University of Glasgow

How to survive questions about the cardiac action potential….
In any exam…. Ever….

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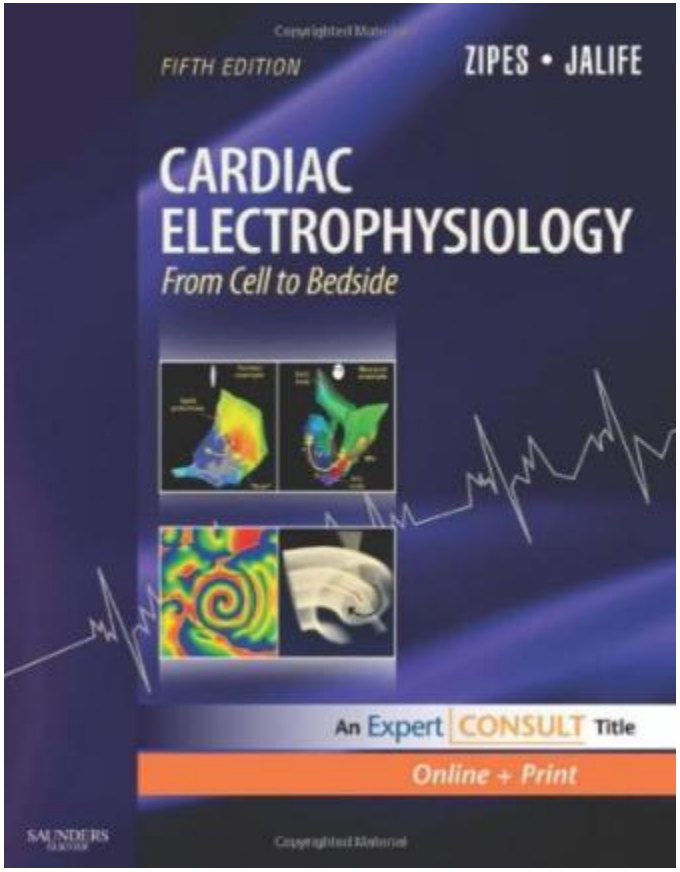
11th October 2016

INSPIRING PEOPLE

Supported by wellcome trust

The safest approach….



The alternative approach…

Membrane potential

The (basic) fluxes underlying the action potential

Action potential specialisation

The importance of context

With zero jargon…..

Action

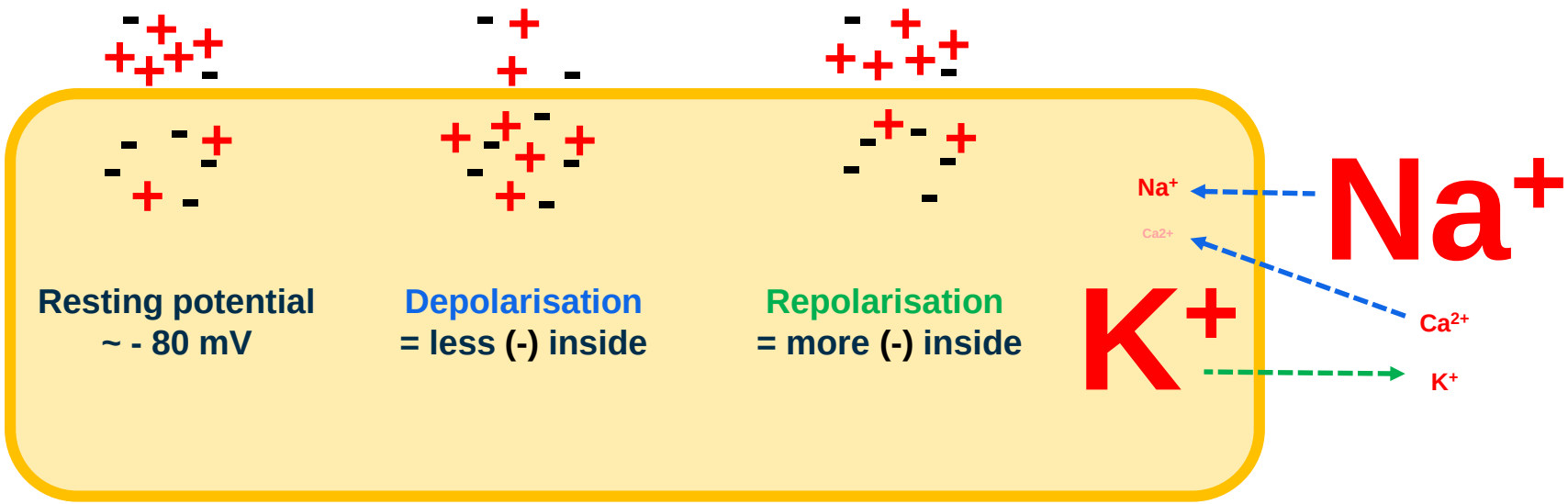
action
ˈakʃ(ə)n/
noun
1.
the fact or process of doing something, typically to achieve an aim.
"ending child labour will require action on many levels"
a thing done; an act.
"she frequently questioned his actions“
verb
1.
take action on; deal with.
"your request will be actioned"

Potential

potential
pə(ʊ)ˈtɛnʃ(ə)l/
adjective
1.
having or showing the capacity to develop into something in the future.
"a campaign to woo potential customers"
noun
1.
latent qualities or abilities that may be developed and lead to future success or usefulness.
"a young broadcaster with great potential“
2.
PHYSICS
the quantity determining the energy of mass in a gravitational field or
of charge in an electric field.
"a change in gravitational potential"

Google Dictionary

Membrane potential (V_m)



