CHAPTER

3

Movement Analysis

Movement analysis helps coaches and athletes understand the different types of movements within specific sports. Part of your exam asks you to analyse specific movements that take place in sport. To do so you need to fully understand movement analysis and be confident in the terminology used.

THE BIG QUESTION

Imagine gymnasts preparing for a major competition. They will require a range of movements to complete a fluent routine. As you complete this chapter, you will develop the knowledge, understanding and skills you need to analyse the movements of the gymnasts and answer the Big Question. By the end of each topic in this chapter you should be able to answer one of the question parts outlined below.

These are the topics you'll need to answer the big question:

A **Muscle contraction:** When performing a handstand in a routine, what contractions will take place in the arms?

B **Lever systems:** If a gymnast performs a split leap and pushes off the floor with one foot, what class of lever do they use and how much mechanical advantage does it benefit from?

C **Planes and axes of movement:** As the gymnast runs to gain speed in preparation for a somersault, what plane would she be moving through? When performing a cartwheel, what axis would the gymnast rotate around?

D **Sports technology:** How can the gymnast and her coach use technology to help improve her performance?

As you work through this chapter, we will cover all the skills and knowledge you'll need to be able to answer the Big Question. If you can do that, you will have brilliant AO1 and AO2 skills ready to use in your GCSE.

In this chapter you will learn about:

- the major muscle groups and their antagonistic muscle actions
- isotonic and isometric muscle contractions with application to sporting examples
- the classification of each lever system, identifying the mechanical advantages and disadvantages of each lever system
- the different planes and axes of movement, as well as how they relate to joint and muscle movements in different sporting activities
- the role of technology in the analysis of movement and how it can be used by coaches to improve sporting performance
- the role of technology in officiating.

In this chapter you will be using the following key terms. You can look up the meaning of these terms in the Glossary (p. X onwards).

Key Terms

Agonist (prime mover)	Antagonist	Axis (plural axes)	Effort
Effort arm	Fulcrum	Lever arm	Load
Load arm	Mechanical advantage	Mechanical disadvantage	Motivation
Notational analysis	Perpendicular	Plane	Qualitative data
Quantitative data	Technology	TMO	VAR

3A Muscle Contraction

In this topic we will work towards answering part a) of the Big Question:

1. Athletes preparing for major competitions require a range of movements to compete fluently.

a) A gymnast performs a handstand during his routine. Explain which contractions must take place in the gymnast's arms to hold his balance. (4 marks)

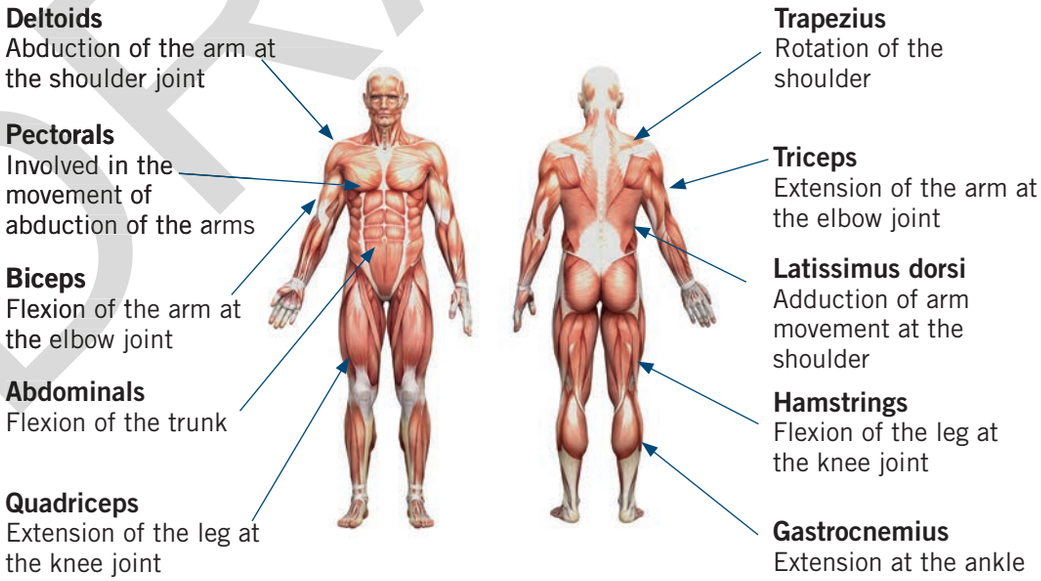
AO2 – *4 marks*

Analysing muscular contractions helps the athlete and coach to develop training programmes meeting the specific needs of their sport or activity. It allows identification of movement patterns, contractions and the development of specific actions and muscles.

Muscle Contractions

You need to know about **muscle contractions** so that you can understand how the muscles of the body work to produce movement. **Skeletal muscles** are responsible for producing movement through different muscle contractions which pull on the skeletal system to cause movement at a joint. It is important to understand the different types of muscle contractions and how muscles work together to produce different movements.

Before we can explore the different muscle contractions, it is a good opportunity to recap on the major skeletal muscles covered in Chapter 2:



In order to produce movement our muscles must shorten, lengthen or remain the same length. Muscle contractions can be divided into two types: **isotonic** and **isometric**.

