1.1 The Cardiovascular System

Teacher Answer Booklet
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</tbody>
</table>
Health & Fitness:
There is no doubt that health and fitness can be affected by exercise and activity levels. Use the key words given below to help you to define health and fitness:

Health –
Complete physical, mental and social well-being, not merely the absence of disease and infirmity

Fitness- The ability to meet the demands of the environment

<table>
<thead>
<tr>
<th>Key Words:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical</td>
</tr>
<tr>
<td>Environment</td>
</tr>
<tr>
<td>Social</td>
</tr>
<tr>
<td>Demands</td>
</tr>
<tr>
<td>Emotional</td>
</tr>
<tr>
<td>Disease</td>
</tr>
</tbody>
</table>

Health = Fitness?
Health and fitness are often used together in the same sentence, but does good health necessarily mean good fitness according to the official definitions?

The pictures shown below look at darts player Andy Fordham and long distance runner Mo Farah. Using your definitions to help you, discuss whether each performer can be described as fit and healthy.
Andy Fordham:

Shows a good level of fitness as he meets the demands of his environment for darts, where very limited cardiovascular fitness is required. However he is clearly overweight which shows that his physical health is poor.

Mo Farah:

Clearly meets the demands of his environment in terms of fitness as he is a World champion long distance runner. His physical health appears to be very good due to his fitness demands. His mental and social health also appear to be good, although there may be underlying issues that are not externally visible.

**Physical Health and the Cardiovascular System:**

The following words are all problems that can occur as a result of poor physical fitness.

Heart disease, High blood pressure, Effects of cholesterol, Stroke

Using these words, explain the process of high cholesterol leading to a stroke or heart attack.

Cholesterol is found in fatty foods and can build up in the arteries. This can lead to high blood pressure as a more powerful contraction is required from the heart to send the blood through the partially blocked artery. If the cholesterol continues to block the artery a clot may form which prevents the flow of blood around the body. This can lead to a heart attack or stroke.

‘Lifestyle Choices’ are day to day decisions that we make that can make a difference to our health and fitness. What lifestyle choices can lead to a lower chance of heart disease/Stroke?

**Regular Exercise/Balanced Diet**

**Fitness & The Cardiovascular System:**

Name 3 sports which require good cardiovascular fitness:

1. Long Distance Running
2. Rowing
3. Cycling
In order to assess ‘fitness’ in sports such as these, we can look at a performer’s stroke volume and cardiac output.

**Stroke Volume** = The volume of blood pumped out by the heart *ventricles* in each contraction.

**Cardiac Output** = The volume of blood pumped out by the heart *ventricles* per minute. (Heart Rate x Stroke Volume)

<table>
<thead>
<tr>
<th>Ventricles</th>
<th>Volume</th>
<th>Minute</th>
<th>Volume</th>
<th>Ventricles</th>
</tr>
</thead>
</table>

Explain what you believe will happen to stroke volume and cardiac output as a result of exercise.

The common consensus and belief is that stroke volume and cardiac output will always tend to increase during exercise.

We will now look into whether this is completely true.....

Exercise can be done at maximal or sub-maximal intensity. What is the difference between the two?

**Maximal** – Exercising past an intensity of 85% of your maximum heart rate

**Submaximal** – Exercising at an intensity up to 85% of your maximum heart rate
**Stroke Volume at Sub-Maximal Exercise:**

The following table shows the stroke volume (ml) of a performer exercising at sub-maximal intensity.

**Table 1**

<table>
<thead>
<tr>
<th>Time</th>
<th>Stroke Volume (ml)</th>
<th>HR Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1min (30% max effort)</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>2min (40% max effort)</td>
<td>120</td>
<td>80</td>
</tr>
<tr>
<td>3min (50% max effort)</td>
<td>140</td>
<td>101</td>
</tr>
<tr>
<td>4min (60% max effort)</td>
<td>160</td>
<td>121</td>
</tr>
</tbody>
</table>

The performer in the table above is 18 years old. Use the column to state how high you think their HR was for each minute of exercise. Explain your estimates below.

