KS4 Physical Education

The Circulatory System
Learning objectives

What we will learn in this presentation:

- The functions of the circulatory system: transportation, control and protection
- To identify cardiac structures
- How the heart acts as a pump in the double circulatory system
- Definitions of heart rate, stroke volume and cardiac output
- The roles of blood vessels in the circulatory system
- How exercise and training effect the circulatory system
- The components of blood.
The circulatory system has three functions:

1. **Transporting** substances around the body. These include oxygen, glucose, carbon dioxide, nutrients, water and waste products.

2. **Controlling** body temperature.

3. **Protecting** the body. Blood contains cells and anti-bodies that fight infection and clotting agents to stop bleeding.

The circulatory system is described as a double system because it has two loops.
Deoxygenated blood is pumped from the heart to the lungs through the pulmonary artery.

Deoxygenated blood returns to the heart through the vena cava.

Oxygenated blood is pumped at high pressure from the heart to the body through the aorta.

Oxygenated blood returns to the heart through the pulmonary vein.
The double circulatory system

The **pulmonary circulation** carries:
- deoxygenated blood from the heart to the lungs
- oxygenated blood back from the lungs to the heart, ready to be pumped out to the body.

The **systemic circulation** carries:
- oxygenated blood to the rest of the body through the arteries
- deoxygenated blood back to the heart through the veins.
The circulatory system

Which way does blood flow in the circulatory system?
Blood vessels

There are **three types of blood vessels**, as shown in this magnified part of the circulatory system.

- **Artery**
  - Carries blood away from the heart

- **Capillary**
  - Carries blood to and from the body’s cells

- **Vein**
  - Carries blood back into the heart

**Why are there different types of blood vessels?**
Blood vessels

**ARTERY**
- Thick outer wall
- Thick inner layer of muscle and elastic fibres
- Narrow central tube (lumen)

**VEIN**
- Thin outer wall
- Thin inner layer of muscle and elastic fibres
- Wide central tube (lumen)

**CAPILLARY**
- Wall only one cell thick
Blood vessels: valves

When blood is flowing against gravity, or when a vein is squeezed by muscle action, there is a risk that blood will flow in the wrong direction. **Veins have valves** to prevent backflow.

The valves allow blood to flow in the correct direction…

...but close if blood starts to flow in the wrong direction.
Can you tell the difference between the three types of blood vessels?

Click **start** to begin this quiz.

- **artery**
- **capillary**
- **vein**
The four chambers of the heart have special names:

An **upper** chamber is called an **atrium** (plural: atria).

A **lower** chamber is called a **ventricle**.
Here are some other important parts of the heart:

The walls are made of cardiac muscle.

The wall dividing the left and right sides of the heart is called the septum.

The semi-lunar valves prevent expelled blood flowing back into the heart.

Bicuspid (mitral) valve

Tricuspid valve

These two valves prevent blood flowing back into the atria from the ventricles.
View the heartbeat animation on a loop or in stages.
Heart rate (or pulse rate) is the number of times your heart beats every minute.

It is expressed in beats per minute (bpm).

Resting heart rate varies from individual to individual and is affected by fitness.

The fitter you are, the lower your resting heart rate will be.

The average resting heart rate is about 70–75 bpm.
The heart during exercise

Each individual has a **maximum heart rate** – the fastest that their heart is able to beat. Testing it properly is difficult and unpleasant, as it involves pushing your body to its absolute limit.

However, maximum heart rate can be **estimated** using a simple formula:

\[
\text{Maximum Heart Rate (MHR) = 220 – age}
\]

So, a 25 year-old would have a maximum heart rate of

\[220 – 25 = 195 \text{ bpm}\]

What would your maximum heart rate be?
The pulse rate is not the only way of measuring the heart.

**Stroke volume** is the amount of blood pumped out of the left ventricle per beat.

**Cardiac output** is the amount of blood pumped out of the left ventricle of the heart per minute.

Cardiac output can be calculated by multiplying the stroke volume by the heart rate:

\[
\text{cardiac output} = \text{stroke volume} \times \text{heart rate}
\]

What is the cardiac output of someone with a heart rate of 60 bpm and stroke volume of 90 ml?
The heart during exercise

During exercise, the body uses up oxygen and nutrients at a much faster rate. To keep the body supplied with what it needs, the heart beats faster and with greater force.

