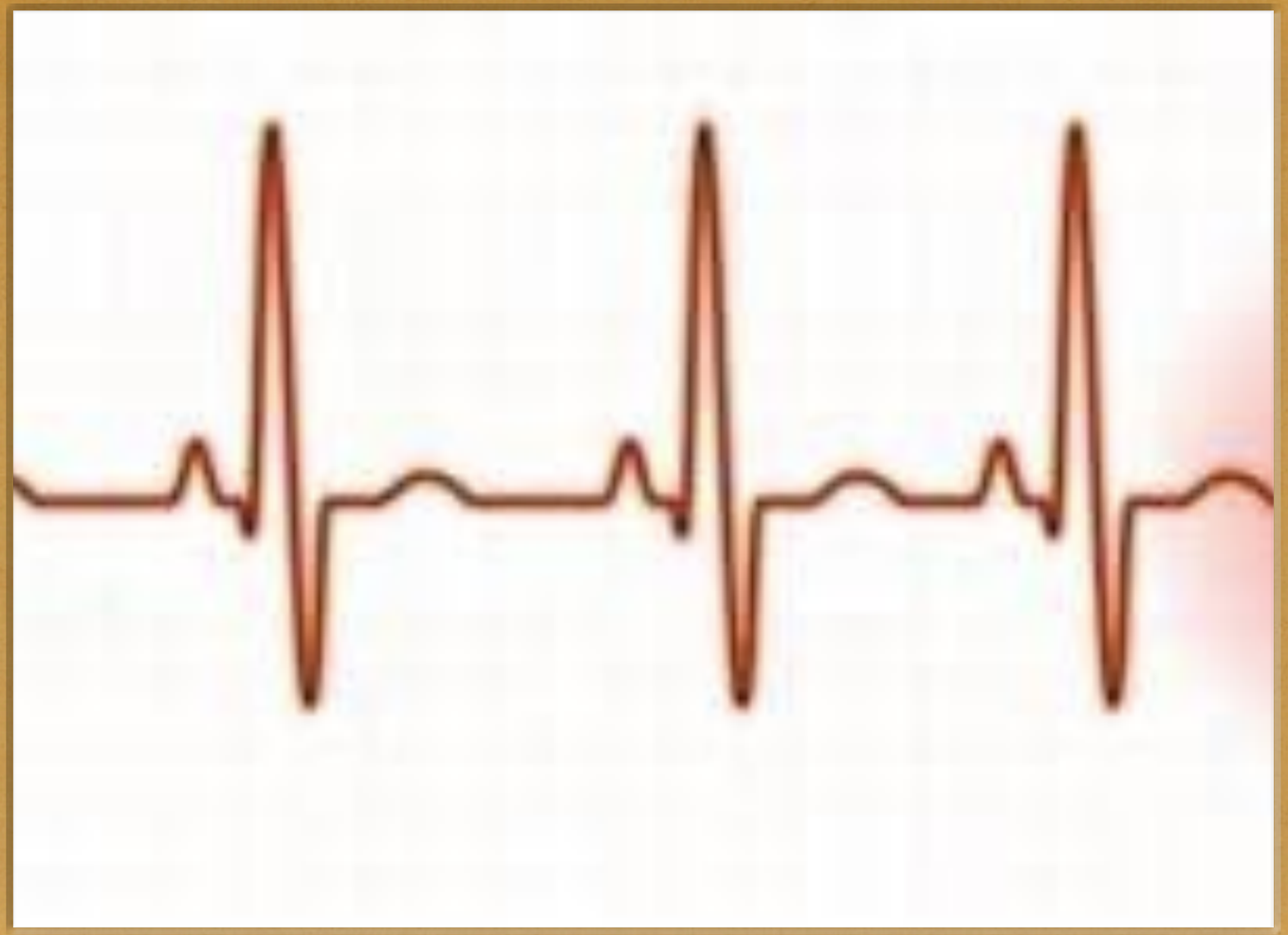


Ask Mish

EKG INTERPRETATION

PART I

What is EKG?

- EKG or ECG= electrocardiogram(~graphy)
- means the recording of the heart electrical activity
- from Greek kardio= heart, graphein= to write

Ask Mish

CARDIAC CELL PHYSIOLOGY

- Cardiac Cell Phases: Resting, Depolarization and Repolarization

- Types of Cardiac Cells

- Membrane Potential vs Action Potential

- Ion Channels

- Cardiac Muscle contraction and relaxation

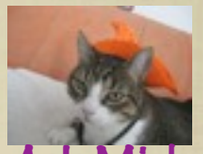
Cardiac Cell Physiology 1

Ask Mish

- 3 phases of cardiac cells:
- 1.RESTING
- 2.DEPOLARIZATION
- 3.REPOLARIZATION

- 1.At rest, cell is more negative inside than outside mainly due to ATP pumps, e.g. Na/K pump (3Na out/2K in).Proteins and phosphates are big negative molecules found inside the cell.

