Chapter 12 – Homeostasis

Subject content

Content
- Principles of Homeostasis
- Skin

Learning outcomes
(a) define homeostasis as the maintenance of a constant internal environment
(b) explain the basic principles of homeostasis in terms of stimulus resulting from a change in the internal environment, a corrective mechanism and negative feedback
(c) identify on a diagram of the skin: hairs, sweat glands, temperature receptors, blood vessels and fatty tissue
(d) describe the maintenance of a constant body temperature in humans in terms of insulation and the role of: temperature receptors in the skin, sweating, shivering, blood vessels near the skin surface and the coordinating role of the hypothalamus

Use the knowledge gained in this section in new situations or to solve related problems.

Definition

Phrase	Definition
homeostasis	maintenance of constant internal environment within narrow limits
norm	set-point to be maintained
stimulus	change in internal environment from normal conditions
receptor	cells / tissue which detect stimuli and send signal to control centre
corrective mechanism	automatic / self-regulatory mechanism to bring about opposite effect to stimuli
feedback sent to receptor	signals receptor that normal conditions have been restored in internal environment → cause corrective mechanism to stop
negative feedback process	sequence of events where body brings about opposite effect to restore body to original state

12.1 The Need for Homeostasis

Homeostasis

Homeostasis

- enable body to function optimally
- constant state of readjustment, because negative feedback works on the basis of deviation from the set point / norm
- examples in body:
  1. Regulation of **body temperature**
  2. Regulation of **blood glucose concentration**
  3. Regulation of **blood water potential**

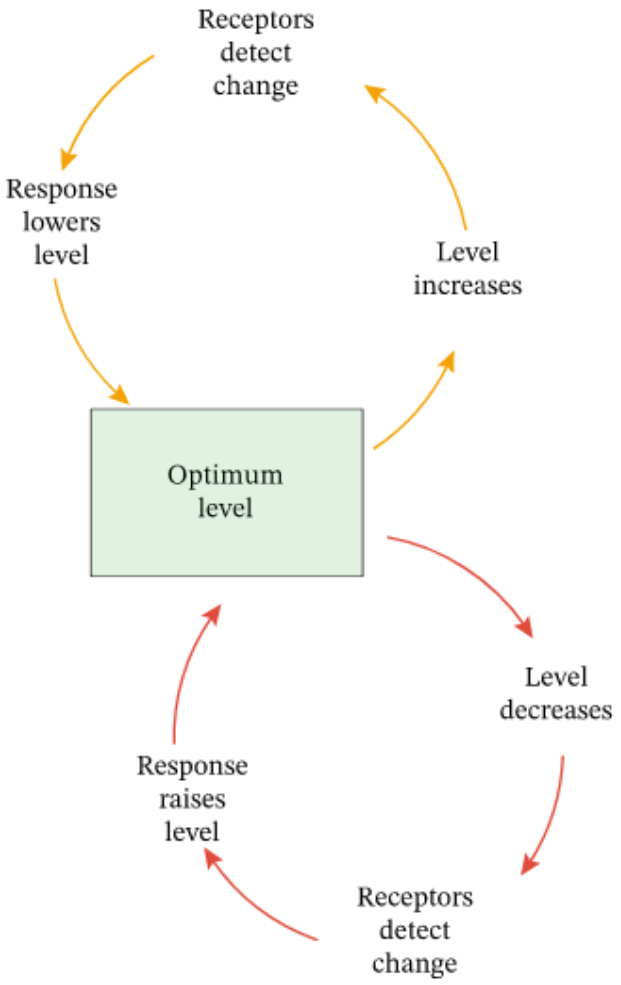
Body conditions kept constant:

1. **body temperature**
2. **pH**
3. **water potential**

Negative feedback

Negative feedback process

1. **norm**
2. **stimulus**
3. **receptor**
4. **corrective mechanism**
5. **feedback to receptor**



Regulation of blood glucose concentration:

Stimulus	Blood glucose conc	increase above normal	decrease below normal
Receptor	**islets of Langerhans** (pancreas)	detect stimulus, is stimulated	
Corrective mechanism	islets of Langerhans secrete hormone into bloodstream	more insulin	more glucagon
	blood transports hormone to liver + muscles	insulin	glucagon
Effects	hormone	• increase permeability of cell surface membrane of liver + muscle cells to glucose → glucose molecules diffuse into these cells more quickly • cause liver + muscles: convert excess glucose → glycogen (stored in liver & muscles)	• cause liver + muscles: convert glycogen → glucose • from liver, glucose molecules diffuse out of cells into bloodstream
Outcome	Blood glucose conc	decrease back to normal	increase back to normal
	feedback	sent to receptor to reduce (hormone) production	

