

Homeostasis

Revision notes · IB Biology D3.3: homeostasis and negative feedback, blood glucose, diabetes and thermoregulation.

For IB Diploma Biology SL undefined. **HL only** is additional higher level content, for HL students only.

Homeostasis Spec D3.3

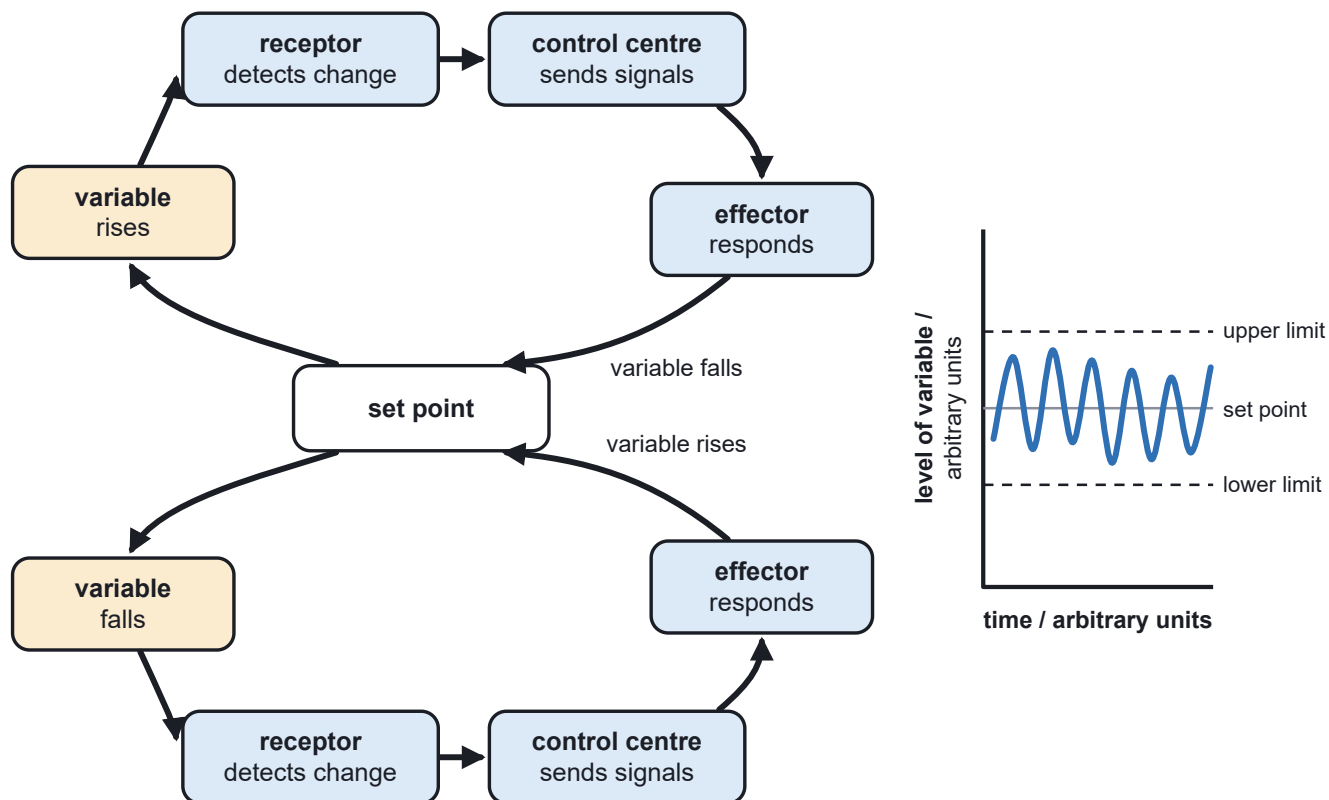
Homeostasis and negative feedback Spec D3.3.1, D3.3.2

Homeostasis is the maintenance of the internal environment of an organism. Variables are **kept within preset limits**, despite fluctuations in the external environment, so that cells, and especially enzymes, work reliably.