Cardiac Cell Physiology 2



- 2.DEPOLARIZATION:cell turns from negative to positive inside.
- The cause of depolarization is an influx of ions of Na and Ca inside the cell.
- Depolarization is propagated from cell to cell producing a wave of depolarization that can be transmitted to the entire heart.This wave represents a flow of electrons(negative charges outside),an electrical current that can be detected by electrodes placed on the surface of the body.
- 3.REPOLARIZATION:cardiac cells restore their resting polarity (negative inside)
- Cause: Na and Ca channels close and K channels open so an efflux of K ions leaves the cell.
- Repolarization can be sensed by recording electrodes.
- All of the different waves that we can see on an EKG are manifestations of these 2 processes: depolarization and repolarization.

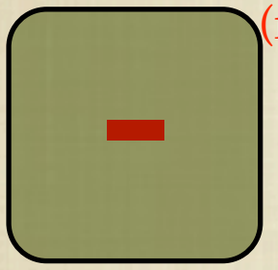
Cardiac Cell Physiology 3

	resting	depolarization	repolarization
inside of the cell	negative	positive	negative
due to	proteins phosphates Na/K pump	influx Na, Ca	efflux K
propagation from cell to cell	no	yes	yes

Cardiac Cell Physiology 4

Ask Mish

1.Resting cell=polarized cell

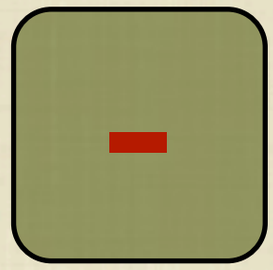


(more negative inside than outside)

2.Depolarization

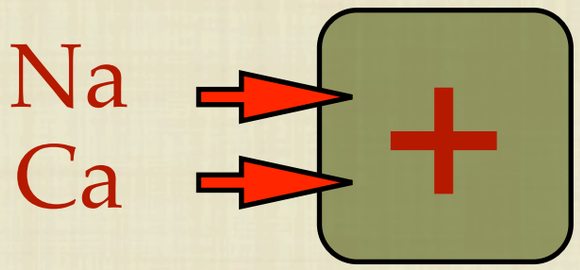
(cell turns positive inside)

3.Repolarizarion

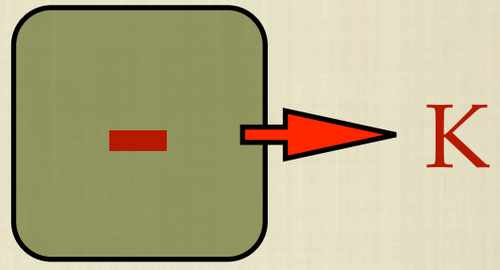


(cell returns to resting polarity)

