



## 2.1 Biomechanical Principles

### 2.2 Levers

Name

Class



<b>Content</b>	<b>Additional Information</b>	<b>Pupil comments – How confident do you feel on this topic?</b>
Newton's three laws of linear motion applied to sporting movements.	First law (inertia), second law (acceleration), third law (action/reaction). Force.	
Definitions, equations and units of example scalars.	Speed, distance.	
Centre of mass.		
Factors affecting stability.	Height of centre of mass, area of base of support, position of line of gravity and body mass.	
Three classes of lever and examples of their use in the body during physical activity and sport.		
Mechanical advantage and mechanical disadvantage of each class of lever.		

## Newton's Three Laws of Motion

### Newton's First Law of Motion – **The Law of Inertia:**

This states that 'Unless acted upon by an external force, an object at rest remains at rest, or if in motion, it continues to move in a straight line with constant speed.'

Think about a swimmer stood on the blocks before a race. They will remain stationary on the blocks until there is an act of force. What provides this force?

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As they dive through the air they will begin at a constant pace, before the **resistance of the water** slows them down.

Now think about the sport of badminton.

Using Newton's First Law explain how the shuttlecock travels through the air following a smash shot.



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What about a long jumper as they prepare to begin their run up? Using Newton's First Law, as well as your knowledge of the **neuromuscular system**, analyse how the jumper is able to begin their movement.

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Newton's Second Law of Motion – **The Law of Acceleration:**

This states that 'a force upon an object causes it to accelerate according to the formula **force = mass x acceleration**'.

Think back to the swimmer on the blocks. Their mass will remain constant, therefore the force exerted by their muscles will define the size of acceleration produced.



Now think about a 100m sprinter. Using Newton's Second Law, explain how a 100m sprinter starts a race.



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Imagine that the 100m sprinter accelerated out of the blocks at 8.5 m/s and that they weighed 80kg. What force (in newtons) will be applied?

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Put your knowledge of the first two laws together for this next question.

A tennis player is preparing to serve the ball. Using Newton's First and Second Law of motion, explain how the serve will take place.

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### Newton's Third Law of Motion – **The Law of Action/Reaction**

This states that 'for every action (force) there is an equal and opposite reaction'.

Once again, consider the swimmer standing on the blocks at the start of the race. In order to generate force they push back as hard as possible into the block. As a result the block pushes back the same amount of force against the swimmer, allowing them to dive into the water.



As the swimmer enters the water they will then begin to swim. As they draw back their hand in the water, an action has taken place. The reaction in this case is the water creating a reaction and pushing the swimmer forwards.

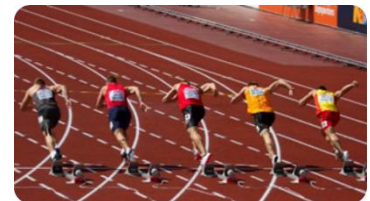
Now think about a 100m runner at the start of the race. Using Newton's Third law of Motion, explain how they will generate acceleration from the start line?

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What about a tennis player producing a forehand shot. Using Newton's Third Law of Motion, explain how they will produce a powerful shot.



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Using the table below, explain how the Laws of Motion can be applied to a sport of your choice.

Newton's Law	Application in the sport of _____
Law of Inertia	
Law of Acceleration	
Law of Action/Reaction	

### Scalars & Equations

A scalar is used when 'measurements are described in size or magnitude, without direction being taken into account'.

The scalars that you need to be able to work out include **speed, distance and mass**.

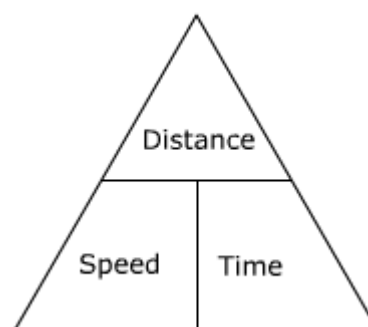
### **Working out Speed, Distance and Time:**

The triangle on the right helps to remember how to work out each measurement.

