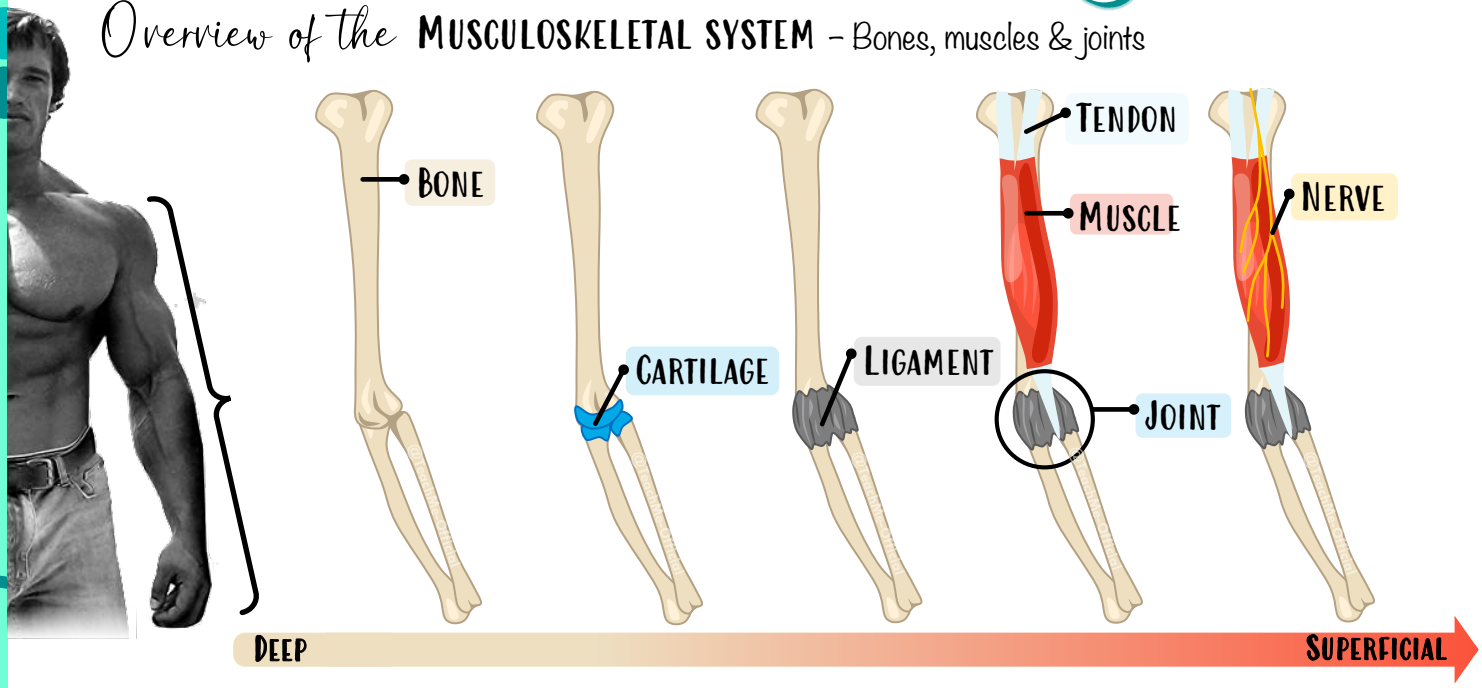
B3.3

Muscles & Motility (HL)

Overview of the MUSCULOSKELETAL SYSTEM – Bones, muscles & joints



BONE
- Provide a strong framework
- Protect vital organs (rib cage protects the lungs and heart)
- Blood cell synthesis (bone marrow)
- Storage of minerals (like calcium)
- Act as levers (for movement)

CARTILAGE
- A smooth protective surface on bones that reduces friction (makes it slippery) to allow smooth movement and absorbs pressure (like a cushion for example in the knee joint)

MUSCLE
- Tissues that provide force by contracting and relaxing to enable movement.

NERVE
- Contains neurons (cells) which stimulate the muscle contraction.

LIGAMENT
- Tough connective tissue that attaches bones to one another (bone to bone)

TENDON
- Connective tissue that attaches each muscle to it's appropriate bone

JOINT
- A place where two or more bones meet. A joint can involve bones, muscle, cartilage, ligament, tendons and nerves.

Why THE NEED FOR LOCOMOTION? (movement)

REASON	ANIMAL	DESCRIPTION
Escape Danger	Flying fish	Escape predators by means of swimming fast and using their very long fins to glide over water.
Foraging for food	Honeybees	Flying from flower to flower to collect nectar and pollen.
Search for mate	Loggerhead sea turtle	Both males and females swim back to the beach where they were hatched to mate and lay eggs.
Migration	Arctic tern	Move from their arctic breeding grounds to the Antarctic region and back each year, to take advantage of available food.
Dispersal	Hoary bat	North American populations have established permanent colonies on the Hawaiian islands.