The estimates in the table above have been worked out after considering max effort in regards to maximum HR which is 220-age. For example the performers maximum HR is 202. 30% of 202 is 60 beats per minute.
**Stroke Volume at Maximal Exercise:**

When exercising at maximal levels, things start to change for stroke volume. A performer’s stroke volume will only continue to rise up to around 60% of maximal effort. At this point the heart rate is too high for the ventricles to have enough time to fill up with blood, meaning that there is a **plateau** in stroke volume.

<table>
<thead>
<tr>
<th>Time</th>
<th>Stroke Volume (ml)</th>
<th>HR Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>1min (30% max effort)</td>
<td>80</td>
<td>60</td>
</tr>
<tr>
<td>2min (40% max effort)</td>
<td>100</td>
<td>80</td>
</tr>
<tr>
<td>3min (50% max effort)</td>
<td>120</td>
<td>101</td>
</tr>
<tr>
<td>4min (60% max effort)</td>
<td>140</td>
<td>121</td>
</tr>
<tr>
<td>5min (70% max effort)</td>
<td>140</td>
<td>141</td>
</tr>
<tr>
<td>6min (80% max effort)</td>
<td>140</td>
<td>162</td>
</tr>
<tr>
<td>7min (90% max effort)</td>
<td>140</td>
<td>182</td>
</tr>
</tbody>
</table>

Using the information above, fill in the table to show what you would expect to happen to both stroke volume and HR as a result of maximal exercise.

So if stroke volume does not increase at maximal exercise, how do your working muscles continue to get the oxygen they require as exercise intensity increases?

**Muscles will continue to get more oxygen as intensity increases because HR continues to increase.** This means that the amount of oxygen being supplied per minute (cardiac output) continues to increase.
Cardiac Output at Sub-Maximal & Maximal Level:

As discussed earlier, Cardiac Output is HR x Stroke Volume.

Repeat your answers from the table above, but this time add in cardiac output by using the equation shown above.

Table 3

<table>
<thead>
<tr>
<th>Time</th>
<th>Stroke Volume (ml)</th>
<th>HR</th>
<th>Cardiac Output (litres/min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1min (30% max effort)</td>
<td>80</td>
<td>60</td>
<td>4.8</td>
</tr>
<tr>
<td>2min (40% max effort)</td>
<td>100</td>
<td>80</td>
<td>8</td>
</tr>
<tr>
<td>3min (50% max effort)</td>
<td>120</td>
<td>101</td>
<td>12.2</td>
</tr>
<tr>
<td>4min (60% max effort)</td>
<td>140</td>
<td>121</td>
<td>16.9</td>
</tr>
<tr>
<td>5min (70% max effort)</td>
<td>140</td>
<td>141</td>
<td>19.7</td>
</tr>
<tr>
<td>6min (80% max effort)</td>
<td>140</td>
<td>162</td>
<td>22.7</td>
</tr>
<tr>
<td>7min (90% max effort)</td>
<td>140</td>
<td>182</td>
<td>25.5</td>
</tr>
</tbody>
</table>

After completing the table above, explain what happens to Cardiac Output when exercising at submaximal and maximal levels.

Cardiac Output continues to increase during both submaximal and maximal exercise. It increases very quickly during submaximal exercise as both stroke volume and heart rate are increasing. It continues to increase but at a slower rate during maximal exercise, this is because heart rate increases but stroke volume is now showing a plateau (staying the same).

Now use graph paper in order to plot one line graph showing the results from table 2, and a separate graph to show your results from table 3.
Q1.
Paul and Mark are both 20 years old. Paul does no exercise. Mark is a cross country runner who trains three times a week.

How would maximal cardiac output differ between Paul and Mark? Justify your answer.

Marks available for:
- Mark would have a higher maximum cardiac output.
- This is because Mark would have a greater maximum stroke volume
- Due to cardiac hypertrophy/more efficient cardiovascular system
- Both runners would have the same maximum HR
- Mark will be able to get closer to his maximum HR during maximal exercise

(Total 3 marks)

Q2.
Paul has a high level of cholesterol.

Identify one possible effect of high cholesterol levels on health.

Marks available for:
Heart Attack/Stroke

(Total 1 mark)

Q3.
Many people play tennis as a way of improving their fitness.

