SURFING

NATIONAL BIOLOGY

Unit 4 Maintaining the Internal Environment

• Kerri Humphreys •

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Science Press

Science Press
Bag 7023 Marrickville NSW 1475 Australia
Tel: (02) 9516 1122 Fax: (02) 9550 1915
sales@sciencepress.com.au
www.sciencepress.com.au

Contents

Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory parts of the syllabus, along with questions and answers.

All types of questions – multiple choice, short response, structured response and free response – are provided. Questions are written in exam style so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions. These cover every aspect of the topic, and are useful for revision and exam practice.

Words To Watch

account, account for State reasons for, report on, give an account of, narrate a series of events or transactions.

analyse Interpret data to reach conclusions.

annotate Add brief notes to a diagram or graph.

apply Put to use in a particular situation.

assess Make a judgement about the value of something.

calculate Find a numerical answer.

clarify Make clear or plain.

classify Arrange into classes, groups or categories.

comment Give a judgement based on a given statement or result of a calculation.

compare Estimate, measure or note how things are similar or different.

construct Represent or develop in graphical form.

contrast Show how things are different or opposite.

create Originate or bring into existence.

deduce Reach a conclusion from given information.

define Give the precise meaning of a word, phrase or physical quantity.

demonstrate Show by example.

derive Manipulate a mathematical relationship(s) to give a new equation or relationship.

describe Give a detailed account.

design Produce a plan, simulation or model.

determine Find the only possible answer.

discuss Talk or write about a topic, taking into account different issues or ideas.

distinguish Give differences between two or more different items.

draw Represent by means of pencil lines.

estimate Find an approximate value for an unknown quantity.

evaluate Assess the implications and limitations.

examine Inquire into.

explain Make something clear or easy to understand.

extract Choose relevant and/or appropriate details.

extrapolate Infer from what is known.

hypothesise Suggest an explanation for a group of facts or phenomena.

identify Recognise and name.

interpret Draw meaning from.

investigate Plan, inquire into and draw conclusions about.

justify Support an argument or conclusion.

label Add labels to a diagram.

list Give a sequence of names or other brief answers.

measure Find a value for a quantity.

outline Give a brief account or summary.

plan Use strategies to develop a series of steps or processes.

predict Give an expected result.

propose Put forward a plan or suggestion for consideration or action.

recall Present remembered ideas, facts or experiences.

relate Tell or report about happenings, events or circumstances.

represent Use words, images or symbols to convey meaning.

select Choose in preference to another or others.

sequence Arrange in order.

show Give the steps in a calculation or derivation.

sketch Make a quick, rough drawing of something.

solve Work out the answer to a problem.

state Give a specific name, value or other brief answer.

suggest Put forward an idea for consideration.

summarise Give a brief statement of the main points.

synthesise Combine various elements to make a whole.

SURFING

Homeostasis

1 Assumed Knowledge

1. What is meant by the term 'metabolism'?
2. Distinguish between the internal and external environment of an organism.
3. Define receptor and effector.
4. List the five main senses found in animals.
5. Name the five sense organs found in animals.
6. Figure 1.1 shows most of the sense receptors found in the skin.

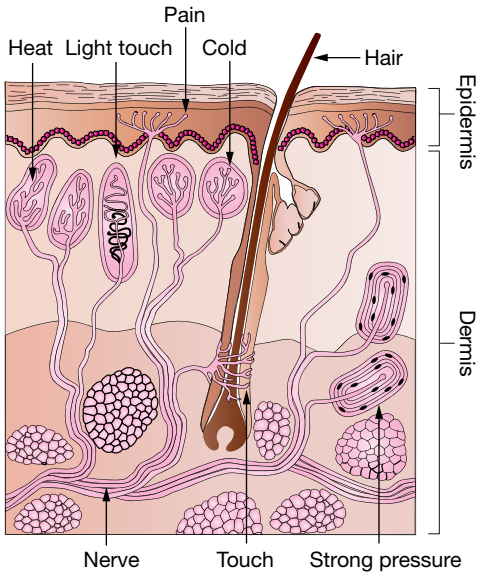


Figure 1.1 Senses in the skin.

Identify the different types of receptors found in the skin.

7. What is interstitial fluid?
8. Distinguish between an endotherm and an ectotherm.
9. Outline the function of the nervous system.
10. The nervous system is often divided into the central nervous system and the peripheral nervous system. Compare these two systems.
11. What is meant by ambient temperature?
12. Describe the function of the circulatory system.
13. The following diagram shows cellular components found in blood.

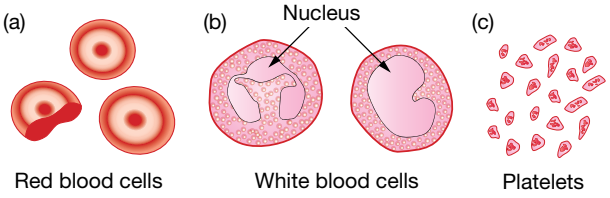


Figure 1.2 Blood cells.

Outline the function of each of the three types of cellular components shown in the diagram.

14. Define artery, vein and capillary.
15. Define diffusion.
16. In an experiment, what is a control?
17. Briefly describe the lymph system.
18. The following diagram shows a cross-section of the human brain.

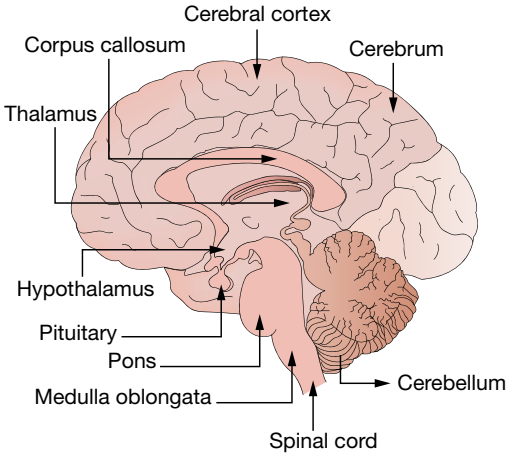


Figure 1.3 Cross-section of human brain.

Outline the function of the spinal cord and cerebrum.

19. The following diagram shows gas exchange in the lung.

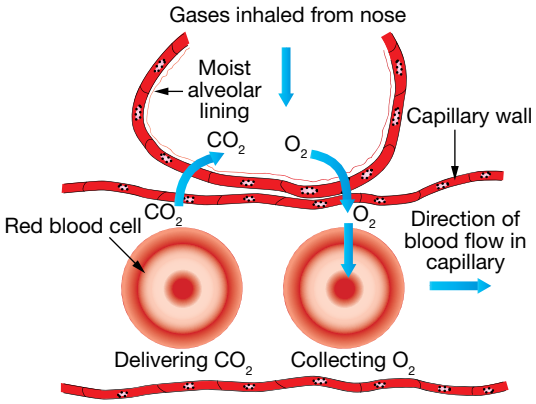


Figure 1.4 Gas exchange.

Describe the movement of gases in and out of the alveoli of the lungs.

20. The following diagram shows the distribution of body water.

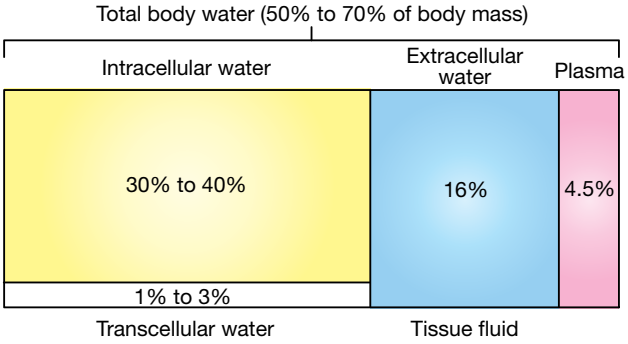


Figure 1.5 Distribution of body water.

Describe why water is an important molecule in organisms.

21. Define parasite.
22. Briefly describe bacteria.
23. Briefly describe viruses.
24. What is a pathogen?
25. Define a hormone.

2 Homeostasis

Homeostasis is the process by which organisms maintain a relatively stable internal environment within narrow limits. To maintain homeostasis, organisms need to detect stimuli from both their internal environment and from the external environment. Homeostasis is vital for the survival of all cells as all the chemical processes of life can only function within a narrow range of conditions. It maintains optimal metabolic efficiency.

Homeostasis consists of two stages:

- Detecting changes.
- Responding to the change.

Receptors detect the change from the stable state and the **effector** counteracts the change from the stable state with an appropriate response.