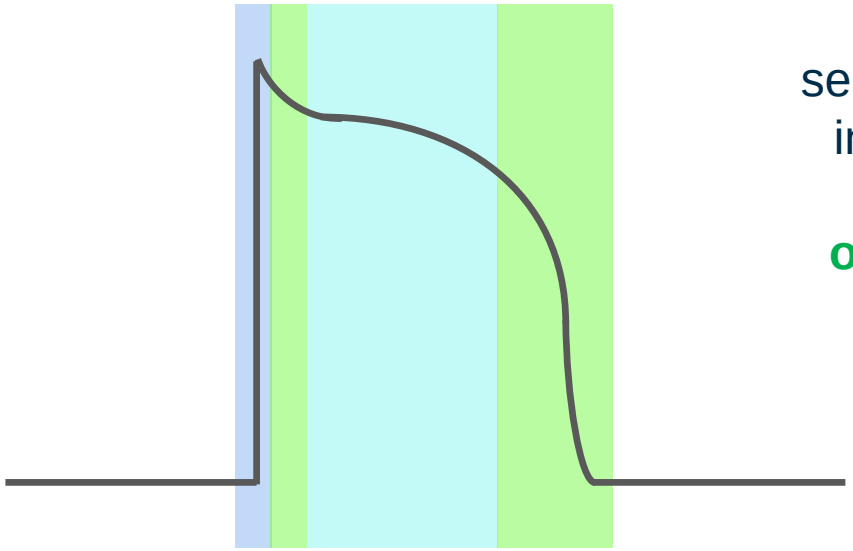
Determined by ion* concentration inside vs. outside the cell

***protons (+)** ≠ **electrons (-)** i.e. charged molecule

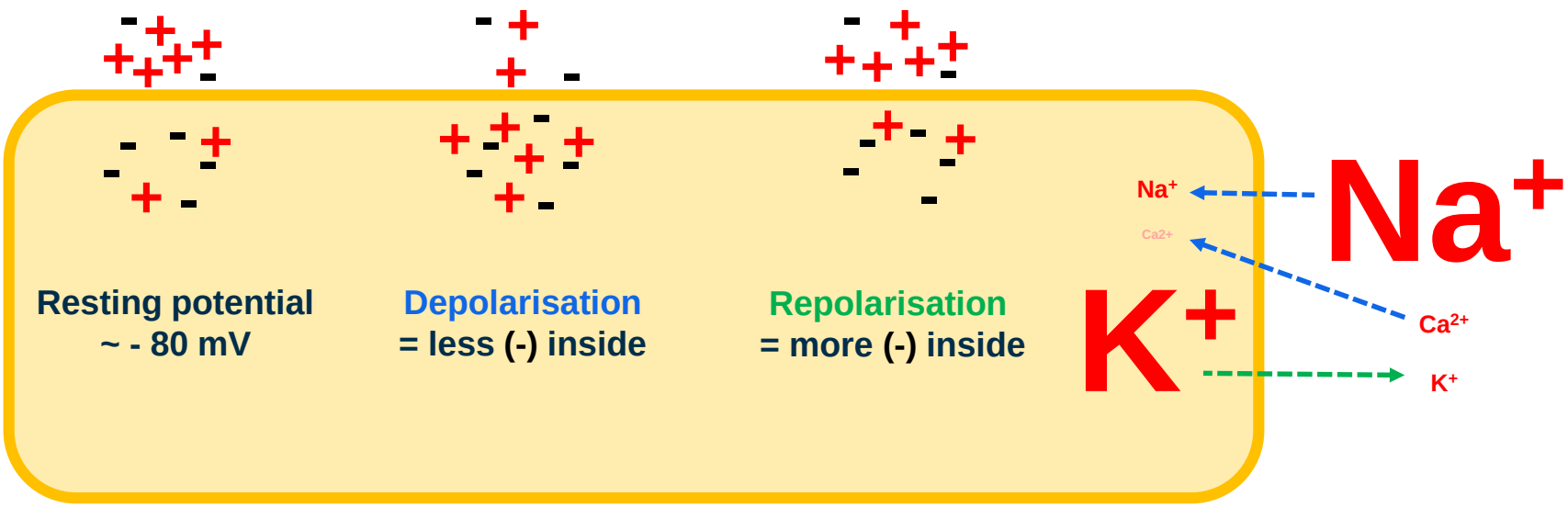
Na^+ and **Ca^{2+}** currents = **(+)** inwards = **depolarising**

K^+ currents = **(+)** outwards = **repolarising**

Action potential



sequential activation and inactivation of **inward (Na^+ and Ca^{2+})** and **outward (K^+)** currents

