Muscle Contraction, Adaptation & Ecological Niches

IB HL Study Guide

Contents

Complete Study Guide

Topics Covered

Aligned to IB Biology HL 2025 syllabus — B3.1, B4.1, B4.2

Section 1: Muscle Contraction (B3.1) HL

Muscle contraction is one of the most commonly examined HL topics. You must be able to describe the structure of skeletal muscle from the whole-muscle level down to the molecular arrangement of filaments within a sarcomere, and explain every step of the sliding filament mechanism.

1.1 Structure of Skeletal Muscle

Skeletal muscle is composed of bundles of elongated cells called **muscle fibres** (also known as muscle cells). Each muscle fibre is multinucleated — it forms from the fusion of many embryonic cells and therefore contains multiple nuclei and a shared cytoplasm called **sarcoplasm**.

MEMORISE THIS

Key structural terms to memorise:

Term	Definition
Muscle fibre	A single multinucleated muscle cell, up to several centimetres long
Myofibril	A cylindrical organelle running the length of the fibre, made up of repeating sarcomere units
Sarcomere	The functional unit of contraction, from one Z-line to the next
Sarcoplasm	The cytoplasm of a muscle fibre; rich in glycogen and myoglobin
Sarcoplasmic reticulum (SR)	Specialised smooth ER that stores and releases Ca^{2+} ions
T-tubules	Infoldings of the sarcolemma (plasma membrane) that carry the action potential deep into the fibre
Sarcolemma	The plasma membrane of a muscle fibre

1.2 The Sarcomere — Structure and Bands

Each myofibril is divided into repeating units called **sarcomeres**, which are the basic contractile units. The banding pattern of sarcomeres produces the characteristic striations visible under a light microscope.

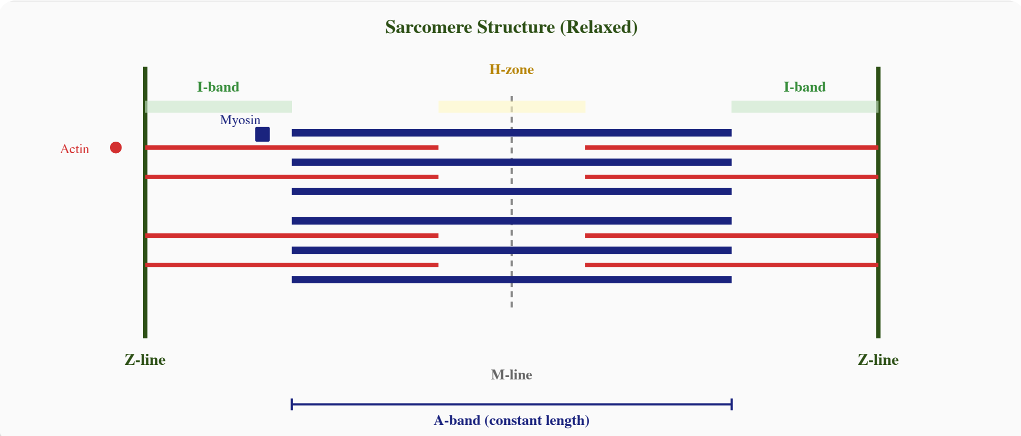
MEMORISE THIS

Sarcomere bands and zones:

Structure	Description	Behaviour during contraction
Z-line (Z-disc)	Boundary of the sarcomere; anchors thin (actin) filaments	Z-lines move closer together
I-band	Light band; contains thin filaments only (no myosin overlap)	Shortens
A-band	Dark band; the full length of the thick (myosin) filaments	Stays the same length
H-zone	Lighter region within the A-band; thick filaments only (no actin overlap)	Shortens
M-line	Centre of the sarcomere; holds thick filaments in place	Stays in the centre

EXAM ALERT

Critical exam point: The **A-band does NOT change length** during contraction — it is defined by the length of the myosin filaments, which do not shorten. The **I-band and H-zone both shorten** as actin slides over myosin. This is one of the most frequently tested distinctions on Paper 2.



IB TIP

IB mnemonic — "HAI" shrinks: During contraction, the **H**-zone, the distance between **A**-band edges (which is the same as H-zone), and the **I**-band all get shorter. The **A**-band stays the same. Remember: **H** and **I** shrink; **A** stays.