The vertebrates, especially the endotherms, have the greatest ability to control their internal environment. **Endotherms** use metabolic heat to regulate body temperature, e.g. birds and mammals. Their body temperature can vary quite markedly from ambient temperature. In humans, homeostasis maintains body temperature at approximately 37°C, maintains pH of interstitial fluid within a tenth of 7.4 and maintains the sugar concentration of the blood at approximately 0.1%. The homeostatic control is carried out by the nervous and endocrine systems.

The nervous system has receptors in the sense organs to detect changes in the external environment. For example, the retina at the back of the eye has rods and cones that can detect light; the cochlea in the ear has hair cells that detect pressure waves in the cochlear fluid; the tongue has taste buds; the nose has olfactory receptors and the skin has a range of mechanoreceptors, thermoreceptors and pain receptors.

A message being carried by the nervous system usually follows the stimulus-response model.

Stimulus → receptor → sensory neuron → interneuron → motor neuron → effector → response

Figure 2.1 Stimulus-response model.

QUESTIONS

1. Define homeostasis.
2. Explain why a constant internal environment is necessary.
3. Identify the two stages of homeostasis.
4. Identify some variables in 'higher' vertebrates that are controlled by homeostasis.
5. Explain why endotherms require the greatest capacity to control their internal environment.
6. Outline the conditions of homeostasis maintained by the human body.
7. Construct a table to show the sense organ, its receptor and the stimuli it detects.
8. Draw a flow diagram to show the steps in the stimulus-response model.
9. The diagram shows a control system.

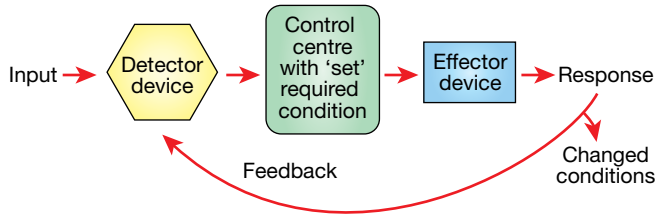


Figure 2.2 Control system.

Outline the functioning of a control system.

10. Define an endotherm.
11. Which of the following best defines homeostasis?
    (A) Inputs such as food and oxygen equal outputs such as faeces and carbon dioxide.
    (B) Metabolic processes are stationary.
    (C) Maintaining constant body temperature.
    (D) Internal environment is kept constant.
12. What are the two stages of homeostasis?
    (A) Detecting and responding to changes.
    (B) Positive and negative feedback.
    (C) Sensory stimuli and nervous impulse.
    (D) Nervous messages and endocrine hormones.
13. Which of the following correctly identifies the stimulus-response pathway?
    (A) Stimulus → control centre → effector → receptor → response
    (B) Stimulus → effector → control centre → receptor → response
    (C) Stimulus → receptor → control centre → effector → response
    (D) Stimulus → effector → receptor → control centre → response
14. Which of the following correctly identifies the stimulus, type of receptor and organ?

	Stimulus	Receptor	Organ
(A)	Light	Photoreceptor	Eye
(B)	Heat, cold	Chemoreceptor	Skin
(C)	Sound	Olfactory receptor	Ear
(D)	Pressure	Thermoreceptor	Nose

15. What is meant by ambient temperature?
    (A) Maximum temperature reached during the day.
    (B) Lowest temperature reached during the day.
    (C) Temperature of surroundings.
    (D) Range of temperatures over one day.

3 The Role of the Nervous System

The nervous system is involved in coordination – sending messages when stimuli are detected to bring about appropriate responses. For example, the nervous system coordinates the activities of the heart, lungs and legs muscles.

The nervous system can be divided into two sections.

- The **central nervous system** (CNS) consists of the brain and spinal cord.
- The **peripheral nervous system** (PNS) consists of all nerves outside the brain and spinal cord.

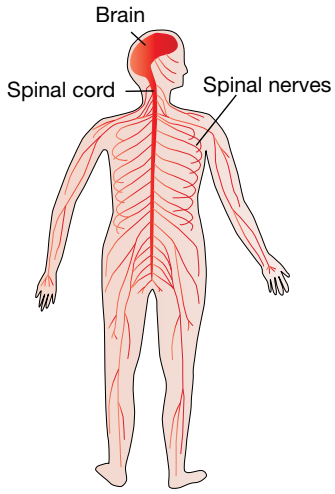


Figure 3.1 Human nervous system.

The nervous system consists of nerve cells called neurons. Sensory neurons carry an electrochemical impulse from a receptor in a sense organ to the CNS. Motor neurons carry the electrochemical impulse from the CNS to an effector which can be a muscle or a gland. Multipolar neurons (or connector neurons) make connections to other neurons inside the CNS.

The nervous system carries out a vital role in detecting and responding to environmental changes.

Detecting environmental changes

Sense organs contain receptors that detect changes in the environment. Sensory nerve endings in the skin respond to touch, pain, pressure, and heat and cold. Taste buds on the tongue recognise four classes of chemicals – sweet, sour, salty and bitter. Olfactory receptors in the nasal cavity determine the 'flavour' of food and detect smell. The retina in the eye has receptor cells called rods and cones. Cones respond to bright light and determine colour while rods respond to dim light. The cochlea in the inner ear has sensory nerve endings that detect vibrations and messages sent to the brain are interpreted as sound.

Responding to environmental change

Some responses of the CNS involve reflex arcs which are involuntary reactions. Reflex arcs are important in protecting the body, e.g. blinking if dirt flicks in your eye, coughing if particles touch the lining of the windpipe. You cannot stop this reflex and often are not aware it is happening, e.g. iris dilation in dim light.

The brain determines voluntary actions in response to stimuli. The brain sends a message along motor neurons to instruct the effector to carry out a particular action, e.g. put on a jumper because you 'feel' cold.

QUESTIONS

1. Identify the two sections of the nervous system.
2. Trace the pathway from receptor to effector.
3. Outline the main role of the nervous system.
4. The diagram shows a simple spinal reflex arc.

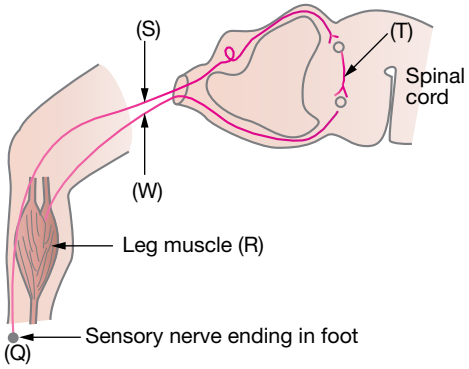


Figure 3.2 Spinal reflex arc.

Identify the type of neuron labelled (T) and explain its function.

5. Use examples to show how the tongue can be both a receptor and an effector.
6. The diagram shows a flow chart for the coordination of body temperature in response to changes in environmental conditions.

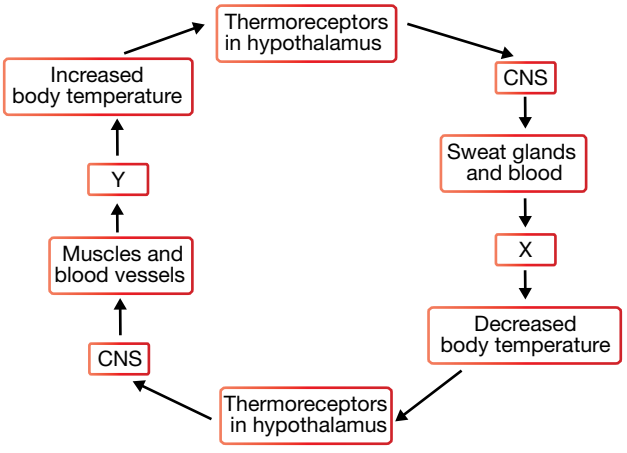


Figure 3.3 Coordination of body temperature.

Suggest suitable responses for part X and part Y.

4 The Stimulus-Response Model

The stimulus-response model gives the basic pathway for a nervous impulse where a receptor picks up a stimulus, the message is interpreted and another message is transmitted to an effector which carries out the response.

A **stimulus** is a change in the environment of an organism that is detected.

Stimulus → receptor → nervous system → effector → response

Figure 4.1 Simple stimulus-response model.

The three main parts of the stimulus-response model are:

- **Receptor** – there are many types of receptors in the body that can detect specific stimuli both internal and external. The receptor converts the stimulus into a nerve impulse which is transmitted by a sensory neuron to the central nervous system (CNS).
- **CNS** – connector neurons in the spinal cord and brain take the message to a control centre where the information is processed.
- **Effector** – motor neurons that connect to the CNS transmit a resultant nervous impulse from the CNS to an effector organ which is a muscle or a gland. The effector carries out the response.

