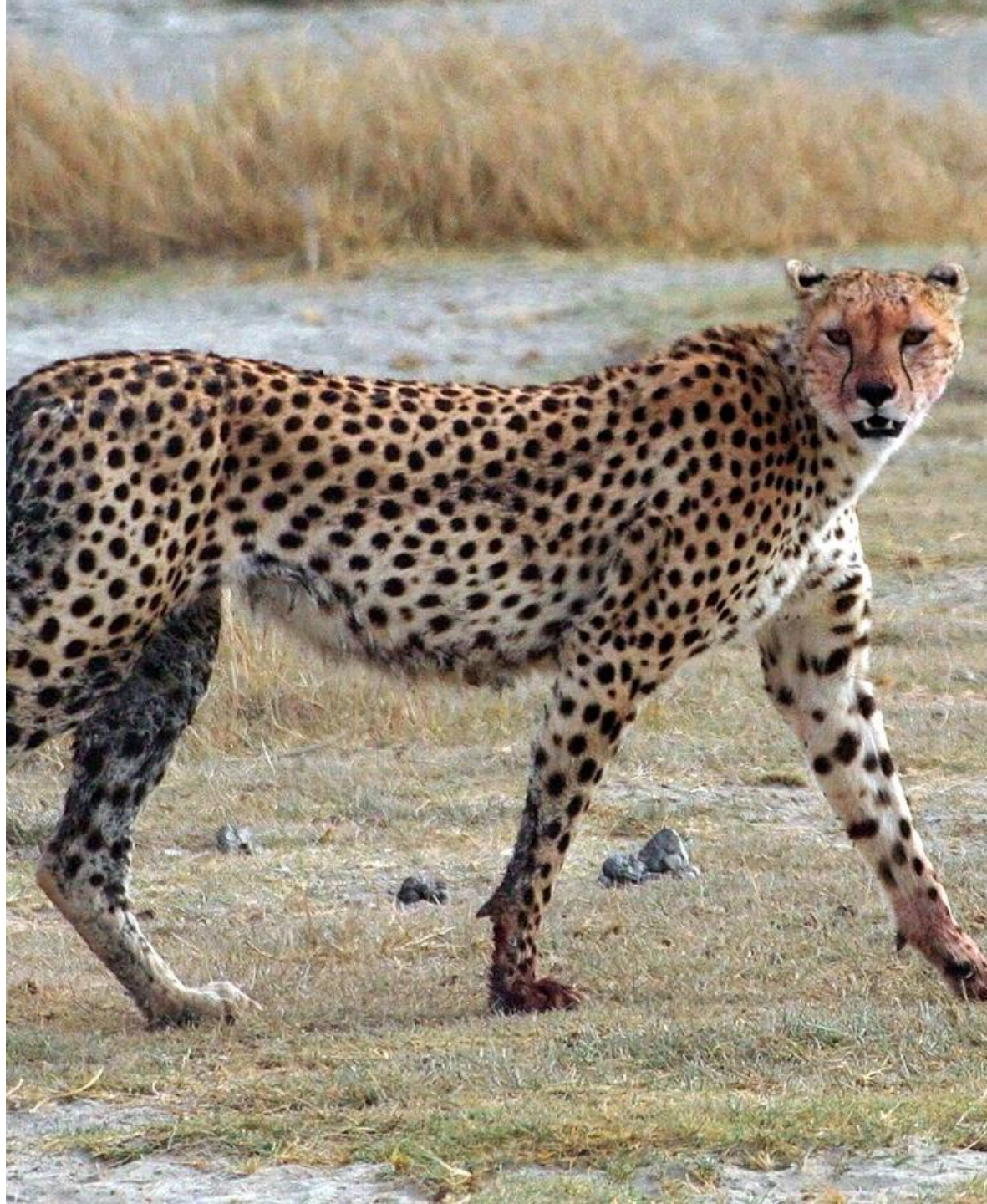
DP Biology – C3.1

Integration of body systems

- What do nerves and hormones each do to coordinate body systems?
- How does feedback help to control body systems?

Statements C3.1.1–16, SL and HL. Textbook pp. 490–509.
Image: cheetah. Author's modification of an original by Rob, CC BY 2.0.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	C3.1.1–3	Explain integration and emergent properties, and compare nervous and hormonal signalling
2	C3.1.4–8	Outline the roles of the brain and spinal cord, and of sensory and motor neurons and nerves
3	C3.1.9–10	Describe a pain reflex arc, and the role of the cerebellum
4	C3.1.11–12	Explain how melatonin and epinephrine act
5	C3.1.13–14	Outline control by the hypothalamus and pituitary, and feedback control of heart rate
6	C3.1.15–16	Explain control of ventilation rate and of peristalsis

Overview of this chapter

Part	Statements	What it covers
Working together	C3.1.1–3	Hierarchy, emergent properties, nerves, hormones, blood
The nervous system	C3.1.4–10	Brain, spinal cord, neurons, reflexes, cerebellum
Hormones	C3.1.11–13	Melatonin, epinephrine, hypothalamus, pituitary
Feedback	C3.1.14–15	Heart rate and ventilation rate
The gut	C3.1.16	Control of peristalsis

What system integration means

C3.1.1

- Living things are made of many interacting parts
- **Integration** is the coordination of these parts, so that together they carry out an overall function
- It is needed at every level, from molecules to ecosystems
- Without coordination, the parts would work against one another