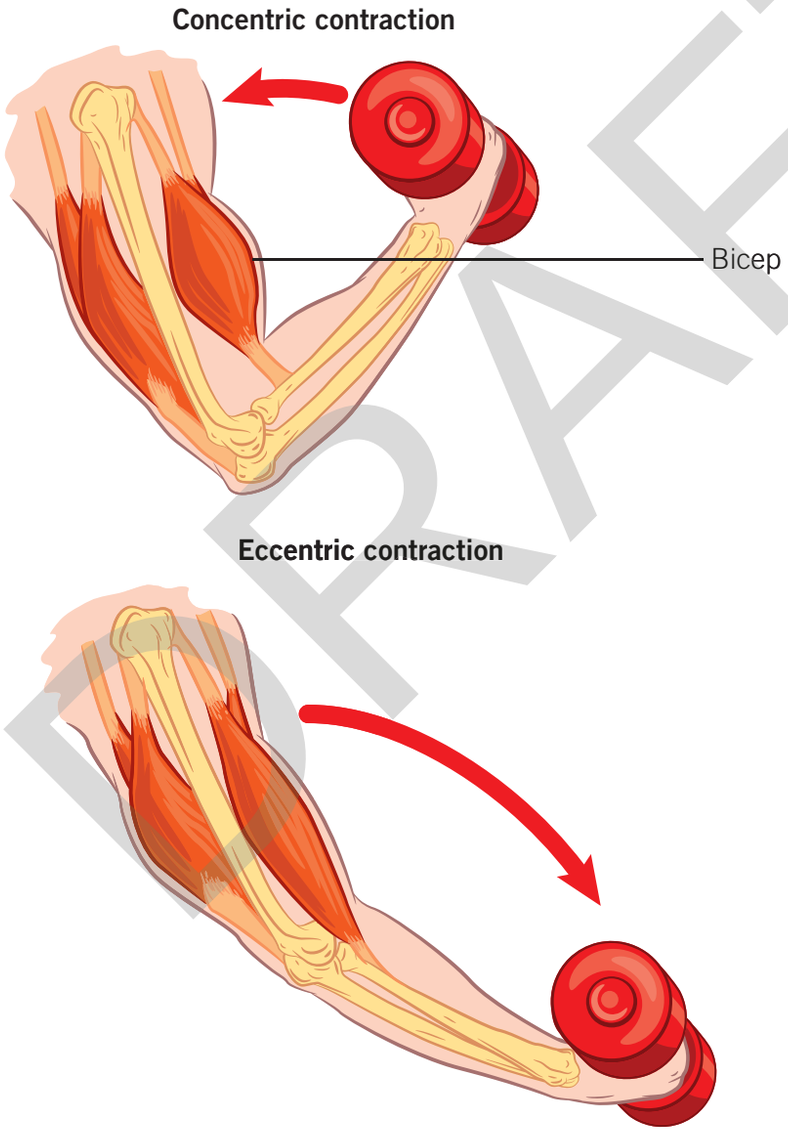
Isotonic Contraction

An isotonic contraction produces movement. The muscles involved in the contraction produce tension which controls the speed and types of contraction. There are two types of isotonic contraction:

- concentric contraction
- eccentric contraction.

The image shows a bicep curl. To lift the weight, the bicep muscle will need to contract. This means the muscle becomes shorter under tension, causing flexion at the elbow joint. This is known as a **concentric contraction**.

When lowering the weight, the bicep muscle will need to lengthen under tension so that the weight is lowered under control causing extension at the elbow. This is known as an **eccentric contraction**.



Top Tip

Here is one way to remember the two main types of contraction.

Is**o**t**o**nic contraction = movement. Two 'o's in isotonic = two movements (concentric and eccentric).

Is**o**metric contraction = Static. One 'o' in isometric looks like a zero = no movement.

Isometric Contraction

In an isometric contraction the muscle is under tension but there is no movement. When holding the plank position during a workout, the abdominal muscles are under tension, keeping the body in a static position. There is no movement.

Muscle contraction	Details
Isotonic	The muscle contracts under tension producing movement through the shortening or lengthening of the muscle
Isometric	The muscle contracts under tension but there is no movement
Concentric contraction	A type of isotonic contraction where the muscle contracts and get shorter
Eccentric contraction	A type of isotonic contraction where the muscle contracts, but is lengthening under a load