1.3 Thick and Thin Filaments

Thick filaments are composed of the protein **myosin**. Each myosin molecule has a globular head that can bind to actin and hydrolyse ATP. Many myosin molecules bundle together with their heads projecting outward.

Thin filaments are composed of:

- **Actin** — a globular protein (G-actin) that polymerises into two helical strands (F-actin) forming the backbone of the thin filament
- **Tropomyosin** — a fibrous protein that wraps around the actin helix, blocking the myosin-binding sites when the muscle is relaxed
- **Troponin** — a globular protein complex bound to tropomyosin at regular intervals; troponin has a binding site for Ca^{2+} ions

MEMORISE THIS

Filament summary:

Filament	Protein(s)	Role
Thick	Myosin (with ATPase heads)	Pulls actin filaments toward the M-line using cross-bridge cycling
Thin	Actin + tropomyosin + troponin	Provides binding sites for myosin heads; tropomyosin/troponin regulate access

1.4 The Sliding Filament Theory — Step by Step

The sliding filament theory explains how sarcomeres shorten during contraction. The key principle is that **filaments do not shorten** — actin slides over myosin, pulling the Z-lines closer together.

MEMORISE THIS

The cross-bridge cycle (you must know every step):

1. **At rest:** Tropomyosin covers the myosin-binding sites on actin. The myosin head is in the “cocked” (high-energy) position, with ADP and P_i bound from a previous ATP hydrolysis.

2. **Calcium release:** An action potential reaches the sarcoplasmic reticulum via T-tubules. The SR releases Ca^{2+} ions into the sarcoplasm.

3. **Troponin-tropomyosin shift:** Ca^{2+} binds to **troponin**, causing a conformational change that moves **tropomyosin** away from the myosin-binding sites on actin, exposing them.

4. **Cross-bridge formation:** The myosin head binds to the exposed site on actin, forming a **cross-bridge**.

5. **Power stroke:** ADP and P_i are released from the myosin head. The head pivots, pulling the actin filament toward the M-line. This is the **power stroke** — the step that generates force and movement.

6. **ATP binding and detachment:** A new molecule of **ATP** binds to the myosin head, causing it to detach from actin.

7. **ATP hydrolysis and re-cocking:** The myosin head hydrolyses ATP to ADP + P_i, and the energy released returns the head to the cocked (high-energy) position, ready for the next cycle.

8. **Cycle repeats** as long as Ca^{2+} and ATP are available.

⚠ EXAM ALERT

Common exam mistake: Students often say ATP provides energy for the power stroke. ATP is hydrolysed to **re-cock** the myosin head (step 7) and to **detach** the head from actin (step 6). The power stroke itself is driven by the release of ADP and P_i, not by ATP hydrolysis. This distinction is worth marks on Paper 2.

IB TIP

IB key concept — rigor mortis: After death, ATP production stops. Without ATP, myosin heads cannot detach from actin (step 6 fails). The cross-bridges become locked in place, causing the stiffness known as rigor mortis. This is a common exam application question.

1.5 Relaxation

When nervous stimulation stops:

1. Ca^{2+} is actively pumped back into the sarcoplasmic reticulum by Ca^{2+}-ATPase pumps (requires ATP)
2. Ca^{2+} dissociates from troponin
3. Tropomyosin slides back over the myosin-binding sites on actin
4. Cross-bridges cannot form, so the muscle relaxes passively (antagonistic muscles or elastic recoil return it to original length)

1.6 The Neuromuscular Junction

The **neuromuscular junction (NMJ)** is the synapse between a motor neuron and a muscle fibre. The signal to contract arrives here.

Sequence of events at the NMJ:

1. An action potential arrives at the **motor neuron axon terminal**.
2. Voltage-gated Ca^{2+} channels open; Ca^{2+} enters the terminal.
3. Ca^{2+} causes synaptic vesicles containing **acetylcholine (ACh)** to fuse with the presynaptic membrane and release ACh into the synaptic cleft by exocytosis.

4. ACh diffuses across the cleft and binds to **nicotinic ACh receptors** on the sarcolemma (postsynaptic membrane of the muscle fibre).
5. These receptors are ligand-gated Na^+ channels — they open, allowing Na^+ to flow in, depolarising the sarcolemma.
6. The depolarisation generates a **muscle action potential** that spreads along the sarcolemma and into the T-tubules, triggering Ca^{2+} release from the SR.
7. ACh is rapidly broken down by **acetylcholinesterase** in the synaptic cleft, preventing continued stimulation. The choline is recycled back into the presynaptic terminal.

