breathing & the heart

VO_2 max is a measure of maximum oxygen consumption per minute; it is an indicator of aerobic capacity.

Contributing factors:

» Efficient uptake of oxygen by the lungs , achieved through increased vascularisation.
» Efficient transport by the cardiovascular system
» Efficient use by muscles

An individual gets cardiovascularly fitter as their VO_2 increases.

Measurement is done with a running machine; you perform maximal exercise to the point of exhaustion. Less trying exercises can provide an estimate of VO_2 max.

Moderating Oxygen Provision

This is achieved by altering:

1. Cardiac output
2. Breathing rate
3. Breathing depth

1. Cardiac Output

This is the amount of blood pumped by the heart in a minute, and is approximately $5dm^3m^{-1}$ in trained and untrained individuals, rising to 30 in trained athletes at maximum intensity.

$$CO = SV \times HR$$

Cardiac Output = Stroke Volume x Heart Rate

Stroke Volume changes during exercise as increased venous return from exercising muscles leads to greater stretching of the heart muscles, resulting in a stronger contraction during systole. These stronger contractions eject much of the residual blood from the heart where previously it would have hung around.

Heart rate is usually inversely proportional to stroke volume; the greater your stroke volume (i.e the fitter you are) the lower your heart rate. The heart is myogenic; it can beat without external stimulation. This is evidenced by the fact that it will continue to beat if placed in a glucose and salt solution; however, it is still influenced by the CNS and hormones, notably adrenaline.

It is the medulla oblongata that controls heart rate, via the use of a sympathetic (accelerator) and the vagus parasympathetic (decelerator) nerve. Impulses from these nerves to the SAN node control heart rate. These impulses are based upon information on the CO_2, lactate, O_2 and temperature of the blood.

The rise in blood pressure equating to the higher cardiac output is moderated by stretch receptors in the aorta & carotid arteries, and inhibited to safe levels.

Breathing

Inhalation: A vacuum is created by the flattening of the diaphram and the contraction of the external intercostal muscles, expanding the thoracic space.

Exhalation: Pressure raised by relaxation and bending of the diaphram and the contraction of the internal intercostal muscles, thoracic volume falling.

The amount of gas we breathe in and out with every breath is called tidal volume.

As exercise begins we increase breathing rate and depth of breathing.

The maximum amount we can inhale and exhale is the Vital capacity (peak flow). In large and fit people this is around $5dm^3$. Singers and woodwind players have a similar capacity.

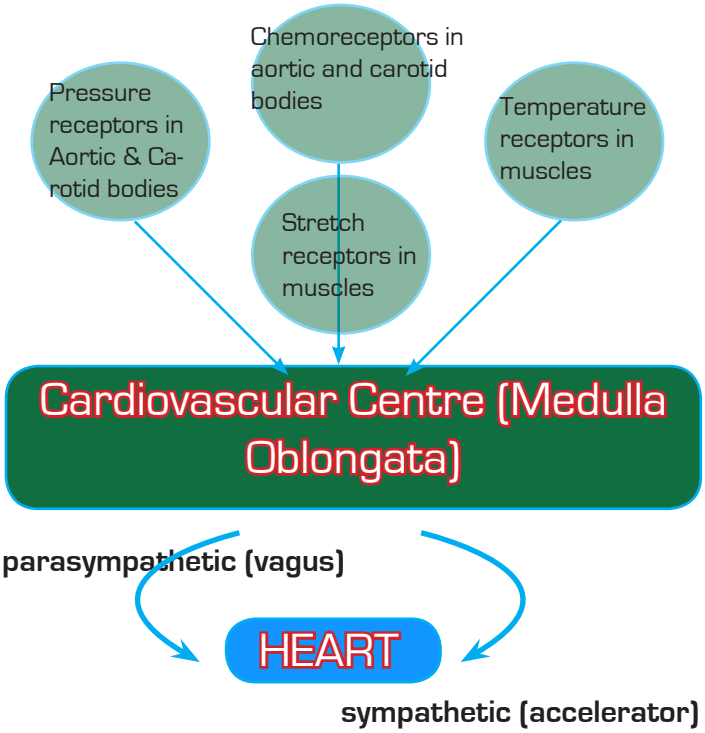
Tidal volume and vital capacity can be measured by spirometer. Soda lime is used to absorb exhaled CO_2, as a bag floating on water controls a needle (kymograph), whose movement plots the individual's breathing.

In one minute, the amount of air taken into the lungs is the minute ventilation.

$$MV = TV \times BR$$

Minute ventilation = Tidal volume x Breathing rate

Again, it is the medulla oblongata that moderates breathing, as shown below. Part of the autonomic nervous system, is has an inspiratory and an expiratory centre, and carries out homeostasis through negative feedback, based upon blood acidity.



Chemoreceptors

These respond chiefly to the pH of the blood. This is proportional to the CO_2 content of the blood, as shown below:

$CO_2 + H_2O \rightarrow H_2CO_3 \rightarrow H^+ + HCO_3^-$

The medulla oblongata senses the increase in acidity caused by increased CO_2 in the blood as carbonic acid is formed.
Chemoreceptors monitor H^+ concentrations in the blood, leading the medulla oblongata's inspiratory centre to send nervous impulses to the external intercostal muscles and the diaphragm.
This increases breathing rate and the volume of the lungs during ventilation.

Central chemoreceptors

» Located on the surface of the medulla oblongata and detects changes in pH of cereberospinal fluid
» Does not repsond to O_2

Peripheral

» Aortic body [Aorta]: detects changes in O_2, CO_2 but NOT PH.
» Carotid body [Carotid arteries]: detects all 3.
» The effect of these peripheral receptors only influence breathing rate slightly; they are auxiliary.

Expiration uses stretch receptors to tell when to breathe out. The abdominal muscles contract during forced exhalation.