Top Tip

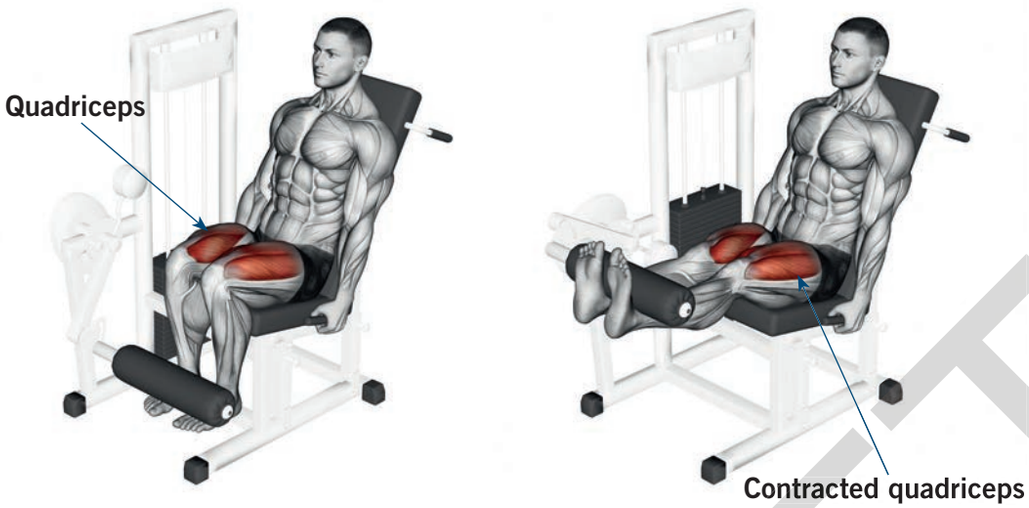
The agonist controls the movement, so it is also known as the prime mover.

Antagonistic Muscle Actions

Muscles work in pairs to produce movement at a joint. In order to produce movement, one muscle will need to contract (shorten), pulling on a bone, and another muscle will need to relax. To produce the opposite movement, the roles of the muscles will change. This is known as an **antagonistic muscle action**.

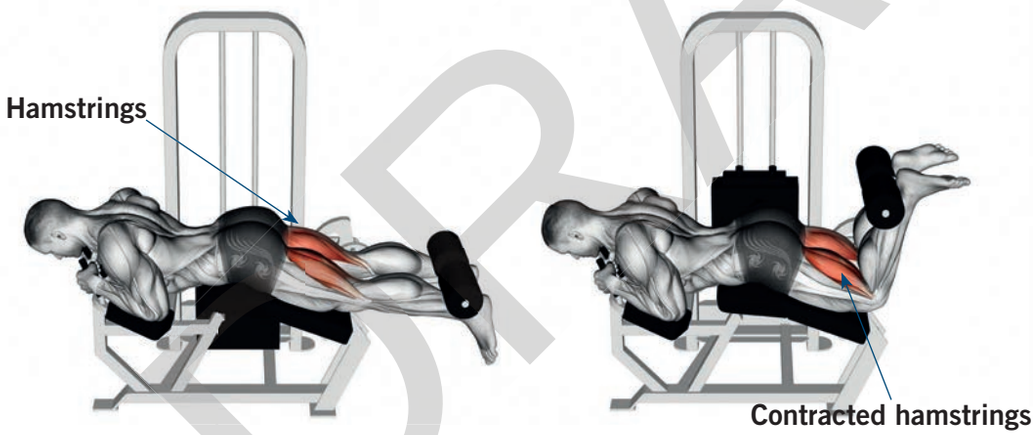
The quadriceps and the hamstrings work in pairs to flex and extend the leg at the knee.

Look at the images.



During a leg extension the quadriceps muscles are used to extend the leg at the knee joint. The quadriceps muscles contract (shorten), controlling the movement, so the quadriceps are the **agonist** or **prime mover**.

The hamstring muscles relax (lengthen) to allow the movement to take place. They are the **antagonist**.



A hamstring curl is the reverse of the previous action. In a hamstring curl, the hamstrings contract to produce flexion at the knee. In this exercise the hamstrings now become the agonist or prime mover as they are controlling the movement.

The quadriceps relax (lengthen) to allow this movement to take place. They are the antagonist.

Top Tip

Skeletal muscles contract to produce movement at a joint.

Skeletal muscles work in antagonistic pairs, e.g. biceps and triceps.

Quick Check

Identify the two types of movement that can be produced by an isotonic contraction. AO1

During the lifting phase of a biceps curl, which muscle is the agonist (prime mover)? AO1

AO2

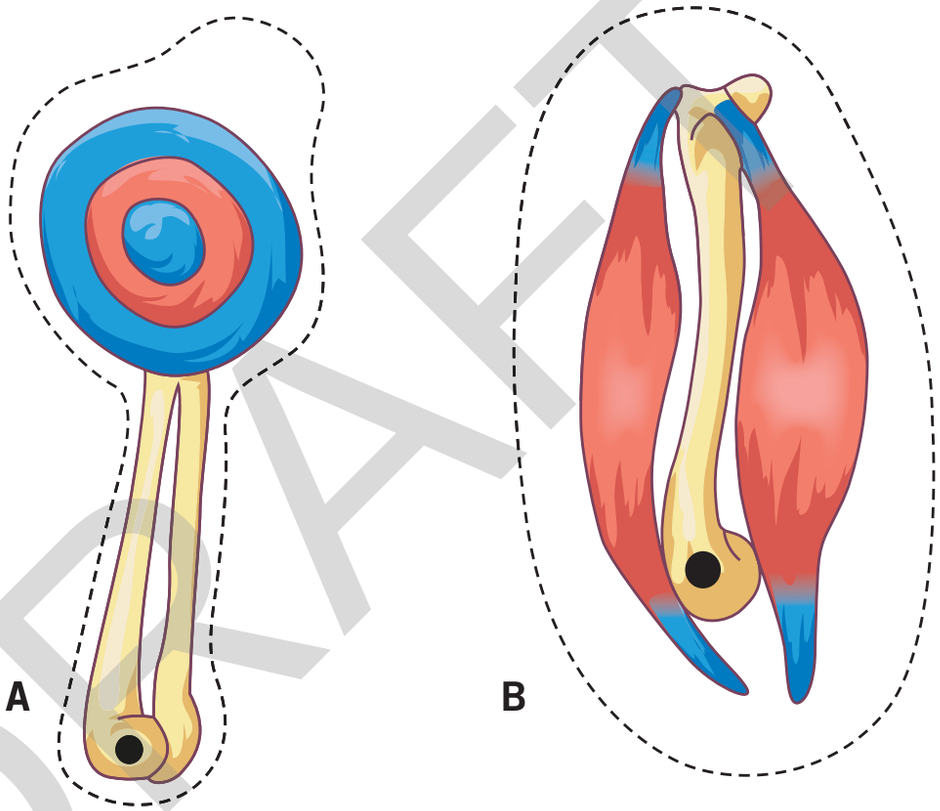
You will need to apply your knowledge of specific terms such as 'flexion' and 'extensions'.

