Electrophysiology of the heart

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Part 1 - Overview

Definition

- *“Cardiac electrophysiology is a term that covers everything associated with the electrical activity of the heart”*

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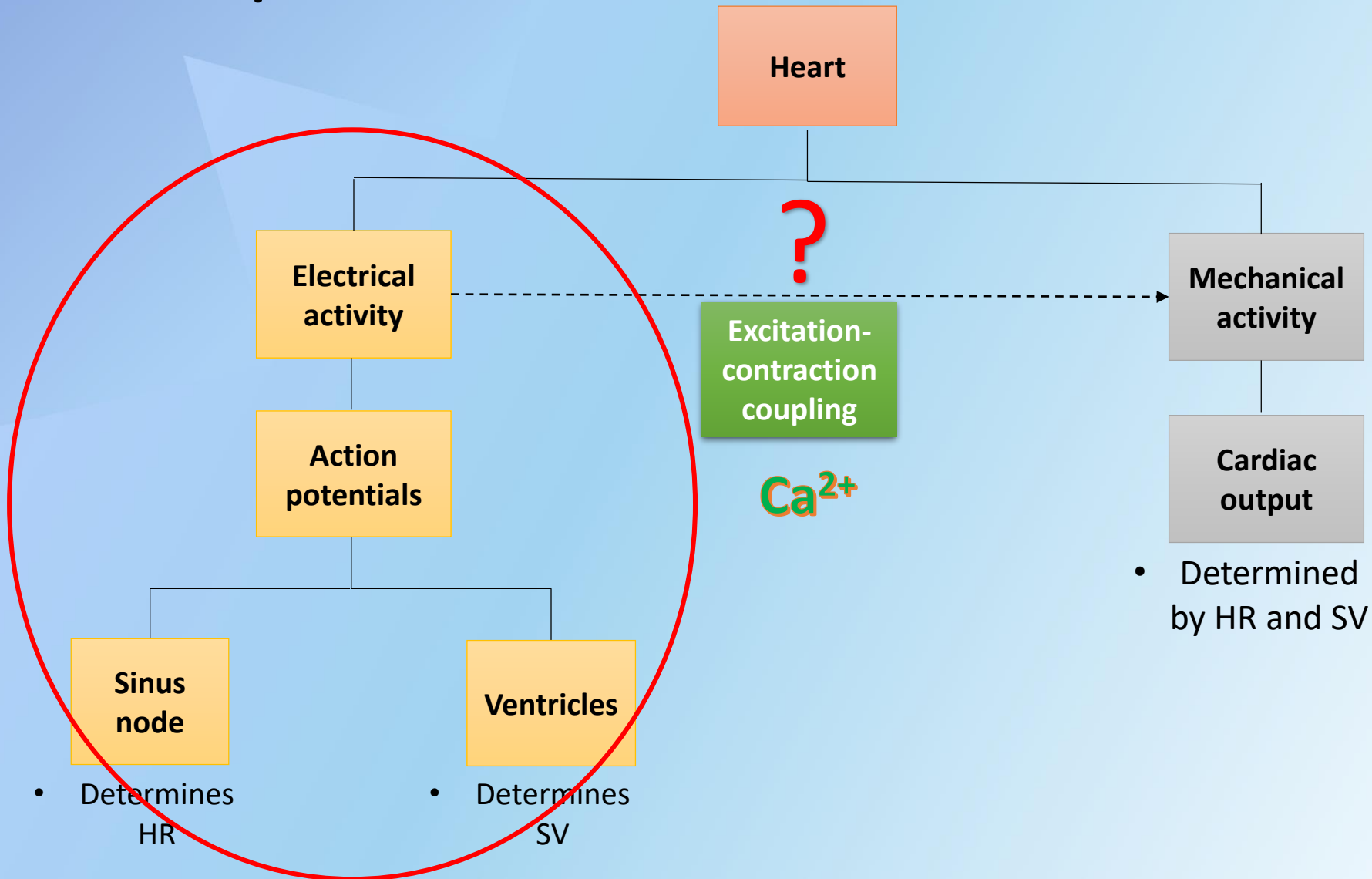
Connection between electrical – and mechanical activity of the heart



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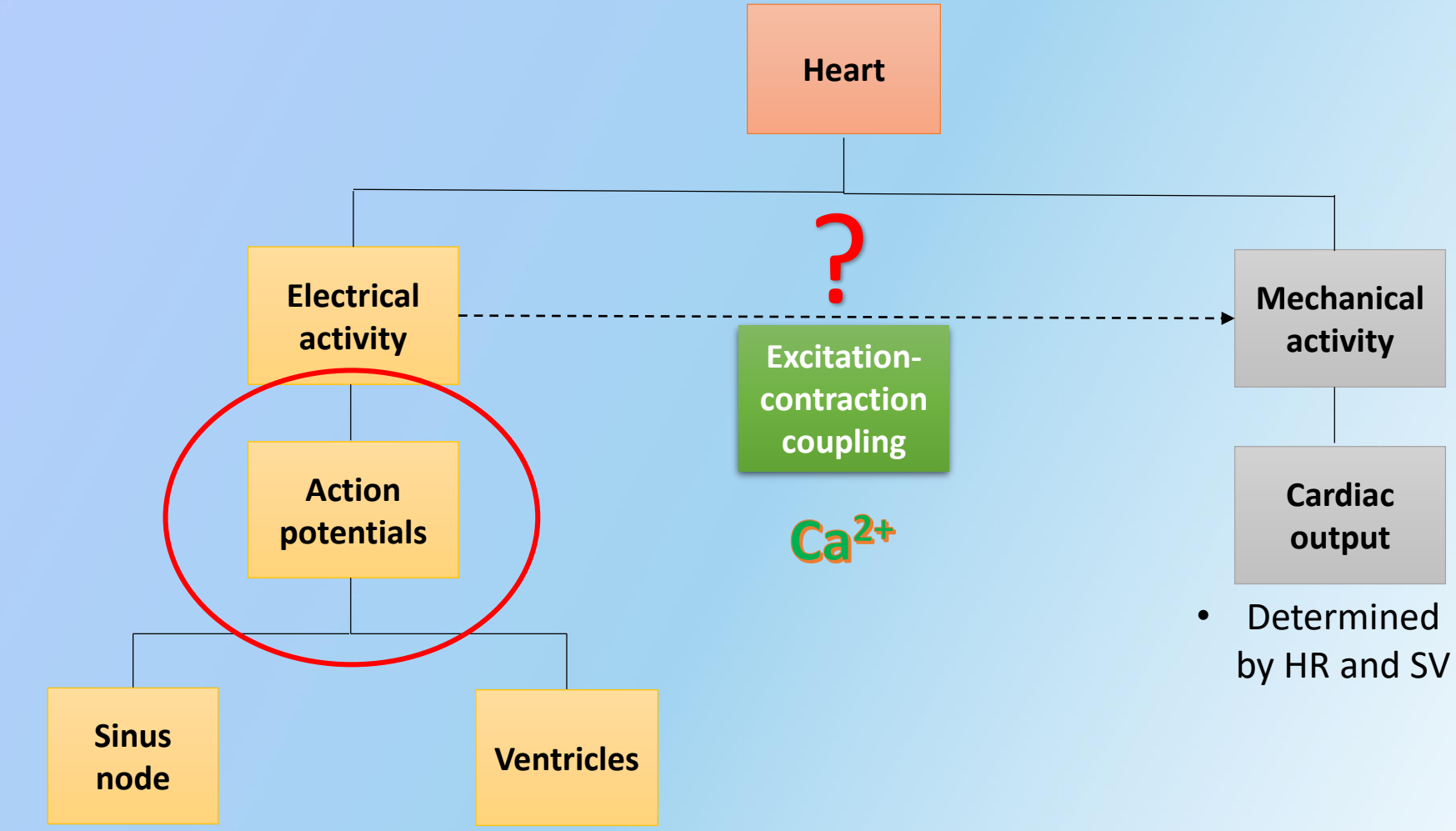
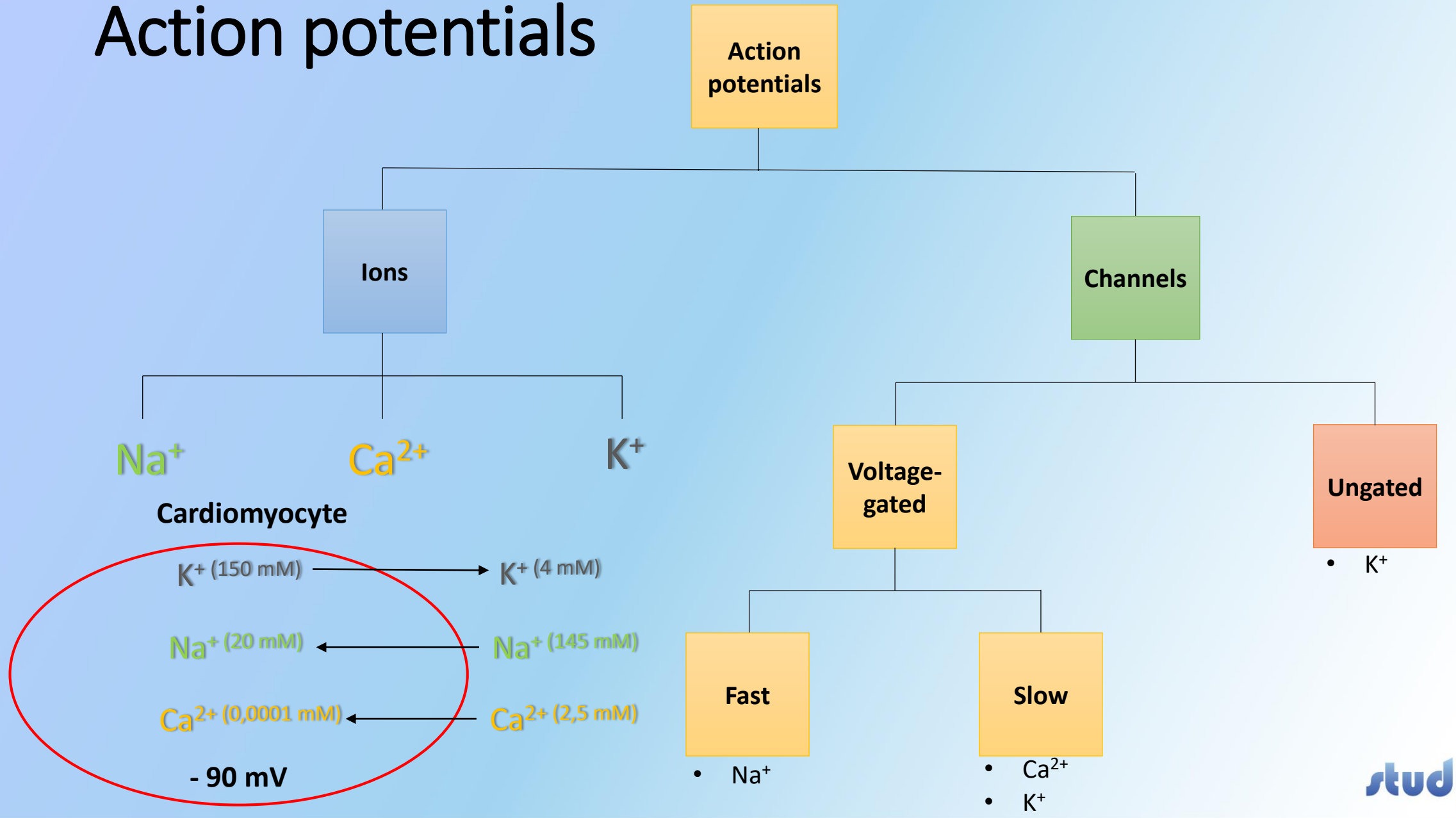
Part 2 - Specifics