⚠ EXAM ALERT

Exam link — nerve agents and muscle relaxants: Substances that inhibit acetylcholinesterase (e.g. nerve agents, some insecticides) prevent ACh breakdown, causing continuous muscle stimulation and potentially fatal spasms. Curare blocks ACh receptors, causing paralysis. These are common application questions.

1.7 Fast-Twitch vs Slow-Twitch Muscle Fibres

Skeletal muscles contain a mixture of fibre types, but the proportion varies depending on the muscle's function.

MEMORISE THIS

Comparison of muscle fibre types:

Feature	Slow-twitch (Type I)	Fast-twitch (Type IIa/IIx)
Contraction speed	Slow	Fast
Fatigue resistance	High (sustained activity)	Low (rapid fatigue)
Myoglobin content	High (red colour)	Low (pale colour)
Mitochondria	Many	Few
Capillary supply	Dense	Sparse
Primary energy pathway	Aerobic respiration	Anaerobic respiration (glycolysis)
Glycogen stores	Lower	Higher
Example activity	Marathon running, posture	Sprinting, weightlifting
Motor unit size	Small (fine control)	Large (powerful bursts)

IB TIP

IB key concept: The proportion of fibre types is largely genetically determined but can be influenced by training. Endurance training increases mitochondrial density and capillary supply in existing fibres but does not convert fast-twitch to slow-twitch (or vice versa) in a significant way. This is a nuance examiners test.

1.8 Anaerobic Cell Respiration in Muscle — The Lactate Pathway

During intense exercise, oxygen supply cannot meet demand. Muscle fibres (especially fast-twitch) switch to **anaerobic respiration** to regenerate ATP rapidly.

The lactate pathway:

$$\text{Glucose} \xrightarrow{\text{glycolysis}} 2\text{ pyruvate} \xrightarrow{\text{lactate dehydrogenase}} 2\text{ lactate} + 2\text{ NAD}^+$$

- Glycolysis produces a net gain of **2 ATP** per glucose (far less than aerobic respiration's ~30-32 ATP)
- The conversion of pyruvate to lactate regenerates NAD^+, which is essential for glycolysis to continue when the electron transport chain is not operating
- Lactate accumulation lowers intracellular pH, which inhibits enzyme activity and contributes to **muscle fatigue**
- Lactate is transported to the **liver** via the blood, where it is converted back to pyruvate and then to glucose (the **Cori cycle**) — this requires oxygen, contributing to the **oxygen debt** after exercise

⚠ **EXAM ALERT**

Common exam mistake: Students write "lactic acid" — in physiological conditions the molecule is almost entirely in its dissociated form, **lactate**, not lactic acid. Use "lactate" in IB exams. Also, lactate itself does not directly cause muscle soreness — the drop in pH (from H^+ ions) is what impairs enzyme function and contraction.

Section 2: Adaptation to Environment (B4.1)

2.1 Types of Adaptation

An **adaptation** is an inherited characteristic that increases an organism's fitness (ability to survive and reproduce) in a particular environment. Adaptations arise through natural selection over many generations.

MEMORISE THIS

Three categories of adaptation:

Type	Definition	Examples
Structural	Physical features of the body	Thick fur in Arctic mammals; cactus spines instead of leaves; streamlined body shape in fish
Behavioural	Actions that improve survival	Migration; nocturnal activity in desert animals; courtship displays
Physiological	Internal body processes	Antifreeze proteins in Arctic fish; production of venom; CAM photosynthesis in succulents

EXAM ALERT

Exam tip: When asked to classify an adaptation, some adaptations can fit multiple categories. A desert fox with large ears has a **structural** adaptation (large surface area for heat loss) that serves a **physiological** function (thermoregulation). In exams, justify your classification — state the feature and explain *how* it increases fitness.

2.2 Adaptation vs Acclimatization

MEMORISE THIS

	Adaptation	Acclimatization
Timescale	Evolutionary (many generations)	Within an individual's lifetime (days to weeks)
Mechanism	Natural selection acting on heritable genetic variation	Reversible physiological adjustment
Heritable?	Yes — encoded in DNA and passed to offspring	No — not passed to offspring
Example	Tibetan populations have genetic variants for efficient oxygen transport at high altitude	A lowland athlete training at high altitude increases red blood cell count over several weeks

IB TIP

IB key concept: Acclimatization is a **phenotypic** response to environmental change within the norm of reaction of the genotype. It does not involve changes to DNA. This distinction is critical in evolution questions — Lamarck's "inheritance of acquired characteristics" would suggest acclimatization is heritable, but it is not.

