Chapter 15 – Hormones

Subject content

Content

- Effectors – Endocrine Glands

Learning outcomes

(a) define a hormone as a chemical substance, produced by a gland, carried by the blood, which alters the activity of one or more specific target organs and is then destroyed by the liver

(b) explain what is meant by an endocrine gland, with reference to the islets of Langerhans in the pancreas

(c) state the role of the hormone adrenaline in boosting blood glucose levels and give examples of situations in which this may occur

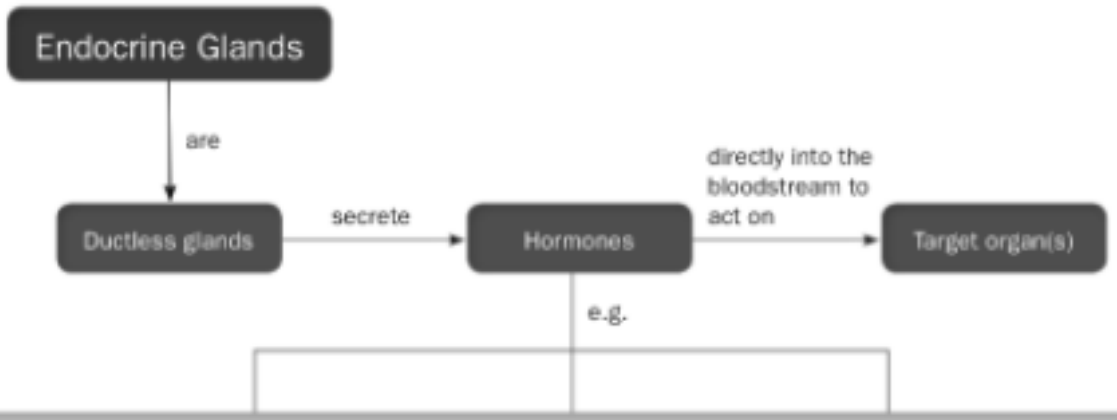
(d) explain how the blood glucose concentration is regulated by insulin and glucagon as a homeostatic mechanism

(e) describe the signs, such as an increased blood glucose level and glucose in urine, and the treatment of diabetes mellitus using insulin

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

Definition

Phrase	Definition
Hormone	Chemical substance[1] produced in minute quantities[2] by endocrine gland[3], transported in bloodstream[4] to target organs where it alters activity of specific target organs[5], destroyed by liver after performing functions[6]
Endocrine gland	ductless gland that secrete hormones directly into blood



	Insulin	Glucagon	Adrenaline
Produced by	Islets of Langerhans in the pancreas	Islets of Langerhans in the pancreas	Adrenal medulla in the adrenal gland
Action	• Increases glucose uptake and cell metabolism • Stimulates the conversion of glucose into glycogen	• Stimulates the conversion of glycogen into glucose • Stimulates the conversion of fats and amino acids into glucose	• Speeds up glycogen breakdown • Increases metabolic rate • Increases heart rate and blood pressure • Increases rate and depth of ventilation • Increases rate of blood clotting • Constricts arterioles in the gut and skin • Causes pupils to dilate • Contracts hair muscles
Effect	• Decreased blood glucose concentration	• Increased blood glucose concentration	• Increased blood glucose concentration • More energy released in tissue respiration • Oxygen and glucose carried to the muscles faster • More blood is channelled to the muscles • Enhanced vision

15.1 Hormones

Hormone production + secretion: coordinated & controlled by

1. **nervous system**
2. **hormonal system** (hormones from endocrine glands)

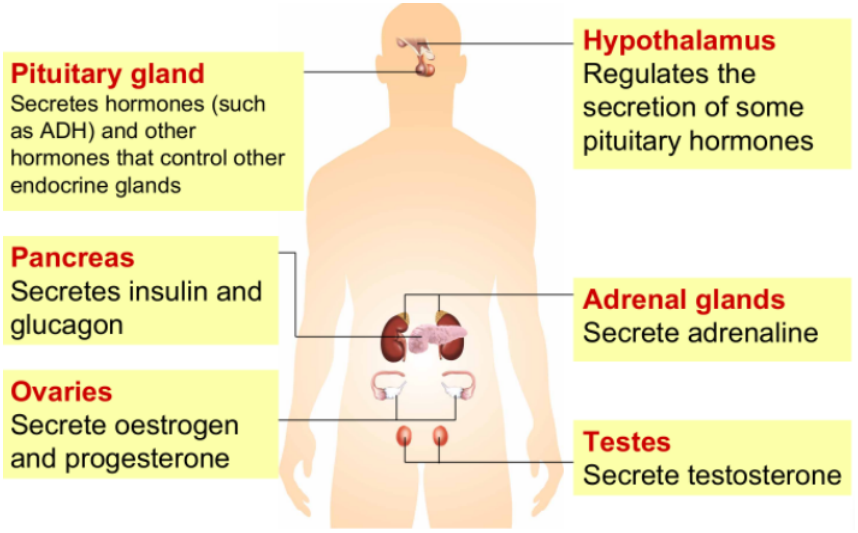
Types of glands:

Endocrine gland	Exocrine gland
Ductless gland: secrete chemical substances directly into bloodstream	Ducts (tube): transport secretions to target organs
• adrenal gland • pituitary gland • pancreas	• sweat gland • salivary gland • pancreas

Pancreas: endocrine + exocrine

Exocrine	Endocrine
secrete pancreatic juice via pancreatic duct	islet of Langerhans secrete insulin and glucagon to regulate blood glucose concentration

15.2 Endocrine Glands



Endocrine gland	Hormone
1. **Pituitary gland**	antidiuretic hormone (ADH)
2. **Hypothalamus**	[regulate secretion of pituitary hormones]
3. **Islets of Langerhans** (pancreas)	insulin + glucagon
4. **Adrenal gland** (adrenal medulla)	adrenaline
5. **Ovary**	oestrogen + progesterone
6. **Testis**	testosterone

15.3 Effects of Hormones

Insulin

Secretion:

Secretion	Effect
Normal	Decrease blood glucose conc 1. Stimulate liver to convert excess glucose → glycogen (stored) 2. Increase permeability of CSM of liver + muscle cells to glucose mol more glucose mol diffuse → liver + muscle cells 3. Increase oxidation of glucose by cells during respiration
Insufficient	Abnormally high blood glucose conc 1. Diabetes mellitus 2. Weight loss 3. Ketonuria
Excessive	Abnormal low blood glucose conc 1. Insulin shock (low blood glucose conc) ● hunger → no glucose ● rapid heartbeat → transport glucose faster for constant rate of respiration (more blood transporting per unit time, make up for blood glucose conc) 2. Irritability → eat sugar 3. Coma, death → no energy (no respiration) → cells die

Diabetes mellitus: cannot regulate blood glucose conc → persistently high

- Cause:
  - increased blood glucose conc → proximal convoluted tubule cannot completely reabsorb all glucose (speed is not fast enough)
  - glucose mol. not reabsorbed → excreted in urine
- Types

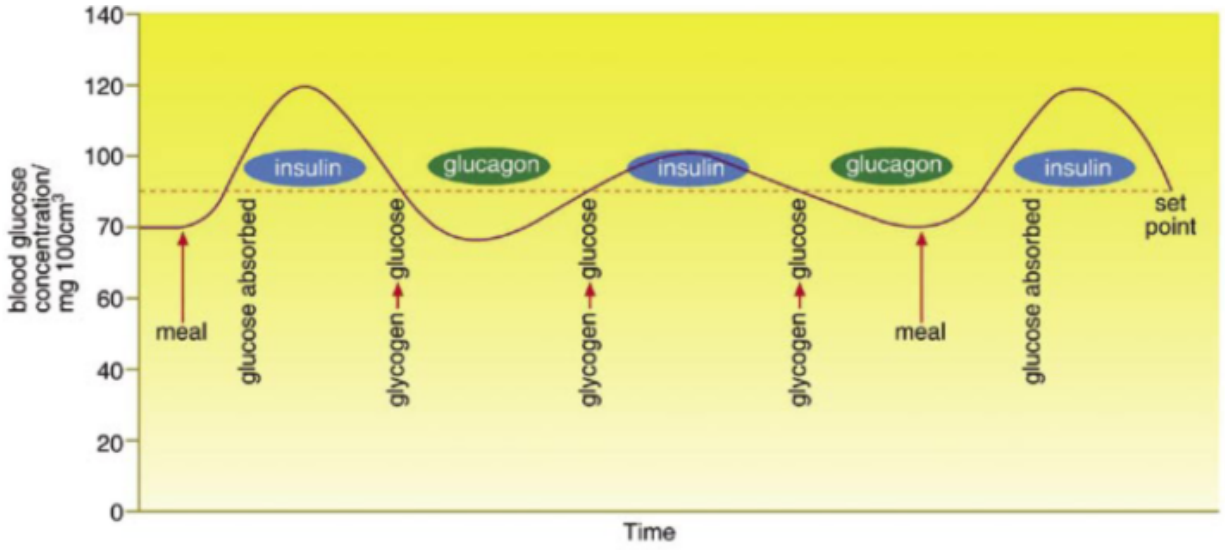
Type 1 (genetically inherited)	**Type 2** (lifestyle)
juvenile / early-onset diabetes (develop early in life)	late-onset diabetes (occur later in life)
insufficient / no insulin produced	target cells do not respond well to insulin (increase tolerance to effects of insulin)
Treatment: regular insulin injection	Treatment: control dietary intake (regulate carbohydrate content) + exercise