Practical Investigation

Equipment

You will need the following:

- a photocopy of the cut-out images in Appendix 3.1
- scissors
- glue
- split pin



Method

1. Using scissors, carefully cut around the dotted lines of images A and B of the humerus and the radius and ulna.
2. Carefully pierce the paper where the black dots are. The holes will then be used to place the split pin.
3. Use the split pin and push it through hole A of the radius and ulna and then through hole B at the bottom of the humerus. This will create the elbow joint.
4. Now that your model is together, identify an area on a blank page of your book where you will stick your model. **Make sure you position your model so you have space around the outside to annotate to complete the investigation**. On the back of the humerus **only**, paste some glue on the top half of the image and stick this section only to your page. Make sure you leave room so that the radius and ulna can move freely.

Investigation

Using your model, annotate your page to identify the following:

1. biceps
2. triceps
3. humerus
4. radius
5. ulna
6. tendon

1. An arm lifting a weight using this movement creates a _____ muscle contraction.
2. The _____ muscle contracts (shortens) to control this movement and is known as the _____ or _____ mover.
3. In this movement the _____ muscle works with the biceps. It relaxes (lengthens) and is the _____.
4. When the arm lowers the weight, it creates an _____ muscle contraction where the bicep muscle is still under tension but lengthens during the lowering of the weight.
5. The bicep muscle is attached to the radius by a _____ which pulls on the bone to produce movement at the _____ joint.

Use the following words to fill the gaps:

bicep	elbow
tricep	eccentric
tendon	agonist
concentric	antagonist
prime	

Extension

Explore your model and complete this task. You may wish to complete the sentences in your book around your model if you have space.

Topic Test

A gymnast preparing for a major competition requires a range of movements to complete a fluent floor routine.

a) Identify the movement shown in the image in the knee, labelled A. 1 mark
Tick (✓) one box only.

	Tick (✓)
Flexion	
Extension	
Abduction	
Adduction	

b) Explain the antagonistic muscle actions causing flexion at the knee. 3 marks

When reading the question, look at what the key words and phrases are asking you to do:

- **Command word:** This is based on the assessment objective (AO). The assessment objective for part a) is AO1 and the assessment objective for part b) is AO2: you need to demonstrate and apply your knowledge and understanding.
- **Topic:** This is the key area of study the question is about.
- **Qualifying words or phrases:** This is the specific area you need to focus on in your answer.

Doing this will help you to build your answer so that you can access the AO for each question.

Step 1 Demonstrate your knowledge (AO1)

You need to **demonstrate your knowledge and understanding** by **identifying** the movement at the knee. Tick the correct box in the table.

Step 2 Apply your knowledge and understanding (AO2)

You need to **apply your knowledge and understanding** of antagonistic muscle actions in order to **explain** the movement.

Use the terms in the tick list of terminology. Look at how many marks are available to help you decide how much detail to include.

Isotonic	
Isometric	
Concentric	
Eccentric	
Static	
Flexion	
Extension	
Quadriceps	
Hamstrings	
Knee	

THE BIG QUESTION

RECAP

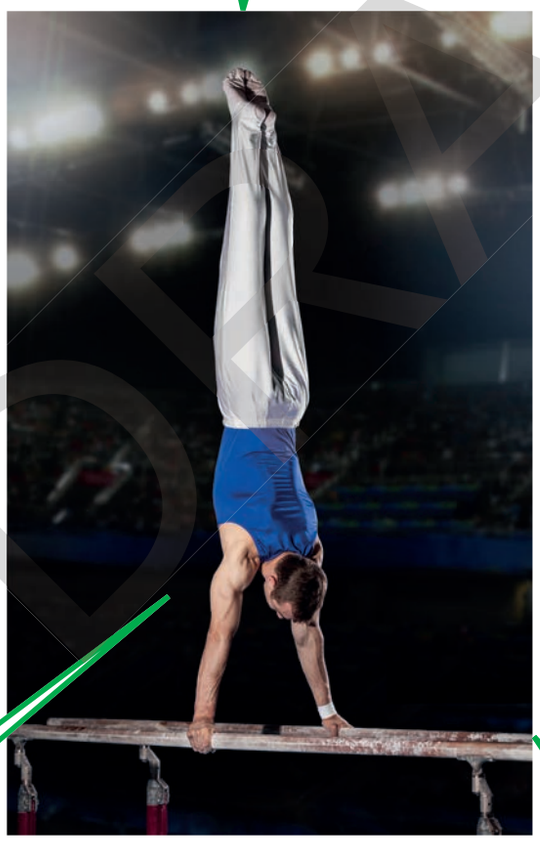
A Now that you have developed a knowledge and understanding of muscle contraction and completed the Topic Test, have a go at part a) of the Big Question.