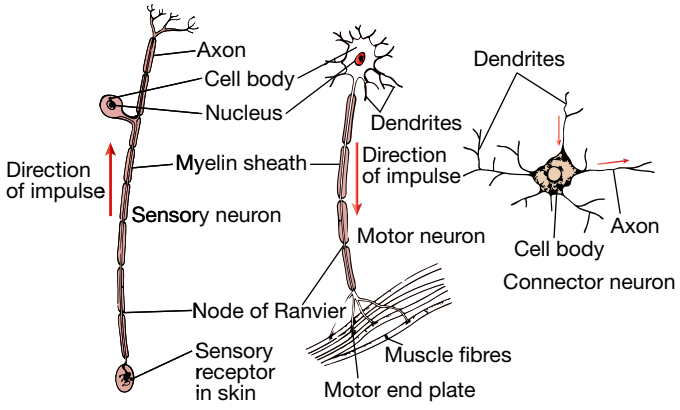


Figure 4.2 Three types of neurons.

Types of neurons

There are three main types of neuron which have specific functions – sensory, motor and connector neurons.

Sensory neurons carry messages from receptors in the sense organs, or in the skin to the brain and spinal cord.

Motor neurons carry messages from the brain and spinal cord to the effectors. A motor neuron to a muscle has many branches in the muscle fibre forming a motor end plate.

Connector neurons are located in the brain and spinal cord. These neurons are also called relay neurons, association neurons or interneurons.

A **nerve** is a bundle of nerve fibres, e.g. axons held together by connective tissue.

A **synapse** is a small gap at the junction between adjacent neurons.

A **neuromuscular junction** is the small gap between the end of an axon and a skeletal muscle cell.

Neurotransmitters are substances that diffuse across a chemical synapse transmitting the message from the synaptic terminal of a neuron to the postsynaptic cell triggering a response, e.g. from the axon to dendrite or from axon to cell body. There are many neurotransmitters, e.g. acetylcholine, adrenaline and dopamine. Acetylcholine is the neurotransmitter at neuromuscular junctions between a neuron and a skeletal muscle.

QUESTIONS

1. What is meant by the stimulus-response model?
2. Define a stimulus.
3. Draw a flow chart to show the steps in the stimulus-response model.
4. Construct a table to summarise the three main parts of the nervous system.
5. Distinguish between a motor neuron and a sensory neuron.
6. What is a nerve?
7. What is the synapse?
8. Outline the function of neurotransmitters.
9. Identify the following cell.

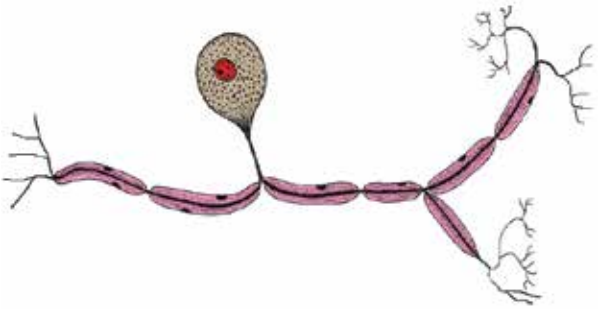


Figure 4.3 Type of cell.

(A) Motor neuron.
(B) Sensory neuron.
(C) Connector neuron.
(D) Muscle cell.

10. Which neurons are never myelinated?
(A) Motor neurons and sensory neurons.
(B) Sensory neurons.
(C) Motor neurons.
(D) Connector neurons.

5 Reflexes

A reflex is a fast response that is involuntary and does not involve the brain in the decision making process. Reflexes help maintain homeostasis. In some reflexes the message from the receptor enters the spinal cord and is passed to motor neurons at the same level in the cord or may travel a few segments up the cord before travelling out through a motor neuron. Once the response has been made a person becomes consciously aware of the situation.

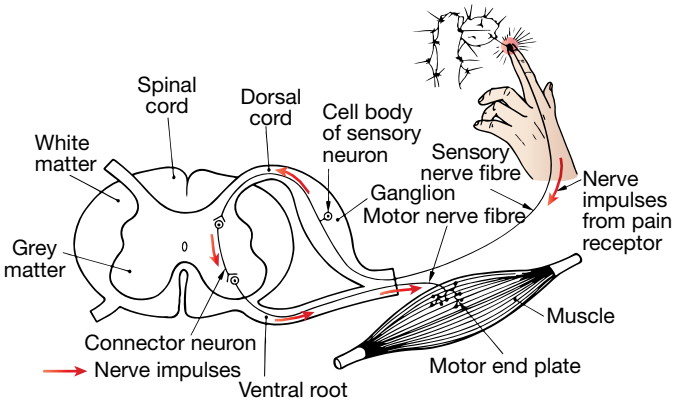


Figure 5.1 Reflex arc.

The brain and spinal cord contain grey matter and white matter. **Grey matter** is mainly the cell bodies of neurons, dendrites and unmyelinated axons. **White matter** consists of axons with myelin sheaths. In the spinal cord the white matter is on the outside to allow linking of the CNS to sensory and motor neurons of the PNS. The grey matter in the spinal cord is roughly in the shape of the letter H. Most of the grey matter in the brain is on the outside surrounding the white matter.

In a **monosynaptic reflex** there are only two neurons – a sensory neuron and a motor neuron, e.g. peripheral muscle reflexes such as the Achilles reflex. In a polysynaptic reflex arc there are one or more connector neurons in the circuit. Most reflexes are **polysynaptic**.

Autonomic nervous system

The autonomic nervous system is a subdivision of the motor nervous system of vertebrates that controls the internal environment. It controls involuntary muscle, e.g. it is the nerves that control cardiac muscle, glands and the smooth muscle that is found in the walls of blood vessels and in the digestive, respiratory, excretory and reproductive tracts. The autonomic nervous system is subdivided into the sympathetic nervous system and the parasympathetic nervous system. The **parasympathetic nervous system** generally produces responses that maintain the body during quiet conditions while the **sympathetic nervous system** usually produces response that prepare the body for activity, e.g. fight or flight responses.

QUESTIONS

1. What is a reflex?
2. When does a person know a reflex has happened?
3. Distinguish between grey matter and white matter.
4. Identify the location of grey matter and white matter:
   (a) In the brain.
   (b) In the spinal cord.
5. Distinguish between a monosynaptic reflex arc and a polysynaptic reflex arc.
6. The diagram shows a reflex arc.

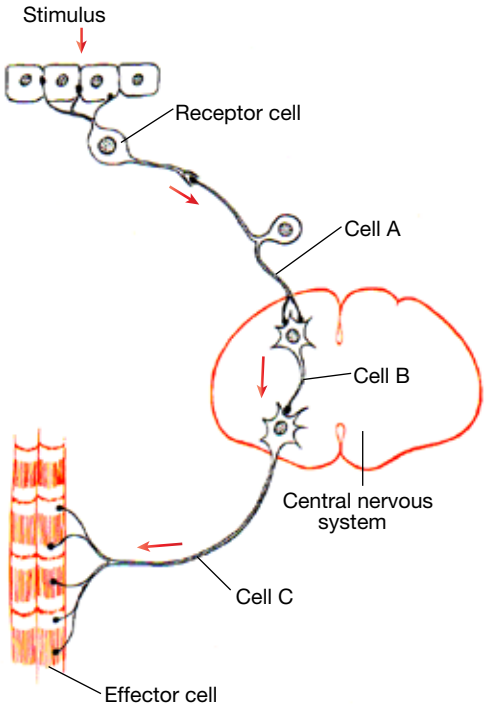


Figure 5.2 Reflex arc.

Identify the cells labelled A, B and C and explain your reasoning.

7. What is the autonomic nervous system?
8. The change in the size of the pupil of the eye is controlled by the autonomic nervous system. Explain why the size of the pupil needs to be a reflex caused by involuntary muscles.
9. Which of the following would *not* be part of the autonomic nervous system?
   (A) Muscle layer in wall of arteries.
   (B) Cardiac muscle.
   (C) Skeletal muscle.
   (D) Muscle layer in wall of intestines.
10. A flexor reflex is a spinal reflex that moves a limb away from a stimulus detected by a skin receptor. Which of the following would cause a flexor reflex?
    (A) Your hand touches a hot object.
    (B) You smell some pepper.
    (C) You see a ball coming towards you.
    (D) You hear a loud noise behind you.

6 Receptors

One of the characteristics of living things is that they can respond to stimuli. A stimulus may come from the external environment (e.g. light intensity, sound) or may come from the internal environment (e.g. hormone levels, arrival of food). Receptors detect stimuli. There are many types of receptors: **proprioceptors** are in muscles, tendons and joints; **mechanoreceptors** respond to stretching, movement, touch, pressure, gravity; **chemoreceptors** respond to chemicals; **photoreceptors** detect light; **thermoreceptors** detect heat and cold; and some animals (e.g. fish) have **electroreceptors** that detect electrical energy.