Due to: Proteins, Phosphates, Na/K pump



influx

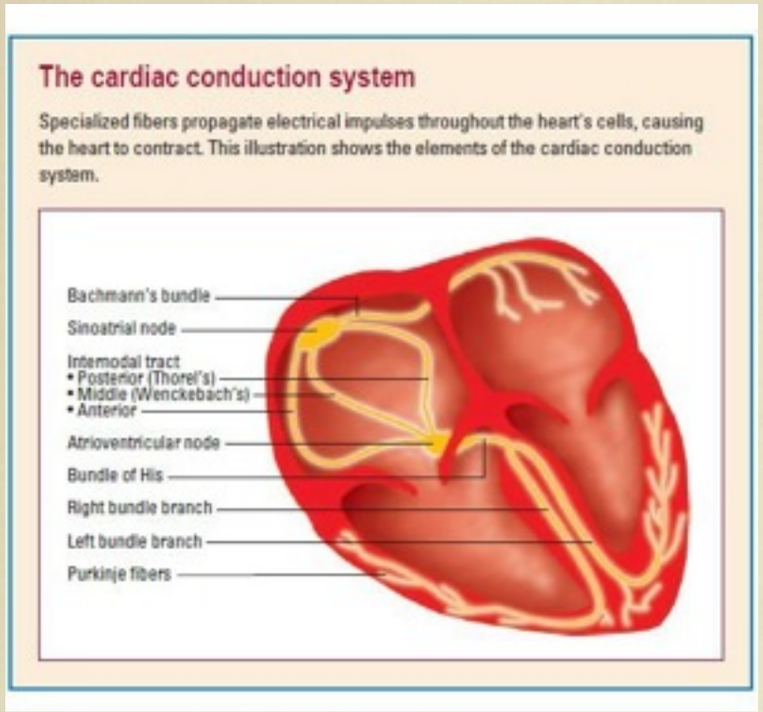


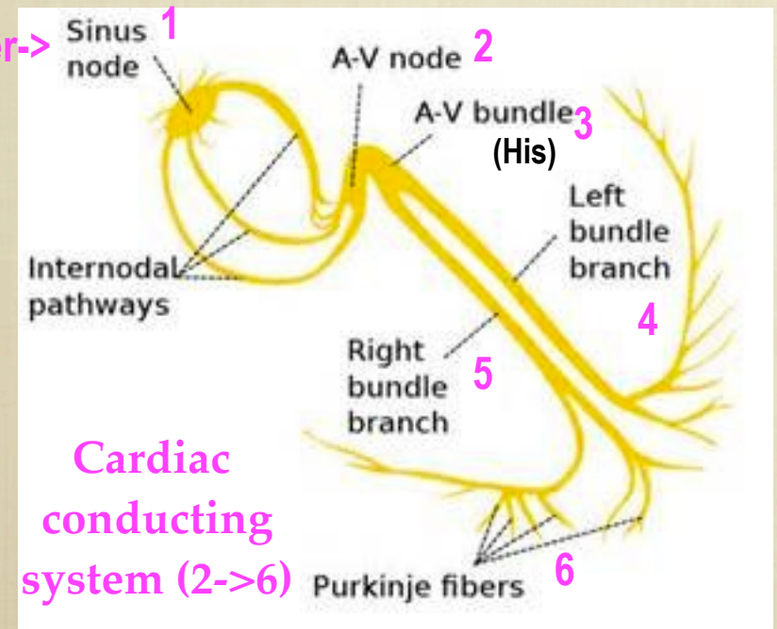
efflux

	MEMBRANE POTENTIAL	ACTION POTENTIAL
def	difference in electrical charge (voltage) across the cell membrane in resting state	short living event including Depolarization and Repolarization
cell	ALL CELLS	EXCITATORY CELLS only (nerve,cardiac*,muscle,endocrine)