1. Athletes preparing for major competitions require a range of movements to compete fluently.

a) A gymnast performs a handstand during his routine. Explain which contractions must take place in the gymnast's arms to hold his balance. (4 marks)

The image shows a gymnast holding a handstand during part of his routine on the parallel bars.

We know that a handstand is a balance – not a movement. So what is the role of the muscles?



Think about the muscles used in the upper arm and shoulder.

What type of muscle contraction is taking place in the arms and shoulder?

3B Lever Systems

In this topic we will work towards answering part b) of the Big Question.

1 Athletes preparing for major competitions require a range of movements to compete fluently.

b) In order to perform a split leap, a gymnast pushes off the floor with one foot.

(i) Identify the class of lever shown in the image. (1 mark)

(ii) Explain the mechanical advantages and disadvantages of the class of lever shown in the image. (2 marks)

AO1 – *3 marks*

Imagine you are coaching the gymnast in the question. You will need an understanding of the mechanics of levers and how they produce movement. You will also need an understanding of the relationships between the muscular and skeletal systems, and how they allow the body to apply a **force** to create movement. For this information to be helpful to both the coach and the athlete, specific terminology is used to analyse the movements taking place.

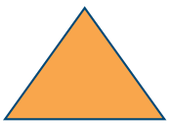
Components of a Lever

Levers are normally used to make physical work easier, for example to move a heavy load or to move something quickly. When we exercise, most of our movements will involve the use of levers; for example, when we run, lift weights, kick or throw a ball, all of these actions use levers.

A lever system within the body uses a **lever arm** (a bone) to move an object. For example, when we run, we are the object being moved, but when kicking a ball, the object being moved is the ball.

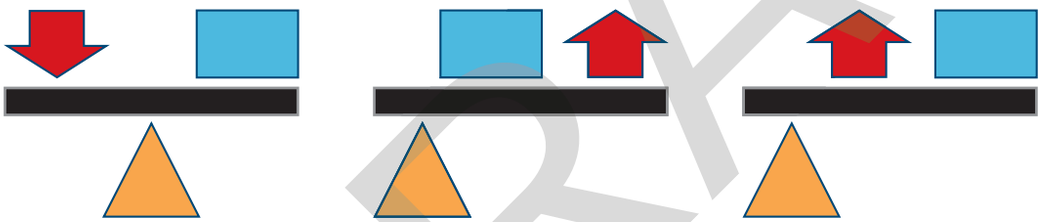
All lever systems are made up of **four components** called the lever arm, **fulcrum**, **load** and **effort**. These terms describe the relationships between the part of the body producing the movement and the load which the body part is trying to move.

Look at the table and familiarise yourself with each component name, image and how it links to the body or mass being moved.

Component	Description
 Lever arm	In the body, a lever arm is a bone that helps to produce a movement
 Fulcrum	The fulcrum is a pivot. This is a joint of the body from which the lever produces movement
 Load	The load is the resistance (weight/mass) that the athlete is trying to move. This can be body weight or an external weight like a dumb-bell
 Effort	The effort is the force created by a muscle which is connected to the bone that is trying to move the load

Classification of Levers

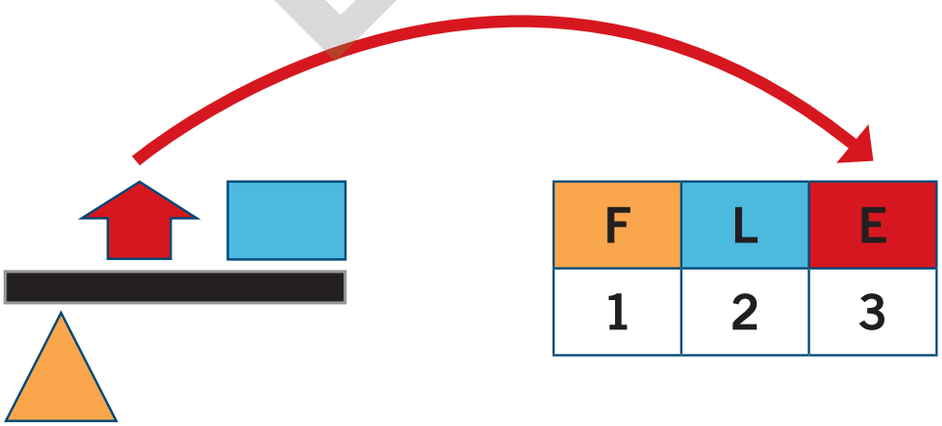
Levers are classified based on the relationships between the components. Levers can be classified as first class, second class or third class. Each class of lever has its own advantages and disadvantages.