Heart
?
Electrical activity
Excitation-contraction coupling
Mechanical activity
Action potentials
Ca^{2+}
Cardiac output
Sinus node
Ventricles
• Determines HR
• Determines SV
• Determined by HR and SV

Action potentials



Voltage-gated channels

	Mechanics	Ions	Rest	Depolarization
FAST voltage-gated channels	- Open fast - Close fast	- Na^+	Closed	Open
SLOW voltage-gated channels	- Open slowly - Close slowly	- Ca^{2+} - K^+	Open	Closed

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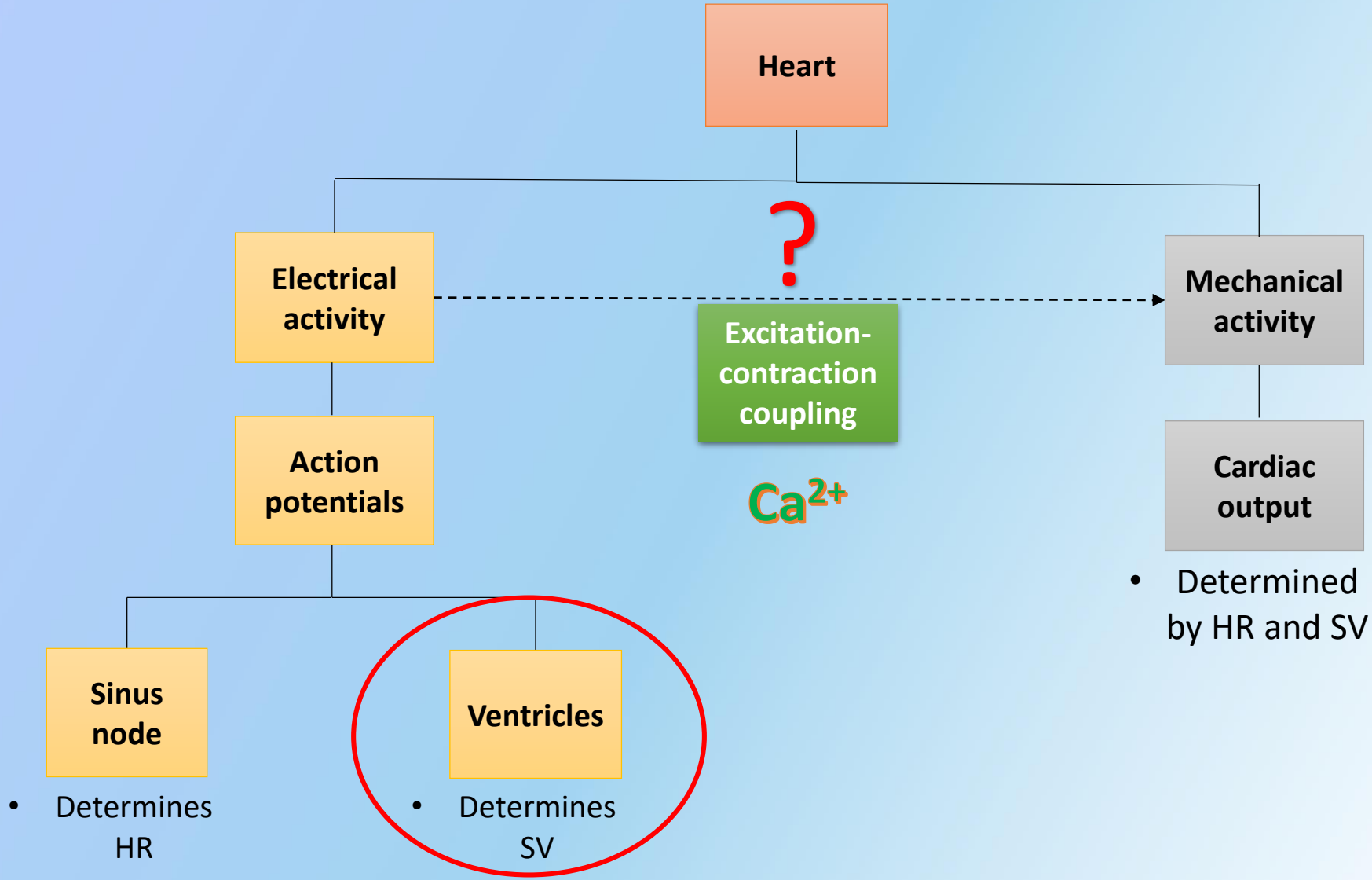
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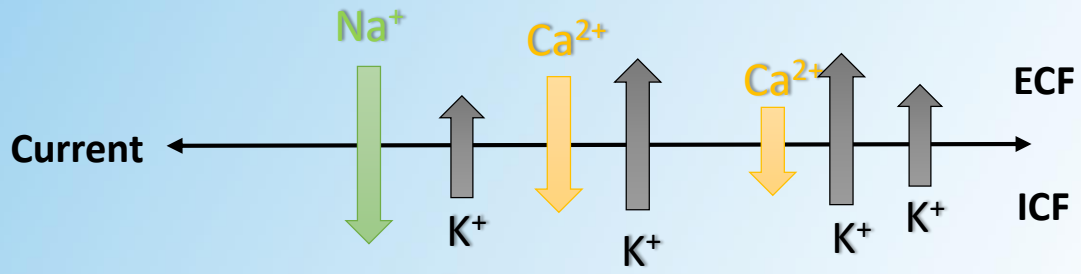
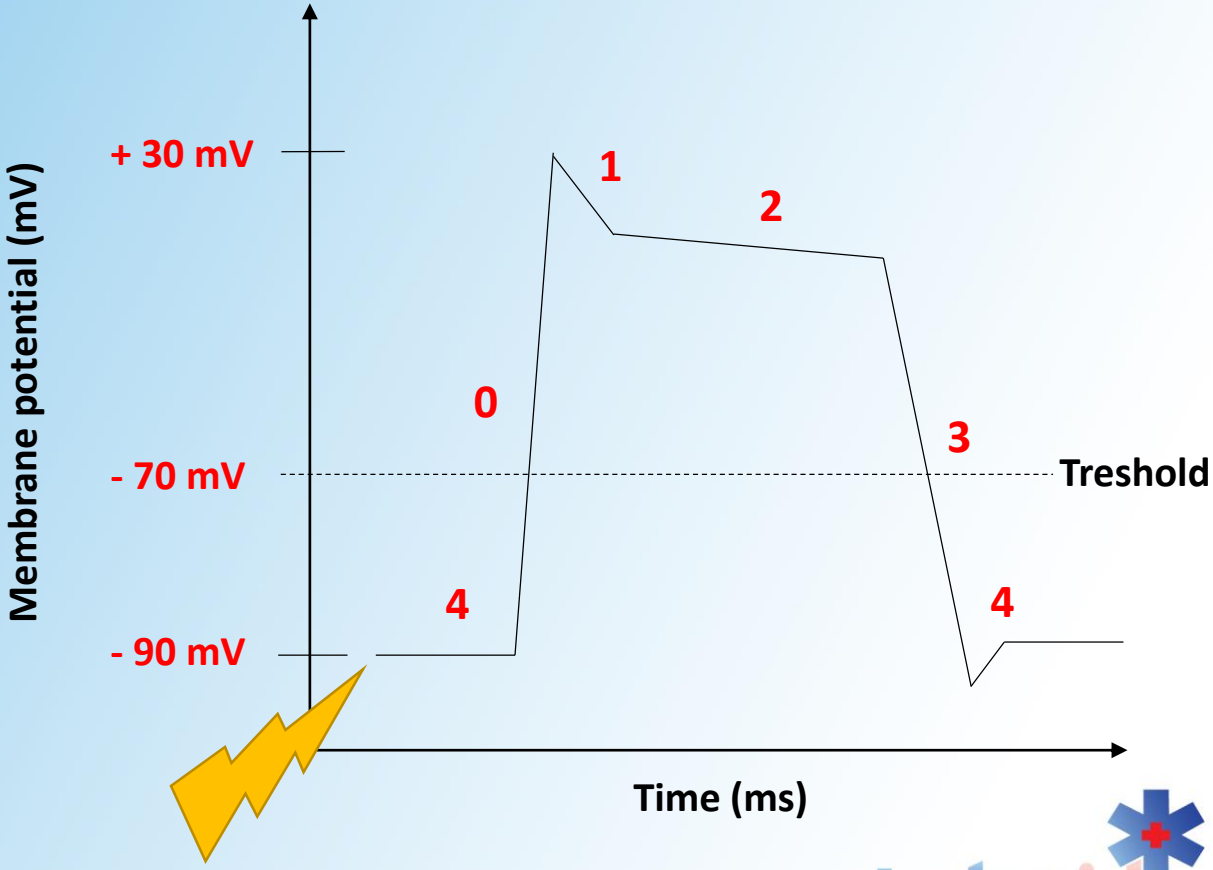
• Determines HR
• Determines SV

