Unit 1 - Anatomy and Physiology

Assessment Outcomes

AO1 – Demonstrate knowledge of body systems, structures, functions, characteristics, definitions and other additional factors affecting each body system.

AO2 – Demonstrate understanding of each body system, the short- and long-term effects of sport and exercise on each system and additional factors that can affect body systems in relation to exercise and sporting performance.

AO3 – Analyse exercise and sports movements, how the body responds to short-term and long-term exercise and other additional factors affecting each body system.

AO4 – Evaluate how body systems are used and how they interrelate in order to carry out exercise and sporting movements

AO5 – Make connections between body systems in response to short-term and long-term exercise and sport participation. Make connections between muscular and all other systems, cardiovascular and respiratory systems, energy and cardiovascular systems.

Learning Aim C – The effect of exercise & sports performance on the respiratory system

Learning objectives

C1 + C2 – To understand the structure and function of the respiratory system.

C3 – To understand the lung volumes used in exercise and a typical response.

C4 – To describe the control mechanisms of breathing.

C5 – To be able to describe the responses of the respiratory system to exercise

C6 + C7 – To understand the adaptations of the respiratory system to exercise and other additional factors.

The Respiratory System

The respiratory system provides oxygen to body tissues and removes waste products.

Watch me

What is the key function of the respiratory system?

The Respiratory System

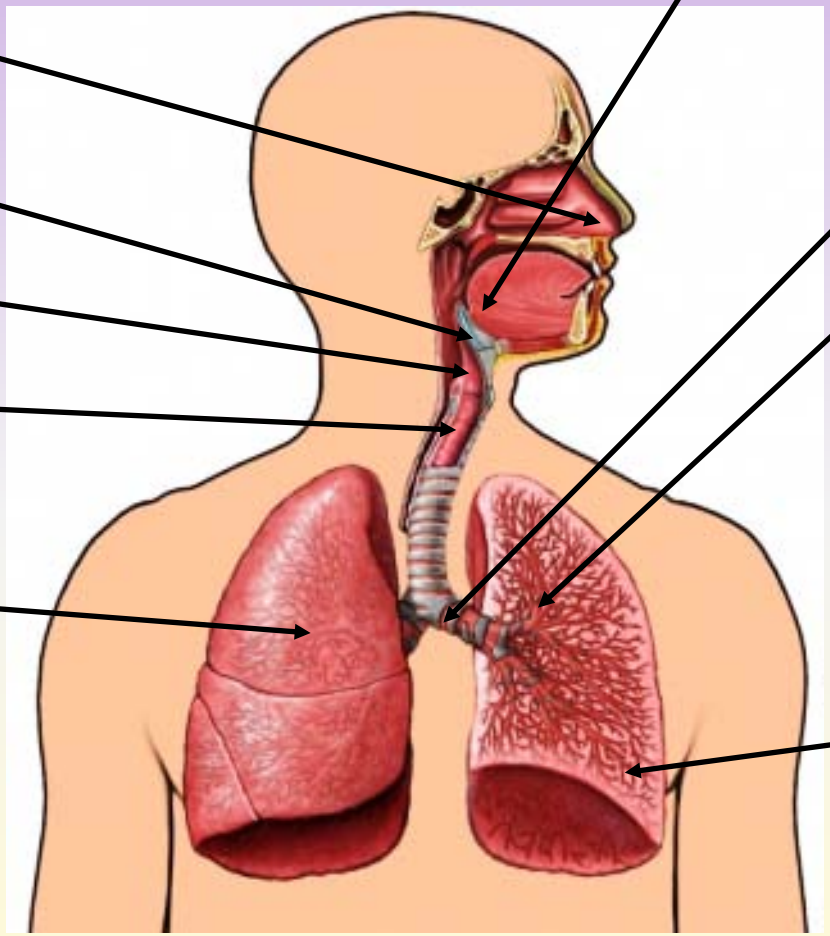
The respiratory system has two main functions:

1. Pulmonary ventilation (inspiration and expiration)
2. Gaseous exchange.

The cardiovascular system provide the link between these two processes by transporting the deoxygenated blood to the lungs.

