HL IB Biology

Your notes

Muscle & Motility

Contents

Your notes

Adaptations for Movement (HL)

Adaptations for Movement

- Movement is a unifying feature of all living organisms
- The way in living organisms move varies hugely with some organisms being more **motile** and others being more **sessile**

Motile Organisms

- **Motile organisms** are those that are capable of **moving from place to place** (you will be familiar with many organisms that have this trait)
- Note that **all** motile organisms can **also exhibit movement shown by sessile organisms,** this means that internal parts of their bodies can move in response to stimuli e.g. peristalsis in the digestive system
- Many living organisms are motile, such as the majority of members of the **animal kingdom,** many bacteria, particularly those which are predatory

Sessile Organism

- Sessile organisms **cannot move from place to place** but are able to move parts of their body in response to **environmental stimuli**
- This type of movement might include orientation of plant stems towards the sun or movement of cytoplasm within a unicellular organism
- Some animals are sessile including:
  - **Sponges, corals** and **anemones**
  - Most **fungi** species
  - **All plant species**

Examiner Tip

You are required to know **one example of a motile species** and **one example of a sessile species** for your examination.

Your notes

Mechanism of Muscle Contraction (HL)

Sliding Filament Model

The structure of skeletal muscle

- Muscles in the body that are attached to the skeleton and aid movement are called **skeletal muscles**
- Skeletal muscle is **striated** as it has a stripy appearance when viewed under a microscope
- Striated muscle cells are bundled up into **fibres**
- The fibres are highly specialised cell-like units
  - Each muscle fibre contains:
    - An organised arrangement of **contractile proteins** in the cytoplasm
    - **Many nuclei** – this is why muscle fibres are not usually referred to as cells
    - Specialised endoplasmic reticulum called the **sarcoplasmic reticulum** (SR) which stores calcium and conveys signals to all parts of the fibre at once using protein pumps in the membranes
    - Specialised cytoplasm called the **sarcoplasm** contains **mitochondria** and **myofibrils**
      - The mitochondria carry out **aerobic respiration** to generate the ATP required for muscle contraction
      - Myofibrils are bundles of **actin and myosin filaments**, which slide past each other during muscle contraction

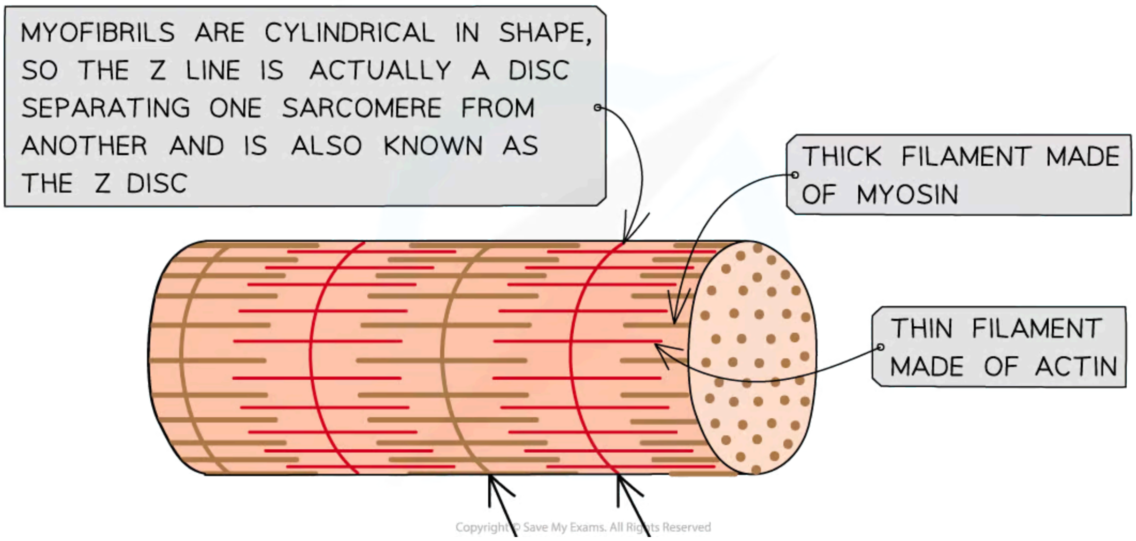
Myofibrils

- Myofibrils are located in the **sarcoplasm**
- Each myofibril is made up of two types of protein filament:
  - **Thick filaments** made of **myosin**
  - **Thin filaments** made of **actin**
- These two types of filament are arranged in a particular order, creating different types of **bands and lines**

Part of Myofibril	Description
H band	Only thick myosin filaments present
I band	Only thin actin filaments present
A band	Contains areas where only myosin filaments are present and areas where myosin and actin filaments overlao
M line	Attachment for myosin filaments

Z line	Attachment for actin filaments
Sarcomere	The section of myofibril between two Z lines