Ventricular action potential

- Phase 0 (upstroke)
  - Rapid Na^+ influx through fast voltage-gated Na^+ channels
- Phase 1 (transient repolarization)
  - Closure of fast voltage-gated Na^+ channels
  - Transient K^+ efflux
- Phase 2 (plateau)
  - Ca^{2+} influx through slow voltage-gated Ca^{2+} channels (**L-type**)
  - K^+ efflux through slow voltage-gated – and ungated K^+ channels
- Phase 3 (repolarization)
  - Closure of slow voltage-gated Ca^{2+} channels (**L-type**)
  - K^+ efflux through slow voltage-gated - and ungated K^+ channels
- Phase 4 (resting phase)
  - Increased activity of the Na^+/ K^+ ATP-ase → restoration of the concentration gradients of $Na^+$and K^+





Clinical correlation

Q: «What are the effects of Ca^{2+} channel blockers on the ventricular action potential and stroke volume?»

- **Ventricular action potential**

- Block L-type Ca^{2+} channels → ↓ Ca^{2+} influx → shortening of the plateau phase

- **Stroke volume**

- Shortening of the plateau phase → ↓ Ca^{2+} influx → ↓intracellular Ca^{2+} → ↓contractility → ↓SV

Q: «What are the effects of K^{+} channel blockers on the ventricular action potential and stroke volume?»

- **Ventricular action potential**

- Block K^{+} channels → ↓ K^{+} efflux → prolongation of the plateau phase

- **Stroke volume**

- Prolongation of the plateau phase → ↑ Ca^{2+} influx → ↑intracellular Ca^{2+} → ↑contractility → ↑SV

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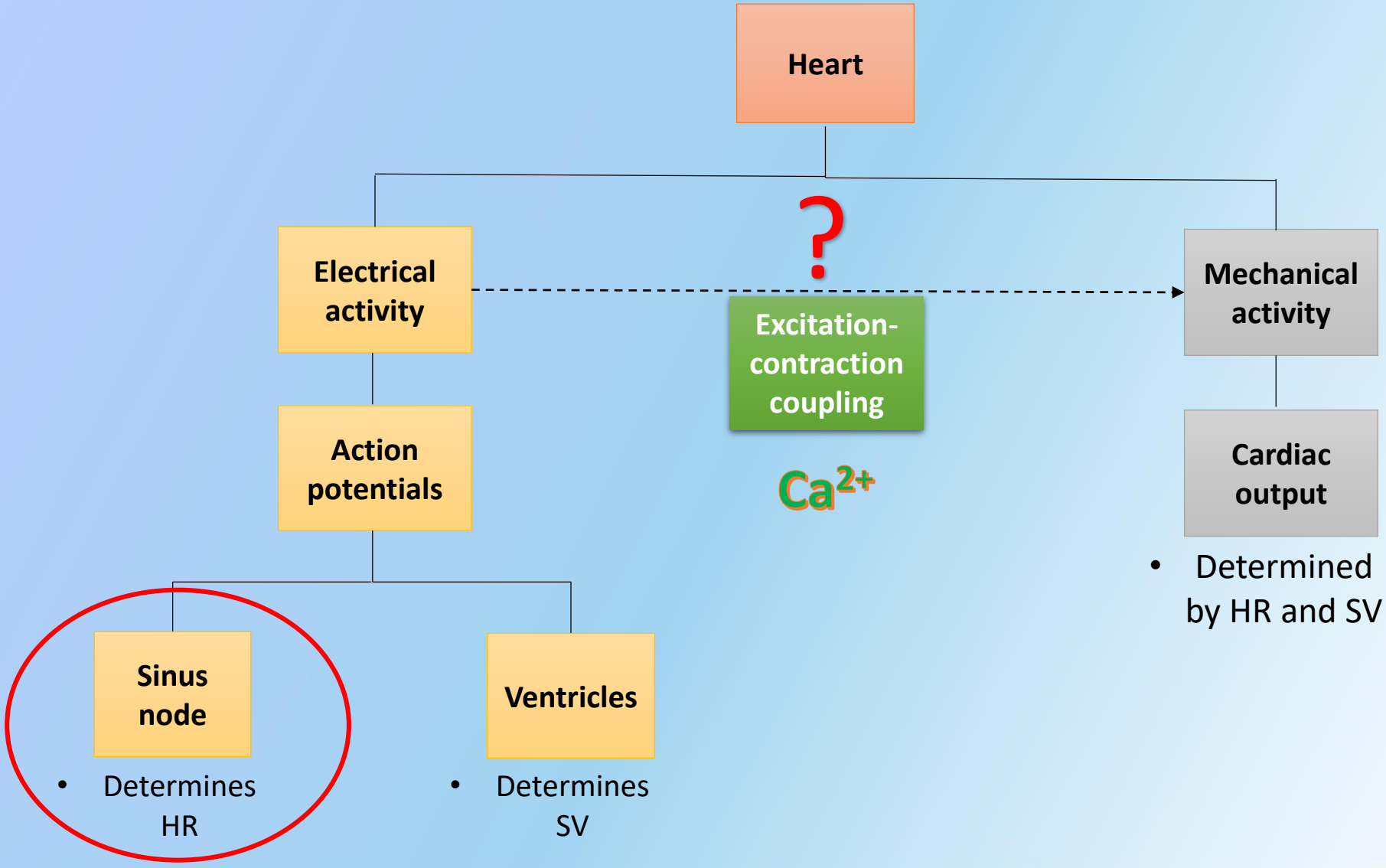
Heart
?
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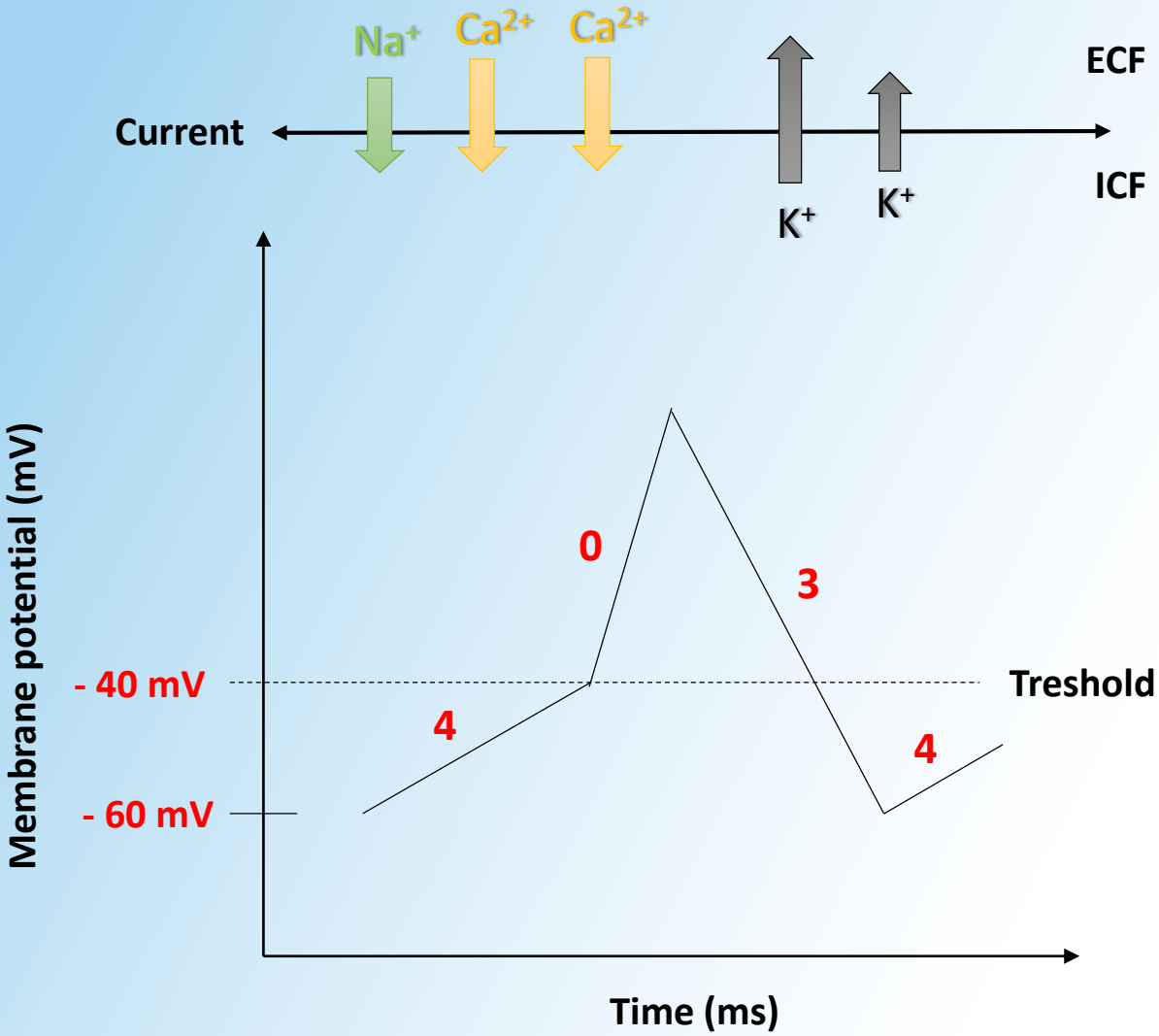
SA-node action potential