2.3 Xerophytes — Adaptations to Dry Conditions

Xerophytes are plants adapted to survive in environments with limited water availability (deserts, sand dunes, exposed rocky habitats).

MEMORISE THIS

Key xerophyte adaptations:

Adaptation	How it reduces water loss
Thick, waxy cuticle	Reduces evaporation from the leaf surface
Sunken stomata	Stomata are recessed in pits, creating a humid microenvironment that reduces the water potential gradient driving transpiration
Rolled leaves	Enclose stomata on the inner surface, trapping moist air and reducing transpiration
Reduced leaf surface area	Spines (e.g. cactus) or small leaves reduce the surface area for water loss
Extensive root systems	Deep taproots reach water tables; shallow spreading roots absorb brief rainfall
Succulent tissues	Store water in stems or leaves (e.g. cacti, aloe)
CAM photosynthesis	Stomata open at night (when it is cooler and more humid) to fix CO_2 as malate; during the day stomata close to conserve water, and malate is decarboxylated to release CO_2 for the Calvin cycle

⚠ EXAM ALERT

Paper 2 favourite: Examiners love asking students to explain how a named xerophyte feature reduces water loss. Always link the structural feature to a physiological mechanism. For example: "Sunken stomata create a pocket of humid air above the stomatal pore. This reduces the water potential gradient between the leaf interior and the surrounding air, decreasing the rate of transpiration."

2.4 Hydrophytes — Adaptations to Aquatic Conditions

Hydrophytes are plants adapted to living in water or very wet conditions. Their challenges are the opposite of xerophytes — they must deal with excess water and limited gas exchange.

MEMORISE THIS

Key hydrophyte adaptations:

Adaptation	Function
Aerenchyma	Large air spaces in stems and roots provide buoyancy and allow internal gas transport (especially O_2 to submerged roots)
Flexible stems	Bend with water currents rather than snapping
Reduced or absent cuticle	No need to prevent water loss; allows direct absorption of water and minerals
Stomata on upper leaf surface	(In floating-leaf species like water lilies) stomata face the air, not the water
Broad, flat floating leaves	Maximise light capture at the water surface
Reduced xylem	Less structural support needed (water provides buoyancy); reduced water transport demand

2.5 Animal Adaptations to Extreme Environments

MEMORISE THIS

Key animal adaptations:

Adaptation	Environment	Mechanism
Counter-current exchange	Cold water (fish gills, flippers of marine mammals)	Blood flows in the opposite direction to the surrounding medium, maintaining a concentration/temperature gradient along the entire exchange surface for maximum efficiency
Blubber (subcutaneous fat)	Arctic/Antarctic	Thick layer of insulating fat reduces heat loss; also serves as an energy reserve
Hibernation	Cold winters	Metabolic rate, heart rate, and body temperature drop dramatically, conserving energy when food is scarce
Estivation	Hot, dry summers	Dormancy state (similar to hibernation) to avoid desiccation and overheating
Large ears / long limbs	Hot environments	High surface area to volume ratio increases heat dissipation (e.g. fennec fox, jackrabbit)
Compact body, small ears	Cold environments	Low surface area to volume ratio reduces heat loss (e.g. Arctic fox, polar bear) — follows **Allen's rule**
Counter-current heat exchange in limbs	Cold environments	Arteries and veins run adjacent in limbs; warm arterial blood heats cool venous blood returning from extremities, reducing heat loss

IB TIP

IB key concept — counter-current exchange: This principle applies to gills (gas exchange), kidney tubules (water reabsorption), and thermoregulation in extremities. The key idea is always the same: by flowing in opposite directions, a gradient is maintained along the entire length of the exchange surface. If flows were in the same direction (concurrent), equilibrium would be reached halfway and exchange would stop. IB examiners test this across multiple topics.