Homeostatic variables in humans	
Variable	Approximate normal value
Body (core) temperature	About 37 °C
Blood pH	7.35-7.45
Blood glucose concentration	About 4-6 mmol L ⁻¹ when fasting
Blood osmotic concentration	About 0.3 osmol L ⁻¹

Negative feedback loops

1. A **receptor** detects a change in a variable away from its **set point**.
 2. A **control centre** (often in the brain or an endocrine gland) compares it with the set point and sends signals by nerves or hormones.
 3. **Effectors** (muscles or glands) respond.
 4. The response **reverses the change**, returning the variable to the set point. The loop then switches off.
- Negative feedback works in **both directions**: it brings a variable down when it is above the set point and up when it is below it.
 - Positive feedback amplifies a change away from the set point, so it would make an imbalance worse. That is why homeostasis uses **negative feedback**; positive feedback is only useful for events that must be completed quickly, such as childbirth.



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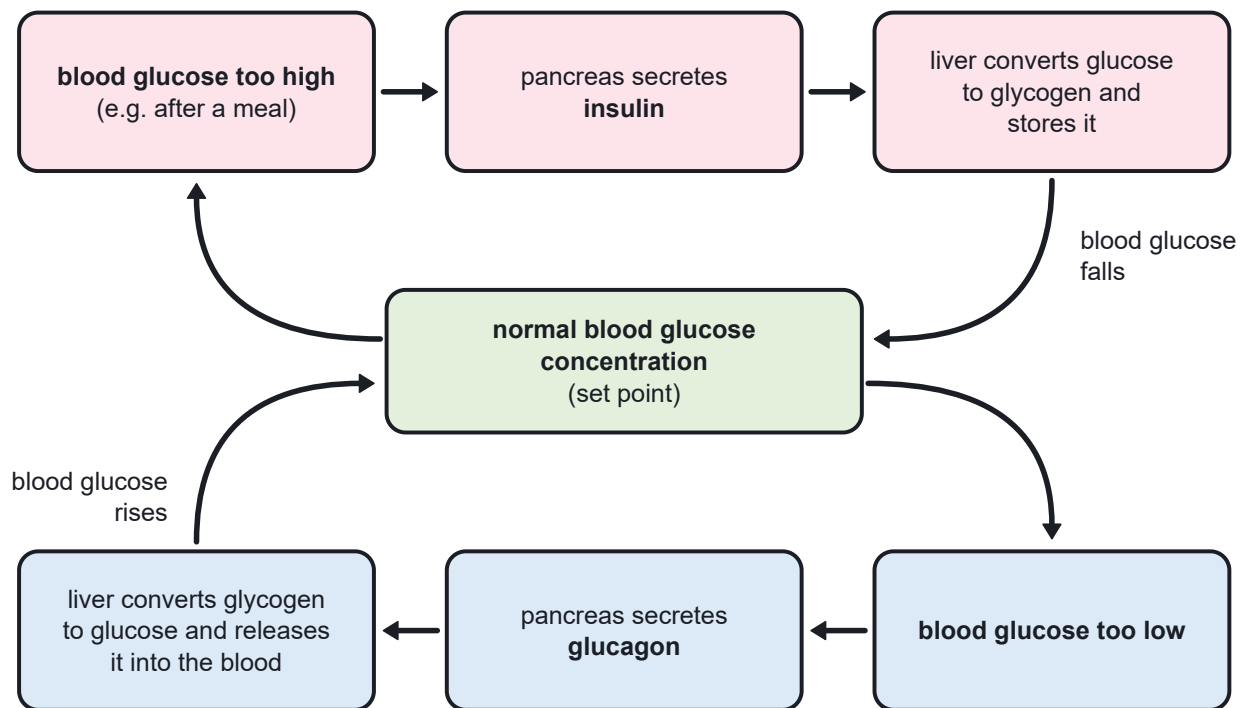
Negative feedback corrects changes in both directions, so the variable fluctuates narrowly around the set point within preset limits.

