



Muscle and motility

Revision notes · IB Biology HL B3.3: movement, sliding filaments, titin, motor units, skeletons, the hip joint, intercostal muscles, locomotion and marine mammals.

For IB Diploma Biology, Standard Level and Higher Level (first assessment 2025). **HL only** is additional higher level content, for HL students only.

Muscle and motility

Spec B3.3

HL only

Movement and reasons for locomotion

Spec B3.3.1, B3.3.9

All living things move in some way, from cytoplasm streaming inside cells to whole animals travelling thousands of kilometres. Organisms are either **motile** (able to move from place to place) or **sessile** (fixed in one place).

A motile and a sessile species

Species	Type	Adaptations for movement
Atlantic salmon (<i>Salmo salar</i>)	Motile	Streamlined body; blocks of muscle along each side contract alternately to bend the body and tail from side to side; fins give stability and steering. Adults migrate from the sea up rivers to spawn.
Venus flytrap (<i>Dionaea muscipula</i>)	Sessile	Rooted in the soil, so it cannot move from place to place. The two lobes of each modified leaf snap shut in about a tenth of a second when trigger hairs are touched twice in quick succession, trapping insects. Plants have no muscle: the movement comes from rapid changes in turgor that make the curved lobes flip shape.

Locomotion is movement of the whole organism from one place to another.

Reasons for locomotion

Reason	Example
Foraging for food	Honeybee workers fly from the hive to flowers to collect nectar and pollen.
Escaping from danger	Squid escape predators by jet propulsion, forcing water out of the mantle cavity.
Searching for a mate	Male silk moths fly towards females by following the pheromone the females release.
Migration	Arctic terns fly between Arctic breeding grounds and the Antarctic each year.

Exam tip: Linking question: in what ways does locomotion contribute to evolution? Moving to find mates, food or new habitats affects which individuals survive and reproduce, and so which alleles are passed on.

Sliding filament model of muscle contraction

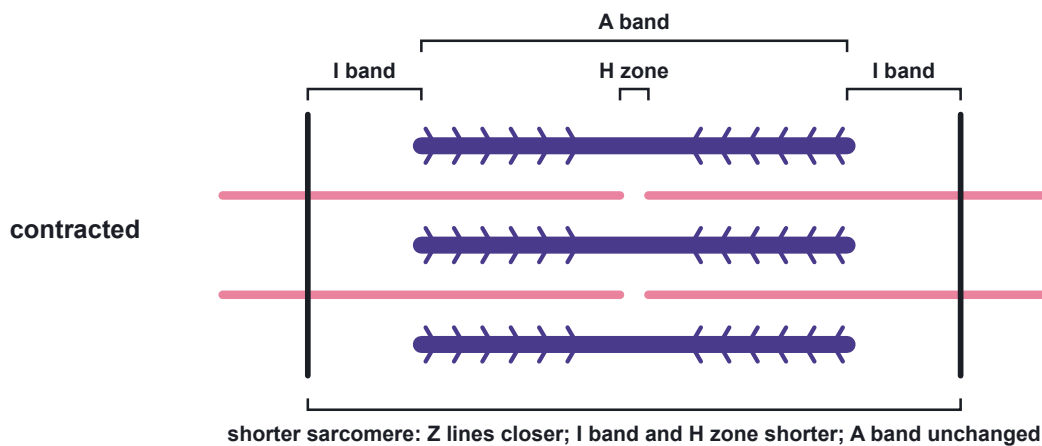
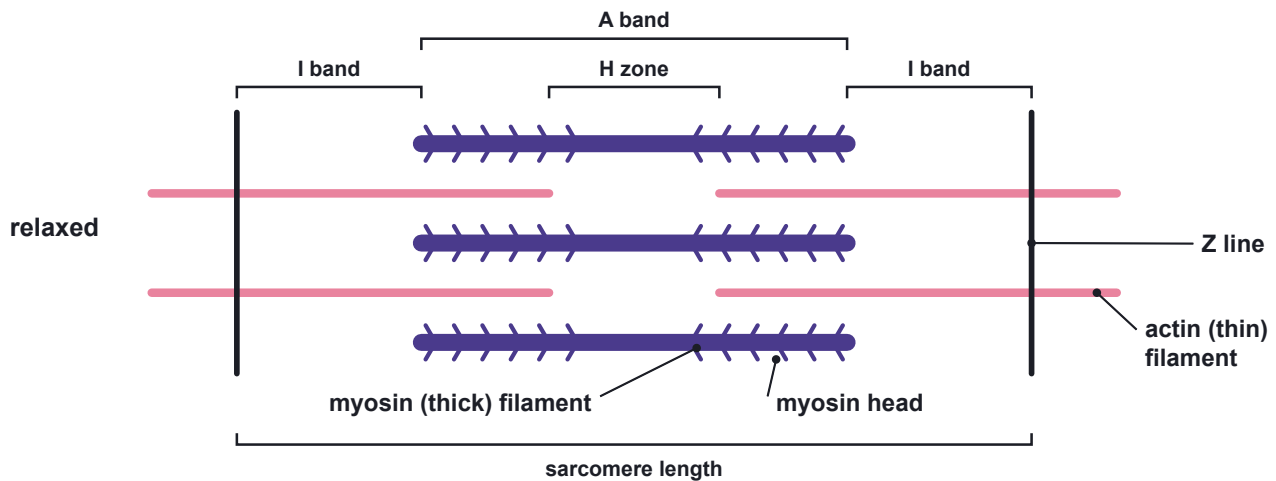
Spec B3.3.2

