



Homeostasis

Revision notes • IB Biology D3.3: homeostasis and negative feedback, blood glucose, diabetes, thermoregulation, and HL kidney function, ADH and blood supply.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Homeostasis Spec D3.3

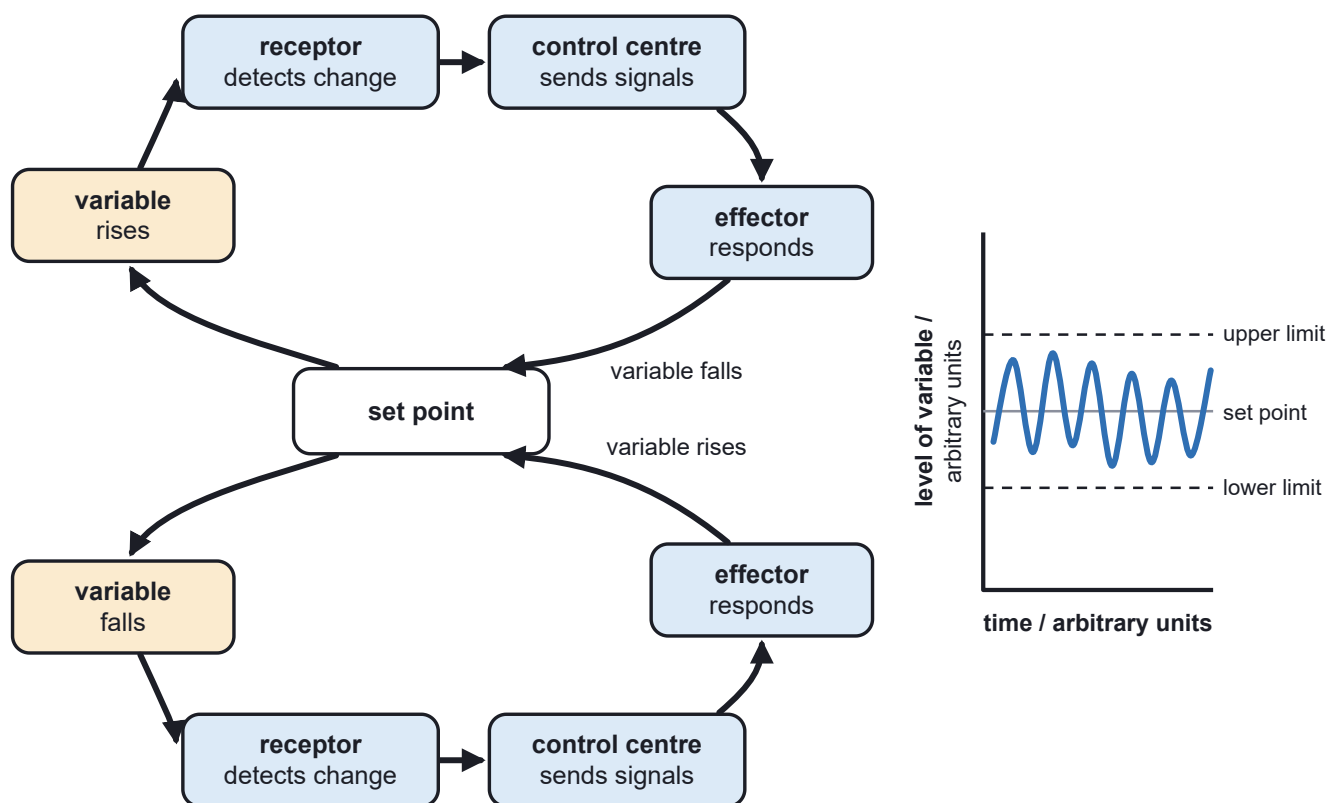
Homeostasis and negative feedback Spec D3.3.1, D3.3.2