Distance = Speed x Time

Speed = Distance ÷ Time

Time = Distance ÷ Speed



For example, if a sprinter covered 15km in 60 minutes, the following equation would be used to work out their speed.

$$15 \text{ (distance)} \div 60 \text{ (time)} = 0.25$$

Therefore the runner is moving at a speed of 0.25km per minute.

The question was in km and minutes – so this is included within the answer

Make sure  
you use the  
correct units

What about a sprinter who covers 100m in 12 seconds? Work out what speed they were travelling at.

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Now imagine a formula one driver has travelled at a speed of 150 miles per hour for 25 minutes. What distance have they covered?

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What about a formula one driver travels at a speed of 180 km per hour for 1 hour?

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Again think  
carefully about  
the units required  
in your answer

The table below shows the distance covered of a player during a basketball match. Calculate the player's average speed during each quarter.

	Distance	Time	Average Speed (m/minute)
1 <sup>st</sup> Quarter	2014m	10 minutes	
2 <sup>nd</sup> Quarter	875m	10 minutes	
3 <sup>rd</sup> Quarter	1035m	10 minutes	
4 <sup>th</sup> Quarter	1187m	10 minutes	

## Practical task

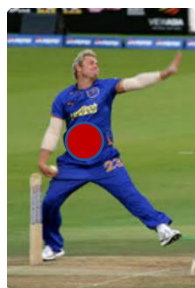
Time yourself to run the distances in the table below, before working out your average speed.

	Distance	Time (seconds)	Average Speed (m/second)
100m			
200m			
400m			
800m			

### Centre of Mass

The centre of mass can be defined as **‘the point of balance’**. It can differ from person to person depending on their height, weight, muscle mass and body shape. The centre of mass also changes as we move, particularly as we take part in sport.

The red circle shows the centre of mass in each of the performers below.



Highlight the centre of mass in the two images below.





### Factors Affecting Stability:

There are four factors that affect stability.

1. **The Height of the Centre of Mass** – Lowering the centre of mass will increase stability
2. **Area of Base of Support** – The more contact points a performer has, the more stable they will become
3. **Position of the Line of Gravity** – This should be central over the base of support
4. **Mass of the Performer** – The greater the mass, the more stable a performer will become

A prop forward has been told that their scrummaging position is unstable. Explain two ways that they can increase their stability in the scrum.

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A volleyball player has been told that they are unstable whilst playing a set shot. Explain two ways that they can increase their stability whilst playing this shot.

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### Lever Systems:

What do you think of when you hear the word 'lever'?

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How do you think parts of your body can be referred to as levers?

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Every lever has 3 components. Use the words below to fill in the gaps.

**Fulcrum** – The \_\_\_\_\_ around which the lever \_\_\_\_\_

**Load** – The \_\_\_\_\_ of the thing that you want to \_\_\_\_\_

**Effort** – The \_\_\_\_\_ that is applied by the user of the \_\_\_\_\_ system

force	axis	move	force	lever	rotates
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Think about a darts player throwing a dart. What would be the....