Receptors are found in the sensory organs. The retina in the eye has rods and cones. There are olfactory receptors in the nasal cavity and gustatory receptors in the taste buds on the tongue. The cochlea has hair cells that detect pressure waves in the ear and there are mechanoreceptors (pressure, touch, stretch receptors), thermoreceptors (heat and cold receptors) and pain receptors in the skin. Internal receptors are found in many locations. For example, chemoreceptors in the medulla of the brain monitor carbon dioxide levels in the blood. If the carbon dioxide level rises, impulses are sent to the inspiratory centre of the hindbrain, which in turn sends impulses to the diaphragm and intercostal muscles to increase the rate of breathing.

The messenger, usually nerve impulses, takes the message from the receptor to the effector (e.g. muscles and glands in multicellular organisms), which carries out the response. The response to the stimuli helps the organism survive.

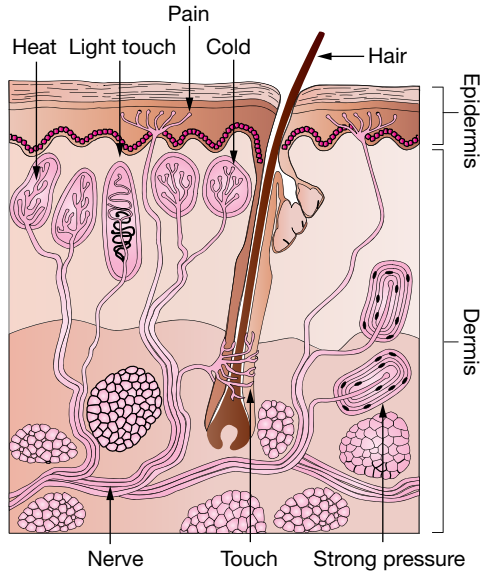


Figure 6.1 Senses in the skin. Most sense receptors in the dermis have capsules around them. Those in the epidermis and those wrapped around the hairs have naked nerve endings.

Senses in other animals

In protozoa (e.g. amoeba), sensitivity is a property of the cytoplasm. An amoeba will move away from unfavourable stimuli, such as very bright light or being poked with a needle, or will move around a food particle. Earthworms have simple sense organs consisting of single cells or small groups of cells. Earthworms can detect vibrations through solid objects and move away from light or if touched. They move deep into the soil in dry periods and very cold weather. They also have internal receptors (e.g. in muscles) and chemical receptors in the mouth. The sense organs of insects are well developed. Grasshoppers have two large compound eyes that detect shape and movement and simple eyes (ocelli) that detect light intensity. Insects also have antennae responsive to chemicals and touch.

Many invertebrates (e.g. crayfish) have statocysts (gravity receptors) where a tiny grain of loose sand or calcium carbonate called the statolith is held in a cavity so that any movement of the statolith stimulates hair cells. The invertebrate interprets these signals to determine which way is 'down'.

Fish and some amphibians have lateral line organs with hair cells, which respond to waves, currents and disturbances in the water. A cupula encloses the tips of the hairs and movement of the water moves the cupula, causing the hairs to bend, which in turn stimulates a nerve message.

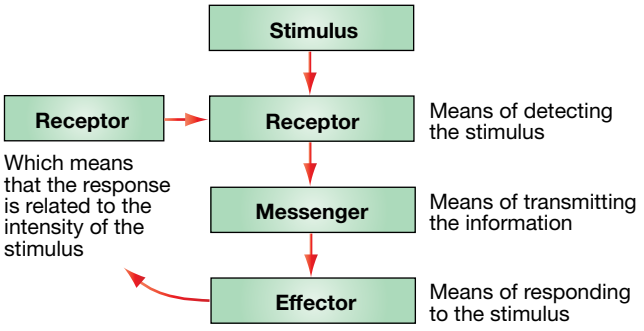


Figure 6.2 Main features of a coordinating system.

QUESTIONS

1. Create a table to show the relationship between the stimulus, the receptor and the sense organ.
2. Distinguish between proprioceptors, mechanoreceptors, chemoreceptors, photoreceptors, thermoreceptors and electroreceptors.
3. Identify the steps in the stimulus-response pathway.
4. Choose one type of sensory receptor found in the skin and briefly describe how it operates.
5. The flow chart shows the control of breathing in humans.

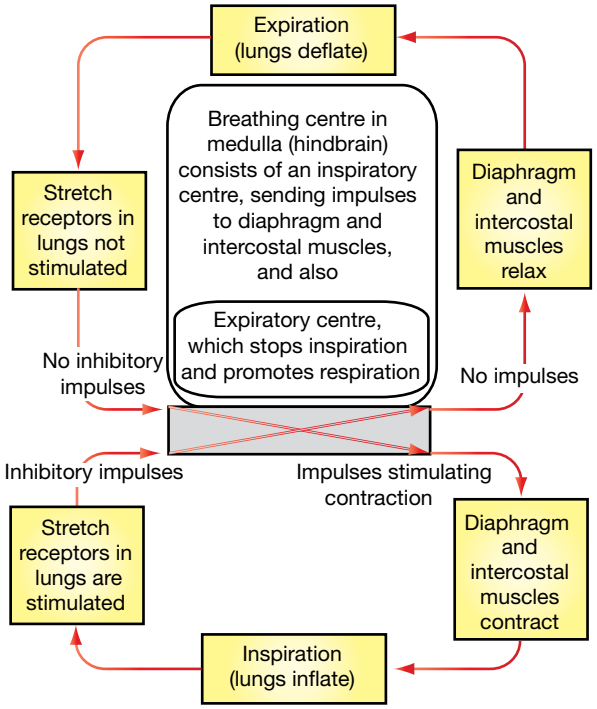


Figure 6.3 Flow chart of breathing in humans.

(a) Identify the receptors involved with the control of the rate of breathing.
(b) Explain a response in this example to show the stimulus, receptor, messenger, effector and response.
(c) Explain how a feedback mechanism could turn off the response you described in part (b).
(d) Use an example to show how the rate of breathing can be influenced by conscious thought.

6. Osmoreceptors in the hypothalamus detect changes in the concentration of solutes in body fluids. For example, the osmoreceptors detect an increase in the salt levels if a person has drunk little water or has been sweating heavily or has eaten large amounts of salty food. The osmoreceptors generate an impulse to the posterior pituitary gland to trigger the release of antidiuretic hormone (ADH) into the bloodstream. The target organ for the hormone is the kidney, where the ADH causes increased permeability of the walls of the collecting ducts so that more water is reabsorbed and the urine becomes more concentrated. Draw a flow chart to show the sequence of events in this stimulus-response example.
7. Use an example to show the response of a named protozoan to a particular stimulus.
8. Compare the sense organs of the earthworm with the sense organs of a human.
9. Suggest a reason why it is important for insects to be very sensitive to chemicals.
10. In a classic experiment, iron filings were substituted for the grains of sand in the statocysts of crayfish. When magnets were placed above the crayfish, they swam upside down. Suggest the mechanism involved in causing the crayfish to swim upside down.
11. Explain how fish identify obstacles in their way and moving objects such as prey, enemies and schooling mates.
12. Identify the range of senses used in communication.
13. Suggest why it is important for organisms to be able to detect changes in their environment.
14. Give an example of touch as a form of communication in humans and in one other animal.
15. Give an example to show the importance of taste as a form of communication in a named animal.
16. The diagram shows the stimulus-response model in a human.

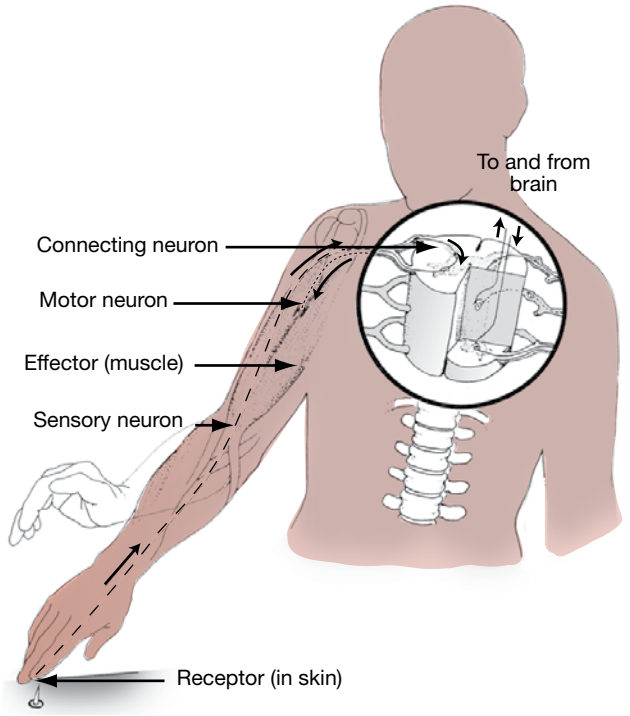


Figure 6.4 Stimulus-response model.