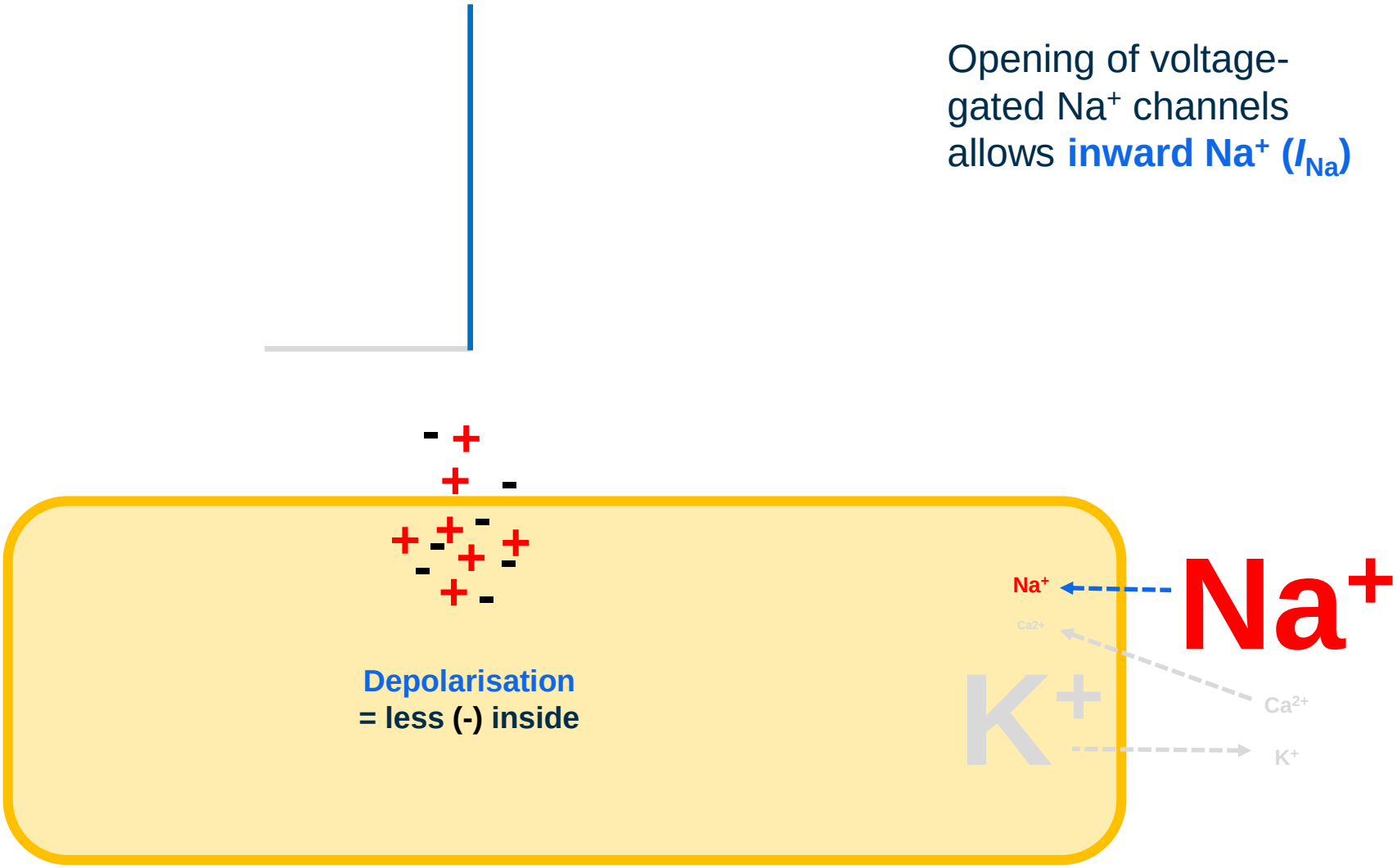


Resting potential

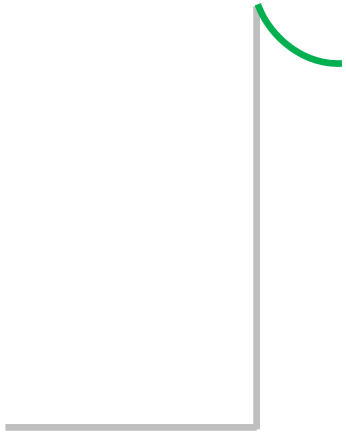
Electrical gradient = **Concentration gradient**

Action potential – upstroke (phase 0)

Opening of voltage-gated Na^+ channels allows **inward Na^+ (I_{Na})**

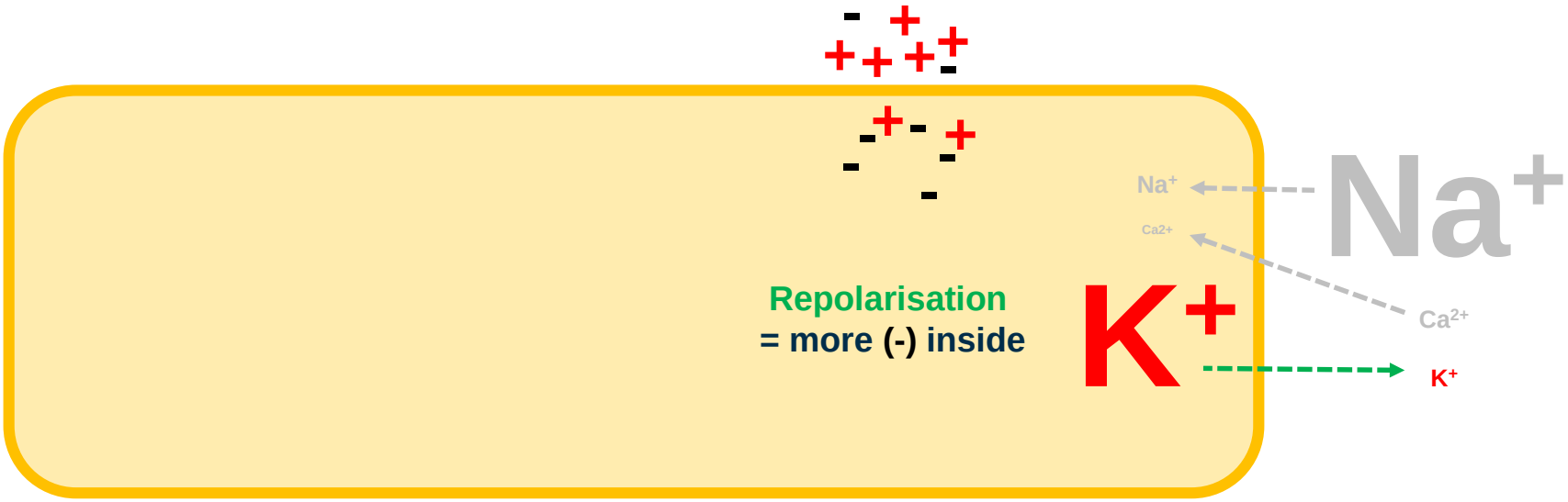


Action potential – notch (phase 1)