(i) Explain the difference between the terms health and fitness.

Marks available for:

Health is complete social, mental and physical well-being, not merely the absence of disease or infirmity. Fitness is the ability to meet the demands of the environment.

Note – The above answer is not required to be word for word (1)
(ii) Explain how the health of a performer may affect their fitness.

Marks available for:

- Poor physical health e.g. cold/flu can prevent training and this can result in a decline in fitness
- However, a performer may suffer from poor mental health but still be able to train. Therefore there would be no effect on fitness.

The Hormonal, Neural and Chemical Regulation of Responses during Physical Activity

The cardiovascular system responds to exercise in a number of different ways. What is meant by the following terms?

Hormonal – Relating to or containing hormones

Neural – Relating to the nervous system

Chemical – Relating to chemicals that are released in the body

Anticipatory Rise

This is the increase in heart rate that occurs just before taking part in exercise. It is caused by an increase in activity from the sympathetic nervous system.

What is the sympathetic nervous system and when is it activated?

The sympathetic nervous system is part of the Autonomic Nervous System and is located in the brain. It is activated when a ‘fight or flight’ response is required and can result in an increase in heart rate.
Just before taking part in exercise, the sympathetic nervous system increases activity which causes the adrenal glands to release adrenaline into the blood stream. This causes the increase in heart rate known as **anticipatory rise**.

What is adrenaline?

Adrenaline is a hormone which results in an increase in heart rate, blood pressure and alertness.

Describe a sporting performance where you feel you have noticeably experienced **anticipatory rise**.

*e.g. playing a league decider, cup final or in front of a large crowd for the first time*

**Redistribution of Blood Flow:**

During exercise blood must be distributed to areas of the body that require an increased level of oxygen. This redistribution of blood flow is known as **vascular shunting**.

How would the following performers benefit from the **vascular shunt mechanism**? Which muscle groups will require more oxygen?

- Increase in oxygen delivery to the quadriceps/hamstrings
- Increase in oxygen delivery to the biceps/triceps/deltoid/pectoralis
- Increase in oxygen delivery to the muscles in the arms/legs
How does eating just before exercising have an effect on vascular shunting?

The digestive system will require oxygen in order to digest your food. Your muscles will require oxygen in order to produce energy during exercise. This conflict can result in stomach cramps and pains.

As you exercise and vascular shunting occurs, your blood vessels help with the process of redistributing blood. This process is known as vasodilation and vasoconstriction.

**Key Point – The brain requires the same amount of oxygen at rest and exercise**

**VasoDILATion** – blood vessels DILATE (get bigger) – allows more blood for the active muscles

**VasoCONSTRICtion** – blood vessels CONstrict (get smaller) – takes blood away from inactive areas and the organs

How is vasodilation used by the body during exercise?

e.g. during a rugby match vasodilation will occur in the arteries delivering oxygenated blood to a performer’s legs. This will allow more oxygenated blood to be delivered to this area, resulting in more energy being produced.

How is vasoconstriction used by the body during exercise?

Vasoconstriction will occur in the arteries delivering blood to areas such as the digestive system and the liver. These areas do not need as much oxygen during exercise as they are inactive. This allows more blood to be delivered to the working muscles.
The Process of Vascular Shunting:

- Increase in Co2 and Lactic Acid detected by the Chemoreceptors
- The Chemoreceptors stimulate the Vasomotor
- The Vasomotor signals for a redistribution of blood flow
- Vasodilation and Vasoconstriction occur and the pre-capillary sphincters adjust blood flow into the capillaries

What are the chemoreceptors and where are they located?

The chemoreceptors are sensors that detect a change in blood acidity/C02 levels. They are located in the walls of the arteries.

What is the Vasomotor and where is it located?

The Vasomotor is located in the Medulla Oblongata in the brain and is responsible for the regulation of heart rate, blood pressure and the redistribution of blood flow.
How does vascular shunting occur in order to benefit a netball player during a match?