Regulation of blood water potential:

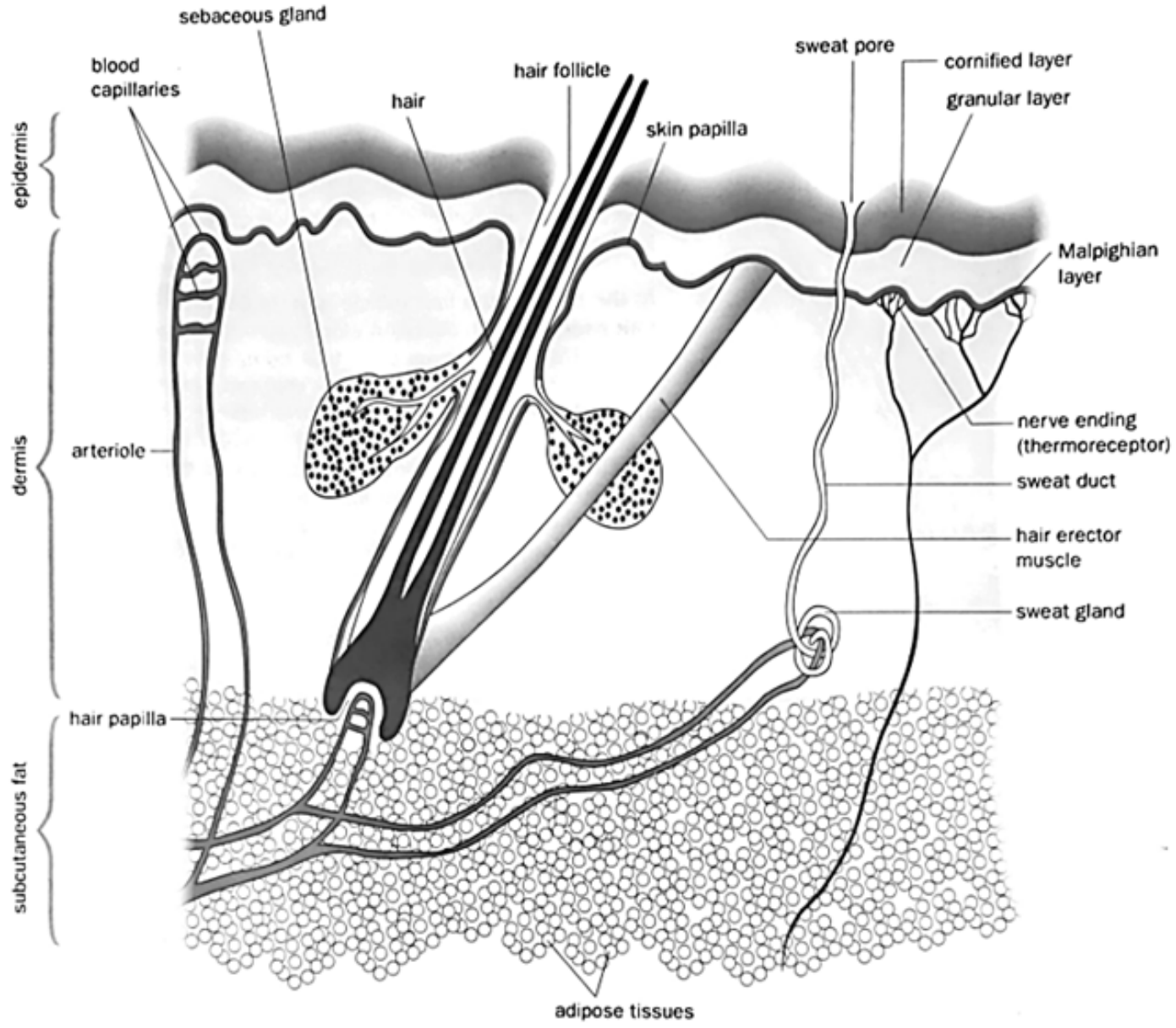
Stimulus	Water potential of blood plasma	increase above normal (large intake of water)	decrease below normal (large loss of water)
Receptor	**hypothalamus**	detect stimulus, is stimulated	
Corrective mechanism	pituitary gland release ADH into bloodstream	less	more
	ADH transported to kidneys	less	more
Effects	cells in walls of collecting ducts become permeable to water molecules	less	more
	water reabsorbed: lumen of collecting ducts → bloodstream	less	more
	water excreted	more	less
	concentration of urine	more diluted	more concentrated
	volume of urine produced	more	less
Outcome	blood water potential	decrease back to normal	increase back to normal
	feedback	sent to receptor to (control) ADH release	