WORKED EXAMPLE

Worked Example: Explain how the counter-current flow in fish gills maximises oxygen absorption. (4 marks)

1. Water flows over the gill lamellae in one direction while blood flows through capillaries in the **opposite direction**. [1]
2. At every point along the lamella, the O_2 concentration in the water is higher than in the adjacent blood. [1]
3. This maintains a **concentration gradient** along the entire length of the exchange surface. [1]
4. As a result, fish can extract up to **80%** of dissolved oxygen from water — far more than would be possible with concurrent flow, where equilibrium would be reached and net diffusion would stop. [1]

Section 3: Ecological Niches (B4.2)

3.1 The Concept of an Ecological Niche

An ecological niche is not simply where an organism lives (that is its habitat) — it encompasses the **totality of an organism's interactions** with its environment, including what it eats, when it is active, what eats it, its tolerance ranges for abiotic factors, and its role in nutrient cycling.

MEMORISE THIS

Core definitions to memorise:

Term	Definition
Ecological niche	The role of a species within its ecosystem, including all biotic and abiotic interactions — habitat, food sources, activity patterns, predators, competitors, and tolerance ranges
Fundamental niche	The full range of conditions and resources a species *could* use in the absence of competition and other biotic interactions
Realized niche	The actual range of conditions and resources a species *does* use, limited by competition and other species interactions
Habitat	The physical environment where an organism lives (not the same as niche)

EXAM ALERT

Critical distinction: The fundamental niche is always **larger than or equal to** the realized niche. Interspecific competition, predation, and parasitism restrict a species from occupying its full fundamental niche. If asked to compare these on an exam, draw two overlapping ranges on an axis (e.g. altitude or food size), with the fundamental niche wider and the realized niche a subset of it.

3.2 The Competitive Exclusion Principle (Gause's Principle)

The **competitive exclusion principle** states that **two species cannot occupy the same niche indefinitely** in the same habitat. If two species compete for exactly the same resources, one will inevitably outcompete the other, leading to the local extinction (competitive exclusion) of the inferior competitor.

Gause's experiment (1934):

- Gause grew two species of *Paramecium* (*P. aurelia* and *P. caudatum*) separately and together
- Grown separately, both species thrived
- Grown together in the same culture (competing for the same food), *P. aurelia* consistently outcompeted *P. caudatum*, which declined to extinction
- Conclusion: two species with identical niches cannot coexist

> **IB TIP**
>
> **IB key concept:** Competitive exclusion is the theoretical outcome. In nature, species often avoid exclusion through **niche differentiation** — they evolve to use slightly different resources or occupy slightly different microhabitats. This is why competitive exclusion is rarely observed in nature compared to resource partitioning.

3.3 Resource Partitioning

Resource partitioning occurs when competing species divide resources to reduce niche overlap and avoid competitive exclusion. Each species specialises on a slightly different subset of the available resources.

Types of resource partitioning:

- **Spatial partitioning** — species use different parts of the habitat (e.g. different heights in a forest canopy; different depths in a lake)
- **Temporal partitioning** — species use the same resource at different times (e.g. diurnal vs nocturnal foraging; seasonal differences in activity)
- **Morphological partitioning** — species evolve different body structures to exploit different food sizes or types (e.g. Darwin's finches with different beak sizes)

WORKED EXAMPLE

Worked Example: Anole lizards in the Caribbean

Five species of *Anolis* lizard coexist on the same Caribbean islands by partitioning their habitat:

- *A. carolinensis* — perches on high branches in the canopy
- *A. distichus* — occupies tree trunks
- *A. sagrei* — forages on lower branches and ground level
- *A. cybotes* — rocky ground habitats
- *A. valencienni* — thin twigs

Each species has evolved different limb proportions and toe pad sizes suited to its microhabitat. This is spatial resource partitioning driven by interspecific competition.

3.4 Character Displacement

Character displacement is the evolutionary divergence of competing species in areas where they coexist (**sympatry**), compared to areas where they occur alone (**allopatry**).

Where two species overlap geographically and compete, natural selection favours individuals that are most different from the competing species, reducing niche overlap. Over time, this leads to measurable morphological divergence.

Classic example — Darwin's finches:

- *Geospiza fortis* and *G. fuliginosa* on islands where they coexist have significantly different beak sizes (one larger, one smaller)
- On islands where only one species is present, beak size is intermediate
- The divergence in beak size reduces competition for seeds of the same size

EXAM ALERT

Exam tip: Character displacement is evidence that **competition is an evolutionary force**. If asked "What evidence supports the competitive exclusion principle?", character displacement and resource partitioning are strong answers — they show species evolving to avoid the exclusion predicted by the principle.