Whilst playing netball, the chemoreceptors will notice an increase in lactic acid and CO2 at the site of the working muscles, such as the quadriceps and hamstrings. A signal is therefore sent from the chemoreceptors to the vasomotor in the medulla oblongata. The vasomotor sends an impulse for the vasodilation to occur within the arteries leading to the active areas, allowing more oxygenated blood to get to the muscles and get rid of the excess lactic acid. Vasoconstriction will restrict the amount of blood getting to the inactive areas such as the digestive system and the liver. The pre-capillary sphincters will also adjust in size to let more oxygen pass into the active muscles, and restrict the amount of oxygen entering the inactive areas.

The Heart – Chambers, Arteries, Veins & Valves

- Vena Cava
- Right Pulmonary Artery
- Right Aorta
- Right Pulmonary Vein
- Tricuspid Valve
- Right Ventricle
- Bicuspid Valve
- Septum
- Left Pulmonary Artery
- Left Pulmonary Vein
- Left Aorta
- Left Ventricle
The Cardiac Conduction System

The cardiac conduction system is a group of cells found in the wall of the heart which are responsible for the electrical impulses that cause the heart to contract.

The heart is ‘myogenic’. This means that it is capable of generating its own impulses.

It is important that you understand the order of events that take place as part of the Cardiac Conduction System:

- **Electrical signal begins in the Sinoatrial Node (SAN)**

- The electrical impulse travels through the atria, causing them to contract and pass blood into the ventricles, before reaching the Atrioventricular Node (AVN)

- A delay of 0.1secs then occurs whilst the atria fully contract.

- The electrical impulse then travels down the bundle of his, which is located in the septum.

- The bundle of his then separates into smaller branches called purkinje fibres. These spread around the ventricles and cause them to contract.
When a performer is running, blood is redirected to the working muscles. Explain how this *redistribution* of blood is achieved.

**Marks available for:**

- Chemoreceptors detect a drop in PH levels in the blood/increased CO2/increased lactic acid
- A signal is sent from the chemoreceptors to the vasomotor (in the medulla oblongata)
- The vasomotor sends impulses that will begin to redistribute the blood/vascular shunting
- Vasodilation will occur in the blood vessels leading to the active muscles/vasoconstriction will occur in the blood vessels leading to the inactive areas e.g. digestive system/liver
- Pre-capillary sphincters will adjust the blood flow to the active/inactive areas

(Total 3 marks)

**Q2.**

The graphs show the heart rates for two athletes before, during and after an exercise session. Each athlete is using a different training method.

![Graphs of heart rates for athletes](image)

State the term used to describe the increase in heart rate labelled A and name the hormone that causes this increase in heart rate.

**Marks available for:**

- Anticipatory Rise
- Adrenaline

(Total 2 marks)
Q3.
During a game of football, a player’s heart rate will vary.

Explain how changes in the acidity of the blood cause the heart rate to increase during a game of football.

Marks available for:

- Chemoreceptors detect an increase in lactic acid/C02/blood acidity
- Impulse sent to the medulla oblongata which activates the sympathetic nervous system
- Medulla oblongata sends an impulse to the Sinoatrial Node which will speed up the rate of contractions in the heart
- This will result in more oxygen being delivered to the muscles and lactic acid being removed

Accept other appropriate answers

(Total 4 marks)

Q4.
Explain why blood flow to the brain remains the same during rest and during maximum effort. (2)

Marks available for:

- The brain is always active/functioning
- Therefore the same amount of oxygen is required whether exercising or resting

Q5. Put the following terms in order to show how an electrical impulse travels through the heart in order to create ventricular systole. Explain what happens at each stage. (5 marks)

Atrioventricular Node (AVN)

Purkinje Fibres

Bundle of His

Ventricular Systole

Sinoatrial Node (SAN)

Marks available for:

- Sinoatrial Node – This is where the electrical signal begins/is created
- Atrioventricular Node – A delay of 0.1 seconds occurs here in order to allow the atria to fully contract, before the electrical signal continues
- The impulse then travels down the bundle of his which is lined within the septum of the heart
• The impulse then branches out across the **purkinje fibres** which surround the ventricles, causing them to contract
• Therefore ventricular systole occurs and blood is pumped from the heart to the rest of the body

**Sympathetic v Parasympathetic Systems:**

The sympathetic system can speed up the cardiac impulses given out by the cardiac conduction system, whereas the parasympathetic system can decrease these impulses and heart rate.