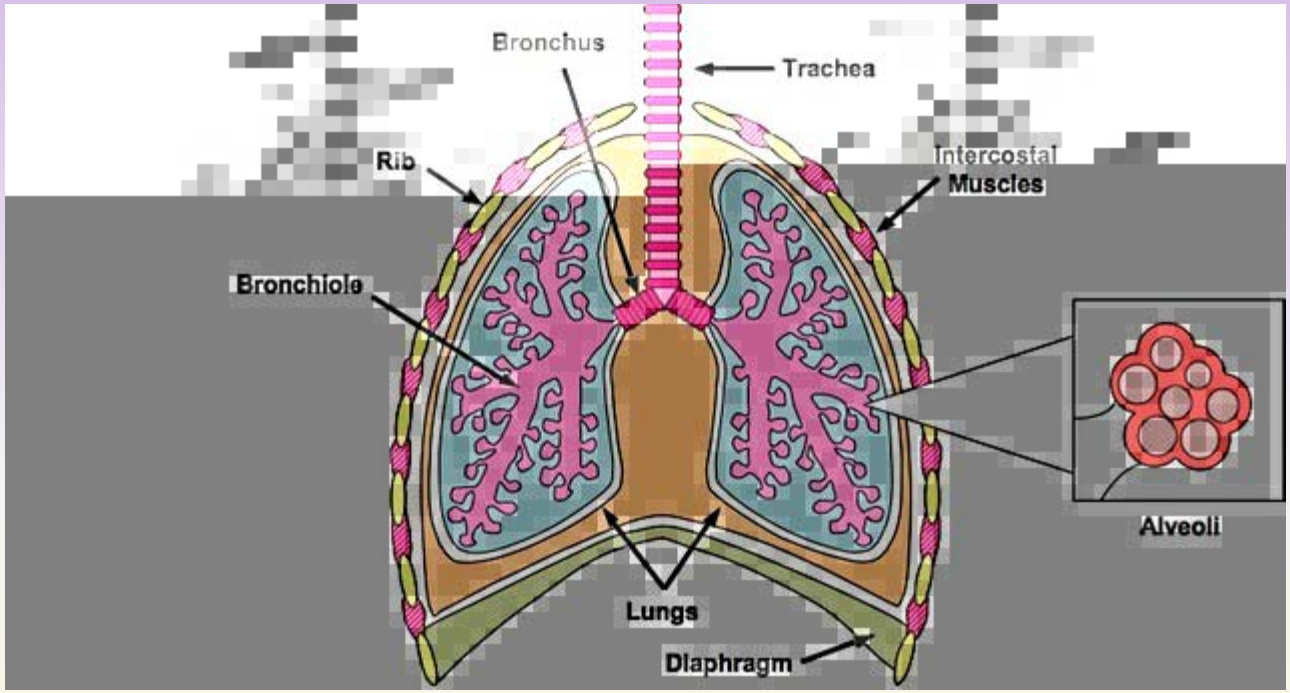
The Respiratory System

Oxygen travels along the following pathway from the nasal cavity to the alveoli.



The Respiratory System

The chamber of the chest is known as the **thoracic cavity**. This is protected by the thoracic wall and separated from the abdominal region by the diaphragm.



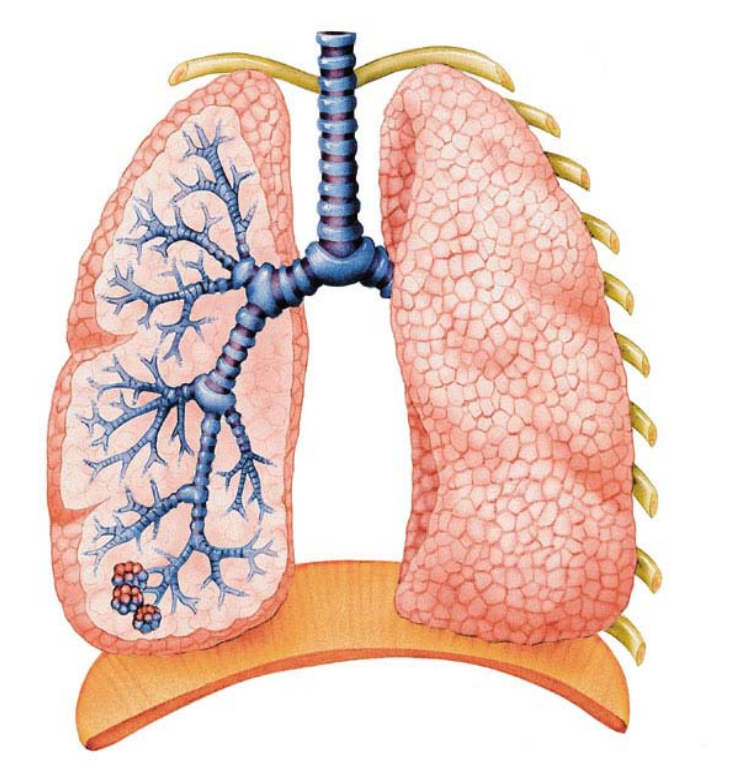
The **intercostal muscles** lie between the ribs and support inhalation and exhalation. The internal and external intercostal muscles are inside and outside the rib cage respectively.