3 Types of Cardiac Cells

Ask Mish

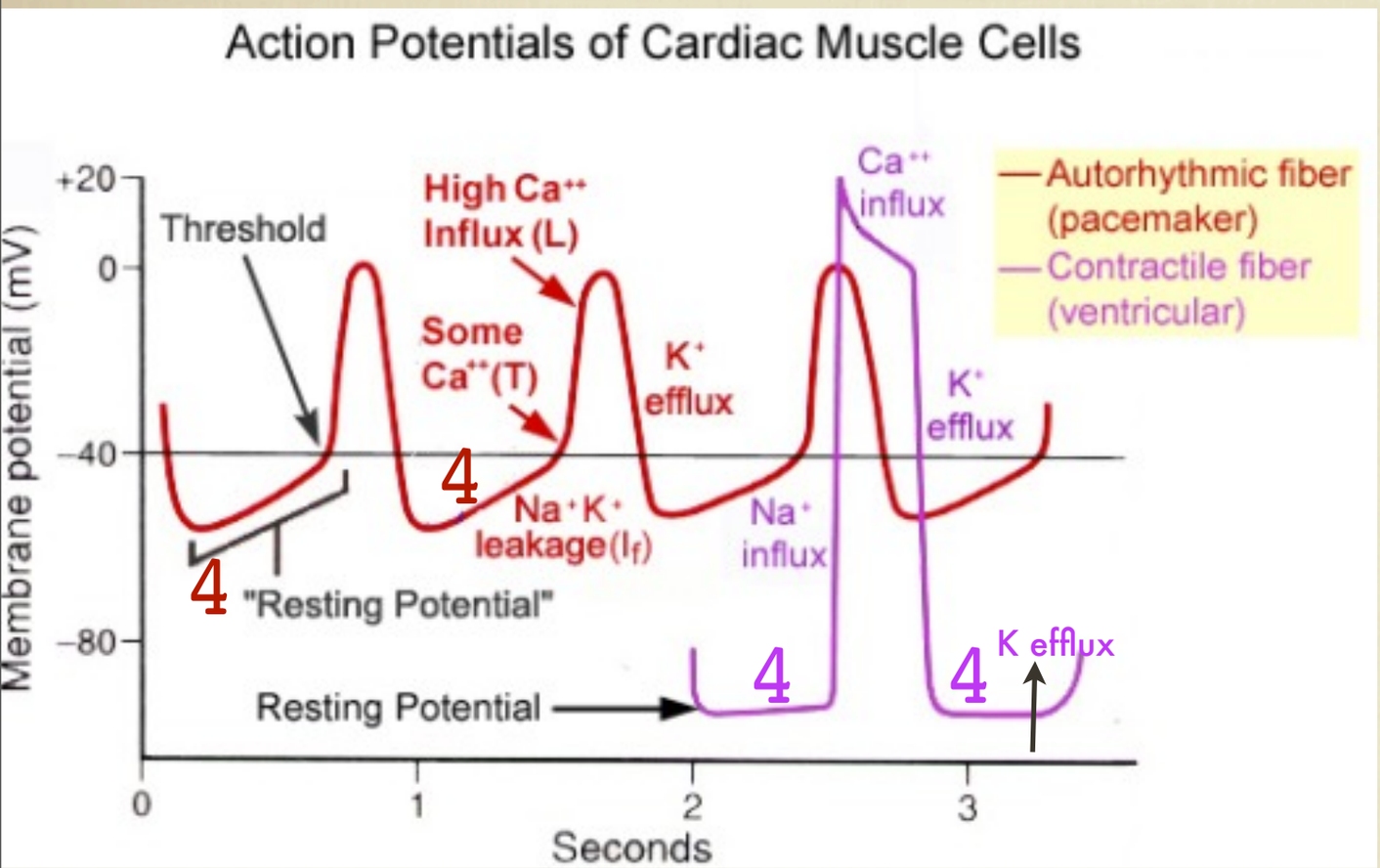




- 3 TYPES of CARDIAC CELLS:
- pacemaker cells
  = electrical power source
  SA node (1) or AV node (2)
- electrical conducting cells
  = wire of the heart
  AV node(2) His bundle(3) with 2 branches(4,5) and Purkinje fibers(6)
- myocardial cells
  = contractile pump of the heart