- Symptoms:
  - persistently high blood glucose level
  - presence of glucose in urine after meal
  - healing of wounds is slow / difficult → amputation

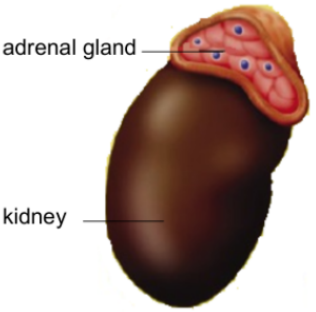
Glucagon

- Main target organ: liver
- Stimulates liver to hydrolyse:
  1. Glycogen → glucose
  2. Fats + amino acids → glucose
  3. Lactic acid → glucose

Secretion of insulin + glucagon: controlled by negative feedback mechanisms



* Hormones are secreted before its effects are brought about

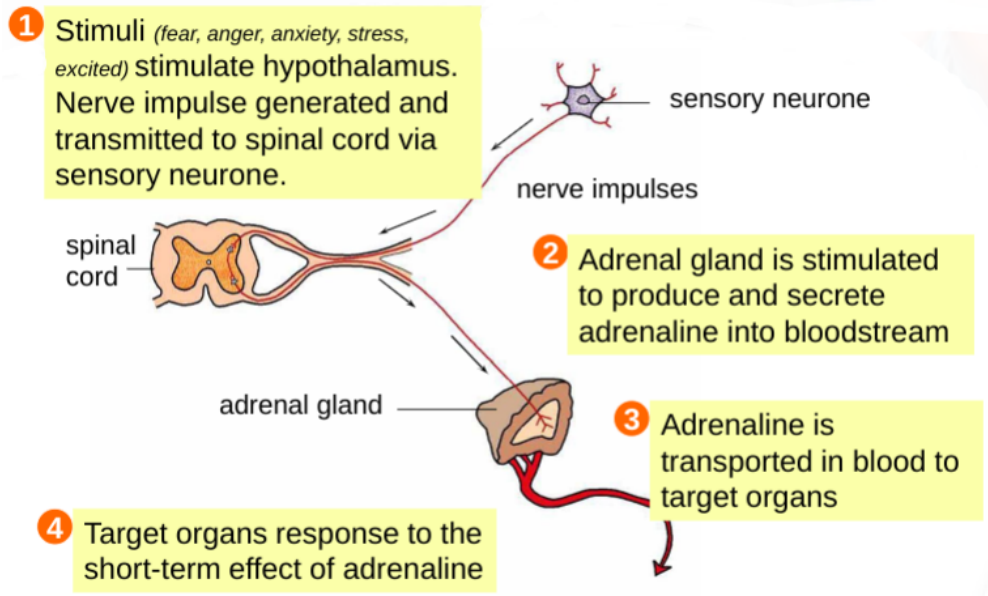


Adrenaline

Adrenaline

- secreted in response to being: (stimuli)
  - **afraid**
  - angry
  - anxious
  - **stressed**
- body respond quickly to sudden demands for energy
- kept very low in concentration during norm (very low baseline) → more secretion
- effects: **short-lived** (secretion drop after stimulus is gone)

Fight or flight response:



Receptor : hypothalamus
CNS : spinal cord
Effector : adrenal gland

Effects:

Effect	Explanation
1. Stimulate liver: convert **glycogen → glucose**	more glucose available for increased muscle contraction (increased respiration for more energy release)
2. Increase **blood glucose level**	more glucose released from liver → bloodstream
3. Increase **metabolic rate**	increase rate of respiration → more energy released in tissue respiration
4. Increase **rate of heartbeat** (blood pressure increase)	transport oxygen + glucose faster to muscles
5. Increase **rate + depth of ventilation** (breathing)	increase rate of uptake of oxygen by lungs
6. Increase rate of **blood clotting** (blood coagulation)	prevent excessive loss of blood when injured
7. Constrict **arterioles** to gut	decrease digestive activities
8. Constrict **arterioles** in skin	less blood to skin surface → reduce heat loss cause paleness, channel more blood to muscles
9. **Dilate pupils**	more light enters eye enhance vision → clearer + sharper
10. Contract **hair erector muscles**	trap insulating layer of air produce 'goose bumps', cause hair to stand on end

15.4 Comparing Endocrine & Nervous Controls

Similarities:

1. Transmission of messages to target organs
2. Mean of communication within body by releasing chemical substances (hormones / neurotransmitters)