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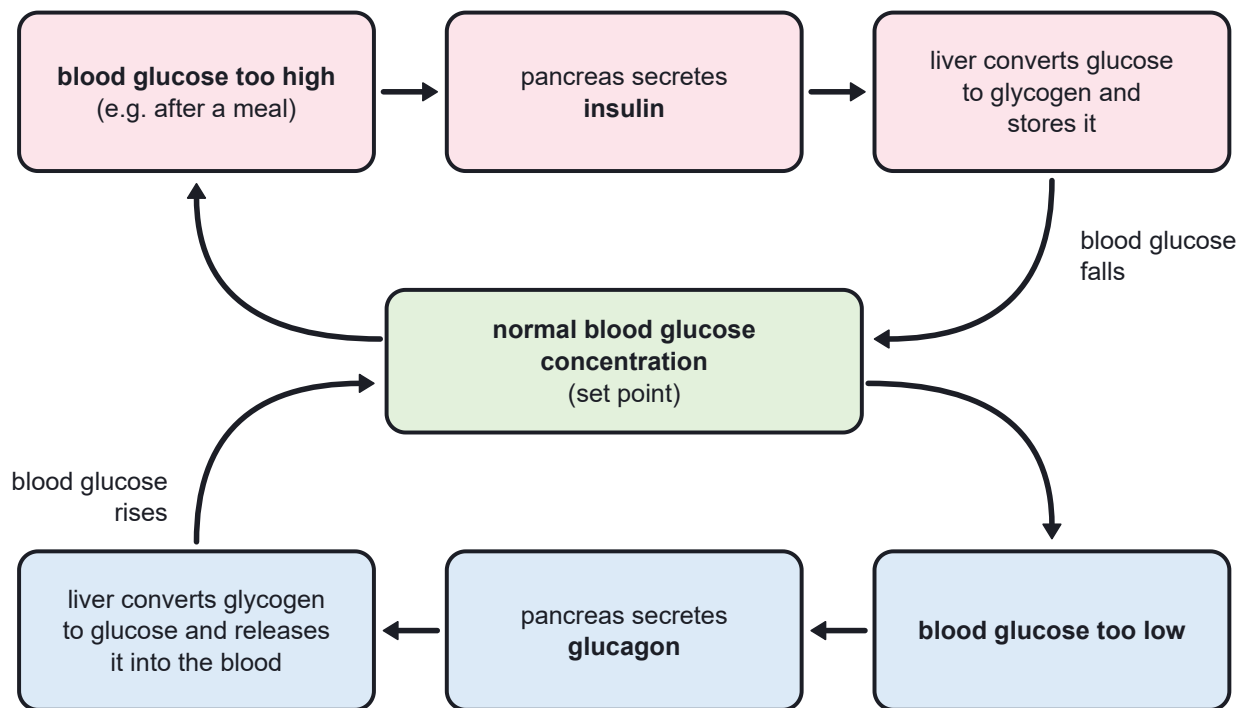
Negative feedback corrects changes in both directions, so the variable fluctuates narrowly around the set point within preset limits.

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.

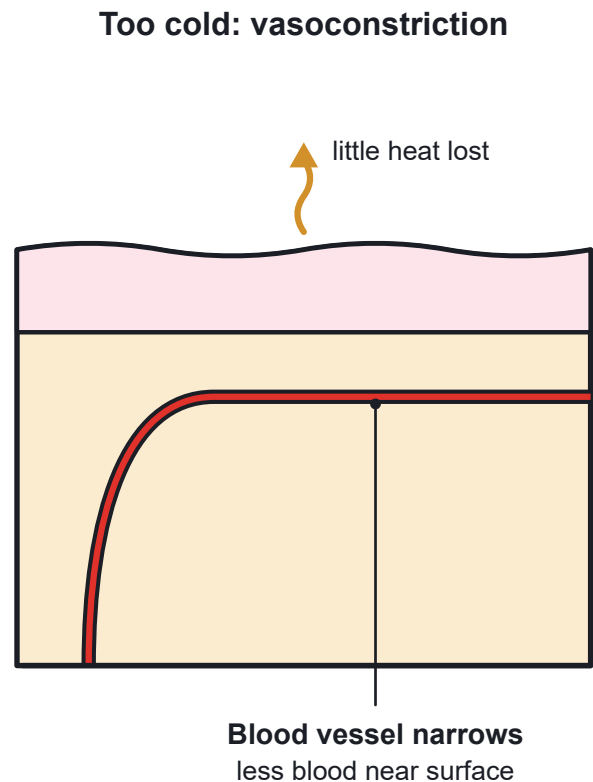
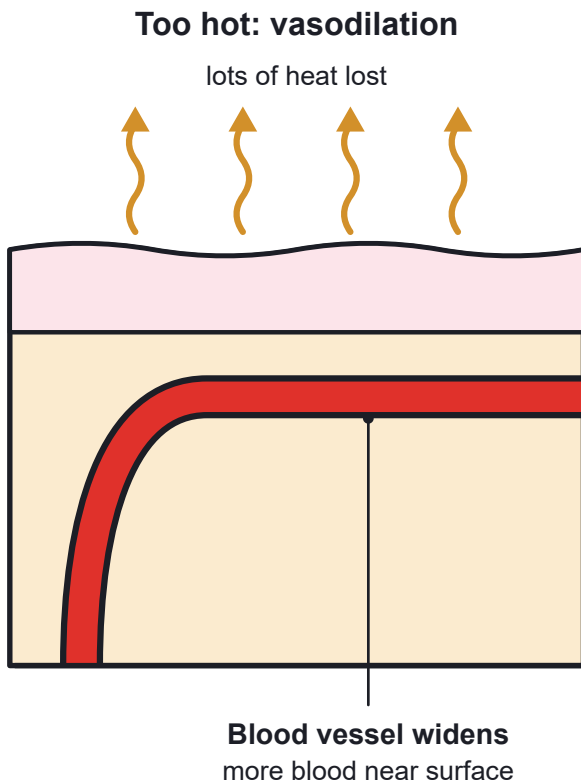
Thermoregulation Spec D3.3.5, D3.3.6