Discussion

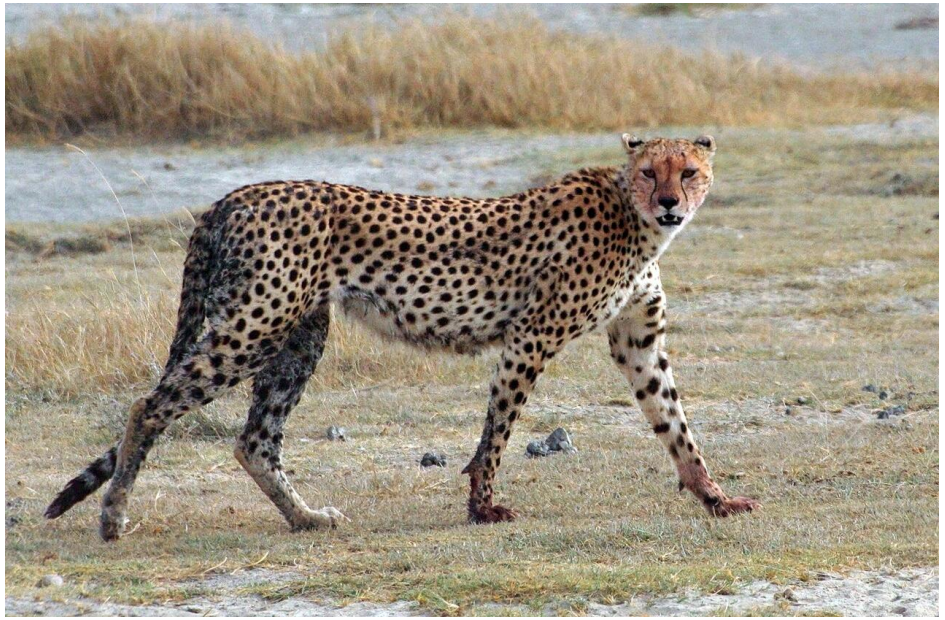
Think about running for a bus. Which systems have to change what they are doing? What would go wrong if your muscles sped up, but your heart and lungs did not?

A hierarchy of subsystems

C3.1.2

Cells → Tissues → Organs → Organ systems → **Organism**

Level	In a cheetah
Tissue	Fast-contracting muscle tissue
Organ	Enlarged heart; flexible spine
Organ system	Breathing and circulation deliver oxygen fast
Organism	An effective predator



Cheetah. Author's modification of an original by Rob, CC BY 2.0.

Key idea

Emergent properties arise when the parts interact. A single muscle cell cannot chase prey: a whole integrated cheetah can.

