DP Biology – D3.3

Homeostasis

- How do humans keep internal conditions constant?
- Why is it useful for organisms to keep internal conditions constant?

Statements D3.3.1–6, SL and HL. Textbook pp. 760–767.
Image: goose bumps, one response to cold. EverJean, CC BY 2.0.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	D3.3.1–2	Define homeostasis, and explain why it depends on negative feedback
2	D3.3.3	Explain how insulin and glucagon regulate blood glucose
3	D3.3.4	Compare type 1 and type 2 diabetes: causes, risk factors, prevention and treatment
4	D3.3.5–6	Explain how hormones and effectors regulate body temperature in humans

Overview of this chapter

Part	Statements	What it covers
Staying steady	D3.3.1	Variables kept within preset limits
The mechanism	D3.3.2	Why negative feedback is used
Blood glucose	D3.3.3	Insulin, glucagon and their target cells
Diabetes	D3.3.4	Type 1 and type 2
Temperature	D3.3.5–6	Receptors, hormones and effectors

What homeostasis is

D3.3.1

- **Homeostasis** keeps conditions inside an organism steady
- Variables are kept within preset limits, despite changes in the external environment

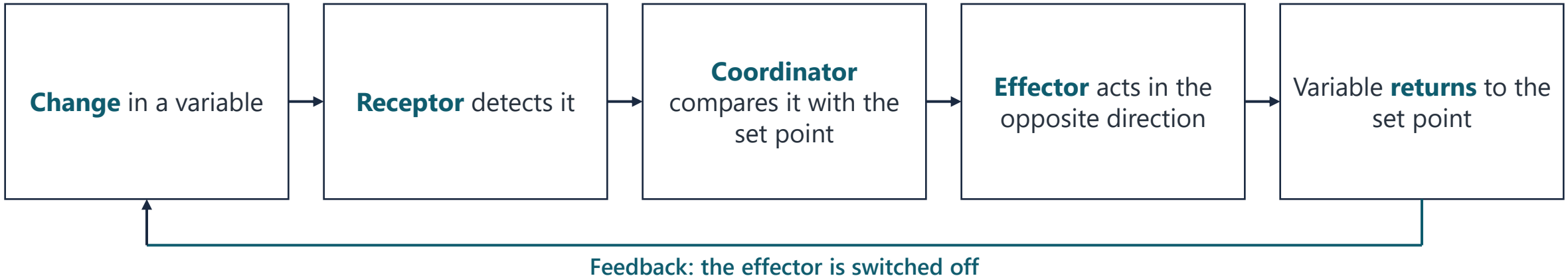
Homeostatic variable in humans	Typical value
Body temperature	Close to 37°C
Blood pH	About 7.4
Blood glucose concentration	About 90 mg per 100 cm^3
Blood osmotic concentration	Kept within narrow limits

Common mistake

Homeostasis is control of the internal environment. It does not involve a person controlling their external environment.

Negative feedback

D3.3.2



- It works in **both directions**, from values above and below the set point
- Variables do fluctuate, but only within narrow limits

Why negative, not positive?

Positive feedback amplifies a change and moves a variable further from its set point. Negative feedback brings it back, which is what keeps conditions stable.

