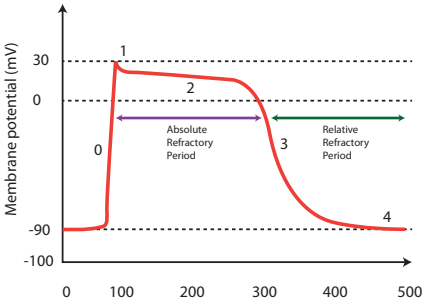
Second 2011
VIVA 6

Draw the cardiac action potential for a ventricular muscle cell.

Subsequent questions sought knowledge of what is the Resting Membrane Potential and how is it created, to describe ionic mechanism for each of the phases of the ventricular action potential, to draw the SA node action potential, compare and contrast the ventricular and SA node action potentials, and which pharmacological agents affect the different phases of the pacemaker potential.

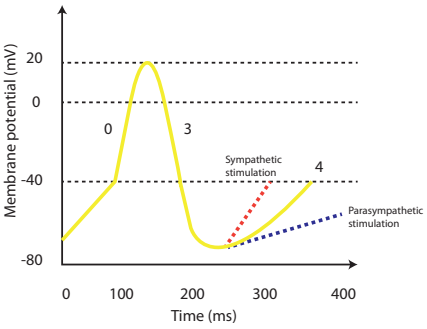
"Please draw the cardiac action potential for a ventricular myocyte"



Ionic basis of the fast-response cardiac action potential Atrial and ventricular muscle and purkinje fibre action potentials differ from those in nerves as they are much longer in duration, with a distinct plateau phase when depolarisation is maintained.

PHASE 0	The cell is rapidly depolarised from the resting membrane potential by a rise in sodium permiability via fast sodium channels. The slope is almost vertical. The the membrane is less negative then many sodium channels will be closed, thus the response will not be as quick.
PHASE 1	Repolarisation begins to occur as sodium channels close and potassium channels open.
PHASE 2	A plateau occurs owing to the opening of L-type Ca^{2+} channels which offset the action of K channels and maintains depolarisation. During this time no further depolarisation is posible, this represents the absolute refractory period.
PHASE 3	The L-type Ca^{2+} channels close and K efflux now causes repolarisation as seen before this accelerates through positive feedback. It is now possible to cause another depolarisation although the force of the contraction will be diminished. This the relative refractory period.

"Please draw the actioon potential of a cell in the SA node"



Ionic basis of the slow-response cardiac action potential The sino atrial node and the AV node have the same ionic basis although the AV node is slower. The adjacent diagram represents the SA node. In the slow response cardiac action potential there is no resting state; rather there is a pacemaker potential which generates cardiac autorhythmicity. Phases 1 and 2 (of the fast response action potential) are absent in the SA/AV node as there is no depolarisation plateau.

PHASE 0	Depolarisation is produced by the opening of voltage-gated calcium channels (L-Type) and inward movement of positive ions.
PHASE 1/2	are absent
PHASE 3	Repolarisation occurs as Ca^{2+} channels close and and K^+ channels open. Efflux of K+ from within the cell repolarises the cell fairly rapidly.
PHASE 4	The pacemaker potential is produced by a fall in membrane potassium permiability and an increase in a slow inward current. The slow inward current consists of a voltage gated increase in calcium permiability (via T-Type channels) and activity of the electrogenic sodium-calium exchange system, driven by inward movement of calcium ions. This pacemaker activity brings the cell to threshold potential.

"What is the resting membrane potential and how is it maintained?"

is a fundamental and essential property of all cells. The membrane potential is an electrical gradient that results from the differences in concentrations of charged organic and inorganic ions across the cell membrane. For most mammalian cells the resting membrane potential is negative to the outside, usually -60 to -70 mV. The predominant ions involved are organic anions and K^+ inside the cell and Na^+ and Cl^- on the outside. This ions have two driving forces, the concentration gradient and the electrical gradient. The distribution of ions across the cell will equal equilibrium when these two forces are balanced. This relationship was first described by Nernst in 1888.

"Please write the Nernst potential equation"

Nerst equation, $E = (RT/zF)\ln([ion_{outside}]/[ion_{inside}]$ where E is the Nerst potential, R is the gas constant, T is the temperature in Kelvins, z is the valence of the ion and F is faraday's constant. This can be simplified, if the ion is single valence (K, Cl, Na) then the first part of the equation can be simplified to 58. Therefore it is possible to calculate the Nernst potential for these important ions. $E_{potassium} = 58\text{Log}_{10}(4/140) = -90$, $E_{chloride} = -58\text{Log}_{10}(116/4) = -85$, $E_{sodium} = 58\text{Log}_{10}(145/12) = 65$. This introduces a new concept which is selective permiability. The Nerst potential for potassium and chloride is similar to the resting membrane potential, and this is consistent with the fact that the cell membrane is highly permiable to these ions. The sodium potential is vastly different to the RMP and it follows that the cell membrane is not permiable to this ion (otherwise the RMP would beome more positive). Two key elements establish and maintain the membrane potenial; cell membrane channels which are selectively permiable to ions and cell membrane pumps which actively transport charged particles against electrochemical gradients. There is a slight permiability to sodium but the Na.K.ATPase pump ensures that the RMP does not become more +