Both of these control mechanisms are controlled by the **medulla oblongata** in the brain.

If **sympathetic** nervous impulses are sent from the brain to the SAN, what will happen?
What might an individual be doing at this point?

**This will result in an increase in heart rate. An individual may well be exercising.**

If **parasympathetic** nervous impulses are sent from the brain to the SAN, what will happen?
What might an individual be doing at this point?

**This would cause a decrease in heart rate and is likely to occur during rest.**
**Chemoreceptors:**

During exercise the chemoreceptors detect an increase in carbon dioxide. Nerve impulses are therefore sent to the medulla oblongata in the brain and the sympathetic nervous system is activated and impulses are sent to the SA node in order for contractions to increase. This will lead to an increase in heart rate and the supply of oxygen for the body.

<table>
<thead>
<tr>
<th>Impulses</th>
<th>Medulla Oblongata</th>
<th>Exercise</th>
<th>Oxygen</th>
<th>Carbon Dioxide</th>
<th>Node</th>
<th>Sympathetic Nervous</th>
</tr>
</thead>
</table>

**Baroreceptors:**

The baroreceptors detect an increase or decrease in blood pressure by detecting the stretching of the arterial wall. An increase in arterial pressure will result in the baroreceptors sending a message to the medulla oblongata in the brain. The parasympathetic system will then be activated and impulses are sent to the SA node for contractions to decrease. However during exercise the baroreceptor set point increases, so that heart rate does not slow down.

<table>
<thead>
<tr>
<th>Arterial</th>
<th>Set</th>
<th>Blood Pressure</th>
<th>Message</th>
<th>Parasympathetic</th>
<th>Medulla Oblongata</th>
<th>Slow</th>
<th>SA</th>
</tr>
</thead>
</table>

**Proprioceptors:**

Proprioceptors are located in muscles, joints and tendons. During exercise they detect an increase in muscle movement. An impulse is sent to the medulla oblongata and the sympathetic nervous system is activated. An impulse is sent to the SA node and heart rate is increased.

<table>
<thead>
<tr>
<th>Movement</th>
<th>SA</th>
<th>Muscles</th>
<th>Nervous</th>
<th>Increased</th>
<th>Medulla Oblongata</th>
<th>Exercise</th>
<th>Impulse</th>
</tr>
</thead>
</table>
A footballer has just started playing in a match. Explain how the player’s receptor systems will enhance his supply of energy during the match.

The chemoreceptors will detect an increase in lactic acid and CO2. A message will be sent to the medulla oblongata which will send an impulse to the SA Node, whereby heart rate will increase. This will allow more oxygen to be delivered to the muscles, allowing the player to work for longer at a higher intensity without becoming tired in the match.

The proprioceptors will detect an increase in muscle movement as the player begins the match. A message will be sent to the medulla oblongata which will send an impulse to the SA Node, whereby heart rate will increase. This will allow more oxygen to be delivered to the muscles, allowing the player to work for longer at a higher intensity without becoming tired in the match.

The baroreceptors will detect an increase in blood pressure as exercise begins. This would usually result in the parasympathetic nervous system being activated and a decrease in heart rate. However during exercise the baroreceptor set point changes, meaning that blood pressure can increase without the parasympathetic nervous system being activated.
The Transportation of Oxygen:

Haemoglobin – An oxygen binding protein found in red blood cells

Oxyhaemoglobin – Found when oxygen combines with haemoglobin

Myoglobin – An oxygen binding protein found in muscle tissue

Plasma – The liquid part of blood

Mitochondria - The part of the cell where respiration and energy production occur

Put each of these key words into the following paragraph in order to explain the transportation of oxygen.

During exercise, oxygen will attach to haemoglobin. As a result Oxyhaemoglobin is formed, whereby it is transported via the blood plasma to the working muscles. Due to the low pressure of oxygen at the muscle tissues, the oxygen will release itself from the haemoglobin and diffuse into the muscle cells. In the muscle cells, myoglobin will be present, which stores oxygen and allows it to be used quickly for energy production. Aerobic respiration will then take place at the mitochondria.
**Dissociation Curve:**

The Dissociation Curve is used to explain how the different partial pressure of oxygen in different areas of the body, will have an effect on the amount of oxygen combining with haemoglobin (to form oxyhaemoglobin).