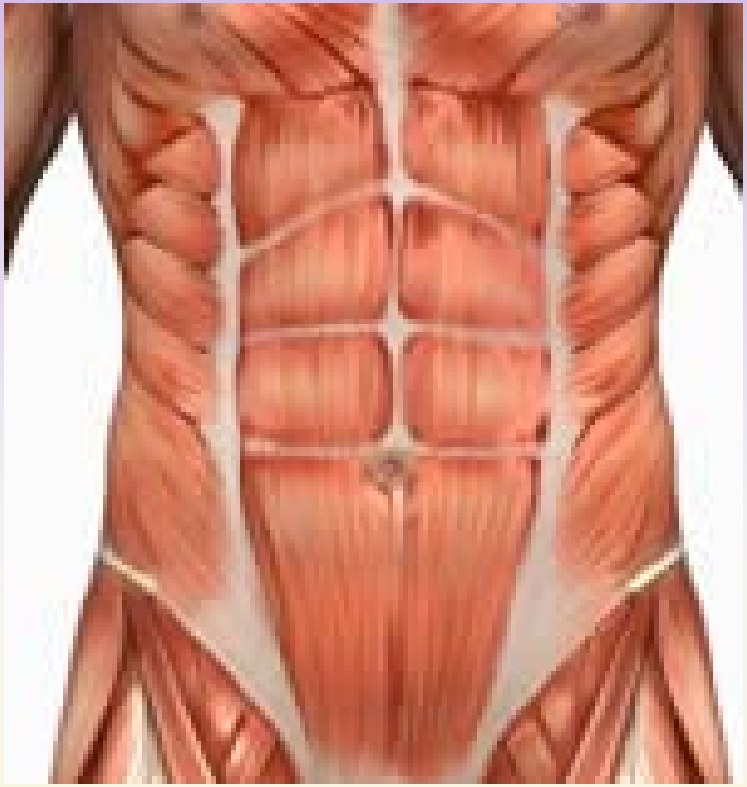
The mechanics of breathing

Think. Pair. Share - During inspiration how does air enter the lungs?

The mechanics of breathing

The lungs can expand more during inspiration due to the use of the diaphragm and assisted by the intercostal muscles.





Changes in air pressure also assist the inhalation and exhalation process.

The mechanics of breathing

Breathing in is the first stage in supplying oxygen to our body cells.

When breathing in (inspiration):

The intercostal muscles contract, lifting the ribs upwards and outwards causing the to chest expand.

The diaphragm contracts. It pulls down and flattens out the floor of the rib cage.

The lungs increase in size as the chest expands.

The pressure inside our lungs falls as they expand. The higher pressure of air outside means air is now sucked into the lungs through the nose and mouth.

The mechanics of breathing

When breathing out (expiration):

The intercostal muscles relax. The ribs move downwards and inwards under their own weight. The cheat gets smaller.

The diaphragm relaxes. It is pushed back into a domed position by the organs underneath it.

The lungs decrease in size as the chest gets smaller. They are squeezed by the ribs and diaphragm.

