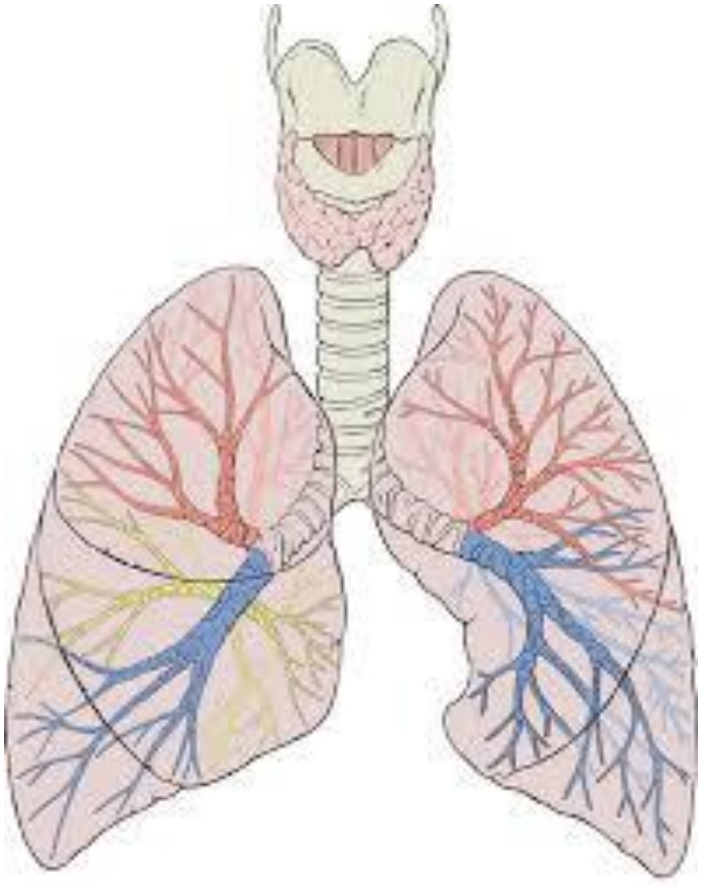
1.3 The Respiratory System

Teacher Answer Booklet



Content	Additional Information	Pupil comments – How confident do you feel on this topic?
Understanding of lung volumes and the impact of and on physical activity and sport.	Residual volume. Expiratory reserve volume. Inspiratory reserve volume. Tidal volume. Minute Ventilation	
Gas exchange systems at alveoli and muscles.	Oxygen and carbon dioxide. Principles of diffusion and partial pressures	
The neural and chemical regulation of pulmonary ventilation during physical activity and sport	Sympathetic and parasympathetic. Carbon dioxide.	
Receptors involved in regulation of pulmonary ventilation during physical activity.	Chemoreceptor, proprioceptor, baroreceptor.	
Impact of poor lifestyle choices on the respiratory system.	Smoking. Oxygen transport.	

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The Pathway of Air:

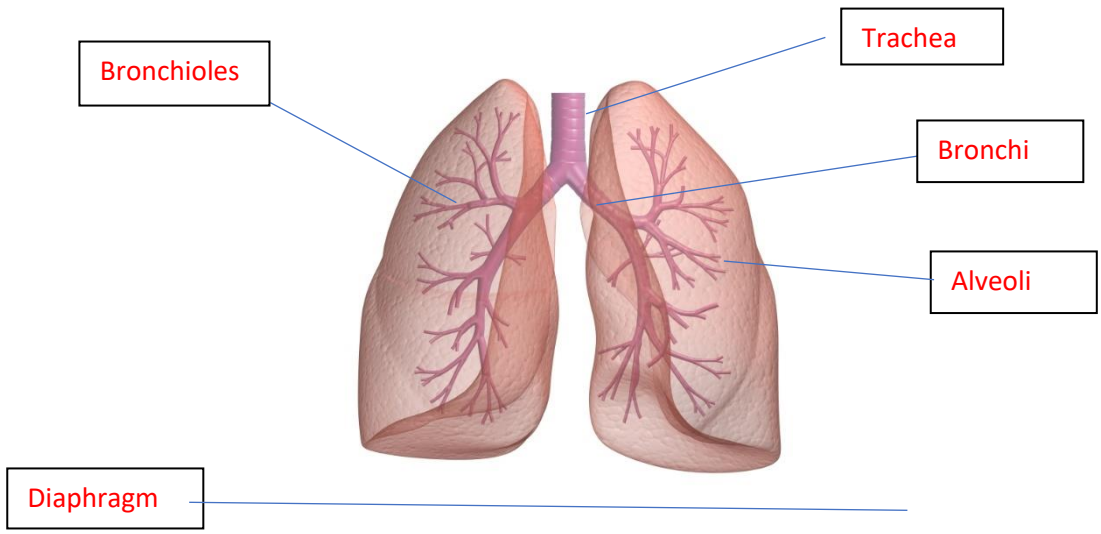
What is the main organ involved in respiration? Lungs