(a) In this diagram, what is the stimulus?
(b) What is the response?
(c) Identify the type of receptor cell.
(d) Draw a flow chart to show the pathway from receptor to response.
(e) The knee jerk stimulus-response is an example of a reflex arc. Compare this example with the stimulus of a ball coming towards you and you deciding to dodge away, rather than catching it.

17. What is the function of proprioceptors?
(A) Senses movement, position of the body.
(B) Senses light.
(C) Senses temperature.
(D) Senses sound.

7 Feedback Mechanisms

Homeostasis usually involves a feedback mechanism. In a feedback mechanism the response is monitored.

Situation monitored	→	changes made	→	situation reassessed	→	changes made

Figure 7.1 Feedback mechanism.

The response becomes the new stimulus.

In a **negative feedback system** a specific change results in a response opposite to the initial situation. For example, in humans if the body temperature becomes too low (stimulus), the person may start shivering (response). The shivering generates heat and the body becomes warmer (new stimulus). The feedback mechanism monitors the rise in temperature and will cause the **opposite** to the initial response – it will **stop** the shivering.

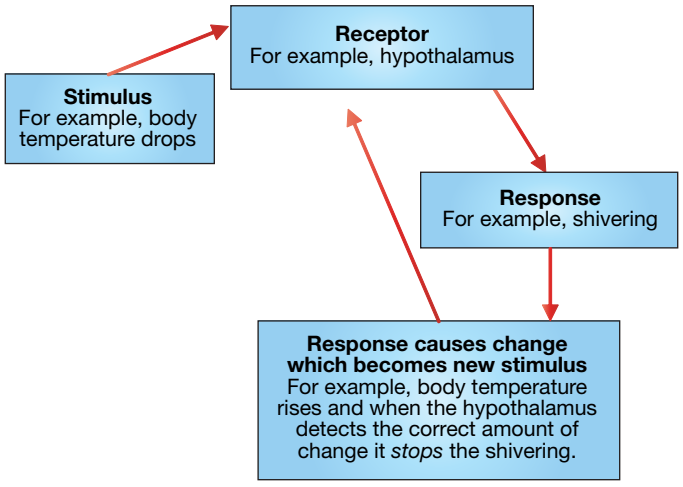


Figure 7.2 Negative feedback mechanism.

In a **positive feedback system** the monitoring will reinforce and amplify the situation, causing more of the same situation to take place. For example, during childbirth oxytocin is released to cause contractions of the uterine muscles and the pressure of the baby's head against the opening of the uterus causes more oxytocin and more contractions. As the baby's head continues to push against the uterus, sensors near the cervix stimulate even more contractions so that the pressure to keep dilating the opening to the uterus increases until the baby is born. Positive feedback is not as common as negative feedback.

QUESTIONS

1. Define feedback mechanism.
2. Compare negative and positive feedback, explaining an example for each.
3. The diagram shows how an air conditioner controls the temperature of a room

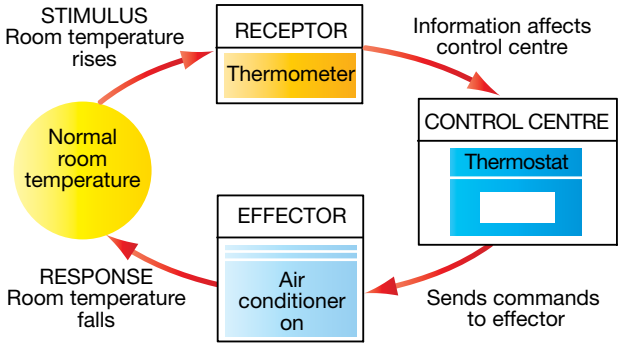


Figure 7.3 How an air conditioner works.

Compare the functioning of the air conditioner with thermoregulation in humans.

4. The diagram shows thermoregulation in humans.

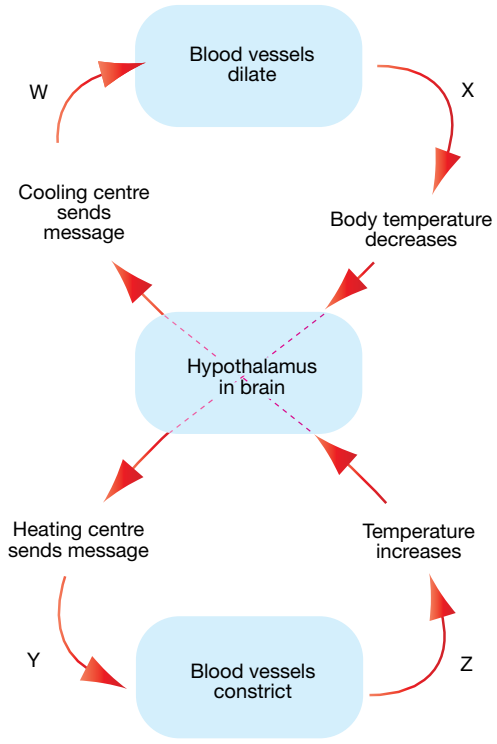


Figure 7.4 Thermoregulation in humans.

Which arrow(s) show negative feedback?

(A) W only. (B) W and Y.
(C) Y and Z. (D) X and Z.

5. When the environmental temperature around a human decreases, receptors in the skin detect the changes and send messages to the hypothalamus which, in turn, initiates a message to the hair erector muscles to contract so the hair can stand up. Which of the following most correctly identifies the type of system involved in this an example?

(A) Positive feedback system.
(B) Negative feedback system.
(C) Enantiostasis.
(D) Stimulus-response system.

8 Homeostasis and Temperature Control

Endotherms maintain a constant internal temperature because of internal processes using metabolic heat, e.g. birds and mammals while **ectotherms** use the energy from their environment and behavioural adaptations to regulate their body temperature, e.g. fish, amphibians, reptiles. The term 'cold blooded' is not used as many animals such as reptiles are not 'cold' when basking in the sun to absorb external heat.

Most organisms live in environments with temperatures between 0°C and 45°C, however living things have been found at the poles with temperatures below –70°C and around black smokers in oceanic trenches where the temperature is above 200°C. Most species have a very specific temperature range in which they can exist.

For example, organisms that inhabit tropical rainforests or coral reefs have a very limited temperature range. Corals, e.g. staghorn coral (*Acropora* spp) form massive reefs in warm tropical waters usually no deeper than 60 metres, and reef fish, e.g. white-tail pygmy angelfish (*Centropyge flavicauda*) are also only found within a narrow range of temperatures and will quickly die if the water temperature suddenly changes.

The main reason most organisms are found within a certain temperature range in particular environments is due to the specificity of their enzymes. If the weather is too cold, the enzyme is stable but will not work while in very hot temperatures the enzyme becomes unstable and will denature.

QUESTIONS

1. Explain why organisms require a constant internal environment.
2. Identify the broad range of temperatures over which life is found.
3. Use an example to show how an individual species is often restricted to narrow temperature limits.
4. Distinguish between an ectotherm and an endotherm.
5. Which of the following correctly compares the enzymes of ectotherms with the enzymes of endotherms?
   (A) The enzymes of each belong to different groups of organic compounds.
   (B) Ectotherm enzymes function over a wider temperature range.
   (C) Ectotherm enzymes function over a more narrow temperature range.
   (D) Ectotherm enzymes require an increase in the activation energy for the reaction to occur.
6. In an experiment to test the ability of animals to survive prolonged cold conditions, scientists measured the respiration rate of four different endotherms at different temperatures.

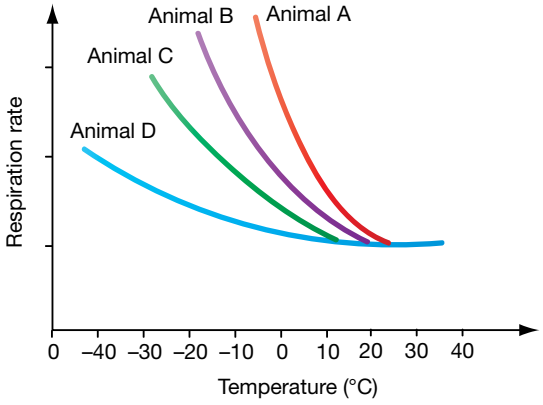


Figure 8.1 Respiration rate of 4 endotherms at different temperatures.

