The ECG

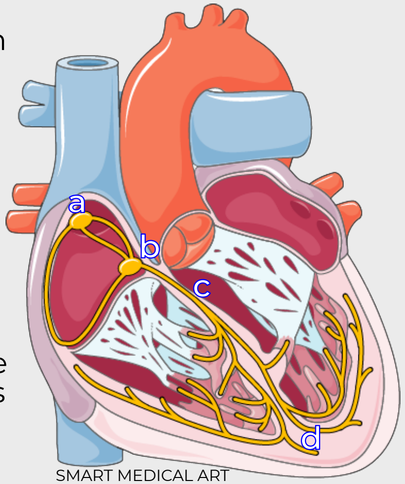
How does it work, and why?

An infographic by Callum Cockburn

University of BRISTOL

1) The Anatomy and Physiology

The heart works by electrical conduction - spikes of voltage are produced in the SA node (a) in the right atrium, which causes a wave of depolarisation to sweep across the heart, through the AV node (b), down the Bundle of His (c), and into the Purkinje fibres (d). This results in contraction of muscle.

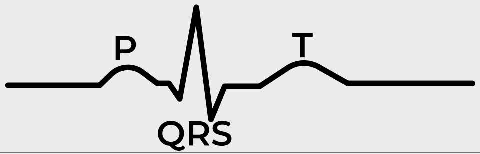


The ECG trace has different parts, which represent the electrical equivalent of the different parts of the mechanical process.

i) P-wave - atrial depolarisation

ii) QRS complex - ventricular depolarisation

iii) T wave - ventricular re-polarisation

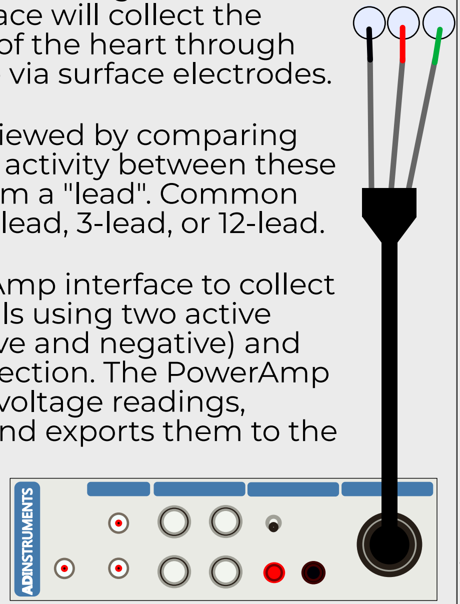


2) Capturing an ECG

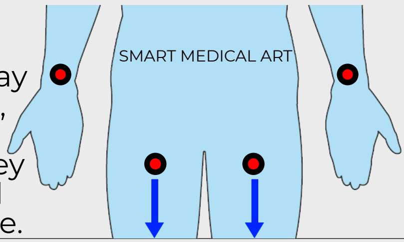
In the Physiology teaching lab, the PowerAmp interface will collect the electrical activity of the heart through detecting voltage via surface electrodes.

The ECG is then viewed by comparing the differences in activity between these electrodes - to form a "lead". Common ECG types are a 1-lead, 3-lead, or 12-lead.

Using the PowerAmp interface to collect an ECG lead entails using two active electrodes (positive and negative) and one ground connection. The PowerAmp then collects the voltage readings, amplifies them, and exports them to the Lab Chart software for further analysis and processing.



Limb electrodes should be placed away from skeletal muscle, on the wrists and ankles. Make sure they are securely fastened and not likely to move.



3) The engineering behind the ECG

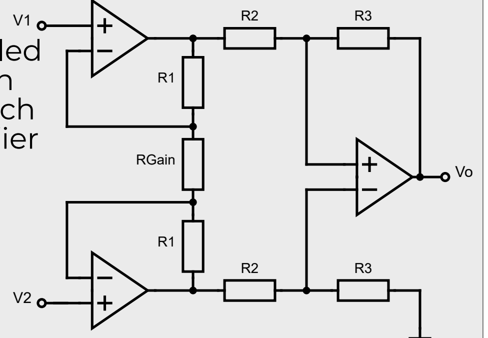
The core engineering principle behind an ECG is the differential amplifier - comparing two voltage readings and amplifying the difference between them.

The diagram below uses resistors and a type of amplifier called an "Op Amp" (the triangle shaped component below) to create an instrumentation amplifier. The benefit of this amplifier is that it has two stages of amplification, which allows the function of the amplifier to be maximised. The equation from the amplifier shows that the values of the resistors set the gain - how much the difference between the inputs is amplified.

$$V_{out} = \left(1 + \frac{2R_1}{R_{gain}}\right)\frac{R_2}{R_3}(V_2 - V_1)$$

One key parameter is called the CMRR, which reflects how much noise the amplifier removes.

This should be maximise by choosing the values of the resistors.



adapted from "Building Scientific Apparatus"

4) The effect of breathing manoeuvres (Valsalva manoeuvre) on the ECG waveforms

The Valsalva manoeuvre is an extended period of straining expiration against a closed glottis. It increases interthoracic pressure, resulting in decreased venous return to the heart. By reducing preload, cardiac output is also reduced, leading to baroreceptor activation as the arterial blood pressure drops. This will stimulate the heart to beat faster, along with other evidence of sympathetic nerve activation [1]. When the strain is released, a transient bradycardia will be evident [2], which is the baroreceptor response to reduce blood pressure now the preload has returned to normal. Heart rate will then stabilise, as the blood pressure returns to normal [3]. This is a great example of physiological mechanisms in ECGs.

ECG captured by Dr Andy James

References and reading accessed below