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



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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.

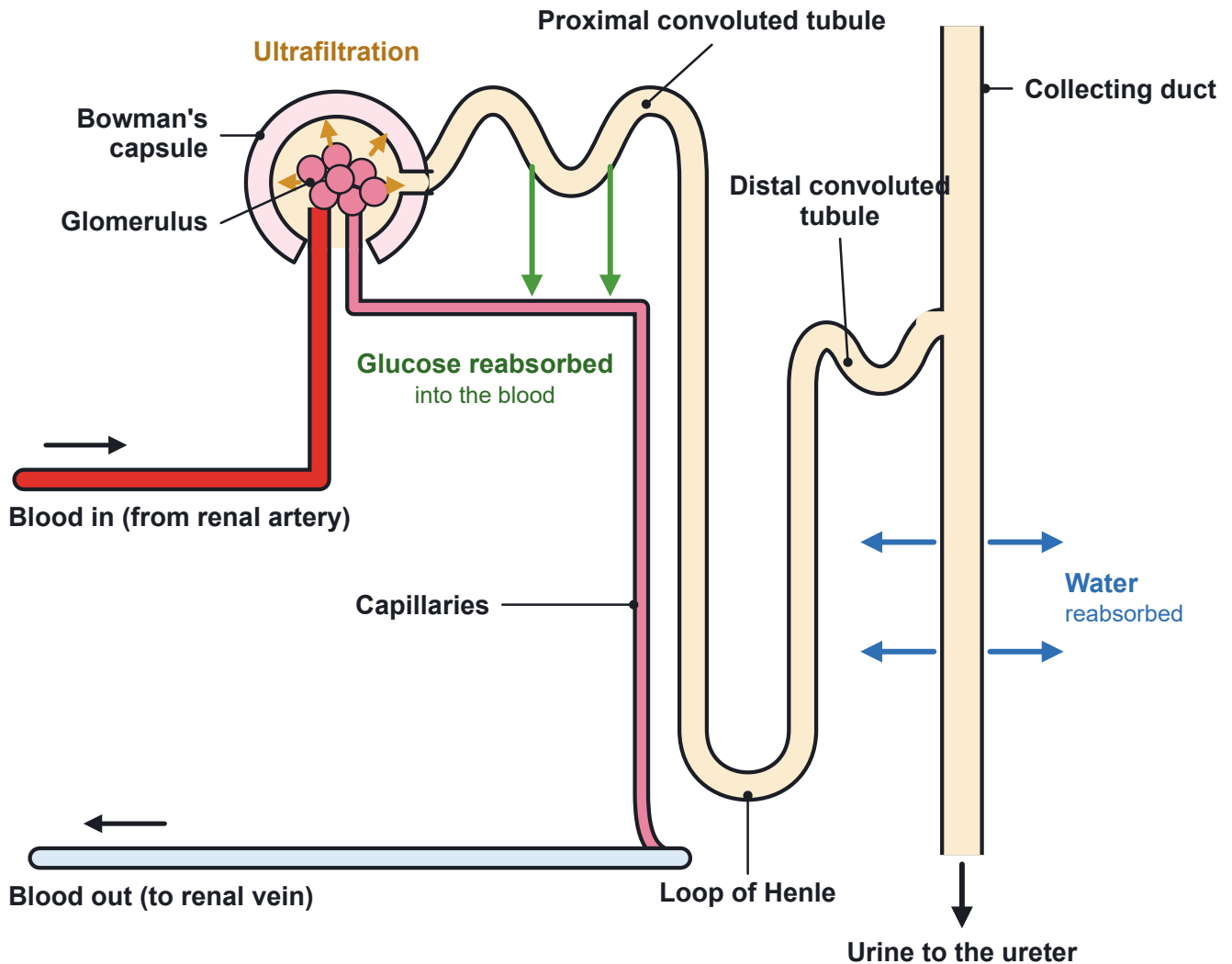
Common mistake: Capillaries do not move up or down in the skin, and they cannot constrict. It is the arterioles supplying them that dilate or constrict.