A skeletal muscle fibre contains many myofibrils. Each myofibril is a chain of repeating units called **sarcomeres**, separated by **Z lines**.

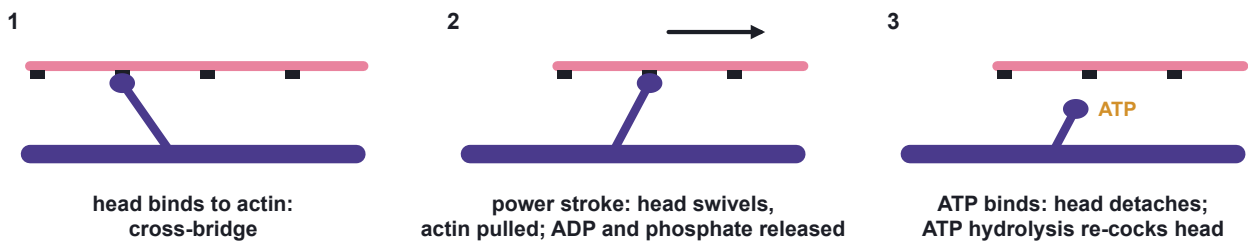
- Thin **actin** filaments are attached to the Z lines and point towards the centre of the sarcomere.
- Thick **myosin** filaments lie in the centre, overlapping the actin. Each has many myosin heads.

- The dark band (A band) is the length of the myosin; the light bands (I bands) contain only actin; the H zone in the centre contains only myosin.
1. A nerve impulse causes calcium ions to be released from the sarcoplasmic reticulum. They bind to regulatory proteins on the actin, exposing binding sites for myosin.
 2. Myosin heads, already energised by hydrolysing ATP, bind to the binding sites on actin, forming **cross-bridges**.
 3. The heads swivel (the power stroke), pulling the actin filaments towards the centre of the sarcomere. ADP and phosphate are released.
 4. A new ATP binds to each myosin head, which then detaches from the actin.
 5. Hydrolysis of ATP re-cocks the head, ready to bind further along the actin. The cycle repeats while calcium is present.

The filaments **slide past each other**; neither changes length. During contraction the Z lines move closer together, the I band and H zone shorten, and the A band stays the same length.



Cross-bridge cycle (one myosin head)



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Sliding filaments: the sarcomere shortens but the A band stays the same length, because actin slides past myosin.

Common mistake: The filaments do not shorten or contract. They slide past each other, so only the sarcomere shortens.

Titin, antagonistic muscles and the intercostal muscles Spec B3.3.3, B3.3.8

Titin

- **Titin** is the largest known protein. Each molecule runs from the Z line to the centre of the sarcomere, alongside the myosin filament.
- When a sarcomere is stretched, titin is stretched too and stores potential energy, like a spring.
- When the stretching force stops, titin **recoils**, helping the sarcomere return to its resting length.
- Titin also **prevents overstretching**, which could pull the actin and myosin filaments apart.

Antagonistic muscles

Muscle tissue can only exert force when it contracts: it pulls but cannot push. A relaxed muscle is lengthened again by a second muscle that pulls the other way. Muscles that produce opposite movements are **antagonistic**, for example the biceps (flexes the elbow) and triceps (extends it).