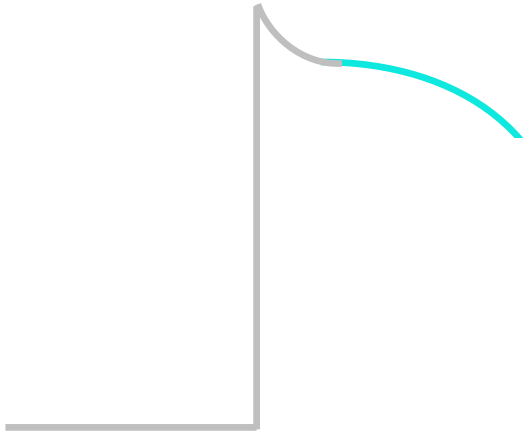


Rapid V_m-dependent inactivation of I_{Na}

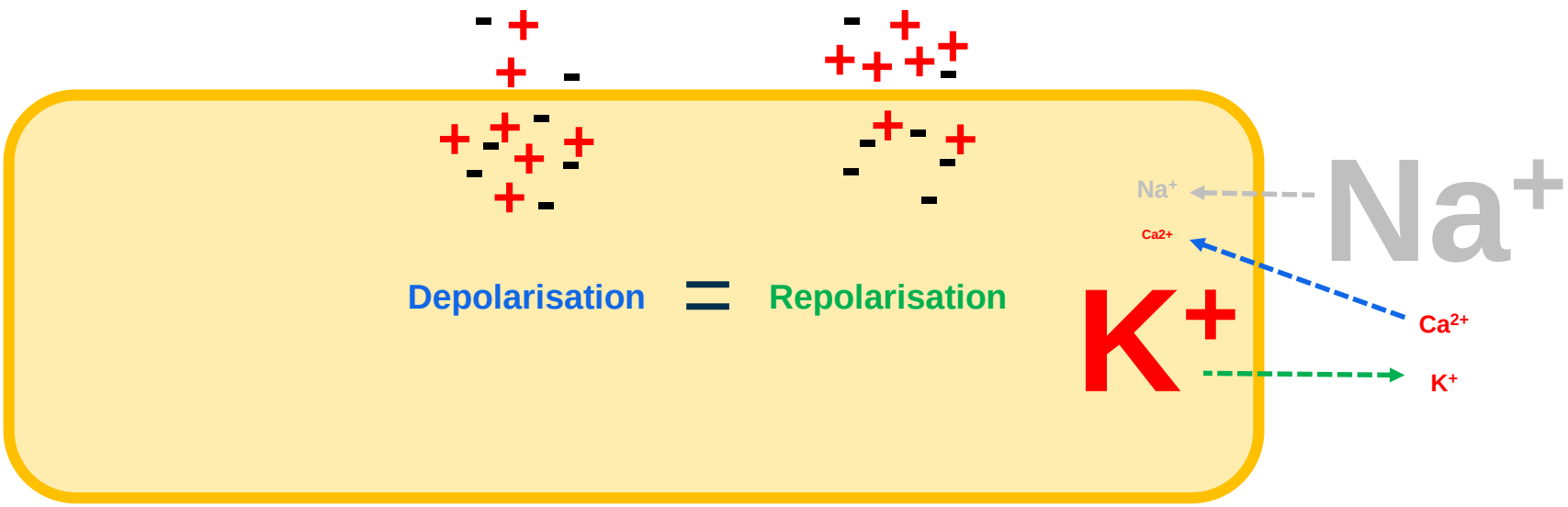
Activation of **outward K^+ (*I*to)**



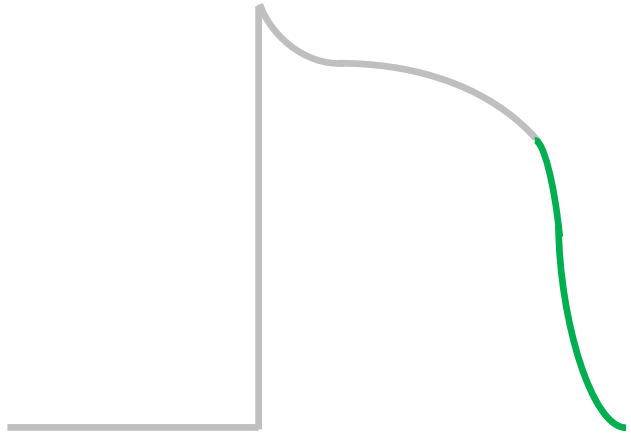
Action potential – plateau (phase 2)



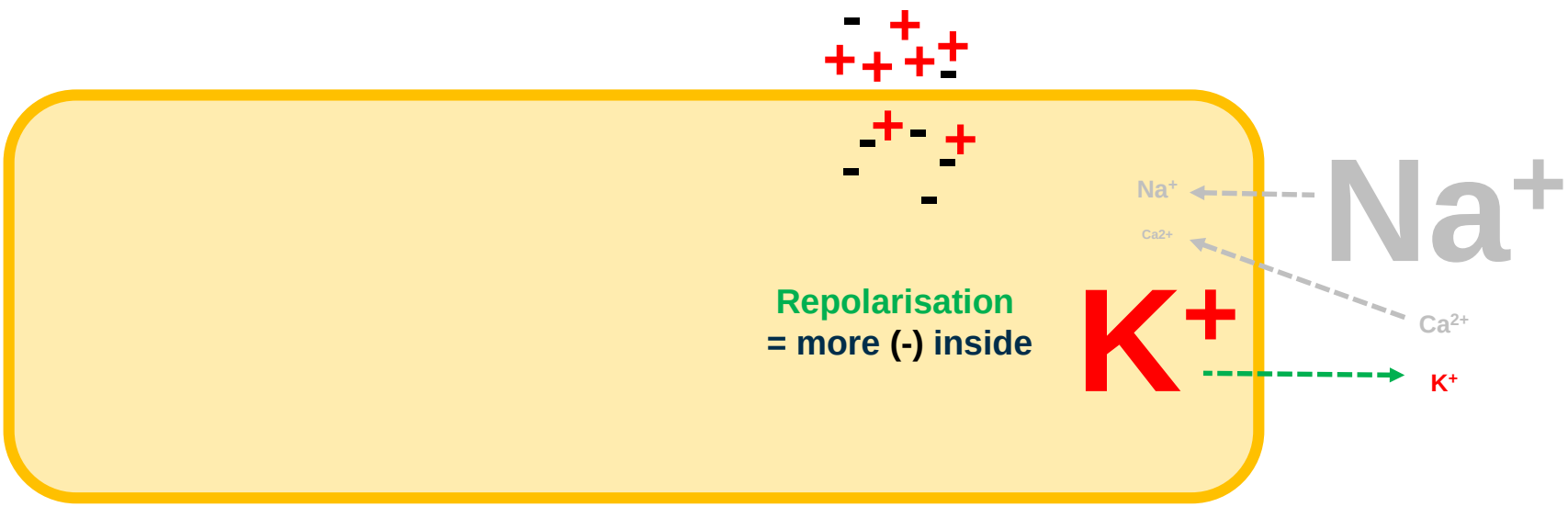
Balance of
inward Ca^{2+} and
outward K^+