12.2 Structure of the Human Skin

Structure of human skin

Layers of skin

1. **Epidermis**
2. **Dermis**
3. **Subcutaneous fat**



Structures involved in temperature regulation

Roles of skin

1. **protective outer covering of body**
2. **regulator of body temperature**
3. **excretory organ**
4. **sense organ**

Epidermis:

Structure	Description	Function
1. **Malpighian layer**	cells contain **melanin** (pigment: skin darker	● shield skin from harmful UV radiation → prevent skin cancer
2. **granular layer**	formation: ● Malpighian layer - constant cell division ● old cells pushed upwards to skin surface → flattened	● produce keratin (water-resistant protein)
3. **cornified layer**	cells reach cornified layer → flattened and died	● waterproof layer ● prevent bacteria from entering

Dermis:

Structure	Description	Function
1. **Arterioles**	Constriction and dilation ● controlled by vasomotor nerves → contraction of muscles in arteriole walls ● **vasodilation**: dilation of arterioles **vasoconstriction**: constriction of arterioles	Regulation of body temperature Arterioles | dilate | constrict amount of blood flow through capillaries in skin | more | less outcome | blush | pale
2. **Hair**	● produced by epidermis, embedded in dermis ● consists of dead cells cornified by keratin ● **hair follicle**: cylindrical depression of epidermis ○ lined up with granular and Mapighian cells ○ hair grows inside hair follicle ● **hair papilla**: base of hair follicle ○ made up of connective tissues containing blood capillaries and nerve endings	

	○ covered with epidermal cells: constantly divide → push new cells outwards → die and harden → hair ● **hair erector muscles** (attached to hair follicles) contract: ○ pull hair upright ○ trap layer of insulating air in the cold	
3. **Sweat glands**	● coiled tube formed by <u>downgrowth of epidermis</u> ● <u>tight knot</u> in dermis, surrounded by blood capillaries	Excretory organ: secrete sweat ● flow through **sweat duct → sweat pore** ● components ○ water ○ dissolved mineral salts ○ urea
4. **Sensory receptors**	nerve endings in skin	Detect stimuli ● temperature (thermoreceptor) ● pain ● pressure
5. **Subcutaneous fat**	layers of adipose cells (adipose tissue)	1) store fat 2) insulating layer → reduce heat loss
6. **Sebaceous gland**	derived from epidermis	Secrete **sebum** (oily substance) → hair follicle 1) lubricate hair → soft and smooth 2) prevent dehydration of skin 3) antiseptic action → prevent growth of bacteria 4) waterproof skin & hair

12.3 Temperature Regulation

Heat gain and loss

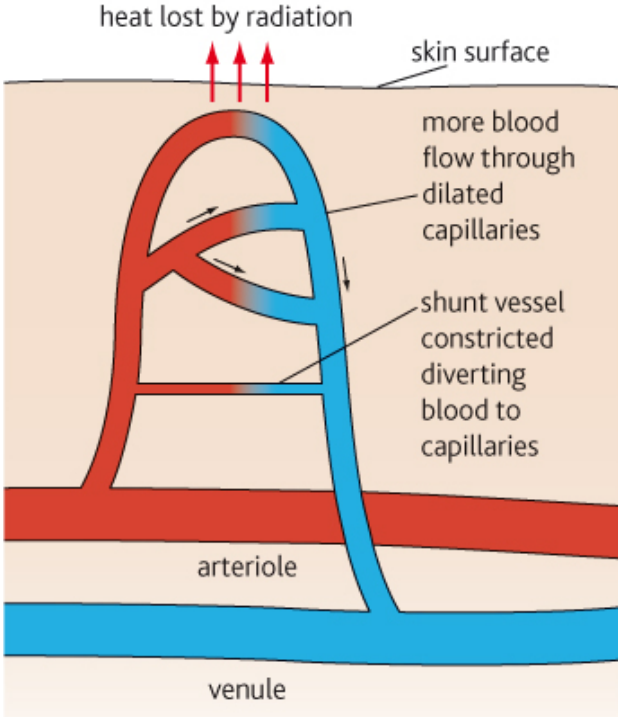
Metabolic activities (cellular respiration) produce heat:
→ large amount of heat released in muscles & liver
→ distributed to rest of body via bloodstream

