Integration of body systems

C3.1 · SL and HL

Running requires coordinated systems rather than one strong organ

Connect information, materials and a combined function

Common C3.1: organization, nervous/endocrine coordination, brain/spinal cord, nerves/reflexes, balance, rhythms, endocrine control, cardiovascular/ventilation feedback and peristalsis.

Use cell specialization, neural signalling, circulation and gas exchange as prerequisites.

All numerical datasets are invented. Use supplied traces and approved seedling observations.

Build a hierarchy without turning an organ into one tissue

1. **Organization.** Cells contribute to tissues; several tissue types contribute to an organ; organs interact within and between systems.
2. **Stomach.** Epithelial, muscle, connective and nervous tissues have different cooperating roles.
3. **Emergence.** Effective whole-animal movement depends on interacting systems; no isolated muscle cell has the animal's hunting behaviour.

Explain what passes between systems during vigorous activity

Connection	Contribution
Lungs → blood → muscle	Oxygen delivery supports aerobic ATP production; carbon dioxide is removed
Gut/stores → blood → cells	Respiratory substrates become available
Nervous system → muscle	Timing and recruitment coordinate movement
Circulation → skin/tissues	Material and heat transfer support internal conditions

Compare routes while keeping receptor specificity

Route	Transmission and limits
Nervous	Impulses along connected neurons, transmitter at synapses; often rapid/local
Endocrine	Hormones enter blood; compatible receptors determine target responses
Time course	Some hormones act rapidly; neural learning effects can persist
Materials	Information does not replace oxygen, substrates or heat transport

Negative feedback opposes a disturbance without demanding perfect constancy

A delayed response can still regulate a suitable range

Homeostasis maintains suitable internal conditions. Receptors detect, integration centres coordinate and effectors respond.

Insulin-linked uptake/storage and reduced liver glucose output oppose high glucose; glucagon-linked liver responses oppose low glucose.

Negative describes the regulatory direction. Diabetes has different mechanisms; not every case is absence of insulin.

A rise and its reversal use different original values

1. **Invented concentrations.** Five $\to$ eight arbitrary units: increase three/original five $\times$ 100 $=$ 60%.
2. **Reverse.** Eight $\to$ five: decrease three/original eight $\times$ 100 $=$ 37.5%.
3. **Doubling.** Two $\to$ four is a 100% increase. These relative changes do not constitute a diagnosis.

Nervous or hormonal control

	nervous control	**hormonal control**
how it travels	electrical impulses along **neurones**	**chemicals** in the blood
speed	very fast	slower
duration	short-lived	longer-lasting

fast but brief, versus slow but lasting

Nervous signals are targeted; hormones are widespread

The brain combines inputs with earlier information

Learning and memory influence later processing

The brain integrates several inputs and prior experience rather than merely forwarding one incoming impulse.

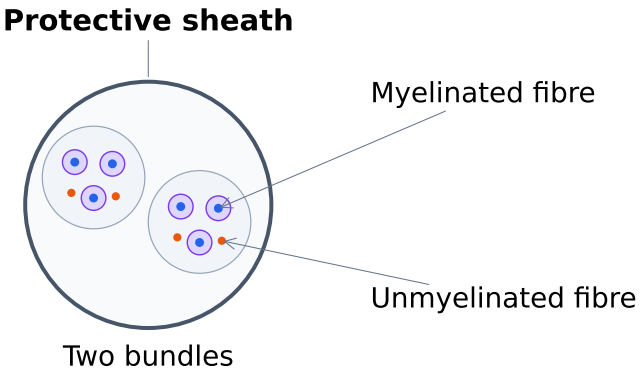
Sensory neurons carry input toward the CNS; pathways reach spinal circuits and cerebral hemispheres.

Motor-neuron output, through intervening circuits, stimulates muscle contraction. The brain does not directly pull tendons.

Separate unconscious integration from conscious awareness

Component	Contribution and limit
Spinal cord	Local circuits can coordinate unconscious protective responses
Cerebral hemispheres	Integrated processing supports conscious information and voluntary output
Cerebellum	Helps coordinate timing/force, posture and balance
Combined system	A reflex can start before conscious pain processing; brain activity can still modulate it

Read a transverse section without inventing fibre direction



A mixed nerve contains separate sensory and motor fibres.

A common sheath does not merge axon membranes

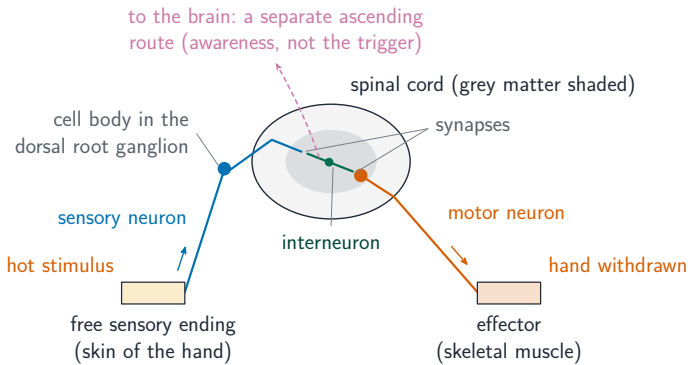
Supporting tissues organize parallel pathways

A nerve bundles axons with connective tissues and protective sheaths; some fibres have myelin and others do not.

Unmyelinated fibres can still have supporting cells. They are not necessarily bare axons floating alone.

A circular profile's shape alone does not identify sensory versus motor function. A mixed nerve does not make each axon exchange those roles.

Trace one interneuron between sensory and motor pathways



Spinal integration can initiate withdrawal before conscious processing.

Follow the route and locate each cell body

1. **Input.** A free hand ending initiates sensory impulses; the sensory cell body lies in a dorsal-root ganglion.
2. **Integration.** The central process enters spinal grey matter and communicates with one interneuron in this model, then a motor neuron.
3. **Output.** Motor axon leaves via a ventral root and stimulates skeletal muscle to flex the limb away.

Involuntary responses can use skeletal muscle

A simple arc is not the complete withdrawal network

The illustrated model has two neuronal synapses within the spinal cord and an effector muscle outside it.

Ascending information reaches brain pathways without requiring conscious permission for initial withdrawal.

Other reflexes have different circuits; normal withdrawal coordinates several muscle groups, including appropriate inhibition.

The pineal signal helps mark biological night

Circadian rhythms are generated internally and synchronized by cues

Melatonin secretion is normally higher at biological night and lower during daytime; light at night can suppress it.

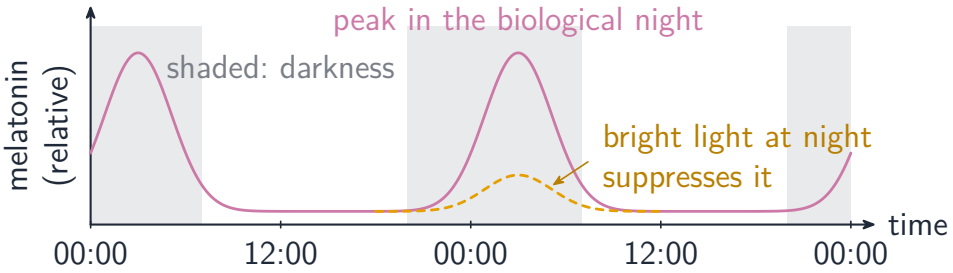
Information about light reaching the eyes helps synchronize brain timing pathways.

Sleep depends on other processes and prior wakefulness too; melatonin is not an instantaneous unconsciousness switch.

Read timing separately from the high–low difference

1. **Phase.** A peak moving later indicates a change in timing.
2. **Amplitude.** A different high–low difference indicates a change in size of the oscillation.
3. **Evidence.** Record repeated days and compare darkness/sleep timing. One fluctuation alone does not establish a stable daily pattern.

Melatonin and the daily rhythm



The pineal gland links light to the body clock

Connect epinephrine effects with vigorous activity

Effect	Functional connection
Heart rate/contractility rise	Supports greater cardiac output
Airways widen	Supports increased ventilation
Fuel mobilization	Makes substrates available for ATP-producing metabolism
Vascular responses	Redistribute flow according to receptor and tissue context

One circulating signal can produce different tissue responses

Receptors and pathways determine the response

The adrenal medulla secretes epinephrine/adrenaline. Some vessels constrict while others can dilate.

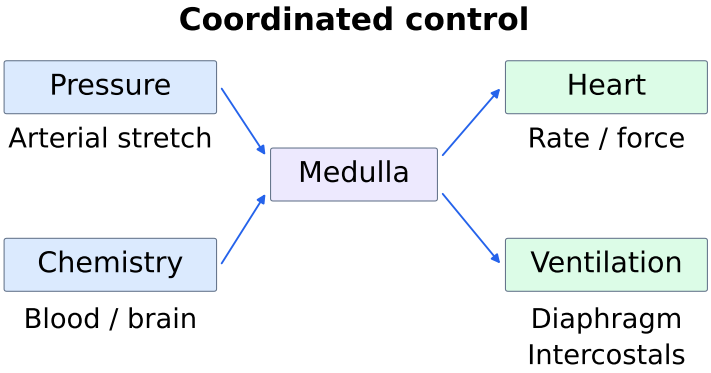
Epinephrine carries information; it is not itself the metabolic fuel supplying every muscle contraction.

Material supply, respiratory metabolism, circulation and neural coordination still need to interact.

Outline a coordinated endocrine control pathway

1. **Integration.** The hypothalamus combines neural/internal information and helps control pituitary output.
2. **Targets.** Pituitary hormones can regulate other endocrine glands; different hormones have different targets.
3. **Feedback.** A peripheral gland's hormone can reduce earlier stimulation. Do not claim every gland uses one identical pathway.

Identify distinct inputs and appropriate effector pathways



Medullary coordination adjusts heart and breathing outputs.

Pressure and chemistry need different named sensors

The carotid sinus is not the carotid body

Baroreceptors detect arterial stretch, notably at carotid sinuses and the aortic arch.

Peripheral chemoreceptors in carotid/aortic bodies inform control about arterial oxygen, carbon dioxide and acidity.

The medulla integrates sensory input and adjusts autonomic cardiac output pathways. The heart's own pacemaker generates the basic rhythm.

Explain a compensating response after a pressure fall

1. **Input.** Reduced arterial stretch usually reduces baroreceptor firing.
2. **Output.** Increased sympathetic and reduced parasympathetic influence can raise heart rate and contractility, supporting output/pressure.
3. **Limit.** Stroke volume depends on filling and other conditions; heart rate alone does not determine every output change.

Calculate two percentage changes without declaring one exclusive cause

1. **Invented pressure.** $110 \to 90$ arbitrary units: $20/110 \times 100 \approx 18.2\%$ decrease.
2. **Heart rate.** $70 \to 84$ beats/minute: $14/70 \times 100 = 20\%$ increase.
3. **Interpretation.** A subsequent recovery is consistent with compensation. Timing/association alone do not isolate every receptor, vascular or filling contribution.

Connect blood carbon dioxide to a brain-fluid signal

1. **Chemistry.** More carbon dioxide can increase hydrogen-ion concentration and lower pH through the carbon dioxide/water/carbonic-acid system.
2. **Central sensing.** Carbon dioxide enters brain fluids and changes local pH; central chemoreceptive pathways respond importantly to that acidity.
3. **Peripheral input.** Carotid/aortic bodies add arterial chemical information, including oxygen. Central pathways are not simply arterial oxygen meters.

Motor output changes muscle activity and gas removal

A returning influence opposes the initiating carbon-dioxide rise

Respiratory centres adjust output to the diaphragm and intercostal muscles, changing breathing frequency and/or depth.

More effective ventilation can remove more carbon dioxide and oppose the rise that stimulated the response.

Exchange surfaces, gradients and circulation remain necessary; breathing frequency alone is not the whole gas-exchange rate.

Minute ventilation includes air that does not reach gas exchange

1. **Invented baseline.** 12 breaths/minute $\times$ 0.50 litres $=$ 6.0 litres/minute.
2. **Changed state.** $20 \times 0.75 = 15$ litres/minute; increase nine/six $\times$ 100 $=$ 150%.
3. **Limit.** Conducting airways contain part of the moved air. This is not automatically alveolar ventilation or an exact blood-gas prediction.

Propulsion needs a coordinated pattern around gut contents

1. **Local integration.** Enteric networks receive information about contents/stretch and coordinate smooth muscle.
2. **Pattern.** Contraction behind and relaxation ahead help propel a bolus; random independent contractions would not coordinate passage.
3. **Central influence.** Autonomic CNS pathways modulate enteric control without conscious direction of each wave.

Voluntary control applies to particular parts of a process

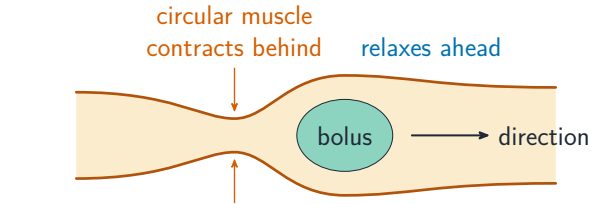
Beginning or controlling an endpoint differs from directing every phase

Swallow initiation can be voluntary, followed by coordinated involuntary phases.

Defecation combines reflex processes with voluntary control of appropriate external sphincter muscles.

Between endpoints, peristalsis normally proceeds involuntarily; the skeletal effector of withdrawal differs from gut smooth muscle.

Peristalsis



The wave pushes food along

Record growth direction and define the angle reference

Qualitative drawings and quantitative measurements answer different questions

Positive shoot phototropism is directional growth toward lateral light, not a whole plant being pushed sideways.

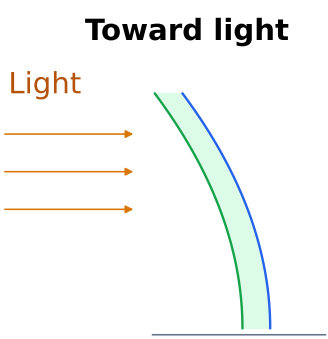
Label stimulus direction and shape in drawings; measure curvature from a stated reference at consistent times/positions.

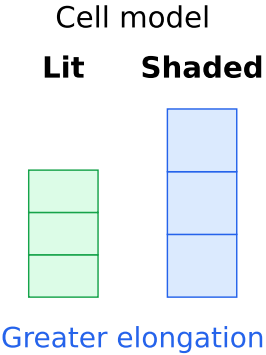
Use fixed camera geometry and comparable independent seedlings. A curved shoot has no single angle at every point.

Separate precision, systematic error and biological replication

1. **Invented angles.** 10°, 12° and 11° give mean 11° and range 2°.
2. **Controls.** Compare lateral/uniform light; standardize species, age, watering, temperature, intensity, orientation and timing.
3. **Measurement.** Finer scale improves granularity, not a biased reference/camera. Repeated readings of one seedling are not independent seedlings; a lamp can also heat or dry one side.

Put the longer shaded side outside the curve





Greater shaded-side elongation bends a shoot toward light.

Plant signals do not require animal-style endocrine glands

Response depends on tissue, concentration and development

Auxins, cytokinins and ethylene are examples of phytohormones controlling growth and responses.

In a simplified lateral-light shoot model, greater shaded-side auxin action promotes more elongation there.

The shoot bends toward light; it is not the lit side becoming longer and pushing the shoot away.

