ORIGYM

Level 2 Certificate In Fitness Instructing Online

MODULE 5:
THE CIRCULATORY & RESPIRATORY SYSTEMS AND WARMING UP CLIENTS

CONTENTS

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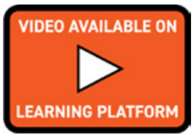


Warm Up And Cool Down

MODULE 5:
THE CIRCULATORY & RESPIRATORY SYSTEMS AND WARMING UP CLIENTS

While the main session, be it resistance training or aerobic training, is the productive part of any workout, going from sedentary to exercising hard is not a good idea as it will reduce the effectiveness of the workout and may result in injury and once the hard work is done, as tempting as it might be to do so, it is never a good idea to come to an abrupt halt. All of this means that instructors must ease their client into and out of exercise which requires well-designed warm-ups and cool downs.

Warm-Ups

Warm-ups are designed to make you warm and also make the transition from inactive to active as smooth and seamless as possible. A good warm-up should prepare your joints, muscles, and neuromuscular system for the workout that follows.

A GOOD WARM-UP WILL:

- **Raise your heart rate**
- **Increase your body temperature**
- **Mobilise your major joints**
- **Stretch your muscles in an appropriate way**

Warming up should never be so intense that the performance of the main session is compromised but neither should it be so gentle that it is ineffective.

A warm-up should mimic the skills of the coming workout and be specific to the demands that face the client i.e. if the client's workout involves running, so too should the warm-up. The same is true of resistance training.

Warm-ups generally consist of a graduated pulse-raising activity, joint mobility exercises, appropriate stretching (usually dynamic in nature) and any drills necessary to fully prepare the client for the session to follow.

WARMING UP HAS THE FOLLOWING BENEFITS:

- **Increased core temperature leading to improved vasodilation and better delivery of oxygen to working muscles**
- **Warmer muscles that will contract and relax more readily**
- **Metabolic processes in the muscles happen more rapidly and efficiently**
- **Muscle viscosity is reduced and so movement is smoother and more efficient**
- **Muscles are able to exert more force after an appropriate warm up because of increased neuromuscular facilitation**
- **Lactic acid production is reduced after a slow and gradual warm-up**
- **Nerve impulses travel faster, reaction times decrease, balance, coordination and general nervous system function improves**
- **Improved cardiovascular response to strenuous exercise due to increased**
- **Joints are lubricated with synovial fluid resulting in increased range of movement and reduced wear and tear**
- **Connective tissue and muscles becomes more flexible**
- **Mental and physical rehearsal effect**

Although it is impossible to unequivocally say that warm-ups prevent injury as people who have warmed up get injured too, it is safe to say that a good warm-up that is specific to the workout that is to follow should reduce the risk of injury.

Types Of Warm-Up

THERE ARE THREE MAIN TYPES OF WARM-UP:

Passive Warm-Ups

Passive warm-ups inevitably involve the use of a sauna, heat lamps, taking a hot bath, using a heat pack, donning extra clothes or getting a massage. While circulation can increase and so to can superficial muscle temperature, core temperature, joint mobility and cardiovascular function will remain largely unchanged. The main value of passive warm-ups is continuing the warm-up process after a more active warm-up, preparing the body for a more active warm-up or warming up when injured.

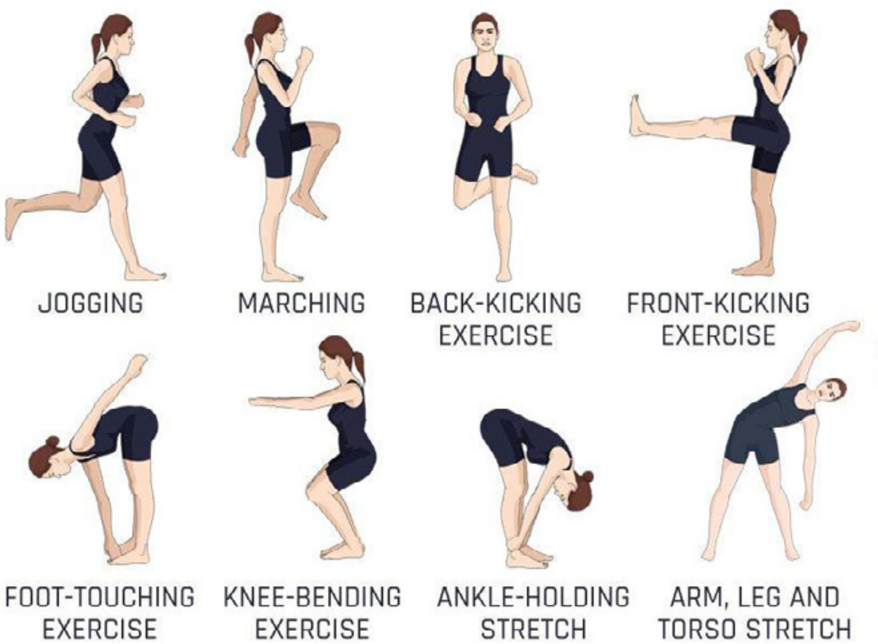
Active general Warm-Ups

General warm-ups are best used before general workouts and involve activities such as jogging and/or light calisthenics. They affect both cardiovascular and neurological systems and are more effective than passive warm-ups.

Active specific Warm-Ups

Specific warm-ups involve using movement patterns that are very similar or even identical to those of the coming workout but with reduced intensity. For example, doing several easy but progressively harder sets of deadlifts before a powerlifting workout. Specific warm-ups also provide an opportunity to practice the skills that will be used in the coming workout; the more intense or skilful the workout, the more important specific warm-ups become. Active specific warm-ups are usually proceeded by active general warm ups.

As a general rule, warm-ups should be gradual and progressive and end when the client feels they are ready to start their main session. There is no set length to a warm-up – it should be as long as necessary but no longer so energy is conserved for the main session. Cold weather, advancing age, injury or muscle soreness and the intensity of the workout to follow will all influence the length of the warm-up.



Cool Downs

Cool downs help return the body to its pre-exercise state and just as a warm-up should be gradual, so too should a cool down. A sudden halt to physical activity can leave a client sore and suffering from DOMS and could cause blood pooling.

THE OBJECTIVES OF THE COOL DOWN ARE:

- **Gradually decrease pulse rate**
- **Decrease body temperature**
- **Stretch muscles in the appropriate way**

Cool-downs generally involve a short period of aerobic exercise where intensity is gradually decreased over several minutes facilitating in venous return and prevention of blood pooling.

Blood Pooling

Blood pooling describes how blood is preferentially directed to the working muscles and then, when exercise ceases, some remains in that area until venous return occurs fully. Blood pooling is most commonly observed in the large muscle groups of the lower body. This can give rise to symptoms of nausea, dizziness and fainting but can be avoided by doing low-intensity cardiovascular exercise as part of the cooldown reducer to facilitate venous return.

On completion of this “pulse reducer”, stretching is performed according to the needs of the client. Stretches are generally static in nature and are designed to maintain or improve the client’s current level of flexibility.

The Circulatory System

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Composition of Blood

Once oxygen has been inhaled and has diffused into the blood, it has to be moved around your body for use by the cells, tissues and organs. This is the job of the circulatory system. The circulatory system consists of three main parts:

- **The blood**
- **The cardiac muscle or heart**
- **The blood vessels**

The Blood

Scientists estimate the volume of blood in a human body to be approximately 7% of body weight. An average adult body with a weight of 150 to 180 pounds will contain approximately 4.7 to 5.5 litres (1.2 to 1.5 gallons) of blood. The body uses blood as a universal transporter for a great many substances, not least oxygen.

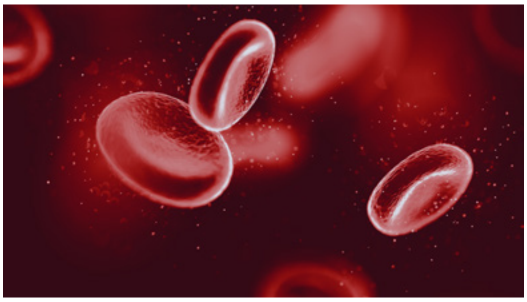
Blood is made up of four major components:

- **Red blood cells (RBCs)**
- **White blood cells (WBCs)**
- **Platelets**
- **Plasma**

Red Blood Cells (Erythrocytes)

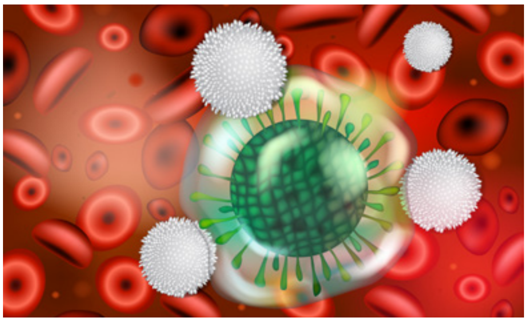
A single drop of blood contains between 240-270 million RBCs so it's safe to say they are pretty prolific. RBCs contain a protein called haemoglobin (Hb) which carries oxygen and carbon dioxide around the circulatory system. RBCs are produced in the red bone marrow and are pigmented which is what gives blood its characteristic red colour. RBCs make up approximately 40% of total blood volume.

A sound diet containing adequate iron ensures that there are plenty of RBCs – too few can result in anaemia which is characterised by fatigue and poor exercise performance.