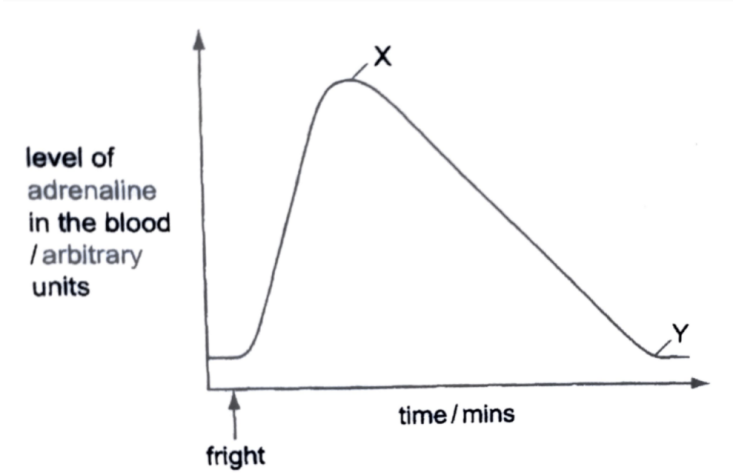
Differences:

Endocrine control	Nervous control
chemical transmission of hormones	electrical transmission of nerve impulses chemical transmission of neurotransmitters
hormones transported by bloodstream	nerve impulses transmitted by neurones
response is always involuntary	response is voluntary / involuntary
widespread; hormones travel along bloodstream, can have > 1 target organ	localised; 1 target organ
slow transmission	very fast transmission
effects of response may be short-lived (adrenaline) or long-lived (growth hormone)	effects of response are short-lived
long distance travelled over the body	very short distance travelled by messages

Typical questions

Multiple choice questions

1 In an experiment, a student is threatened by a large dog and has to run away to escape. During the incident, the adrenaline levels in the student's blood are measured. The graph shows the results.

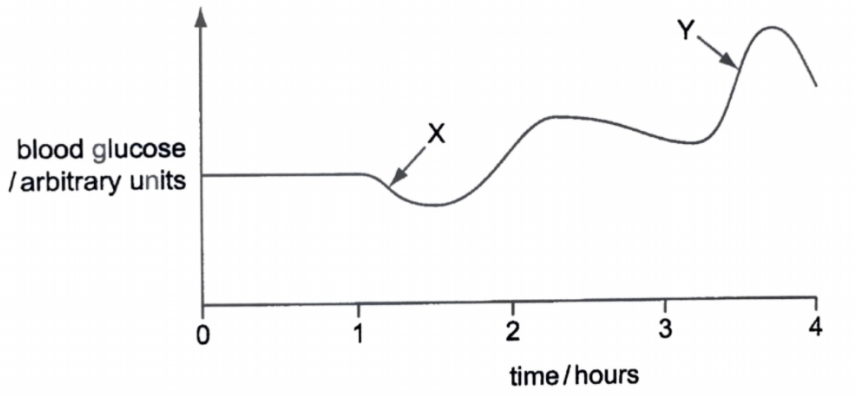


Which statement explains the change in adrenaline levels between points X and Y?

(N2011/P1/Q26)

A Adrenaline is being broken down by the liver.
B Adrenaline is being excreted by the kidneys.
C Adrenaline is being returned to the endocrine gland that produced it.
D Adrenaline is being used up by the contracting muscles.

2 The graph shows changes in a student's blood glucose concentration over a four hour period.



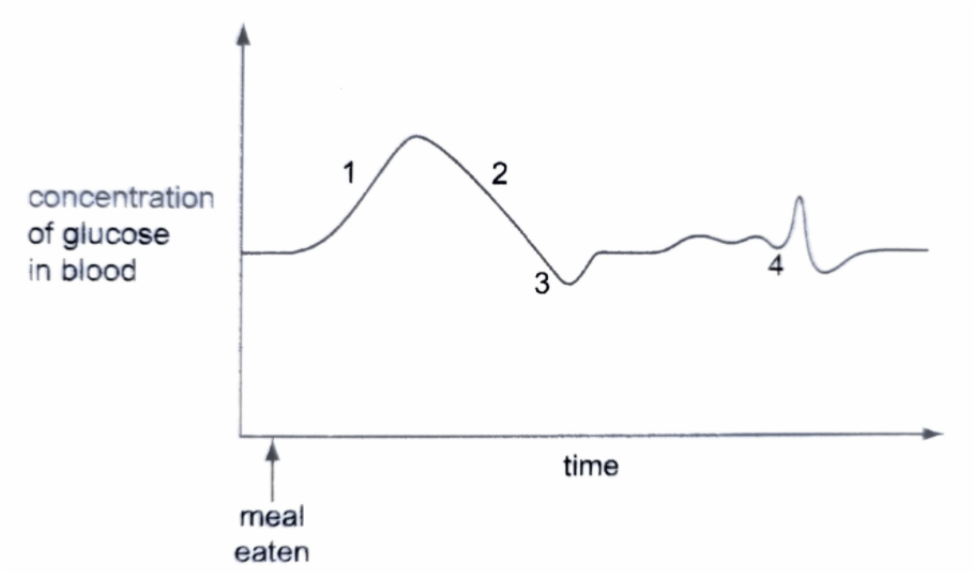
What causes the changes at X and Y? (N2012/P1/Q26)