First class lever | Second class lever | Third class lever

You can use **FLE123** to help you remember the classes of lever. Forget about the lever arm for now and concentrate on the fulcrum, load and effort (FLE). Whatever component is in the middle will determine the class of lever.

In the illustration below we can see that the **effort** is between the **fulcrum** and the **load**. When we look at the FLE123 grid, we can see that the **effort** sits above **3**, therefore the example is a **third class lever**.



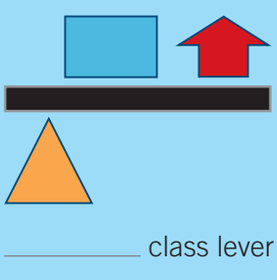
Top Tip

to identify the class of a lever. Whichever component is in the middle of the diagram determines the class of lever.

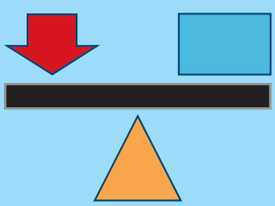
F	L	E
1	2	3

Quick Check

Can you identify the following levers using FLE123? AO1



_____ class lever



_____ class lever

Levers in the Body

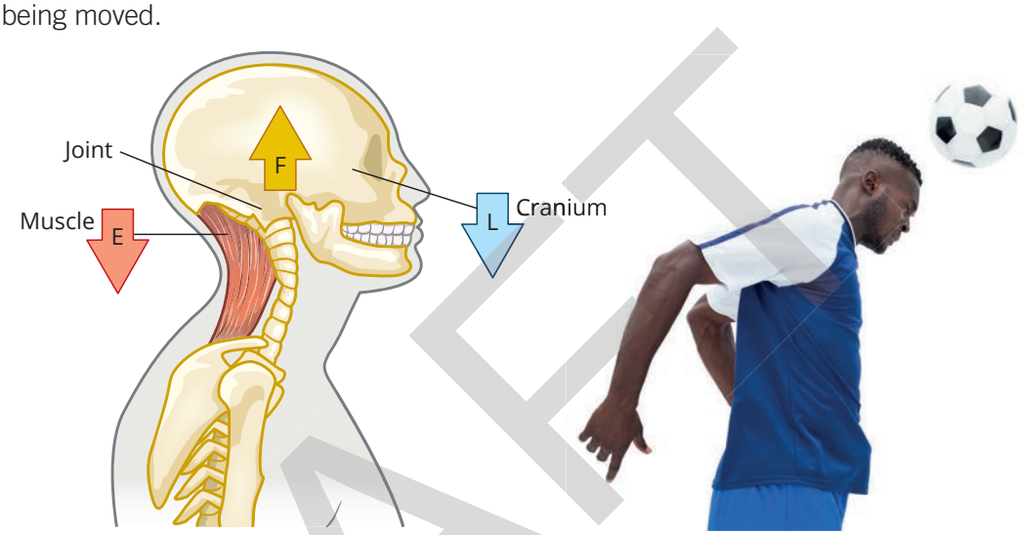
Each classification of lever can be found in the body. The images below will help you to identify the relationships between the muscle and skeletal systems that help the body produce movement.

First Class Lever

Quick Check

Which part of the human body acts as the fulcrum in all lever systems? AO1

The image shows first class levers in action. The components are arranged in the order EFL. The **effort** is the muscle used to produce the movement, the **fulcrum** is the neck joint where the movement takes place and the **load** is the weight of the cranium that is being moved.



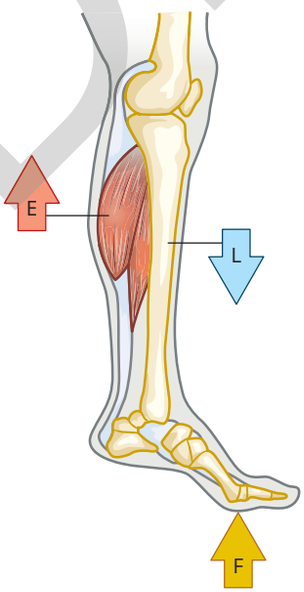
There are not many examples of first class levers in the body. Nodding of the head is an example so sports that require head movement, e.g. heading a ball or watching the flight of an object, are examples of a first class lever in sport.

Second Class Lever

For a second class lever the components are arranged in the order of ELF. The image shows an example of a second class lever. The **effort** is the muscle (calf/gastrocnemius) used to produce the movement, the **load** is the weight of the body that is being moved and the **fulcrum** is the ball of the foot where the movement takes place.

Quick Check

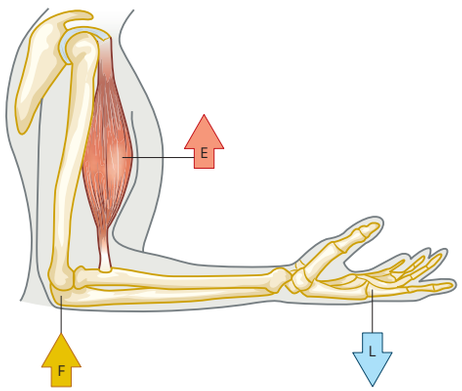
In the image of a second class lever, which muscle is producing the effort? AO1



Again, there are not many examples of second class levers in the body. However, there are many sporting examples where body weight is lifted up on the ball of the foot, e.g. running or preparing to jump.