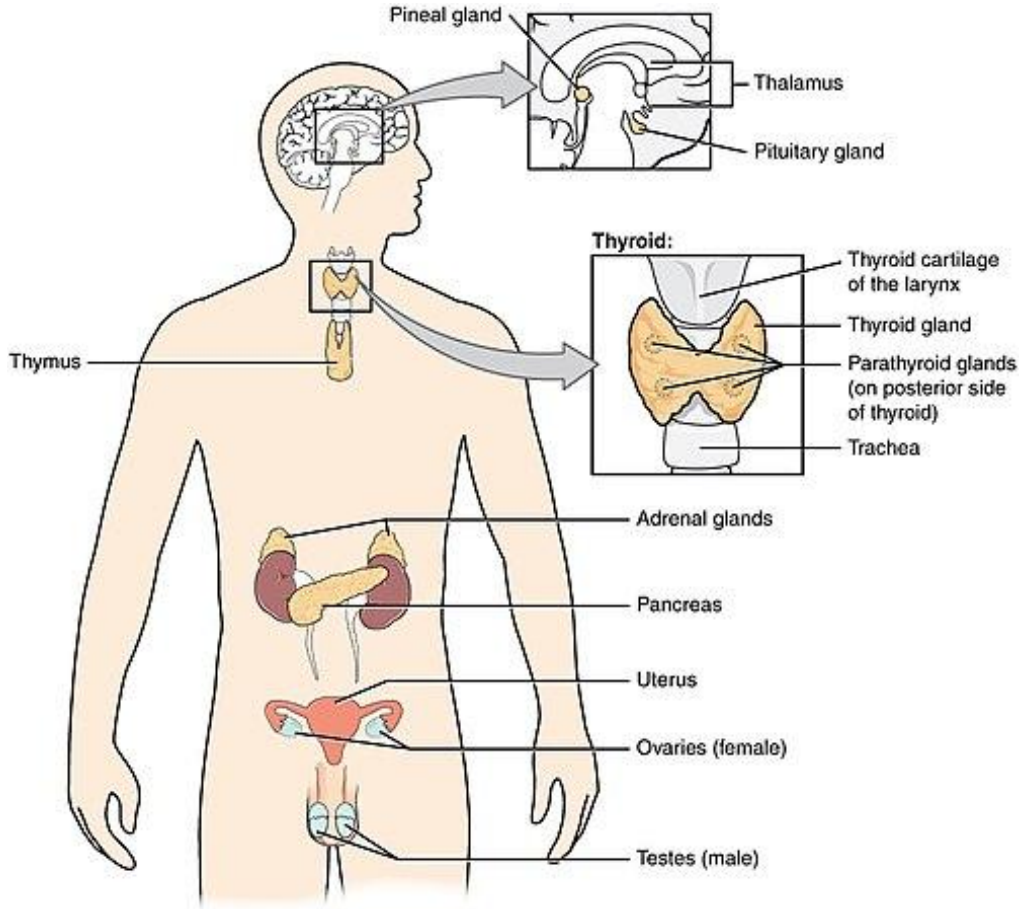
Nervous and hormonal signalling

C3.1.3

	Nervous	Hormonal
Signal	Electrical impulses and neurotransmitters	Chemical messengers
Travels by	Neurons and nerves	Bloodstream
Destination	Specific muscles or glands	Target cells around the body
Speed	Very rapid	Can be slow
Duration	Short	Long
Examples	Blinking, pain reflex	Growth, reproductive cycles, homeostasis

The endocrine system

C3.1.3



Endocrine glands. OpenStax College, CC BY 3.0.

- **Endocrine glands** are ductless and secrete hormones directly into the blood
- Hormones reach every part of the body
- Only **target cells** with the right receptors respond
- Very small amounts are effective
- Hormones are broken down in the liver, so long-acting ones must be secreted continually

Blood transports materials between organs

C3.1.3

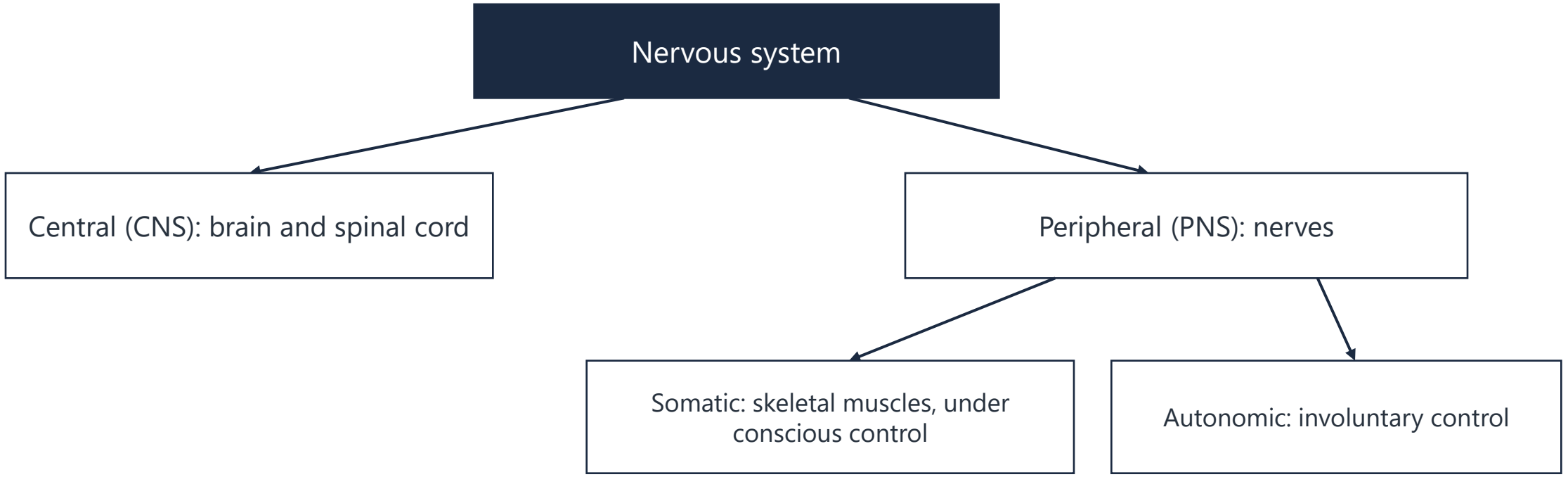
Material	From	To
Glucose	Small intestine, liver	All respiring cells
Oxygen	Lungs	All respiring cells
Carbon dioxide	Respiring cells	Lungs
Urea	Liver	Kidneys
Hormones	Endocrine glands	Target cells

Key idea

The blood system integrates organs by moving materials and energy-rich molecules between them.