	X	Y
A	decreased insulin	decreased adrenaline
B	decreased insulin	increased adrenaline
C	increased adrenaline	increased insulin
D	increased insulin	increased adrenaline

3 What results in the release of insulin? (N2013/P1/Q24)

A a decrease in the level of glucagon in the blood
B an increase in the level of adrenaline in the blood
C an increase in the level of glucose in the blood
D an increase in the number of nerve impulses passing to the pancreas

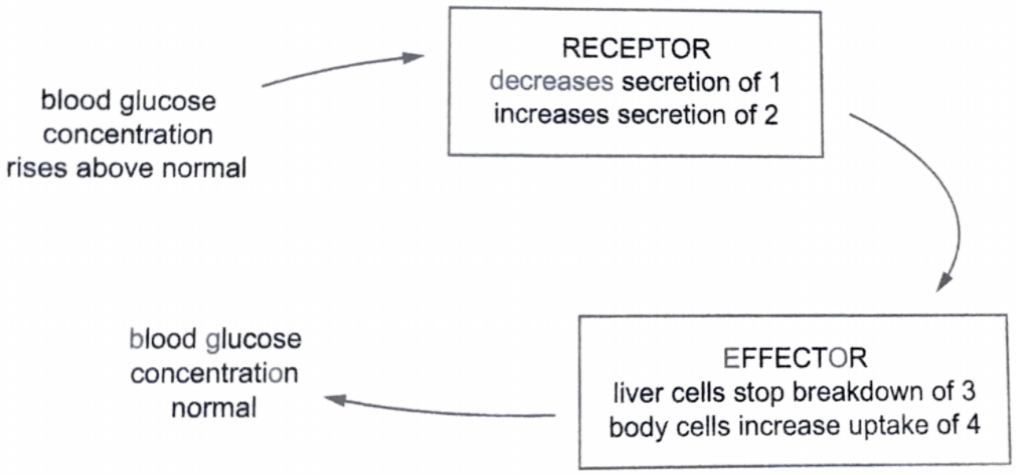
4 The graph shows a person's blood glucose concentration over a period of time.



At which points are adrenaline and glucagon being secreted? (N2016/P1/Q26)