Exam tip: Negative feedback does not keep a variable perfectly constant: it fluctuates slightly around the set point within preset limits.

Regulation of blood glucose Spec D3.3.3

The pancreas contains clusters of endocrine cells called **islets of Langerhans**. They secrete hormones directly into blood capillaries, which carry them around the body to **target cells** with the right receptors.

Insulin and glucagon		
	Insulin	Glucagon
Secreted by	β (beta) cells of the islets	α (alpha) cells of the islets
Stimulus	Blood glucose above the set point (e.g. after a meal)	Blood glucose below the set point (e.g. fasting, exercise)
Target cells	Liver, skeletal muscle and adipose cells	Mainly liver cells (hepatocytes)
Effects	More glucose transporters inserted into membranes, so cells absorb glucose; glucose converted to glycogen (and fat); more glucose used in respiration	Glycogen broken down to glucose, which is released into the blood; glucose also made from other compounds
Result	Blood glucose falls	Blood glucose rises



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Blood glucose is controlled by **negative feedback**: insulin lowers it and glucagon raises it. The figure shows the liver; insulin also makes skeletal muscle and adipose cells absorb glucose.

Common mistake: Glucagon, glycogen and glucose are easily confused. Glucagon is the hormone; glycogen is the storage polysaccharide; glucose is the sugar in the blood.

Type 1 and type 2 diabetes Spec D3.3.4

Comparing type 1 and type 2 diabetes		
	Type 1	Type 2
Physiological change	Autoimmune destruction of the β cells, so little or no insulin is secreted	Target cells become less responsive to insulin (insulin resistance), e.g. fewer working insulin receptors or glucose transporters; insulin is still produced, though output may fall later
Usual onset	Often in childhood or adolescence	Usually in adults, increasingly in younger people
Risk factors	Genetic predisposition; possibly environmental triggers such as viral infection	Obesity, physical inactivity, diets high in sugar and fat, increasing age, family history (genetic factors) and ethnicity
Prevention	No known method	Healthy diet, regular exercise and keeping a healthy body mass
Treatment	Regular insulin injections or an insulin pump, matched to blood glucose monitoring, meals and activity	Diet low in sugars and refined carbohydrates, exercise, weight loss; drugs that improve insulin sensitivity; insulin in some cases

In both types, blood glucose rises after meals and stays high (**hyperglycaemia**). Glucose appears in the urine and, over many years, high glucose damages blood vessels, nerves, kidneys and the retina.

Exam tip: For 'distinguish' questions, state the difference in physiology directly: type 1, no insulin is produced; type 2, insulin is produced but target cells do not respond to it.

Thermoregulation Spec D3.3.5, D3.3.6

Birds and mammals keep a constant body temperature by both **physiological** and **behavioural** means (for example seeking shade, huddling, or in humans putting on clothes). The details below are for humans.