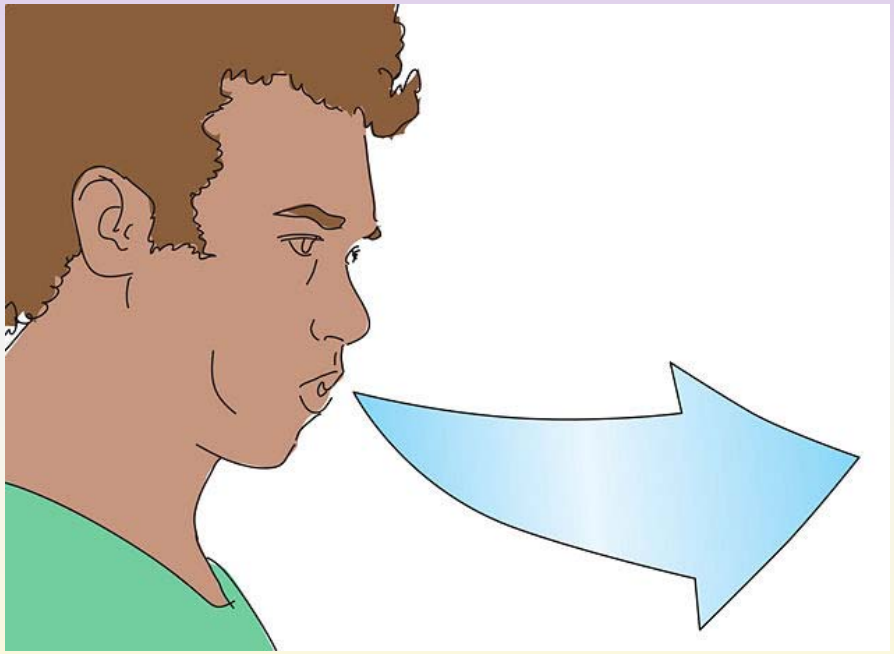
The pressure inside the lungs increases as they get smaller. The air pressure outside is now lower than in our lungs. Air is forced out of the lungs through the nose and mouth.

Control of breathing

The nervous system can increase or decrease the rate, depth and rhythm of breathing.

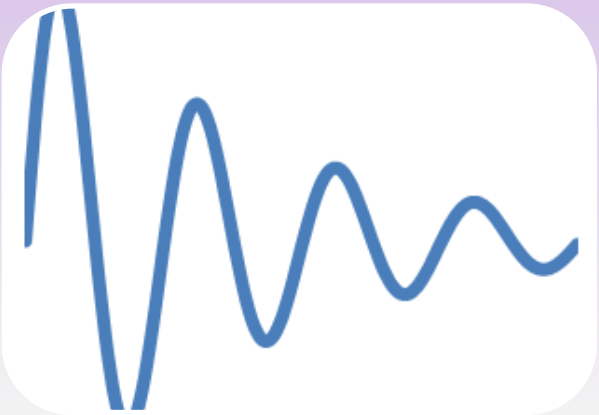
The respiratory control centre located in the **medulla oblongata** of the brain controls breathing.

An increased concentration of carbon dioxide in the blood stimulates the respiratory centre to increase respiratory rate.



Control of breathing

Respiratory Control Centre



The inspiratory centre sends out impulses via the phrenic nerve to the inspiratory muscles.

The expiratory centre stimulates the expiratory muscles during exercise, when stretch receptors detect changes in the rate and depth of breathing.

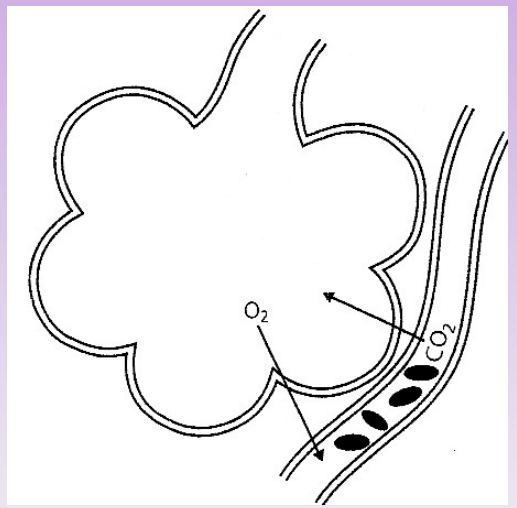
Control of breathing

During exercise, conditions in the body change. These changes are detected by:

Chemoreceptors which detect changes in pH. Blood acidity increases as a result of an increase in the plasma concentration of carbon dioxide and lactic acid production. Signals send to the medulla cause breathing rate to change.