	adrenaline	glucagon
A	1	2
B	2	3
C	3	4
D	4	3

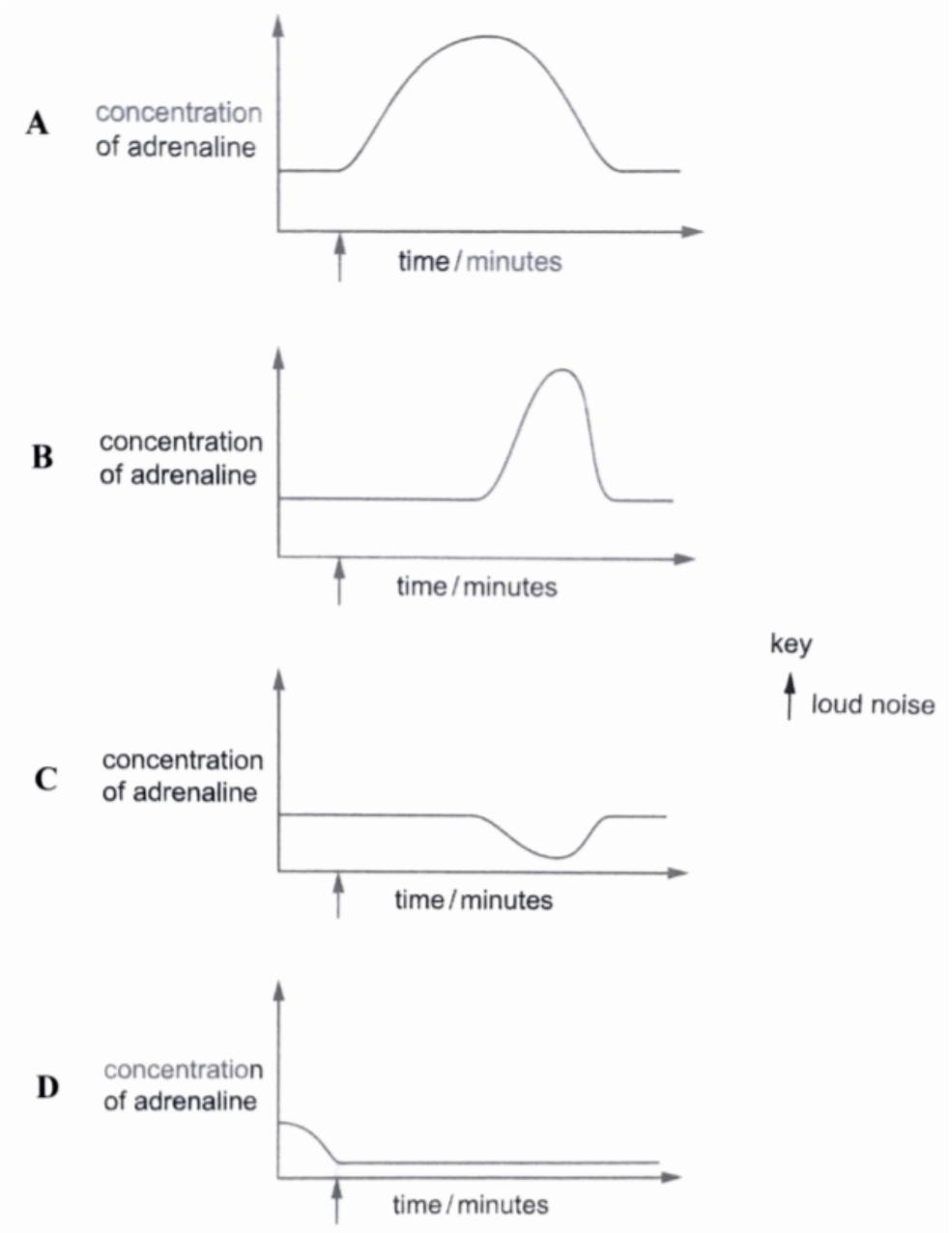
5 The diagram shows a mechanism for regulating blood glucose concentration.



What are 1, 2, 3 and 4 in humans? (N2019/P1/Q23)

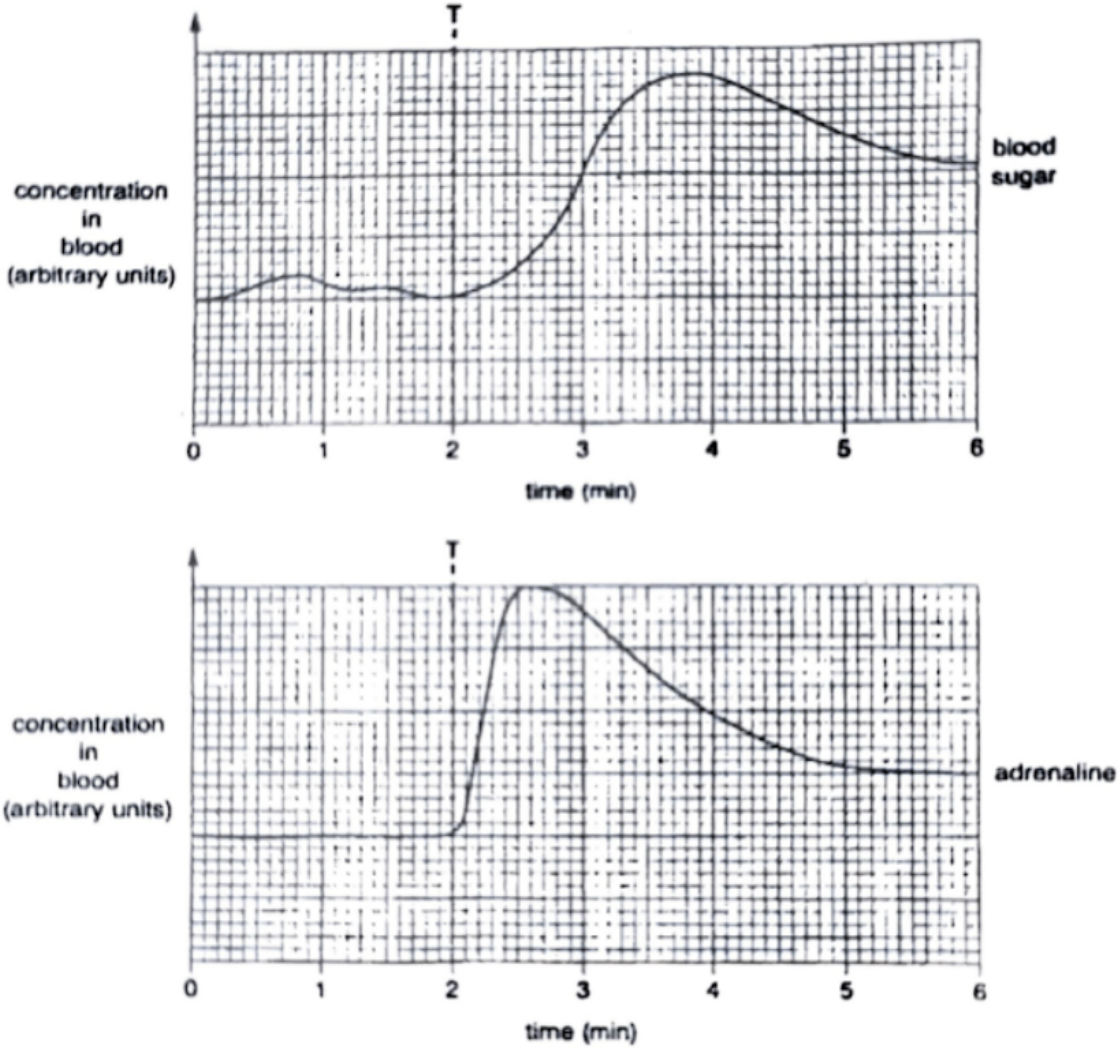
	1	2	3	4
A	glucagon	insulin	glucose	glycogen
B	glucagon	insulin	glycogen	glucose
C	insulin	glucagon	glucose	glycogen
D	insulin	glucagon	glycogen	glucose

