

Muscles and movement

Revision notes · How muscles, tendons, ligaments and bones produce movement, the structure of a muscle fibre, and the sliding filament theory.

For Pearson Edexcel International AS Biology XBI11 and International A Level Biology YBI11. **A Level only** is IA2 content (Units 4 to 6), not needed for the International AS.

Muscles and movement **Spec 7.9-7.11** **A Level only**

Muscles, tendons, the skeleton and ligaments **Spec 7.9**

Skeletal muscles are attached to bones by **tendons**. Tendons are strong, inelastic bands of collagen, so the force of the muscle contracting is transmitted directly to the bone without being lost by stretching.

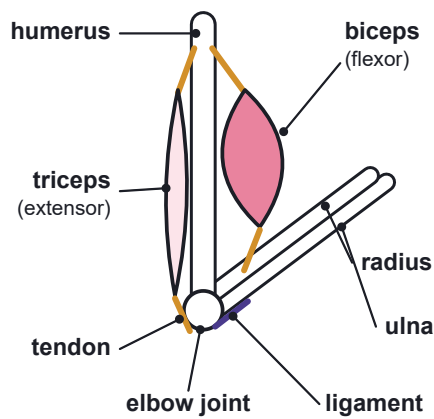
Ligaments join bone to bone at a joint. They are strong and slightly elastic, and they hold the bones in place and stabilise the joint. The skeleton provides rigid levers, and the joint acts as the pivot.

A muscle can only pull when it contracts. It cannot push. To move a joint in both directions, muscles work in **antagonistic pairs**: when one muscle of the pair contracts, the other relaxes and is stretched.

Antagonistic muscles at the elbow		
Feature	Biceps	Triceps
Type of muscle	Flexor	Extensor
Action when it contracts	Bends (flexes) the elbow, decreasing the angle	Straightens (extends) the elbow, increasing the angle
Attached to	Radius (by a tendon)	Ulna (by a tendon)
State while the other contracts	Relaxes when the triceps contracts	Relaxes when the biceps contracts

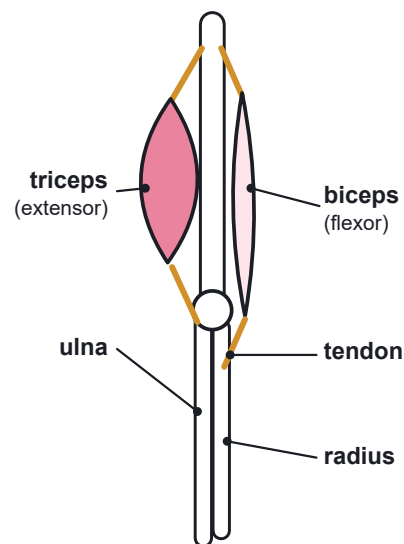
A **flexor** is a muscle whose contraction bends a joint; an **extensor** is a muscle whose contraction straightens a joint. Another example is the hamstring (flexor of the knee) and quadriceps (extensor of the knee).

Common mistake: Do not say that the relaxed muscle 'pushes'. It is the contracting muscle that pulls, and the relaxed antagonist is stretched. Tendons join muscle to bone; ligaments join bone to bone.



arm bent

biceps contracts, triceps relaxes



arm straight

triceps contracts, biceps relaxes

An antagonistic pair: the muscle that contracts **pulls**, and the other relaxes (darker pink = contracted).

Structure of a skeletal muscle fibre Spec 7.10(i)