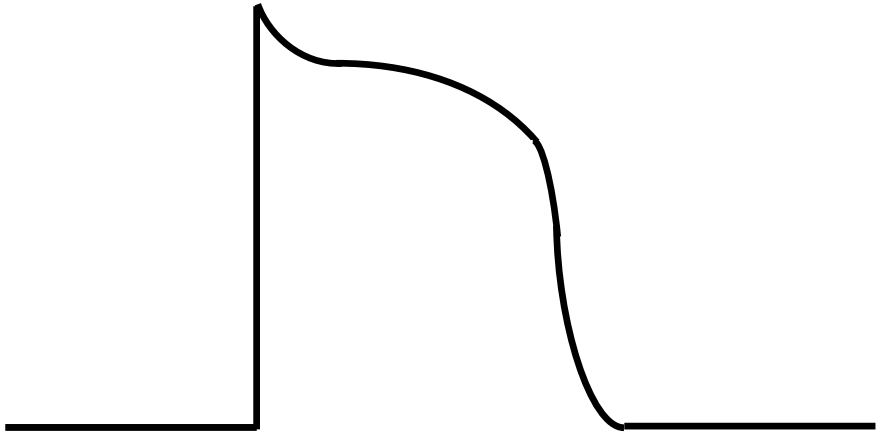
Action potential – repolarisation (phase 3)



Inward currents are inactivated and **outward K^+ (I_K)** predominate



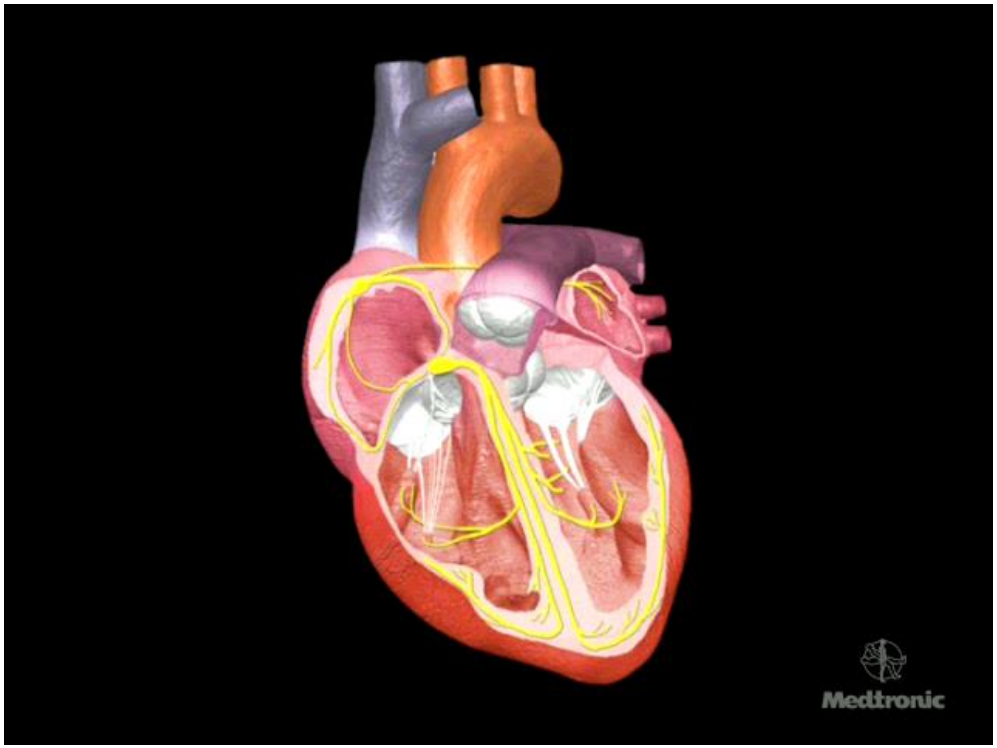
Action potential – resting (phase 4)