B3.3

Muscles & Motility (HL)

Endoskeleton

Skeleton (bone) is on the *inside* of the body.
Muscles attach to the outside of their bone.

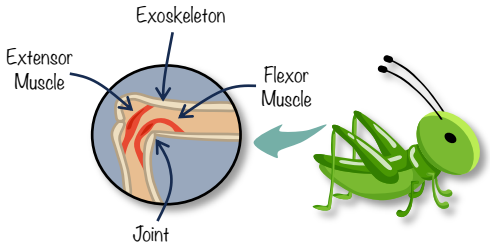
Who?
Vertebrates
(Animal that has a backbone & skeleton)

Examples; Amphibians, reptiles, mammals, and birds...

Exoskeleton

Skeleton (chitin) is on the *outside* of the body.
Muscles attach to the inside of their skeleton.

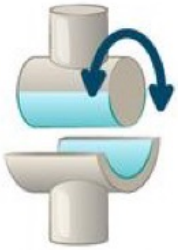
Who?
Arthropods
Examples; Insects



1. Joints

A place where two or more bones meet. A joint can involve bones, muscle, cartilage, ligament, tendons and nerves.

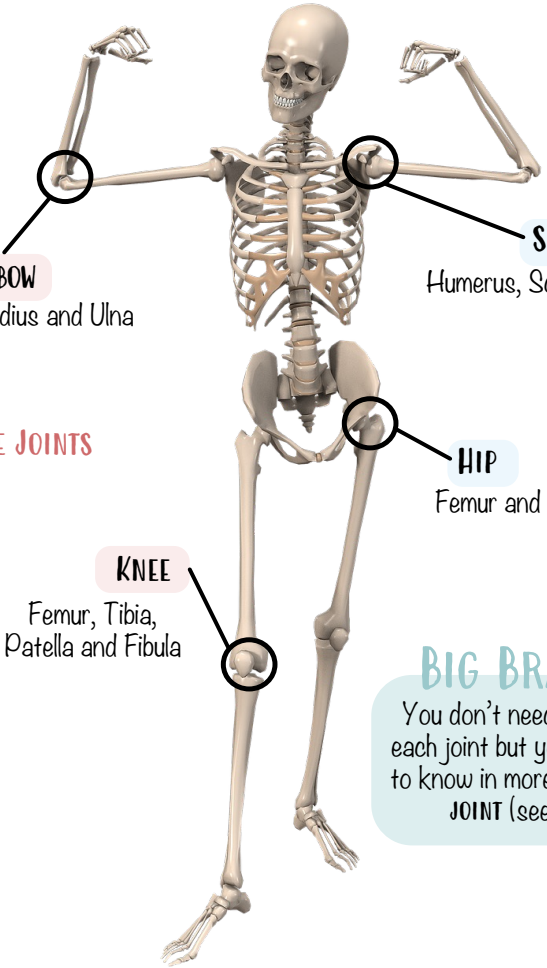
Types of Joints



Hinge Joint
Allows movement in **1** plane

Ball & Socket Joint
Allows movement in **3** planes

Some example of joints and the bones that comprise them;

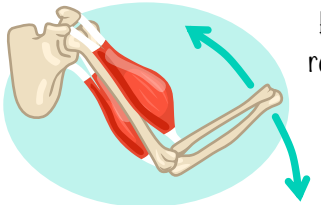


Big Brain Tip!

You don't need to memorize each joint but you are required to know in more detail the **hip joint** (see page 3)

Range of Motion (ROM)

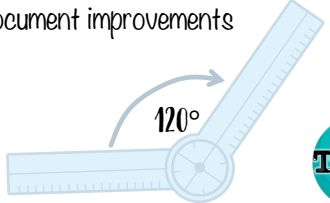
Distance and direction a joint can move (usually measured in degrees)



Bones act as **levers** (a rod able to rotate about a fixed point).

The fixed point is known as a **fulcrum** (joint).