Heat gain	Heat loss
• vigorous muscular exercise • metabolic activities • warm external environment	• radiation, convection, conduction • evaporation of water in sweat from skin surface • faeces and urine (defecation) • exhaled air

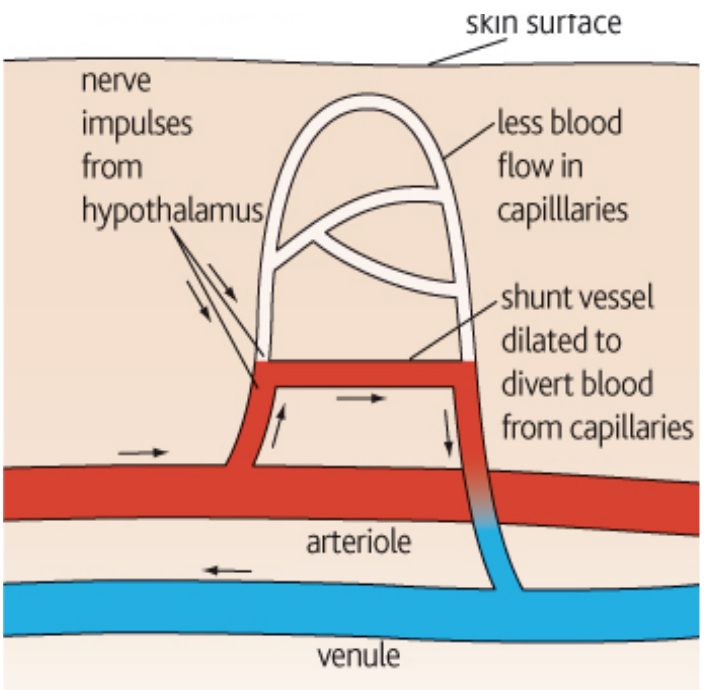
Shunt vessel

- connect skin arterioles with skin venules → blood flow bypass skin capillaries
- control amount of blood flow through skin capillaries → heat loss through skin surface

Warm conditions: **vasodilation**



Cold conditions: **vasoconstriction**



Body temperature regulation

Hypothalamus (brain): monitor & regulate body temperature

- Receive information about temperature changes from thermoreceptors
- Thermoreceptors
  - in skin : detect temperature from environment
  - in hypothalamus : detect temperature of blood

Stimuli & receptor:

Stimulus	Body temperature	higher than norm	lower than norm
Receptor	Thermoreceptors	stimulates thermoreceptors to send nerve impulses to hypothalamus (change) in temperature of blood is detected by hypothalamus hypothalamus send nerve impulses → relevant body parts	

Corrective mechanism:

Mechanism	Body temperature	rise	fall
heat loss	① **Skin arterioles**	dilate	constrict
	② **Shunt vessels**	constrict	dilate
	Amount of blood flow through blood capillaries in skin	larger	smaller
	Heat carried to skin surface	more	less
	Heat lost through skin by radiation, convection, conduction	more	less
	③ **Sweat glands**	more active	less active
	Production of sweat	increase	decrease
	Water in sweat evaporate from skin surface	more	less
	Latent heat of vaporisation lost from body	more	less
heat production	④ **Metabolic rate**	decrease	increase
	Amount of heat released within body	decrease	increase