RAHCAET	Trachea
VLAOILE	Alveoli
PRADIGMH	Diaphragm
RNIHBCO	Bronchi
RNIHBCOSLOE	Bronchioles

When inhaling the diaphragm tightens, changing from a dome shape to a flatter shape. This action opens up the lungs and allows air to rush in. When we exhale the diaphragm relaxes, moving up and back to a dome shape.

When breathing in, air passes through the wind pipe, which is also known as the trachea. From here, the air enters one of two branches called the bronchi, through which air passes into each lung. Smaller branches called bronchioles extend out from the bronchi and at the very end of these there are millions of tiny sacs called alveoli. Here is where gaseous exchange takes place and oxygen is passed into the blood so that it can supply the body.

Label the diagram below and also outline the position of the diaphragm when inhaling.



Lung Volumes:

Tidal Volume - The amount of air inspired and expired with each normal breath

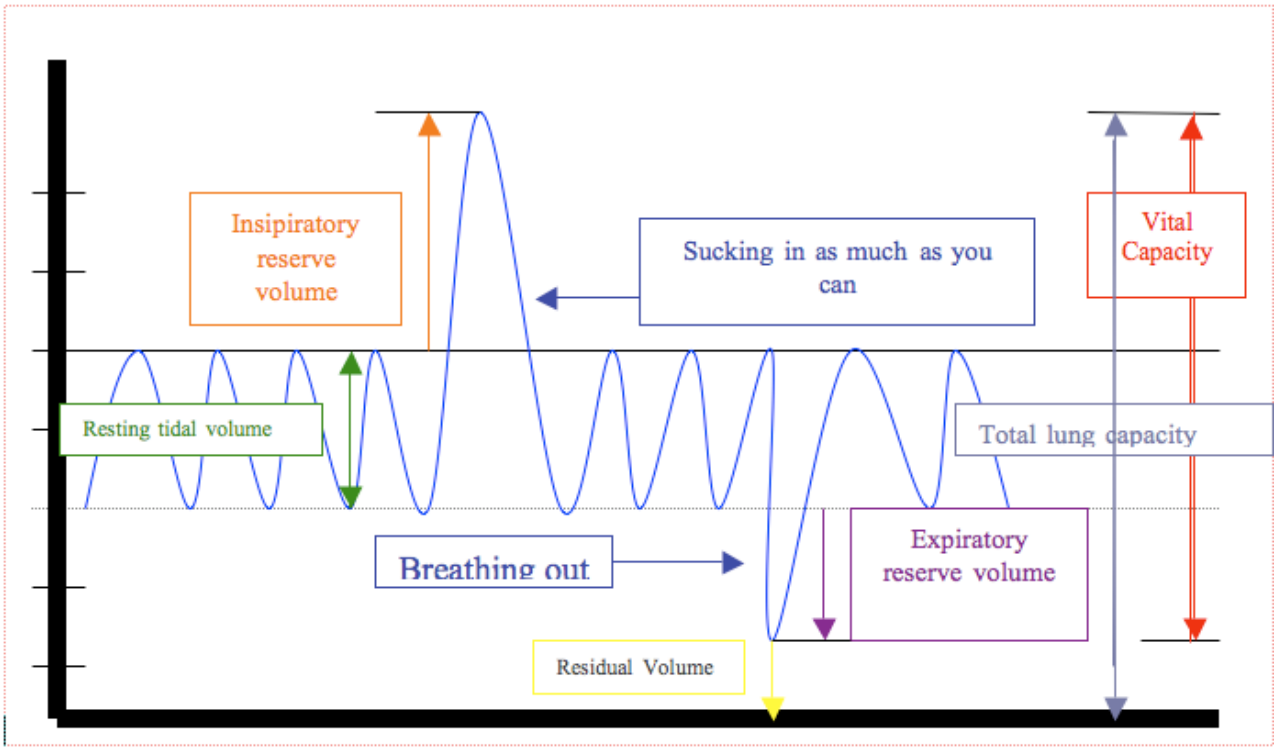
Expiratory Reserve Volume - the additional amount of air that can be expired from the lungs by determined effort after normal expiration