Third Class Lever

The third class lever in the image below shows the components arranged in the order F**E**L. The **fulcrum** is the elbow joint where the movement takes place, the **effort** is the muscle (biceps) used to produce the movement and the **load** is the weight of the object being held in the hand and moved.



Quick Check

During flexion of the elbow which muscle contracts and acts as the effort? AO1

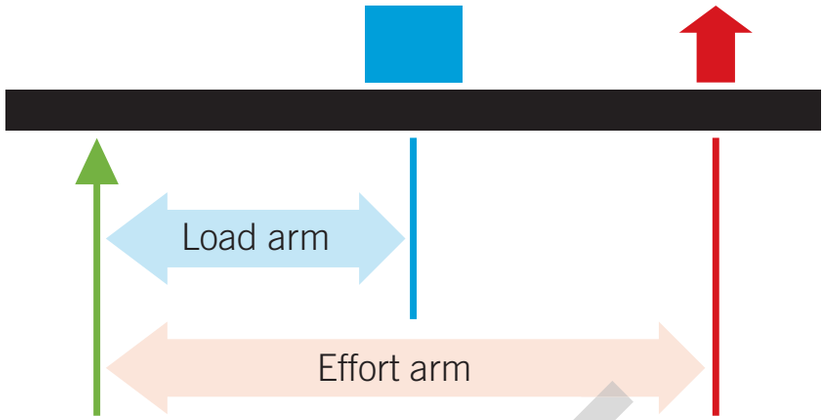
The third class lever is the most common lever in the body. This lever is involved in many movements and there are many examples of their use in sport, e.g. the elbow when performing bicep curls, and the use of the arm in racket sport or striking activities. Third class levers can also be found in the knee (when kicking a ball), the hip (when running) and the shoulder (when moving the arm out and upwards).

Mechanical Advantages of Levers

Mechanical Advantage

The main functions of levers are to move heavy loads and to move loads at speed. Some levers operate with a **mechanical advantage**. This means that the lever can move a large load with relatively little effort.

In general terms levers have more mechanical advantage where the fulcrum is closer to the load. These levers tend to move slowly but are good at lifting a heavier load.



A second class lever has a mechanical advantage. You can easily lift your body weight (load) by contracting your calf muscle (effort) to raise your body up onto its tiptoes to perform a layup in basketball.

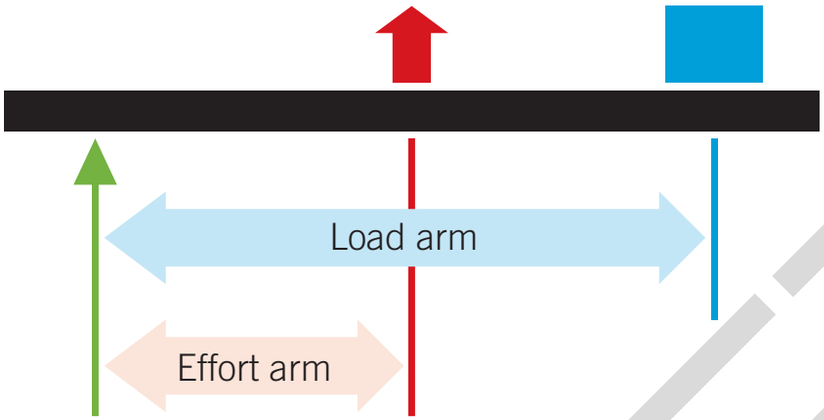
The term **effort arm** refers to the distance between the fulcrum (joint) and the effort (muscle). The **load arm** is the distance between the fulcrum and the load. The image shows a second class lever with the effort arm and the load arm labelled.

When a lever's **effort arm** is longer than its **load arm**, it is said to have high mechanical advantage. Levers with high mechanical advantage can move large loads with a relatively small amount of effort. Second class levers always have high mechanical advantage. First class levers can have high mechanical advantage but only if the fulcrum is close to the load.

Mechanical Disadvantage

A **mechanical disadvantage** occurs If the **effort arm** is shorter than the **load arm**. This means that more effort will be required to overcome the load.

Third class levers are not advantageous for applying large amounts of force so they are the least efficient. However, they are good for accelerating objects quickly. They amplify the speed of the movement.

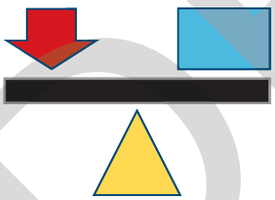
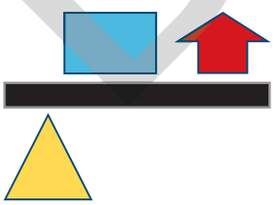
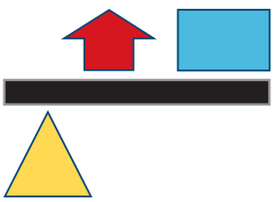


So, to summarise:

Mechanical advantage = a shorter **load arm** and a longer **effort arm**, allowing a heavier load to be lifted.

Mechanical disadvantage = a shorter **effort arm** and a longer **load arm**, allowing for faster movements over a larger range.