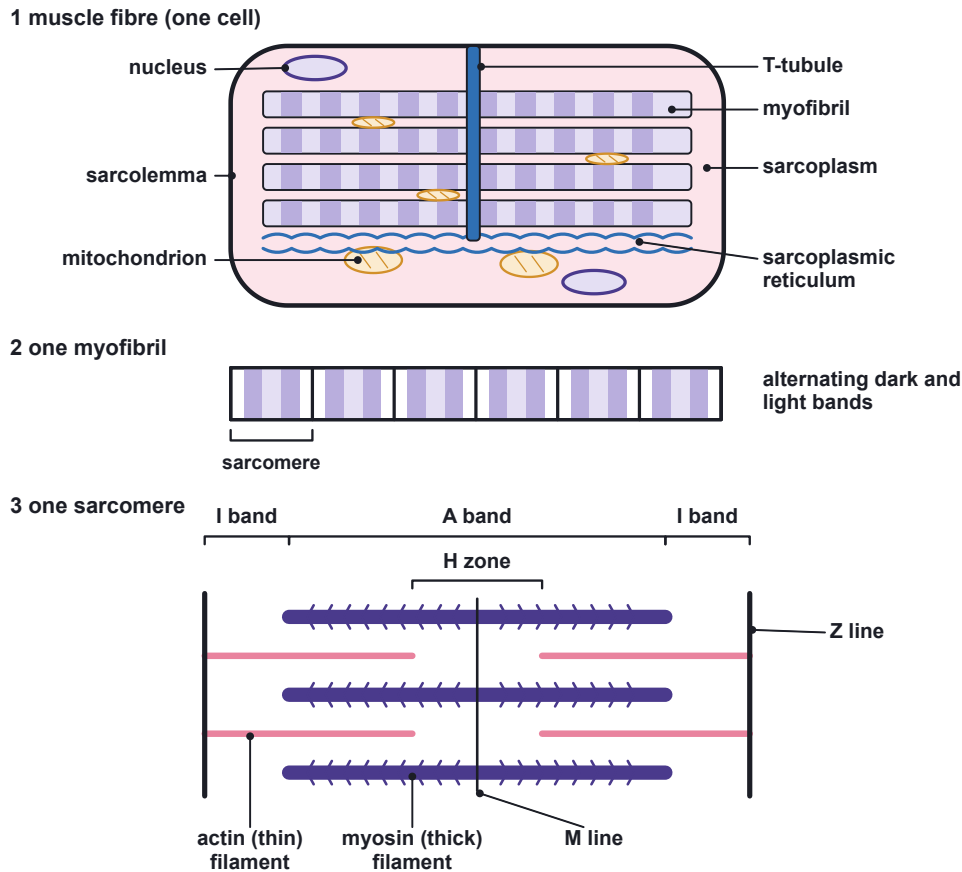
A skeletal muscle fibre is a single, long, cylindrical cell with many nuclei. Its cell surface membrane is the **sarcolemma** and its cytoplasm is the **sarcoplasm**. The sarcolemma folds inwards to form T-tubules (transverse tubules), which carry action potentials deep into the fibre.

- Myofibrils: long, thin, cylindrical bundles of protein filaments that run along the length of the fibre and cause contraction.
- Sarcoplasmic reticulum: a network of membranes around each myofibril that stores calcium ions (Ca^{2+}).
- Many mitochondria: lying between the myofibrils, to supply the ATP needed for contraction.
- Many nuclei, lying just under the sarcolemma.

The sarcomere

Each myofibril is divided along its length into repeating units called **sarcomeres**, from one Z line to the next. Two kinds of filament lie in the sarcomere: thick filaments of **myosin** and thin filaments of **actin** (with the proteins troponin and tropomyosin). Their arrangement gives the striped (striated) appearance under the microscope.

Bands of a sarcomere		
Region	Appearance	What is present
A band	Dark	The full length of the myosin filaments (including where actin overlaps them)
I band	Light	Actin filaments only (no myosin)
H zone	Lighter region in the middle of the A band	Myosin only (no actin overlap)
Z line	Thin dark line	Boundary of the sarcomere; actin is attached here
M line	Centre of the sarcomere	Myosin filaments held together



From fibre to **sarcomere**: each myofibril is a chain of sarcomeres.

Exam tip: In a contracted muscle the A band stays the same length, but the I band and H zone get shorter. Examiners often test this.

Fast and slow twitch muscle fibres Spec 7.10(ii)

Skeletal muscle contains two main types of fibre, and their proportions differ between muscles and between people. Their structure matches their role.

Fast twitch and slow twitch fibres		
Feature	Slow twitch	Fast twitch
Speed of contraction	Slow	Fast
Force produced	Lower	Higher
Resistance to fatigue	High: contract for long periods	Low: tire quickly as lactate builds up
Main way of making ATP	Aerobic respiration	Anaerobic glycolysis (producing lactate)
Mitochondria	Many	Fewer
Myoglobin (stores oxygen)	A lot, so the fibres look red	Little, so the fibres look pale / white
Capillary supply	Dense	Fewer
Glycogen store	Lower	Higher
Sarcoplasmic reticulum	Less extensive	More extensive: releases Ca^{2+} quickly
Used for	Posture and endurance, e.g. marathon running	Sprinting and lifting heavy weights

Exam tip: Link each structural feature to its function. 'Many mitochondria' is not enough; add 'for aerobic respiration to make ATP for a long time'.