White Blood Cells (Leukocytes)

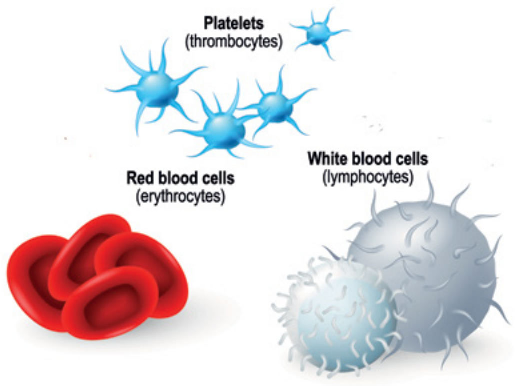
WBCs are clear and contain no haemoglobin. There are fewer of them but they too are produced in the red bone marrow. WBCs are the cells that fight infection and as infections come in various shapes and sizes, so too, do WBCs.



Platelets (Thrombocytes)

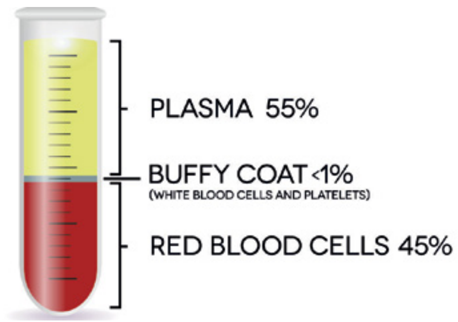
Platelets are responsible for stopping blood loss and are part of the clotting process.

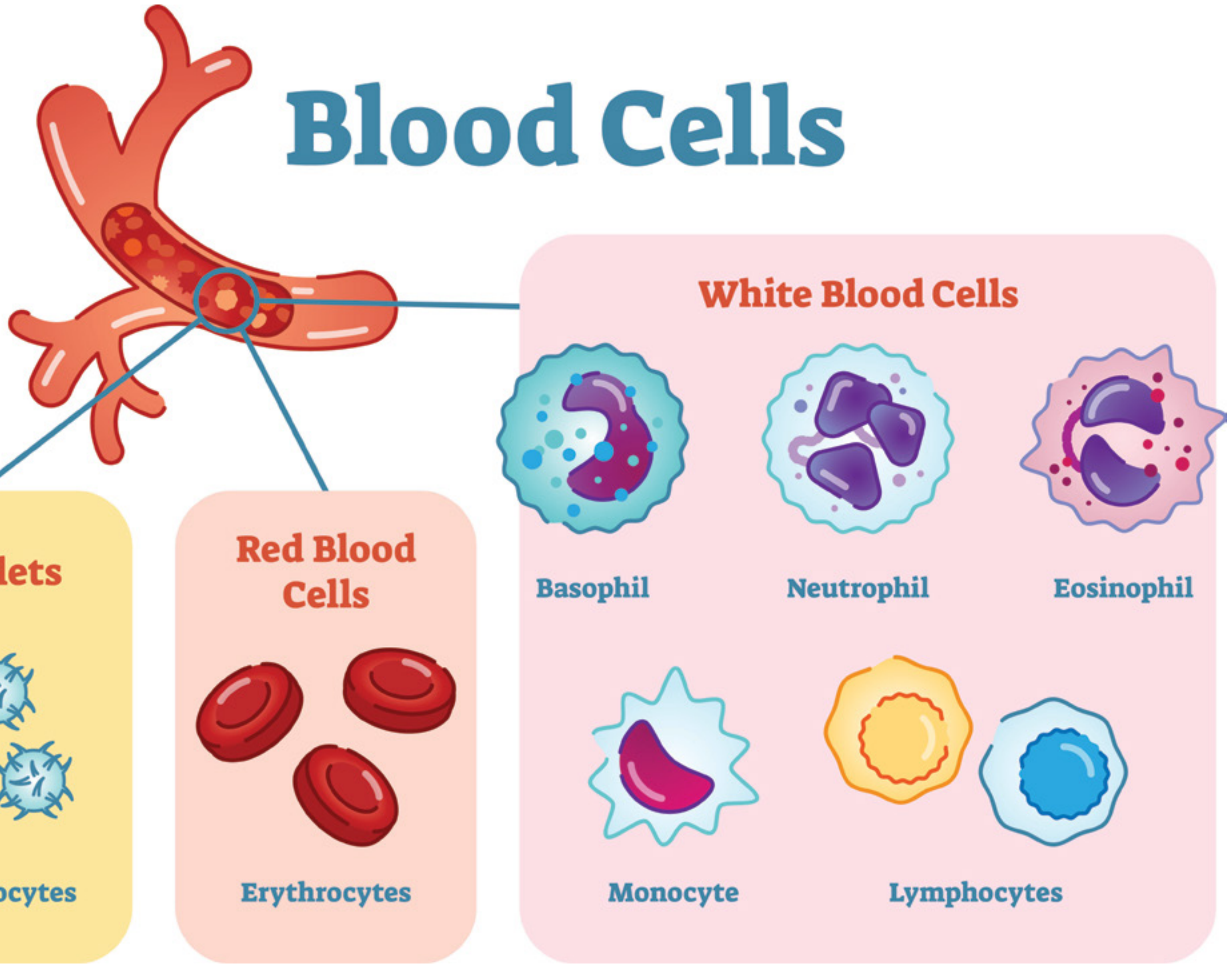
If you cut or otherwise injure yourself, platelets form "plugs" to stop your precious blood escaping. Some medications and diseases can inhibit platelet formation, in particular haemophilia and anticoagulants such as warfarin.



Plasma

Plasma is the carrier medium in which all the other blood cells are supported and transported. It also contains proteins and other nutrients, electrolytes, gases, enzymes, minerals, vitamins and metabolic waste products. Plasma is 91.5% water and 8.5% solids and solutes.





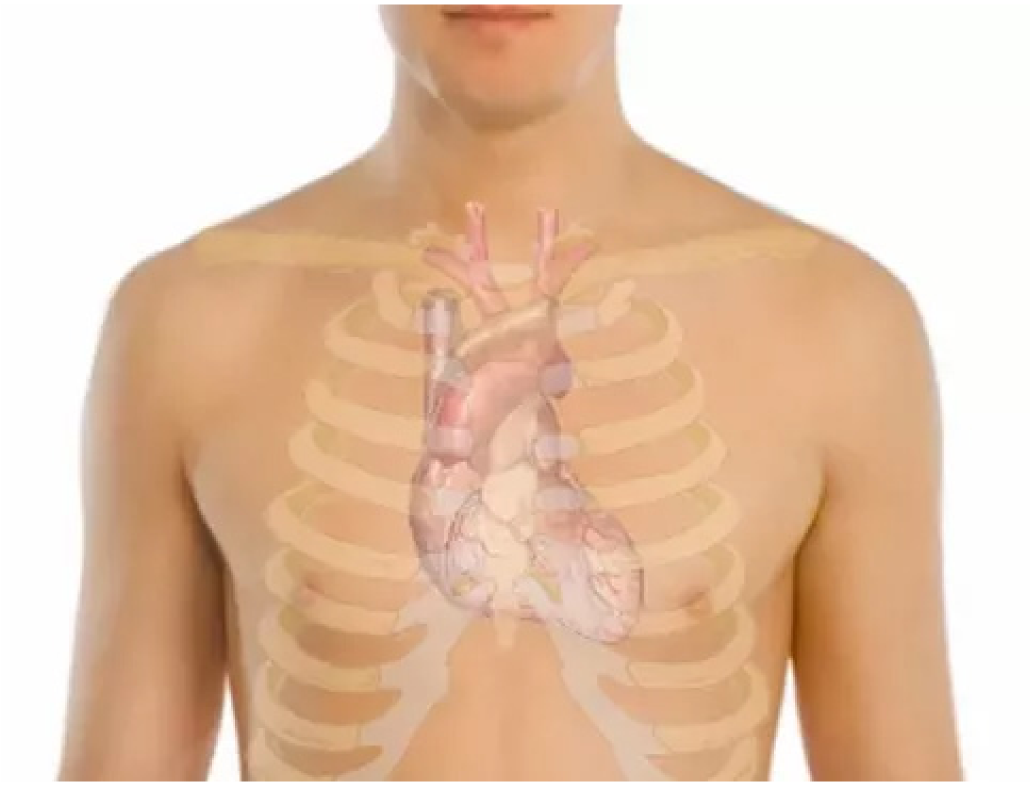
The Heart: Location and Function

Of all the muscles in the body, the heart is arguably the most important as its sole job is to pump life-giving blood and therefore oxygen around your body. An average heart will beat over 3-billion times in a lifetime and if it stops prematurely or its function is in some way inhibited, major and potentially terminal health issues will ensue.