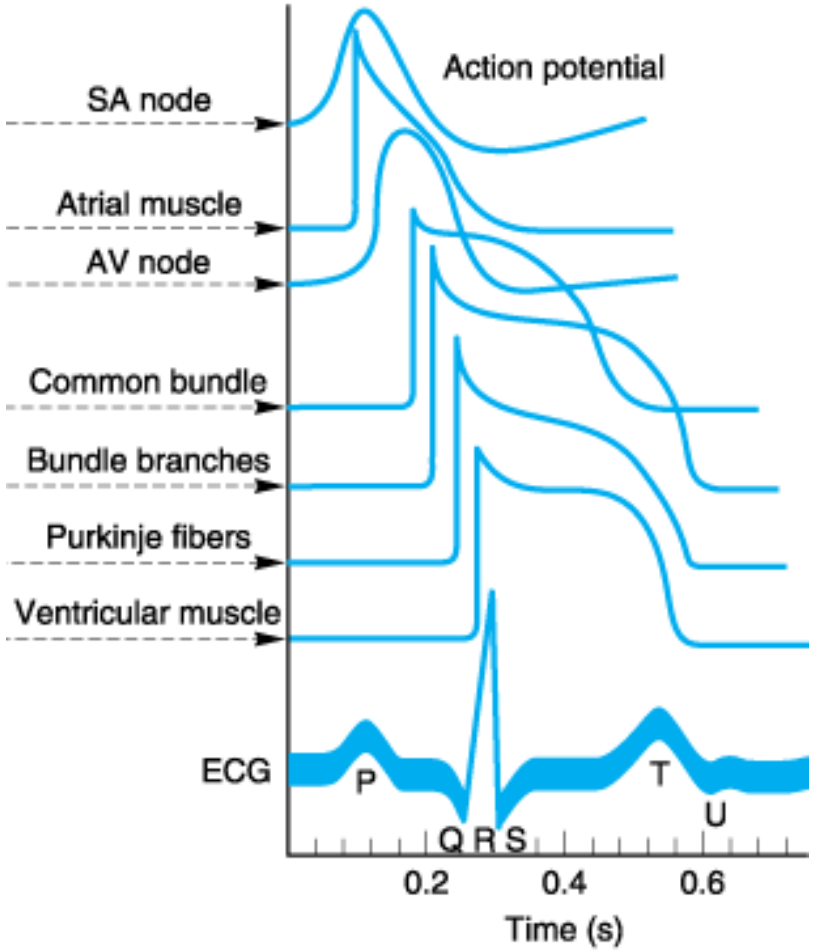


Understanding pathology should be easy

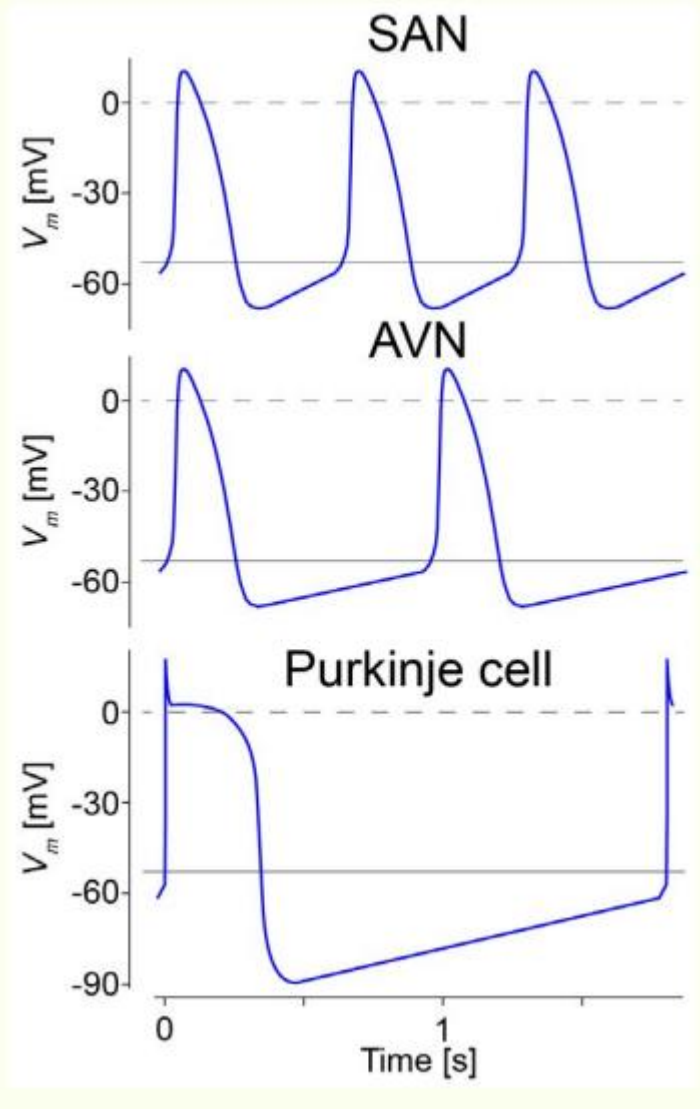
	Na^+ currents (upstroke)	Ca^{2+} currents (plateau)	K^+ currents (repolarisation)
↑	Long APD	Long APD	Short APD
↓	Slowed conduction	Short APD	Long APD

Specialised APs mediate normal rhythm





A hierarchy of pacemakers



70bpm

50bpm

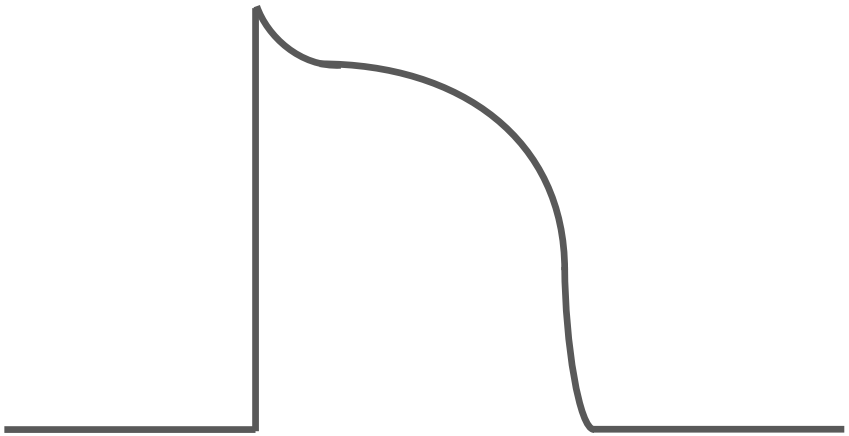
30bpm

Context is important

Time (or AP restitution)