Inspiratory Reserve Volume - the maximal amount of additional air that can be drawn into the lungs by determined effort after normal inspiration

Residual Volume - the amount of air that remains in a person's lungs after fully exhaling.

Minute Ventilation – the volume of air breathed in or out per minute

The image below shows how these terms can be displayed on a graph. This graph is showing the values for a person **at rest.** Take some times to understand this graph before having a go at the questions below.



Tidal volume increases during exercise. Why does this occur?

This is because **breathing rate** and **breathing depth** both increase in order to supply the working muscles with the oxygen they require in order to produce energy whilst exercising.

Does **residual volume** change during exercise?

Residual Volume does not change during exercise as the amount of air left in your lungs after forceful expoiration will be the same as when at rest.

Hint: Think carefully before answering this question

It is important that you are able to understand how the graph shown above will vary at exercise.

Task – Think carefully before using a separate piece of paper to draw out the same graph to show a trace for a 1500m runner towards the end of a race.

Hint: Think about both **breathing rate** and **breathing depth** and how each of these will affect the tidal volume readings

Use the knowledge that you have gained to describe what happens to each volume during exercise.

Lung Volume	Definition	Change during exercise
Tidal Volume	The amount of air inspired and expired with each normal breath	Increase
Inspiratory Reserve Volume	The maximal amount of additional air that can be drawn into the lungs by determined effort after normal inspiration	Decrease
Expiratory Reserve Volume	The additional amount of air that can be expired from the lungs by determined effort after normal expiration	Decrease
Residual Volume	The amount of air that remains in a person's lungs after fully exhaling.	Stays the same
Minute Ventilation	The volume of air breathed in or out per minute	Increase

Gas Exchange:

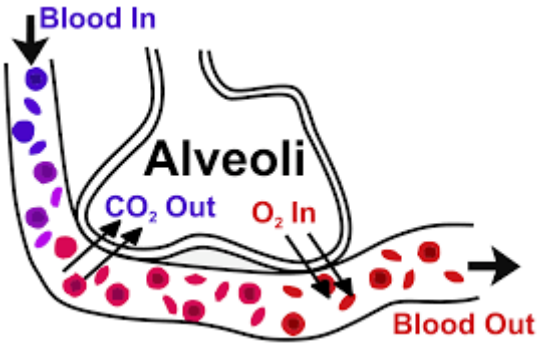
This takes place at the site of the **alveoli** and at the site of the **muscle tissue.** The process of gas exchange allows us to get oxygen to our muscles and for us to get rid of waste products such as carboin dioxide and lactic acid.

There are three key parts to gas exchange and they are outlined below:

Diffusion – The movement of a substance from an area of high concentration to an area of low concentration.

Partial Pressure – The pressure of an individual gas when it exists amongst a mixture of gases

Concentration Gradient – The process of particles moving through a solution or gas from an area with a higher number of particles to an area with a lower number of particles



At the alveoli, the blood stream contains a large partial pressure of C02 and a small partial pressure of oxygen. The alveoli contains a high partial pressure of oxygen and a small partial pressure of C02. Therefore a concentration gradient is present and diffusion will occur.

At the site of the lungs:

Location	**Partial Pressure of Oxygen (P02)**	**Partial Pressure of Carbon Dioxide (PC02)**
Alveoli	100 mm Hg	40 mm Hg
Blood Capillary	40 mm Hg	46 mm hg

Use the table above to explain how diffusion takes place at the alveoli:

At the site of the lungs, there is 100mm Hg of oxygen in the alveoli and only 40mm HG in the blood capillary. Therefore there is a concentration gradient which results in oxygen moving from the alveoli (high concentration) to the blood capillary (low concentration).

