SKELETOMUSCULAR SYSTEM

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MOVEMENT

Movement is an essential function of life and living organisms must possess adaptations to allow for some level of movement to occur. Movement occurs within cells (e.g. cytoplasmic streaming), within organisms (e.g. blood circulation) and to allow for interaction with the external environment (e.g. swimming). **Sessile** organisms are permanently attached to a stable surface and lack any capacity for independent movement (e.g. plants), while **motile** organisms move independently using their own energy supplies (e.g. mammals).

REASONS FOR MOVEMENT

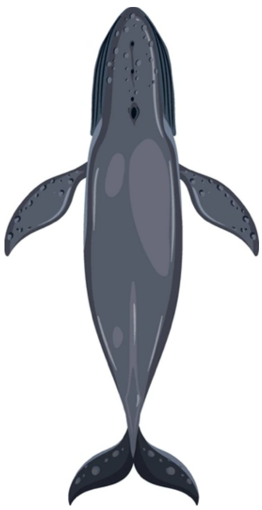
Locomotion is the movement of an organism from one location to another and is used for many purposes:

- *Foraging* (e.g. worker bees spend a significant proportion of their adult lives finding food for the hive)
- *Avoiding danger* (e.g. a squid expels water from a mantle cavity to propulsively escape from predators)
- *Searching for a mate* (e.g. salmon can swim from the ocean to freshwater rivers in order to reproduce)
- *Travel / migration* (e.g. many bird species migrate long distances each year in response to the seasons)

ADAPTATIONS FOR MOVEMENT

Organisms will possess specific adaptations to support a form of locomotion suited to their environment – e.g. marine mammals evolve features to support swimming.

Adaptation	Function
Flippers for limbs	Supports greater control of movement in water (steering)
Improved airways	Dorsal blowholes enable periodic breathing between dives
Streamlined body	Reduces drag in water to increase the speed of movement
Horizontal flukes	Allows for powerful propulsion via up-down movements

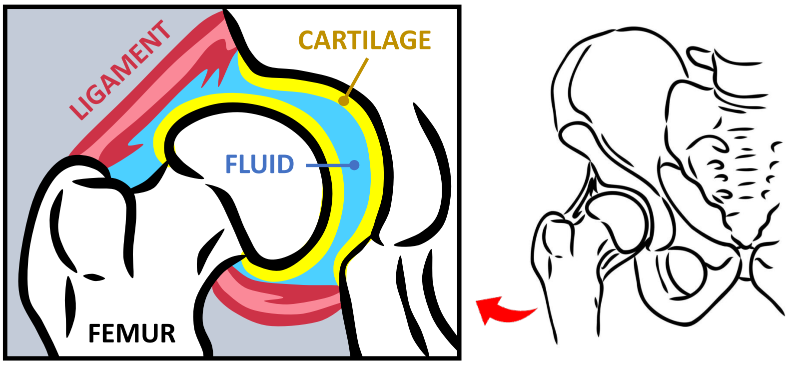


SKELETON

Skeletons are rigid frameworks that provide a surface for muscle attachment and thus facilitate movement. Skeletons can be composed of internal bones (**endoskeleton**) or external segments of chitin (**exoskeleton**). Bones and exoskeletons act as *levers*, moving in response to muscular contractions. Bones are attached to other bones by connective tissues called *ligaments*, while bones are connected to the muscles by *tendons*.

JOINTS

A joint describes the part of the body where two or more bones meet to allow for potential movement. The most common type of joint is a *synovial joint*, which consists of three components – a **joint capsule** to seal the space and provide stability by restricting the range of movements, **cartilage** that lines the bone surfaces to absorb shock and **synovial fluid** which provides lubrication to reduce friction. Different types of joints allow for different ranges of motion, which can be determined using a *goniometer* or *computer analysis*.

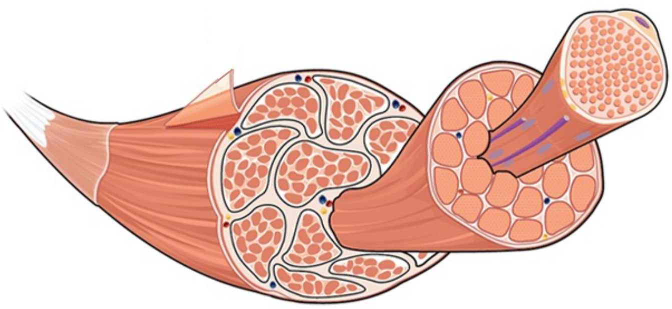


The human hip joint connects the femur and the pelvis and represents a ball and socket joint that enables:

Flexion (up) or *extension* (down)
Abduction (out) or *adduction* (in)
Rotation (twisting on an axis)
Circumduction (circular motion)

MUSCLES

Skeletal muscles consist of tightly packaged **muscle bundles** (fascicles) composed of multiple **muscle fibres**. Each muscle fibre represents a fusion of muscle cells and are therefore *multinucleated*. The membrane that surrounds the muscle fibre is called the *sarcolemma* and the fibres have a specialised ER network called the *sarcoplasmic reticulum*. Muscle fibres contain long protein structures called **myofibrils** which are composed of two myofilaments called *actin* and *myosin*. The myofibrils provide the force for muscular contraction and so are supported by many mitochondria. Muscle fibres are innervated by motor neurons and a **motor unit** represents a single motor neuron and all of the muscle fibres it stimulates (more motor units = ↑ intensity).