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

The kidney: excretion, ultrafiltration and reabsorption Spec D3.3.7, D3.3.8 HL only

Excretion	Removal from the body of the waste products of metabolism, such as urea, and of toxins and other unwanted solutes.
Osmoregulation	Regulation of the osmotic concentration of body fluids (the amount of water relative to solutes), in osmoles per litre (osmol L ⁻¹).

The kidneys do both. Each contains about a million **nephrons**, the tubules that make urine.



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A nephron. **Ultrafiltration** happens at the glomerulus; useful substances are reabsorbed along the tubule.

Ultrafiltration: glomerulus and Bowman's capsule

- The **glomerulus** is a knot of capillaries. Its incoming arteriole is wider than the outgoing one, so blood pressure inside is high.
- Pressure forces plasma out through gaps in the capillary wall, a fine filter (the basement membrane) and slits between the cells lining **Bowman's capsule**.
- The filtrate contains water, glucose, amino acids, mineral ions, urea and other small solutes. Blood cells and most plasma proteins are too large and stay in the blood.

Selective reabsorption: proximal convoluted tubule

- In the **proximal convoluted tubule** all of the glucose and amino acids are reabsorbed into the blood, by active transport and co-transport with sodium ions.
- Most of the mineral ions and most of the water (by osmosis) are also reabsorbed here.
- The tubule wall cells have microvilli for a large surface area and many mitochondria to supply ATP for active transport.
- Toxins, urea and other unwanted solutes are not reabsorbed (or only partly), so they stay in the filtrate and are excreted in urine.

Common mistake: Filtration is not selective: it is based on size. The selection happens afterwards, when useful substances are reabsorbed.