Gaseous exchange at the alveoli

Gaseous exchange takes places at the **alveoli**. The alveoli are tiny air sacks inside the lungs.

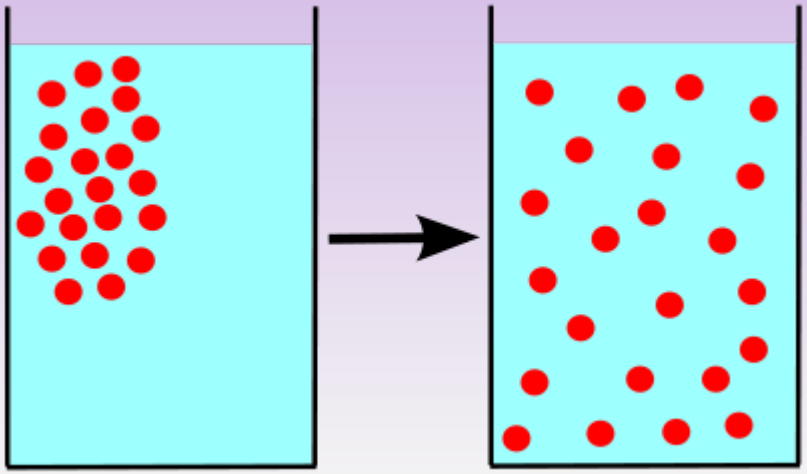


The alveoli are covered in **tiny capillaries** (blood vessels). Gases can pass through the thin walls (**respiratory membrane**) and travel into the blood stream.

With training this process of gaseous exchange becomes more efficient and therefore improves performance.

Gaseous exchange at the alveoli

Capillaries very near to alveoli, so diffusion distance is very short. Gases will always **diffuse** from areas of high concentration to areas of a low concentration.



Alternatively think of it as….

A gas will always move from areas where there is more of it, to areas where there is less of it.

Lung Volumes

The volume of air inspired or expired per breath is referred to as the **tidal volume.**

The volume of air inspired or expired per minute is the **pulmonary ventilation** and can be calculated with the equation below:

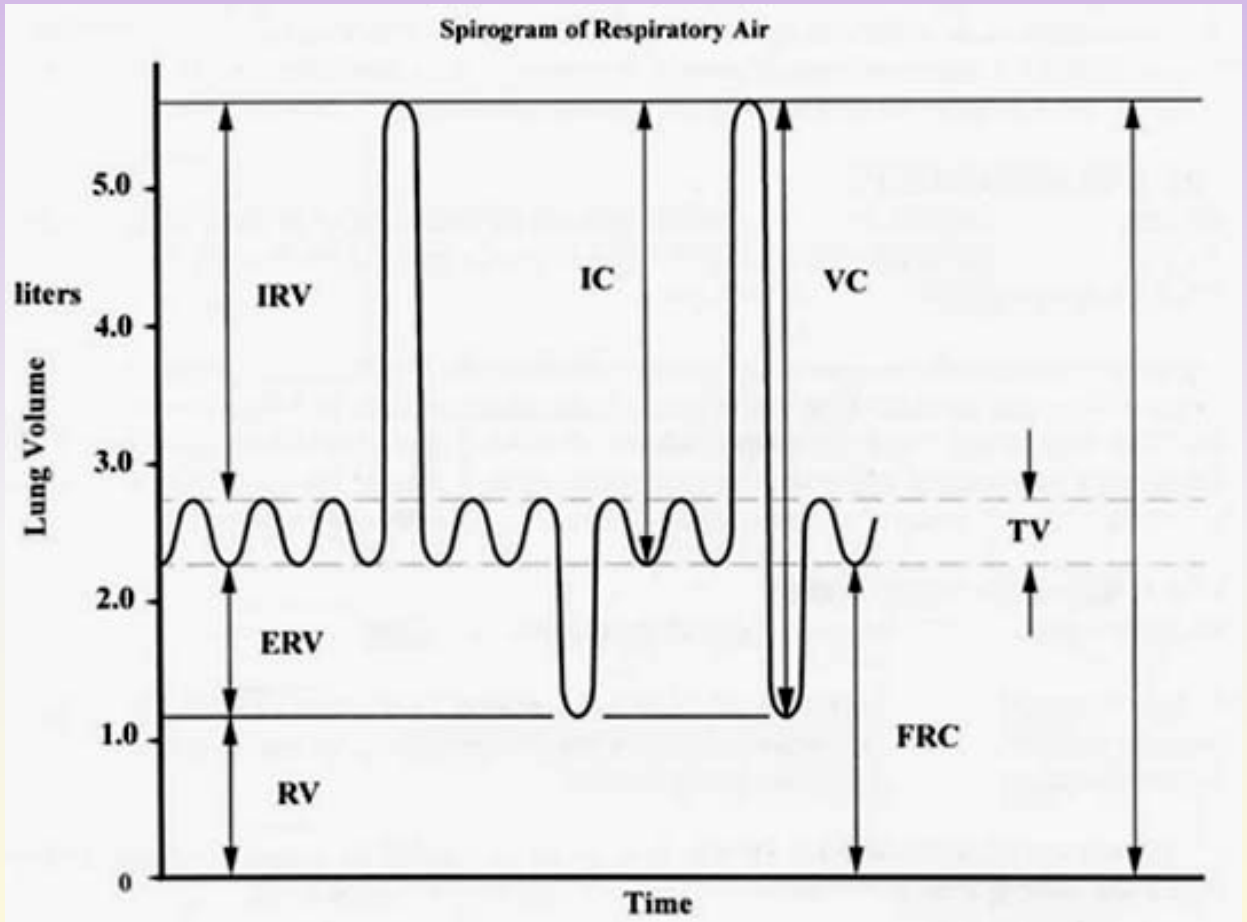
Breathing rate (f) x Tidal volume (TV)
= Pulmonary Ventilation (VE)

e.g. 12 breaths x 0.5 litres =
6 litres per minute.

Lung Volumes

The total lung capacity is calculated by adding the **vital capacity** of the lungs to the **residual volume**.

Lung volumes can be shown on a **spirometer trace**.



Lung Volumes

Complete the table below from the information provided.

Lung Volume	Definition	Average value at rest	Change during exercise
Tidal Volume			
Inspiratory Reserve Volume			
Expiratory Reserve Volume			
Residual Volume			
Pulmonary Ventilation *(VE = TV x f)*			

Tidal Volume

- The volume of air inspired or expired per breath
- Average at rest – 0.5 litres
- Change during exercise – (increase)

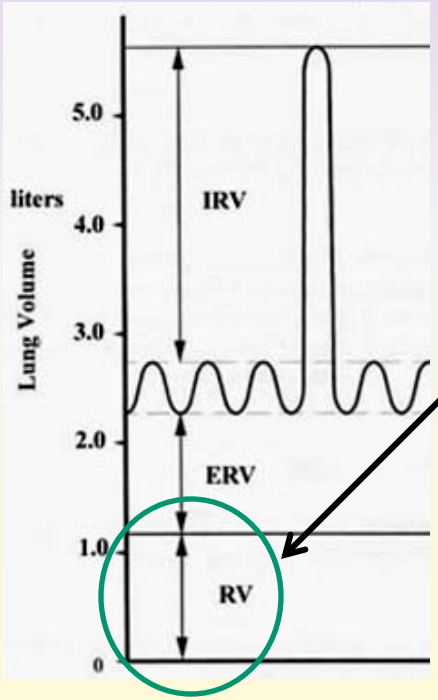
Inspiratory Reserve Volume

- The volume able to be forcibly inspired during normal breathing
- Average at rest – 3.0 litres
- Change during exercise (decrease)

Expiratory Reserve Volume

- The volume able to forcibly expired, after a normal breathe
- Average at rest – 1.3 litres
- Change during exercise – Small decrease

Residual Volume



- The volume of air that remains in the lungs after forced maximum expiration
- Average at rest – 1.2 litres
- No change

Pulmonary Ventilation

- Ventilation is the amount of air breathed in one minute.
- Average at rest – 6.0 litres
- Changes during exercise = BIG increase

Pulmonary ventilation calculation

Pulmonary ventilation (VE) = Tidal Volume (TV) X Breathing Rate (f)

	VE		TV		f
At rest –	7,200 ml/min	=	600 ml	X	12
At submax –	60,000 ml/min	=	2400 ml	X	25
At max –	121,000 ml/min	=	2200 ml	X	55

Lung Volumes

Tidal volume:

This is the amount you breathe in and out in one normal breath.