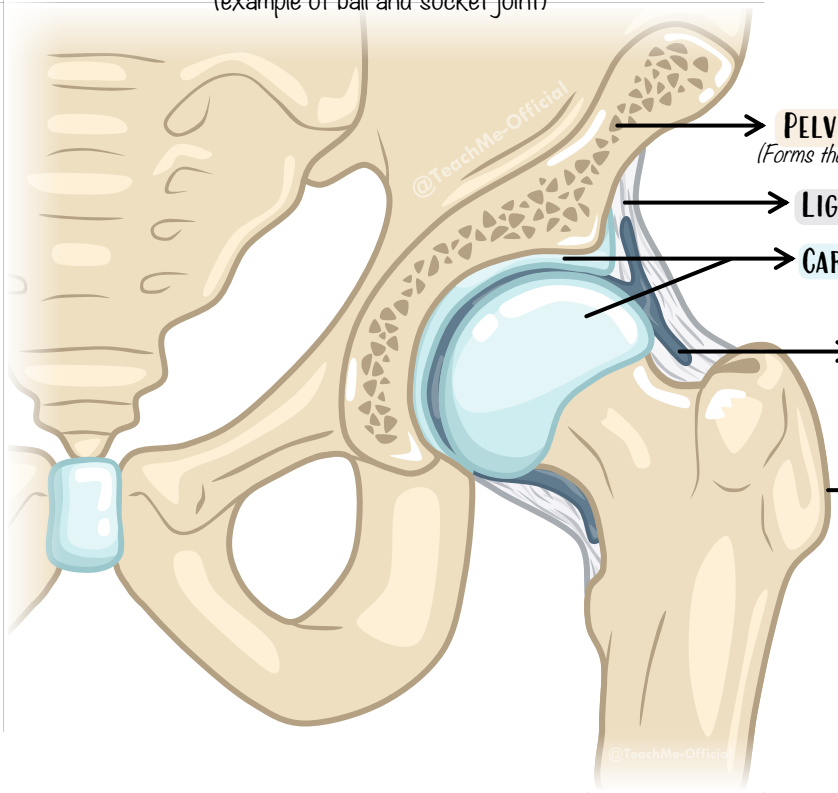
A **goniometer** is used to measure **ROM**, usually to document improvements



Muscles & Motility (HL)

The Hip Joint

(example of ball and socket joint)

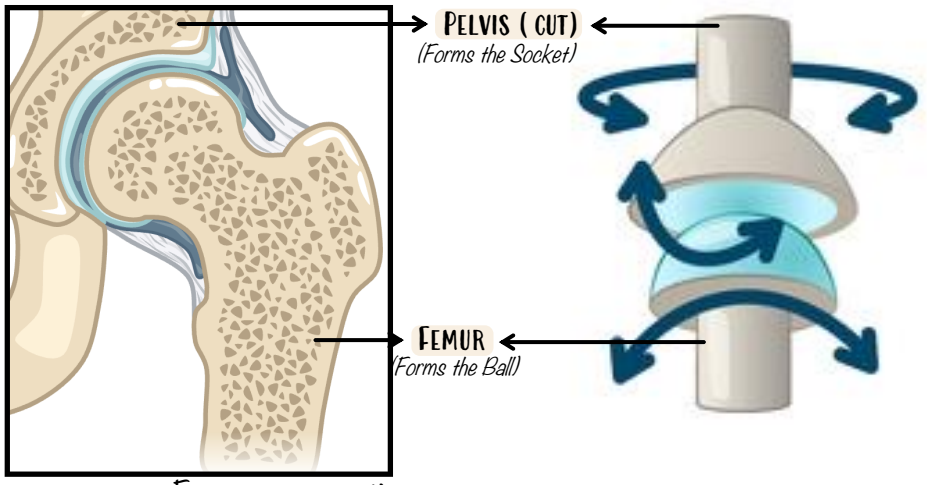


lubricating fluid within the hip joint that reduces friction.

Are not illustrated in this diagram

Big Brain Tip!

For the exam, you do not need to know the name of the ligaments and muscles of the hip. Make sure you know the function of each structure!



Femur cross section

II. Muscles

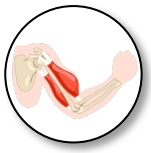
There are three different types of muscles:

Skeletal/Striated	Cardiac	Smooth
Voluntary contraction	Involuntary contraction	Involuntary contraction

We focus on the structure and function of **striated (skeletal) muscle;**

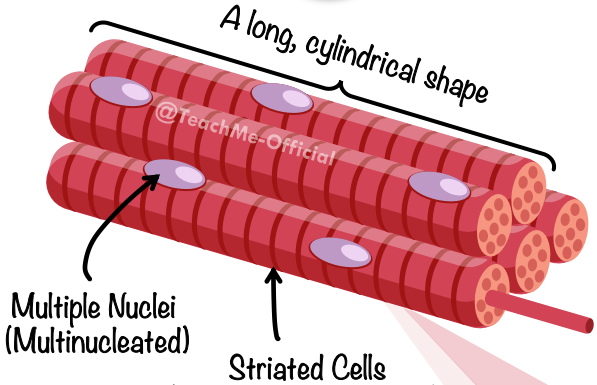
Muscles & Motility (HL)