Contraction and the sliding filament theory Spec 7.11

Muscle contracts when the thin actin filaments slide between the thick myosin filaments, pulling the Z lines closer together. The filaments themselves do not shorten.

Roles of the proteins and ions

- **Actin**: thin filament with binding sites for myosin heads.
- **Tropomyosin**: fibrous protein that lies along actin and covers the myosin-binding sites when the muscle is relaxed.
- **Troponin**: a protein attached to tropomyosin that binds Ca^{2+} .
- **Myosin**: thick filament with globular heads that bind actin and act as an ATPase enzyme.
- **Ca^{2+}** : released from the sarcoplasmic reticulum; triggers the change that exposes the binding sites.
- **ATP**: provides energy for the myosin head to move, and allows it to detach.

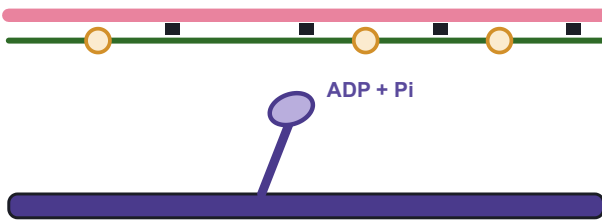
1. An action potential arrives at the neuromuscular junction and spreads along the sarcolemma and down the T-tubules.
2. This causes the sarcoplasmic reticulum to release Ca^{2+} into the sarcoplasm.
3. Ca^{2+} binds to troponin, changing its shape. This pulls tropomyosin away from the myosin-binding sites on actin.
4. A myosin head (with ADP and P_i attached) binds to actin, forming an actin-myosin cross-bridge.
5. The head changes shape, tilting and pulling the actin filament towards the centre of the sarcomere. ADP and P_i are released. This is the power stroke.
6. A new ATP binds to the myosin head, which detaches from the actin.
7. Myosin ATPase hydrolyses ATP to ADP and P_i , releasing energy that returns the head to its original position, ready to bind again further along the actin.
8. Steps 4 to 7 repeat while Ca^{2+} and ATP are available, and the filaments slide past each other.

When stimulation stops, Ca^{2+} is actively pumped back into the sarcoplasmic reticulum using ATP. Troponin returns to its original shape, tropomyosin covers the binding sites again, and the muscle relaxes.

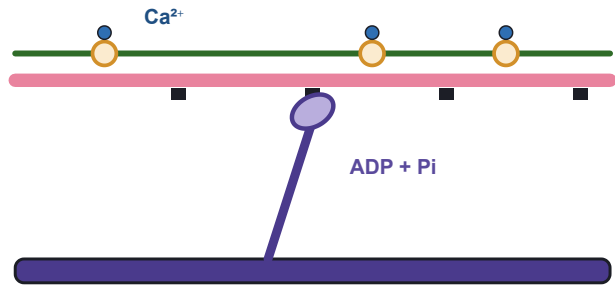
Changes in a sarcomere during contraction	
Part	Change
Sarcomere (Z line to Z line)	Gets shorter
I band	Gets shorter
H zone	Gets shorter (or disappears)
A band	Stays the same length

Common mistake: ATP is needed to detach the myosin head from actin, as well as to move it. Without ATP the heads stay attached, as in rigor mortis.

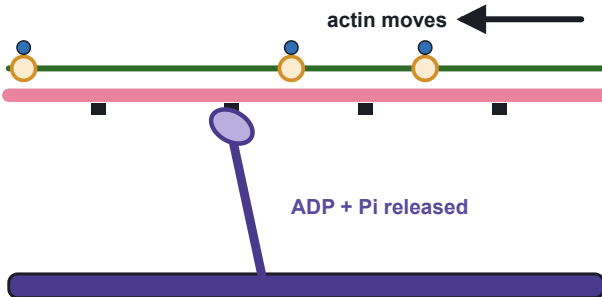
1 Relaxed: tropomyosin blocks the binding sites on actin