Internal and external intercostal muscles

The intercostal muscles lie in two layers between the ribs. Their muscle fibres run in different orientations, at roughly right angles to each other, so they move the ribcage in opposite directions.

Intercostal muscles as an antagonistic pair		
Muscle	When it contracts	Effect on the other layer
External intercostal muscles	Pull the ribcage up and out (inspiration)	Stretch the internal intercostals, storing potential energy in titin
Internal intercostal muscles	Pull the ribcage down and in (forced expiration)	Stretch the external intercostals, storing potential energy in titin

This is an example of antagonistic muscle action that moves part of the body internally rather than moving the body from place to place.

Exam tip: Link to B3.1.5: in ventilation answers, name the external intercostals for inspiration and the internal intercostals (with abdominal muscles) for forced expiration.

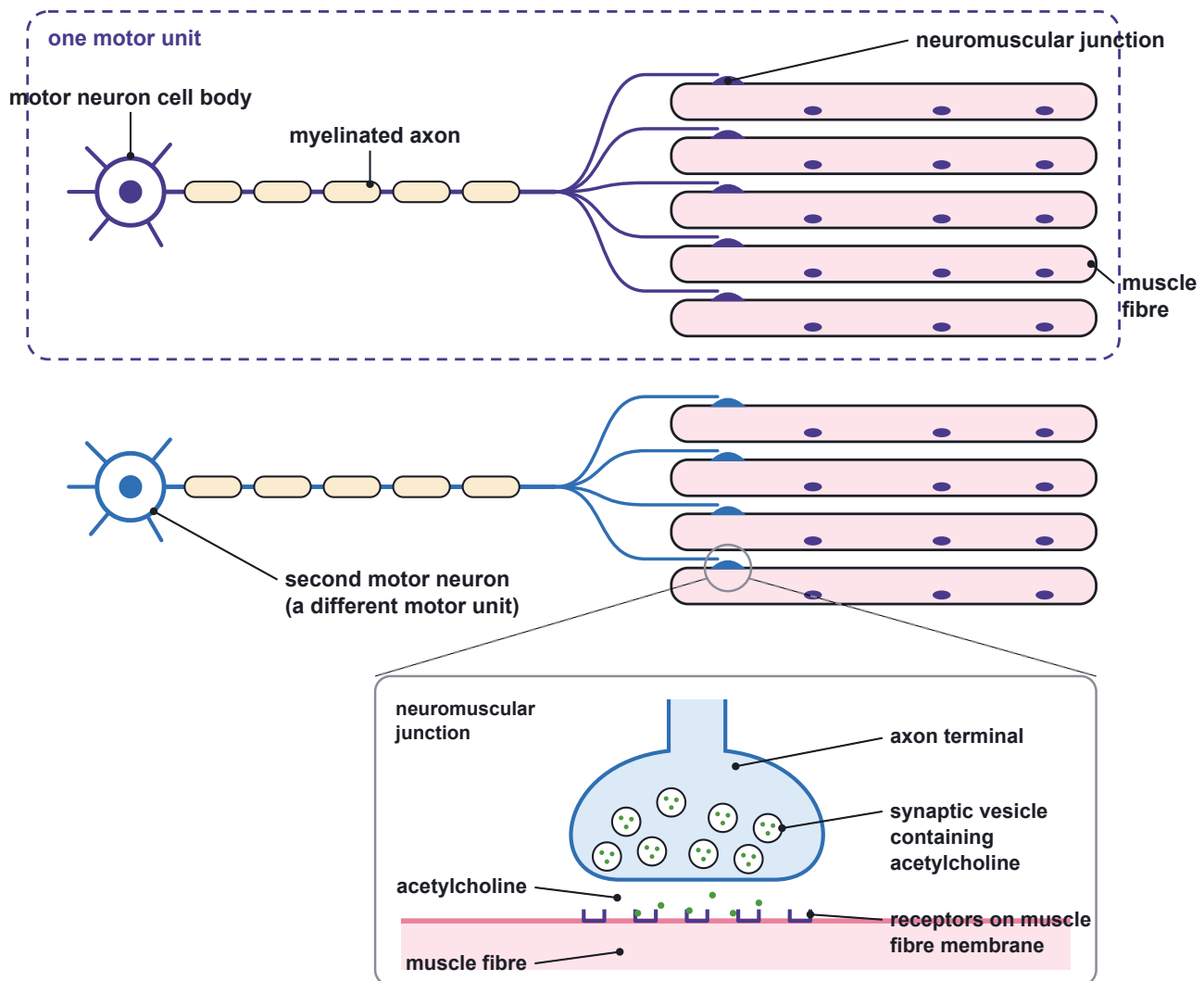
Motor units in skeletal muscle Spec B3.3.4