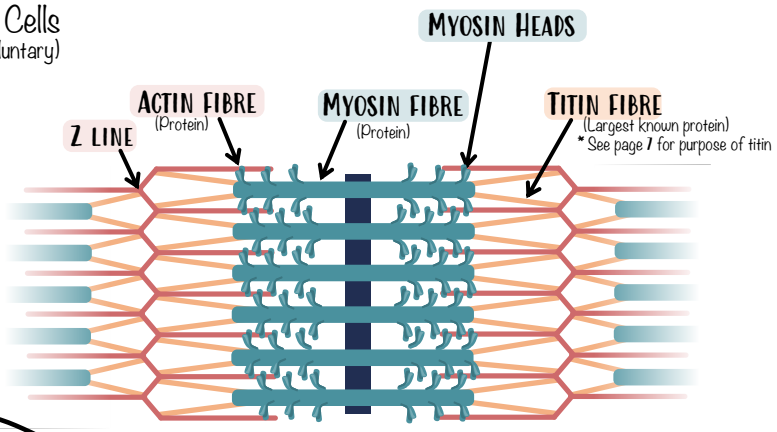
Structure

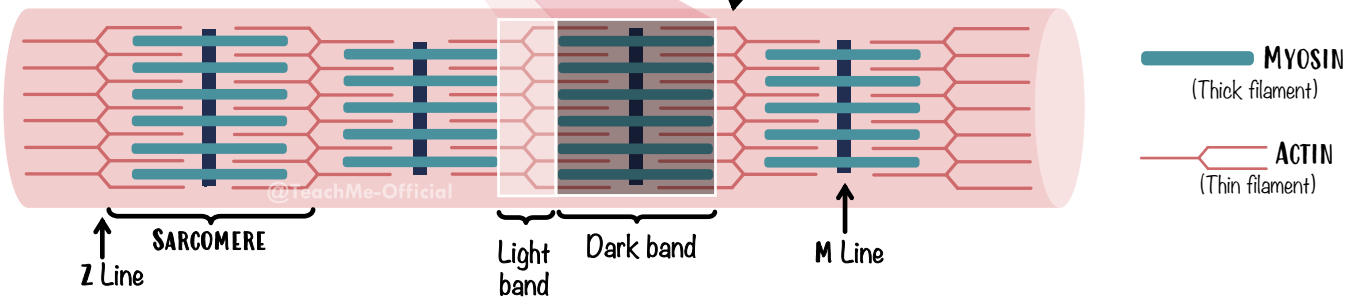


Muscle fibers (cells)

Skeletal Muscle Cells
(Occur on skeleton, voluntary)



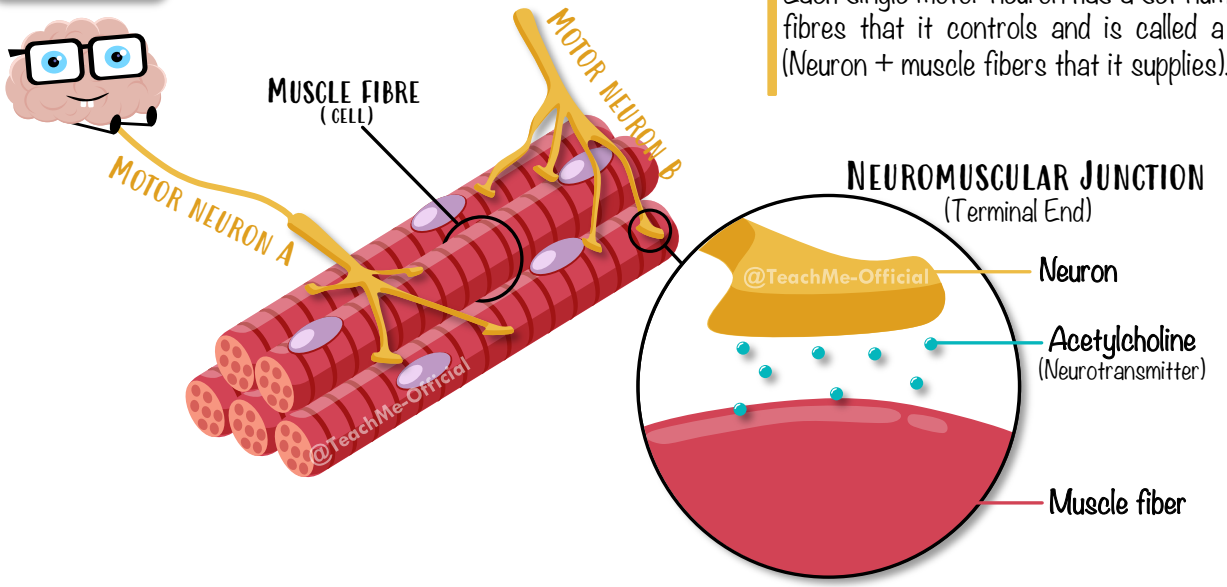




Function

What causes the muscles to contract?