Name	Tidal volume at rest (ml)	Tidal volume during exercise (ml)
James	500	3500

Think. Pair. Share - Look at the two tidal volume readings below. What changes have taken place and why?

Lung Volumes and Exercise

Name	Tidal volume at rest (ml)	Tidal volume during exercise (ml)
James	500	3500

Exercise causes an increase in breathing rate and depth of breathing. This is due to a greater need for oxygen in the body and removal of carbon dioxide.

Tidal volume can increase up to 5-9 times higher than at rest to cope with exercise demands.

Responses of the respiratory system to exercise

Depth and rate of breathing increases in direct proportion to the intensity of the exercise. The greater the exercise intensity the higher the concentration of carbon dioxide in the blood. The respiratory system reacts by:

1. Increased breathing rate – CO_2 production stimulates faster and deeper breathing. Small increases in breathing at the onset of exercise is known as an **anticipatory rise.**

Responses of the respiratory system to exercise

2. Increased tidal volume – this is elevated for both aerobic and anaerobic activity. This rise may be as much as 7 times from resting state.

Adaptations of the respiratory system to exercise

The respiratory system undergoes specific adaptations in response to training.

Increased vital capacity:

An athlete lung size and efficiency will increase with training. This increased capacity ensures oxygen supply to muscles is continuous.

Adaptations of the respiratory system to exercise

Efficient gaseous exchange at the alveoli:

This allows better delivery of oxygen and removal of Carbon dioxide to and from working muscles. The increased rate of diffusion across tissues allows athletes to train harder and longer.

Adaptations of the respiratory system to exercise

Increased strength of diaphragm and intercostal muscles:

Training will increase the efficiency of the respiratory muscles responsible for breathing and gaseous exchange. This allows for a greater expansion of the chest cavity.

Additional factors affecting the respiratory system

Asthma is a common condition where airways can become restricted. Individual's can become wheezy and short of breath which will affect performance. The tightening of the muscles surrounding the trachea prevent gases from freely moving in or out.

Regular exercise will strengthen the respiratory system and help prevent the effects of asthma. Additionally, an **inhaler** can be used to relax the airways and minimise the symptoms.

Additional factors affecting the respiratory system

Watch me

How does altitude effect athletic performance?

Additional factors affecting the respiratory system

The environment within which the athlete trains in can dramatically affect the outcome. Training at altitude will effect air quality and initiate a bodily response.

At high altitudes there is less oxygen present and reduces oxygen carrying capacity.

Additional factors affecting the respiratory system

As a result, haemoglobin is not fully saturated at altitude, and the body compensates by making more red blood cells to carry oxygen.

Adaptations of the respiratory system to exercise

The percentage of oxygen (O2) in the air is the same at sea level and at altitude. However, the **partial pressure** of oxygen decreases as altitude increases. This causes a reduction in the diffusion gradient between the air and the lungs and between the alveoli and the blood.

Altitude	Venue	pO2 (mmHg)
Sea level	Football – Wembley, London	159
1609 m	NFL – Denver Broncos (Mile high stadium, Colorado)	132
2240 m	Mexico City football stadia	115

Additional factors affecting the respiratory system

As a result, the diffusion gradient at sea level (Wembley, London) is 119 (159 – 40 = **119mmHg**) compared with that at stadiums in Mexico city (115-40 = **75mmHg**) This reduction severely affects oxygen diffusion into the blood stream.

As a result, haemoglobin is not fully saturated at altitude, which results in a lower oxygen-carrying capacity of the blood.

Additional factors affecting the respiratory system

As less oxygen is delivered to working muscles there is an earlier onset of fatigue. This results in a decrease in aerobic energy production and performance.