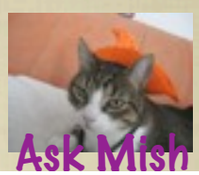
2 Types of Resting Potential

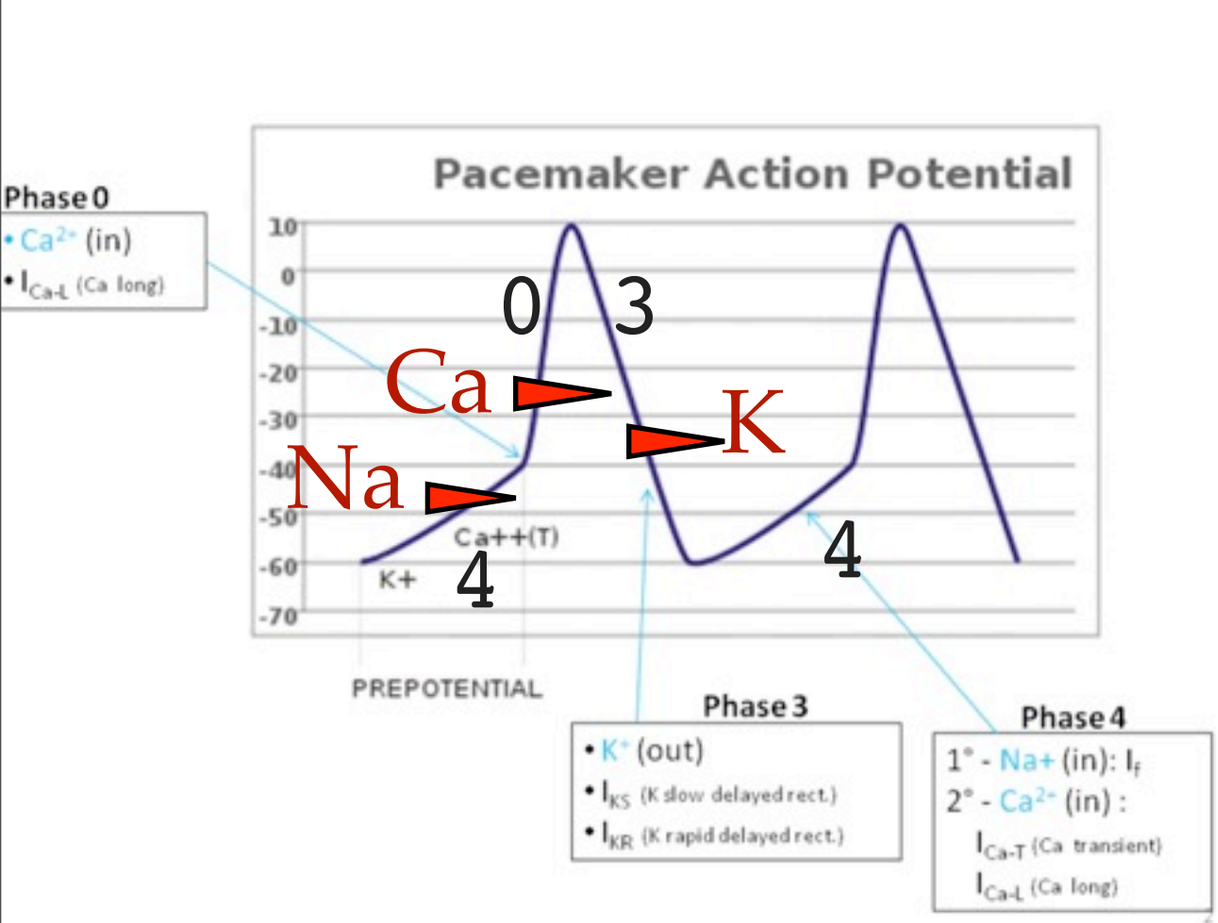
Ask Mish

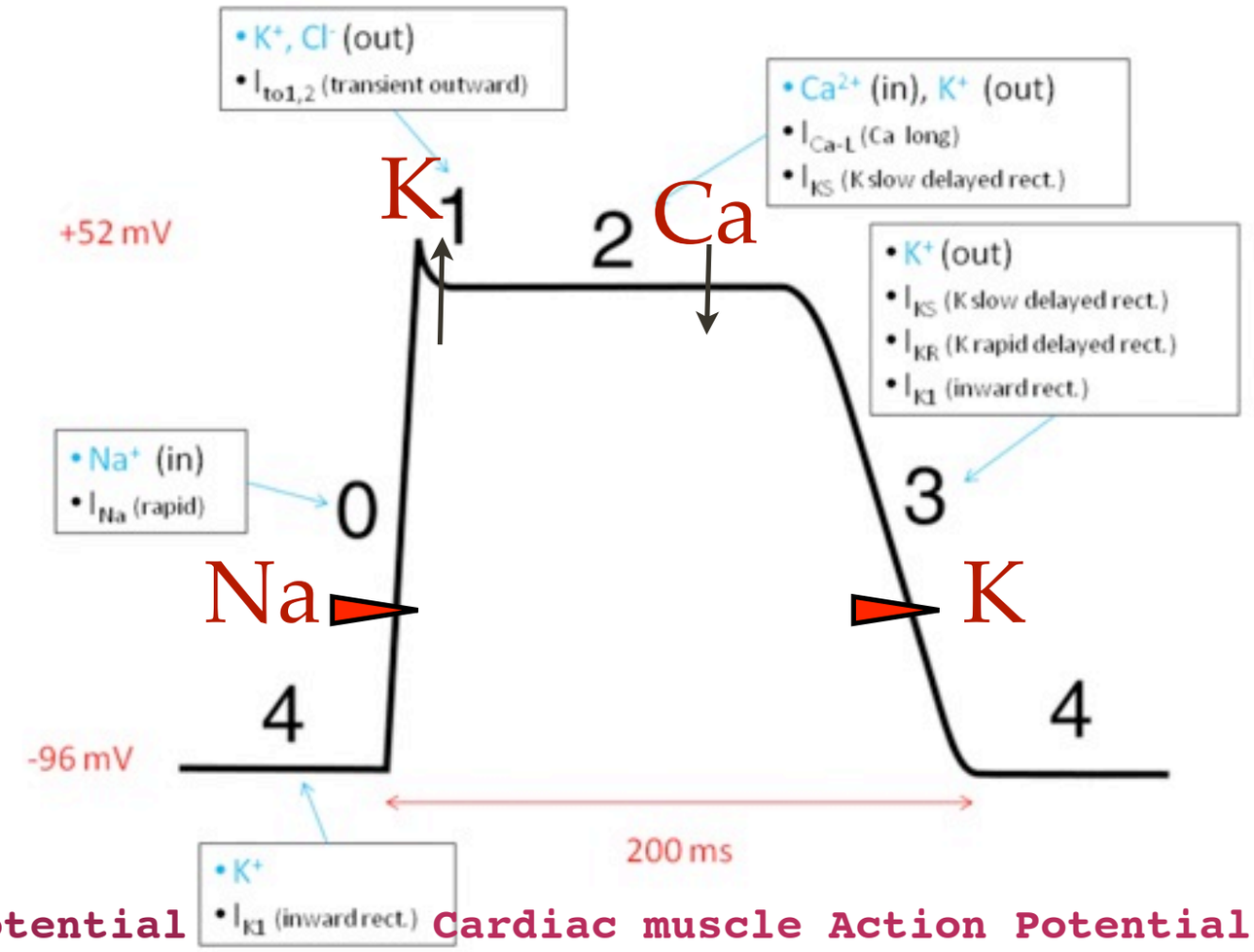


	Pacemaker	Cardiac muscle
Resting Potential (4)	variable -60 to-40 mV	stable -96 mV
Due to:	slow influx of Na= "funny current"(I_f) and some CaT (transient)	ions inside vs outside the cell; K efflux (I_{K1})

2 Types of Action Potential







SA node, AV node Action Potential — Cardiac muscle Action Potential

0	Depolarization	Ca influx	Na influx
3	Repolarization	K efflux	K efflux
1-2	Rapid repolarization(1) and Plateau (2)	-	K efflux(1) & Ca influx(2)