Location of the Heart

The heart is located:

- **Within the Thoracic cavity of the chest (rib cage)**
- **It is slightly left and behind the sternum**

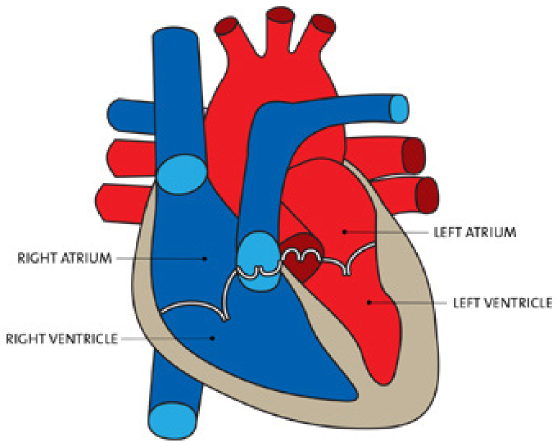


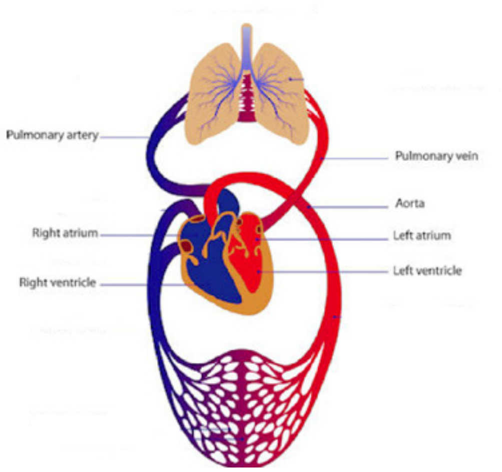
The Function of the Heart

The heart is a fist-sized, four-chambered dual action muscular pump . **The sole function (job) is to pump life giving blood to the body as well as to the lungs to recycle the blood of carbon dioxide and replenish with oxygen.**

The Structure of the Heart

The heart is **divided into two sides – left and right.** Each side functions independently of the other and has a different job. The left-hand side of the heart receives and pumps out oxygenated blood while the right-hand side receives and pumps out deoxygenated blood.





Remember, when describing the heart, left and right are reversed so imagine you are describing the heart of someone facing you rather than your own heart.

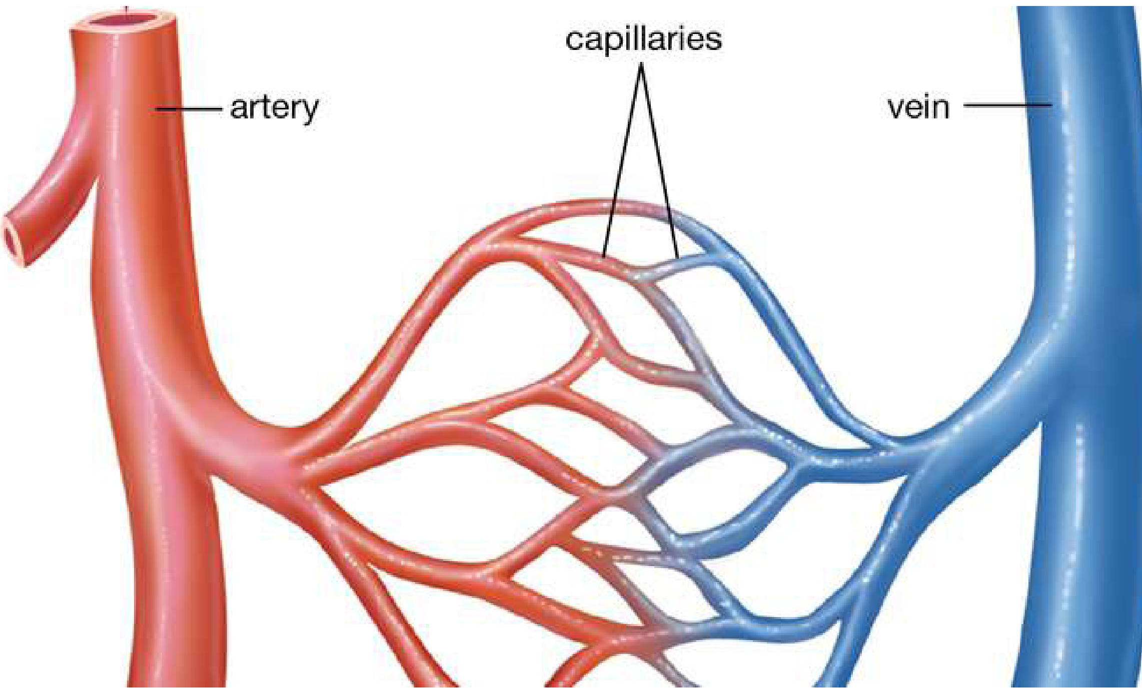
There are **four chambers** in total; **two upper chambers** called **atria** (the plural of atrium) and **two lower chambers** called **ventricles.** The atria are the receiving chambers and the ventricles are the ejecting chambers. The term atrium comes from the Latin for entranceway and houses often have atriums which, in more modern language, are called hallways. The ventricles eject or vent blood out of the heart. This is an easy way to remember which chambers are which.

Of the four chambers, the ventricles have to work the hardest and so they are the largest and most powerful with the left ventricle being the biggest as it has to pump blood the furthest. As the ventricle contracts to eject blood, it is said to be in **systole** whereas when it relaxes (and refills) it is said to be in **diastole**. In contrast, the atria never have to pump especially hard as they are only pushing blood into the next chamber.

Blood enters the atria partly because of gravity and partly because of the pressure in the blood vessels; their contractions are relatively small and therefore their size is also considerably smaller and less muscular than the ventricles for instance.

Blood vessels

Blood vessels are hollow tubes made from smooth muscle whose function is to transport blood around the body and although there are different types of blood vessel it's important to always remember that they all form a closed, continuous loop and each blood vessel splits to form another type of blood vessel or joins to another blood vessel.



There are three main types of blood vessels:

- **Arteries**
- **Veins**
- **Capillaries**

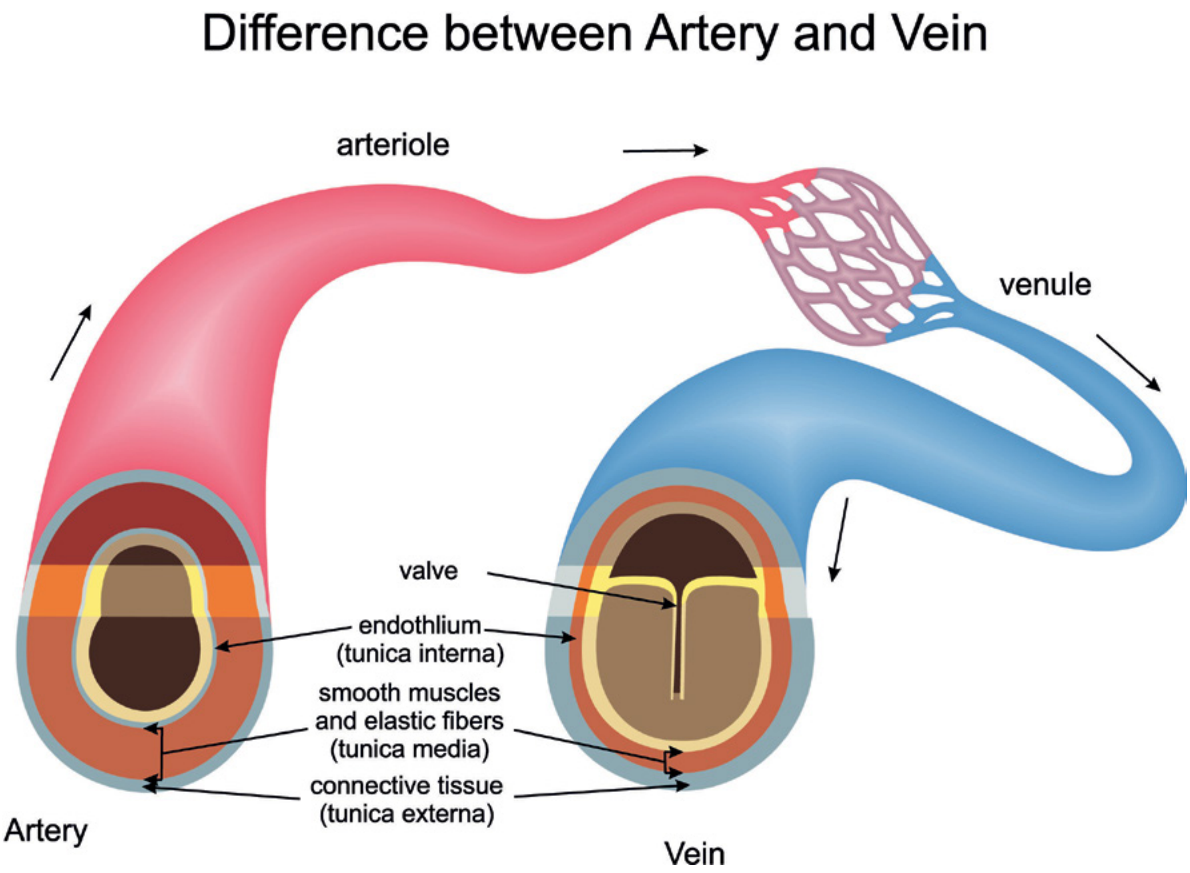
There are also two sub-categories of blood vessel:

- **Arterioles: small arteries**
- **Venules: small veins**

The structure and Function of Blood Vessels

Arteries

Arteries are thick and muscular, they are under tremendous pressure and their physical characteristics reflect this. They always carry blood away from the heart hence the high pressure within them. The **largest artery in the body is the aorta**. They are elastic so that they can expand as the heart beats. If you place your fingertips on your radial artery, just below your thumb on the side of your wrist, you can feel the artery expand each time your heart beats. This is called your radial pulse.