The body reacts by:

1. Breathing frequency increases both at rest and during exercise.
2. Blood volume decreases and increases the density of red blood cells.
3. Stroke volume decreases which causes heart rate to increase to compensate.

Additional factors affecting the respiratory system

Reduction in VO2 max places a greater strain on the anaerobic energy system leading to earlier lactic acid production. Altitude training is popular with endurance events and those reliant on aerobic capacity.

The body's response to the reduced levels of oxygen provides a number of advantages.

Think. Pair. Share – Discuss and write down all the advantages and disadvantages of the exercising at altitude.

Additional factors affecting the respiratory system

Acclimatisation is the process with which an athlete goes through to adapt to the environment. A summary of the advantages and disadvantages of altitude training are below:

Advantages	Disadvantages
Increase in red blood cell production due to release of erythropoietin.	Expensive to setup due to travel and accommodation costs.
Increased concentration of haemoglobin	Altitude sickness
Better O2 transport	Training is tough and requires high levels of motivation.
Altitude training effect will last for up to 2 weeks. Useful when preparing for competition.	Benefits can be lost quickly so will no benefit competition all year round.

Apply it!

What has stuck with you?

The Respiratory system

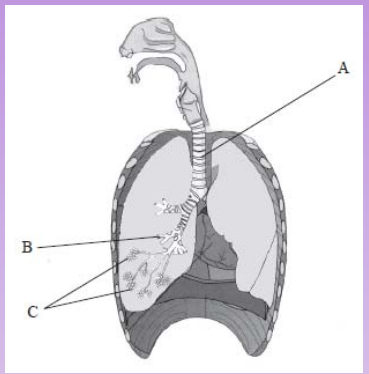
Explain the principle of diffusion and how it can be seen in the respiratory system.

Describe what is meant by the terms ‘tidal volume’ and ‘pulmonary ventilation’

Describe ‘gaseous exchange’?

Explain the mechanics of inspiration and expiration at rest and during exercise?

Practice it!



Exam questions

1. Figure 1 is a diagram of the respiratory system.

(a) Give the anatomical names of the parts labelled A, B and C.

A .....

B .....

C ..... (3)

(b) Breathing enables gaseous exchange to occur at the alveoli. Outline how two features of the alveoli assist in gaseous exchange. (2)

1.

2.

Practice it!

Exam questions

2. Explain how neural factors regulate Evan's respiratory system during the cycling section of his race. (4)

3. Analyse the immediate effects of altitude training on Evan's respiratory system. (6)

Practice it!

Marks Scheme:

1. a) A– Trachea, B – Bronchiole, C – Alveoli/ Alveolus.

   b) Large surface area of alveoli to allow larger volumes of gases / oxygen and carbon dioxide to move between the lungs and the bloodstream (1) Moist thin walls / one cell thick creating a short distance for diffusion / short diffusion pathway (1) Lots of capillaries around the alveoli so large area for gas exchange (1) Large blood supply to carry gases / oxygen and carbon dioxide (1) Movement of gas from high concentration to low concentration means there is a pressure gradient which allows diffusion to occur.

Practice it!

Marks Scheme:

2. Increased CO2 is produced by the body in response to exercise (1) CO2 is dissolved in the blood and detected by Chemoreceptors (1) these send a message to the medulla oblongata/Respiratory control centre/RCC (1) which responds by sending nervous signals to the respiratory system to increase the tidal volume/depth and breathing rate/frequency.

Practice it!

Marks Scheme:

3. Effects of Altitude on the Respiratory System

- Could get altitude sickness so unable to train
- There is a reduced partial pressure of oxygen so there is less oxygen available for respiration which leads to hypoxia
- Decrease in air pressure causes an increase in breath frequency/ventilation rate
- Partial pressure/volume of oxygen in the air is less, therefore oxygen supply to the alveoli is less
- Reduces the concentration/diffusion gradient of oxygen at the alveoli, therefore less oxygen diffuses into the blood.
- Less oxygen combines with haemoglobin therefore less oxygen is transported in the blood
- Reduces the concentration/diffusion gradient of oxygen at the muscle tissue
- Could result in hyperventilation and short, rapid ineffective breaths are taken.
- Performance at altitude deteriorates and fatigue sets in sooner.