3 Types of Ion Channels

Ask Mish

	Type of Channels	Description
I	Voltage gated	"GATED" called like this because of an imaginary gate that opens or closes in this case at voltage variation across the cell membrane allowing or not ions inside the cell. There are voltage gated channels for Na, Ca and K, usually more than one type for each ion. When one channel opens (is activated) in one phase, the previous opened channel usually closes (is inactivated). Order of activation/inactivation in action potential: Na -> Ca ->K
II	Receptor gated	"GATE" opens or close in this case in response to a molecule binding to a receptor. e.g. ATP binding to a receptor on a K channel or Acetylcholine binding to a receptor on a K channel
III	Ligand gated (Specific ions and Chemical Ligands)	opens in response to ions influx in the cell e.g. Ca influx in vascular smooth muscle opens a K channel

3 Types of Ion Channels

Ask Mish

I

Na channels	
slow Na I_f	"funny current" in phase 4 of pacemaker potential
fast Na	phase 0 (depolarization) of non-pacemaker cardiac action potential
K channels	
transient outward I_{to}	phase 1 of non-pacemaker cardiac action potential
slow delayed rectifier I_{KS}	phase 3 of cardiac action potential, starts in phase 2
rapid delayed rectifier I_{KR}	phase 3 of cardiac action potential, continues in phase 4
inward rectifier I_{K1} or I_{ir}	phase 4 of cardiac action potential and late 3
Ca channels	
L-type $I_{Ca\text{-}L}$	long-lasting current: phase 0 (depolarization) of pacemaker AP, phase 2 of non-pacemaker cardiac AP
T-type $I_{Ca\text{-}T}$	transient current: phase 4 of pacemaker action potential in SA and AV node