Veins

Veins take blood back toward your heart. Under considerably less pressure than arteries, they are not as thick or as muscular. Because they are under less pressure, it is possible that blood could flow backward through a vein so to prevent this, veins have one-way valves to ensure blood does not flow back from whence it came. These one-way valves sometimes go wrong and blood pools within sections of veins. This condition is commonly called varicose veins.

Capillaries

Capillaries are one cell thick to allow diffusion, capillaries are semi-permeable to allow various substances pass through them. Capillaries spread through all parts of the body so they can deliver or pick up essential substances. There are **more capillaries than any other type of blood vessel** and a high density area of capillaries is called a capillary bed. **Exercise can cause an increase in the number of capillaries**; this is called capillarisation.

The Cardiac Cycle

The conduction system allows the heart to function effectively by causing different compartments of the heart to contract and relax in a coordinated manner. The cardiac cycle is described as all the events associated with one beat. The key elements of the cardiac cycle relate to the contraction and relaxation of the heart's chambers.

A chamber during contraction is referred to as being in 'systole', whereas one which is relaxing is referred to as being in 'diastole'.

THE FOLLOWING IS A BRIEF SUMMARY OF THE KEY EVENTS OF THE CARDIAC CYCLE:

Relaxation (diastole): relaxation of the atria allows blood to refill them from the pulmonary veins and vena cava. This precedes, and continues with, the ventricular relaxation which allows blood to flow in from the atria.

Atrial systole (contraction): sstimulation from the SA node causes the atria to contract and push any remaining blood into the ventricles.

Ventricular systole (contraction): the ventricles contract causing a rise in pressure. This closes off the AV valves and directs the blood to be ejected from the heart via the pulmonary artery and aorta.

Relaxation (diastole): the atria relax followed by the ventricles until all four chambers are in diastole and the cardiac cycle begins over again.

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The Autonomic System

Whilst the sinoatrial (SA) node dictates the basic rhythm of the heartbeat, the autonomic system is able to exert significant control over the amount of work the heart does. This is primarily directed by the medulla oblongata of the brain. It responds to a variety of different stimuli, such as; **input from other brain centres** (e.g. the cerebral cortex and the hypothalamus), **chemical changes in the blood, variations in blood pressure and movement of the limbs.**

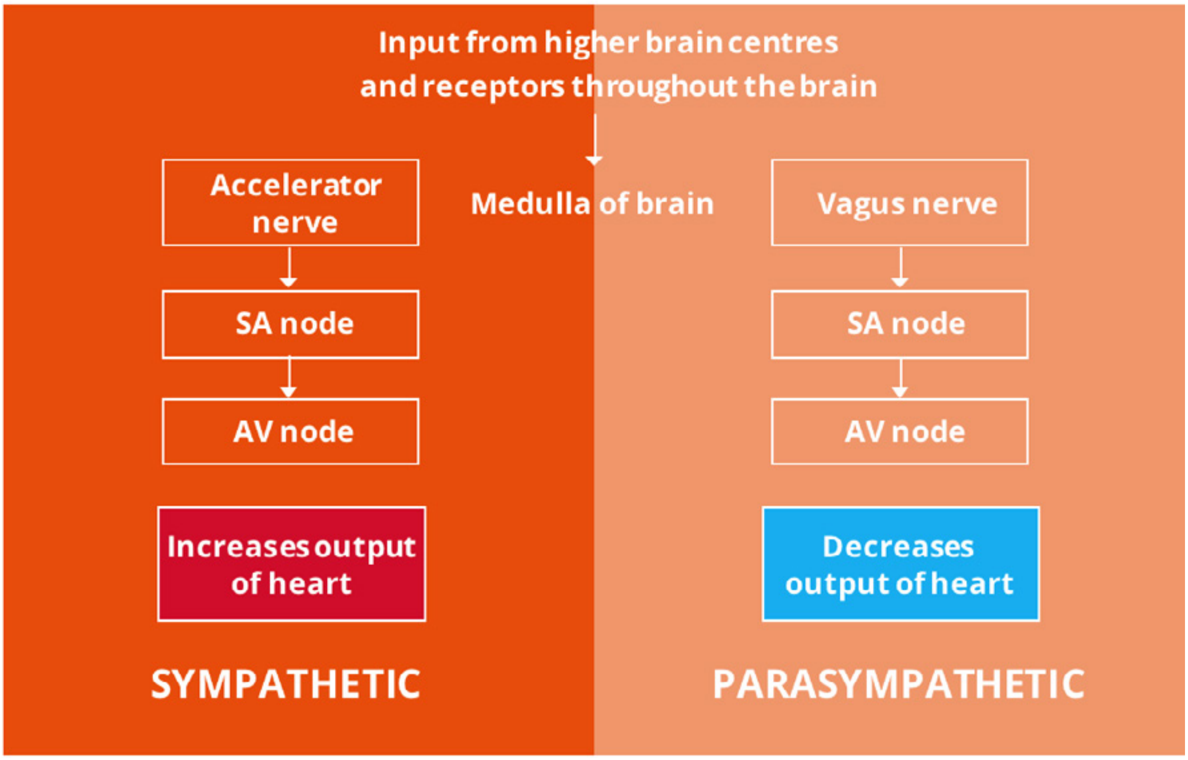
THE ACTIVITIES OF THE AUTONOMIC SYSTEM CAN BASICALLY BE DIVIDED INTO TWO:

- **Those which prepare the body for activity (The Sympathetic Nervous System)**
- **Those which return the body to rest (The Parasympathetic Nervous System)**

The sympathetic system will increase the output of the heart, whereas the parasympathetic system will decrease the output.

When the need arises (e.g. starting to run), the autonomic system can increase the volume of work done by the heart via two cardiac accelerator nerves running from the medulla of the brain. These stimulate the SA node to generate action potentials more rapidly, as well as directly causing the myocardium to contract more forcefully (the heart beats quicker and harder).

In contrast, in a resting state, the vagus nerve (also from the medulla) causes the SA node to generate action potentials less rapidly; consequently lowering the heart rate. The SA node will naturally generate between 90 – 100 beats per minute, the influence of the vagus nerve will usually reduce this to approximately 60 – 85 beats per minute. For the trained athlete, however, Wilmore and Costill (2004) note that this may drop to less than 30 beats per minute.



Heart Control And Rhythm

The **speed and power of each heartbeat** is controlled by something called the **conductive system** which ensures the chambers contract in a synchronised rhythm rather than all four chambers contracting at the same time. **Your heart's natural "pacemaker" is a bundle of nerves called the sinoatrial node** or SAN for short. Along with the **atrioventricular node** or AV node, your heart will speed up when more blood needs to be pumped around the body e.g. during exercise, and slow down when less blood is needed e.g., while you sleep.

The average resting heart rate is 72 beats per minute (bpm) although an exercising heart can beat over 200 times per minute. A resting heart rate above 72 bpm is called tachycardia while a resting heart rate of 60 bpm or less is called bradycardia. Low resting heart rates are generally seen as an indicator of good circulatory fitness but this is not always the case and unexpected low resting heart rate readings should be investigated.

Heart Circulation

As previously discussed, the two sides of the heart have different jobs. The left side receives and pumps oxygenated blood around the body whereas the right side receives and pumps deoxygenated blood back to the lungs. The process of returning deoxygenated blood back to the heart is called 'venous return'.

Oxygenated blood is bright red in colour whereas deoxygenated blood tends to have a bluish hue. Air is inhaled and passes through the:

FROM THE NOSE AND/OR MOUTH:

1. **Pharynx**
2. **Larynx**
3. **Trachea**
4. **Primary bronchi**
5. **Bronchioles**
6. **Alveoli where oxygen is extracted and diffused into the blood via the capillaries**

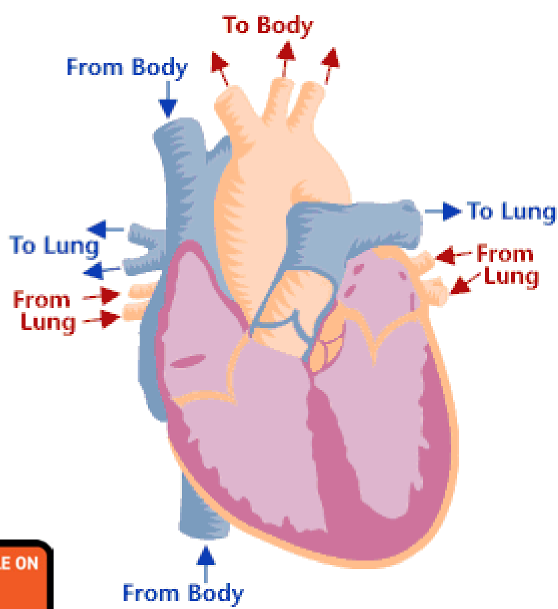
FROM THE LUNGS:

1. **Oxygenated blood enters the left atrium via the pulmonary vein.**
2. **Oxygenated blood flows from the left atrium to the left ventricle**
3. **Into the aorta to be circulated around the body. This is called systemic circulation.**

The oxygen is used by the cells, organs and systems of the body and carbon dioxide is produced.

FROM THE BODY:

1. **Deoxygenated (CO_2 rich) blood is then directed back to the heart via the superior and inferior vena cava where it enters the right atrium**
2. **Is pumped down into the right ventricle**
3. **From the right ventricle, the deoxygenated blood is pumped into the pulmonary artery and sent back to the lungs**
4. **Its payload of CO_2 diffuses into the alveoli via the capillaries for exhalation and blood is then reoxygenated. This is called pulmonary circulation.**



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Venous Return

The flow of blood back to the heart via veins (often against gravity) is called 'venous return'. The pressure in the veins is relatively low and so several mechanisms combine to ensure that blood circulates in a timely fashion.