6 A person is frightened by a loud noise.
Which shows the change in the adrenaline concentration in the person's blood?
(N2019/P1/Q26)



Structured questions

1 The concentration of sugar and adrenaline in a person's blood were measured at the same time over a period of 6 minutes. The figure below shows these measurements.



(a) Explain why the concentration of blood sugar changed after time T. [3]

- Adrenal medulla in the adrenal glands secrete adrenaline into the bloodstream, which is transported to the liver.
- In the liver, adrenaline stimulates liver cells to convert stored glycogen to glucose.
- Glucose molecules diffuse from liver cells into the bloodstream, thus increasing blood glucose concentration.

(b) Explain how the concentration of blood sugar and adrenaline are returned to their original levels.

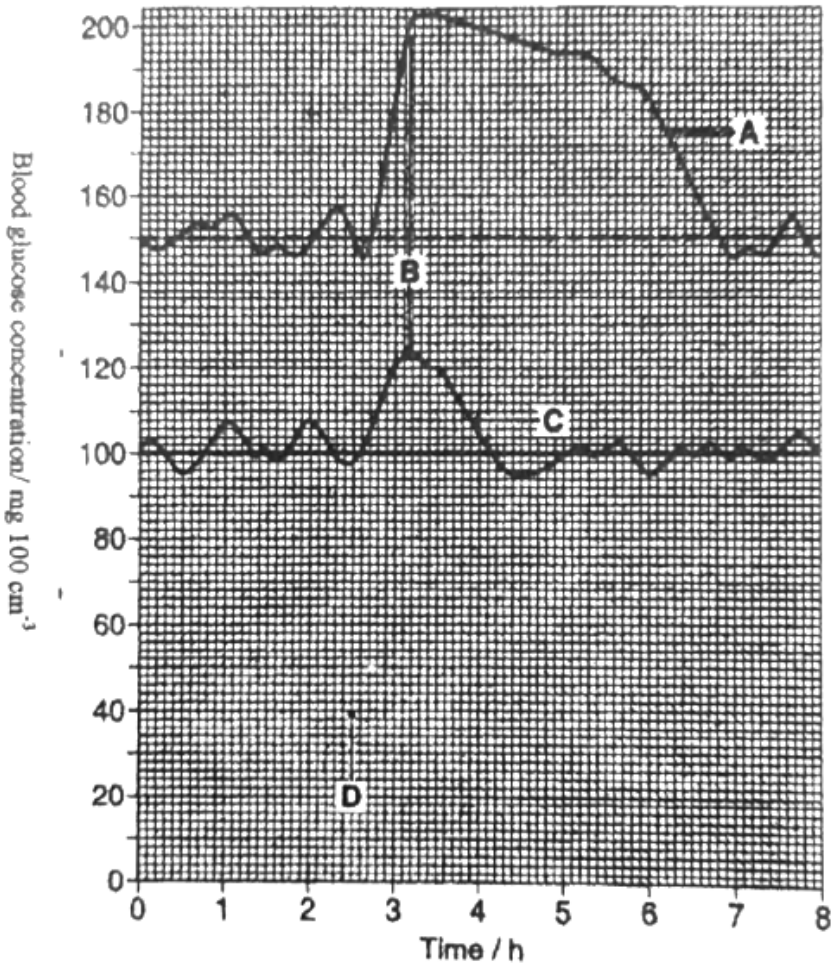
(i) Blood sugar [3]

1) Glucose is oxidised during cellular respiration to release energy.
2) More insulin is secreted to stimulate the liver to convert excess glucose into glycogen stored in the liver.
3) Decrease in secretion of adrenaline, so less glycogen is hydrolysed to form glucose.