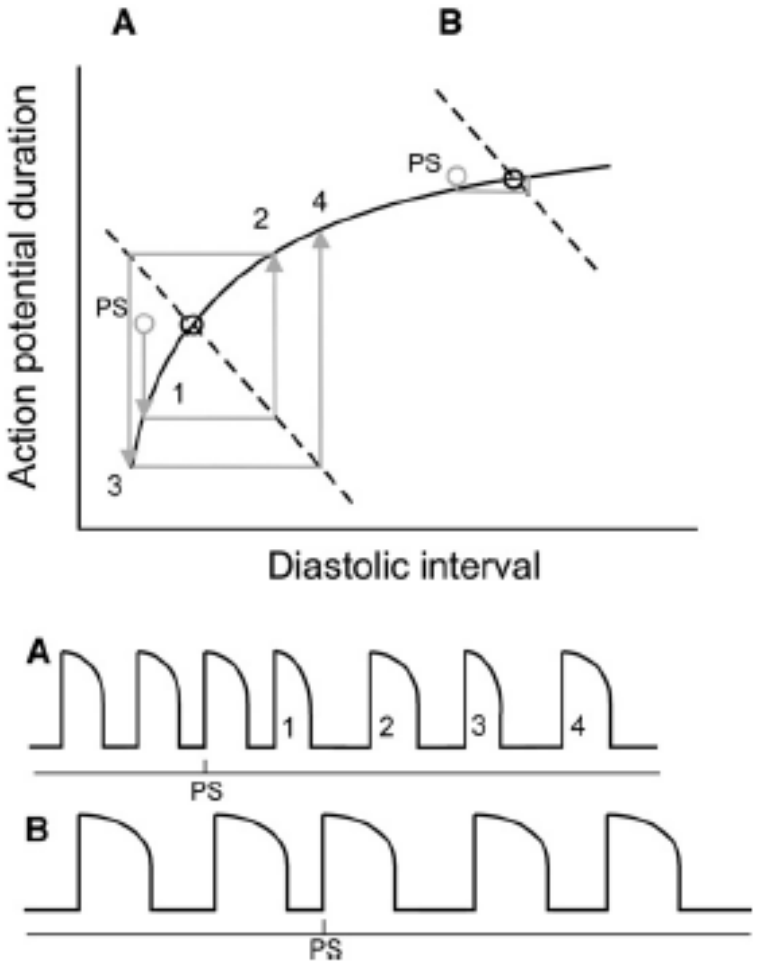
Space (or electrotonic coupling)

Calcium (or bidirectional coupling)



Context is important – AP restitution*

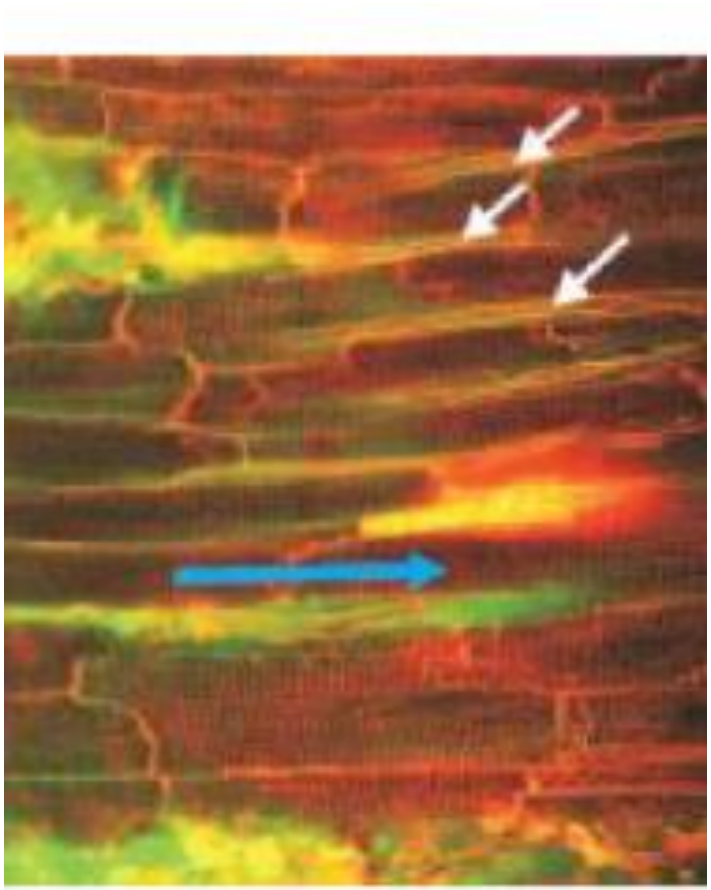
*** Response to change in rate preceding diastolic interval**