Structure of a Myofibril Diagram



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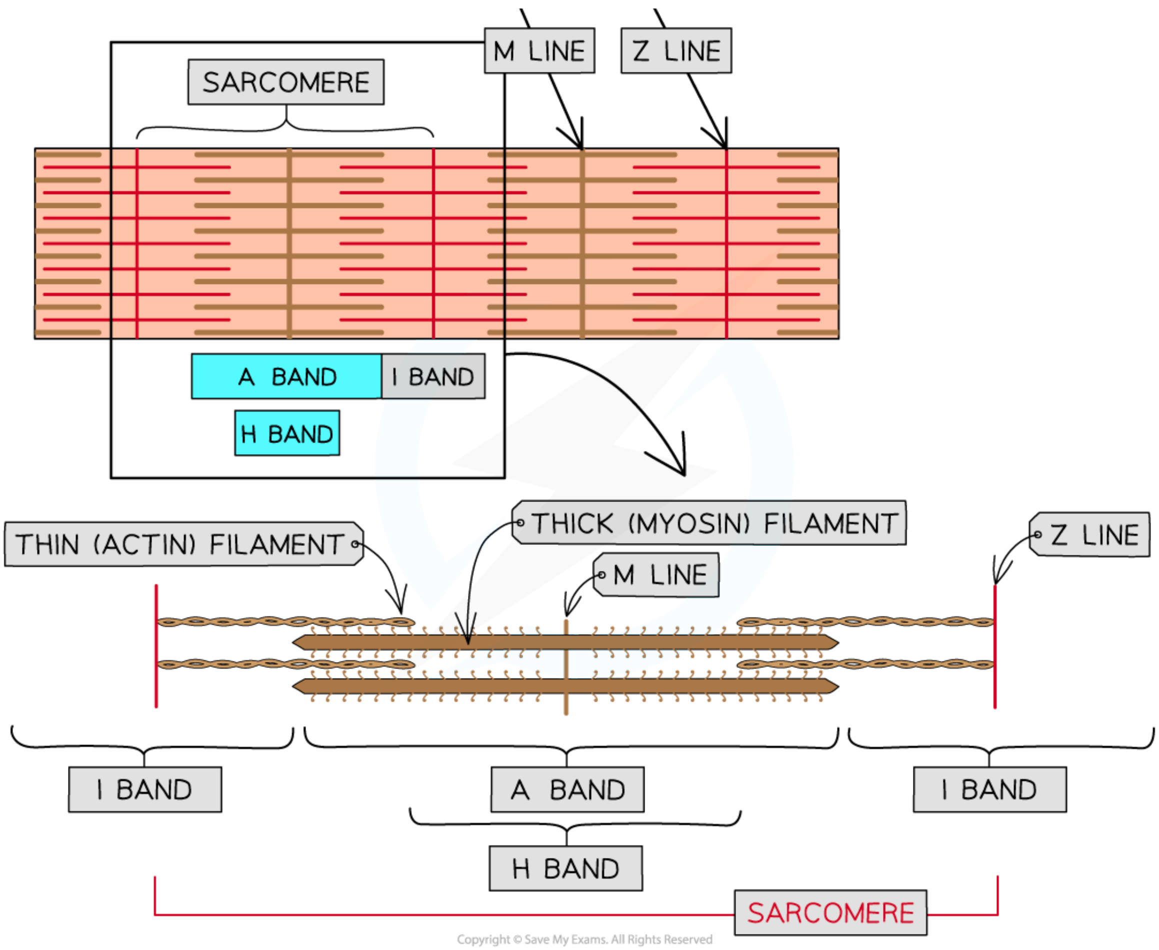

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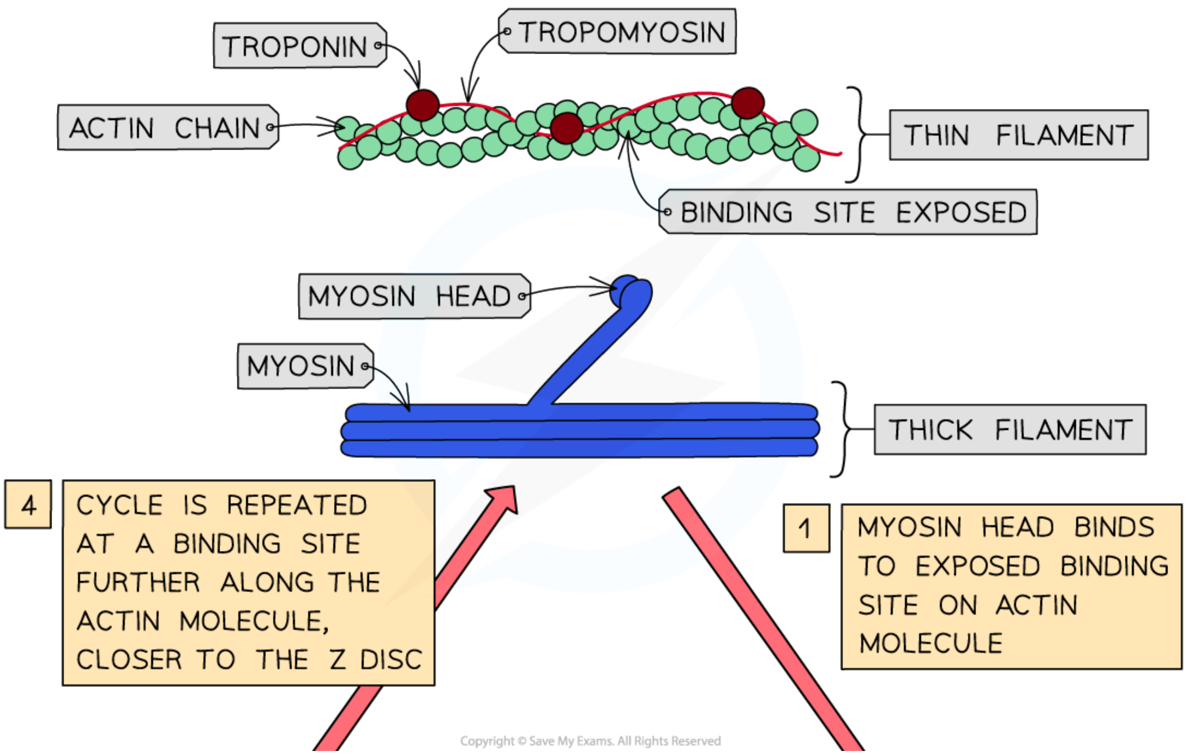
Sliding Filament Model

- The **thick filaments** within a myofibril are made up of **myosin** molecules
  - These are **fibrous protein** molecules with a **globular head**
  - The fibrous part of the myosin molecule **anchors** the molecule into the thick filament
  - In the thick filament, many myosin molecules lie next to each other with their globular heads **all pointing away from the M line**
- The **thin filaments** within a myofibril are made up of **actin** molecules
  - These are **globular protein** molecules
  - Many actin molecules link together to form a **chain**
  - **Two actin chains** twist together to form **one thin filament**
  - A fibrous protein known as **tropomyosin** is twisted around the two actin chains
  - Another protein known as **troponin** is attached to the actin chains at regular intervals
- Muscles cause movement by contracting
  - During muscle contraction, **myosin heads form cross-bridges** by binding with sites on the actin filaments

- The myosin heads then **change orientation** which **pulls the actin filaments** so that they **slide** next to the myosin.
- This is called a **power stroke**
- **Sarcomeres** within myofibrils **shorten** as the Z lines are pulled closer together