This means that the heart rate and stroke volume increase.

What do you think happens to the cardiac output?

Regular exercise causes changes to the heart.

- The heart gets larger
- The muscular wall become thicker and stronger
- Stroke volume at rest increases, leading to a lower resting heart rate.
The circulatory system - Select the correct answers from the drop down lists to complete the passage.

Resting heart rate is measured in beats per [ ] .

During exercise the heart beats more rapidly. Blood pressure increases with [ ] and [ ] .

In the long-term the heart becomes [ ] and [ ] , causing the resting heart rate to [ ] .

Click on start to begin.
Blood pressure

The higher the water shoots, the higher the blood pressure in the hose.

Flow volume and blood vessel diameter affect blood pressure. Adjust the tap and the size of the nozzle on this hose to see how the water pressure is affected.

Press **start** to begin.

**start**
Blood pressure depends on the speed of the blood coming into a vessel and the width of the vessel itself.

<table>
<thead>
<tr>
<th>Arteries</th>
<th>Capillaries</th>
<th>Veins</th>
</tr>
</thead>
<tbody>
<tr>
<td>Speed: high</td>
<td>Speed: medium</td>
<td>Speed: low</td>
</tr>
<tr>
<td>Width: medium</td>
<td>Width: narrow</td>
<td>Width: wide</td>
</tr>
<tr>
<td>Pressure: high</td>
<td>Pressure: medium</td>
<td>Pressure: low</td>
</tr>
</tbody>
</table>
An individual’s blood pressure is affected by a number of factors.

- **Age** – it increases as you get older.
- **Gender** – men tend to have higher blood pressure than women.
- **Stress** can cause increased blood pressure.
- **Diet** – salt and saturated fats can increase blood pressure.
- **Exercise** – the fitter you are the lower your blood pressure is likely to be.

Having high blood pressure puts stress on your heart. It can lead to **angina**, **heart attacks** and **strokes**.
Effects of exercise on blood pressure

The immediate effect of exercise is to **raise** the blood pressure as the heart beats faster and more powerfully.

During intense exercise, blood flow to the muscles can increase to 35 times its normal volume. Higher blood pressure is necessary in order to get this extra blood to the muscles.

However, in the **long-term**, regular exercise **reduces** blood pressure. The fitter you are, the lower your blood pressure is likely to be.
Blood flow and body temperature

The circulatory system plays an important role in regulating body temperature.

If the body gets too hot, capillaries near the surface of the skin widen. Blood is diverted to the skin where the heat can easily radiate away. This is called **vasodilation**.

Water from the blood is excreted as **sweat** to cool the body.
If the body gets **too cold**, capillaries near the surface of the skin get narrower. Blood is diverted away from the skin to limit heat loss. This is called **vasoconstriction**.

Sweating stops.
Blood

Blood is the body’s means of transporting substances around. It transports:

- **oxygen** from the lungs to the heart and then to the body’s tissues
- **carbon dioxide** from the tissues to the heart and then to the lungs to be expired
- materials like **hormones** from one organ to another
- **nutrients** (especially **glucose**) and **minerals** from the intestines to the tissues
- **waste products** to the kidneys.
### Blood

**Which substances are supplied to the muscles and which are taken from them?**

<table>
<thead>
<tr>
<th>Supplied to the muscles:</th>
<th>Taken from the muscles:</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Do you know which of these substances are supplied to the muscles and which are taken away from the muscles? Press start to begin.

```
start
```

```
solve
```

- **Carbon dioxide**
Red blood cells

Blood is made up of a number of different elements. The most common cell in blood is the **red blood cell**.

- Also called **erythrocytes**.
- **Disc-shaped**.
- Made in the **bone marrow**.
- Contain a red-coloured compound called **haemoglobin** which bonds with oxygen to form **oxyhaemoglobin**.
- Transport oxygen to the tissues.