- Phase 4 (slow, spontaneous depolarization)
  - Na^+ influx through f-channels («*funny current*»)
  - Ca^{2+} influx through slow voltage-gated Ca^{2+} channels (**T-type**)
- Phase 0 (upstroke)
  - Ca^{2+} influx through slow voltage-gated Ca^{2+} channels (**L-type**)
- Phase 3 (repolarization)
  - K^+ efflux through slow voltage-gated – and ungated K^+ channels until the membrane potential is - 60 mV



Clinical correlation

Q: «What are the effects of beta-blockers on the SA-node action potential and heart rate?»

- **SA-node action potential**

- Block B_1-receptors in the SA-node → closure of Na^+ - and Ca^{2+} channels, opening of K^+channels → K^+ efflux → ↓slope of phase 4

- **Heart rate**

- ↓Slope of phase 4 →↓HR

Q: «What are the effects of atropine on the SA-node action potential and heart rate?»

- **SA-node action potential**

- Block M_2-receptors in the SA-node → opening of Na^+ - and Ca^{2+} channels, closure of K^+ channels → Na^+ - and Ca^{2+} influx →↑slope of phase 4

- **Heart rate**

- ↑Slope of phase 4 →↑HR

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Comparison of the action potentials

	Depolarization	Plateau	Repolarization	APD	Event
SA-node action potential	- Ca^{2+} influx - Slow	-	K^+ efflux	150 ms	HR
Ventricular action potential	- Na^+ influx - Fast	Ca^{2+} influx	K^+ efflux	250 ms	SV

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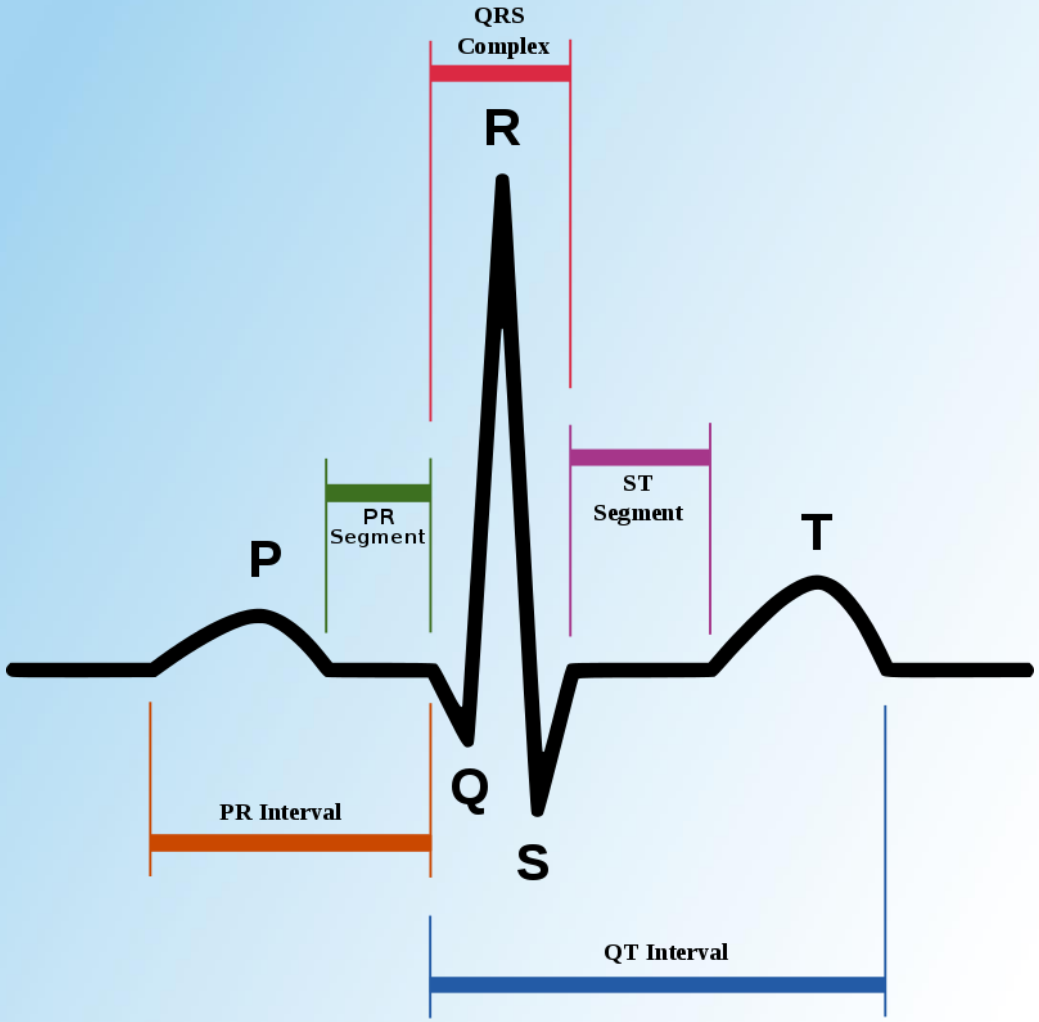
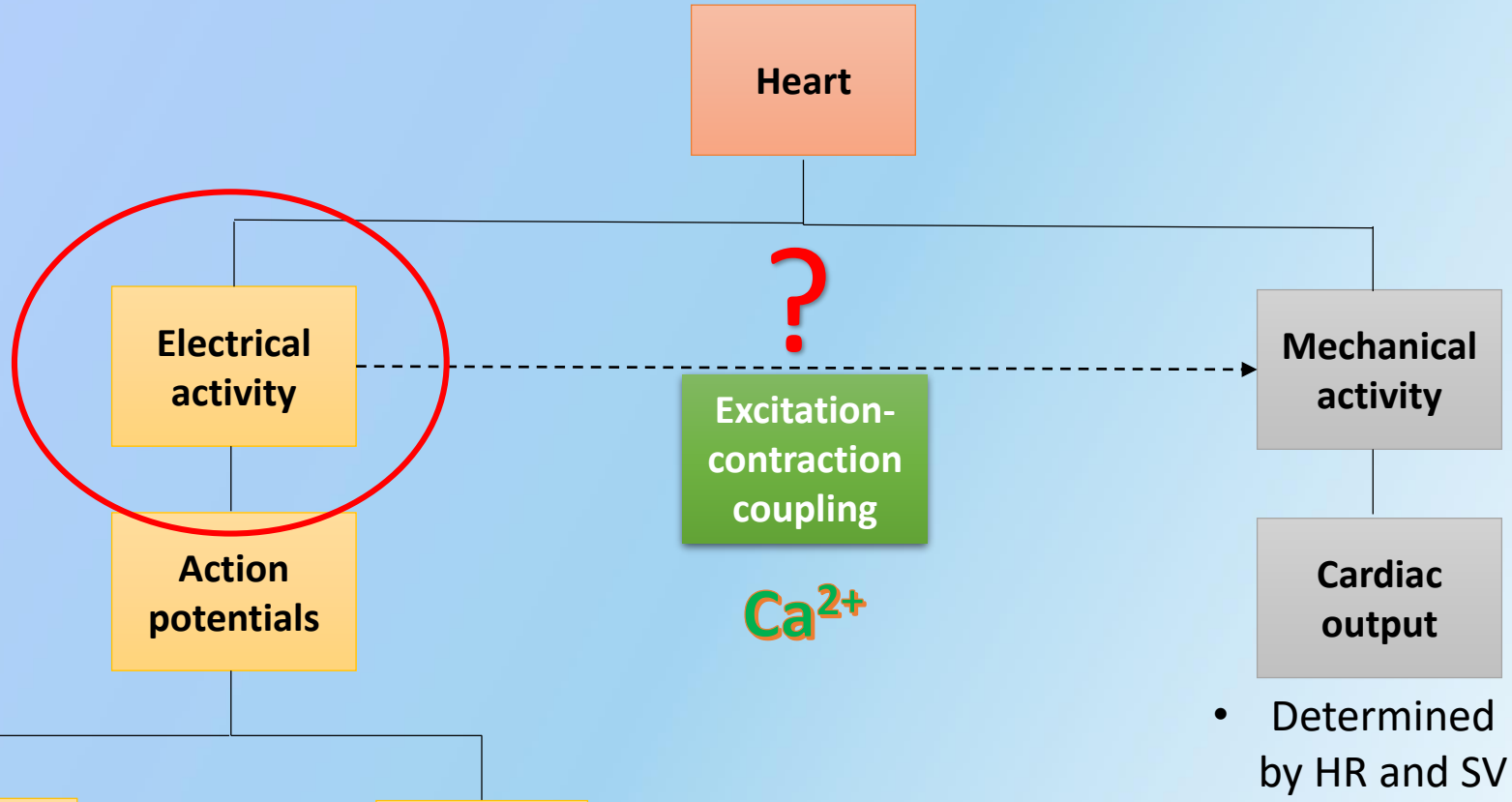
Part 3 - ECG