Each single motor neuron has a set number of muscle fibres that it controls and is called a **motor unit** (Neuron + muscle fibers that it supplies).

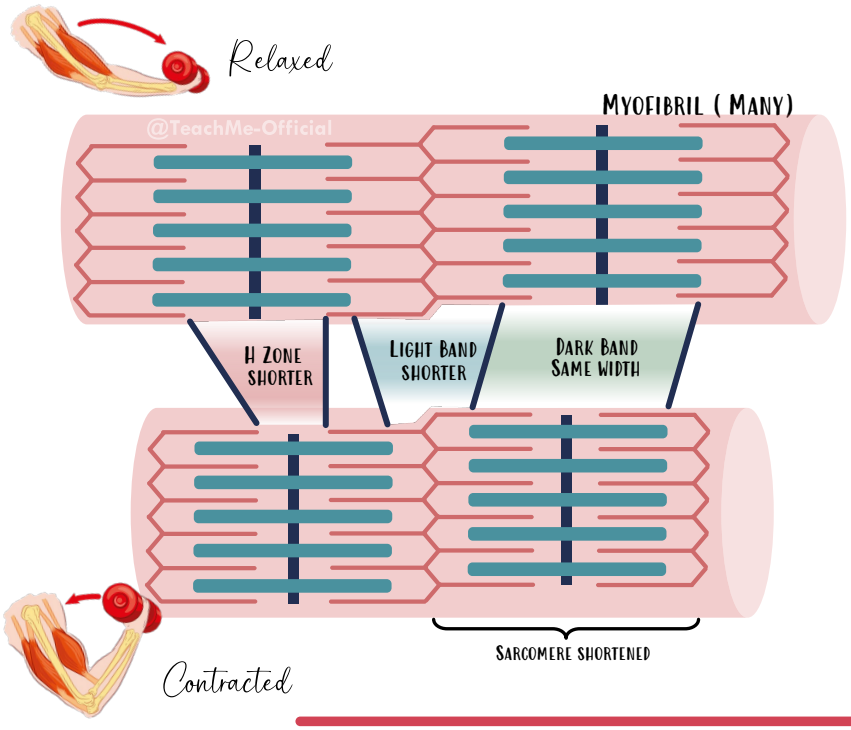


- At **low intensity** activities, only few motor neurons are required (for example only neuron **A**)
- At **high intensities**, more motor neurons are recruited (for example both neurons **A** and **B**)
  -> If a load is heavier than anticipated, additional motor units are recruited to generate the necessary force.

Muscles & Motility (HL)

Sliding Filament Theory

Actin filaments slide over the myosin fibres. This results in each sarcomere shortening.



During contraction;

- The filaments (thick & thin), do not change length.
- The sarcomere gets shorter.
- Myosin filament stays still, actin moves.
- The dark band stays the same.
- The light band decreases.
- The H zone gets shorter.

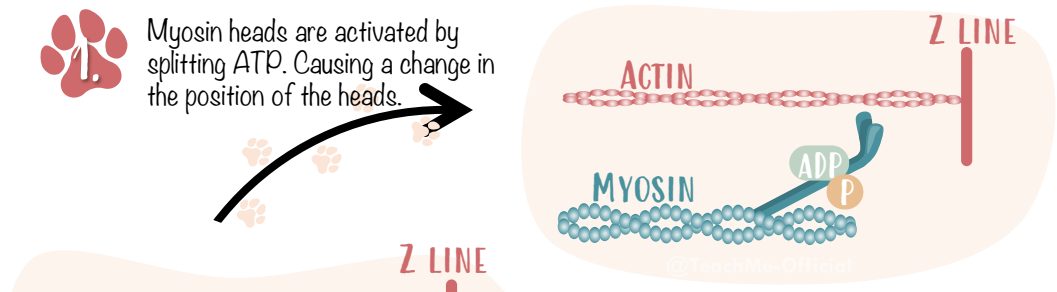
Did you know?