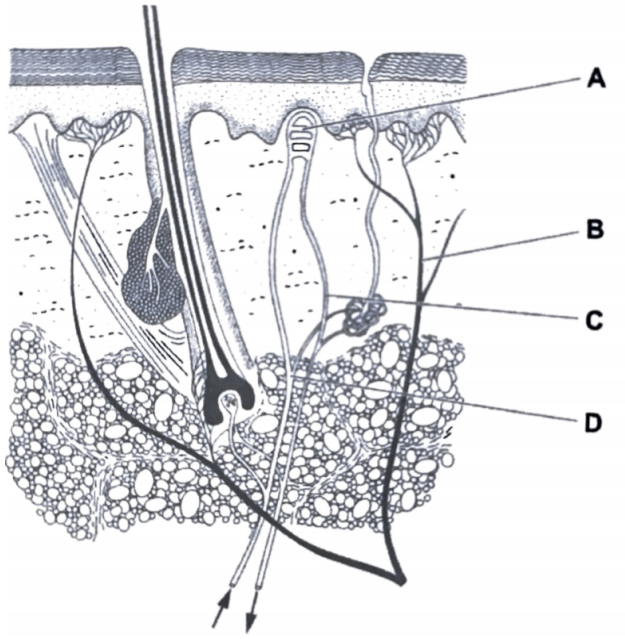
Typical questions

Multiple choice questions

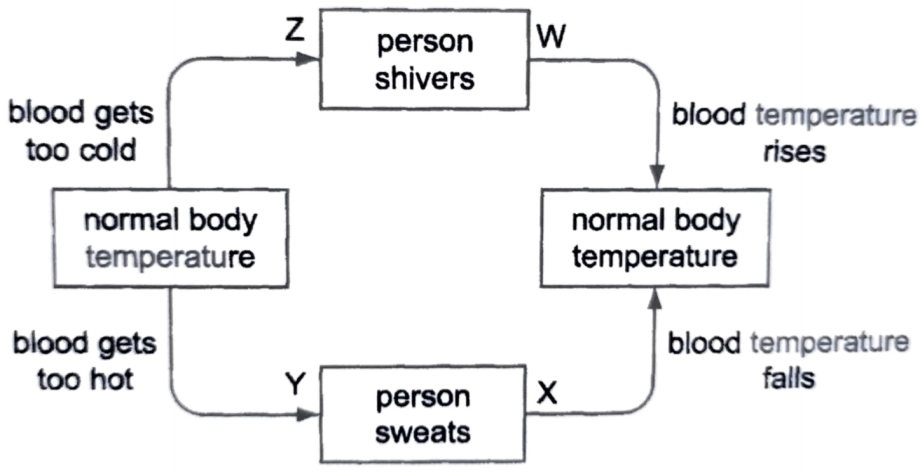
1 Which factors are controlled by homeostasis? (N2011/P1/Q22)

	blood glucose concentration	water content in ileum	temperature in stomach	pH in duodenum
A	✔		✔	
B	✔		✔	✔
C	✔	✔		✔
D		✔	✔	

2 The diagram below shows a section through the skin.
On a cold day, which labelled part of the skin will be warmed?
(N2012/P1/Q22 / N2018/P1/Q22)



3 The diagram shows an example of homeostasis in a person.



Which two letters represent negative feedback changes? (N2012/P1/Q23)

A W and X
B W and Y
C X and Z
D Y and Z

4 A swimmer stays too long in very cold water and his body temperature falls below 37°C. After he comes out of the water, what will help his body temperature return to normal?
(N2014/P1/Q22)

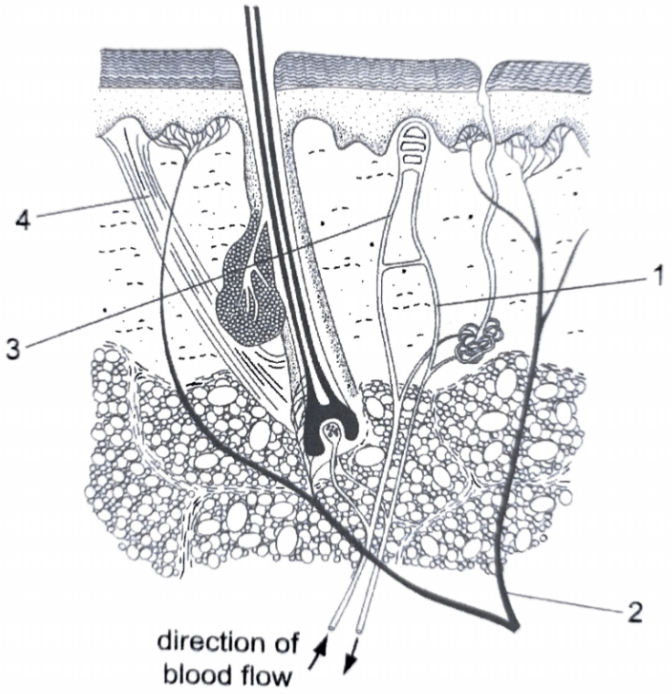
1 blood rushing to the skin surface
2 drying the skin quickly with a towel
3 hair erector muscles relaxing
4 shivering
5 running around