Fulcrum: \_\_\_\_\_

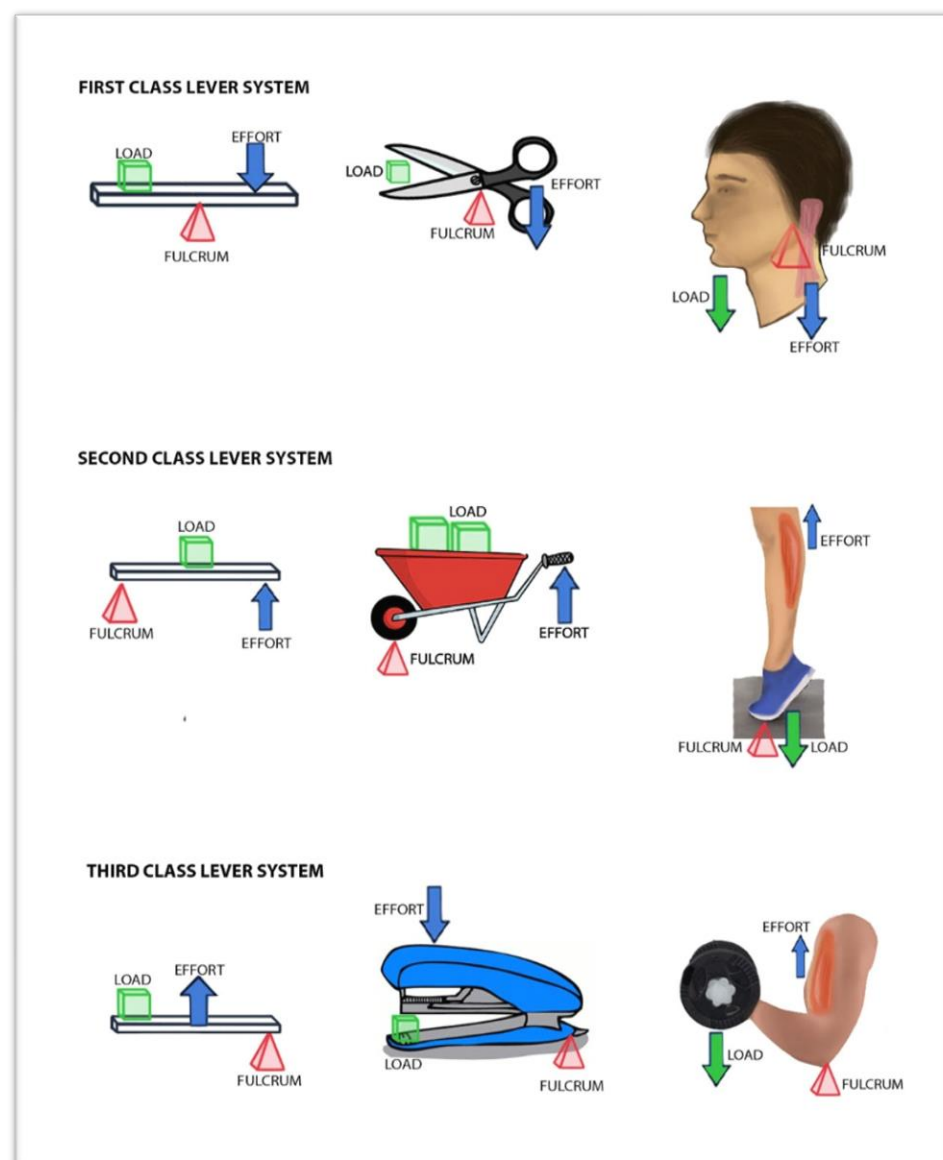
Load: \_\_\_\_\_

Effort: \_\_\_\_\_



### Different Classes of Lever:

Levers are classified as either **First Class**, **Second Class** or **Third Class** according to the placement of the fulcrum, load and effort.



1<sup>st</sup> class =  
**fulcrum** in  
the middle

2<sup>nd</sup> class =  
**load** in the  
middle

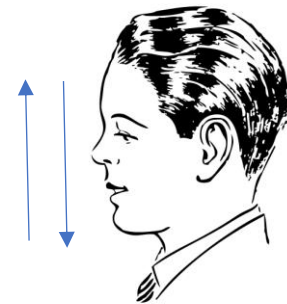
3<sup>rd</sup> class =  
**effort** in  
the middle

To  
remember  
what is in  
the middle  
you simply  
need to  
think **FLE**.  
Think 'FLY  
LITTLE ELF'  
to  
remember  
this.

### First Class Levers: Load – Fulcrum - Effort

In this lever system the fulcrum sits in the middle, between the load and the effort.

For the pictures shown, fill in the table below.

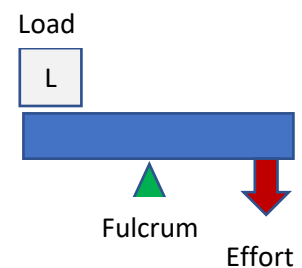


Exercise/Activity	Load	Fulcrum	Effort
Tricep dips			
Rowing			
Nodding			

Can you think of any other first class lever systems?

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This diagram is **very important** – if asked to draw a lever system in an exam, this is what you will need to present.



