Muscles and movement

How muscles, tendons, bones and ligaments produce movement, the structure of skeletal muscle, fast and slow twitch fibres, and the sliding filament theory.

Movement

Bones form a **skeleton** that supports the body and acts as a lever. At **joints**:

- **Muscles** are attached to bones by **tendons** (inelastic, strong collagen).
- **Ligaments** join **bone to bone**, stabilising the joint (slightly elastic).
- Muscles can only **pull** (by contracting), so they work in **antagonistic pairs**.

In the elbow: the **biceps** (the **flexor**) contracts to bend the arm, and the **triceps** (the **extensor**) relaxes. To straighten the arm, the triceps contracts and the biceps relaxes. The muscle that contracts is the **agonist**, and the muscle that relaxes is the **antagonist**.

Skeletal muscle fibres

A **muscle fibre** is a long, multinucleate cell (a **syncytium**) formed by the fusion of many cells. It contains:

- **Sarcolemma**: the cell surface membrane, which folds into the fibre as **T-tubules**, spreading the action potential through the fibre.
- **Sarcoplasmic reticulum**: a specialised ER that stores and releases **calcium ions**.
- Many **mitochondria** for ATP, and many **myofibrils**.

Myofibrils and sarcomeres

A **myofibril** is a bundle of two types of **protein filaments**, arranged in repeating units called **sarcomeres**.

- **Actin**: **thin** filaments.
- **Myosin**: **thick** filaments, with **myosin heads** (projections).

The **banding pattern** seen with the microscope:

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Band	Description
A band	The **dark** band: the whole length of the **myosin** (including where actin overlaps). Its length is **constant**
I band	The **light** band: **actin only**. It gets **narrower** in contraction
H zone	The centre of the A band: **myosin only**. It gets **narrower** (or disappears)
Z line	The boundary of a sarcomere, where actin is attached
M line	The middle of the sarcomere, where myosin is attached

Sliding filament theory

During contraction, the actin filaments **slide past** the myosin filaments, so the **sarcomere shortens**. The filaments themselves **do not change in length**.

1. An **action potential** spreads along the sarcolemma and down the **T-tubules**, and causes the sarcoplasmic reticulum to **release calcium ions (Ca^{2+})** into the sarcoplasm.
2. Ca^{2+} binds to **troponin** on the actin filament, which changes its shape and moves **tropomyosin** away from the **myosin binding sites** on actin.
3. A **myosin head** (which has ADP and P_i attached) binds to the exposed site on actin, forming an **actin–myosin cross-bridge**.
4. The myosin head **changes shape** (the **power stroke**), pulling the actin towards the centre of the sarcomere, and releases ADP and P_i.
5. A new **ATP** binds to the myosin head, which causes it to **detach** from actin.
6. **ATPase** on the myosin head **hydrolyses** ATP to ADP and P_i, which provides the energy to return the head to its original position (**re-cocking**). It can then bind further along the actin, and the cycle repeats while Ca^{2+} is present.

When stimulation stops, Ca^{2+} is **actively pumped** back into the sarcoplasmic reticulum, tropomyosin covers the binding sites again, and the muscle relaxes.

> **ATP is needed for detaching the myosin head (not for binding) and for re-cocking it, and for the calcium pumps. This is why dead muscles stiffen (rigor mortis): there is no ATP, so the cross-bridges stay attached.**

> TRY IT
>
> Explain why the I band gets shorter, but the A band stays the same length, when a muscle contracts.

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The actin filaments slide in between the myosin, so the region with only actin (the I band) shortens. The A band is the length of the myosin filaments, which do not change length.

Fast and slow twitch fibres

	Slow twitch	Fast twitch
Contraction	**Slow**, sustained	**Fast**, powerful
Fatigue	**Resistant** to fatigue	Fatigue **quickly**
Respiration	**Aerobic**	Mostly **anaerobic** (glycolysis)
Myoglobin	**Lots** (red colour), stores oxygen	**Little** (pale)
Mitochondria	**Many**	Few
Capillaries	Dense network	Fewer
Glycogen stores	Lower	**High**
Creatine phosphate	Lower	High
Use	Posture, **endurance** (marathon running)	**Sprinting**, lifting
Example sites	Back muscles, calf muscle (soleus)	Eye muscles, arm muscles

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