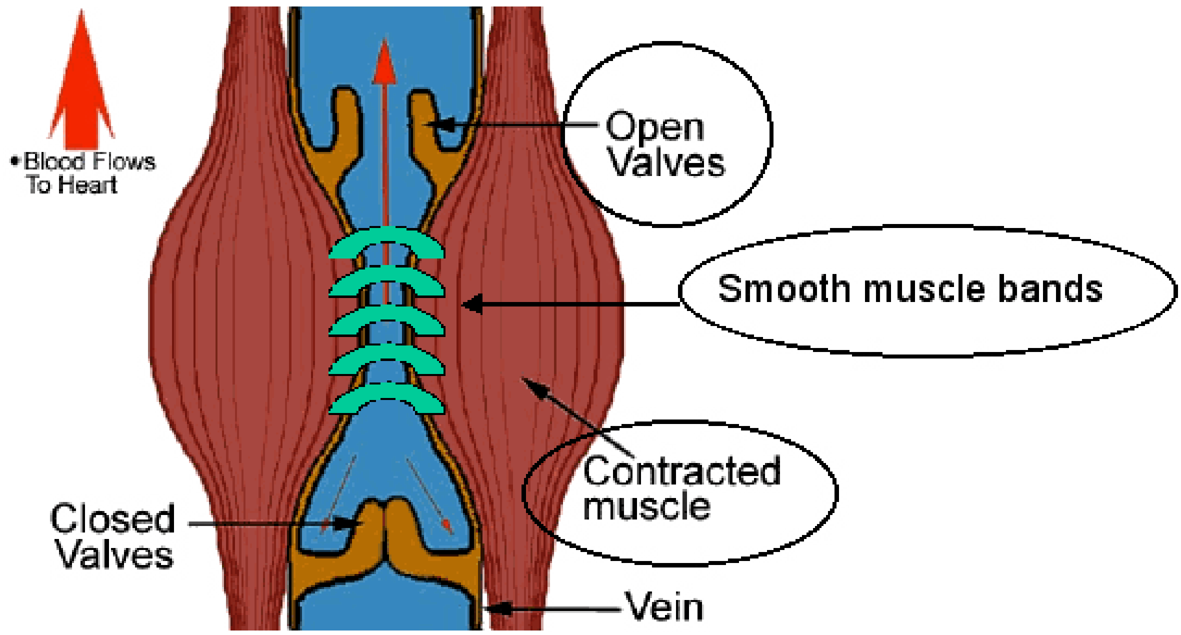
- **Peristalsis:** Made from smooth muscular tubes, all blood vessels can contract. When they contract they squeeze inward and that helps to push the blood they contain along their length. This is called peristalsis. To understand peristalsis, imagine a snake swallowing an egg; the walls of the snake's digestive tract push inward and, using a wave-like motion, push the egg down the length of the snake's body.
- **Skeletal muscle pump:** as skeletal muscles contract, they push against the walls of the veins which in turn pushes the blood through them.
- **One-way valves:** to prevent the backflow of blood and aid venous return, veins have valves which prevent blood from flowing the wrong way or from "pooling" in one area.
- **Right atrium:** as the right atrium refills, it creates a slight vacuum effect and pulls blood into it.
- **Diaphragm:** as it relaxes and returns to its slightly domed position, the diaphragm creates a vacuum in the abdominal cavity which helps draw blood upward.
- **Gravity:** blood from above the heart flows downward to the right atrium via the superior vena cava and is aided by gravity.

Control Of Blood Flow

While every part of your body needs oxygen and therefore blood, some areas need more than others at certain times. For example, if you eat a large meal, your digestive system requires lots of blood and if you exercise, your working muscles and heart/lungs require lots of blood.

To ensure there is enough blood in the areas most in need, your body restricts blood flow to one area and increases it to another using vasoconstriction and vasodilation which basically means blood vessels are narrowed or widened respectively and on-demand.

This vasoconstriction and vasodilation are why it's never a good idea to exercise after a heavy meal and why your muscles can look "pumped up" after a workout. Both vasoconstriction and vasodilation are possible because blood vessels are made from smooth muscular tubes that can contract or relax as required.



Measuring the Output of the Cardiovascular System

The work done by the heart is termed cardiac output (Q).

Cardiac Output (Q) = the volume of blood pumped from the heart every minute

The determinants of cardiac output are heart rate (HR) and stroke volume (SV)

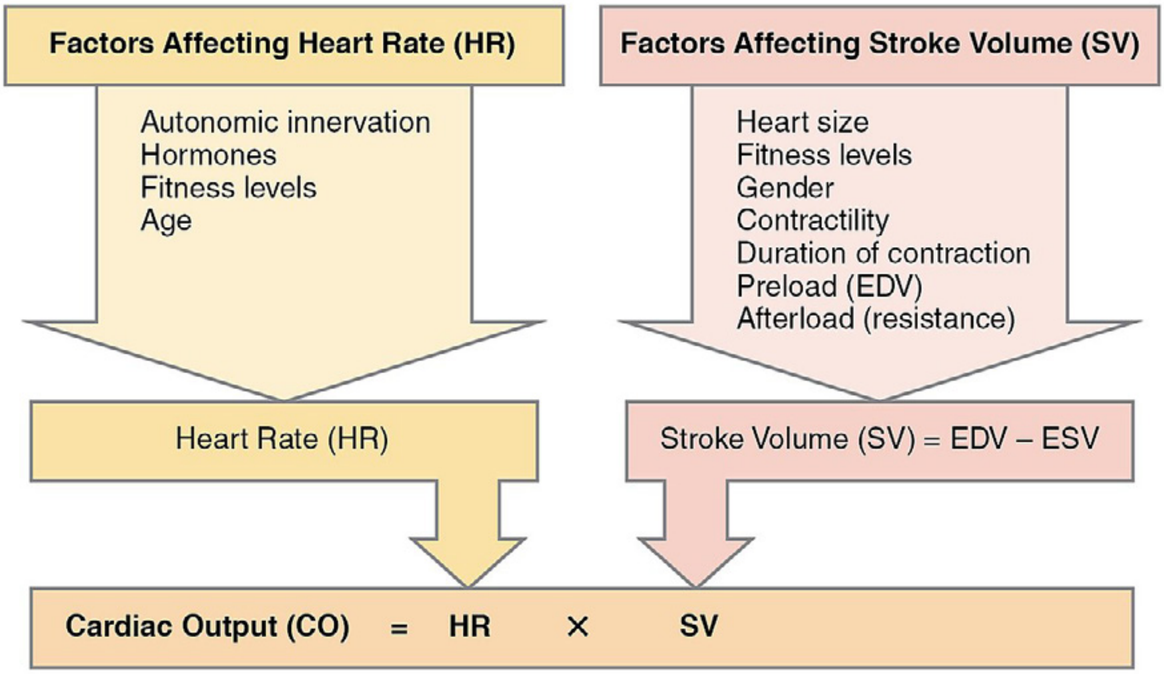
Heart rate (HR) = the number of times the heart beats in a minute.

Stroke volume (SV) = the amount of blood ejected from the ventricles every beat.

Thus to calculate cardiac output, multiply stroke volume by heart rate.

Q = HR x SV

NB: Practically speaking, however, it is difficult to calculate cardiac output as determining stroke volume can involve some fairly invasive procedures.



Blood Pressure

The circulatory system is a closed system and as blood enters one area of the body, the same quantity of blood will be leaving another.

Oxygenated blood

Lungs > pulmonary vein > heart > aorta > arteries > arterioles > capillaries

Deoxygenated blood

Capillaries > venules > veins > vena cava > heart > pulmonary artery > lungs

This means that there is pressure within the blood vessels and that pressure varies constantly. While some variance is normal and necessary, blood pressure can become too high or too low.

The standard definition of blood pressure is "the measure of the force that blood exerts against the walls of the arteries".

There are two measurements associated with blood pressure:

Systolic blood pressure: is the pressure within the arterial system when the heart is beating.

Diastolic blood pressure: is the pressure in the arterial system when the heart is refilling.

Subsequently, if you get your blood pressure checked, you will receive two readings: **a higher reading (your systolic blood pressure) and a lower reading (your diastolic blood pressure).** Blood pressure is normally expressed as one figure over another for example:

117 over 76

Blood pressure is measured in millimetres of mercury or mmHg. This unit of measure is determined by the use of devices called mercurial sphygmomanometers which measure blood pressure against a vertical scale and how high a column of mercury moved during the test.

Mercurial sphygmomanometers are no longer widely used in favour of more machine/computerised devices but the same unit of measure still is.

Blood Pressure Stages

Blood Pressure Category	Systolic mm Hg (upper #)		Diastolic mm Hg (lower #)
Low blood pressure (Hypotension)	less than 80	or	less than 60
Normal	80-120	and	60-80
Prehypertension	120-139	or	80-89
High Blood Pressure (Hypertension Stage 1)	140-159	or	90-99
High Blood Pressure (Hypertension Stage 2)	160 or higher	or	100 or higher
High Blood Pressure Crisis (Seek Emergency Care)	higher than 180	or	higher than 110

Source: American Heart Association

Blood Pressure Categories

Mercurial Sphygmomanometer

Machine Sphygmomanometer

Effects of Exercise on Blood Pressure

Short Term

As cardiac output increases with exercise, most forms of exercise will cause systolic blood pressure to increase. This response is linear and an increase in exercise intensity will cause a similar increase in blood pressure. This is not normally of any concern for healthy individuals as blood pressure should return to normal once cardiac output returns to normal. Cardiac output has the greatest effect on systolic blood pressure.