QRS
Complex
R
ST
Segment
PR
Segment
P
T
PR Interval
Q
S
QT Interval

Definition



- Determined by HR and SV
- Determines HR
- Determines SV

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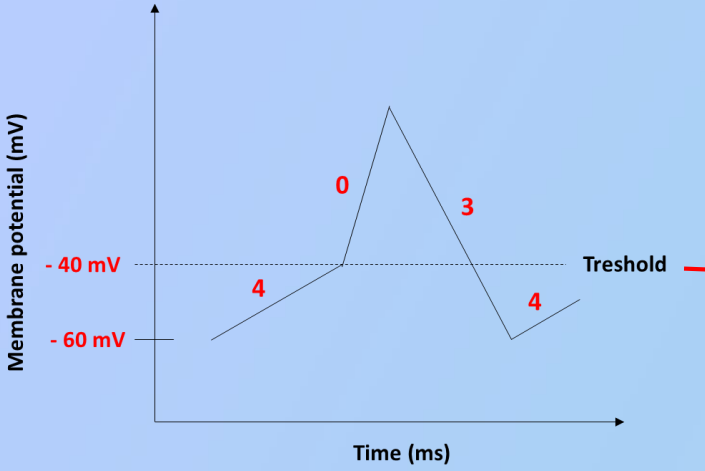
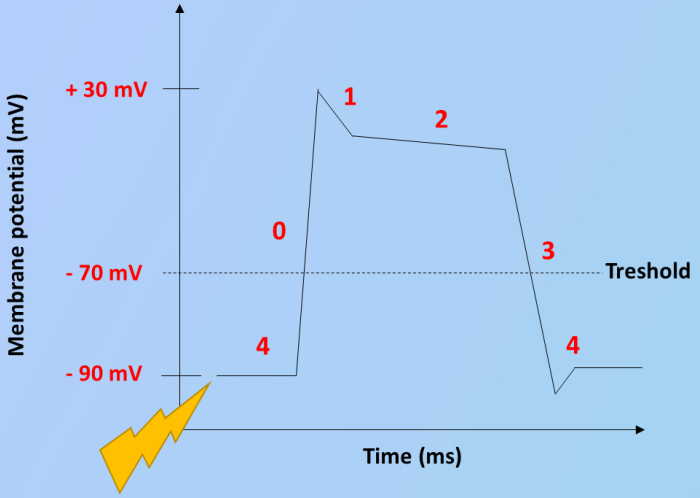
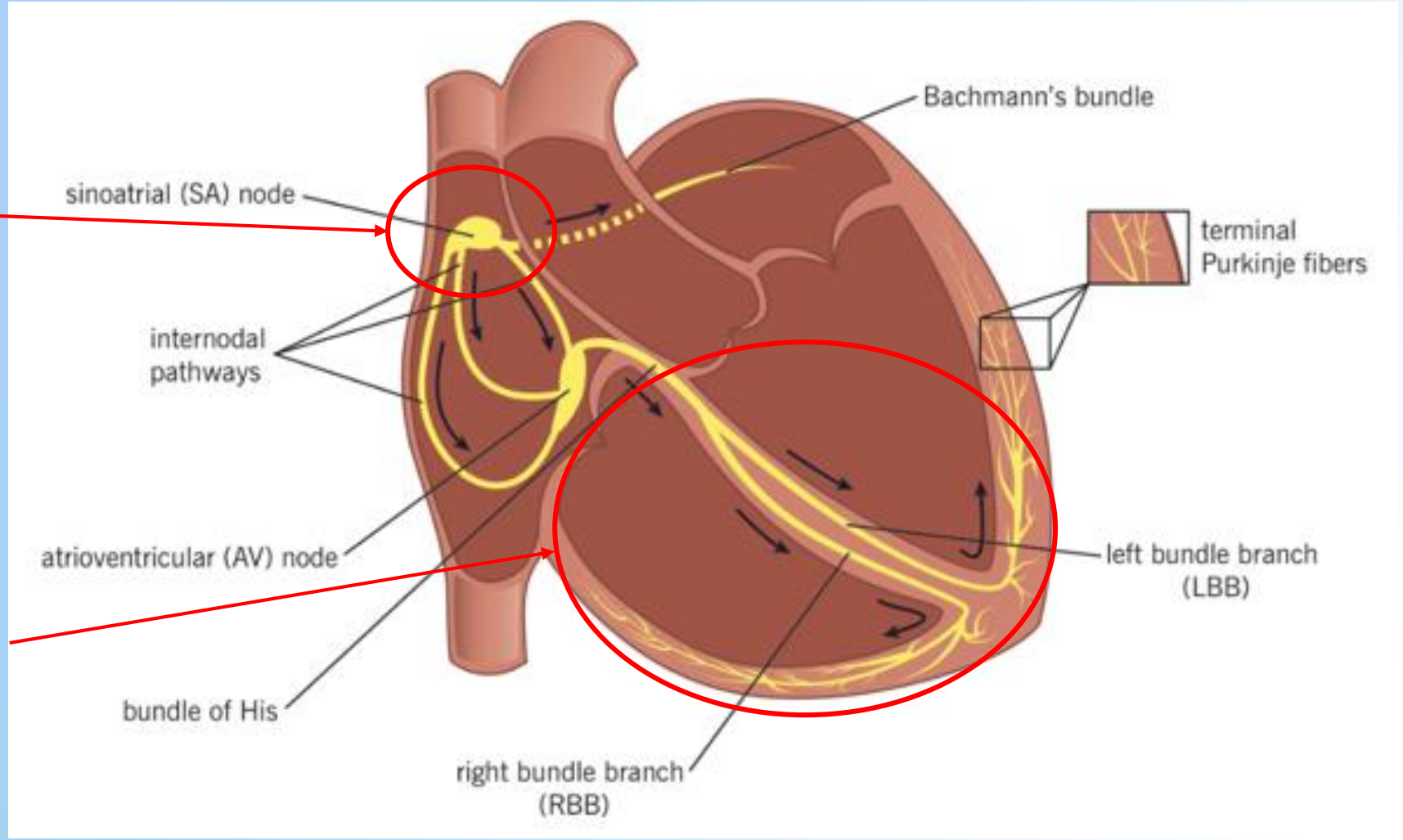
Normal pattern of conduction







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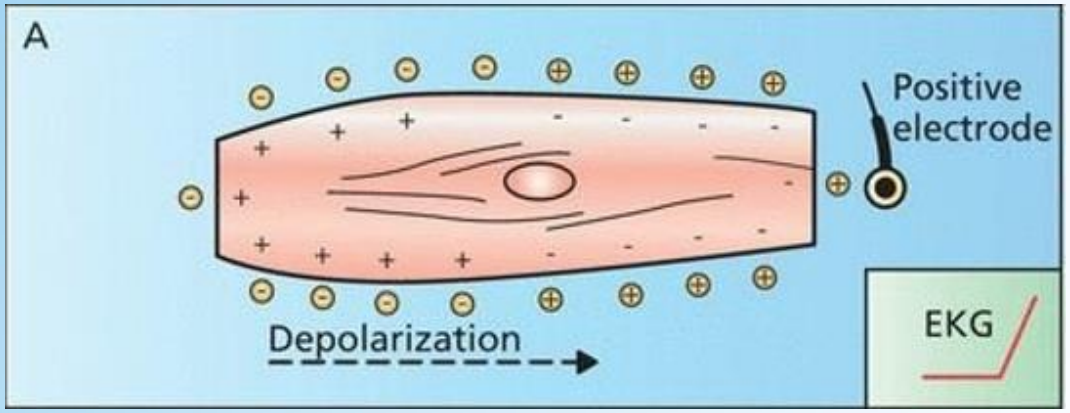
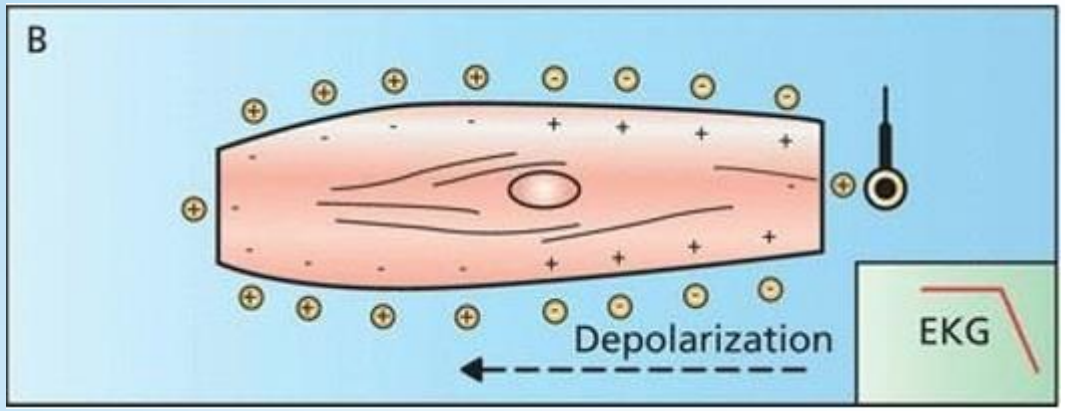
Depolarization