There is 46mm HG of carbon dioxide in the blood capillary and only 40mm Hg in the alveoli. Therefore there is a concentration gradient which results in C02 moving from the blood capillary (high concentration) to the alveoli (low concentration).

At the site of the muscle tissue:

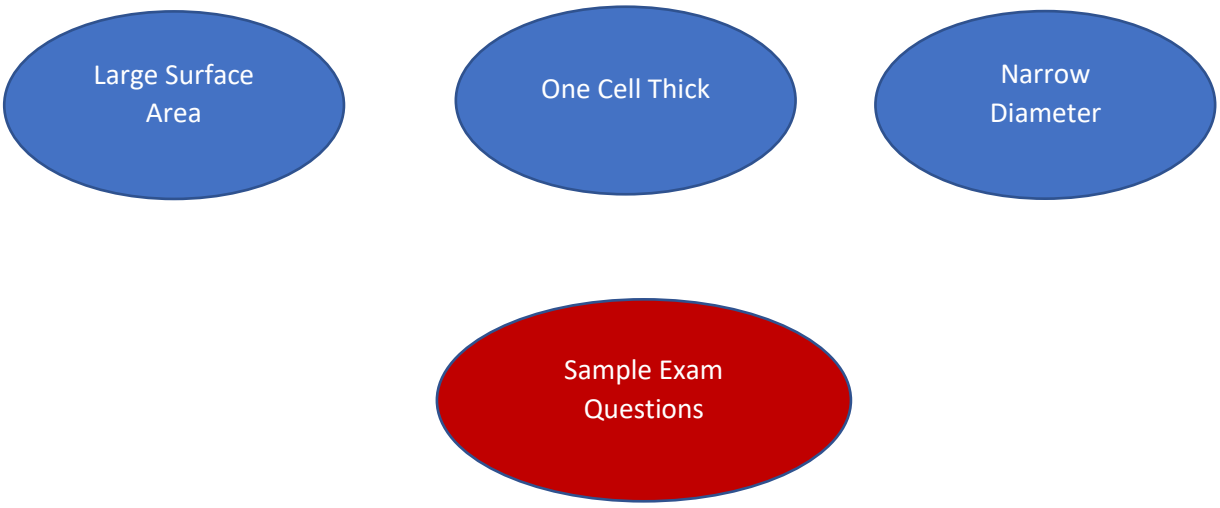
Location	**Partial Pressure of Oxygen (P02)**	**Partial Pressure of Carbon Dioxide (PC02)**
Blood Capillary	100 mm Hg	40 mm Hg
Muscle Tissue	40 mm Hg	46 mm Hg

Use the table above to explain how diffusion takes place at the muscle tissue:

At the site of the muscle tissue, there is 100mm Hg of oxygen in the blood capillary and only 40mm HG in the muscle tissue. Therefore there is a concentration gradient which results in oxygen moving from the blood capillary (high concentration) to the muscle tissue (low concentration).

There is 46mm HG of carbon dioxide in the muscle tissue and only 40mm Hg in the blood capillary. Therefore there is a concentration gradient which results in C02 moving from the muscle tissue (high concentration) to the blood capillary (low concentration).

In order for diffusion to take place effectively, the capillaries and alveoli have the following features:



'Tidal volume × respiratory frequency' is an equation.

Which **one** of these physiological measures does the equation allow you to calculate?

A Expiratory reserve volume ⬭

B Inspiratory reserve volume ⬭

C Minute ventilation ⬭

D Residual volume ⬭

(Total 1 mark)

Mark 1 – C

Identify which **one** of the following statements defines expiratory reserve volume.