Organisation of the nervous system

C3.1.4

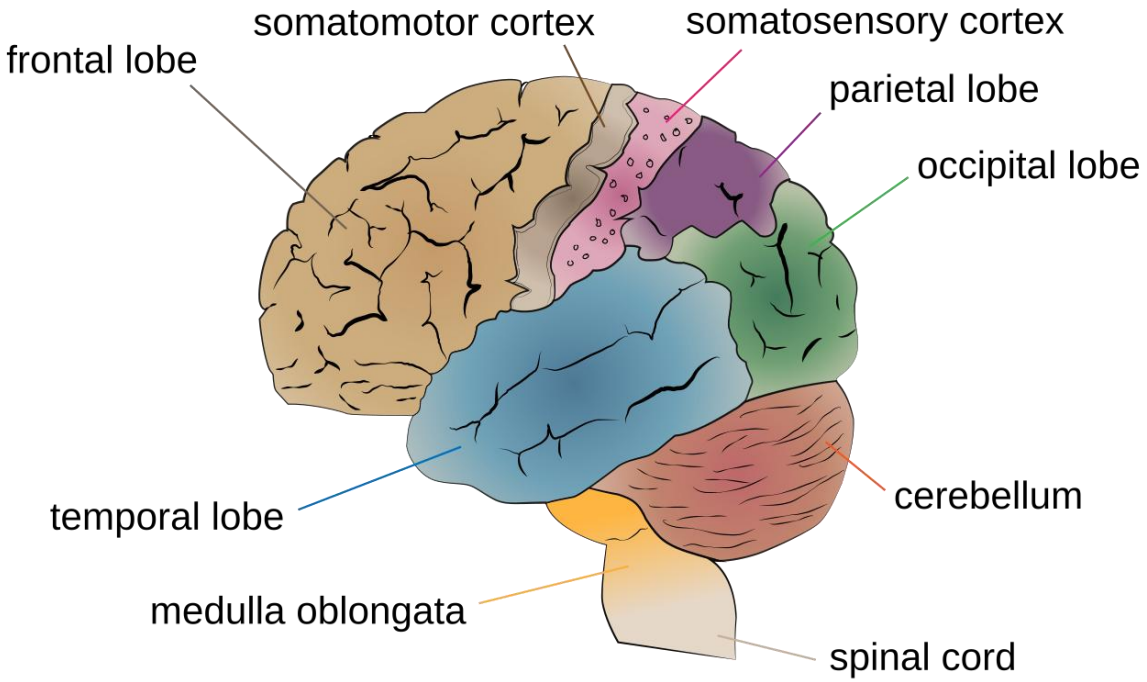


Autonomic branches

Sympathetic signals prepare the body for action. Parasympathetic signals relax it. The enteric nervous system, in the gut wall, is also part of this involuntary system. Do not confuse enteric with autonomic: enteric refers to the gut only.

The brain integrates information

C3.1.4



Cerebral hemisphere, showing its regions. Jkwchui, CC BY-SA 3.0.

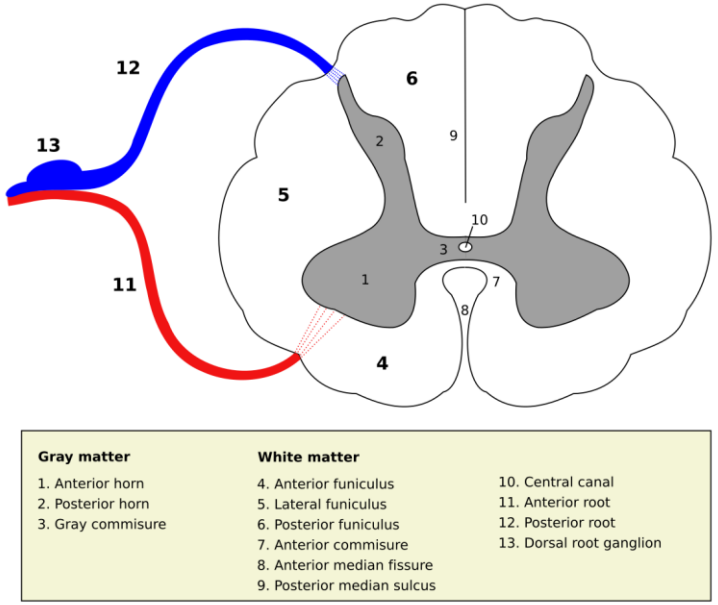
- Receives impulses from sensory receptors
- Combines and processes information from **several inputs** at once
- Sends impulses to muscles and glands
- Stores information: **learning and memory**
- Starts its own activity: thought, planning and personality

Exam note

Keep this general. You do not need detail such as how slow-acting neurotransmitters work.

The spinal cord and unconscious processes

C3.1.5



Spinal cord, cross-section. Polarlys, CC BY 2.5.

- Carries impulses between the brain and the body
- Also coordinates processes **without input from the brain**, especially reflexes
- **Grey matter**: cell bodies and synapses, where processing happens
- **White matter**: myelinated fibres, which carry signals

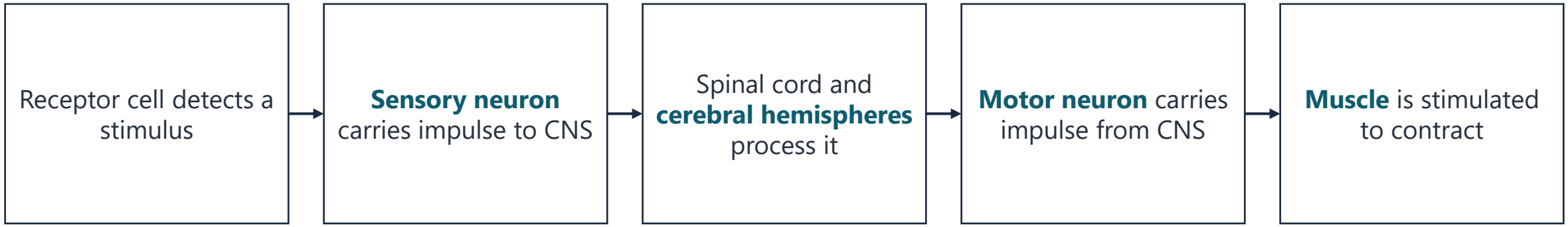
Conscious	Unconscious
Voluntary movement	Heart rate
Thought, speech	Pupil size, moving food

Common mistake

A conscious process is deliberate and something you are aware of. An unconscious one is automatic. Do not treat all brain activity as conscious.

Input and output through neurons

C3.1.6



C3.1.6 covers the input; C3.1.7 covers the output.