How important do you think red blood cells are to sports performance?
Blood also contains **white blood cells**.

- Also called **leucocytes**.
- They are bigger than red blood cells and have large nuclei.
- Act as the body’s **defence system**.

- Some white blood cells **surround and consume** harmful microbes.
- Some produce chemicals called **antibodies** that fight infection.

**How important do you think white blood cells are to sports performance?**
Platelets are also carried in the blood.

- Formed in red bone marrow.
- Produce thrombokinase – a chemical needed for blood clotting.
- Platelets help to repair tissues and close wounds both internally and externally.
- When needed, they grow into irregular shapes and stick together to form a plug over the wound.

How important do you think platelets are to sports performance?
The blood cells and platelets are suspended in a substance called **plasma**. Plasma is made up of:

- 90% water
- inorganic salts
- glucose
- antibodies
- urea and other waste products
- plasma proteins.

*Plasma can be separated from the other components of blood using a centrifuge.*
Match the labels to the blood cells.

**Name of Blood Cell**  
- Name of Blood Cell: ?
- Name of Blood Cell: ?
- Name of Blood Cell: ?

**Function**  
- Function: ?
- Function: ?
- Function: ?

<table>
<thead>
<tr>
<th>Blood Cells</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>White Blood Cell</td>
<td>To carry oxygen</td>
</tr>
<tr>
<td>Platelets</td>
<td>To form blood clots</td>
</tr>
<tr>
<td>Red Blood Cell</td>
<td>To fight microbes</td>
</tr>
</tbody>
</table>
Because **red blood cells** carry oxygen, which is vital to muscle action, it is advantageous for a performer to have a high red blood cell count, especially in endurance events.

When athletes train and live at **altitude**, where there is less oxygen in the air, their bodies compensate by producing extra red blood cells.

This means that they can perform at a higher intensity than other athletes when performing at sea level.
Blood doping

An athlete’s red blood cell count can be *illegally* boosted through **blood doping**. Several months before a competition, blood is removed from a performer. Their body produces more blood to replace the blood that has been removed.

The red blood cells are separated out from the removed blood and stored. Just before the competition, they are **re-injected** into the competitor, giving them an artificially high red blood cell count.

Blood doping can improve performance by **20%**, however, the extra blood can lead to dangerous **blood clots** and all the heart problems associated with **high blood pressure**.
1. During exercise, extra demands are placed on the circulatory system.
   a) Describe what happens to heart rate, stroke volume and cardiac output during intensive physical activity.
   b) Describe how the circulatory system helps to regulate body temperature during exercise.

2. Blood contains several different types of cell.
   a) Explain the function of red blood cells in the body.
   b) Describe one way in which a performer could increase their red blood cell count.
How much can you remember?
Read the definition at the bottom and then click on the right answer...

Press **start** to begin.
<table>
<thead>
<tr>
<th>Can you remember all these keywords?</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aorta</td>
</tr>
<tr>
<td>Vena cava</td>
</tr>
<tr>
<td>Pulmonary artery</td>
</tr>
<tr>
<td>Pulmonary vein</td>
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<tr>
<td>Pulmonary circulation</td>
</tr>
<tr>
<td>Systemic circulation</td>
</tr>
<tr>
<td>Oxygenated</td>
</tr>
<tr>
<td>Deoxygenated</td>
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<tr>
<td>Arteries</td>
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<tr>
<td>Veins</td>
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<tr>
<td>Capillaries</td>
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<td>Lumen</td>
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<td>Atria</td>
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<td>Ventricles</td>
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<tr>
<td>Septum</td>
</tr>
<tr>
<td>Tricuspid valve</td>
</tr>
<tr>
<td>Bicuspid (mitral) valve</td>
</tr>
<tr>
<td>Semi-lunar valve</td>
</tr>
<tr>
<td>Heart rate</td>
</tr>
<tr>
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<tr>
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<td>Vasoconstriction</td>
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<td>Red blood cells</td>
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<tr>
<td>Plasma</td>
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<td>Blood doping</td>
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