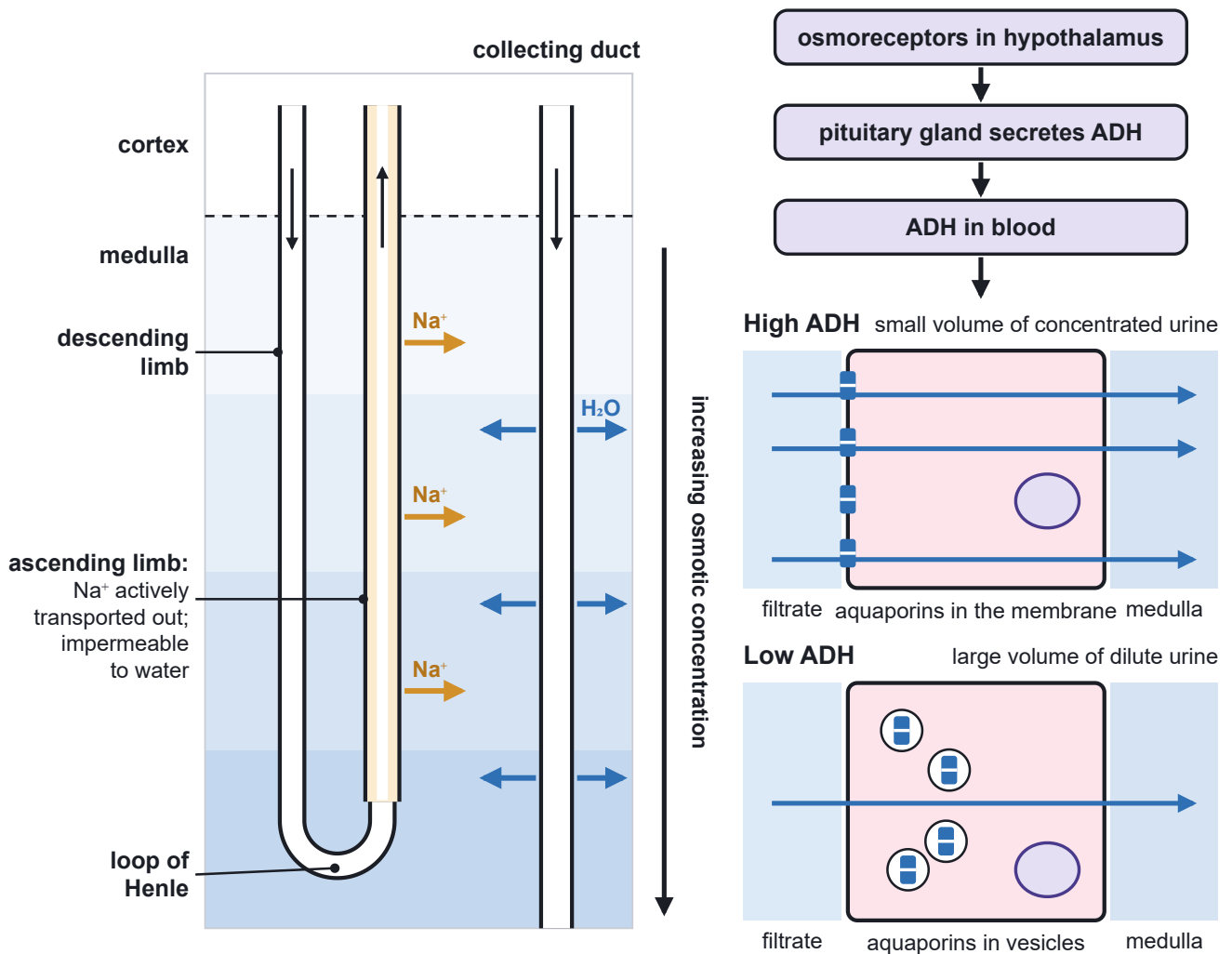
Loop of Henle and osmoregulation in the collecting ducts Spec D3.3.9, D3.3.10 HL only

Role of the loop of Henle

- Cells of the **ascending limb** use ATP to **actively transport sodium ions** out of the filtrate into the tissue fluid of the medulla.
- The ascending limb wall is impermeable to water, so water cannot follow the ions.
- This maintains a **high osmotic concentration in the medulla**. Collecting ducts pass through the medulla, so water can leave them by osmosis whenever their walls are permeable.

Osmoregulation by the collecting ducts

1. **Osmoreceptors** in the hypothalamus detect the osmotic concentration of the blood.
2. If the blood is too concentrated (for example after sweating or not drinking), the pituitary gland increases its secretion of **antidiuretic hormone (ADH)**.
3. ADH travels in the blood to the collecting duct cells. It causes intracellular vesicles containing **aquaporins** (water channels) to fuse with the cell membranes facing the filtrate.
4. With more aquaporins, more water moves by osmosis out of the collecting ducts into the concentrated medulla and back into the blood. A small volume of concentrated urine is produced.
5. If the blood is too dilute, ADH secretion decreases. Aquaporins are taken back from the membrane into intracellular vesicles, so less water is reabsorbed and a large volume of dilute urine is produced.
6. Either way, the blood osmotic concentration returns to its set point: negative feedback.



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The ascending limb keeps the medulla concentrated. ADH moves aquaporins into the collecting duct cell membrane, so more water leaves by osmosis.