The nerve signal causes the actin filaments to become available for the myosin heads to bind to them. (The nerve signal cause release of Calcium in the muscle cell, which causes the actin filaments to be exposed)

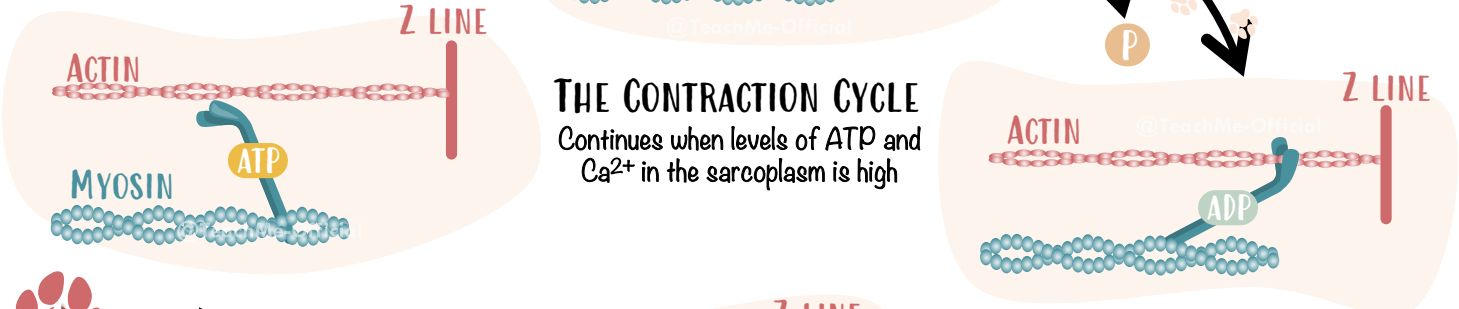
The Contraction Cycle

Continues when levels of ATP and Ca^{2+} in the sarcoplasm is high

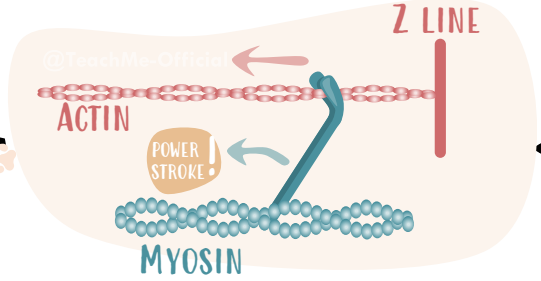
1. Myosin heads are activated by splitting ATP. Causing a change in the position of the heads.



2. Myosin heads attach to the exposed binding sites of actin to form cross-bridges. Inorganic phosphate is released.



3. As myosin forms cross-bridges, ADP is released, and the myosin bends due to loss of energy. The bending is towards the center of the sarcomere ad the actin is moved inwards.



4. Myosin binds to ATP and this allows detachment of the myosin heads from the actin attachment sites.

After death, as ATP is not being generated anymore and thus myosin heads cannot detach from the actin binding sites, resulting in the muscle staying rigid: called **Rigor Mortis**. It starts to decrease about 36 hours after death as the proteins degenerate.

Muscles & Motility (HL)

Summary

Muscle Contraction Process

Big Brain Tip!
This process could be asked to be described in your final exam!

I. Nerve impulse arrives at the end of the motor neuron.

II. Neurotransmitter (acetylcholine) released, causing action potential in muscle. Results in sliding filament model (see steps 3-6).

III. Binding of ATP to myosin causes its release from its current attachment to actin.

IV. Conversion of ATP to ADP and Pi causes myosin heads to change angle. Release of Pi results in attachment to new site on actin filaments (cross-bridges).