### Second Class Levers: Fulcrum – Load - Effort

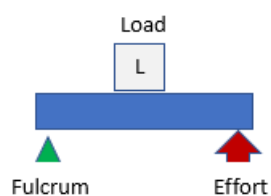
In this lever system, the load sits between the fulcrum and the effort. For the pictures shown, fill in the table below.



Exercise/object	Fulcrum	Load	Effort
Calf raises			
Wheelbarrow			

Can you think of any other second class lever systems?

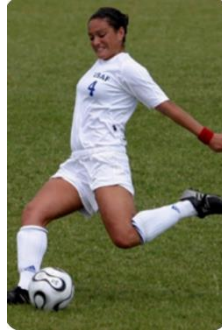
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### Third Class Levers: Fulcrum – Effort - Load

In this lever system, the effort is applied between the fulcrum and the load.

For the pictures shown, fill in the table below.

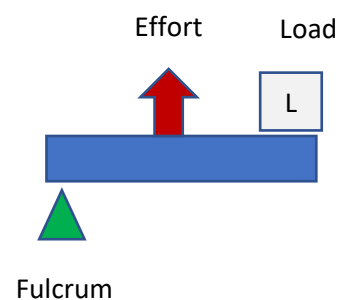


Exercise/Activity	Fulcrum	Effort	Load
Bicep curl			
Kicking a football			
Digging			

Can you think of any other third class lever systems?

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**Hint** – you must know the difference between each lever system and the location of the fulcrum, effort and load



### Advantages/Disadvantages of lever systems:

Lever Systems can be seen to have a **mechanical advantage** or a **mechanical disadvantage**.

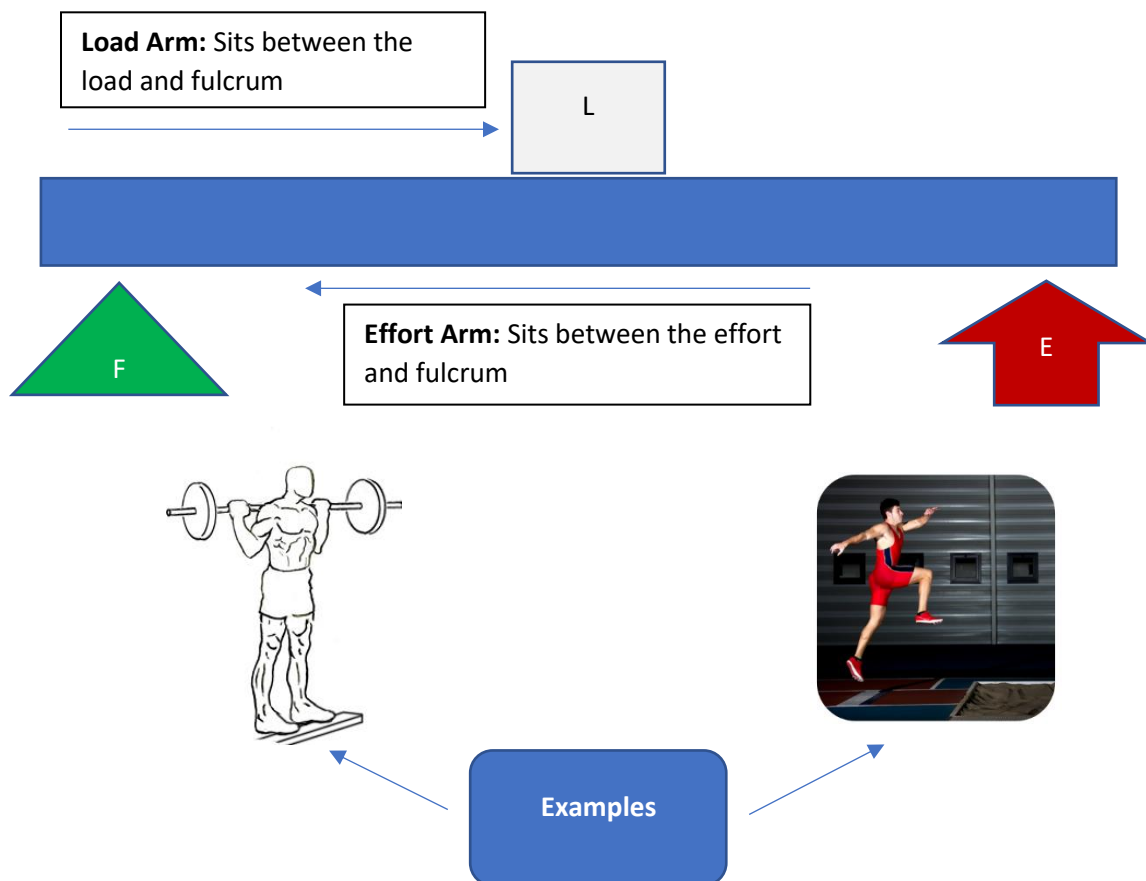
**Mechanical Advantage = Effort Arm ÷ Load Arm.**