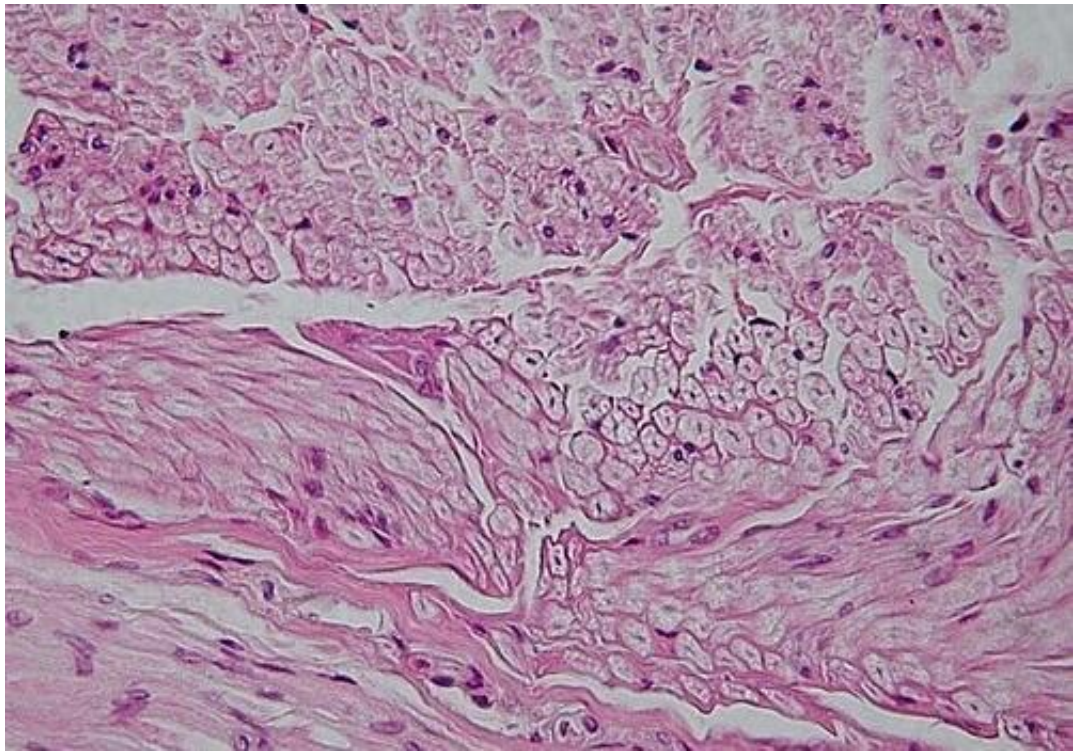
- The left hemisphere controls the right side of the body, and the right hemisphere controls the left
- Writing with a pen uses this whole route, with touch sensed as well as movement controlled
- Many activities combine conscious control with automatic adjustment

Activity

Test your reaction time with the falling ruler practical. Trace the route of the signal from the eye to the fingers, naming each type of neuron.

Nerves are bundles of nerve fibres

C3.1.8



A peripheral nerve, stained cross-section. CC BY-SA 3.0.

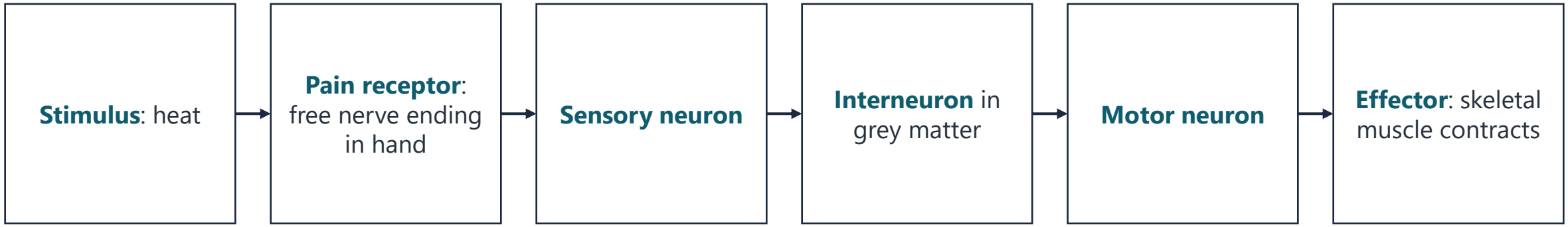
- A nerve holds fibres from **sensory neurons and motor neurons**
- A protective sheath of connective tissue surrounds the nerve
- Fibres are grouped into bundles
- Most nerves contain both **myelinated** and **unmyelinated** fibres

Common mistake

A neuron is a single cell. A nerve is a group of many nerve fibres from many neurons. Do not use the words as if they are the same.