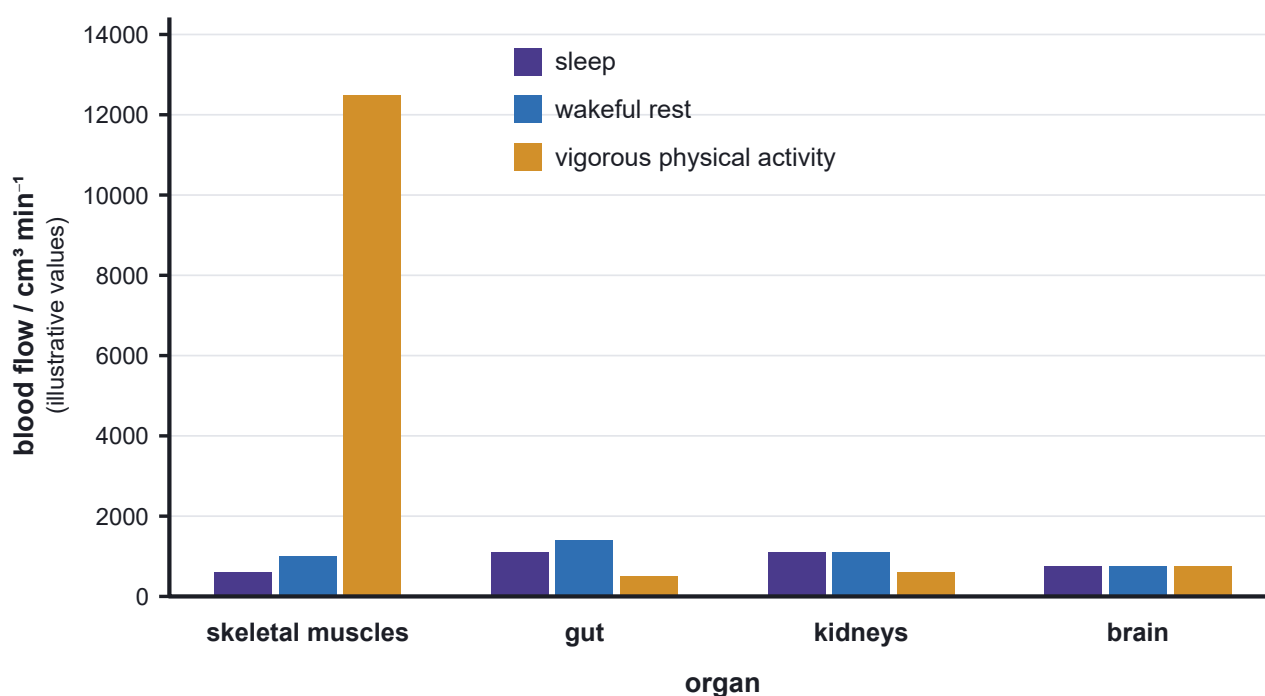
Exam tip: Say that ADH changes the location of aquaporins, between intracellular vesicles and the cell membrane. It does not make the duct 'absorb' water actively; water always moves by osmosis.

Changes in blood supply to organs with activity Spec D3.3.11 HL only

The heart's output is shared between organs. Smooth muscle in the walls of arterioles contracts (vasoconstriction) or relaxes (vasodilation), so blood can be redistributed to match each organ's needs.

Pattern of blood supply in three states			
Organ	Sleep	Wakeful rest	Vigorous physical activity
Skeletal muscles	Low: muscles relaxed and inactive	Moderate share	Greatly increased: by far the largest share, for oxygen and glucose supply and removal of CO ₂ and heat
Gut	Substantial supply continues for digestion and absorption	Large share, especially after a meal	Reduced by vasoconstriction, so blood is diverted to muscles
Kidneys	Large share for filtration	Large share for filtration	Reduced, so less filtration and less urine
Brain	Roughly constant	Roughly constant	Roughly constant in volume, so a smaller percentage of the increased cardiac output

- During vigorous activity, cardiac output rises (faster heart rate and larger stroke volume) and arterioles in active muscles dilate.
- During sleep, cardiac output is at its lowest, and skeletal muscles receive little blood.
- The brain needs a steady supply of oxygen and glucose at all times, so its flow is kept almost constant.



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Blood is **redistributed** between organs by vasodilation and vasoconstriction of arterioles. Values are illustrative.

Exam tip: Linking question: for what reasons do organisms need to distribute materials and energy? Redistribution of blood matches oxygen and glucose supply to the organs working hardest.

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?
5. **HL only** What does ADH do to collecting duct cells?

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.
5. Moves aquaporins from intracellular vesicles into the cell membrane, increasing water reabsorption.