At the **lungs**, there is a high partial pressure of oxygen in the lungs, and a low partial pressure of oxygen in the blood stream, meaning that lots of oxygen diffuses into the bloodstream and attaches to haemoglobin. This leaves a lower level of partial pressure of oxygen in the blood stream.

At the **muscle tissue**, there is a high partial pressure of oxygen in the blood stream and low partial pressure of oxygen within the Muscle Tissue, therefore haemoglobin will separate from oxygen, which diffuses into the muscle tissue. This leaves a lower level of partial pressure of oxygen in the blood stream.

The process of diffusion will make sure that oxygen is always finding its way into the blood stream at the lungs, and into the tissue at the site of muscles.
Bohr Shift:

During exercise, oxygen separates (dissociates) from haemoglobin even more quickly in order to get more oxygen to the working muscles.

This increase in oxygen dissociation from haemoglobin happens for three reasons:

- There is an increase in blood temperature
- The partial pressure of carbon dioxide increases
- An increase in carbon dioxide means that there is a decrease in pH level of the blood. Therefore the blood is more acidic
Q1.
The Bohr Shift is the movement of the oxyhaemoglobin disassociation curve to the right during exercise.

Identify the two factors that cause the Bohr Shift.

A Decrease in carbon dioxide, decrease in temperature.
B Decrease in carbon dioxide, increase in temperature.
C Increase in carbon dioxide, decrease in temperature.
D Increase in carbon dioxide, increase in temperature.

(Total 1 mark)

Q2.
The transport of oxygen during a continuous training session is vital for athletes to make sure that oxygen supply meets oxygen demand.

What is the difference between haemoglobin and myoglobin when transporting oxygen?

Marks available for:
- Haemoglobin is an oxygen binding protein found within red blood cells
- Myoglobin is an oxygen binding protein found within the muscle tissue

(Total 2 marks)

Q3.
(i) Where is myoglobin found in the body and what is its role during exercise?

Marks available for:
- Myoglobin is found in the muscle tissue
- The role of myoglobin during exercise is to release oxygen at a fast rate, allowing more energy to be produced

(2)
(ii) The figure below shows the oxyhaemoglobin dissociation curve.

During a 400 metre hurdles race, the curve shifts to the right.

Explain the causes of this change to the curve and the effect that this change has on oxygen delivery to the muscles.

Marks available for:

- There is an increase in blood temperature
- The partial pressure of carbon dioxide increases
- There is a decrease in pH level of the blood/the blood is more acidic
- These changes mean that more oxygen will dissociate from haemoglobin in the blood stream and enter the site of the muscle tissue
- This will result in more oxygen being available for aerobic respiration, and more energy being produced

(4)

Q4.

For effective performance, games players require oxygen to be delivered to the muscles and carbon dioxide to be removed.

Explain how oxygen is taken up by haemoglobin from the lungs and released at the muscle site.

Marks available for:

- A high partial pressure of carbon dioxide in the blood stream at the site of the lungs, and a high partial pressure of oxygen in the alveoli
- Means that there is a high concentration gradient, resulting in diffusion and oxygen passing into the blood stream where it combines with haemoglobin
- A low partial pressure of oxygen in the blood stream at the site of the muscle tissue, and a high partial pressure of carbon dioxide in the muscle tissue
- Means that there is a high concentration gradient, resulting in diffusion and oxygen being released from haemoglobin

(Total 3 marks)
**Venous Return:**

Venous return is the flow of blood back to the heart, via the veins and specifically the vena cava. During exercise, *venous return* increases. As a result of this, more blood will also be ejected from the heart (stroke volume).

Venous Return Mechanisms:
The blood in the veins is at a much lower pressure than in the arteries, particularly as it goes through the Vena Cava and into the heart. Why do you think this is?