A 1, 2 and 3
B 1, 3 and 4
C 2, 4 and 5
D 3, 4 and 5

5 Which homeostatic mechanism controls body temperature? (N2015/P1/Q23)

A negative feedback and the endocrine system
B negative feedback and the nervous system
C positive feedback and the endocrine system
D positive feedback and the nervous system

6 The diagram shows a section through the skin.



Which structures contain muscle that contracts when the body is too cold? (N2016/P1/Q22)

A 1 and 2
B 1 and 4
C 2 and 3
D 3 and 4

7 The sentences describe the homeostatic function of the skin when the body temperature rises above normal.

The blood vessels near the skin surface …… 1 …… .
Glands in the skin release …… 2 …… .
These actions are controlled by the …… 3 …… .
The body cools when water …… 4 …… .

Which words correctly complete the sentences? (N2019/P1/Q22)

	1	2	3	4
A	narrow	oils	pancreas	is absorbed
B	narrow	sweat	hypothalamus	is absorbed
C	widen	oils	pancreas	evaporates
D	widen	sweat	hypothalamus	evaporates

Structured questions

1 Explain what is meant by the terms homeostasis and negative feedback.

(N2008/P2/B11a OR)

(a) homeostasis

- maintenance of a constant internal environment within narrow limits
- blood glucose concentration above norm + islets of Langerhans of pancreas secrete insulin into bloodstream to stimulate the liver and muscle cells to convert excess glucose to glycogen + reducing the blood glucose concentration back to normal

(b) negative feedback

- sequence of events that brings about the opposite effect to the changes detected to bring the condition back to norm
- e.g. when water potential of blood plasma rises above norm, a sequence of events occur to bring down the water potential back to norm.

2 The table below shows the relative volumes of blood flowing through different organs at rest and during exercise. (N2009/2A/Q3)

organ	at rest	during light exercise	during heavy exercise
brain	1.0	1.1	1.1
skin	1.0	2.4	3.1
kidneys	1.0	0.8	0.5
muscles	1.0	3.8	11.0
heart	1.0	1.6	2.5

(a) State which organ has the greatest increase in blood supply. [1]

muscles

(b) State and explain the changes in blood volume for the skin. [2]

State: blood volume in the skin increased by 0.7 cm^3

Explain:

- Vigorous muscular contraction during heavy exercise + more heat released + blood temp increases above norm + stimulate thermoreceptors in the hypothalamus which send nerve impulses to arterioles in the skin

- Vasodilation of arterioles + more warm blood flow to capillaries in the skin surface, allowing more rate of heat loss via conduction, convection and radiation;

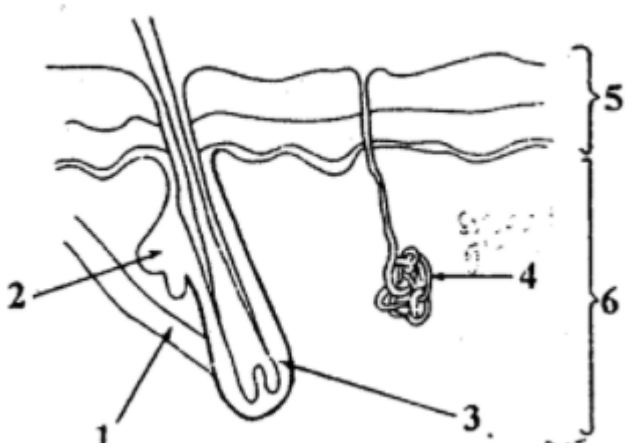
This cools down the body and reduces the body temperature back to norm.

3 Most of the body mass lost is in the form of water. Explain how this loss of body mass helps survival in the hot desert environment. [3]

(N2006/2A/Q3bii)

- Hot desert temperature + body gains more heat + body temperature increases above norm
- Thermoreceptors in the skin (and hypothalamus) stimulated + thermoreceptors in the skin send nerve impulses to hypothalamus, which sends nerve impulses to sweat glands become more active + more sweat produced
- More water in sweat evaporates from the skin surface + more latent heat of vapourisation removed from skin + cools the body and reduce body temperature back to normal
- Thus, the loss of body mass in the form of sweat helps to regulate body temperature and increases the survival rate of the person

4 The figure below represents a diagrammatic section through a piece of human skin.



(a) Label the parts numbered. [3]

1: hair erector muscle
2: sebaceous gland
3: hair follicle
4: sweat gland
5: epidermis
6: dermis

(b) Describe the function of part 4 in temperature regulation. [3]