Diastolic blood pressure normally remains relatively unchanged or may even fall slightly when performing low to moderate-intensity aerobic exercise. However, heavy weight training and especially isometric contractions or where the breath is held to increase intra-abdominal pressure using the Valsalva manoeuvre (exhaling against a closed epiglottis) can increase diastolic blood pressure in the short term. Again, in healthy individuals, blood pressure should normalise on cessation of exercise.

If an exerciser is hypertensive, care should be taken not to exasperate their health issues by straining so hard that diastolic blood pressure rises excessively. This means that hypertensive exercisers should avoid holding their breath and only exercise to form failure. It is also recommended that hypertensive follow a circuit weight training program rather than use the more traditional multi-set system and avoid overhead and declined exercises.

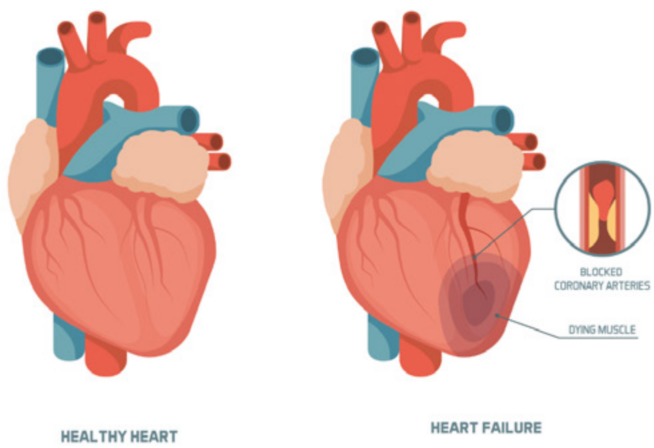
Long Term

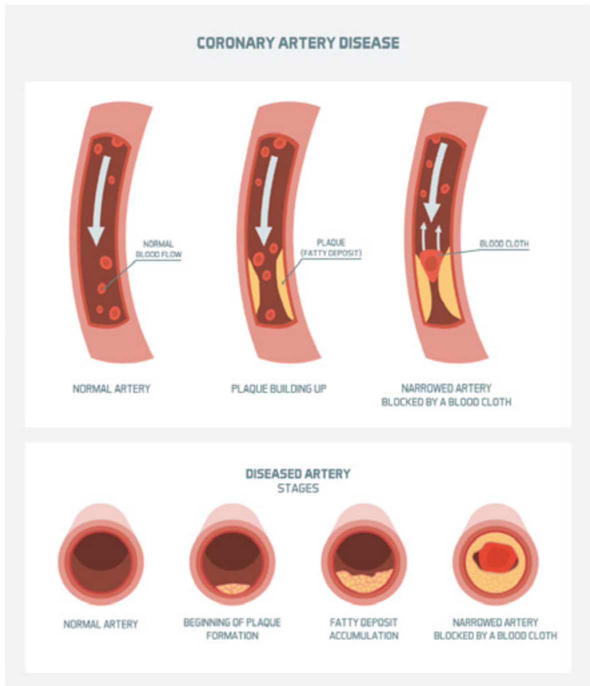
Low to moderate-intensity aerobic exercise has been shown to have a positive effect on cardiovascular health and can help normalise blood pressure in the long term. Regular aerobic exercise can lower systolic and diastolic blood pressure by an average of 10mmHg each.

The Effect Of Exercise On Circulatory Measures

Exercise affects the function of your heart and blood vessels, both acutely (as you exercise) and as a result of your body adapting to the exercise (chronically). These changes are caused by increased heart size and strength, increased blood vessel elasticity and increased blood volume.

Each artery is responsible for delivering oxygen to some part of the heart. The heart also must have some mechanism to rid itself of blood that is now low in oxygen after supplying the tissues. This is done via coronary veins that carry the blood away, straight back to the heart. It will then be pumped to the lungs for reoxygenation before again becoming part of the coronary circulation.





The Respiratory System

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Introduction

The respiratory system is responsible for taking oxygen into the body and removing the waste product of aerobic respiration – carbon dioxide. And while you have limited control over breathing, i.e. you can choose to hold your breath, ultimately breathing is controlled by your autonomic or involuntary nervous system.

The cells of the human body require a constant stream of oxygen to stay alive. The respiratory system provides oxygen to the body's cells while removing carbon dioxide, a waste product that can be lethal if allowed to accumulate.

There are 3 major parts of the respiratory system:

- **The airway.**
- **The lungs.**
- **The muscles of respiration.**

The airway, which includes: the **nose, mouth, pharynx, larynx, trachea, bronchi, and bronchioles**, carries air between the lungs and the body's exterior. The lungs act as the functional units of the respiratory system by passing oxygen into the body and carbon dioxide out of the body. Finally, the muscles of respiration, including the diaphragm and intercostal muscles, work together to act as a pump, pushing air into and out of the lungs during breathing.

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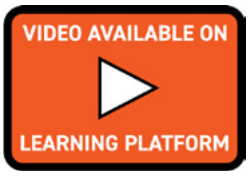
The Anatomy of the Respiratory System

- **Nose or mouth**
- **Pharynx**
- **Larynx**
- **Trachea**
- **Primary bronchi**
- **Bronchioles**
- **Alveoli**
- **Capillaries**

Carbon dioxide exits the body through the same structures but in reverse.



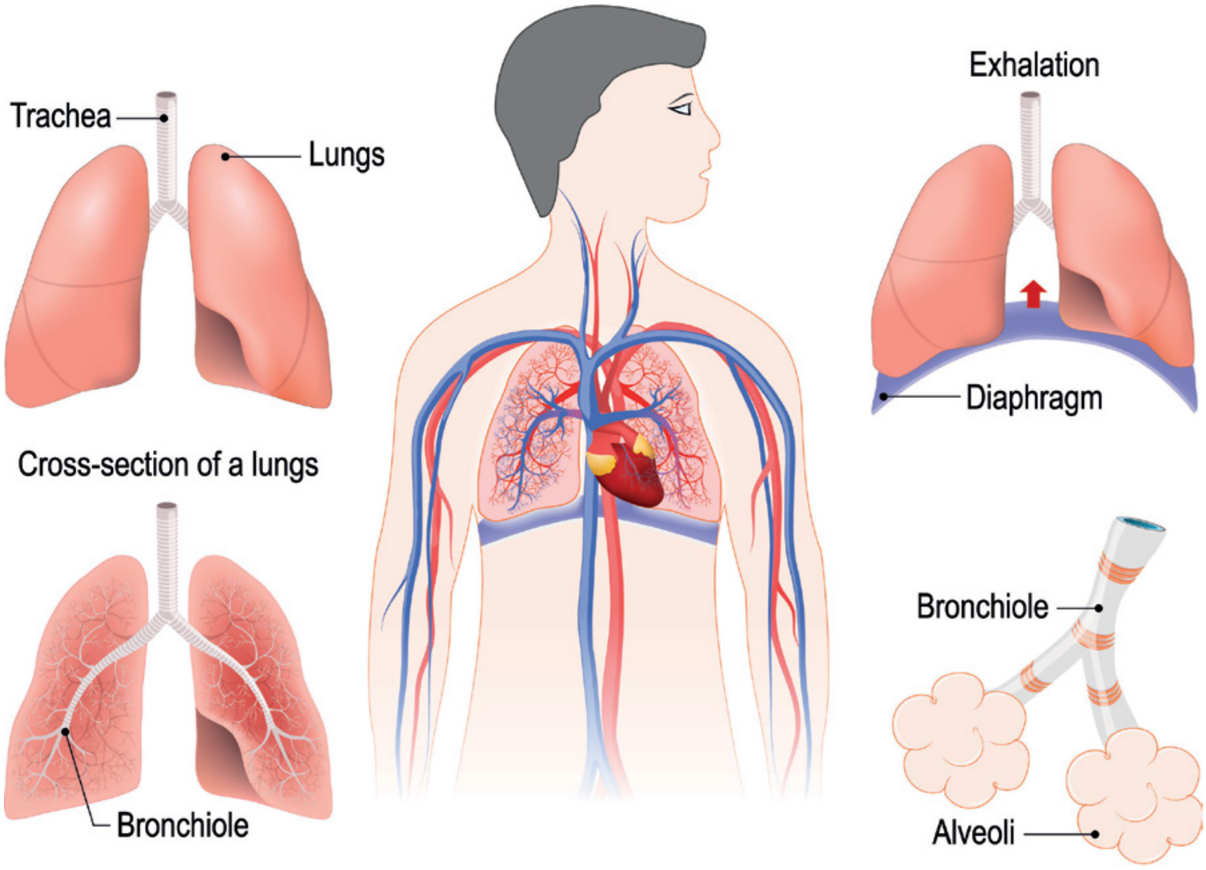
The Lungs

Location:

- **In the rib cage or thoracic cavity**

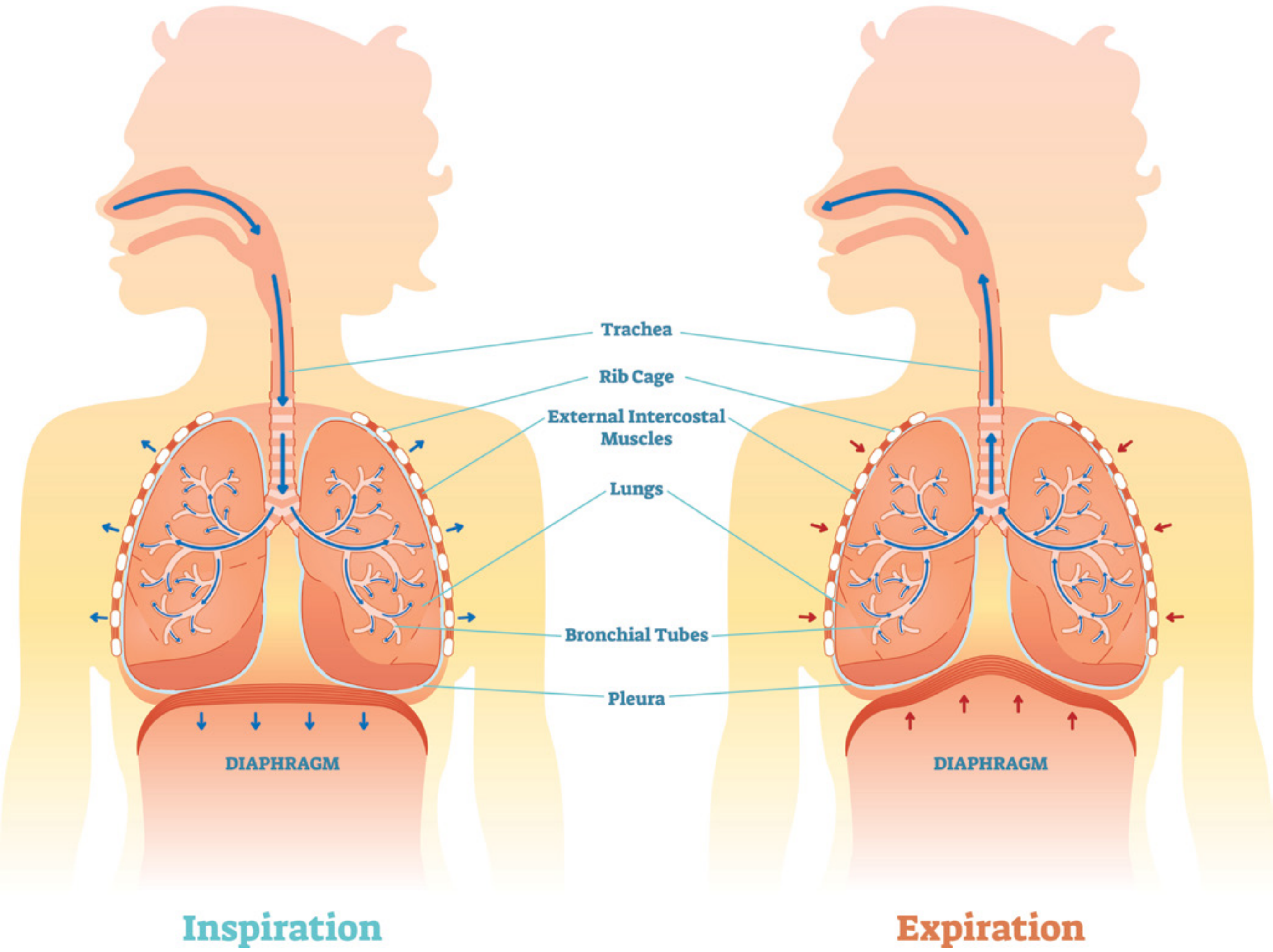
Function:

- **Remove carbon dioxide**
- **Take in oxygen**



Essential terminology:

- **Inhalation or inspiration:** Taking air down and into the lungs.
- **Expiration or exhalation:** Expelling the air from the lungs.
- **External respiration:** The exchange of gasses between the lungs and blood.
- **Internal respiration:** The exchange of gasses between the blood and the cells.



Mechanics of Breathing

Inhalation

To draw air into your body, your diaphragm, a dome-shaped muscle across the bottom of your ribs, contracts and depresses. At the same time, your intercostal muscles, which are located between your ribs, contract and pull your ribs upward and outward. This increases the volume of your chest cavity which in turn, creates a vacuum. Air is then drawn into your lungs until the pressure inside your lungs is equal to the pressure outside.

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Diaphragmatic Versus Costal Breathing

When you are at rest and oxygen demands are low, your primary breathing muscle should be your diaphragm. Diaphragmatic breathing is characterised by abdominal distension and very little chest expansion. To experience this, lie on your back and place one hand on your abdomen and the other on your chest. Now breathe normally but ensure only your lower hand moves.

To increase your oxygen intake, for example when exercising, more costal breathing is necessary so that sufficient air can be taken into the lungs.

Again, lying on your back, inhale but this time make sure the hand resting on your chest also moves.

Diaphragmatic breathing is linked to relaxation and is part of yoga, tai chi and can help reduce stress and blood pressure.

Combining diaphragmatic with costal breathing will create the largest possible chest cavity expansion and, therefore, the greatest intake of air.

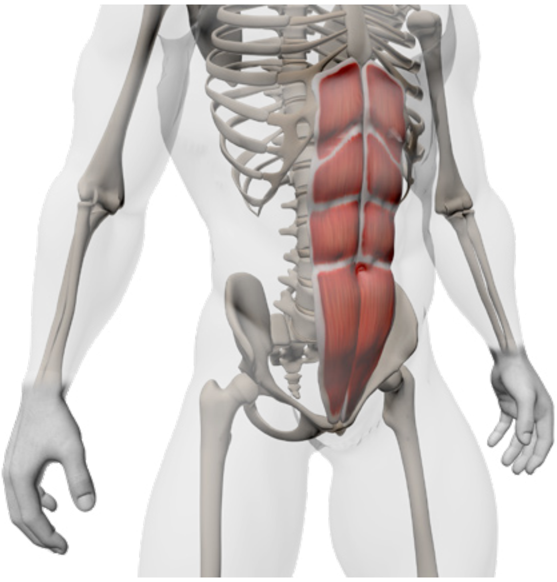
Exhalation

To drive air out of your lungs, the diaphragm relaxes and so does the intercostals. This causes the ribcage to deflate which pushes the air out of your lungs. Although you can push most of the air out of your lungs, some always remains which is called your Residual Volume (RV).

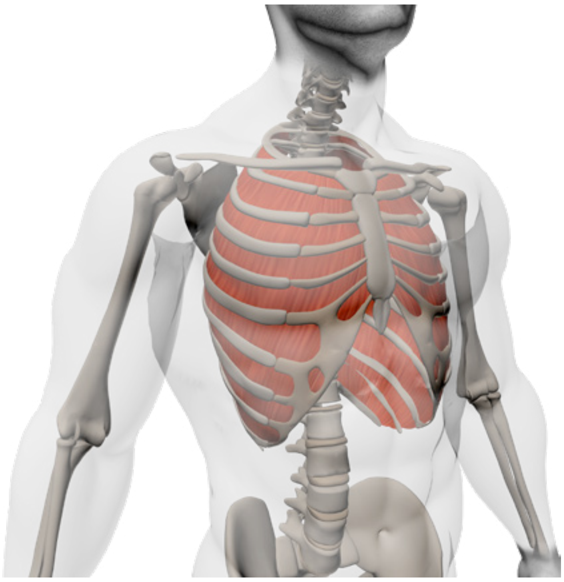
In addition to the action of the diaphragm and intercostals, you can use your rectus abdominus to compress your abdominal cavity to exhale more forcefully e.g. when blowing up a balloon.

The Muscles used in Breathing

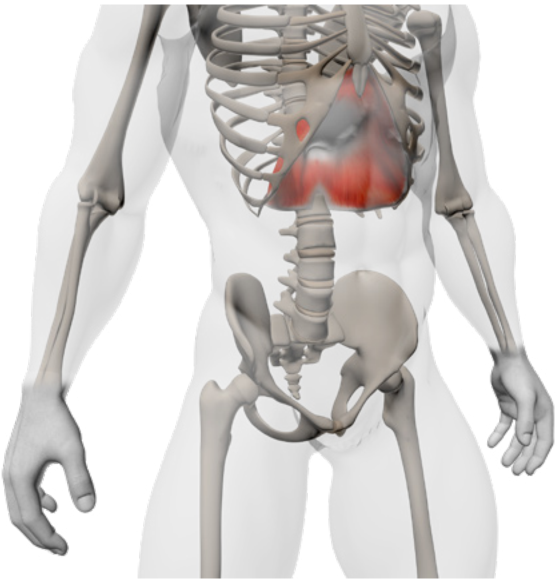
- Diaphragm
- Intercostals
- Rectus abdominus