The general rules of mechanical advantages and disadvantages can be seen in the following table:

Class of Lever	Diagram	Mechanical advantage/ disadvantage	Movement example
First class lever		Can have a mechanical advantage (if the effort arm is longer than the load arm) or a mechanical disadvantage (if the load arm is longer)	Nodding the head
Second class lever		Always has a mechanical advantage, because the effort arm is longer than the load arm	Rising on to the ball of the foot
Third class lever		Always has a mechanical disadvantage, because the load arm is longer than the effort arm	Flexing the elbow or knee

Quick Check

Which of the following equations best describes a mechanical advantage? AO1

1. Effort arm + resistance arm
2. Effort arm ÷ resistance arm
3. Effort arm × resistance arm

AO2

You will need to apply your knowledge of the components of a lever and how they link to the skeletal and muscular systems. Make sure you know the terminology.

Quick Check

Match the class of levers to the components list. AO1

- First class lever
- Second class lever
- Third class lever

fulcrum – load – effort

load – fulcrum – effort

load – effort – fulcrum

Practical Investigation

Equipment

You will need the following:

- a range of sporting equipment linked to your chosen exercise/sporting activity
- a camera to capture the images of your chosen activities
- a pencil and paper to sketch the class of lever shown and record your results.

Method

1. Take part in either an exercise or a sporting activity that uses each of the lever systems.
2. Using a camera, capture an image which best shows the example of the lever system you are trying to demonstrate. (If you have no access to a camera then describe your chosen activity.)
3. Record your results.

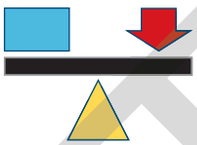
Investigation

Analyse the movements involved in each of your chosen activities and complete a table like the one below:

Class of Lever	Mechanical advantage or disadvantage	Exercise or sporting activity	Image or description of activity	Sketch of the lever involved

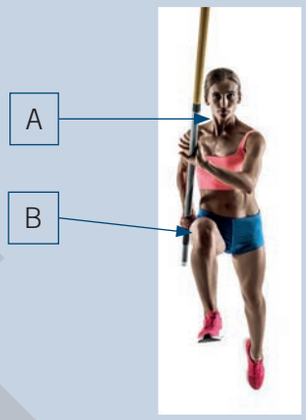
Results

- identifying whether the type of lever has mechanical advantage or disadvantage
- identifying your activity
- taking a picture or describing your activity
- sketching the lever involved in the activity, including the fulcrum, load and effort.

Class of Lever	Mechanical advantage or disadvantage	Exercise or sporting activity	Image or description of activity	Sketch of the lever involved
First class	*Mechanical advantage if the load is closer to the fulcrum than the effort*	*Heading a ball in football*		

Topic Test

Look at the image of a pole-vaulter who is running to gather speed as she approaches the bar.



a) Identify the classification of lever shown at point A and point B in the image. 2 marks

Point	Classification of lever
A – neck	
B – knee	

b) Assess the differences between the two classifications of lever. 4 marks

When reading the question, look at what the key words and phrases are asking you to do:

- **Command word:** This is based on the assessment objective (AO). The assessment objective for part a) is AO1 and the assessment objective for part b) is AO3: you need to demonstrate your knowledge and understanding and perform some analysis or evaluation.
- **Topic:** This is the key area of study the question is about.
- **Qualifying words or phrases:** This is the specific area you need to focus on in your answer.

Doing this will help you to build your answer so that you can access the AO for each question.

Step 1 Demonstrate your knowledge (AO1)

To answer part a) you need to **demonstrate your knowledge and understanding** of levers. Note down the components of a lever then use them to determine the class.

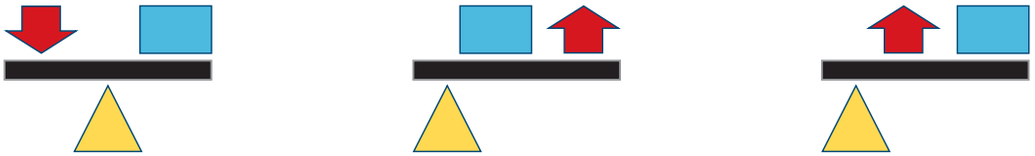
F	L	E
1	2	3

Use FLE123 to help you answer:

Step 2 Analyse and evaluate (AO3)

You need to **analyse and evaluate** the properties of levers in order to **assess** the classifications of lever.

Think about the lever components. Which differences between the levers helped you work out their classifications? Will each lever have a mechanical advantage? How will they affect movement?



THE BIG QUESTION

B You are starting to build the knowledge and understanding you need to answer the Big Question. You have already answered part a) at the end of the last topic. So now it's time to answer part b) and apply your knowledge and understanding of lever systems.

1. Athletes preparing for major competitions require a range of movements to compete fluently.

b) In order to perform a split leap, a gymnast pushes off the floor with one foot.

(i) Identify the class of lever shown in the image. (1 mark)

(ii) Explain the mechanical advantages and disadvantages of the class of lever shown in the image. (2 marks)

RECAP

Top Tip

Annotate the question using the colours we've used in this book: **topic**, **command word**, **qualifying words**.

The fulcrum is the ball of the foot. Where are the load and the effort?

What component is in the middle?

Does the lever give a mechanical advantage or disadvantage?

How easy is it to lift your body weight up on to your tiptoes?