- A wave of depolarization moving towards an electrode gives a positive deflection



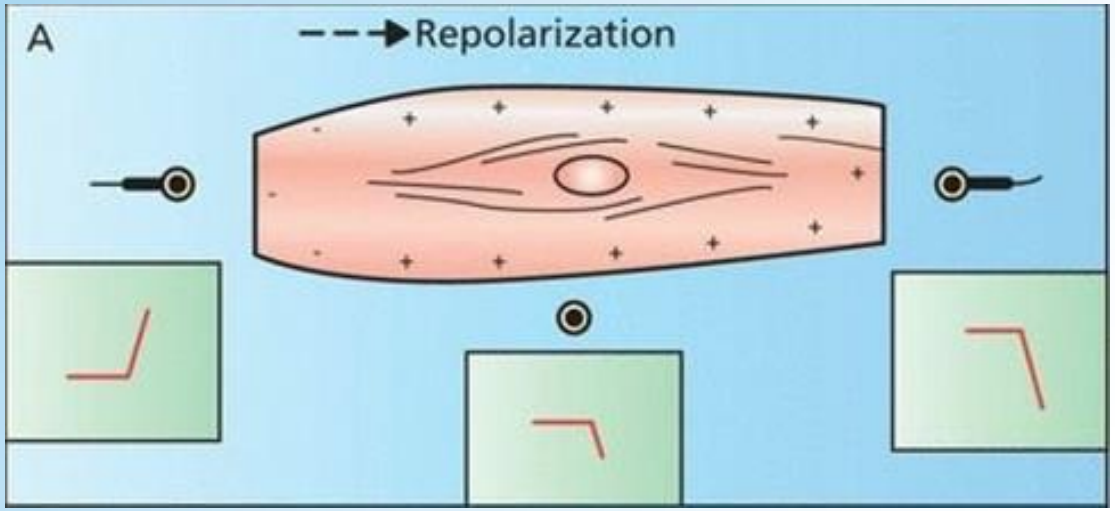
- A wave of depolarization moving away from an electrode gives a negative deflection



Repolarization

- A wave of repolarization moving towards an electrode gives a negative deflection

- A wave of repolarization moving away from an electrode gives a positive deflection



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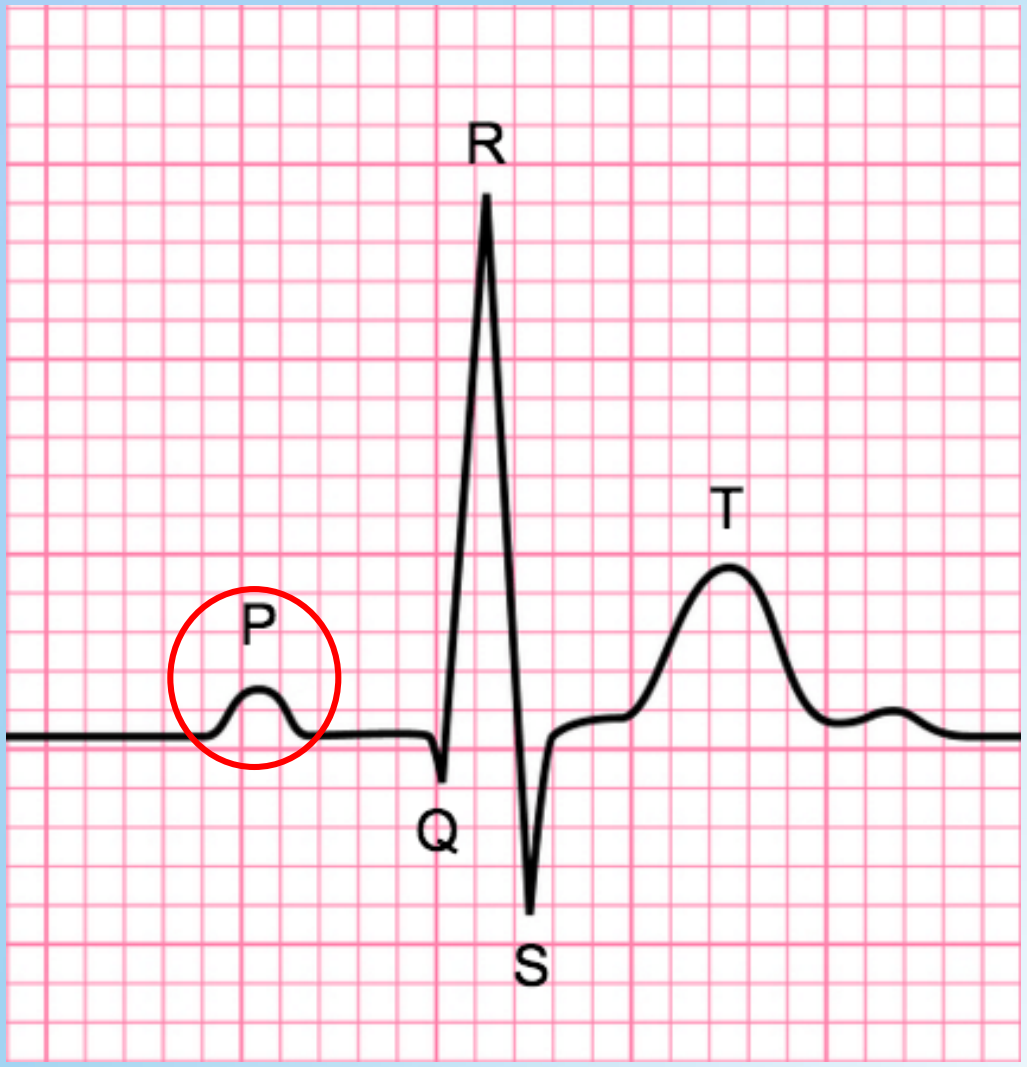
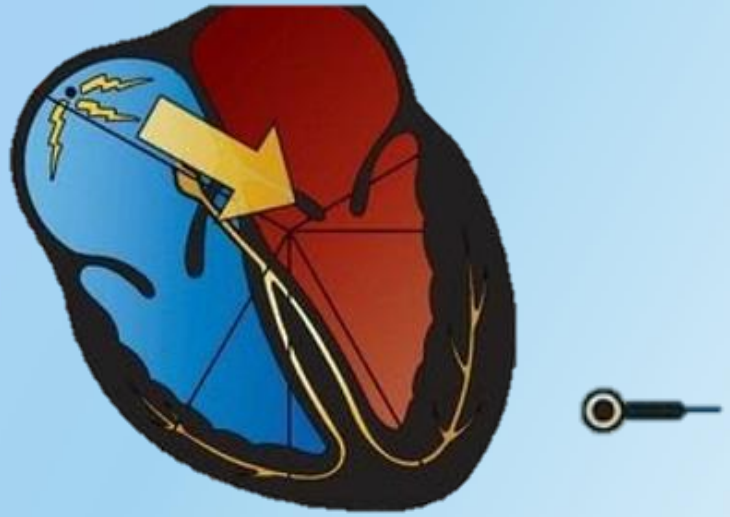
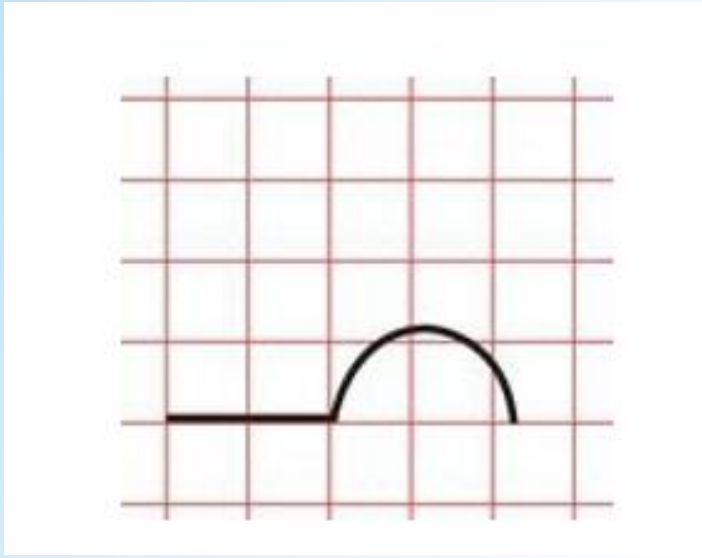
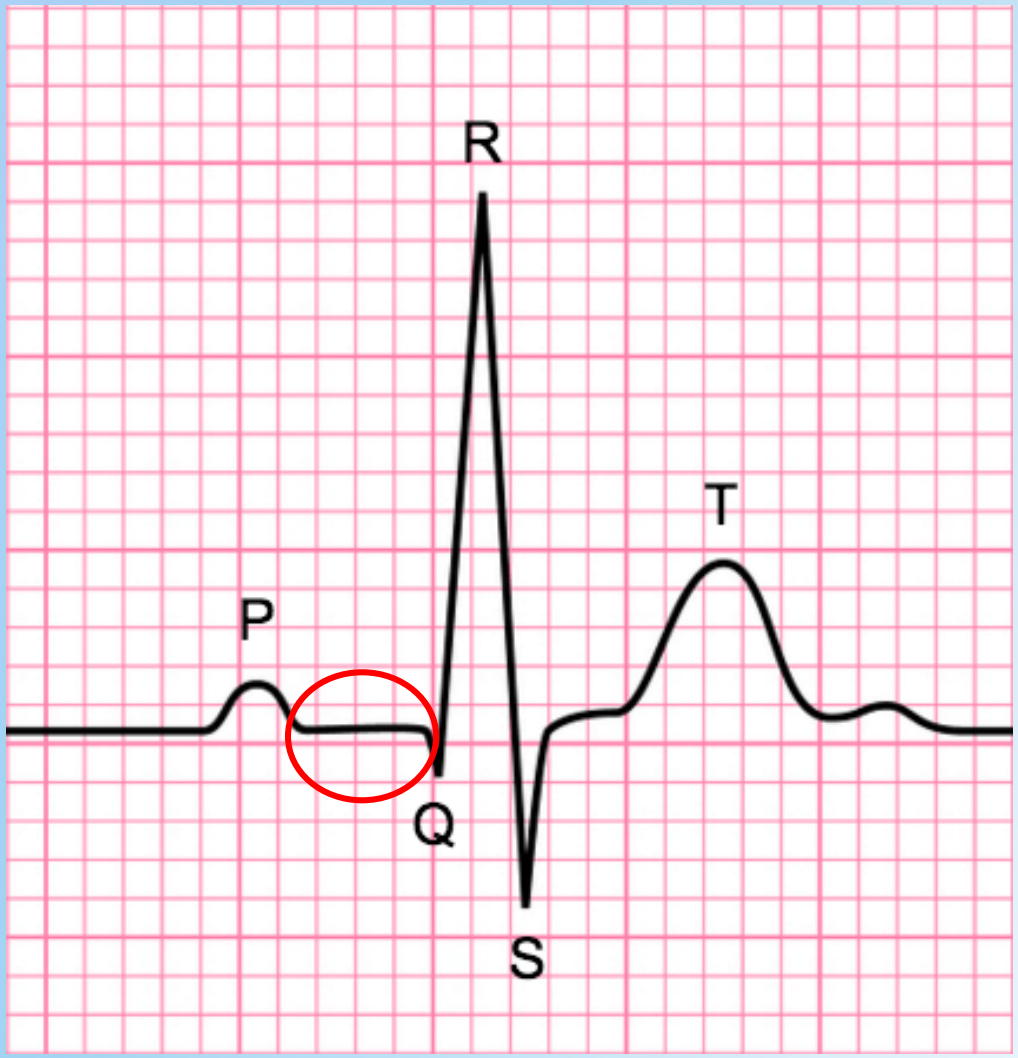