Skeletal Muscle Organisation:

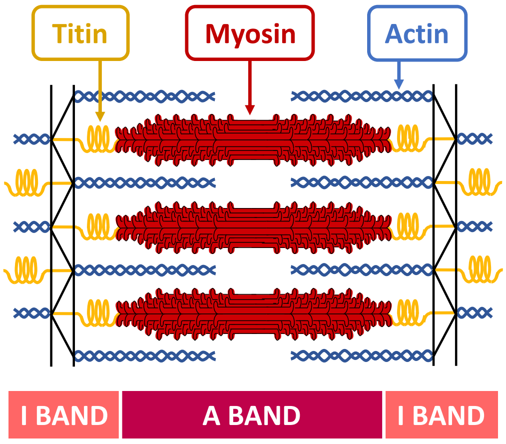
Skeletal muscles consist of *muscle bundles*
Each bundle contains multiple *muscle fibres*
Muscle fibres are composed of *myofibrils*
Myofibrils are proteins composed of two *myofilaments* called *actin* and *myosin*

MUSCLE ACTION

Muscles only do work when they contract – they cannot supply the force needed to length. Consequently, skeletal muscles exist in **antagonistic pairs** to enable opposing movements (when one contracts, the other relaxes). An example of a muscle pair are the intercostal muscles in the ribs which facilitate breathing. The external intercostal muscles contract to pull the ribs outwards (inhalation), while the internal intercostals contract to pull the ribs inwards (exhalation). When one muscle contracts the other muscle is stretched.

SARCOMERES

The myofibrils within muscle fibres are composed of contractile units called **sarcomeres**. Each sarcomere is bordered by **Z lines**, to which actin and myosin attach. Actin filaments are connected directly to the Z lines, while the myosin filaments anchor to the Z lines via the protein **titin**. The myofilament arrangement gives skeletal muscle a *striated* appearance. Darker regions (**A bands**) represent where actin and myosin overlap, while lighter regions (**I bands**) represent areas of actin alone. Individual sarcomeres consists of two lighter I-bands flanking a central darker A-band.

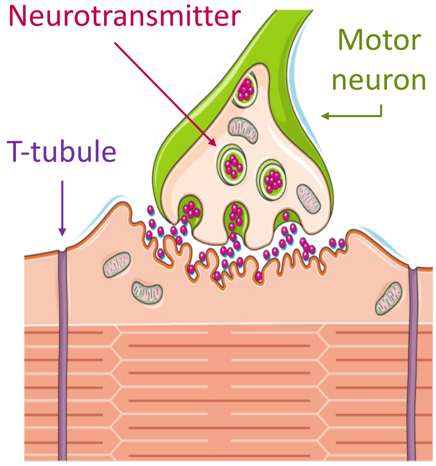


MUSCLE CONTRACTION

Muscular contraction involves the shortening of individual sarcomeres and proceeds via a number of steps:

1. Calcium Ion Release

The contraction of a skeletal muscle begins when an action potential from a motor neuron acts to trigger the release of **acetylcholine** into the neuromuscular junction (synapse). Acetylcholine will result in the opening of ligand-gated ion channels on the sarcolemma, which will cause depolarisation to occur within the sarcolemma. This is spread throughout a muscle fibre via invaginations of the membrane called **T tubules**. Depolarisation will cause the **sarcoplasmic reticulum** to release stores of **calcium ions** into the cytosol, which interacts with myofibrils to initiate muscle contraction. The intensity of the muscle contraction is determined by the number of motor units activated.

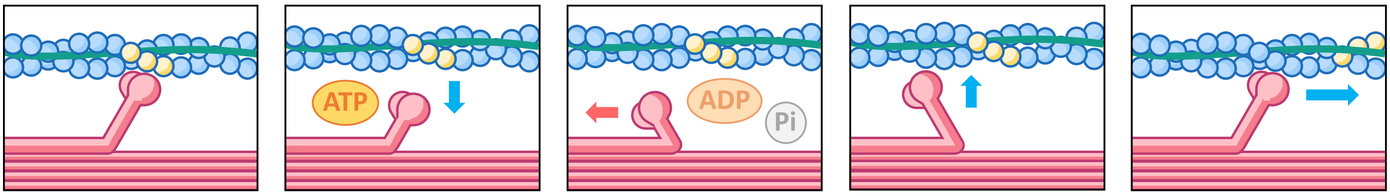


2. Cross-Bridge Formation

The calcium ions bind to a blocking complex located on the actin filaments of the myofibrils. This complex consists of 2 subunits – **troponin** and **tropomyosin**. The ions attach to troponin and displace tropomyosin, which exposes binding sites for myosin. Myosin heads will bind to actin filaments and form a cross-bridge.

3. Sliding Mechanism

ATP binds to the myosin head and breaks the cross-bridge between the two myofilaments. **ATP hydrolysis** causes the myosin head to swivel and move towards the next actin binding site. The myosin head attaches to this new binding site and returns to its original conformation, which will slide the actin along the myosin. This causes actin to pull the Z lines of a sarcomere closer together, shortening the sarcomere (contraction).



MUSCLE RELAXATION

Muscle relaxation relies on **titin**, which connects myosin filaments to Z lines. Titin can store elastic potential energy and is compressed or stretched. When titin recoils, it converts the potential energy to kinetic energy moving the Z lines apart (if compressed) or closer (if stretched). Hence titin supports antagonistic muscles.