Why blood glucose must be controlled

D3.3.3

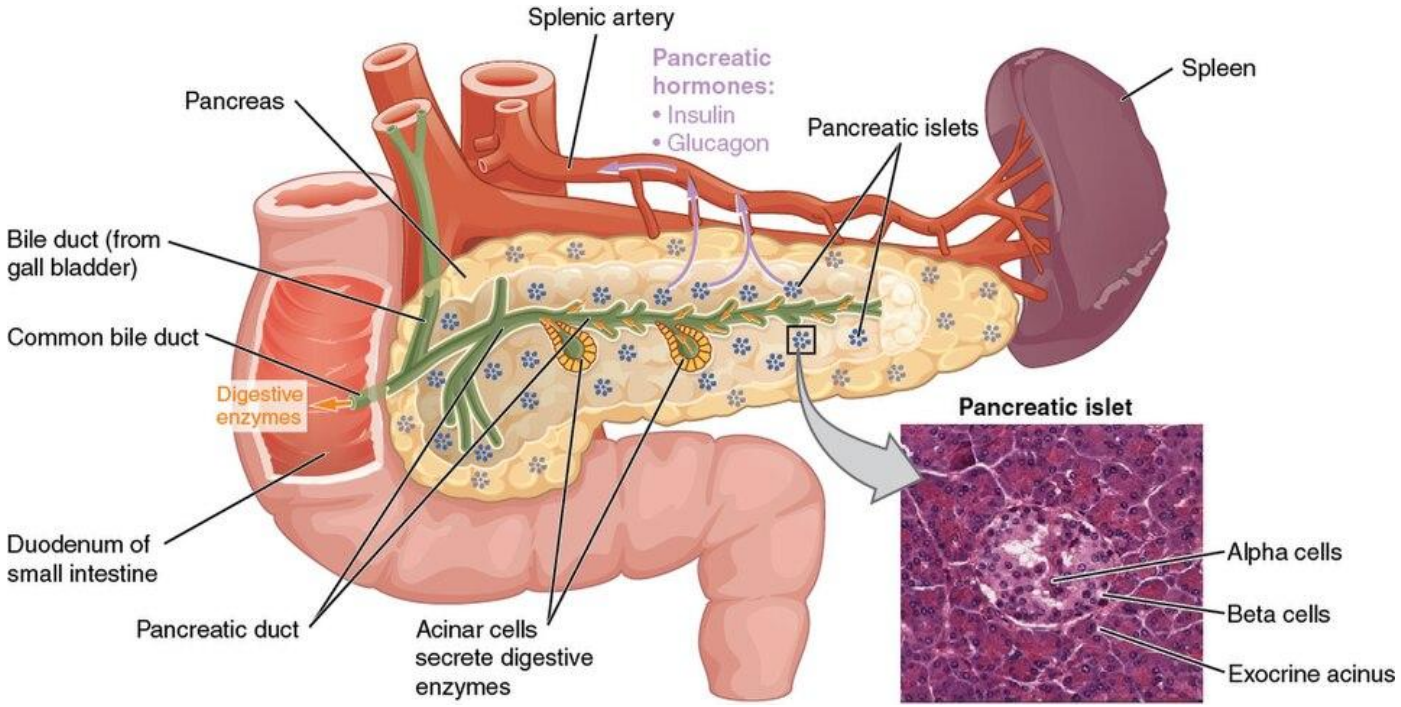
Condition	Blood glucose	Consequence
Hypoglycaemia	Too low	Too little for the brain: fainting, convulsions, coma
Normal	About 90 mg per 100 cm^3	Cells receive a steady supply
Hyperglycaemia	Too high	Water drawn from tissues into the blood: dehydration and damage

Key idea

Brain cells depend on a constant supply of glucose from the blood, as they hold no glycogen store. Blood glucose can fall to about 70 mg without food and rise to about 150 mg after a meal.

The pancreas makes two hormones

D3.3.3



The pancreas, with islets of Langerhans among exocrine tissue. OpenStax College, CC BY 3.0.

- Endocrine cells are in **islets of Langerhans**
- **Beta cells** secrete **insulin**
- **Alpha cells** secrete **glucagon**
- Hormones travel in the blood to target cells

Common mistake

The beta cells themselves monitor blood glucose. The hypothalamus is not involved. Also, do not mix up glucagon, the hormone, with glycogen, the storage product.

How insulin and glucagon work

D3.3.3

	Glucose too high	Glucose too low
Detected by	Beta cells in pancreas	Alpha cells in pancreas
Hormone secreted	Insulin	Glucagon
Target cells	Liver, muscle, other tissues	Liver
Effect	Cells take up glucose; liver and muscle store it as glycogen; more used in respiration	Liver breaks down glycogen and releases glucose
Result	Blood glucose falls	Blood glucose rises

Common mistake

Glucagon is a hormone and not an enzyme, so it does not itself break down glycogen.