- blood temp increases above norm + thermoreceptors in skin stimulated and send nerve impulses to hypothalamus + hypothalamus sends nerve impulsse to sweat glands
- sweat gland become more active + increased sweat secretion + more evaporation of water in sweat from skin surface
- removes latent heat of vapourisation from skin + cools body for temperature regulation

(c) Describe three other functions of the skin. [3]

- Protects body against entry of pathogens / UV radiation
- A sense organ (receptor) to detect changes in the environment (stimulus) such as changes in temperature, pain and pressure
- Store fats in adipose tissues to insulate body against heat loss + serves as an energy reserve
- As an excretory organ to remove excess water and urea in body

5 (N2008/2/Q11)

(a) In extremely cold conditions people may get frostbite. This causes the cells in the toes and fingers to die. Explain why this takes place even if thick gloves, socks and shoes are worn. [5]

- In extremely cold conditions, humans lose heat at a faster rate to the environment even if thick gloves, socks and shoes are worn + body temperature decreases below normal
- This decrease in body temperature is detected by the thermoreceptors in the skin and hypothalamus + thermoreceptors in skin stimulated and send nerve impulses to the hypothalamus + which stimulate hypothalamus to send nerve impulses to arterioles in skin
- nerve impulses sent to the arterioles in the skin + vasoconstriction of arterioles
- Decreased blood flow to capillaries near skin surface + less heat lost to the environment by conduction, convection and radiation
- Reduced blood flow to organs furthest away from the heart (e.g. toes and fingers) + lesser glucose and oxygen transported to these cells + cells unable to respire + cells die, resulting in frostbite

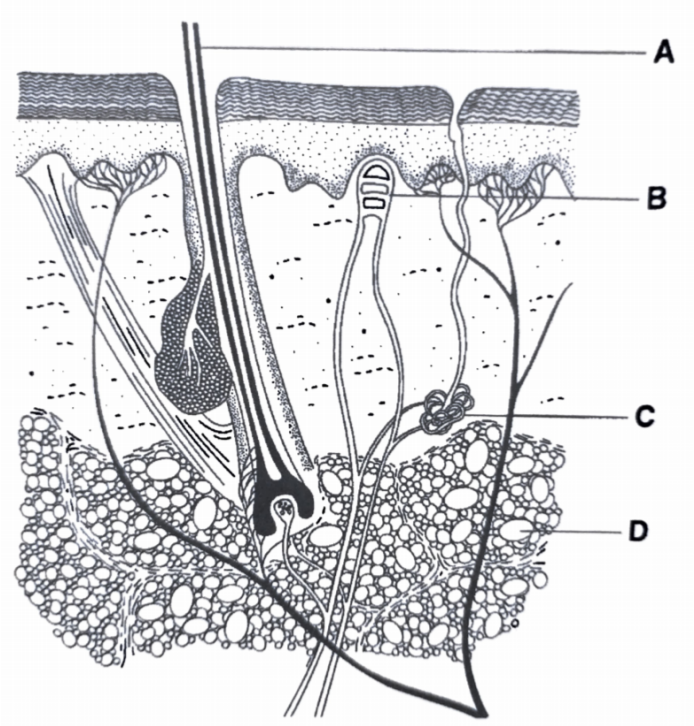
(b) Cold environments cause the body to shiver. Explain why shivering takes place in cold conditions. [3]

- Increased rate of heat loss in cold + body temp below normal + detected by thermoreceptors in the skin which send nerve impulses to hypothalamus to stimulate hypothalamus to send nerve impulses to skeletal muscles
- Increased muscular contraction during shivering + increased rate of respiration to release more energy
- More heat is released + body temperature increases back to normal

(c) Explain how the mechanisms for controlling body temperature are coordinated. [2]

- Thermoreceptors in the skin detect changes in the temperature of the environment + thermoreceptors in the hypothalamus detect changes in blood temperature
- Hypothalamus acts as a control center + is stimulated + sends nerve impulses to the relevant body parts (e.g. arterioles, sweat glands) to return body temperature back to normal by means of a negative feedback mechanism

6 The figure below shows a vertical section of the skin. (N2012/P2/A3)



(a) Identify the parts labelled A, B and D. [3]