This is when a large load can be lifted with relatively little effort. It is usually due to the effort arm being longer than the .

#### **Mechanical Disadvantage:**

This is when it takes a lot of effort to lift a relatively small load.

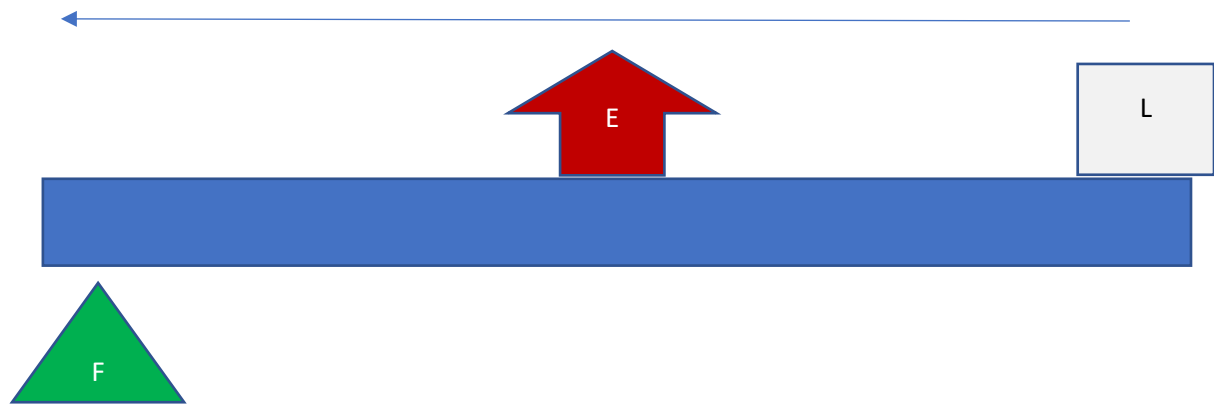
A **Second Class Lever System** will always have a mechanical advantage due to the **effort arm being longer than the load arm**.



A **Third Class Lever System** will always have a mechanical disadvantage due to the **load arm being longer than the load arm**.