Sliding Filament Model Diagram



Your notes

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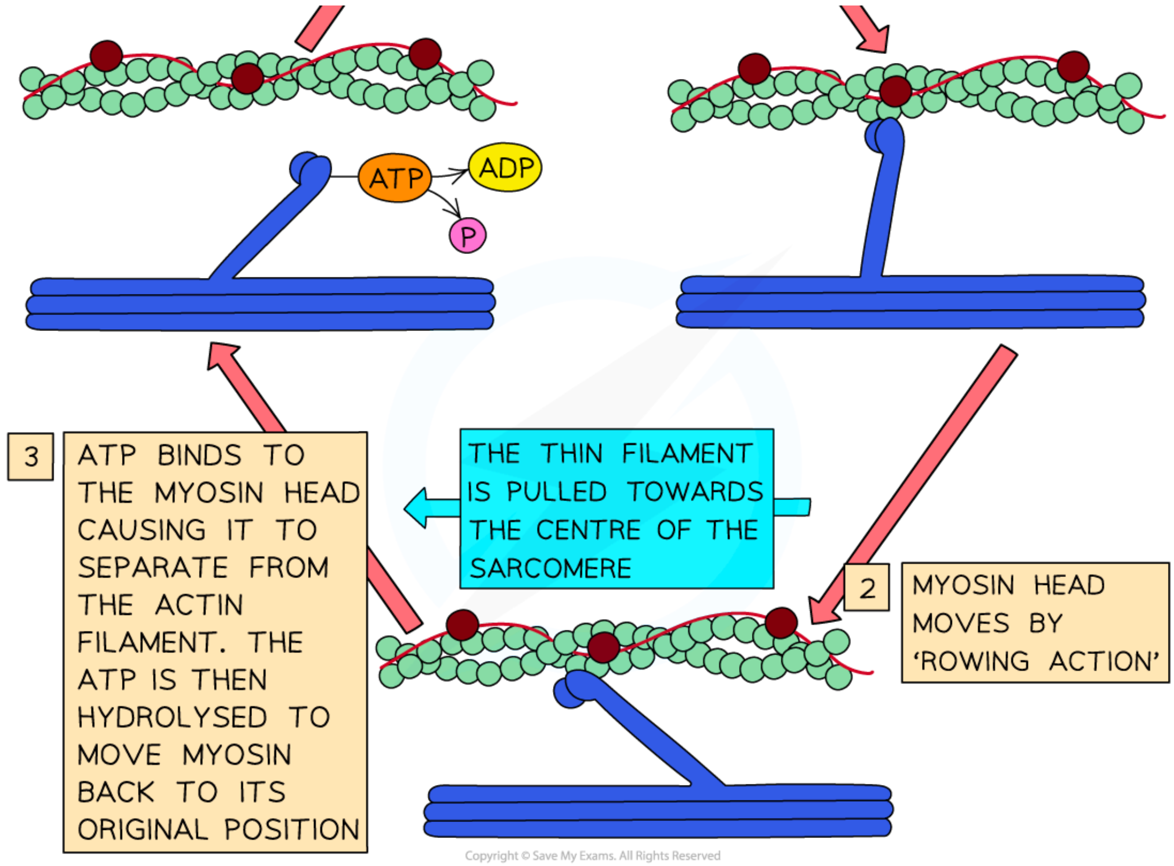
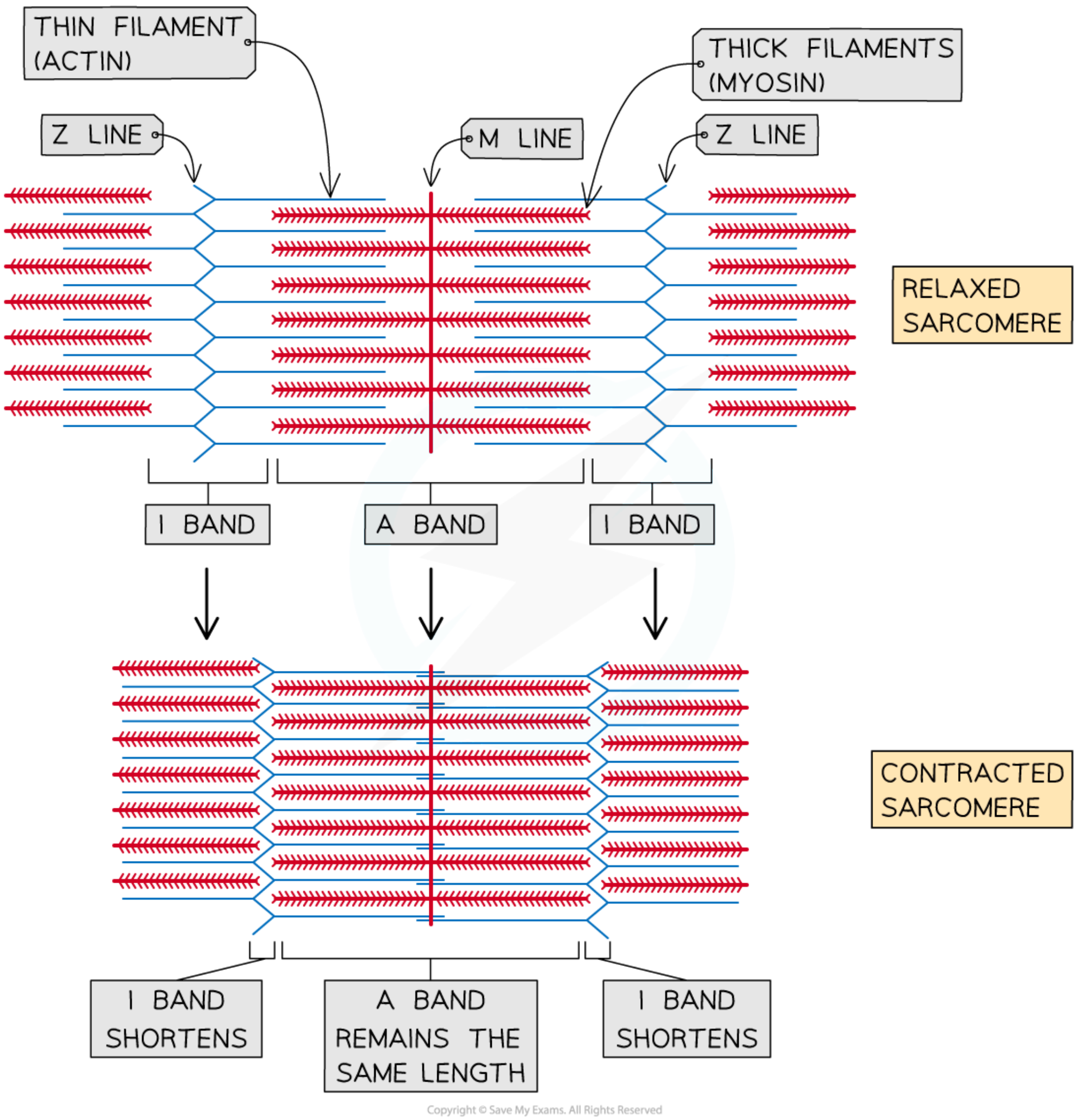