A **motor unit** consists of:

- **One motor neuron**, whose cell body is in the spinal cord or brainstem and whose axon branches at its end.
- **The muscle fibres** it controls: long, multinucleate cells packed with myofibrils.
- **Neuromuscular junctions**: the synapses where each axon branch meets a muscle fibre.

1. An action potential travels along the motor neuron to its axon terminals.
2. At each **neuromuscular junction** the neurotransmitter **acetylcholine** is released and diffuses across the gap.
3. It binds to receptors on the muscle fibre membrane, which depolarises and passes an impulse along the fibre.
4. Calcium ions are released inside the fibre and the sarcomeres contract.

All the fibres in one motor unit contract at the same time. Muscles that need fine control, such as those moving the eye, have small motor units with few fibres each. Large leg muscles have large motor units. The nervous system controls the strength of contraction by changing how many motor units are active.



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A motor unit is **one motor neuron and all the muscle fibres it controls**; they all contract together.

Skeletons, the hip joint and range of motion Spec B3.3.5, B3.3.6, B3.3.7

Skeletons as anchorage and levers

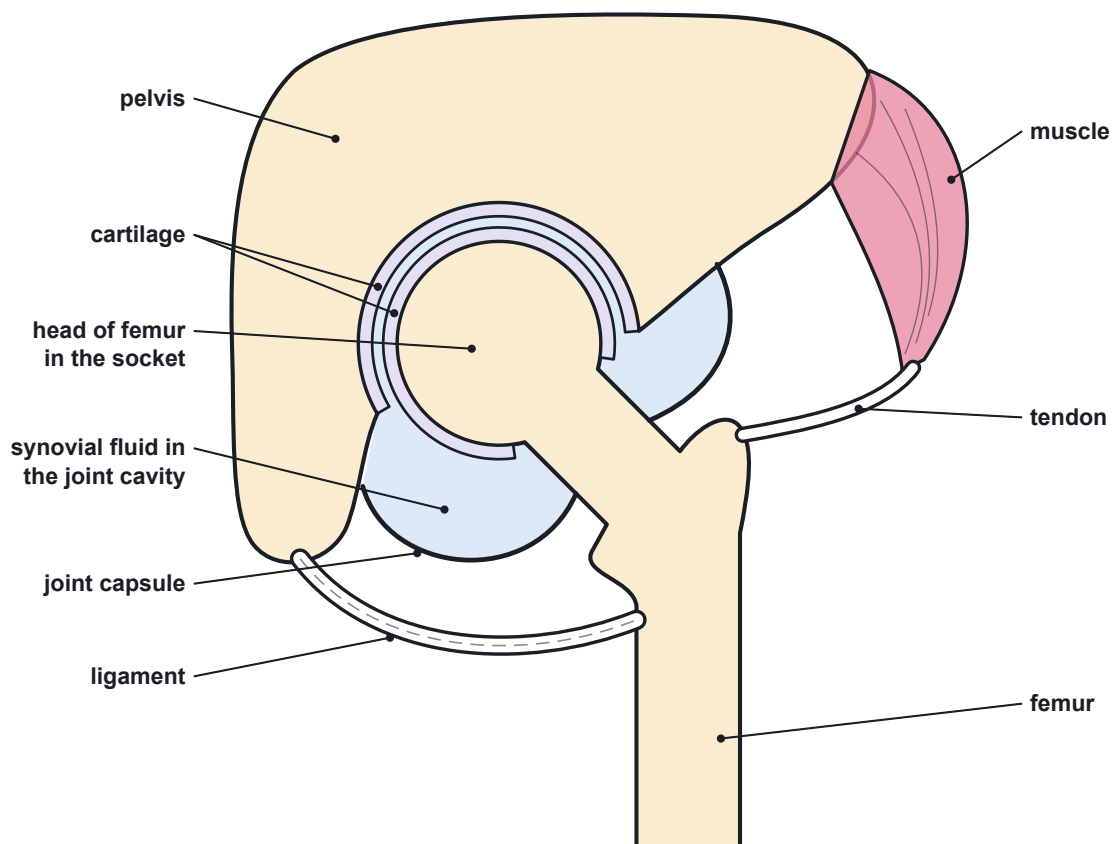
- **Anchorage:** muscles are attached to the skeleton, so when they contract they pull on something firm.
- **Levers:** rigid parts of the skeleton pivot at joints. A muscle applies force to one point and the bone transmits it to another, changing the size or direction of the force or movement.
- **Arthropods** (such as insects and crabs) have an **exoskeleton** on the outside of the body; the muscles are attached to its inner surface.
- **Vertebrates** have an **endoskeleton** of bone and cartilage inside the body; muscles are attached to its outer surface by tendons.