3.5 Generalist vs Specialist Species

MEMORISE THIS

Comparison of generalist and specialist species:

Feature	Generalist	Specialist
Niche breadth	Wide — uses many different resources	Narrow — depends on specific resources
Diet	Varied (omnivores, opportunistic feeders)	Restricted (often one food type)
Habitat tolerance	Broad range of conditions	Narrow range of conditions
Population stability	More stable — can switch resources if one declines	More vulnerable — population crashes if key resource is lost
Competitive ability	Lower for any single resource	Higher for its specific resource
Vulnerability to extinction	Lower	Higher (especially under environmental change)
Examples	Raccoon, rat, cockroach, crow	Koala (eucalyptus), giant panda (bamboo), monarch butterfly (milkweed)

IB TIP

IB key concept: Specialist species are often the focus of conservation biology because they are disproportionately vulnerable to habitat loss and climate change. If their specific resource disappears, they cannot switch to alternatives. Generalists tend to be more resilient and may even benefit from human-altered environments (urban adapters).

3.6 Niche Overlap and Interspecific Competition

Niche overlap occurs when two or more species use the same resource or occupy the same environmental conditions. Greater overlap leads to more intense **interspecific competition**.

Types of interspecific competition:

- **Exploitation competition (indirect)** — species compete by consuming shared resources, reducing availability for others (e.g. two bird species eating the same insect prey)
- **Interference competition (direct)** — species directly prevent others from accessing resources through aggression, territory defence, or chemical inhibition (e.g. allelopathy in plants, where chemicals are released into the soil to inhibit competitors)

Outcomes of interspecific competition:

1. **Competitive exclusion** — one species is eliminated locally
2. **Resource partitioning** — species evolve to reduce overlap (coexistence)
3. **Character displacement** — morphological divergence in sympatry

⚠ EXAM ALERT

Paper 2 structure tip: Questions on niches and competition often ask you to connect multiple concepts. A strong answer links: niche overlap → interspecific competition → competitive exclusion principle → resource partitioning or character displacement as the outcome. Show the examiner you understand the logical chain, not just individual definitions.

Mixed Practice — Exam Style

⚠ EXAM ALERT

Instructions: These questions integrate material from all three sections of this guide. For each multiple-choice question, select the single best answer. Detailed explanations are provided below.

1. **[Sarcomere]** During contraction of a sarcomere, which of the following changes occurs?

   A. The A-band shortens and the I-band stays the same

   B. Both the A-band and H-zone shorten

   C. The I-band and H-zone shorten, but the A-band stays the same length

   D. The actin and myosin filaments both shorten

2. **[Cross-Bridge Cycle]** What is the immediate role of ATP in muscle contraction?

   A. ATP hydrolysis provides the energy for the power stroke

   B. ATP binding to the myosin head causes it to detach from actin, and ATP hydrolysis re-cocks the head

   C. ATP binds to troponin, causing tropomyosin to move

   D. ATP is required for the release of acetylcholine at the neuromuscular junction only

3. **[Muscle Fibres]** A sprinter's leg muscles would be expected to contain a higher proportion of:

   A. Slow-twitch fibres with many mitochondria and high myoglobin content

   B. Fast-twitch fibres with few mitochondria and high glycogen stores

   C. Slow-twitch fibres with high glycogen stores and few capillaries

   D. Fast-twitch fibres with many mitochondria and high myoglobin content

4. **[Xerophytes]** CAM photosynthesis is an adaptation to dry conditions because:

   A. Stomata remain open during the day to maximise CO_2 fixation

   B. CO_2 is fixed at night when stomata are open, then stomata close during the day to conserve water

   C. CAM plants do not use stomata at all, absorbing CO_2 through their roots

   D. CAM plants photosynthesise only at night when temperatures are lower

5. **[Adaptation]** A population of mice living in a cold environment has shorter tails and smaller ears than a related population in a warm environment. This is best explained by:

   A. Acclimatization — individual mice in the cold grow shorter tails

   B. Natural selection favouring a lower surface area to volume ratio in cold environments, reducing heat loss

   C. Genetic drift randomly producing shorter tails in the cold population

   D. The cold environment directly causing mutations that shorten tail length

6. **[Ecological Niche]** The realized niche of a species is smaller than its fundamental niche because:

   A. The species cannot tolerate the full range of abiotic conditions

   B. Interspecific competition, predation, and parasitism restrict the species from using all available resources

   C. The species chooses to occupy only part of its fundamental niche

   D. Intraspecific competition forces individuals into a narrower range

7. **[Competitive Exclusion]** In Gause's experiment with *Paramecium*, *P. caudatum* was driven to extinction when grown with *P. aurelia*. This result supports the principle that:

   A. Two species can coexist indefinitely if they share the same niche

   B. Two species occupying the same niche cannot coexist — one will be competitively excluded

   C. Predation is the main factor limiting population growth

   D. *P. caudatum* was unable to reproduce in laboratory conditions

8. **[Counter-Current Exchange]** Counter-current flow in fish gills is more efficient than concurrent flow because:

A. It allows water to flow faster than blood, increasing pressure

B. It maintains a concentration gradient along the entire length of the exchange surface, maximising diffusion

C. It allows active transport of oxygen from water to blood

D. It reduces the surface area needed for gas exchange

9. **[Neuromuscular Junction]** Acetylcholinesterase in the synaptic cleft of the neuromuscular junction prevents:

   A. Calcium ions from entering the presynaptic terminal

   B. Continuous stimulation of the muscle fibre by rapidly breaking down acetylcholine

   C. The release of acetylcholine from synaptic vesicles

   D. Sodium ions from entering the muscle fibre

10. **[Resource Partitioning]** Five species of warbler coexist in the same spruce forest by foraging at different heights in the trees. This is an example of:

    A. Character displacement

    B. Competitive exclusion

    C. Spatial resource partitioning

    D. Temporal resource partitioning

▶ Show Answers

May 2026 Prediction Questions

⚠ **EXAM ALERT**

These are NOT official IB questions. These are trend-based practice questions written to reflect the topic areas and question styles most likely to appear on the May 2026 IB Biology HL Paper 2. Based on recent exam patterns (2022—2025), B3.1 Muscle contraction appears approximately every other session, and B4.1/B4.2 adaptation and niche questions are consistently tested on Paper 2 Section B.

WORKED EXAMPLE

Question 1 [Sliding Filament Theory] [~8 marks]

(a) Draw a labelled diagram of a sarcomere in relaxed and contracted states. Identify the I-band, A-band, H-zone, Z-lines, and M-line in both states. (4 marks)

(b) Outline the role of calcium ions, tropomyosin, and troponin in the initiation of muscle contraction. (4 marks)

▶ Show Solution

WORKED EXAMPLE

Question 2 [Xerophyte Adaptations] [~6 marks]

A student observes a cross-section of a leaf from a desert plant under the microscope. The leaf has a thick waxy cuticle, sunken stomata with hair-like trichomes, and a tightly rolled structure.

(a) Explain how each of these three features reduces water loss by transpiration. (3 marks)

(b) Distinguish between adaptation and acclimatization, using a named example for each. (3 marks)

▶ Show Solution

WORKED EXAMPLE

Question 3 [Ecological Niches and Competition] [~8 marks]

Two species of seed-eating birds, Species A and Species B, live on an island. Species A eats seeds 2—5 mm in diameter; Species B eats seeds 4—7 mm in diameter.

(a) Define the terms *fundamental niche* and *realized niche*. (2 marks)

(b) Identify the region of niche overlap between the two species and predict the outcome according to the competitive exclusion principle. (2 marks)

(c) Explain how resource partitioning and character displacement could allow the two species to coexist. (4 marks)

▶ Show Solution

WORKED EXAMPLE

Question 4 [Muscle Contraction and Energy] [~6 marks]

During a 400 m sprint, an athlete's leg muscles initially use aerobic respiration but switch to anaerobic respiration partway through the race.

(a) Explain why the switch to anaerobic respiration occurs. (2 marks)

(b) Describe the lactate pathway and explain why it is essential for continued muscle contraction under anaerobic conditions. (2 marks)

(c) After the race, the athlete continues to breathe heavily. Explain the concept of oxygen debt (excess post-exercise oxygen consumption). (2 marks)

▶ Show Solution

IB Biology HL — Muscle Contraction, Adaptation & Ecological Niches — Complete Study Guide — 2025 Syllabus — Good luck!