Sarcomere Muscle Contraction Diagram

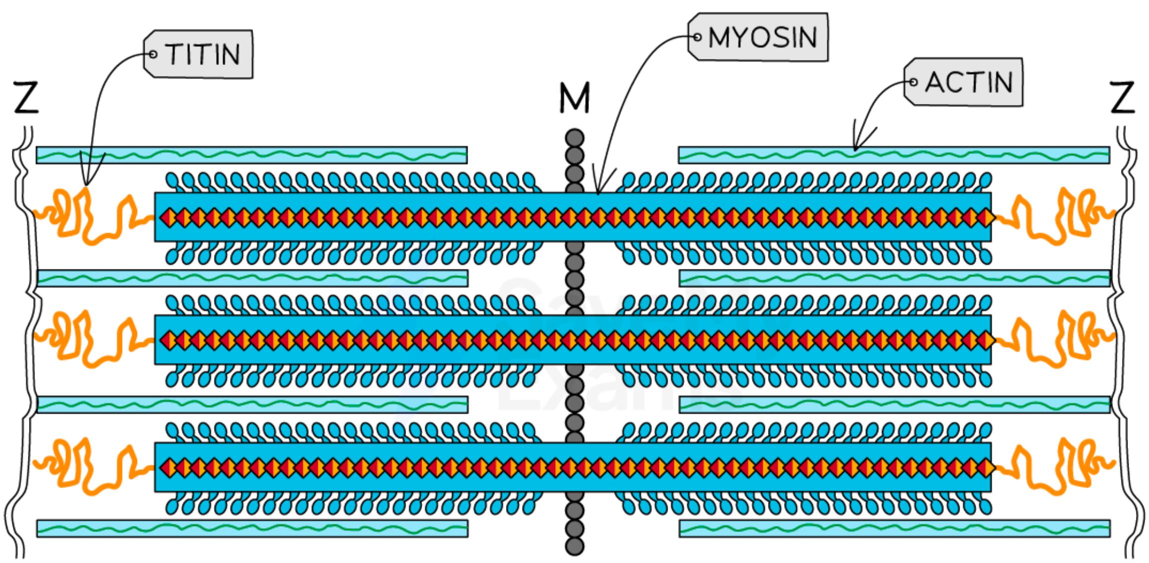


When the muscle contracts, the sarcomere shortens due to the sliding of the actin and myosin filaments.

Muscle Relaxation

- Muscles are only capable of contracting or **pulling,** they cannot push
- As a result of this limitation muscles generally operate in **pairs**
- A muscle pulls in one direction **at a joint** and the other muscle **pulls in the opposite direction**
  - This is described as **antagonistic** muscle action
- Muscles **maintain posture** by antagonistic muscles **both contracting at joints** to keep the joint at a certain angle
  - This is known as **isometric contraction** - a muscle contraction without motion
- Muscle contraction and relaxation relies on a protein called **titin**
  - Titin is a **large protein** that joins the ends of the myosin filaments to the z-line
  - The many folds in the titin molecule give **spring like properties** which aid muscle contraction
  - In a **relaxed muscle**, the sarcomere lengthens and the titin is stretched out
    - Titin stores **chemical energy** within the structure when it is stretched
    - The presence of titin **prevents overstretching**
  - During **muscle contraction**, the sarcomeres shorten and titin proteins **recoil** releasing the stored chemical energy
    - Energy released from titin adds to the **force of the contraction**

Sarcomere Relaxed Diagram



The sarcomere is relaxed and the titin spring like properties can be seen

Your notes

Skeletal Muscle (HL)