Which animal would be the most adapted to live in a cold environment?
(A) Animal A (B) Animal B
(C) Animal C (D) Animal D

7. Which of the following correctly identifies the main process by which endotherms maintain a constant internal temperature?
   (A) Behavioural adaptations dependent upon the external environment.
   (B) Body metabolism independent of the external environment.
   (C) Structural adaptations for the environment.
   (D) Metabolic activities dependent on the external environment.
8. The graph shows the internal temperatures of four animals measured at different times during the day.

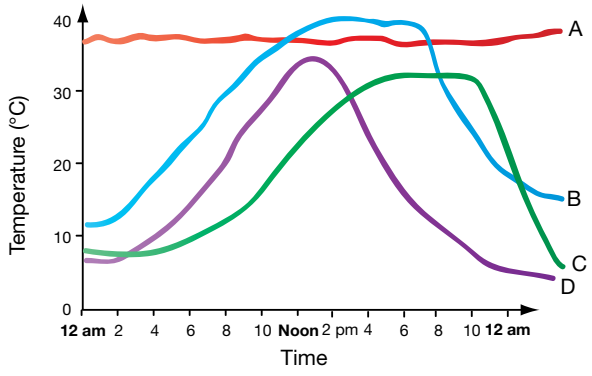


Figure 8.2 Body temperature of four animals during one day.

Which of the graphs is most likely to be an endotherm?
(A) Graph A
(B) Graph B
(C) Graph C
(D) Graph D

9 Modelling Human Thermoregulation

Normal human core body temperature is 37°C. If the thermometer is placed under the tongue the accepted normal range is 36.8°C ±0.4°C. Skin temperature, not like core temperature, can rise and tall with the temperature of the surroundings.

Body temperature is balanced by controlling heat production with heat loss. If core body temperature falls below 35°C a person will suffer hypothermia. The low temperature affects normal metabolism and body functioning. If core body temperature rises above the normal set point, without a change in the temperature set point the person has hyperthermia, e.g. heat stroke. A fever occurs when the core temperature is set higher by the heat control centre and hypothalamus in response to an infection.

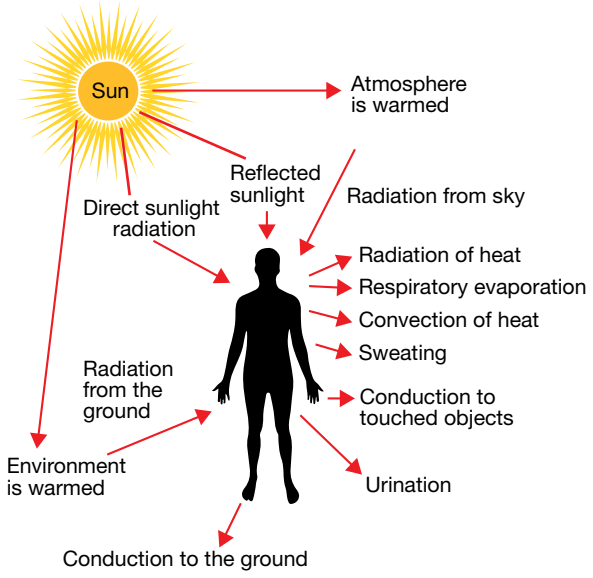


Figure 9.1 Heat transfer with the environment.

Heat is produced as a by-product of metabolism. The rate of heat production depends on the basal chemical reactions occurring in cells and any additional reactions, e.g. due to muscle activity and/or the action of some hormones such as thyroxine and growth hormone. Most heat is produced in the deep organs – the liver, brain and heart with skeletal muscles producing heat during exercise.

Computer models

Computer models of human thermoregulation responses have been developed for use in the design of clothing and environments that aim to protect humans from hyper- and hypothermia. The models have data about heat transfer, perspiration, respiration and blood flow and produce designs of military chemical suits, industrial protective clothing and space suits.

Computer models using data about human thermoregulation are also used to design and monitor environments such as space stations, aircraft, vehicles and buildings.

Computer simulations using different values for required conditions aid designers and enable scientists to study and predict the effects of extreme environments on the human body. This assists in establishing essential safety regulations for people working in extreme environments such as firefighters, pilots, foundry workers and soldiers.

QUESTIONS

1. What is normal human core body temperature?
2. What is hypothermia?
3. Construct a table to show the heat transfer with the environment for a person.
4. What produces heat in the body?
5. What determines the rate of heat production?
6. Distinguish between a fever and hyperthermia.
7. Explain why firefighters need special clothing that needs to be correctly designed.
8. List some clothing designs that have been improved by using computer models of human thermoregulation responses.
9. Why do scientists and engineers need to run computer simulations when designing buildings for people who will be living and working in extreme environments?
10. Firefighters wear overtrousers made of synthetic fabric with high temperature resistance for increased protection. How does the loose fit of the overtrousers over the other pair of trousers aid thermal protection?
    (A) Air between the layers of trousers helps stabilise temperature.
    (B) Convection currents in the layers of trousers remove heat from the firefighter's body.
    (C) The air layer increases radiation of heat from the firefighter.
    (D) Loose clothing increases the mobility of the firefighter.
11. What human responses are considered in the computer modelling for thermoregulation?
    (A) Heat transfer.
    (B) Perspiration rates.
    (C) Blood flow rates.
    (D) All of the above.
12. What will happen if an animal cannot maintain a constant internal environment for a period of time?
    (A) Metabolic efficiency will increase.
    (B) Metabolic efficiency will decrease.
    (C) The animal will go to sleep.
    (D) The animal will immediately die.

10 Homeostasis and Blood Composition

Water is essential for life. Many compounds and substances dissolve in water and most of the chemical reactions in organisms involve solutes dissolved in water. Water has a high specific heat and helps maintain the temperature of organisms. Water also has a high heat of vaporisation which takes heat from an organism in evaporative cooling.

Water is constantly lost from organisms, e.g. urine, sweat and homeostatic mechanisms are needed to maintain water balance. When the water is lost from the body fluids the dissolved solutes become more concentrated.

The blood circulating through blood vessels transports needed materials to cells and transports wastes from the cells to the excretory organs. As substances are delivered or picked up, the composition of blood changes as it travels around the body and the concentration of different solutes is different in different parts of the body. Homeostasis maintains the composition of fluids within the body within specific ranges.

Small intestine

Glucose, mineral salts, vitamins and some of the products of fat digestion pass through the walls of the villi of the small intestine into the capillaries. Most movement into the capillaries is by diffusion (passive transport) as the concentration of the food molecules is higher in the small intestine than in the capillaries. Sometimes active transport is needed if blood sugar levels are high. The capillaries join veins and the digested food molecules are transported in the blood to the liver in the hepatic portal vein.

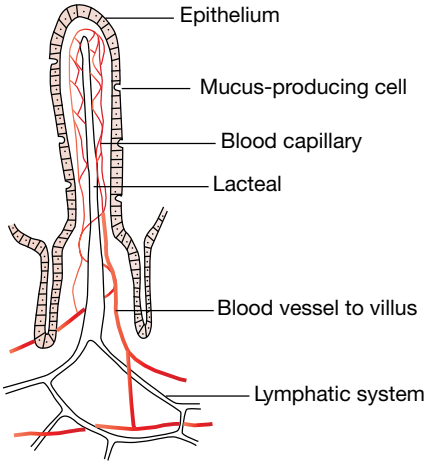


Figure 10.1 Structure of a villus.

A large proportion of the products of lipid digestion, e.g. fatty acids and glycerol move into the lacteal and are transported in the lymphatic system.

Liver

The liver has many functions. It receives the products of digestion and adjusts the blood concentration for each substance. Four functions of the liver include: control of suger levels; deamination; detoxification; and storage of iron.

Control of sugar levels – The liver removes excess glucose from the blood and converts it to glycogen in a process called **glycogenesis**. Glycogen cannot be used by the cells so that when the blood is low in glucose the liver will convert the stored glycogen back to glucose or other monosaccharides in a process called **glycogenolysis**. The glucose is released into the bloodstream.

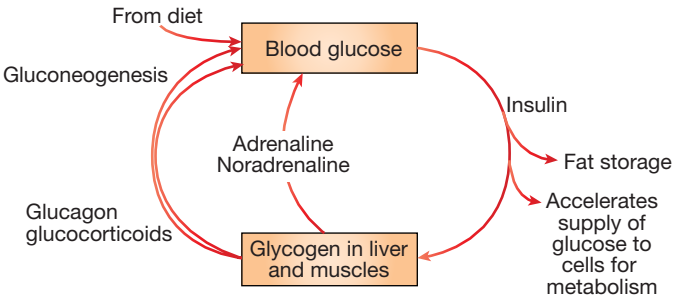


Figure 10.2 Homeostasis of sugar levels in the blood.