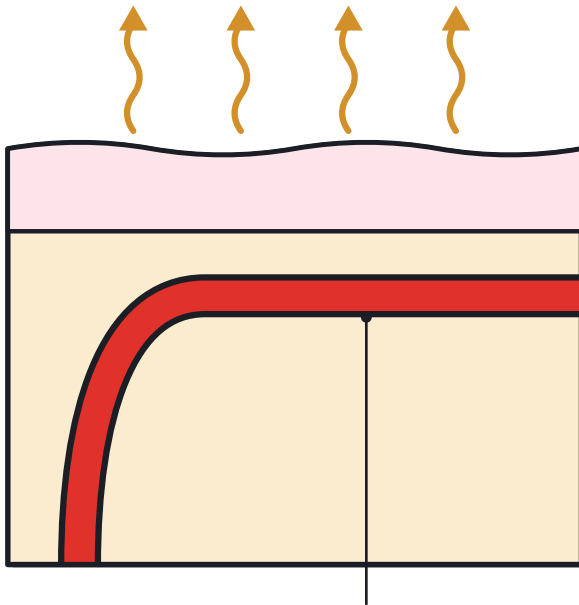
The feedback loop

- **Receptors:** **peripheral thermoreceptors** in the skin detect skin temperature; thermoreceptors in the hypothalamus detect blood (core) temperature.
- **Control centre:** the **hypothalamus** compares temperature with the set point (about 37 °C) and sends nerve impulses to effectors.
- **Hormonal route:** when cold, the hypothalamus stimulates the pituitary gland to secrete TSH, which stimulates the thyroid gland to secrete **thyroxine**. Thyroxine raises the basal metabolic rate, so cells generate more heat.
- **Effectors:** skeletal muscle, brown adipose tissue, skin arterioles, sweat glands and hair erector muscles.

Thermoregulation mechanisms in humans		
Mechanism	When	How it works
Vasoconstriction	Too cold	Arterioles supplying skin capillaries narrow, so less blood flows near the surface and less heat is lost
Shivering	Too cold	Rapid involuntary contractions of skeletal muscle; respiration releases heat
Uncoupled respiration in brown adipose tissue	Too cold	Brown fat cells have many mitochondria with a protein (thermogenin) that lets protons leak back across the inner membrane, so energy is released as heat instead of making ATP
Hair erection	Too cold	Hair erector muscles raise body hairs, trapping a layer of air; much less effective in humans than in furry mammals
Vasodilation	Too hot	Arterioles supplying skin capillaries widen, so more blood flows near the surface and more heat is lost by radiation
Sweating	Too hot	Sweat glands secrete sweat; evaporation of water from the skin removes heat

Too hot: vasodilation

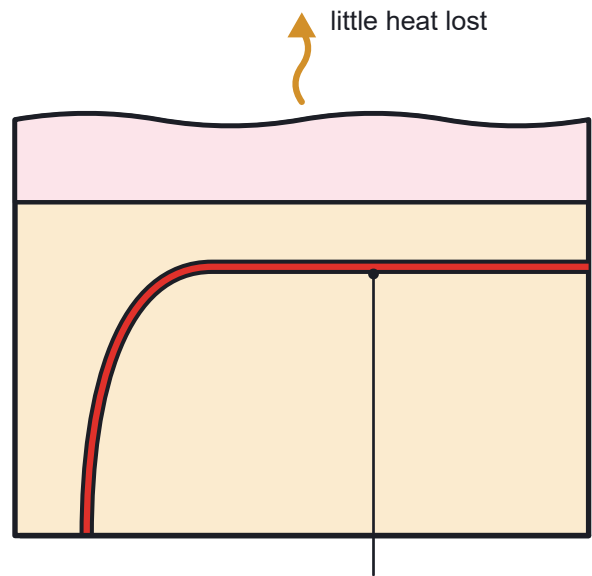
lots of heat lost



Blood vessel widens
more blood near surface

Too cold: vasoconstriction

little heat lost



Blood vessel narrows
less blood near surface

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Vasodilation and **vasoconstriction** of the arterioles supplying skin capillaries change how much blood flows near the skin surface. The vessels widen or narrow; they do not move.

Common mistake: Capillaries do not move up or down in the skin, and they cannot constrict. It is the arterioles supplying them that dilate or constrict.

Exam tip: Linking question: what biological systems are sensitive to temperature changes? Enzyme activity, membrane fluidity and nerve conduction all change with temperature.

Quick check

1. Name four homeostatic variables in humans.
2. Which pancreatic cells secrete glucagon?
3. State the physiological cause of type 1 diabetes.
4. How does brown adipose tissue generate heat?

Quick check answers

Homeostasis

1. Body temperature, blood pH, blood glucose concentration and blood osmotic concentration.
2. α (alpha) cells of the islets of Langerhans.
3. Autoimmune destruction of the β cells, so little or no insulin is secreted.
4. Uncoupled respiration: energy is released as heat instead of being used to make ATP.