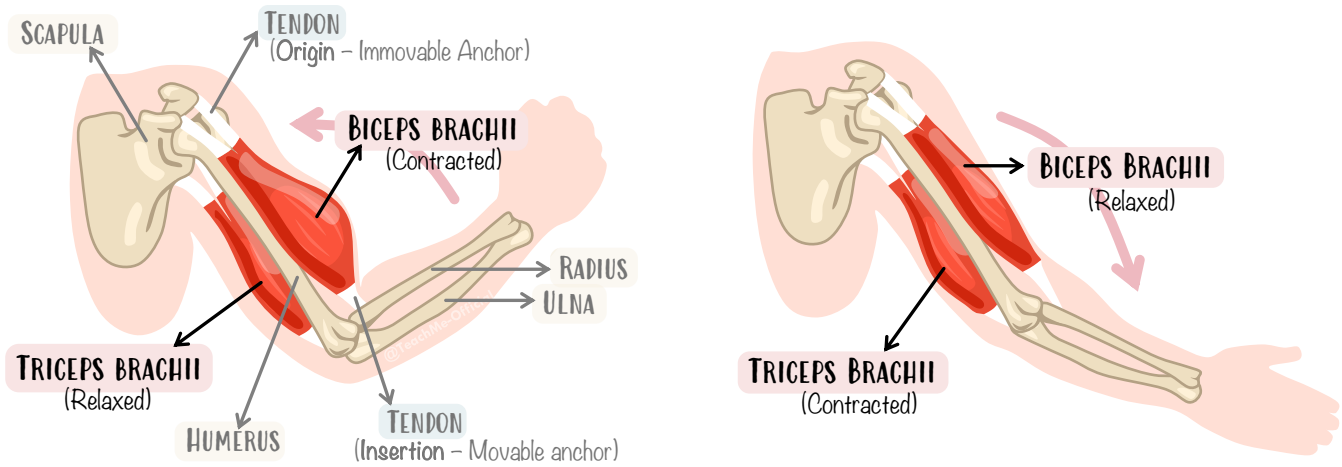
V. The release of ADP results in the myosin heads pulling the actin filaments towards the center of the sarcomere (Power stroke).

VI. Cycle repeated (ATP binds to myosin to release it from current position).

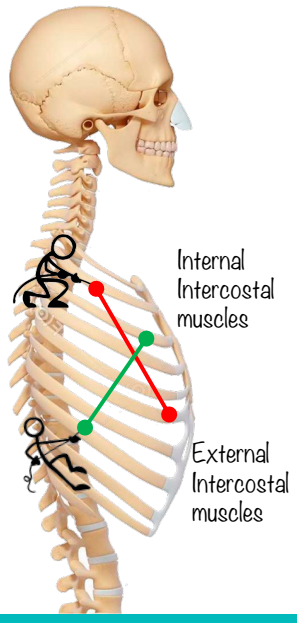
Antagonistic Muscle Pairs

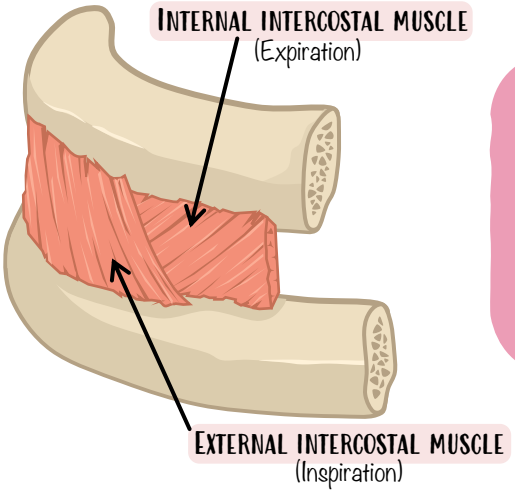
[Muscles that have the opposite function with contraction]

Example 1 – **Triceps brachii** and **biceps brachii** in the arm

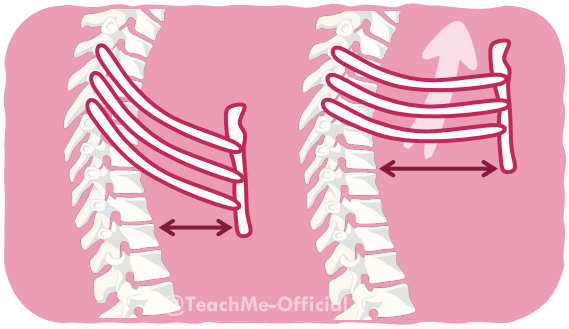


Example 2 – **Internal and external intercoastal muscles*** between ribs





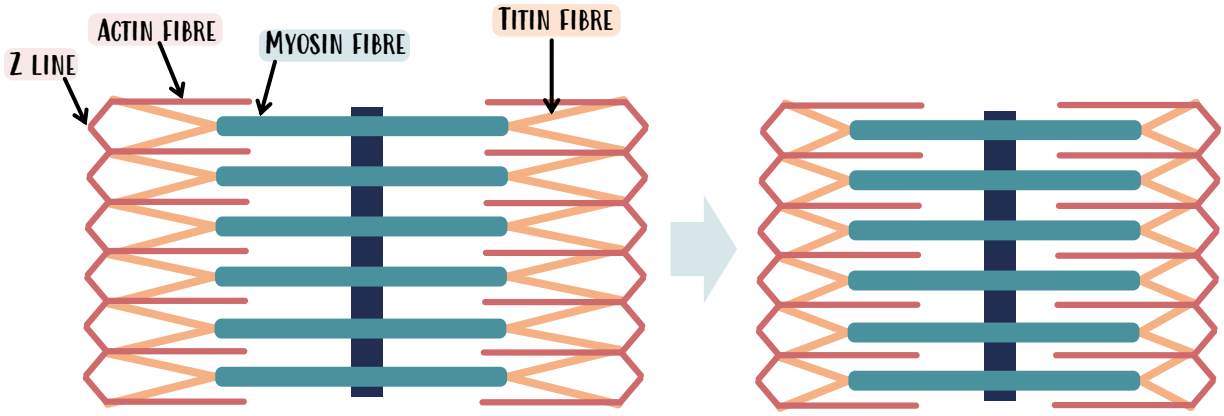
These muscles exert opposite direction of force to expand and reduce the size of the thorax during respiration.