Deamination – If there are surplus amino acids, the liver will remove the amino section (NH_2) of the amino acid. This nitrogen-containing section is changed to urea to be excreted by the kidney. The remaining section of the amino acid is converted to glycogen to be stored in the liver.

Detoxification – Many toxic compounds that are ingested and absorbed into the blood are made harmless in the liver.

Storage of iron – Old red blood cells are broken down in the liver and the iron from the haemoglobin is stored in the liver.

Lungs

Oxygen dissolves in the moist lining of the alveoli in the lungs and diffuses into surrounding capillaries, while carbon dioxide in the capillaries diffuses out of the blood and into the alveoli. When air enters the alveolus some of the moisture lining the sac evaporates and saturates the air with water vapour.

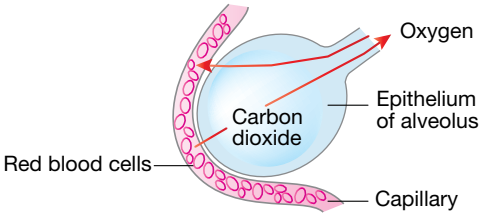


Figure 10.3 Gas exchange in an alveolus.

Kidney

The renal artery delivers blood to the kidneys. The kidneys are bean shaped organs that are at the back of the abdomen and filter the blood removing nitrogenous waste and excess salts. The kidneys are also involved in osmoregulation controlling the amount of water in the blood and thus the osmotic strength of the blood.

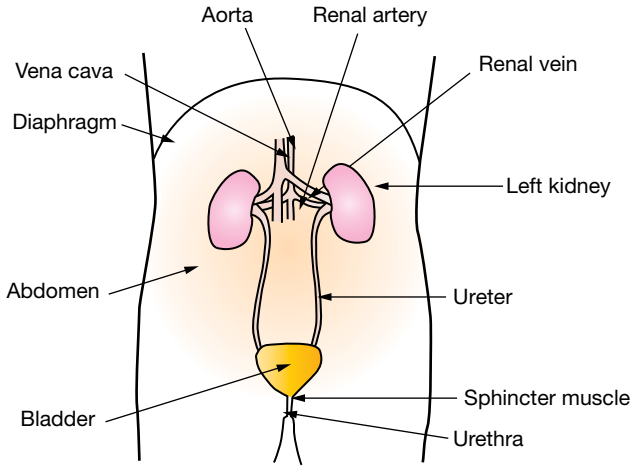


Figure 10.4 Kidney excretory system.

QUESTIONS

1. Compare blood composition in arteries going to the small intestine and veins leaving the small intestine and explain why any differences occur.
2. The table shows the difference between inhaled and exhaled air.

Substance	Inhaled (%)	Exhaled (%)
Oxygen	21	16
Carbon dioxide	0.04	4
Water vapour	Variable	Saturated

   Explain how the difference in the concentration of inhaled and exhaled air reflects changes in blood composition in the lungs.
3. Discuss why both the lungs and the kidneys are considered to be organs of excretion.
4. A healthy diet for a human requires carbohydrates. The main types of carbohydrates are cellulose, starch and sugar.
   (a) How does the body use each of these carbohydrates?
   (b) Which of these carbohydrates cause a change in blood composition?
5. Osmoregulation is concerned with controlling the water balance in the body. How can water be lost from the body?
6. The diagram shows the cycle of a red blood cell around the body.

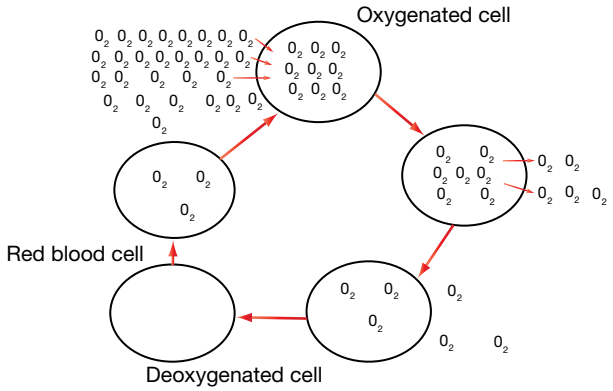


Figure 10.5 Cycle of a red blood cell.

   Identify the section on the diagram that relates to:
   (a) Lungs.
   (b) Body cell.
   (c) Area of high concentration of oxygen.
   (d) Area of low concentration of oxygen.
7. In which blood vessel would you expect to find the highest concentration of each of the following substances?
   (a) Oxygen.
   (b) Carbon dioxide.
   (c) Glucose.
   (d) Urea.
8. Complete the table to show where substances enter the circulatory system and where they travel to.

Substance	From	To
Oxygen		
Carbon dioxide		
Glucose		
Urea		

9. If an athlete was strenuously exercising what change in blood composition would you expect in the muscles of the athlete?
   (A) Increase in oxygen and decrease in carbon dioxide.
   (B) Decrease in oxygen and increase in carbon dioxide.
   (C) Increase in oxygen and increase in carbon dioxide.
   (D) Decrease in oxygen and decrease in carbon dioxide.
10. Hormones are chemicals produced by endocrine glands and travel in the blood to their target organ. Insulin is a hormone produced in the pancreas and stimulates the conversion of glucose to glycogen. What is the target organ for insulin?
    (A) Kidney.
    (B) Lungs.
    (C) Heart.
    (D) Liver.

Answers

1 Assumed Knowledge

1. Metabolism is the sum of all the chemical reactions occurring within a cell or other parts of an organism.
2. The environment is everything, both living and non-living, around an organism. The external environment refers to anything outside the body; the internal environment refers to anything inside the body.
3. A receptor is a cell or organ that can detect variations of some kind in an organism's environment. An effector is a structure that causes a response to counteract changes from the stable state.
4. Five senses are hearing, sight, touch, taste and smell.
5. Five sense organs are eyes, ears, tongue, nose and skin.
6. Skin has heat and cold receptors, light touch, pain and strong pressure receptors.
7. Interstitial fluid is the intercellular fluid which fills the spaces between the cells.
8. Endotherms maintain a constant internal environment because of internal processes while ectotherms use the energy from their environment to regulate their body temperature.
9. The nervous system coordinates sensory information with the body's responses.
10. Both the CNS and PNS are composed of neurons and together make up the nervous system. The CNS consists of the brain and spinal cord and is mainly composed of interneurons, while the PNS consists of the nerves branching from the CNS and passing to all other body parts.
11. Ambient temperature is the temperature of the surroundings.
12. The circulatory system transports materials around the body.
13. Red blood cells transport oxygen from the lungs to needy tissues in the body. White blood cells are part of the body's defence against infection and platelets are involved in clotting the blood.
14. Arteries are vessels which carry blood away from the heart; veins are vessels which carry blood towards the heart; capillaries are vessels which connect arteries to veins.
15. Diffusion is the movement of particles from an area of high concentration of particles to an area of low concentration of particles.
16. A control is part of an experiment that has the identical situation but often without the variable, and is used for comparison.
17. The lymph system is a network of nodes, veins and blind-end capillaries which carry lymph from body tissues and drain into blood vessels.
18. The cerebrum controls conscious thought, memory, sensory reception and motor activities. The spinal cord is involved in reflex actions involving body structures below the neck and sending sensory impulses to the brain and carrying motor impulses from the brain.
19. Carbon dioxide diffuses out of the capillary into the alveoli and oxygen diffuses into the capillary from the alveoli. Both move down a concentration gradient.
20. Water is an important molecule because of its unique properties as a solvent; many solutes dissolve in water. It also enters such reactions as photosynthesis, respiration and digestion. It can also act as a cooling agent, e.g. water evaporates from the skin and removes heat from the body.
21. A parasite lives on or in a host, gaining food, shelter and protection and causing harm to the host.
22. Bacteria are prokaryotes; they are microscopic with a cell wall and a single coiled strand of DNA.
23. Viruses are very small, are not cellular, consist of nucleic acid (either RNA or DNA) and are enclosed in a protein coat.
24. A pathogen is an organism capable of producing a disease.
25. A hormone is an organic chemical produced by one part of the body and transported to another part where it affects the metabolism of the target cells.