Type 1 and type 2 diabetes

D3.3.4

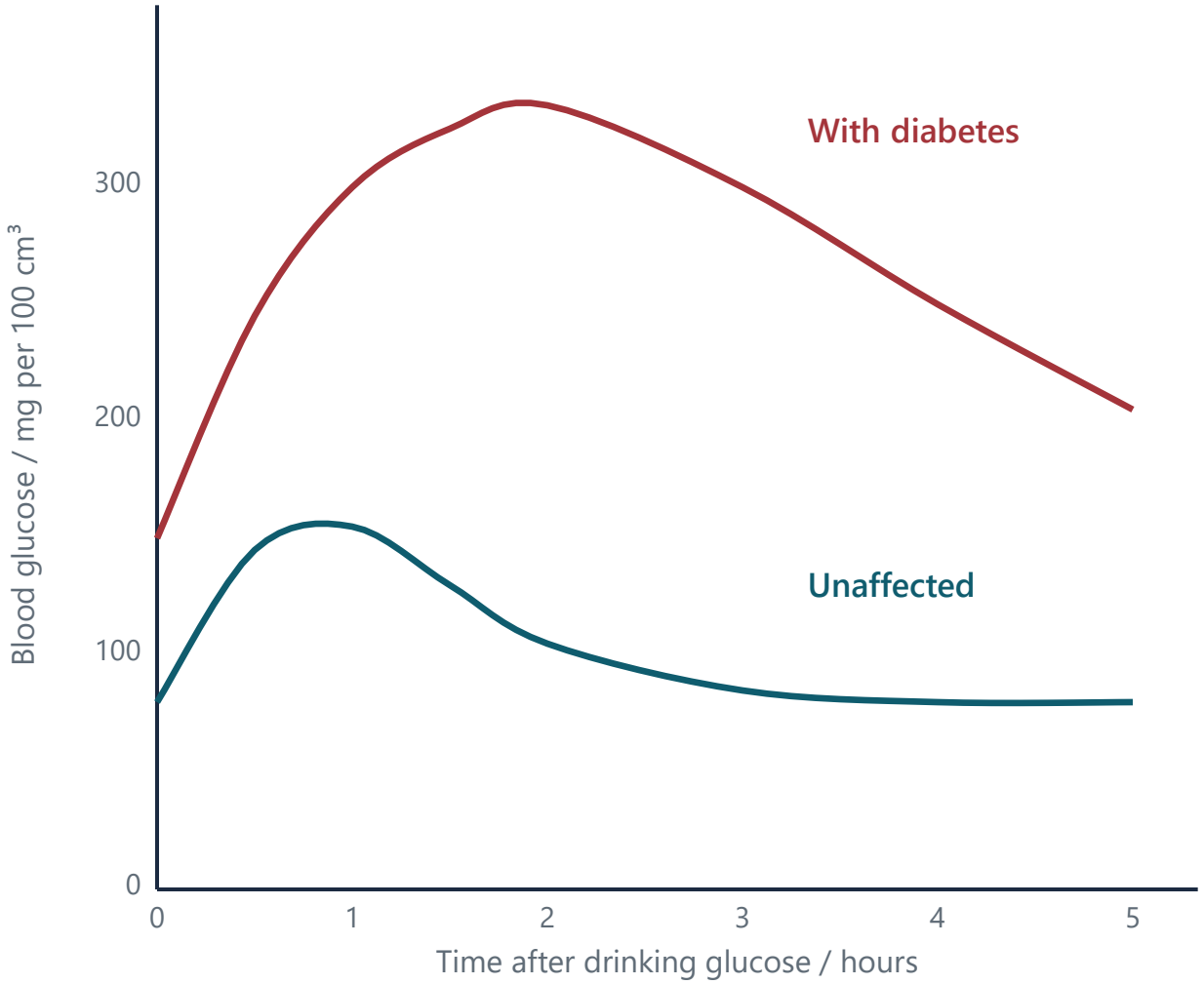
	Type 1	Type 2
What goes wrong	Beta cells are destroyed, so no insulin is produced	Insulin is produced, but target cells do not respond
Cause	Autoimmune attack on beta cells	Faulty receptors on target cells
Typical onset	Usually young	Usually older, increasingly younger
Risk factors	Genes; possibly viruses	Overweight, inactivity, age, family history
Treatment	Insulin, with glucose monitoring	Diet and exercise; sometimes medicine



Monitoring blood glucose. Image: David-i98, CC BY-SA 3.0. Prevention: a healthy diet and regular exercise lower the risk of type 2. Type 1 cannot currently be prevented.

Interpreting a glucose tolerance test

D3.3.4



Invented values, based on a realistic pattern.

- After a fast, a person drinks a standard dose of glucose
- Blood glucose is measured for several hours
- Unaffected: a small rise, and a return to normal in about 2–3 hours
- Diabetic: higher at the start, a greater peak, and a very slow fall

Activity

Compare the peak values and time to return. Why is a sample taken at both 0 and 2 hours?

Thermoregulation as negative feedback

D3.3.5

Peripheral thermoreceptors in skin detect a change → **Hypothalamus** compares this with the set point → Sends signals to **effectors** → Effectors change heat loss or production → Temperature **returns** to the set point



Heat loss seen in infrared: warm areas appear bright. NASA/IPAC, public domain.