The blood leaves the heart at high blood pressure as a contraction has just occurred and lots of power has been generated. As the blood flows around the body this power and pressure is steadily lost. By the time the blood is returning to the heart via the veins it will contain a much lower blood pressure.

Due to this low pressure of blood in the veins, the *venous return mechanisms* are required in order to help Venous Return. These are as follows:

1. **The Skeletal Muscle Pump** – Muscles *contracting* and relaxing are constantly changing shape. This results in muscles pressing on nearby veins. This causes a pumping action, which pushes blood back towards the heart.

2. **The Respiratory Pump**

Breathing in and out causes *contractions* in many muscles, as well as the diaphragm. This causes a constant change in the *pressure* of the thoracic (chest) cavity, compressing the veins and causing venous return.

3. **Pocket Valves**

Veins are full of pocket valves. As blood passes through these valves, they *close* in order to prevent the *backflow* of blood.
Venous return is also aided by ‘smooth muscle’, ‘gravity’ and the ‘suction pump’ of the heart. Do some of your own research to find out about these factors within venous return.

**Smooth Muscle** – This lines the walls of the veins and makes it easier for blood to travel through the veins without disturbance.

**Gravity** – Veins above the heart will be assisted by gravity, making it much easier for blood to flow back to the heart.

**Suction Pump of The Heart** – As the heart relaxes and refills, the low pressure generates a ‘suction’ action, making it easier to take in blood from the veins.

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**How would swimming effect the venous return mechanisms?**

**The Skeletal Muscle Pump** – As a performer swims there are many muscles constantly contracting and relaxing, such as the biceps, triceps, hip flexors and gluteals. These muscle pairs working together will constantly press on nearby veins, squeezing the blood back to the heart.

**The Respiratory Pump** – As breathing increases during swimming, there will be a larger change in pressure within the thoracic cavity. This will result in compression on the veins and as a result will help to squeeze blood back to the heart.

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Tip – Don’t just repeat what you have learned about the mechanisms. Make sure that you are relating your answer to exercise.
Starling’s Law:

Starling’s law of the heart states that stroke volume increases in response to an increase in venous return.

This process, outlined by Starling, follows six key steps.

1. There is an increase in venous return.
2. Therefore greater diastolic filling of the heart occurs.
3. This causes the cardiac muscle to be stretched.
4. Resulting in a more powerful contraction.
5. And an increased ejection fraction (stroke volume).
Blood Pressure:

Blood Pressure – The pressure of the blood in the circulatory system

Systolic Blood Pressure – The pressure of the blood against the wall of the arteries as the heart contracts

Diastolic Blood Pressure – The pressure of the blood in the heart as it relaxes and refills

Cardiovascular Drift:

Think back to the work you did earlier on stroke volume. What did you find happened to stroke volume during submaximal exercise?

During submaximal exercise stroke volume increased. It continues to increase whilst exercising up to approximately 60% of maximum effort.

When exercising for longer than 10 minutes at a steady state (where the body should be able to cope with the demands of the exercise), heart rate will begin to rise. However this should only occur in a warm environment. This is because stroke volume decreases due to a reduction of fluid in the blood plasma. This means that venous return has also decreased and that heart rate must begin to rise in order to keep cardiac output at the required rate.
Exercising in a warm environment:

Practical Activity:
Within a 'warm' environment, take part in running at a steady state. If you are using a treadmill this should be around level 8. You should not increase the intensity as you exercise.

Take your heart rate every minute in order to complete the table below:

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<tr>
<th>Minute</th>
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<td>15</td>
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</tbody>
</table>

Extension:
Repeat this task in a cool environment to see if there are changes in the results.

Double Extension:
Repeat this task over a much longer period of time to see what happens in terms of cardiovascular drift. This should give you even more accurate results.
Explain your results in order to identify if they support the concept of Cardiovascular Drift?

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Arterio-venous oxygen difference (A-V02 diff):

Quite simply this is “The difference in the volume of oxygen between the arteries and the veins”.

How will the volume of oxygen differ between the arteries and veins?

The arteries will carry a much higher volume of oxygen than veins. This is because the arteries are carrying oxygen in order to supply the muscles with energy.

During exercise many parts of cardiovascular system become more efficient, meaning that the arterio-venous oxygen difference becomes higher. Use the words below in your explanation of why this happens.