The pain reflex arc

C3.1.9

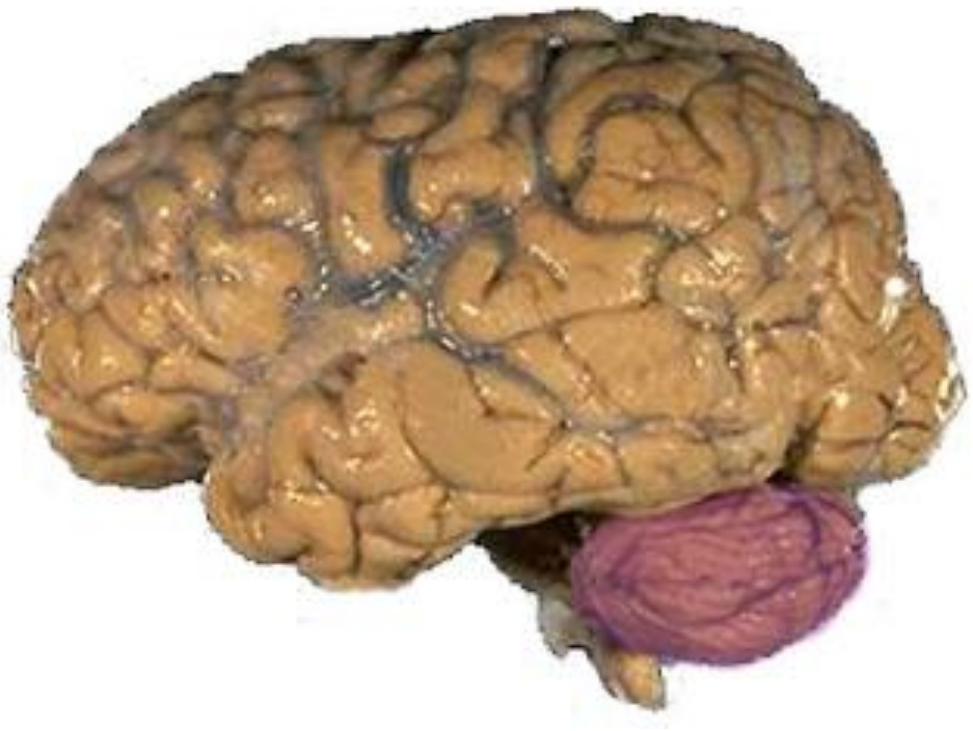


- A **reflex** is a rapid, involuntary response to a particular stimulus
- The hand moves away before you feel pain, because the signal need not reach the brain first
- Other fibres also take the message to the brain, so you do become aware of it

Exam note

This is the example to learn: one interneuron in the grey matter, a free sensory nerve ending as the pain receptor in the hand, and skeletal muscle as the effector.

The cerebellum



The cerebellum, at the back of the brain. NIH, public domain.

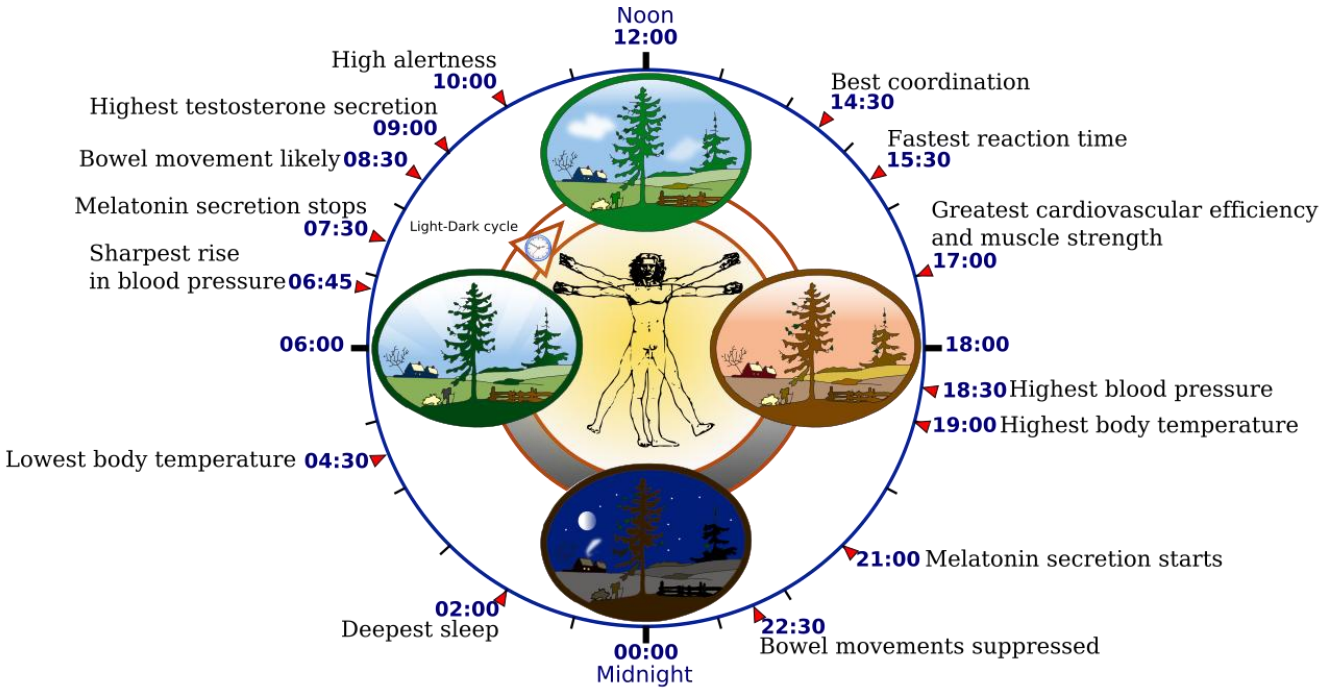
- Part of the hindbrain, at the back of the skull
- **Coordinates** skeletal muscle contraction, making movements smooth and precise
- Controls **balance** and posture
- Receives input from receptors, and adjusts commands to motor neurons
- It coordinates movement, but does not start it

Question

Alcohol affects the cerebellum. Which of the tests used for suspected drunk drivers would you expect to be affected, and why?

