00

2. Which substances were completely reabsorbed into the plasma? (9.5) K/U T/I
   (a) U, V, Y (b) W, Y, Z (c) U, W, X (d) W, X, Z
3. Which substances were excreted? (9.5) K/U T/I
   (a) U, V, Y (b) W, Y, Z (c) U, W, X (d) W, X, Z
4. A family doctor has a patient with the following symptoms: very high blood sugar levels; high sugar level in the urine; constant thirst; produces large quantities of urine. Which condition should the doctor investigate? (9.5) K/U T/I
   (a) diabetes insipidus
   (b) Bright's disease
   (c) diabetes mellitus
   (d) kidney stones
5. Indicate whether each statement is true or false. If you think a statement is false, rewrite it to make it true. K/U
   (a) Some animals sun themselves or retreat to shade as a way of regulating their body temperature. (9.2)

   (b) Kidneys remove waste, balance blood pH, and maintain water balance. (9.4)

   (c) Wastes are filtered from the blood by the kidneys and conducted to the urinary bladder by the urethra. (9.5)

6. The nitrogen that mammals excrete comes from what source? (9.4) K/U

7. Which environment is more dangerous to an endotherm: one above its critical temperature or one below its critical temperature? Explain. (9.3) KU TI

8. How do you think the quantity of urine formed by a frog would change when the frog moves from a pond onto land? Would the quantity of urine formed by a beaver change under the same circumstances? Explain your answer. (9.5) KU TI A

9. Imagine you are playing an active game and you begin to sweat. Soon you feel cooler. Construct a labelled diagram to represent the feedback loop involved in this homeostatic system. On the diagram, indicate the receptor(s), the control centre(s), and the effector(s). (9.2) KU TI C

10. Complete **Table 2** to compare the concentrations of substances found in the excretion of urine by a healthy person's kidneys. (9.5) KU C

Table 2 Substance Concentration

Substance	Blood of the afferent arteriole	Bowman's capsule filtrate	Urine
blood protein			
glucose			
sodium ions			
urea			

11. Describe how each process below is involved in the removal of nitrogenous wastes by a human nephron. (9.5) KU
    (a) filtration

    (b) reabsorption

    (c) active transport: