Communication

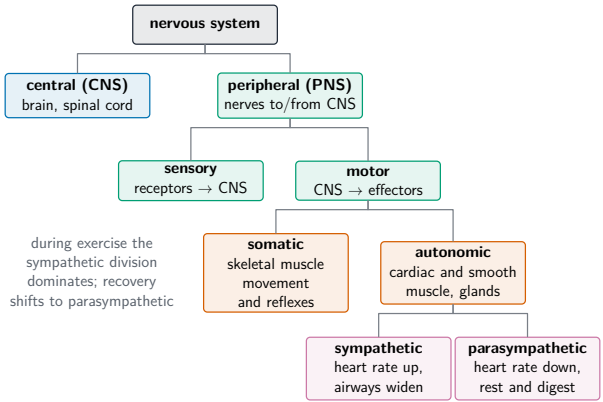
A.1 · SL and HL

Measure a response; distinguish a rule

Measured start response includes sensing, processing, signalling and force development.

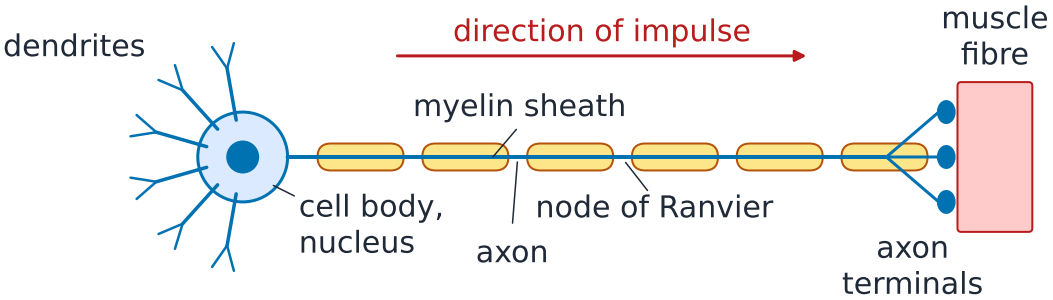
- Berlin 2009: Bolt 9.58 s; recorded reaction 0.146 s.
- A response below 0.100 s flags a possible false start for examination.
- A competition **threshold** is not proof of an absolute biological limit.

Divisions of the nervous system



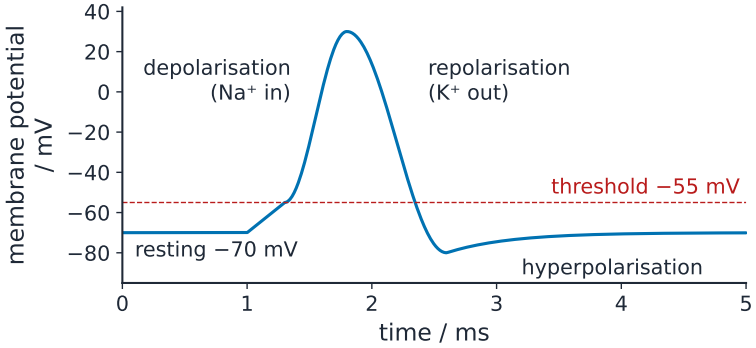
Somatic control includes automatic skeletal-muscle reflexes.

A motor neuron



Myelin supports conduction; action potentials are regenerated at nodes.

The action potential



All-or-none electrical activation is not maximum mechanical force.

The neuromuscular junction

Acetylcholine triggers an **action potential** in the muscle fibre.

- The impulse releases acetylcholine, which crosses the gap.
- Acetylcholinesterase breaks it down so the muscle can relax.

Controlling force

Recruitment

More motor units active.

Small units first, then large.

Frequency

Faster impulses.

Twitches merge into tetanus.

Proprioceptors and reflexes

A simplified spinal **reflex**: **receptor** $\rightarrow$ sensory pathway $\rightarrow$ spinal circuit $\rightarrow$ motor pathway $\rightarrow$ **effector**.

- Muscle spindles report length/stretch; tendon organs report force.
- Reflexes can involve spinal or brainstem circuits without conscious choice.

Where the reaction time goes

1. **Conduction.** $1.5 \div 100 = 0.015$ s
2. **Fraction.** $0.015 \div 0.150 = 10\ \%$
3. **The rest.** Synapses, deciding, building force

Decision

Conduction is one component; this calculation does not isolate a training effect.

Electrical activation and graded force

All-or-none

A motor **action potential** normally activates its innervated fibres.

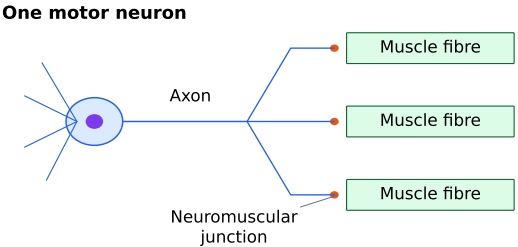
An action potential does not simply grow taller with demand.

Variable force

Recruitment and firing frequency grade whole-muscle force.

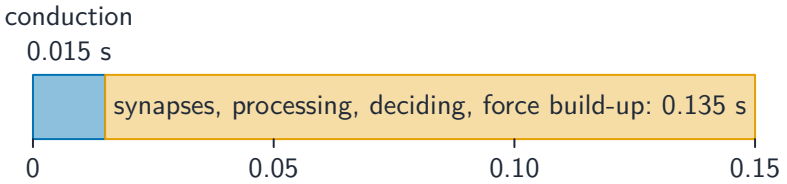
Length, fatigue and twitch summation also affect mechanical output.

A motor unit



More units recruited means more force

Where reaction time goes



reaction time 0.150 s; conduction $= 1.5\ \mathrm{m} \div 100\ \mathrm{m\,s^{-1}} = 0.015$ s, only 10%

Processing, deciding and force build-up take the other 90%

Hormones and exercise

Hormone	Effect during exercise
Adrenaline	Raises heart rate, releases glucose
Glucagon	Breaks down liver glycogen
Insulin	Falls during exercise
Cortisol	Promotes fuel mobilisation and liver glucose production
EPO	More red blood cells

Nerves and hormones

Nervous

Electrical, milliseconds.

Short, precise.

Endocrine

Hormones circulate in blood; targets need suitable receptors.

Timescale and duration vary; effects can be rapid or prolonged.

ADH: synthesis, release and target

Brain-to-blood signal

Synthesised in hypothalamic neurons.

Released from posterior-pituitary nerve terminals.

Kidney response

Increases water reabsorption in response to relevant signals.

Retention reduces further loss; it does not replace lost water.

Reproductive hormones: mechanisms and variation

Relevant effects

Progesterone: temperature, sleep and fuel effects.

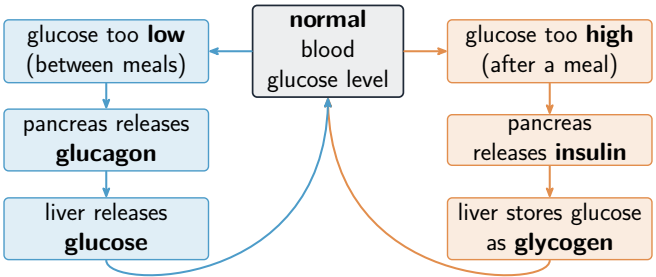
Oestrogen: substrate/connective-tissue effects; testosterone: protein, bone and erythropoietic pathways.

Interpretation

Concentrations and individual responses vary.

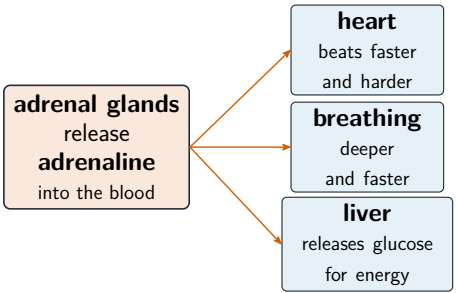
Cycle day or sex alone does not prescribe a performance ranking.

Keeping blood glucose steady



Both return glucose to normal: **negative feedback**

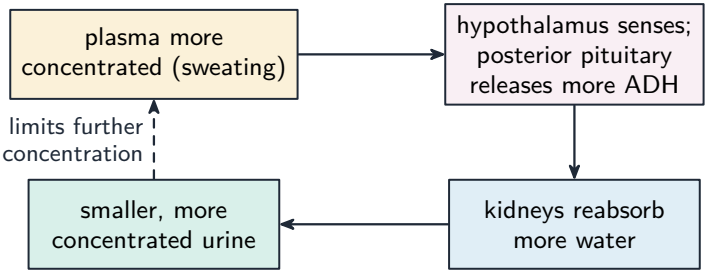
Adrenaline prepares for action



all of this
prepares the body for action
("fight or flight")

One **hormone** acts on many targets

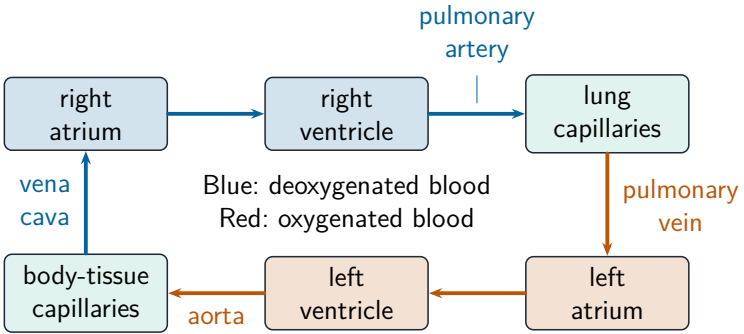
ADH and water balance



ADH conserves water; it does not replace water already lost

Smaller, more concentrated urine limits the loss

The double circulation



Arteries carry blood away from the heart; veins return it.

The heart's pacemaker

SA node → **atria** contract → AV node delay → bundle of His → Purkinje fibres → ventricles contract.

- Heart muscle is **myogenic**: it starts its own beat.
- Nerves and **adrenaline** change the rate.

Arteries, capillaries, veins

Vessel	Key feature
Artery	Thick elastic wall, high pressure
Capillary	One cell thick, exchange
Vein	Valves, low pressure

Adrenaline and cardiac output

1. **Rest.** $70 \times 70 = 4900$ mL/min ≈ 4.9 L/min
2. **Before the race.** $120 \times 80 = 9600$ mL/min $= 9.6$ L/min
3. **Change.** About double, before moving

Decision

Cardiac output = heart rate $\times$ **stroke volume**

Measure a response safely

1. **Before** Voluntary informed participation; teacher-approved low-intensity workload.
2. **Measure** Resting baseline, standardized workload, recovery at fixed times.
3. **Interpret** Match conditions; a lower heart rate alone does not prove fitness.

Decision

Stop for discomfort; no maximal exertion or health diagnosis.

The vascular shunt

A flow share needs its total: 80% of 20 L/min is 16 L/min.

- Arterioles to muscles widen; those to the gut narrow.
- Muscles get about 15 to 20 % of **cardiac output** at rest.

Intrinsic rhythm and baroreceptor feedback

Initiate and modify

The SA node generates the normal rhythm.

Autonomic and hormonal inputs modify it.

A simplified resting pressure fall

Less arterial stretch can reduce baroreceptor firing.

Brainstem responses support output and resistance; exercise regulation differs.

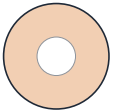
Calculate a swimmer's output

1. **Rest** $65 \times 75 = 4875$ mL/min$=4.875$ L/min.
2. **Exercise** $150 \times 110 = 16\,500$ mL/min$=16.5$ L/min.
3. **Comparison** Use matched workload and participant conditions before interpreting differences.

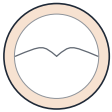
Decision

Heart rate and **stroke volume** jointly determine output; one reading does not measure all fitness.

Three kinds of blood vessel



artery
thick muscular, elastic wall; narrow lumen; high pressure



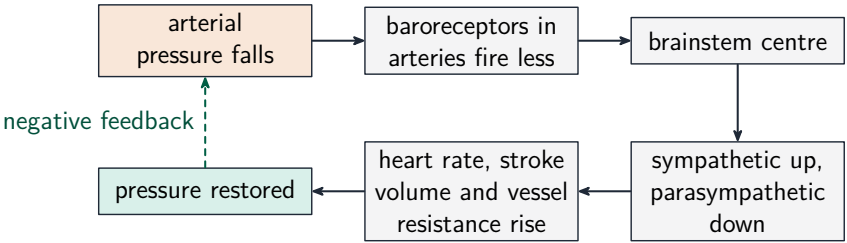
vein
thin wall; wide lumen; has **valves**; low pressure



capillary
wall one cell thick; lets substances be exchanged

Capillary: a wall one cell thick

The baroreflex



the SA node sets the rhythm; these signals only modify it

Heart rate, **stroke volume** and resistance rise, restoring pressure

Breathing in and out

Inspiration

Diaphragm contracts and flattens.

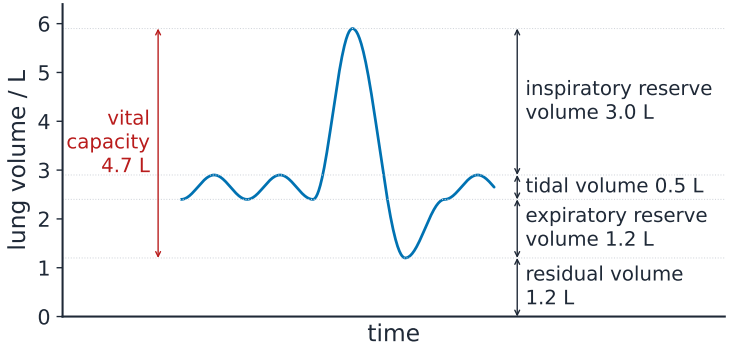
Ribs up and out; pressure falls.

Active expiration

Internal intercostals, abdominals.

Ribs down; air out faster.

Lung volumes



Simple spirometry does not directly measure **residual volume**.

Minute ventilation

1. **Rest.** $0.5 \times 12 = 6$ L/min
2. **Hard run.** $3.0 \times 40 = 120$ L/min
3. **Change.** Twenty times higher

Decision

Minute ventilation = **tidal volume** $\times$ breathing frequency

Gas exchange

> Oxygen and carbon dioxide move by **diffusion** down partial pressure gradients.

- Diffusion depends on the gas's partial-pressure gradient.
- Ventilation can rise while arterial CO_2 remains near its regulated value.

Ventilation need not wait for CO_2 accumulation

Multiple inputs

Chemoreceptors provide CO_2/acidity-related feedback.

Neural feedforward and movement feedback also contribute.

Successful regulation

At steady moderate exercise, ventilation can match production.

Near-stable arterial CO_2 does not mean ventilation failed to respond.

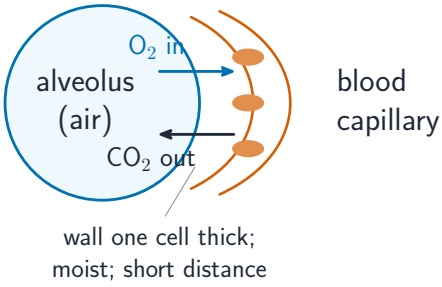
Air movement is not oxygen uptake

1. **Rowing example** 2.5 L/breath $\times$ 36 breaths/min $=$ 90 L/min.
2. **Compare** 90/6=15 times the stated resting ventilation.
3. **Distinguish** Some moved air does not reach gas-exchanging **alveoli**.

Decision

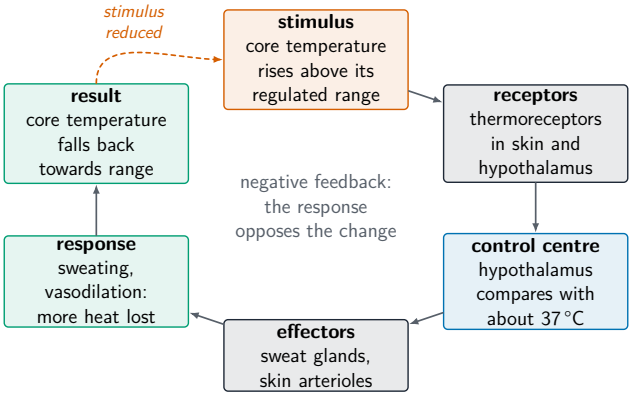
Ventilation, gas exchange, cellular respiration and blood flow are distinct quantities.

Gas exchange in an alveolus



A wall one cell thick keeps the path short

Negative feedback



Negative feedback opposes a deviation; the regulated value is a range.

Exercise in the heat

> More sweat secretion does not guarantee more evaporative cooling.

- Sweat must evaporate to provide its latent heat loss.
- Humidity, airflow, clothing and environmental gradients matter.

Blood glucose in long events

Your turn

Which change helps keep blood glucose stable during a long run?

A. More insulin is released
B. More glucagon is released
C. Liver glycogen is stored
D. Sweating increases

Glucose: liver output and muscle uptake

Maintain supply

Glucagon supports hepatic glycogen breakdown and glucose production.

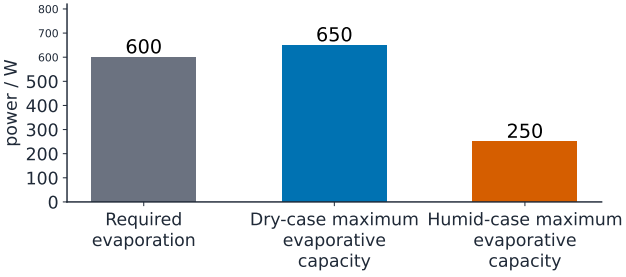
Muscle glycogen is mainly a local fuel store.

Use and limits

Contraction can promote uptake while **insulin** falls.

During prolonged activity demand may exceed supply; fatigue has several causes.

AHL: Evaporative capacity is a limit



Invented model: dry reserve 50 W; humid minimum storage 350 W.
Capacity is a limit, not automatically the actual heat loss.

A capacity limit is not automatically the realised heat loss.

AHL: Calculate a conditional heat budget

1. **Dry reserve** $650-600=50$ W beyond the required evaporation.
2. **Humid storage** $600-250=350$ W minimum under the fixed-other-terms model.
3. **Energy in 120 s** $350\times120=42\,000$ J$=42$ kJ.

Decision

Stored energy alone does not supply a clinical body-temperature prediction.

AHL: Oxygen fraction and pressure differ

1. **Stated dry air** 21% oxygen at total pressure 100 kPa gives 21 kPa oxygen.
2. **Lower pressure** $0.21 \times 75 = 15.75$ kPa at 75 kPa total pressure.
3. **Change** $(21 - 15.75)/21 \times 100 = 25\%$ decrease in partial pressure.

Decision

Oxygen remains 21% in this model; ambient dry values are not alveolar values.

AHL: Acute response versus acclimatisation

Immediate response

Heat: skin flow and sweating can change.

Hypoxia: ventilation and circulation can adjust.

Across repeated exposure

Heat **acclimatisation** can alter plasma volume and sweating responses.

Altitude adaptations take time, vary and do not eliminate risk.

AHL: The event and design determine the claim

Activity demands

Sustained aerobic work and a brief sprint have different demands.

Lower air density can change drag as well as oxygen availability.

Evaluate a strategy

Match workload, timing and environmental conditions.

Account for training and learning; acknowledge incomplete blinding.

Altitude and heat

altitude
lower O_2 pressure: can limit sustained aerobic work
lower air density: less drag, may help a brief sprint

heat
strain depends on metabolic heat, environment and duration, not air temperature alone

judge an adaptation at the same workload and conditions; one repeated test is not a controlled experiment

> Heat strain depends on heat made, the environment and duration

Exam tips

Use the correct names for each division of the **nervous system**.

- Give **action potential** values in order.
- Force control, **recruitment** and frequency.
- Name receptor, control centre, effector and response.

Check yourself

Try these

Heart rate rises from 65 to 150 per minute and stroke volume from 75 to 110 mL. Find both cardiac outputs.

Describe how a signal crosses the neuromuscular junction.

Explain how negative feedback controls temperature during a run.