R
T
P
Q
S

P-wave

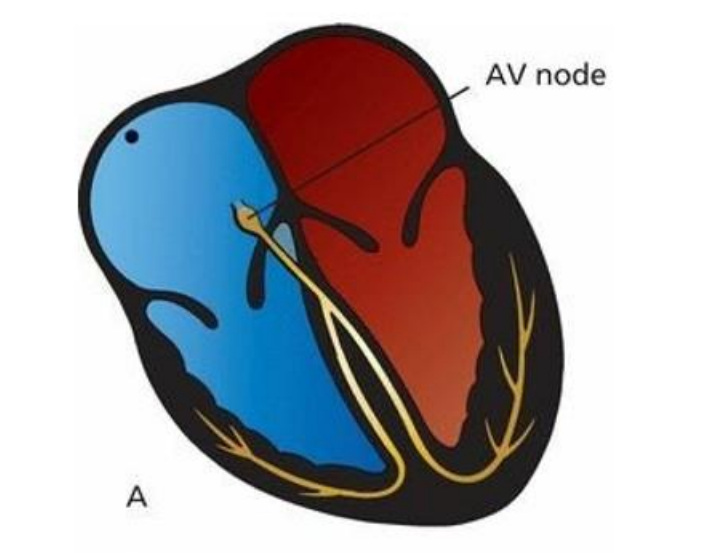


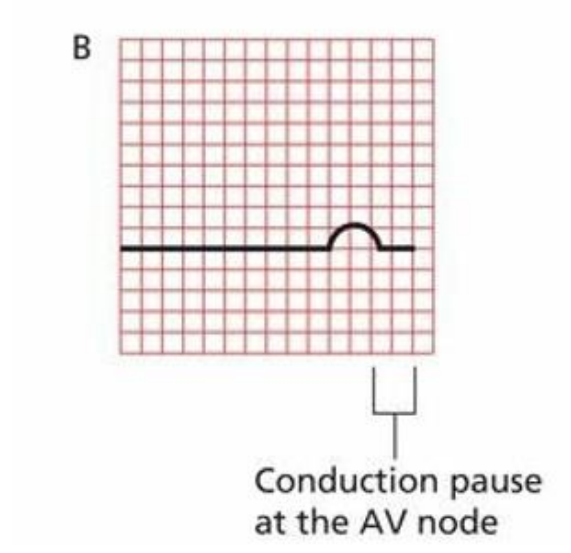


Electrical event	ECG	Mechanical event
Atrial depolarization	P-wave	Atrial contraction