A The amount of air breathed in or out per breath ⬭

B The amount of air left in the lungs after maximal expiration has occurred ⬭

C The amount of air that can be forcibly expelled after a normal breath ⬭

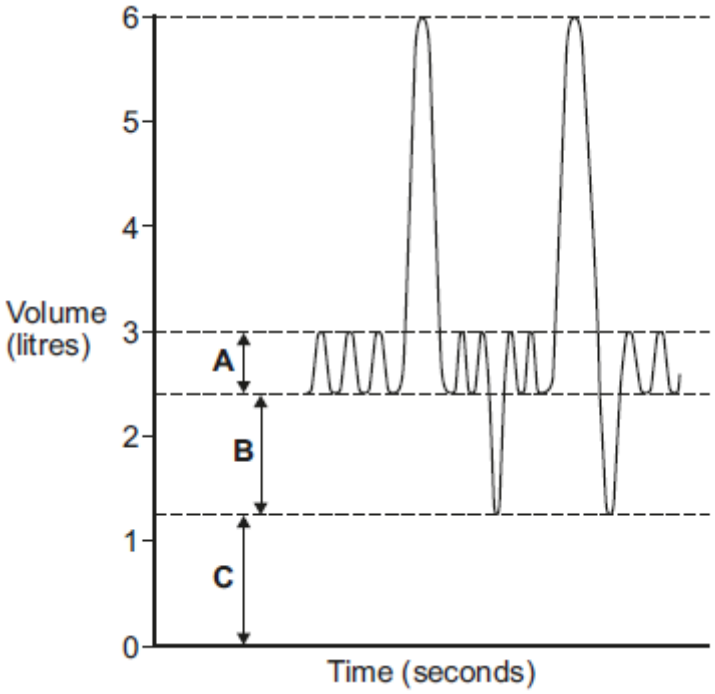
D The amount of air that can be forcibly inspired at the end of a breath ⬭

(Total 1 mark)

Mark 1 – C

Many athletes will use continuous training to maintain a good level of fitness.

The diagram below shows a spirometer trace of an athlete at rest.



(i) Complete the table to identify the type of lung volumes **A**, **B** and **C** shown in the diagram above.

	Lung Volume
A	Tidal Volume
B	Expiratory Reserve Volume
C	Residual Volume

(3)

(ii) What effect does a continuous exercise session have on lung volumes **B** and **C** in the diagram above?

Volume **B**:

Decreases

Volume **C**:

Stays the same

(2)

(Total 5 marks)

The table below shows the partial pressure of oxygen (PO_2) and carbon dioxide (PCO_2) in a blood capillary and a muscle.

	PO_2 (mmHg)	**PCO_2 (mmHg)**
Blood capillary	100	40
Muscle	40	46

Using the table above, describe how oxygen **and** carbon dioxide move between the blood and the muscles.

Mark One – Partial pressure of oxygen is 100mmHG in the blood capillary and only 40mmHG in the muscle tissue

Mark Two – Therefore there is a concentration gradient and oxygen moves from the blood capillary to the muscle

Mark Three – Partial pressure of C02 is 46mmHg in the muscle and 40mmHg in the blood capillary

Mark Four – Therefore there is a concentration gradient and C02 moves from the muscle tissue to the blood capillary

[Total 4 marks]

Neural & Chemical Regulation of Pulmonary Ventilation:

Neural refers to the nervous system whereas **chemical** refers to blood acidity.

As we have discovered whilst learning about the **cardiovascular system,** receptor systems are present in our body in order to detect when an increase or decrease in heart rate are required.

What are the roles of the:

Chemoreceptors: To detect a change in C02/blood acidity/lactic acid (located in the walls of the arteries

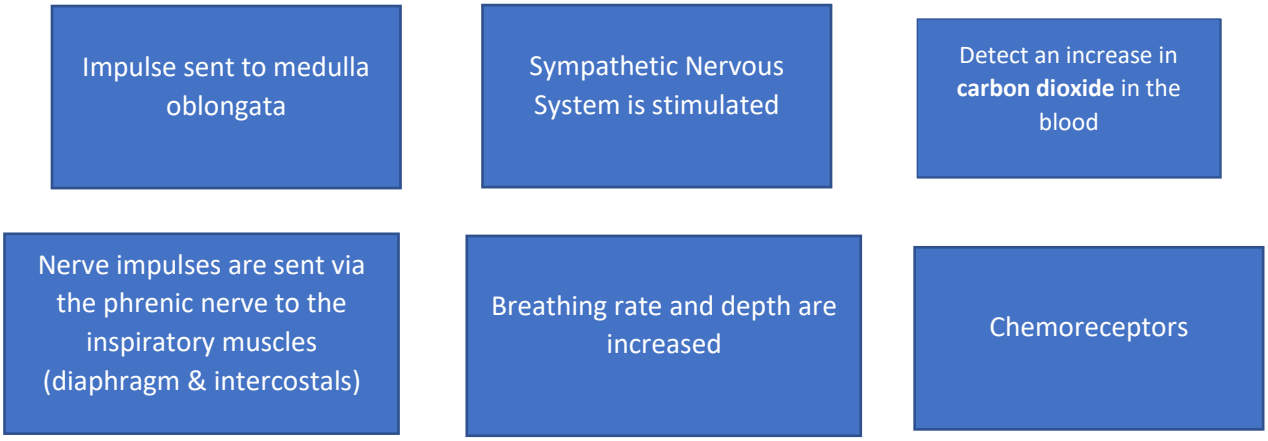
Baroreceptors: To detect a change in blood pressure (located in the walls of the aorta)