Myoglobin  Alveoli  Dissociates  Bohr Shift  Haemoglobin  Chemoreceptors

The chemoreceptors are able to detect an increase in CO2 during exercise, triggering for an increase in heart rate. A higher concentration gradient at the site of the muscles means that oxygen dissociates from haemoglobin faster, causing the Bohr Shift. Myoglobin is an oxygen binding protein found within the muscle tissue. During exercise it can rapidly release oxygen to allow for aerobic respiration. These factors result in a greater use of the oxygen in the bloodstream, meaning that less oxygen travels back to the heart in the veins. Therefore A-VO2 diff has increased.

Trained athletes are able to use their cardiovascular systems much more efficiently, therefore their arterio-venous difference is higher than untrained athletes.
Exam Questions:

Describe how running affects the venous return mechanism.

Marks available for:
- Skeletal Muscle Pump –
  - Contraction in muscles such as the biceps and triceps will squeeze the veins, pushing blood back toward the heart
- Respiratory Pump –
  - Running causes an increase in breathing rate and depth. This causes a greater change in the pressure of the thoracic cavity, which will compress against the veins and cause blood to return to the heart faster

Accept Other Appropriate Answers

(Total 3 marks)

Q2.

Use Starling’s law of the heart to explain how stroke volume increases during activity. (Total 3 marks)

Marks available for:
- During activity, venous return will increase
- This will cause increased diastolic filling
- As a result the cardiac muscle of the heart will stretch
- This will cause a more powerful contraction
- Resulting in a higher ejection fraction (stroke volume)

Q3.

If an athlete performs a continuous exercise session lasting 45 minutes at a sub-maximal pace, cardiovascular drift will occur. Explain the term cardiovascular drift. (Total 3 marks)

Marks available for:
- Cardiovascular drift is when heart rate will continue to slowly increase during ‘steady state’ exercise
- This happens when exercising in a warm environment
- As the liquid in the blood plasma decreases
- Which decreases venous return and as a result stroke volume will decrease
- Therefore heart rate must continue to rise to ensure that cardiac output remains the same

Q4.

Explain what happens to arteriovenous oxygen difference (A-VO2 diff) following the onset of exercise. (Total 2 marks)

Marks available for:
- A-VO2 diff will increase
- This is because the body becomes more efficient at using the oxygen supplied

Accept other appropriate answers
Key Terms:

**Health** – Complete physical, mental and social well-being, not merely the absence of disease and infirmity

**Fitness** – The ability to meet the demands of the environment

**Stroke Volume** – The volume of blood pumped out of the ventricles during each contraction

**Cardiac Output** – The volume of blood pumped out of the ventricles per minute (HR x Stroke Volume)

**Sympathetic Nervous System** – Part of the ANS and can activate an increase in HR

**Parasympathetic Nervous System** – Part of the ANS and can activate a decrease in HR

**Vascular Shunting** – The redistribution of blood flow around the body

**Myogenic** – The heart’s ability to create its own contraction

**Chemoreceptors** – Responsible for detecting a change in C02/Lactic Acid/Blood Acidity

**Baroreceptors** – Responsible for detecting a change in blood pressure

**Proprioceptors** – Responsible for detecting a change in muscle movement

**Plasma** – The liquid part of blood

**Myoglobin** – An oxygen binding protein found in muscle tissue

**Haemoglobin** – An oxygen binding protein found in red blood cells

**Oxyhaemoglobin** – Found when oxygen combines with haemoglobin

**Mitochondria** – The part of the cell where respiration and energy production occur

**Dissociation Curve** – A graphical representation of the rate at which oxygen separates from haemoglobin and diffuses into the muscle cells

**Bohr Shift** – The shift to the right that the dissociation curve makes during exercise

**Venous Return** – The flow of the blood back to the heart via the veins and specifically the vena cava

**Starling’s Law** – Stroke volume increases due to an increase in venous return

**Cardiovascular Drift** – The increase of HR during when taking part in steady state exercise in a warm environment

**Arterio-venous oxygen difference** – The difference between the pressure of the oxygen in the arteries and veins