Movement at the hip joint

The hip is a ball-and-socket synovial joint: the rounded head of the **femur** fits into a socket in the **pelvis**.

Roles of the parts of a synovial joint

Part	Role
Bones (femur and pelvis)	Rigid levers that move relative to each other.
Cartilage	Smooth layer covering the bone ends; reduces friction and absorbs shock.
Synovial fluid	Lubricates the joint to reduce friction; secreted by the membrane of the joint capsule.
Ligaments	Tough bands connecting bone to bone; stabilise the joint and limit movement.
Muscles	Contract in antagonistic groups to move the femur.
Tendons	Connect muscles to bones and transmit the force of contraction.



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The hip is a **ball-and-socket synovial joint**: cartilage and synovial fluid reduce friction; ligaments join bone to bone, tendons join muscle to bone.

Range of motion

Range of motion is how far a joint can move, measured as an angle in degrees, in each plane. The hip moves in several dimensions: flexion and extension (forwards and backwards), abduction and adduction (away from and towards the midline) and rotation. A hinge joint such as the knee moves mainly in one plane.

Practical skill: Measure joint angles with a goniometer: place its pivot over the centre of the joint, line one arm up with the fixed bone and the other with the moving bone, and read the angle. Alternatively, photograph or film the movement and measure the angles with image-analysis software. Repeat three times and compare each dimension.

Comparing range of motion

A student measured hip flexion of a classmate three times with a goniometer: 112°, 118° and 115°. Hip abduction was 38°, 42° and 40°. Calculate the mean of each and how many times larger the flexion range is. (Practice data.)

1. Mean flexion = $(112 + 118 + 115) \div 3 = 115^\circ$
2. Mean abduction = $(38 + 42 + 40) \div 3 = 40^\circ$
3. Ratio = $115 \div 40 = 2.9$

Answer: flexion 115°, abduction 40°; flexion range is about 2.9 times larger

Adaptations for swimming in marine mammals Spec B3.3.10

Marine mammals, such as the bottlenose dolphin (*Tursiops truncatus*), evolved from land mammals but are adapted to swim and dive.

Swimming adaptations of marine mammals

Adaptation	How it helps
Streamlining	A smooth, tapering body with no external ears and little hair reduces drag (water resistance).
Forelimbs form flippers	The bones of the forelimb are enclosed in a stiff, flat flipper used for steering and balance.
Tail forms a fluke	A wide, horizontal tail fluke is moved up and down by powerful back muscles to push the animal forwards; fish tails move from side to side.
Hind limbs reduced	In whales and dolphins the hind limbs are absent externally, improving streamlining.
Changes to the airways	The nostrils have moved to the top of the head as a blowhole, closed by a muscular flap during dives; air can be exchanged rapidly at the surface, so the animal breathes periodically between dives.

Exam tip: When asked to compare with fish, say that the fluke moves up and down (vertical movement) whereas a fish tail fin moves from side to side.

Quick check

1. **HL only** What is the difference between motile and sessile organisms?
2. **HL only** Which bands of a sarcomere shorten during contraction?
3. **HL only** What two roles does titin have in the sarcomere?
4. **HL only** What does a motor unit consist of?
5. **HL only** Which two bones meet at the hip joint?

Quick check answers

Muscle and motility

- 1 . Motile organisms can move from place to place; sessile organisms are fixed in one place but can still move parts of their bodies.
- 2 . The I band and the H zone shorten; the A band stays the same.
- 3 . It helps the sarcomere recoil after stretching and prevents overstretching.
- 4 . One motor neuron, the muscle fibres it stimulates and the neuromuscular junctions connecting them.
- 5 . The femur and the pelvis.