Rectus Abdominus



Intercostal Muscles



Diaphragm

Gaseous Exchange

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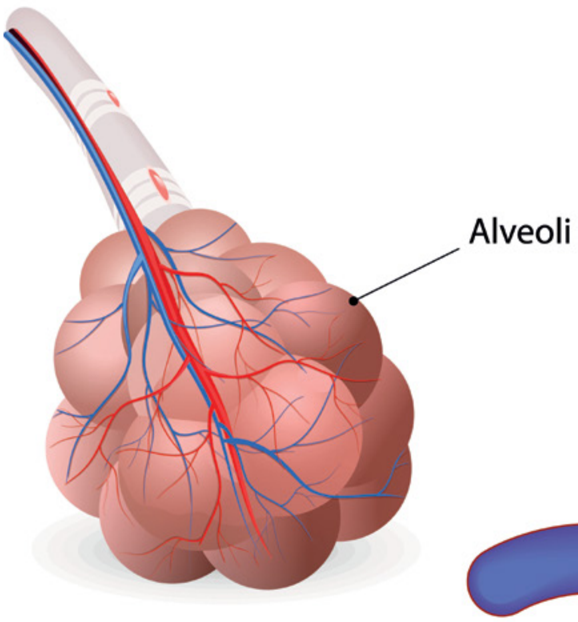

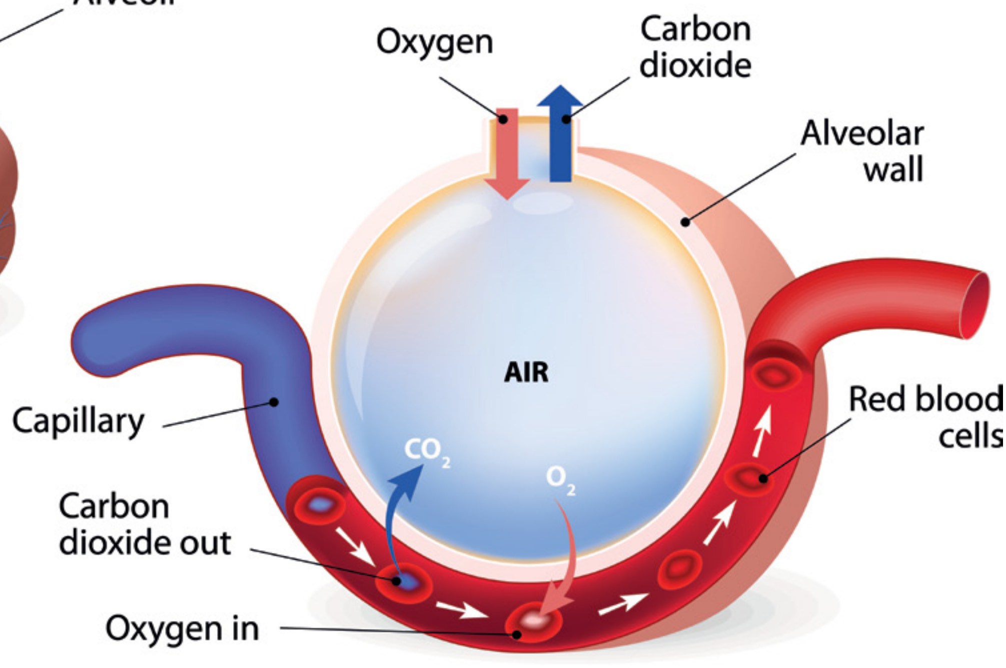

As you breathe in, the air is drawn down into your lungs and ends up in your alveoli which resemble bunches of grapes. The alveoli provide a very large surface area for moving oxygen (O2) into your blood and removing carbon dioxide (CO2) from your blood ready for exhalation. This "swapping" of gasses is called a gaseous exchange and is also known as diffusion. Diffusion can be defined as the movement of gasses from an area of high concentration to an area of low concentration and as this is happening to two gasses simultaneously (O2 and CO2) there is an exchange of equal volumes of gasses.

Diffusion is possible because the alveoli are proliferated with tiny blood vessels called capillaries. Capillaries are one-cell thick so that gasses and other substances can pass through them.

As air is inhaled and reaches the alveoli, O2 is extracted from the air and passed through the capillaries and into the blood. The O2 binds to a substance called haemoglobin (essentially your red blood cells and known as Hb for short) and is then transported around the body and used as required.

Conversely, CO2 from the blood diffuses into the alveoli via the capillaries and is exhaled.

CO2 is also carried by Hb although when haemoglobin is carrying oxygen it is called oxy-haemoglobin and when it is carrying CO2 it is carboxy-haemoglobin.

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The Air We Breathe

Composition of Air

Air is comprised of several gasses, some of which are very important and some of which are less so. Oxygen is essential for human life but nitrogen, which makes up a large percentage of the air we breathe, is inert. Inhaled air has a different composition to exhaled air because some of the oxygen is used in aerobic respiration.

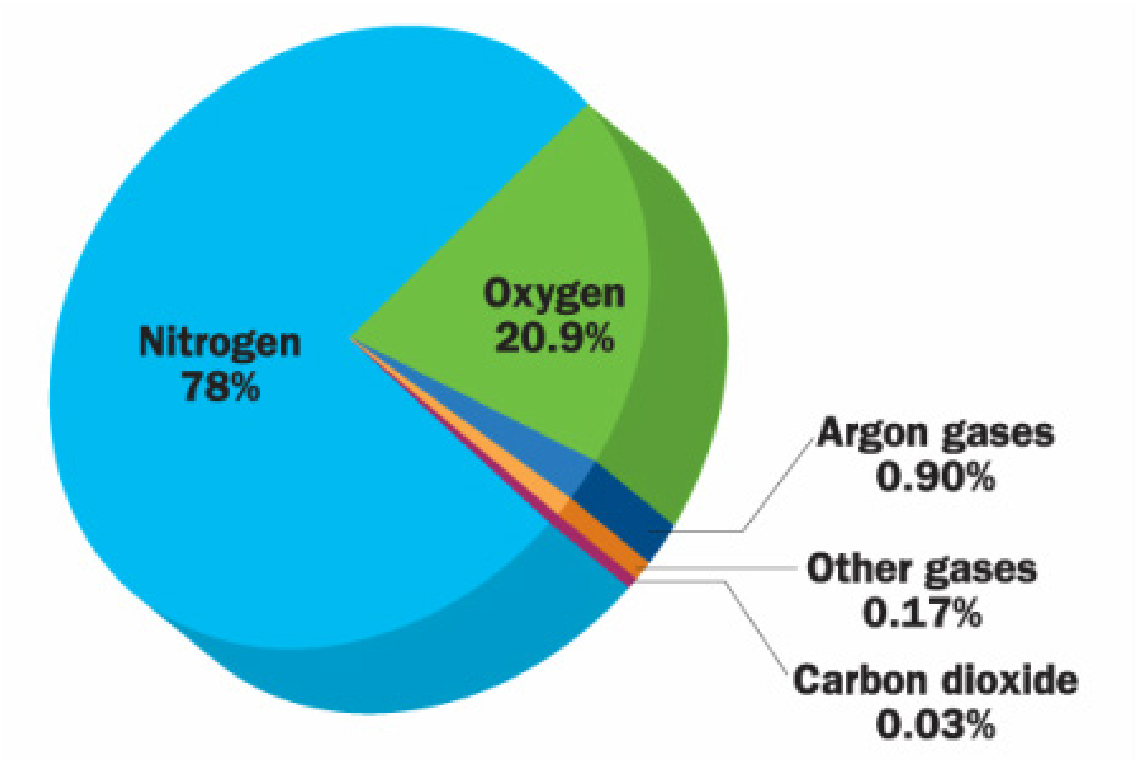
Gas	Inhaled Air	Exhaled Air	Difference
Nitrogen (N_2)	79%	79%	No Change
Oxygen (O_2)	21%	17%	4% decrease
Carbon Dioxide (CO_2)	<1%	4%	4% decrease

The Stimulus for Breathing

While you can voluntarily control the depth and speed of your breathing up to a point, the majority of the time, breathing is controlled by your autonomic nervous system which means it is involuntary.

When blood CO2 levels reach 4%, breathing will occur. This is why you can only hold your breath for so long and why, even underwater, you will attempt to breathe if deprived of oxygen for long enough.

When you exercise, CO2 levels increase quickly and so breathing rate increases significantly to prevent CO2 levels exceeding 4%. In contrast, at rest and especially during sleep, CO2 levels are very low and subsequently so too is the breathing rate.



Measures Associated with Lung Function

Many aspects of lung function can be measured through the use of spirometry tests. These measures can be affected by several factors including **gender, age, general health, body type and illnesses** such as asthma. Spirometry tests involve blowing into measuring devices that analyse and record **volume, velocity and/or duration of airflow.**

The main measures are:

- **Breathing rate (BR): The number of breaths taken per minute**
- **Tidal volume (TV): The amount of air inhaled and exhaled in one breath**
- **Minute ventilation (MV): The total amount of air exhaled and exhaled in one minute**

Therefore minute ventilation (MV) which is measured in millilitres per minute (ml/min) or litres per minute (l/min) equals breathing rate (BR) multiplied by tidal volume (TV)

$$MV = BR \times TV$$

For example:

BR = 12

TV = 500ml

MV = 6000ml/min or 6l/min

Measure	Acute	Chronic
Breathing rate	Increases	Decreases
Tidal Volume	Increases	Increases
Minute Ventilation	Increases	Unchanged or Slightly Increase

The Effect of Exercise on Lung Function Measures

Exercise affects the function of your lungs, both acutely (as you exercise) and as a result of your body adapting to the exercise (chronically). These changes are caused by increased capillarisation at the alveoli, increased haemoglobin density in the blood and improved respiratory muscle strength and endurance.