Proprioceptors: To detect a change in muscle movement (located in the muscles, tendons and joints

During exercise, the receptor systems send impulses to the medulla oblongat in the brain, which then stimulates the sympathetic nervous system and heart rate is increased.

Following exercise, the receptor systems send impulses to the medulla oblongata in the brain, which then stimulates the parasympathetic nervous system and heart rate is decreased.

The same process can be applied to the respiratory system, whereby rather than increasing or decreasing the heart rate, the medulla oblongata can signal for an increase or decrease in breathing rate and depth. The **Inspiratory Centre** and **Expiratory Centre** are found in the medulla oblongata and are responsible for changes in breathing rate. Put the following statements in order to explain how this is achieved:



- **Chemoreceptors detect an increase in carbon dioxide in the blood**
- **Impulse sent to medulla oblongata**
- **Sympathetic nervous system is activated**
- **Nerve impulses are sent via the phrenic nerve to the inspiratory muscles (diaphragm & intercostals)**
- **Breathing rate and depth are increased**

Stretch Receptors:

These are located in the lungs. They prevent the lungs over-inflating by sending signals to the **expiratory centre,** which can signal for a decrease in breathing rate and depth.

In relation to breathing mechanics, how can an athlete's proprioceptors work to aid performance in a 5000m race?

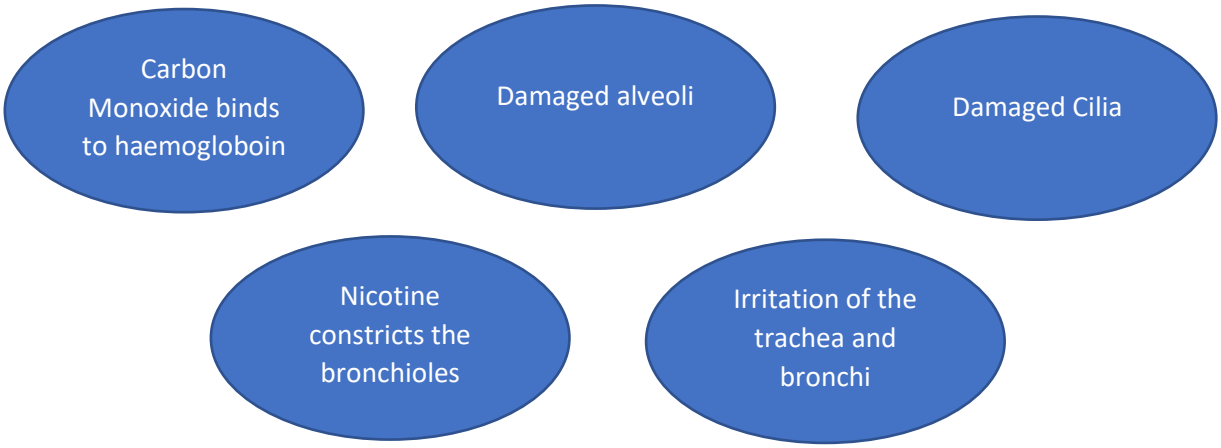
Proprioceptors located in the muscles, tendons and joints will identify movement at the beginning of a race. Therefore an impulse will be sent to the medulla oblongata, which will stimulate the sympathetic nervous system. An impulse is then sent via the phrenic nerve to the diaphragm and intercostal muscles, which will contract at a greater rate to increase breathing rate.

An athlete is close to exhaustion at the end of a 5000m race. How do their stretch receptors respond in order to ensure the safety of the lungs?