Melatonin and circadian rhythms

C3.1.11



- **Circadian rhythms** follow a roughly 24-hour cycle
- **Melatonin** is secreted by the **pineal gland**
- Secretion increases in darkness and decreases in light
- High melatonin promotes sleep
- Falling melatonin prepares the body for waking

The human circadian rhythm over 24 hours. YassineMrabet, CC BY-SA 3.0.

Discussion

Why might jet lag last several days? What could bright screens late at night do to your melatonin levels?

Epinephrine prepares for vigorous activity

C3.1.12

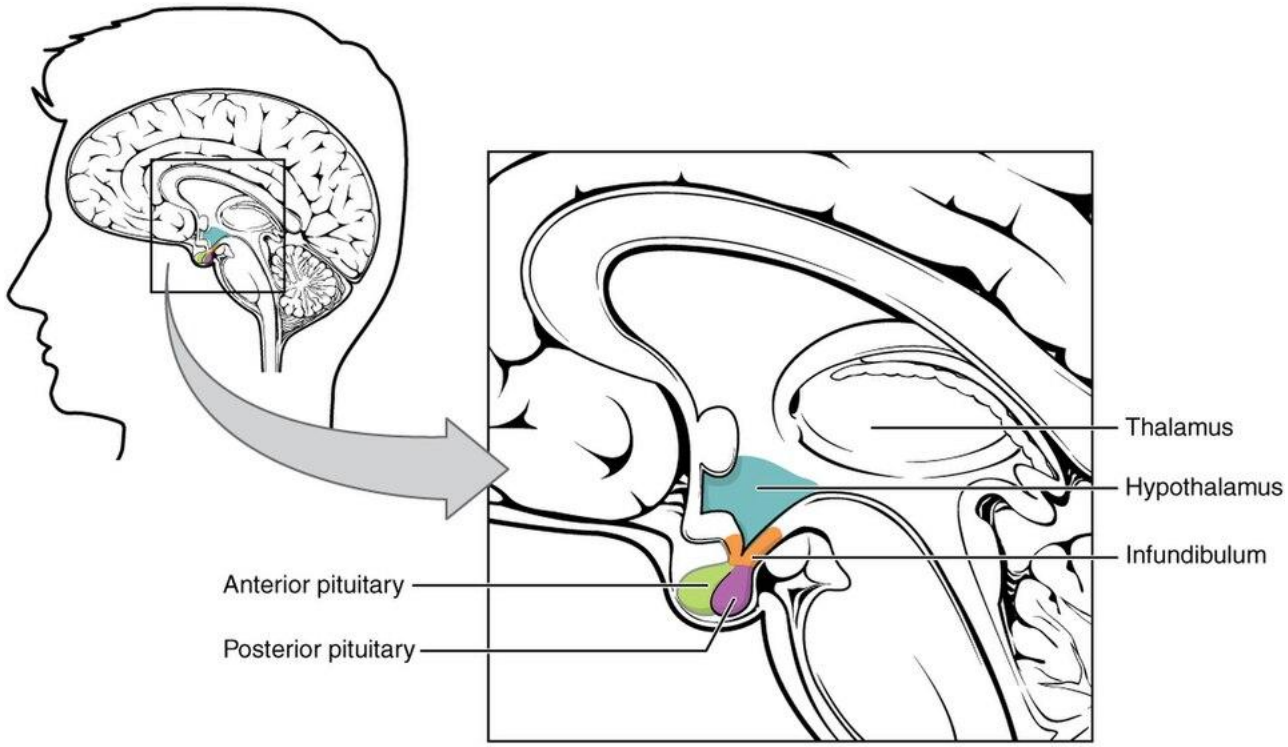
Effect of epinephrine	How this helps muscles to contract intensely
Heart rate rises	More blood, carrying oxygen and glucose, reaches muscles
Breathing rate rises	More oxygen in, and more carbon dioxide out
Glycogen broken down in liver	Blood glucose rises, supplying respiration
Blood diverted to muscles	Delivery goes where it is most needed

Key idea

Epinephrine (adrenaline) is secreted by the adrenal glands when the body is under stress. It travels in the blood and has widespread effects: the fight-or-flight response.

The hypothalamus and pituitary gland

C3.1.13



The hypothalamus and pituitary gland. OpenStax College, CC BY 3.0.

- The **hypothalamus** links the nervous and endocrine systems
- It monitors the blood as it passes through
- It controls secretion by the **pituitary gland**, using hormones and nerve impulses
- Pituitary hormones control growth, development, reproduction and homeostasis

Exam note

A general understanding is enough. You need not know how the anterior and posterior parts of the pituitary differ.