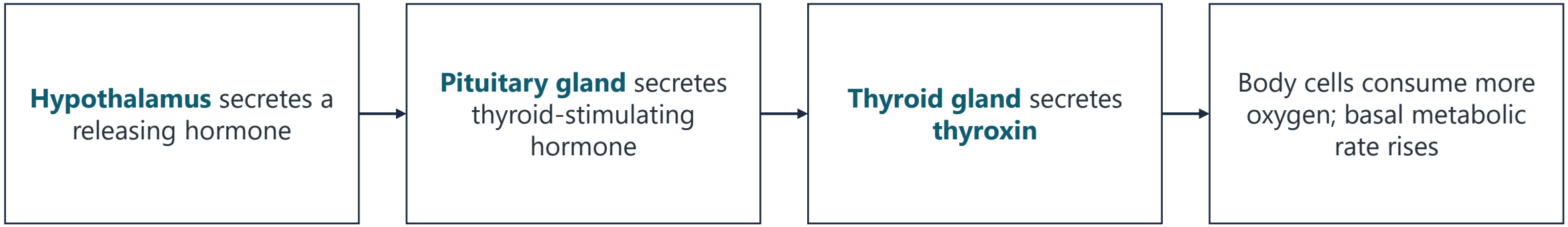
- Effectors include **muscles** and **adipose tissue**
- Thermoreceptors in the hypothalamus also monitor blood temperature
- Core temperature in humans is about 37°C

Key idea

Most heat comes from metabolism, and blood carries it around the body.

Thyroxin controls heat production

D3.3.5



Effector tissue	Role
Skeletal muscle	Contraction in shivering releases heat
White adipose tissue	Insulates, as a long-term response to cold
Brown adipose tissue	Generates heat rapidly by uncoupled respiration

High levels of thyroxin in turn reduce secretion by the hypothalamus and pituitary, which is negative feedback.

Responses to heat and to cold

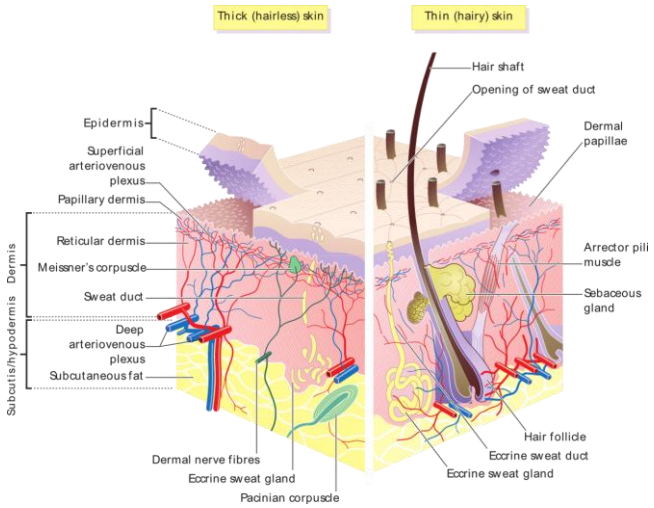
D3.3.6

	Too hot	Too cold
Skin arterioles	**Vasodilation**: more blood to the skin	**Vasoconstriction**: less blood to the skin
Sweat glands	More sweat, which evaporates	Less sweat
Hair	Muscles relax; hairs lie flat	Muscles contract; hair erection traps air
Muscle	No shivering	**Shivering** generates heat
Brown fat	Little activity	Uncoupled respiration releases heat

Common mistake

Blood vessels do not move up or down in the skin. Arterioles dilate or constrict, changing how much blood flows through the surface capillaries.

Two mechanisms in detail



Skin, with sweat glands and hair erector muscles.
Madhero88, CC BY-SA 3.0.

Sweating

- Evaporation breaks hydrogen bonds between water molecules
- This takes heat energy from the skin, cooling it

Uncoupled respiration

- In brown adipose tissue, mitochondria are uncoupled from ATP production
- Energy is released as heat rather than stored in ATP
- Newborn babies rely on this, as they have a large surface area for their size

Beyond humans

Birds and mammals also use behaviour, such as seeking shade or spreading their wings. You need detail only for humans.

Why keep conditions constant?

- Enzymes work close to their optimum, so metabolism stays efficient
- Cells receive a steady supply of glucose and keep their water balance
- Regulators such as mammals can stay active over a wide range of external conditions
- This gives greater freedom in where they can live

Discussion

Keeping warm uses a great deal of energy: a mammal must eat far more than a reptile of the same size. Weigh up the costs and benefits of maintaining a constant body temperature.

Check that you can explain

1. What homeostasis is, with four variables
2. Why negative feedback is used
3. How insulin and glucagon act
4. Differences between type 1 and type 2 diabetes
5. How to interpret a glucose tolerance test
6. The roles of hypothalamus, pituitary and thyroxin
7. Responses to heat and to cold
8. How uncoupled respiration releases heat

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Explain why homeostasis uses negative feedback and not positive feedback.

2. A person has just eaten a large meal. Name the hormone secreted, the cells that secrete it, and one effect on the liver.

3. Give two responses that the body makes when core temperature falls.

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Human-Infrared.jpg – NASA/IPAC – Public domain
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