A: Hair

B: Blood capillary

D: Adipose tissue

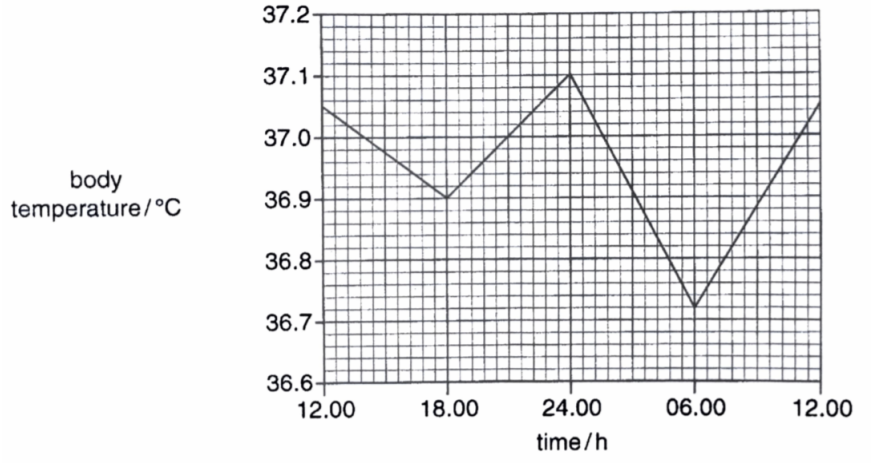
(b) Describe the function of part C in temperature regulation. [3]

Part C secretes sweat. The sweat flows through a sweat duct and a sweat pore to the skin surface. Sweat contains mainly water and a small amount of dissolved salt and urea. The amount of sweat produced varies according to the body temperature.

When the body temperature increases, part C produces more sweat. When more sweat evaporates from the skin surface, more latent heat of vaporisation is removed from the body. Thus, the body loses heat and the body temperature decreases to normal body temperature.

When the body temperature decreases, part C produces less sweat. When less sweat evaporates from the skin surface, less latent heat of vaporisation is removed from the body. Thus, the body reduces heat loss and the body temperature increases to normal body temperature.

(c) The graph below shows changes in the body temperature of a healthy person over a 24-hour period.



(i) State the maximum change in body temperature. [1]

The maximum change in body temperature is –0.38°C.

(ii) Suggest an explanation for the fall in body temperature between 24.00 and 06.00. [2]

Between 24.00 and 06.00, the person is most likely sleeping and his body carries out less metabolic activity. Thus, his body produces less heat and his body temperature falls.

7 Describe the role of sweat glands in body temperature regulation. [3]

(N2015/P2/A3)

When the skin detects a rise in temperature, nerve impulses are sent to the hypothalamus in the brain, which then sends nerve impulses to the sweat glands so that they become more active and produce more sweat. As the sweat evaporates from the skin, latent heat is removed from the skin. This helps the body to lose heat and restored the body back to its normal temperature.

On the other hand, when the skin detects a drop in temperature, the sweat glands become less active and produce less sweat. Less sweat evaporated from the skin and more latent heat is retained in the body. This helps to restore the body back to its normal temperature.

8 Define the term homeostasis. [2]

(N2017/P2/A1a)

Homeostasis is a process that helps the body to maintain a constant internal environment through an automatic corrective mechanism.

9 The human body has processes to prevent overheating. Describe how the body prevents overheating. [3]

(N2013/P2/B8)

The body prevents overheating by regulating its temperature. When the skin detects a rise in temperature, nerve impulses are sent to the hypothalamus in the brain. The hypothalamus then sends nerve impulses to the skin to carry out some measures to lose heat. The arterioles in the skin undergo vasodilation to increase blood flow to the skin so that the skin will receive more heat and lose it to the environment by conduction, convection and radiation. The sweat glands also become more active and produce more sweat. As the sweat evaporates from the skin, latent heat is removed from the skin. These measures help the body to lose heat and restore the body back to its original temperature.

10 Describe how the human body responds to a cold environmental temperature. [5]

(N2019/P2/B9 EITHER b)

- When the surrounding temperature is low, temperature receptors in the skin detect and send a nervous impulse to the hypothalamus. The hypothalamus then sends a nervous impulse to various effectors.
- Vasoconstriction of the arterioles in the skin, together with the dilation of shunt vessels, result in less blood flow through blood capillaries in the skin, resulting in less heat lost through radiation, convection and conduction.
- Sweat glands become less active, decreasing sweat production and thus, less latent heat is lost.
- Shivering due to rapid contraction of skeletal muscles may also occur.
- The metabolic rate of the body also increases to release more heat to keep the body warm.