Sensing blood pressure and blood chemistry

C3.1.14

Receptor	Monitors	Location
Baroreceptors	Blood pressure, by detecting stretch	Aorta, carotid arteries, right atrium wall
Chemoreceptors	Blood pH, and levels of oxygen and carbon dioxide	Carotid arteries, aorta, brainstem

- The **medulla** receives these inputs, and coordinates the response
- It sends impulses along nerves to the **sinoatrial node**, the heart's pacemaker
- A **sympathetic** nerve speeds up the heart, and a branch of the **vagus** nerve slows it down
- Stroke volume can also change

Feedback control of heart rate

C3.1.14

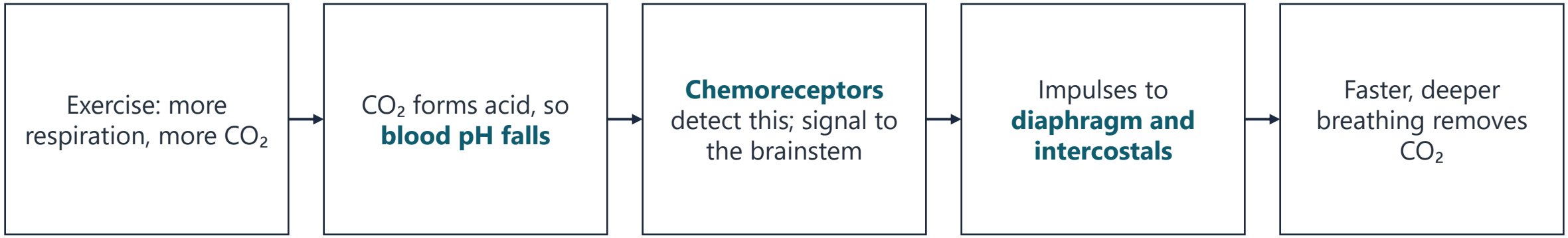
Detected change	Nerve activated	Result
Low blood pressure	Sympathetic	Heart rate rises
High carbon dioxide, low pH, low oxygen	Sympathetic	Heart rate rises
High blood pressure	Vagus (parasympathetic)	Heart rate falls
Low carbon dioxide, higher pH	Vagus (parasympathetic)	Heart rate falls

Key idea

This is negative feedback: the response reverses the change that was detected. During exercise, faster blood flow carries carbon dioxide to the lungs sooner, returning blood pH to safe limits.

Feedback control of ventilation rate

C3.1.15



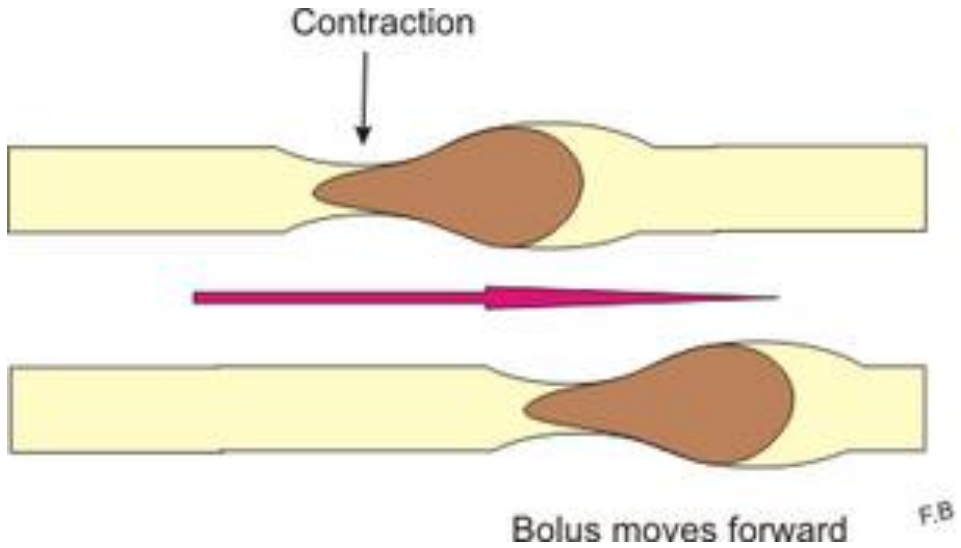
- The respiratory centre in the medulla controls breathing automatically
- After exercise, carbon dioxide falls and the ventilation rate falls too
- You can override this consciously for a time, as when you speak or sing

Common mistake

The main stimulus to breathe faster is a rise in carbon dioxide, detected as a fall in pH. It is not usually a lack of oxygen.

Control of peristalsis

C3.1.16



Peristalsis: muscle contractions push food along. Boumphreyfr, CC BY-SA 3.0.

- **Peristalsis**: waves of muscle contraction that pass along the gut wall
- Circular and longitudinal muscles act in turn
- The **enteric nervous system**, in the gut wall, coordinates it
- It is an involuntary process

Stage	Control	System
Swallowing; egestion of faeces	Voluntary	Central nervous system
Oesophagus to rectum	Involuntary	Enteric nervous system

The two systems together show how conscious and unconscious control are integrated in one organ system.

Check that you can explain

1. Emergent properties in a cheetah
2. Nervous compared with hormonal signalling
3. What the brain and spinal cord each do
4. Sensory and motor pathways, and nerves
5. The pain reflex arc
6. What the cerebellum does
7. Melatonin and epinephrine
8. Hypothalamus and pituitary control
9. Feedback control of heart and ventilation rate
10. Control of peristalsis

Exit activity: 5 minutes

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

1. Give two differences between nervous and hormonal signalling.
2. List, in order, the parts of a pain reflex arc from receptor to effector.
3. Explain why ventilation rate rises during exercise, starting with respiration in muscle.

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