2 Homeostasis

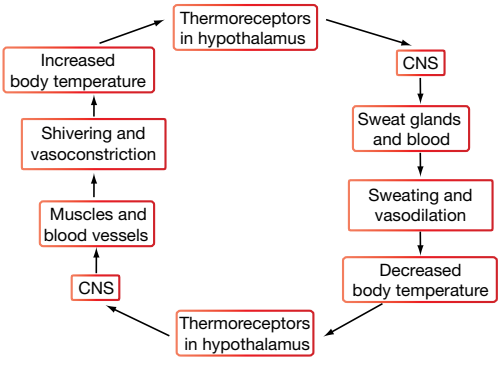
1. Homeostasis is the maintenance of a constant internal environment within narrow limits.
2. Homeostasis is necessary to maintain optimal metabolic efficiency.
3. The two stages of homeostasis are detecting changes from the stable state and counteracting or responding to changes from the stable state.
4. Variables controlled by homeostasis in 'higher' vertebrates include blood composition, e.g. blood sugar level, oxygen and carbon dioxide concentrations, pH and water potential; blood pressure, and in endotherms body temperature.
5. Endotherms use internal processes to keep a constant body temperature and hence they require extremely efficient homeostasis mechanisms to maintain this temperature.
6. In humans, homeostasis maintains body temperature at approximately 37°C, maintains pH of interstitial fluid within a tenth of 7.4 and maintains the sugar concentration of the blood at approximately 0.1%.
7.

Sense organ	Receptor	Stimuli detected
Eye	Rods and cones in retina	Light
Ear	Hair cells in cochlea	Sound
Tongue	Gustatory receptors in taste buds	Chemicals
Nose	Olfactory receptors in nasal cavity	Chemicals
Skin	Mechanoreceptor	Pressure, touch
Skin	Thermoreceptor	Heat, cold
Skin	Pain receptor	pain

8. Stimulus → receptor → sensory neuron → interneuron → motor neuron → effector → response.
9. In a control system there is: 1. A detector device that picks up the input, e.g. detects a change in temperature. 2. A control centre that has a 'set' required condition, e.g. a certain temperature such as body temperature. 3. An effector device functions to counteract the change to return the system to the set condition, e.g. to return the system to body temperature. 4. The return to the set condition is detected by a feedback mechanism and the new change becomes the input.
10. Endotherms use metabolic heat to regulate body temperature, e.g. birds and mammals.
11. D
12. A
13. C
14. A
15. C

3 The Role of the Nervous System

1. The nervous system is divided into the central nervous system (CNS) and the peripheral nervous system (PNS).
2. Receptor → sensory neuron → connector neuron→ motor neuron → effector.
3. The main role of the nervous system is sending messages when stimuli are detected to bring about appropriate responses.
4. Neuron T is a connector neuron in the CNS. Its function is to relay the impulse from the sensory neuron to the motor neuron to enable a fast reflex to occur without waiting for the message to be interpreted by the brain.
5. The tongue acts as a receptor when the receptor cells in taste buds detect sweet, salty, sour or bitter in food. The tongue can act as an effector when it is used for speech to respond to a comment or when it is used to spit something out of the mouth.
6.



4 The Stimulus-Response Model

1. The stimulus-response model gives the basic pathway for a nervous impulse where a receptor picks up a stimulus, the message is interpreted and another message is transmitted to an effector which carries out the response.
2. A stimulus is a change in the environment of an organism that is detected.
3. Stimulus → receptor → nervous → effector → response system.
4.

Part of stimulus-response model	Description
Receptor	Detects stimulus and converts it into a nerve impulse which is transmitted by a sensory neuron to CNS.
CNS	Connector neurons in spinal cord and brain take the message to a control centre where the information is processed.
Effector	Motor neurons connect to the CNS and transmit a resultant nervous impulse from CNS to effector organ, e.g. muscle or gland to carry out the response.

5. A motor neuron takes the nerve impulse from the CNS to an effector whereas a sensory neuron takes the nerve impulse from the receptor to the CNS. The motor neuron usually has a long axon that is myelinated while the axon of the sensory neuron may or may not be myelinated.
6. A nerve is a bundle of nerve fibres, e.g. axons held together by connective tissue.
7. The synapse is the gap at the junction between adjacent neurons.
8. Neurotransmitters are substances that diffuse across a chemical synapse transmitting the message from the synaptic terminal of a neuron to the postsynaptic cell triggering a response.
9. B
10. D

5 Reflexes

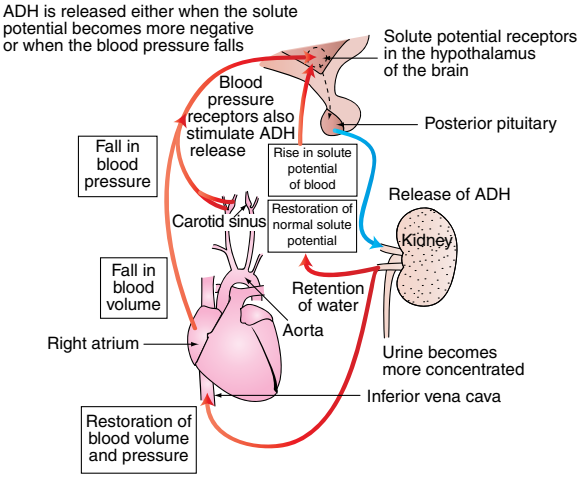
1. A reflex is a fast response that is involuntary and does not involve the brain in the decision making process.
2. A person becomes aware a reflex has happened after it has occurred when the message reaches the brain and is interpreted.
3. Grey matter is mainly the cell bodies of neurons, dendrites and unmyelinated axons. Whereas white matter consists of axons with myelin sheaths.
4. (a) Most of the grey matter in the brain is on the outside surrounding the white matter.
   (b) In the spinal cord the white matter is on the outside to allow linking of the CNS to sensory and motor neurons and the grey matter is on the inside roughly forming a shape like the letter H.
5. In a monosynaptic reflex there are only two neurons – a sensory neuron and a motor neuron, e.g. peripheral muscle reflexes such as the Achilles reflex. Whereas in a polysynaptic reflex arc there are one or more connector neurons in the circuit.
6. Cell A is a sensory neuron as it connects to the receptor cell and takes the message to the CNS. Cell B is in the CNS (spinal cord) and is therefore a connector neuron. Cell C is a motor neuron as it takes the message from the CNS to the effector cell.
7. The autonomic nervous system is part of the motor nervous system that controls the internal environment, e.g. involuntary muscles such as cardiac muscle and the smooth muscle in the walls of blood vessels and in the digestive tract.
8. The change in size of the pupil of the eye is a response to light stimuli. In bright light the pupil will constrict to reduce the amount of light entering the eye to avoid damage to the retina. In dim light the pupil will dilate to let more light through to the retina to aid vision and help the person see in darker conditions. Pupil size needs to be a reflex so that there is a fast and continuous response that adjusts to changing light conditions and does not need conscious thought cluttering the brain with constant decision making about pupil size.
9. C
10. A

6 Receptors

1.

Sense organ	Receptor	Stimuli
Eyes	Retina has rods and cones	Light
Ears	Cochlea has hair cells	Sound
Tongue	Gustatory receptors in taste buds	Chemicals
Nose	Olfactory receptors in nasal cavity	Chemicals
Skin	Mechanoreceptors detect pressure, touch, stretch	Pressure, touch
Skin	Thermoreceptors detect heat and cold	Heat, cold
Skin	Pain receptors	Pain

2. Proprioceptors are in muscles, tendons and joints; mechanoreceptors respond to energy such as stretching, movement, touch, pressure, gravity; chemoreceptors respond to chemicals; photoreceptors detect light; thermoreceptors detect heat and cold and some animals (e.g. fish have electroreceptors that detect electrical energy).
3. Stimulus → receptor → sensory neuron → interneuron → motor neuron → effector → response.
4. Example of touch response – the strong pressure receptor (Pacinian corpuscle) is found deep in the skin and around joints and is deformed when the skin experiences firm pressure. The sense cell converts the stimulation into a nerve impulse.
5. (a) Receptors include chemoreceptors in medulla of brain and stretch receptors in lungs.
   (b) The stimulus could be an increase in the carbon dioxide levels in the blood that is detected by the chemoreceptors in the medulla. This causes a messenger (nerve impulse) to be sent to the inspiratory centre, which in turn sends nerve impulses to the effectors – the diaphragm and intercostal muscles – to increase the rate of contraction. The response is faster and deeper breathing, and an increase in the rate of inspiration.
   (c) The stretch receptors in the lungs are stimulated by the faster breathing rate and send messages back to the expiratory centre of the hindbrain. The inspiratory centre is switched off, followed by the expiratory centre.
   (d) When a person holds their breath or is playing a wind instrument, they can override the impulses that control inspiration for a short time.
6. Stimulus-response model for antidiuretic hormone (ADH)



7. The protozoan amoeba will move away from an unfavourable stimulus such as very bright light.