*More details on these muscles can be found in section **B3.1**

Muscles & Motility (HL)

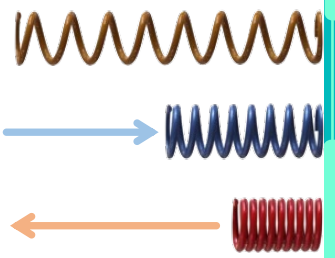
Role of Titin in the sarcomere structure



When sarcomeres shorten during a contraction, two sides of each sarcomere move towards the center. This creates a spring-like tension in titin that is released when the muscle relaxes (**recoil**). This allows each sarcomere of the muscle to undergo a contraction once again. Therefor helps with contraction indirectly.

When a muscle contracts, the antagonistic muscle stretches (titin stretches) resulting in potential energy in titin (**recoil**).

Holds myosin fibres in place in the sarcomere and prevents muscle fibers **overstretching**.

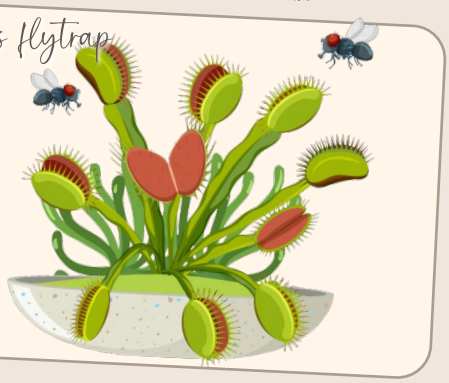


Adaptations for movement

Sessile Organism

Organisms that cannot move from place to place but are still able to alter their body for in response to environmental stimuli.

Venus flytrap



- Live in mineral deficient soil (such as nitrogen).
- Hairs in between the leaves (creating a trap) are triggered by insects crawling or flying.
- The leaves close and trap the insect, whic starts getting digested by enzymes produced by the plant.
- Photosynthesis is STILL main mode of nutrition.

Motile Organism

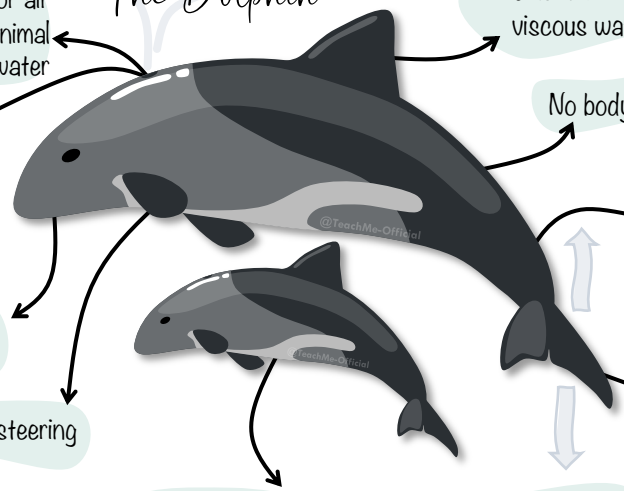
Organisms that have adaptations allowing movement within their habitat.

Brown-throated three-toed sloth

- 4h per kilometer or 24 min per 100m
- A month to process an ingested leaf
- Defecate once a week (a third of its body mass)
- Body is adapted to move using a pulling motion, ideal for hanging on branches

Muscles & Motility (HL)

Swimming Adaptations



BLOWHOLE on top surface of the head for air exchange at periodic intervals and with minimal amounts of the body exiting the water

Closed when underwater to prevent water for entering

Can stay **UNDERWATER** for several minutes - allows deep dives

Front legs as **FLIPPERS** for steering

STREAMLINED body to move through viscous water at high speeds

No body hair to reduce drag in water

No rear legs (replaced by fluke)

FLUKE TAIL – up and down motion for propulsion

Maintained **MAMMALIAN** characteristics: endothermic, milk production, two-sided circulatory system and long-term parental care of the young

notes