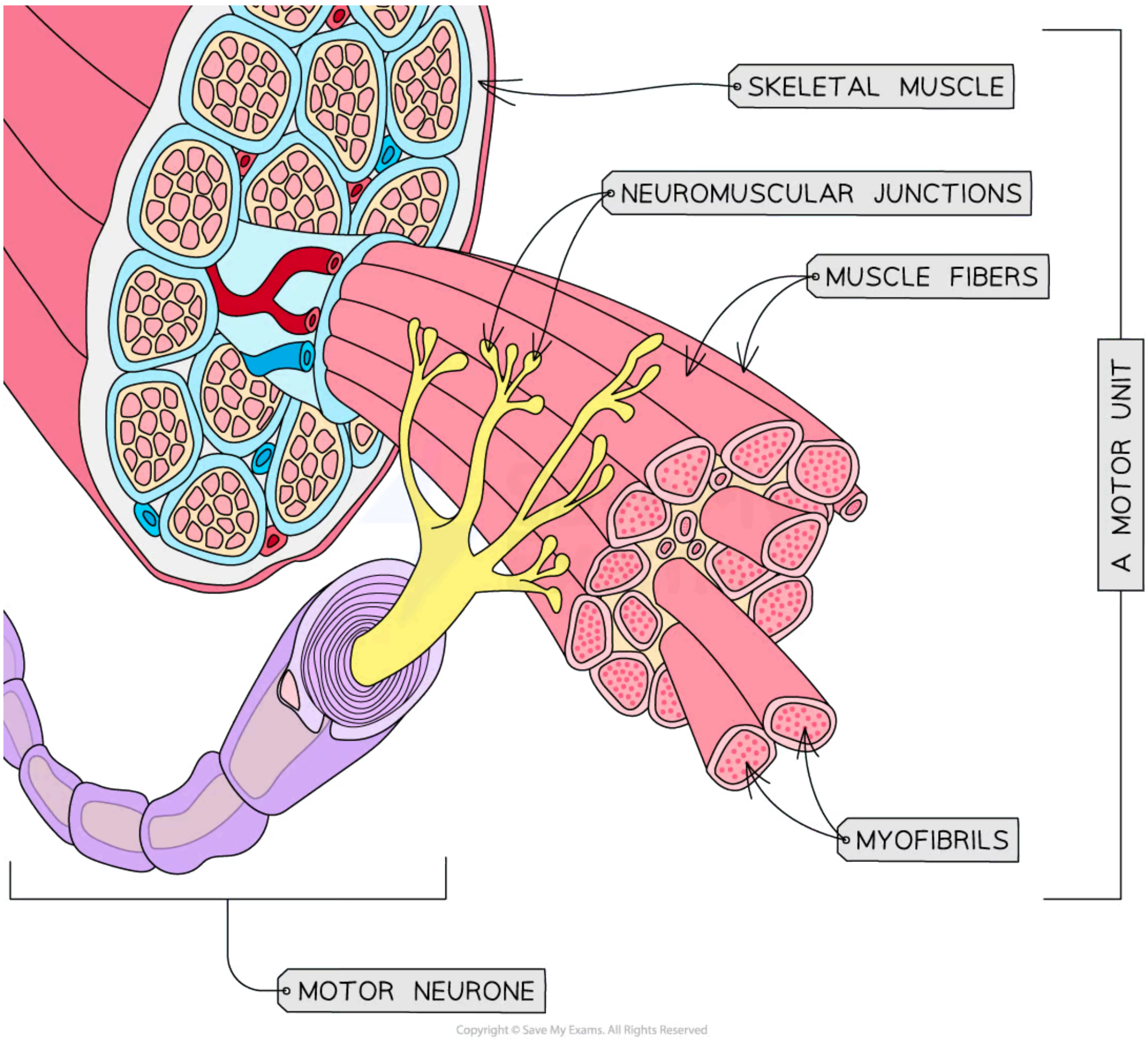
Your notes

Skeletal Muscle

- Skeletal muscle **contracts** when it receives an **impulse** from a **motor neurone** via the **neuromuscular junction**
  - Neuromuscular junctions work in a very similar way to synapses
  - They are located **between a motor neurone and a muscle cell**
- The collection of a motor neurone, the skeletal muscle fibers, the neuromuscular junctions between the neurone and the muscle fibres form a **motor unit**
- There are multiple neuromuscular junctions spread across several muscle fibres within the motor unit and this varies the intensity of muscle contraction
  - During a **low intensity** muscle contraction, a **low number** of motor units are activated
  - For a **high intensity** contraction, **more motor units** receive impulses

Motor Unit Diagram

Your notes



The motor unit of skeletal muscle consists of a motor neurone, muscle fibres, and neuromuscular junctions

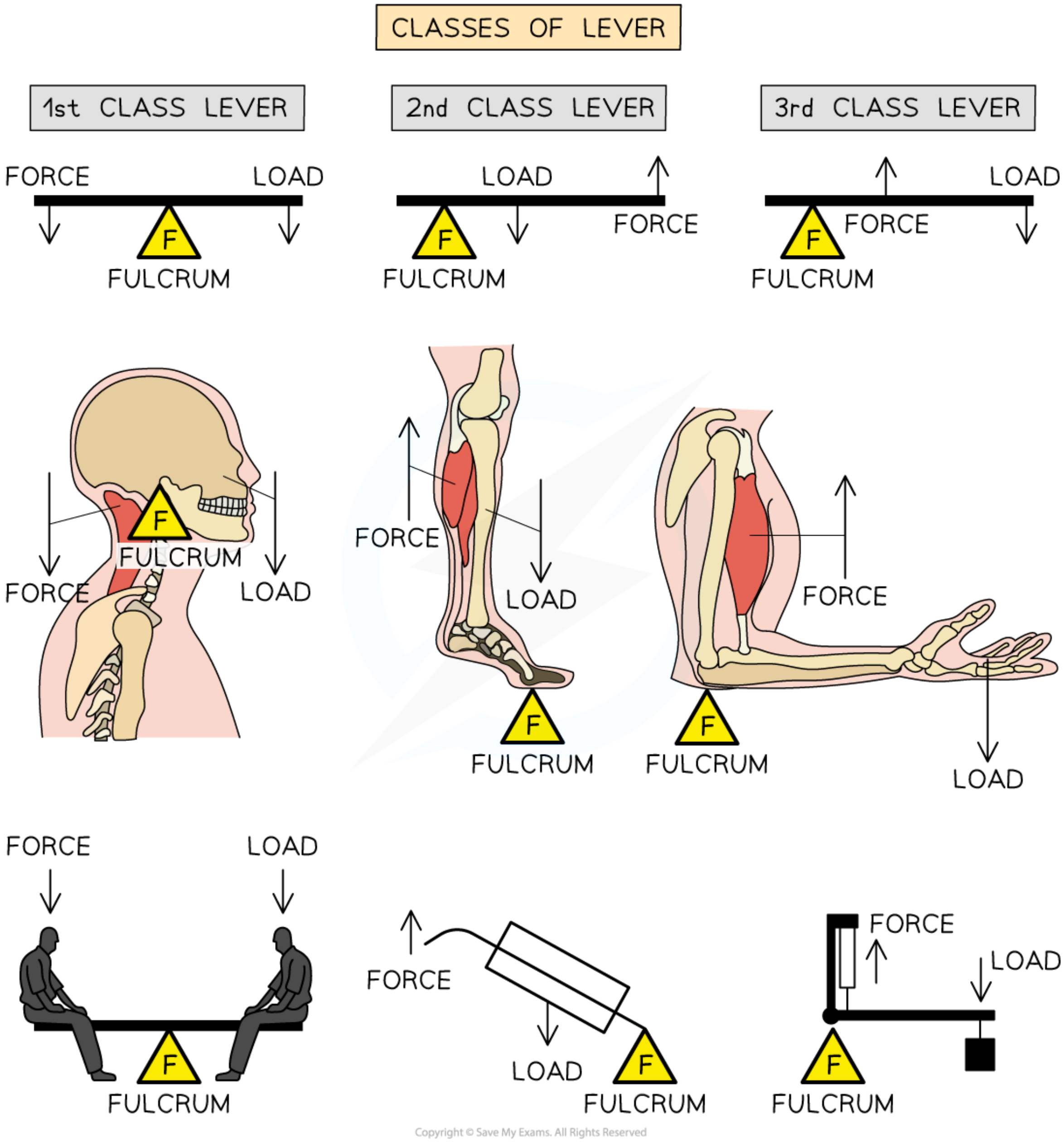
Requirements for Movement (HL)