**Load Arm:**

Sits between the load and fulcrum



**Effort Arm:**

Sits between the effort and fulcrum



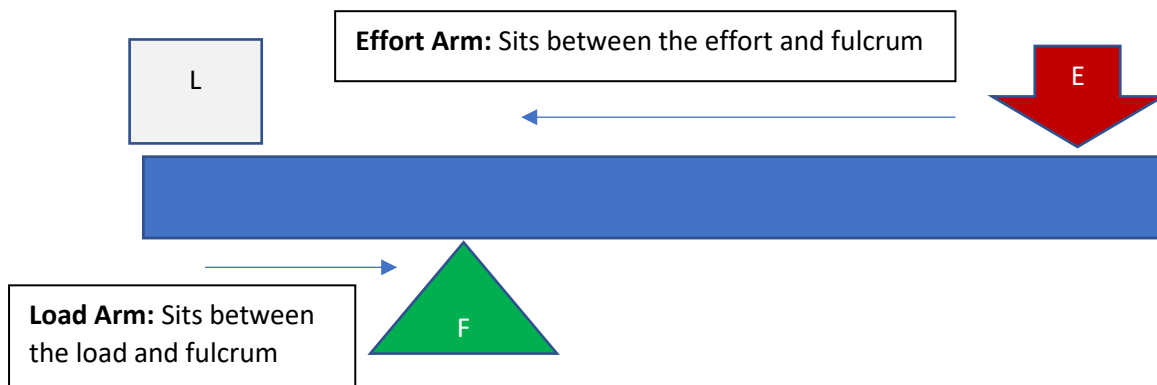
Examples

A mechanical disadvantage has the benefit of producing fast movements

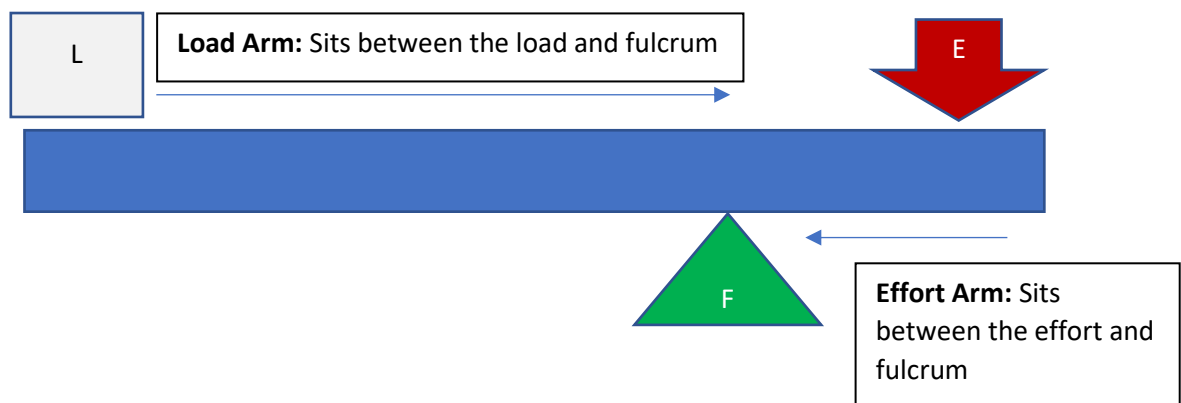
A **First Class Lever System** may have a mechanical advantage or a mechanical disadvantage depending on the length of the effort arm in relation to the resistance arm.

**Remember Mechanical Advantage = Effort Arm ÷ Resistance Arm**

In the following example the effort arm is longer than the load arm, producing a mechanical advantage.



In the following example the load arm is longer than the effort arm, producing a mechanical disadvantage.





Class of lever	Advantage	Disadvantage
<b>First Class</b>	<b>Mechanical Advantage</b> - if the length of the effort arm is greater than the length of the load arm	<b>Mechanical Disadvantage</b> - if the length of the load arm is greater than the length of the effort arm
<b>Second Class</b>	<b>Mechanical Advantage</b> – A large load can be lifted with relatively little effort	Slower Movement
<b>Third Class</b>	Fast Movement	<b>Mechanical Disadvantage</b> – A large effort is needed to lift a relatively small load

What **movement action** is shown through a tricep dip?

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How do you know that a tricep dip is a first class lever system?

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What is the fulcrum when a tricep dip is performed?

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Draw the lever system that operates at the ankle joint, labelling the fulcrum, effort and load.



Analyse the lever system being used at the ankle.

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A bicep curl is an example of which type of lever system?

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Give one advantage and one disadvantage of the lever system used when performing a bicep curl.

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**Key Terms:**

**Inertia** – The resistance an object has to a change in its state of motion

**Newton's First Law (Inertia)** – A force is required to change the state of motion

**Newton's Second Law (Acceleration)** – The magnitude and direction of the force determines the magnitude and direction of the acceleration

**Newton's Third Law (Action/Reaction)** – For every action there is an equal and opposite reaction

**Fulcrum** – The point around which the lever rotates

**Load** – The force of the thing that you want to move

**Effort** – The force that is applied by the user of the lever system

**Mechanical Advantage** – A large load can be lifted with relatively little effort.  $\text{Effort Arm} \div \text{Resistance Arm}$

**Mechanical Disadvantage** – Cannot lift as heavy a load with the same amount of effort