Athletes will work towards the upper limit of their aerobic capacity during a 5000m race. As their breathing becomes deeper, an athlete's stretch receptors will send a signal to the medulla oblongata. The parasympathetic system is activated, and an impulse is sent to the diaphragm and intercostal muscles ensuring that the contractions do not become any more powerful. This will prevent the lungs from overinflating.

The Impact of Poor Lifestyle Choices on the Respiratory System:

Lifestyle choices such as having an unhealthy diet or drinking alcohol can affect the respiratory system. However, **smoking** has a number of negative effects on the mechanics of breathing.



Do some of your own research in order to explain why each of the above factors can have a negative effect on the cardiovascular fitness of a performer.

Carbon Monoxide binds to haemoglobin:

This is a poisonous gas. It is dangerous as it will end up diffusing into the muscles in the same way that oxygen does via a concentration gradient. As a result muscles will become fatigued and tire quickly, decreasing performance.

Damaged Alveoli:

Toxins from smoke damage the thin walls of the alveoli, leaving large air sacs which are less efficient for gaseous exchange.

Damaged Cilia:

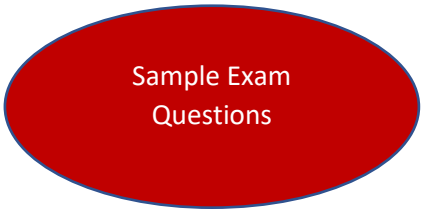
Cilia are tiny hairs found in the trachea. They help to sweep away dust, dirt and mucus so that we find it easier to breath. Smoking damages and eventually destroys cilia. This results in a constant build-up of mucus, often leaving heavy smokers with a nasty cough.

Nicotine Constricts the Bronchioles:

Further to being an addictive substance, nicotine also results in bronchoconstriction. This is where the bronchioles narrow, making breathing more difficult, in a similar way to asthma. Bronchoconstriction can lead to emphysema.

Irritation of the trachea and bronchi:

Smoking causes a constant irritation of the trachea and bronchi which can lead to an inflammation of the bronchi and bronchitis. This will result in a smoker suffering from fatigue, shortness of breath and chest tightness.



How is breathing rate regulated by the body to meet the increasing demands of exercise during a game of netball?

Mark 1 – The chemoreceptors will detect an increase in C02/lactic acid in the blood

Mark 2 – An impulse is sent to the medulla oblongata

Mark 3 – A signal is sent via the phrenic nerve to the diaphragm and intercostal muscles….

Mark 4 – Which will contract more powerfully and quickly, resulting in an increase in breathing rate and depth

Accept other appropriate answers

(Total 4 marks)

Smoking is a poor lifestyle choice because of the negative effect it can have on health and performance.

Identify **one** physiological effect of smoking on the respiratory system **and** explain its impact on performance in endurance events.

Mark 1 – Carbon monoxide binds to haemoglobin

Mark 2 – This is a poisonous gas that will dissociate/diffuse into the muscles

Mark 3 – This means that less oxygen will be available for aerobic respiration

Mark 4 – Resulting in the performer fatiguing much faster and ultimately having a negative effect on performance

(Total 4 marks)

Key Terms:

Tidal Volume – Volume of air breathed in or out per breath

Inspiratory Reserve Volume – Volume of air that can be forcibly inspired following a normal breath

Expiratory Reserve Volume – Volume of air that can be forcibly expired following a normal breath

Residual Volume – Volume of air that remains in the lungs after maximum expiration

Minute Ventilation – Volume of air breathed in or out per minute

Diffusion – The movement of a substance from an area of high concentration to an area of low concentration.

Partial Pressure – The pressure of an individual gas when it exists amongst a mixture of gases

Concentration Gradient – The process of particles moving through a solution or gas from an area with a higher number of particles to an area with a lower number of particles

Stretch Receptors – A sensory receptor that responds to the over-expanding of the lungs

Inspiratory Centre – Located in the medulla oblongata and responsible for breathing (inspiration)

Expiratory Centre – Located in the medulla oblongata and responsible for breathing (expiration)

Cilia – Tiny cells located in the bronchi and bronchioles

Nicotine – An addictive stimulant found in cigarettes

Tar – A toxic substance found in cigarette smoke