Your notes

Role of The Skeleton in Movement

- The effective movement of the human body requires both **muscle** and an **incompressible skeleton**
- Bones and exoskeletons provide **anchorage for muscles** and **act as levers**
- **Vertebrates** have **internal bones,** called an **endoskeleton,** to support their bodies from the inside with tissues surrounding the bone
- Many organisms, such as **arthropods**, have **external skeletons** called **exoskeletons** which are found on the **outside of the organism** to protect the internal tissues
- **Arthropods that have exoskeletons** include:
  - Crustaceans
  - Insects
  - Arachnids
  - Centipedes and millipedes
  - Molluscs
- Exoskeletons are made of polysaccharides called **chitin**
- Key features of both exo and endo skeletons is that they **provide support for the body** of the organism whilst also **facilitating movement**
  - Exoskeletons also provide **protection** for the body's soft tissues within
- **Muscles** are anchored to the skeleton either on the inside (as with exoskeletons) or the outside (as with endoskeletons) and the presence of pivot points means that **skeletons act as levers** transferring the size and direction of force
  - Levers have a point of **effort**, a point of **load** and a **pivot point** called the fulcrum
  - These same three features are seen in skeletons

Levers and Skeleton Diagram



Muscles attach to bones at the joints creating a system of levers

- Arthropod **exoskeletons** also use the mechanisms of **leverage** in the same way as animals use with endoskeletons
- They utilise jointed legs and jointed body parts with muscles attached in **antagonistic pairs**

Your notes

Synovial Joints

- **Synovial joints** are the most common type of joint in the human body
- They are characterised by a **joint cavity filled with a lubricating synovial fluid** which **reduces friction**
- The fluid is produced by the **synovial membrane**, which surrounds the joint
- Synovial joints are **capable of a variety of different movements** which depends on the structure within the joint including the joint type and the ligaments
- The movements possible at the joint are
  - Flexion
  - Extension
  - Rotation
  - Abduction (the movement of a limb away from the body)
  - Adduction (the movement of a limb towards the body)

Examples of Different Joint Types and their Associated Movements Table

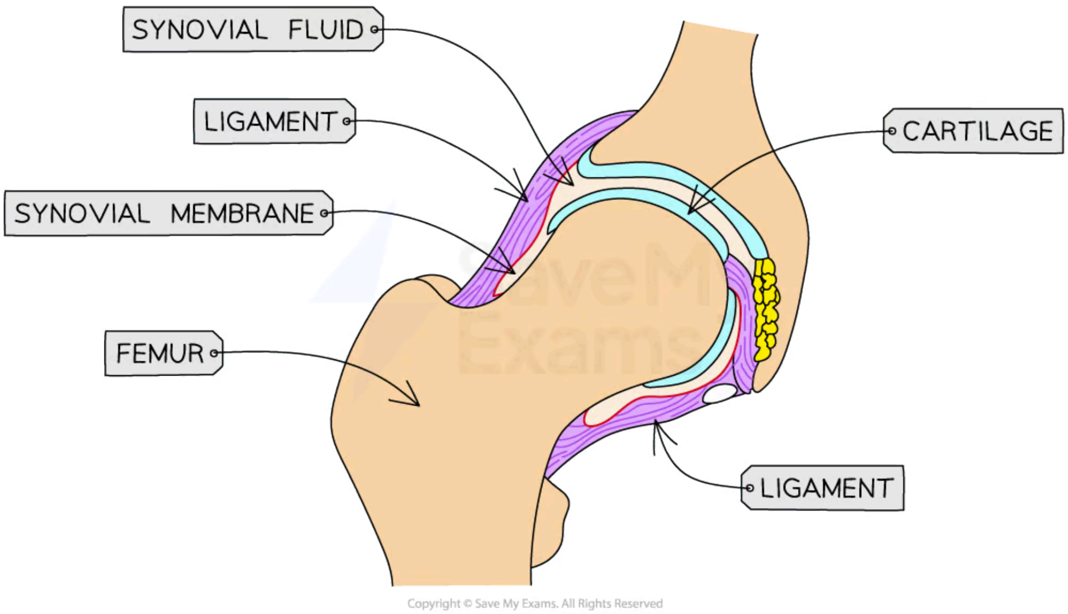
Joint	Movement
Knee (hinge)	Flexion and extension
Elbow (hinge)	Flexion and extension
Hip (ball and socket)	Flex, extend, rotate, sideways and backwards
Shoulder	Abduction and adduction, flexion and extension

The Human Hip Joint

- The hip joint is a ball and socket synovial joint
- Articulation is between the **bones** of the **femur** (the ball), and the **pelvis**, (the socket)
- **Cartilage** covers both bones and provides as surface to prevent the bones rubbing against each other
- **Synovial fluid** is enclosed within the ball and socket by a membrane, it's function is to provide lubrication for smooth movement
- The whole joint is encircled by **ligaments** which hold the bones in place; ligaments are made of a tough connective tissue
- Skeletal **muscles** are involved to allow the femur to move within the pelvis socket
- The muscles are connected to each bone via **tendons**

Hip Ball and Socket Diagram

Your notes



The structure of the hip synovial joint

Examiner Tip

You are not required to name the muscles and ligaments involved in the hip joint, but you should be able to name the femur and pelvis.