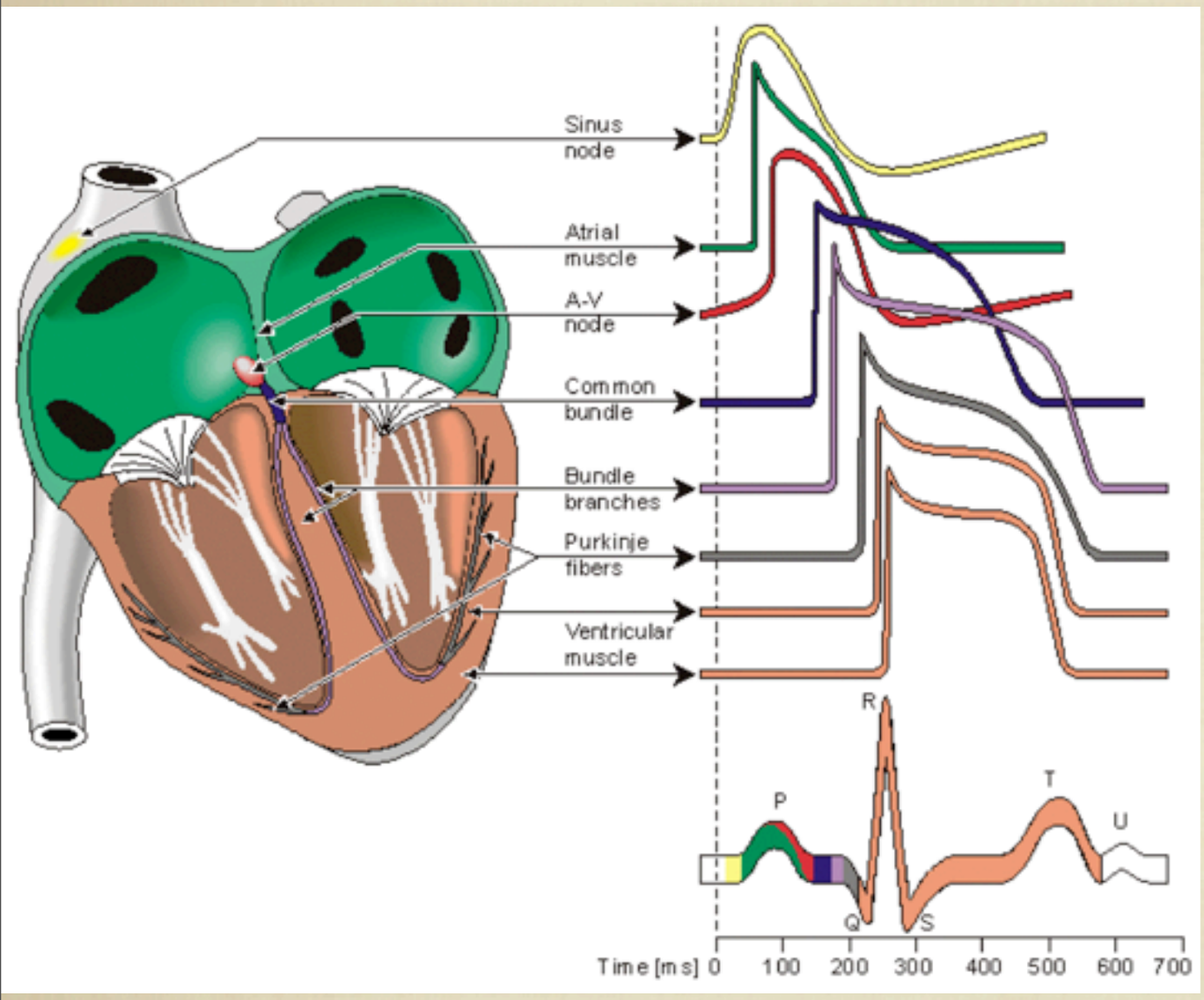
II

K channels	
ATP sensitive $I_{K,\,ATP}$	K_{ATP} channels, inhibited by ATP; in vascular smooth muscle, adenosine (final ATP metabolite) opens K channels resulting hyperpolarization* (more negative repolarization) and vasodilation
Acetylcholine activated $I_{K,\,ACh}$	opened by Acetylcholine; Gi protein coupled

III

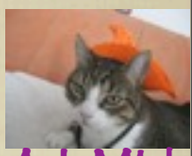
K channels	
Calcium activated $I_{k,\,Ca}$ or BK_{Ca}	open in response to Ca influx in vascular smooth muscle

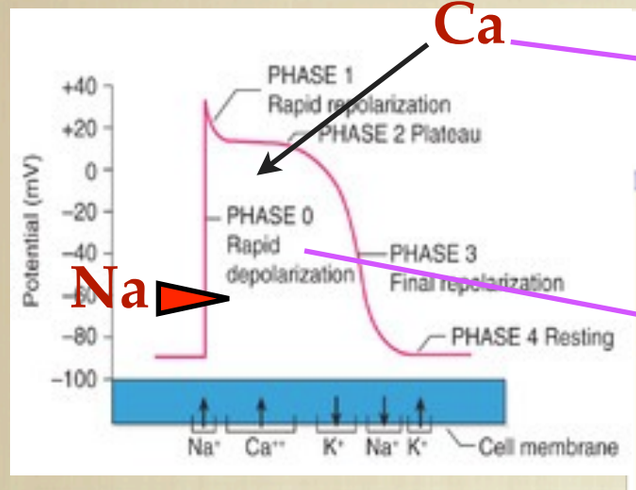
Heart: Action Potentials



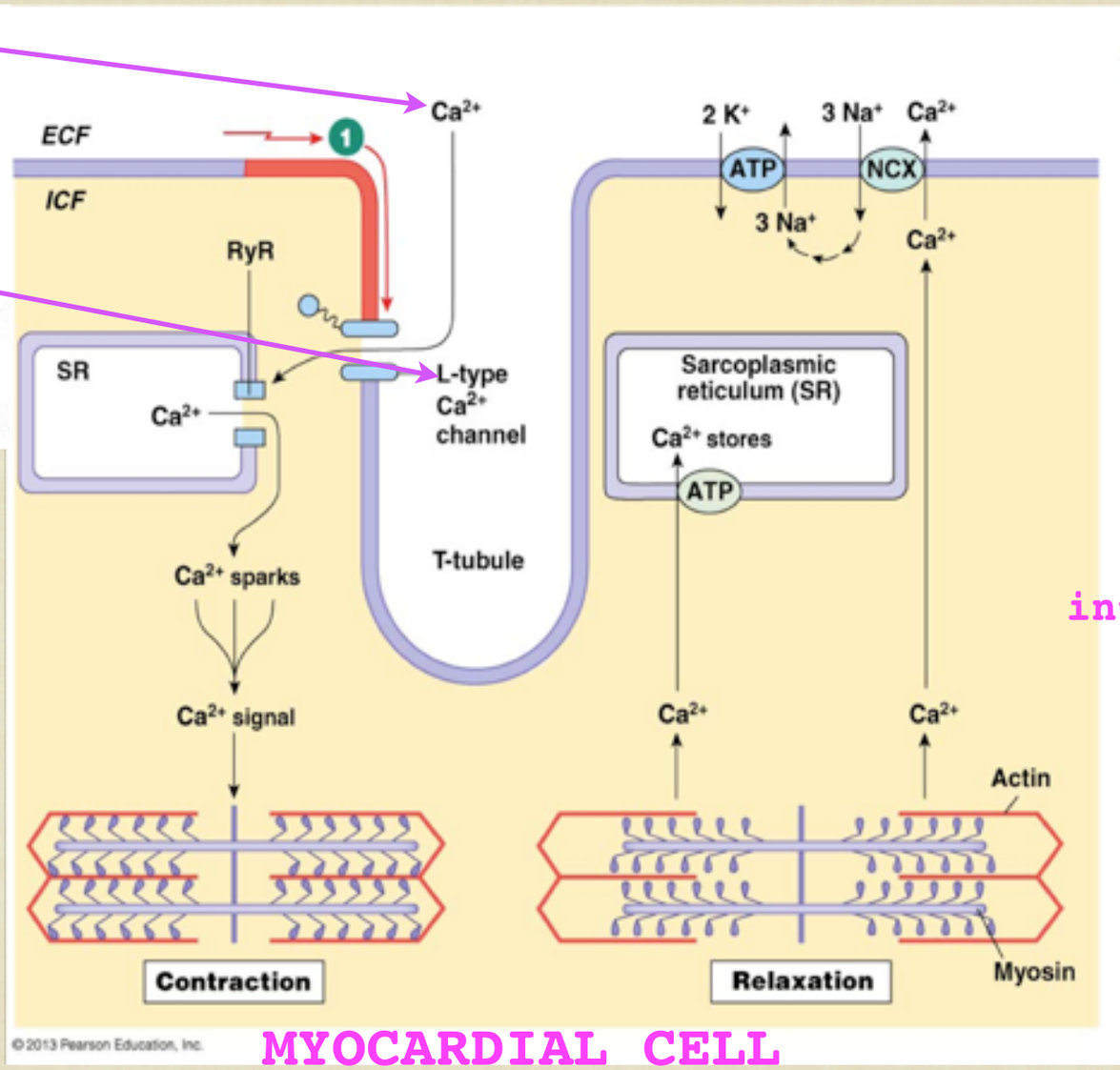
- Action potential (AP) is propagated from cell to cell. It is generated by the pacemaker (sinoatrial node)
- Then is propagated to atrial muscle cells, AV node, bundle of His then bundle branches and finally through Purkinje fibers to the contractile pump which is ventricular myocardium.
- Depolarization and repolarization phases of the action potentials passing through these tissues are recorded on a special paper by electrodes placed on the skin and is called EKG or ECG.