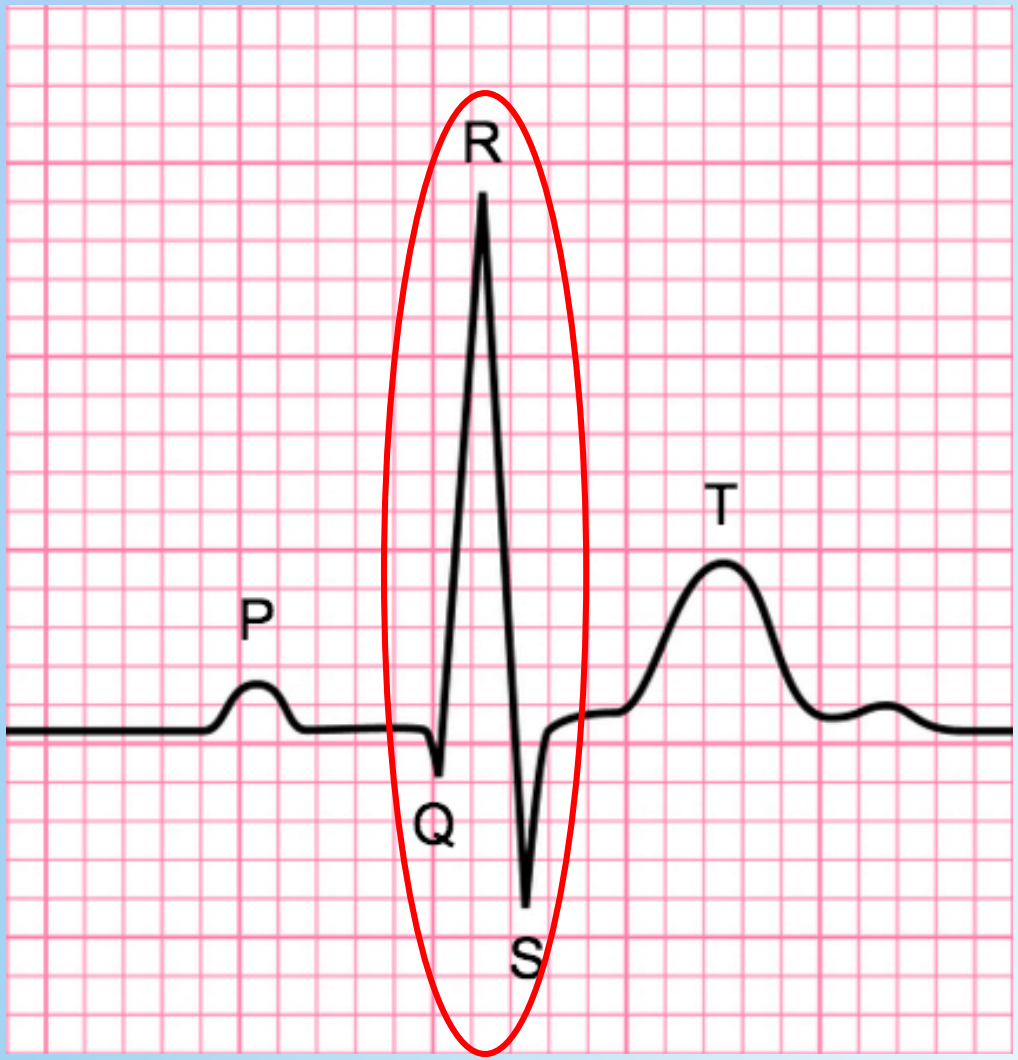

R
T
P
Q
S

PR-segment

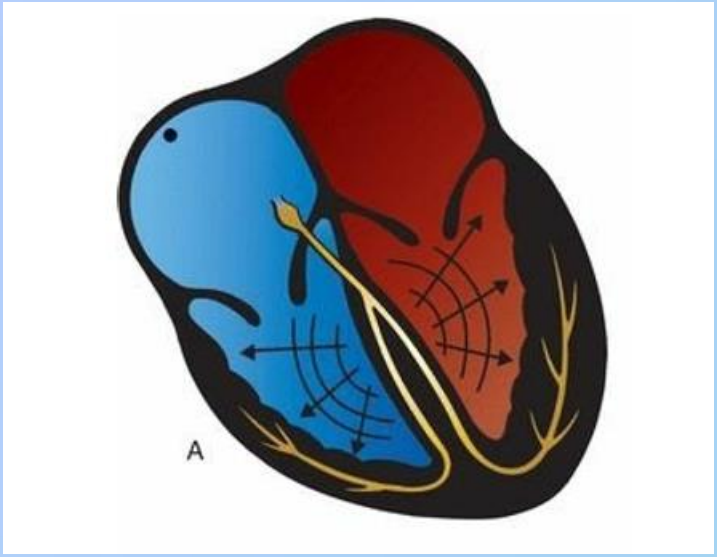


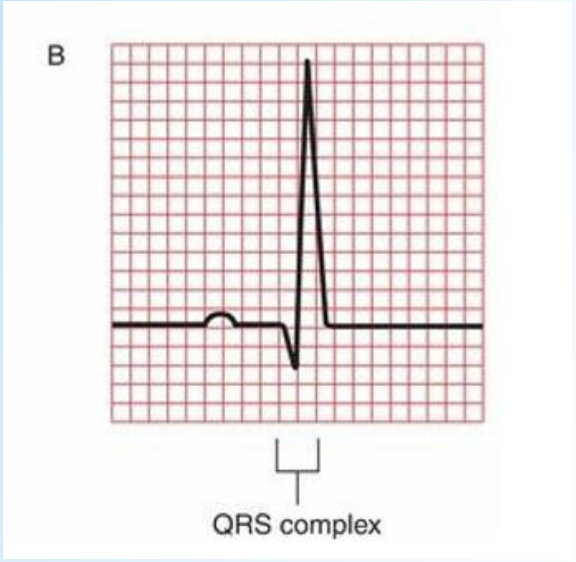


Electrical event	ECG	Mechanical event
Physiological delay in conduction	PR-segment	End of atrial contraction

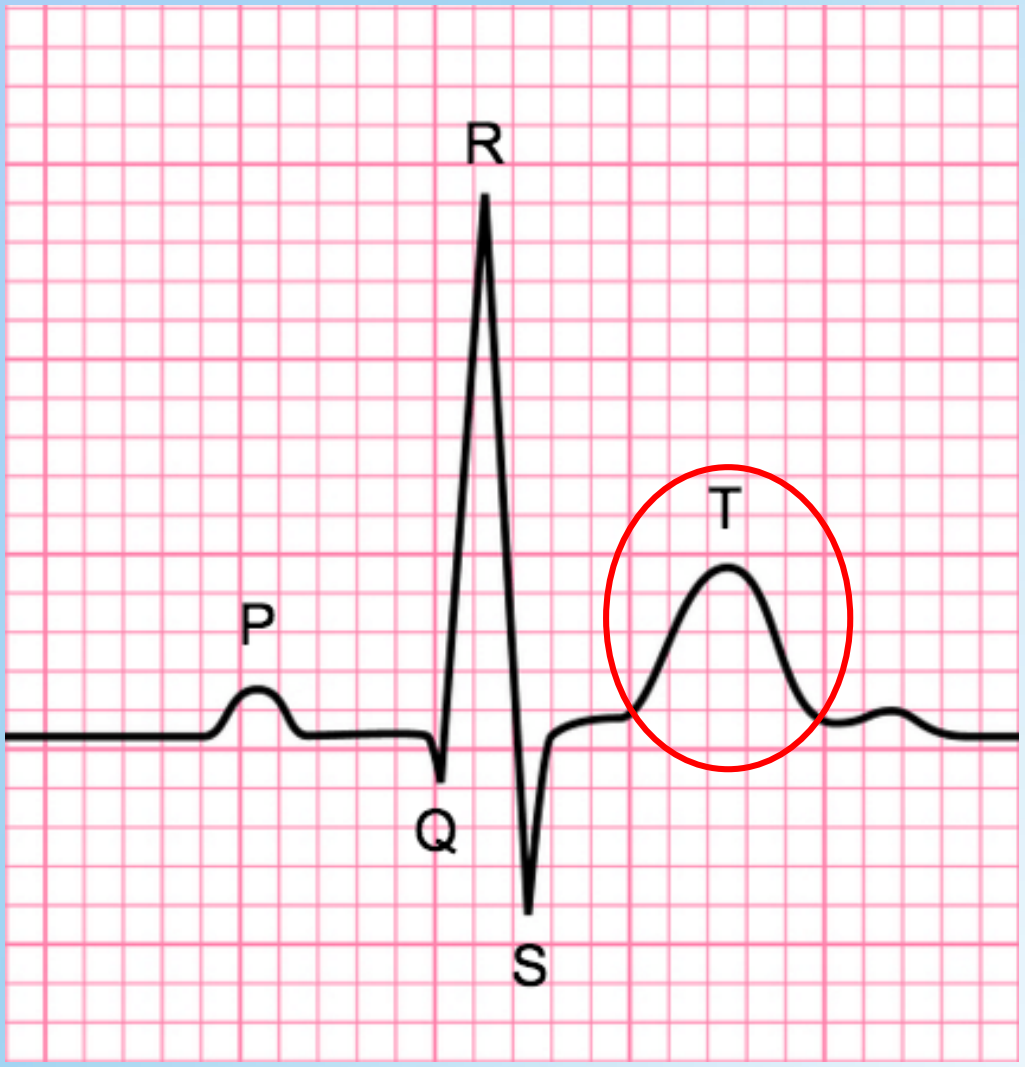

R
T
P
Q
S

QRS-complex

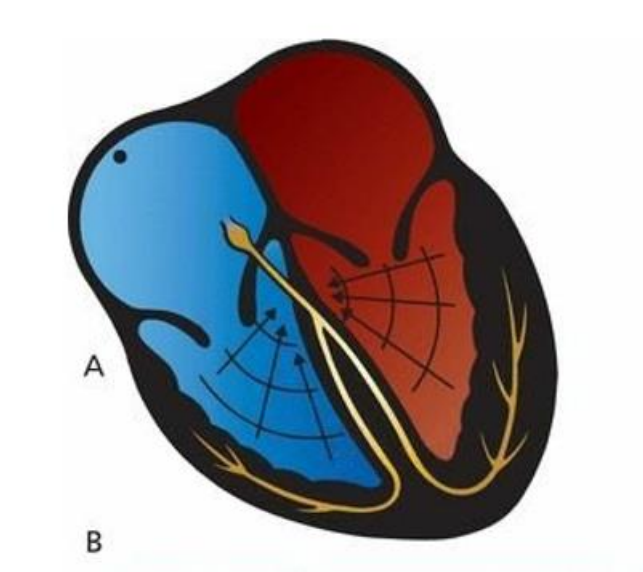


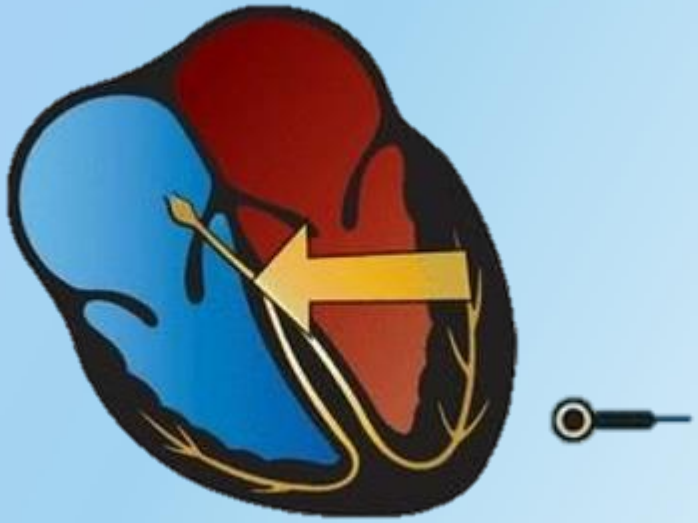


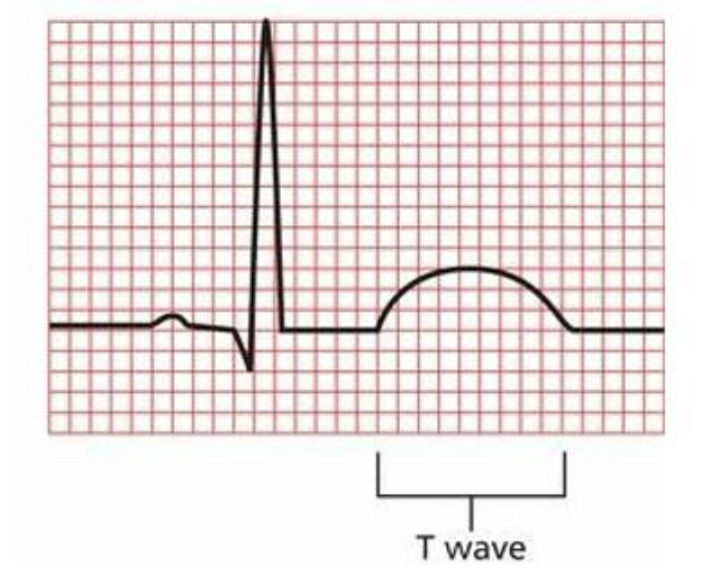
Electrical event	ECG	Mechanical event
- Ventricular depolarization - Atrial repolarization	QRS-complex	- Ventricular contraction - Atrial relaxation


R
T
P
Q
S

T-wave







Electrical event	ECG	Mechanical event
Ventricular repolarization	T-wave	Ventricular relaxation

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Thank you ☺