Electrotonic* coupling

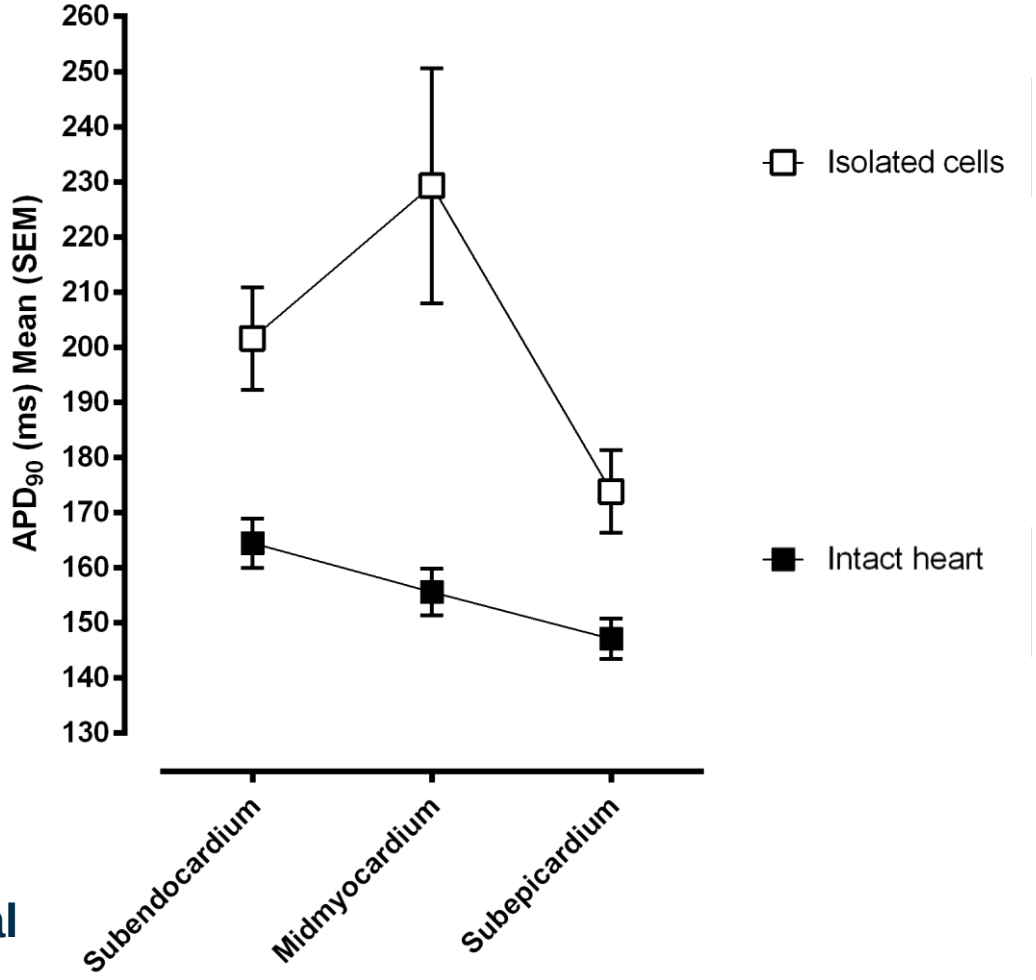
Isolated cells

Intact heart



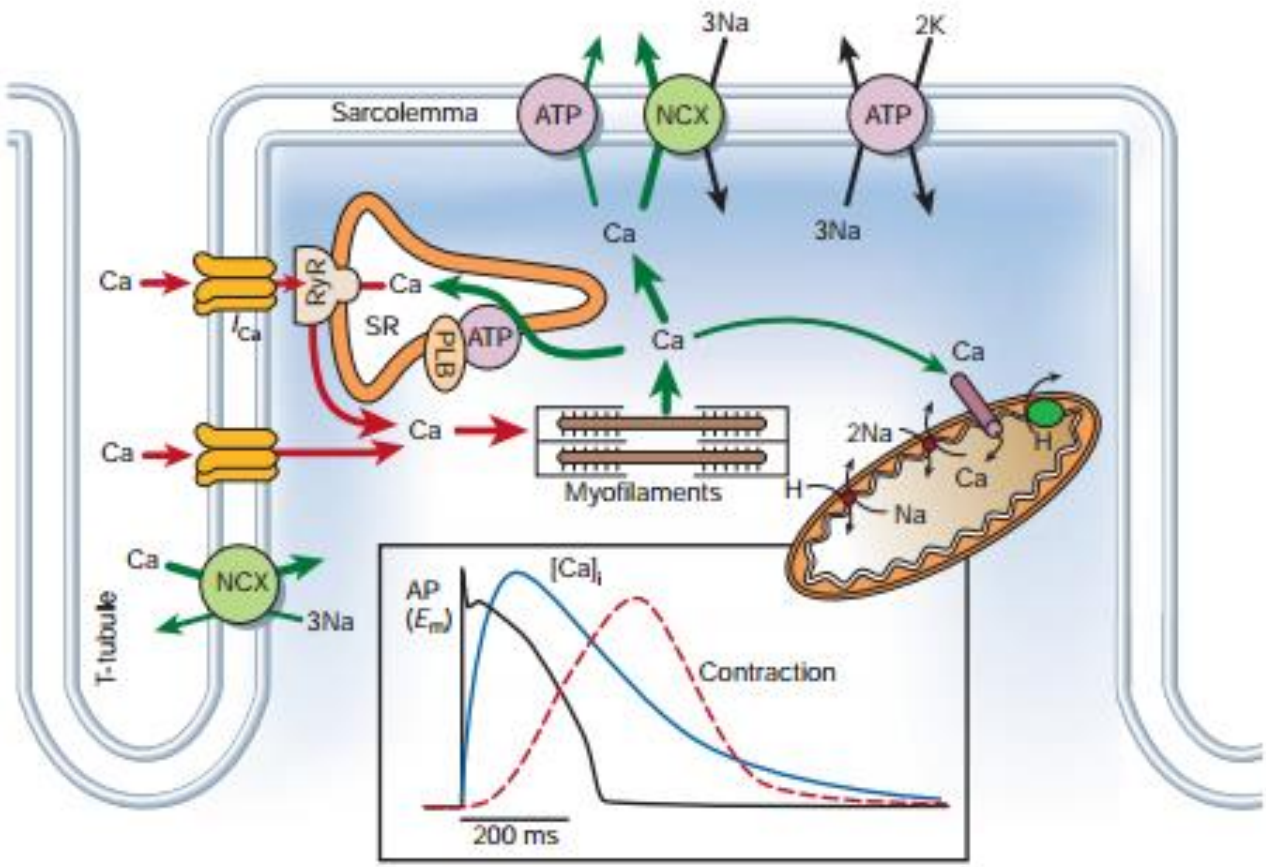
*** Passive spread of electrical activity (i.e. not by an AP)**

Electrotonic* coupling



*** Passive spread of electrical activity (i.e. not by an AP)**

Bidirectional coupling



Inward Ca^{2+} is the trigger for SR Ca^{2+}-release

Inactivation of **inward Ca^{2+}** is Ca^{2+}-dependent

Ca^{2+} efflux on NCX is electrogenic
(net **inward** current)

Bers, Nature, 2002

Understanding pathology should be easy

	Na^+ currents (upstroke)	Ca^{2+} currents (plateau)	K^+ currents (repolarisation)
↑	Long APD	Long APD	Short APD
↓	Slowed conduction	Short APD	Long APD

…. but often isn't

The zero jargon approach

Membrane potential

The (basic) fluxes underlying the action potential

Action potential specialisation

The importance of context

- **time**
- **space**
- **calcium**