Your notes

Antagonistic Muscles

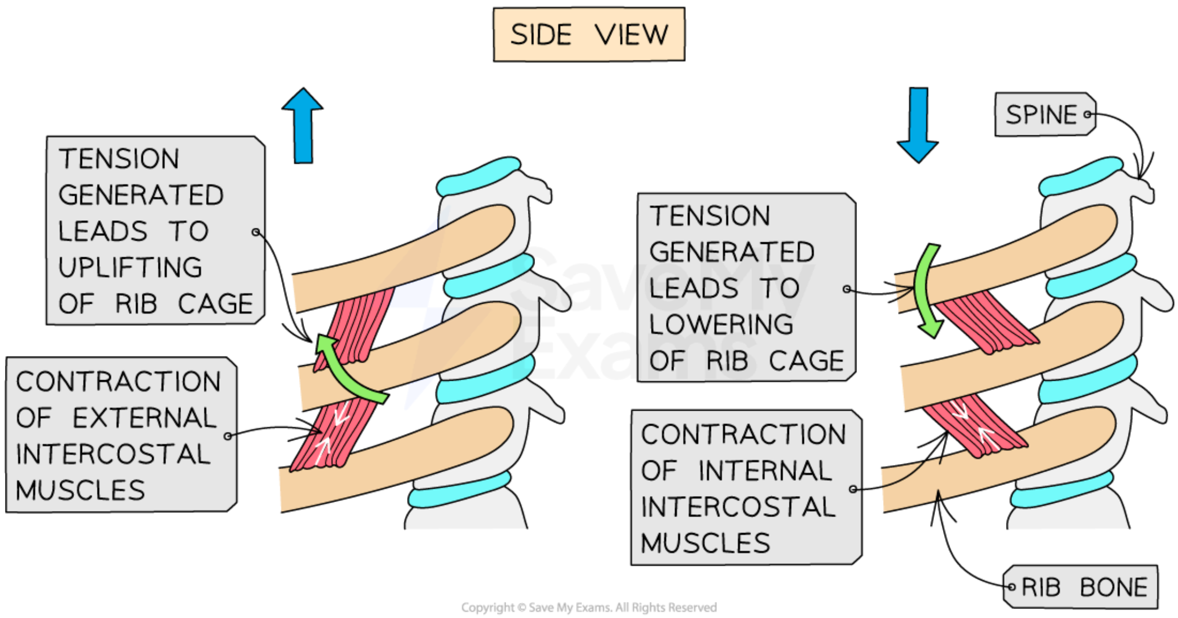
- There are over 600 skeletal muscles in the human body
- Muscles are **effectors**, stimulated by nerve impulses from **motor neurones** (specialised cells adapted to rapidly carry electrical charges called nerve impulses from sensory neurones to the muscles to bring about movement)
- Lengths of strong connective tissue called **tendons**, connect muscles to bones
  - They are **flexible but do not stretch** when a muscle is contracting and pulling on a bone
- Muscles are only capable of **contracting** or **pulling**, they **cannot push**
- As a result of this limitation muscles generally **operate in pairs**
- One muscle pulls in one direction at a joint and the other muscle pulls in the opposite direction
- This is described as **antagonistic muscle action**

Internal and external intercostal muscles

- An example of this can be seen in the **intercostal muscles** of the rib cage
  - **Two sets** of intercostal muscles to work antagonistically to facilitate breathing
    - **External** intercostal muscles, pull the rib cage up
    - **Internal** intercostal muscles pull the ribcage down
  - During inhalation
    - The **external set of intercostal muscles contract** to pull the ribs **up and out:**
    - This **increases the volume** of the chest cavity (thorax)
    - Leading to a **decrease in air pressure** inside the lungs relative to outside the body
    - **Air is drawn in**
  - During exhalation
    - The external **set of intercostal muscles relax** so the ribs **drop down and in**
    - This **decreases the volume** of the chest cavity (thorax)
    - Leading to an **increase in air pressure** inside the lungs relative to outside the body
    - **Air is forced out**
  - Note that the diaphragm also relaxes and contracts during ventilation, but this is not part of an antagonistic muscle pair

- The movement of the rib cage in **opposite directions** is due to the orientation of the muscle fibres in the internal and external layers of the intercostal muscles
  - As the external intercostal muscles contract, their expansion of the rib cage results in the **stretching** of the internal intercostal muscles
  - The stretching results in **stored potential energy within the titin protein of the sarcomere** of the internal intercostal muscles
  - The same is true for the **antagonistic action** of this muscle pair

Intercostal muscles diagram



The intercostal muscles are an example of an antagonistic muscle pair

Your notes

Movement of Joints: Skills (HL)

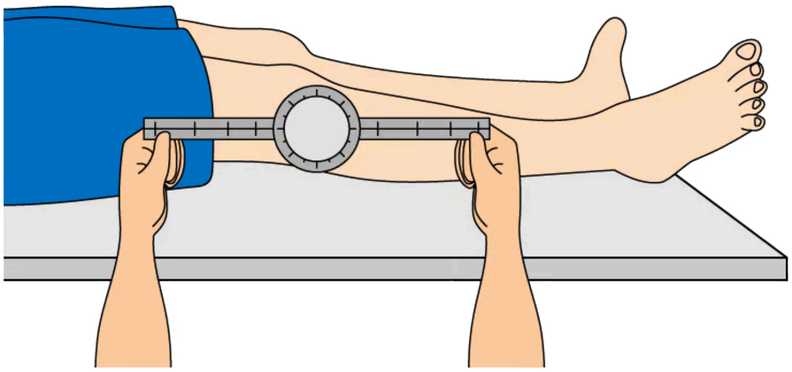
Your notes

Movement of Joints

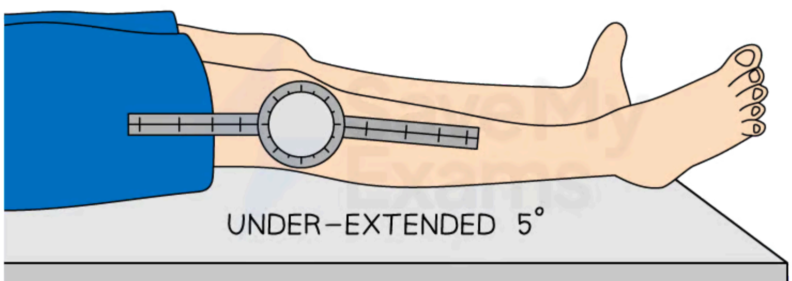
- The **range of motion** of joints are capable of moving in different directions, also called **dimensions**
- An example of a joint which can move in a number of dimensions is the hip joint
- The range of motion of a joint can be **measured** using:
  - A simple tool called a **goniometer** which measures the distance and direction that the joint can move in degrees (°)
  - **Computer analysis** which can be used to track and measure the of the movement of various joints; there are even phone Apps which can be used to simulate a goniometer