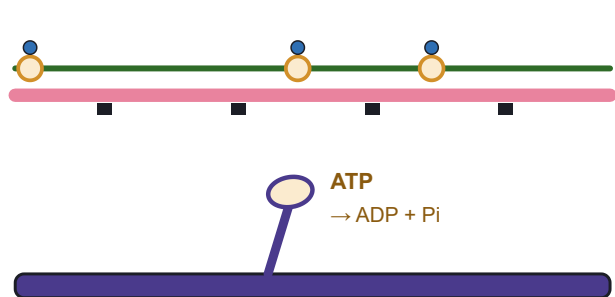
2 Ca^{2+} binds troponin, tropomyosin moves; myosin head (ADP + Pi) forms a cross-bridge



3 Power stroke: head swivels, actin pulled towards the M line; ADP + Pi released

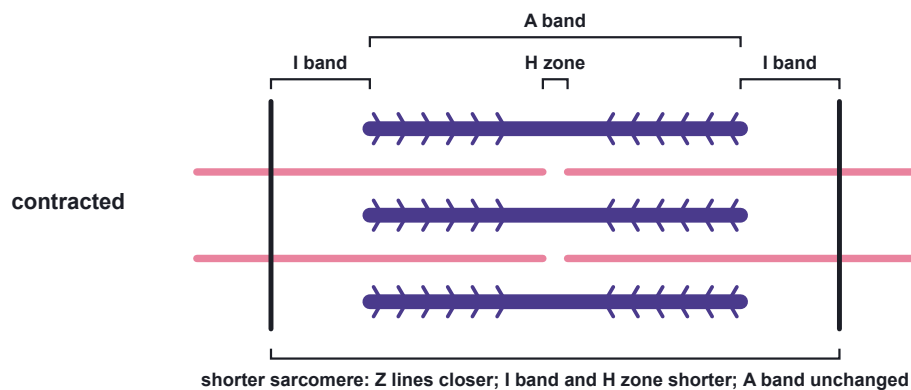
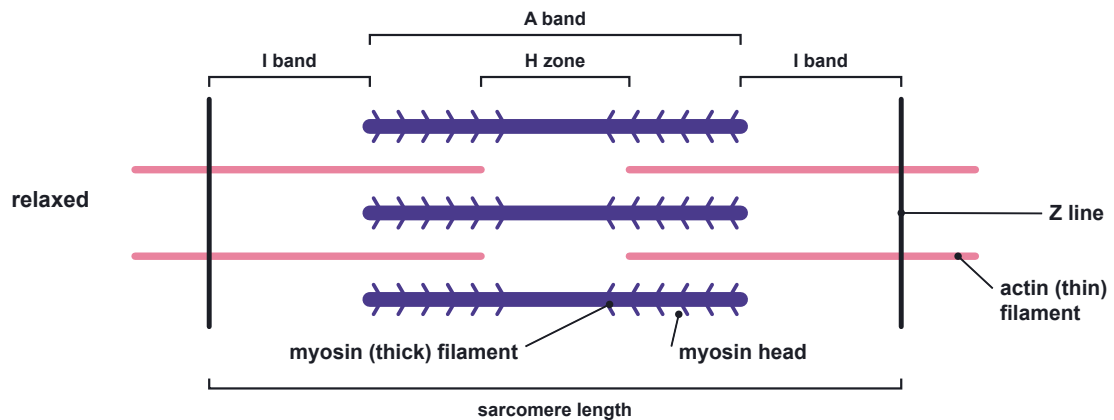


4 ATP binds and the head detaches; ATPase hydrolyses ATP, head re-cocks



actin myosin tropomyosin troponin Ca^{2+} ion myosin-binding site on actin

The **cross-bridge cycle**: calcium ions expose the binding sites, and ATP is needed to detach the head.



In contraction the **I band and H zone shorten**; the A band does not change.

Quick check

- 1 . What is the difference between a tendon and a ligament?
- 2 . What is an antagonistic muscle pair?
- 3 . Which part of a sarcomere stays the same length when a muscle contracts?
- 4 . What does calcium bind to in muscle contraction?
- 5 . Why do fast twitch fibres tire quickly?

Quick check answers

Muscles and movement

1. A tendon joins muscle to bone; a ligament joins bone to bone.
2. Two muscles that have opposite effects at a joint: when one contracts the other relaxes.
3. The A band.
4. Troponin.
5. They use anaerobic respiration, so lactate builds up.