(ii) Adrenaline [2]

1) Adrenaline is destroyed in the liver after performing its functions.
2) Decrease in release / secretion of adrenaline by adrenal glands.

2 The figure below shows the results that were obtained during a glucose tolerance test performed on two hospital patients, one diabetic and the other non-diabetic.



(a) Match the following labels with the letters on the graph. [2]

(i) diabetic patient : A

(ii) non-diabetic patient : C

(iii) glucose injection : D

(iv) increased insulin secretion : B

(b) With reference to the graph, state **two** differences observed between the diabetic and non-diabetic patients.

- The increase in blood glucose concentration of the diabetic patient is higher than that of the non-diabetic patient by 50 mg / 100 cm^3.
- The blood glucose concentration of the diabetic patient takes 2.5 longer than the non-diabetic patient to return back to normal.

3 Suggest and explain why the adrenaline concentration increases during exercise. [3]
(N2015/P2/A5c)

When a person exercises, he requires more energy in order to carry out the more rigorous activity.

- Adrenaline increases the rate of glycogen breakdown into glucose in the liver and muscles. This increases the blood glucose concentration. The glucose is transported to all the vital organs, especially the heart and muscles.
- Adrenaline increases heart rate and blood pressure so that more oxygen and glucose are carried to the muscles per unit time, so more energy is released through tissue respiration, for the body.
- Adrenaline constricts the arterioles in the skin and channels more blood to the muscles.
- Adrenaline also causes the pupils in the eyes to dilate so that a person can see better.

Adrenaline prepares the person for his exercise.

4 (N2016/P2/B10 OR)

(a) Explain, using a named example, what is meant by an *endocrine gland*. [4]

An endocrine gland is a ductless gland. It secretes hormones directly into the bloodstream. A hormone is a chemical substance produced in very small amounts by an endocrine gland. It is transported by blood and acts on one or more target organs.

An example of an endocrine gland is the pancreas. It produces two hormones, insulin and glucagon, which work together to ensure that the concentration of glucose in the blood is kept within a narrow range. When blood glucose concentration drops, the pancreas is stimulated to secrete glucagon into the bloodstream. When blood glucose concentration rises, the pancreas is stimulated to secrete insulin into the bloodstream.

(b) Describe the roles of insulin and glucagon in the human body. [6]

Insulin and glucagon are two hormones that work together to keep the blood glucose concentration in the human body constant.

When blood glucose concentration rises above normal, the pancreas is stimulated to increase the secretion of insulin. The insulin causes the liver and muscles to convert excess glucose into glycogen for storage. Insulin increases the permeability of muscle cells and cells from other parts of the body to glucose. Besides increasing the uptake of glucose by the cells, insulin also increases the metabolic rates of the cells. The cells carry out tissue respiration more quickly to oxidise the glucose. This results in a drop of blood glucose concentration to a normal level.

When blood glucose concentration falls below normal, the pancreas is stimulated to increase the secretion of glucagon. The glucagon causes the liver and muscles to convert the stored glycogen to glucose. Glucagon also causes the conversion of amino acids and fatty acids to glucose in the liver. Glucose is released into the bloodstream to restore the glucose concentration to its normal level.

5 Describe how homeostatic control of glucose occurs in the human body. [5]
(N2019/P2/B9 EITHER a)

As the blood glucose level increases above the basal level, the cells in the islets of Langerhans of the pancreas detect the increase in glucose level and secrete insulin into the bloodstream. Insulin binds to insulin receptors in the liver and muscles to increase permeability of cells to glucose. Metabolism rate increases, increasing the aerobic respiration of glucose by cells. Excess glucose is also converted into glycogen to be stored in the liver and muscle cells. When blood glucose level falls back to normal levels, negative feedback occurs and insulin secretion by the pancreas is reduced.

The islets of Langerhans of the pancreas detect a decrease in glucose level below basal level and secretes glucagon into the bloodstream. The glucagon binds to the glucagon receptors in the liver, causing the conversion of stored glycogen into glucose, which then enters the bloodstream. When blood glucose level increases back to normal levels, negative feedback occurs and glucagon secretion by the pancreas is reduced.