Using a Goniometer Diagram

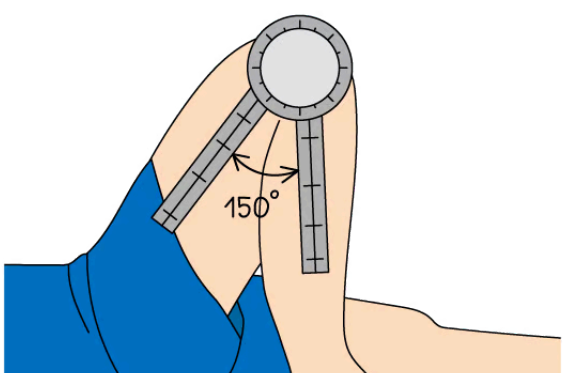
1 START WITH THE JOINT FULLY EXTENDED AND ALIGN THE GONIOMETER AGAIST THE JOINT

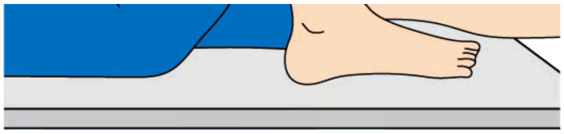


2 MEASURE THE ANGLE OF THE JOINT WHILST IT IS FULLY EXTENDED



3 BEND THE JOINT TO ITS FULLEST AND REALIGN THE GONIOMETER TO MEASURE THE ANGLE





The use of a goniometer to measure range of movement in joints

Your notes

Examiner Tip

You should have had the opportunity within your learning setting to use a goniometer.

Your notes

Locomotion in Organisms (HL)

Reasons for Locomotion

- Locomotion is the movement or the ability to **move from one place to another**
- Locomotion is important to a range of organisms for a variety of reasons
- This trait is particularly important in the Animal kingdom

Example of Reasons for Locomotion Table

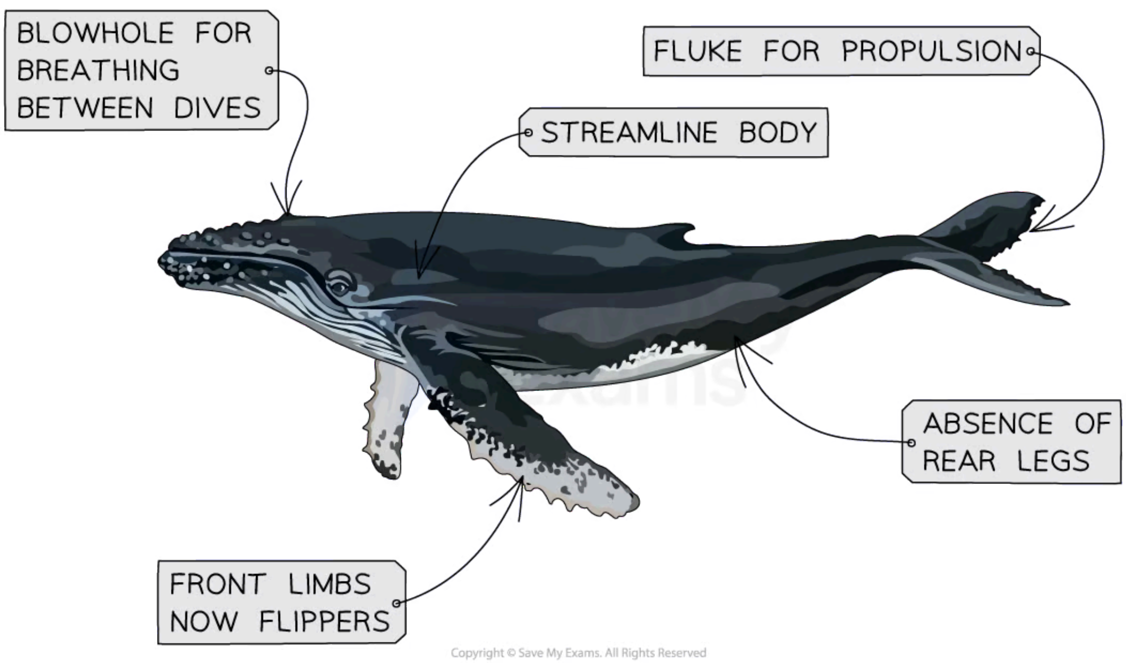
Locomotion reason	Animal	Example
Foraging for food	Guinea pigs	These spend at least 70 percent of their time awake searching and eating plants
Escaping from danger	Salticidae spiders	Jumping spiders use their legs to jump out of the way of potential predators or other dangers
Searching for a mate	Salmon	Spawning of salmon involves male and female salmon swimming from the ocean to freshwater rivers to mate
Migration	Caribou dear	Caribou can travel over 3,000 miles a year between their Southern winter ranges and their Northern calving grounds

Adaptations for Swimming

Your notes

- Aquatic animals are adapted for a specific movement called **swimming**
- **Marine mammals** in particular have many adaptations that make them excellent swimmers
  - Marine mammals might include dolphins or whales
- These mammals have all evolved from ancestral land animals that mean they are now capable of surviving underwater
  - **Streamlining** of their bodies allows marine mammals to move with ease through relatively viscous water with ease and great speeds
  - Front limbs have been adapted to form **flippers** which are used mainly for steering; rear legs have been lost altogether to help with streamlining
  - Tails have adapted to form a **fluke** which is capable of up and down movement and are used for propulsion of the marine mammal
  - Changes to **airways** by the evolution of a blowhole allows periodic breathing between dives; blowholes can be sealed between dives so that water does not enter the airways

Adaptations of marine mammals diagram



Marine mammals have evolved many adaptions from the previous land mammals they once were