Carrier polarity gives direction to cell-to-cell auxin transport

1. **Placement.** Asymmetric efflux-carrier placement in neighbouring membranes supports preferred transport direction and unequal distribution.
2. **Acid properties.** Protonated IAA can enter from acidic apoplast. Much deprotonates in cytosol and crosses lipid poorly without appropriate transport.
3. **Energy.** Carrier-controlled exit and electrochemical gradients matter. Do not give every efflux carrier a direct ATP cost per auxin; proton pumps help establish supporting conditions.

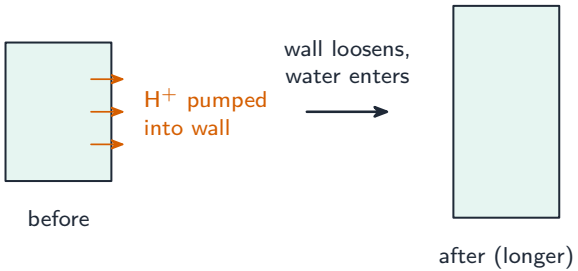
Change wall interactions without dissolving cellulose into glucose

1. **Signal.** Auxin can promote hydrogen-ion pumping into the apoplast.
2. **Wall.** Lower pH favours wall-loosening processes, including expansin-mediated rearrangement of interactions.
3. **Growth.** Water uptake/turgor supports extension; walls remain a network, and sustained growth also needs wall synthesis/organization.

Connect root and shoot signals without inventing exclusive factories

Signal/source	Integration and limit
Auxin: shoot tips/young tissues	Can travel toward roots and influence development
Cytokinins: roots including tips	Can move toward shoots and influence growth
Additional sources	Local production, transport and sensitivity also contribute
Interaction	Tissue and hormone balance matter; one hormone alone does not predict unlimited organ growth

How auxin makes cells longer



Water enters and the cell stretches

Identify the returning influence that makes ripening positive feedback

1. **Compatible fruit.** In climacteric tomato, ethylene signalling supports ripening changes and additional ethylene production.
2. **Spread.** Gas can reach nearby competent fruits, supporting rapid/synchronized change. Developmental state matters.
3. **Limits.** Not all fruits use the same ethylene pattern. Substrates, signal removal, development and senescence constrain the process; positive means reinforcing, not necessarily desirable.

Attempt the common questions before checking

Use named pathways and valid denominators

Connect hierarchy, nervous/endocrine routes, brain/spinal/cerebellar functions, nerves/reflexes and circadian timing.

Trace epinephrine and hypothalamus–pituitary effects, pressure/chemical sensing, ventilation control and enteric coordination.

Calculate pressure, pulse, ventilation and glucose changes while distinguishing association, compensation and diagnosis.

Check the common quantitative examples

1. **Pressure / pulse.** 120 → 96 is a 20% pressure decrease; 60 → 78 is a 30% heart-rate increase.
2. **Ventilation.** $10 \times 0.60 = 6.0$; $18 \times 0.80 = 14.4$ litres/minute: 140% increase, not automatically alveolar ventilation.
3. **Glucose.** Four → five: 25%; five → eight: 60%; eight → five: 37.5% decrease; doubling: 100% increase.

AHL practice: growth measurements and returning signals

1. **Angles.** 8°, 10°, 9°: mean 9°, range 2°. Control geometry and biological conditions; repeat independently.
2. **Direction.** Greater shaded-side elongation puts that side outside the curve and bends the shoot toward light.
3. **Feedback.** Ethylene can promote more ethylene during suitable fruit ripening; pressure feedback instead opposes a disturbance.

Check yourself

Name the connection that supports the integrated function

A nerve is a bundle, a ganglion is not the skin ending, and a spinal reflex need not wait for conscious awareness.

A carotid-sinus baroreceptor detects stretch; carotid-body chemoreceptors detect chemistry. Central carbon-dioxide sensing involves brain-fluid pH.

Hormones need compatible targets; information transfer does not replace transport of oxygen, substrates or heat.