AP:Myocardial Contraction

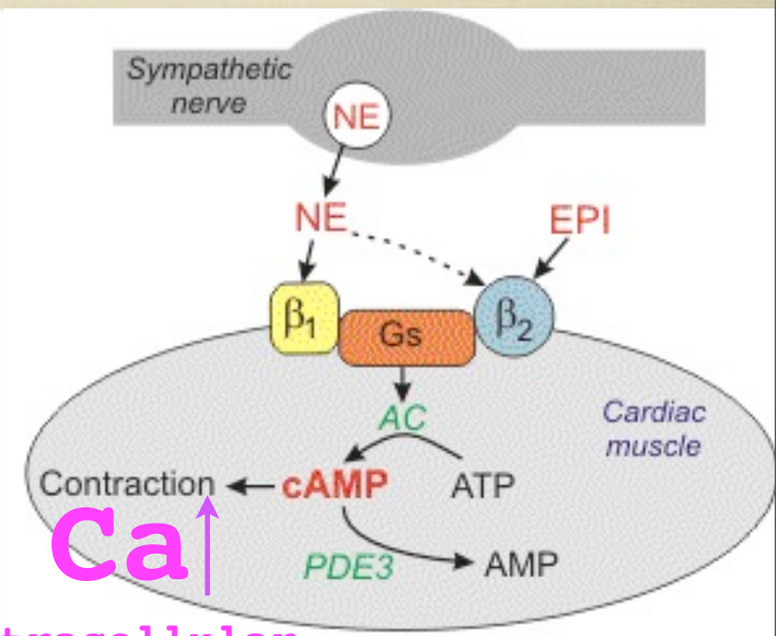




Ca↑ intracellular



MYOCARDIAL CELL



Ca↑ intracellular

Abbreviations: NE, norepinephrine; EPI, epinephrine; Gs, Gs-protein; AC, adenylyl cyclase; PDE3, cGMP-dependent phosphodiesterase (type 3)

AP depolarization(Na in) → activate L typeCa channels

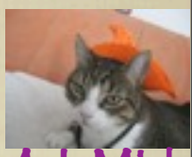
cAMP (NE, EPI) → activate receptor type Ca channels

Ca↑ intracellular

activate ryanodine receptors RyR on SR → **Ca↑ release from SR**

bind troponin C which remove tropomyosin from actin sites → **CONTRACTION** myosin heads(ATP) bind actin free sites

AP: Myocardial Relaxation



Ca^{+2} binds to TnC causing movement of troponin-tropomyosin complex exposing actin's active sites.

As soon as the active sites are exposed myosin heads bind to actin

CONTRACTION

RELAXATION

CYCLE

1) Crossbridges Form

CONTRACTION
Shortening

Working Stroke pulls the Z-lines together.

2) Myosin Head Swivels

ADP + Pi released.

3) Crossbridges Detach

ATP is taken up by myosin. Without available ATP crossbridges are unable to detach

Myosin is in a weak binding state

ATP is hydrolyzed and its energy is transfered to the cocked myosin head

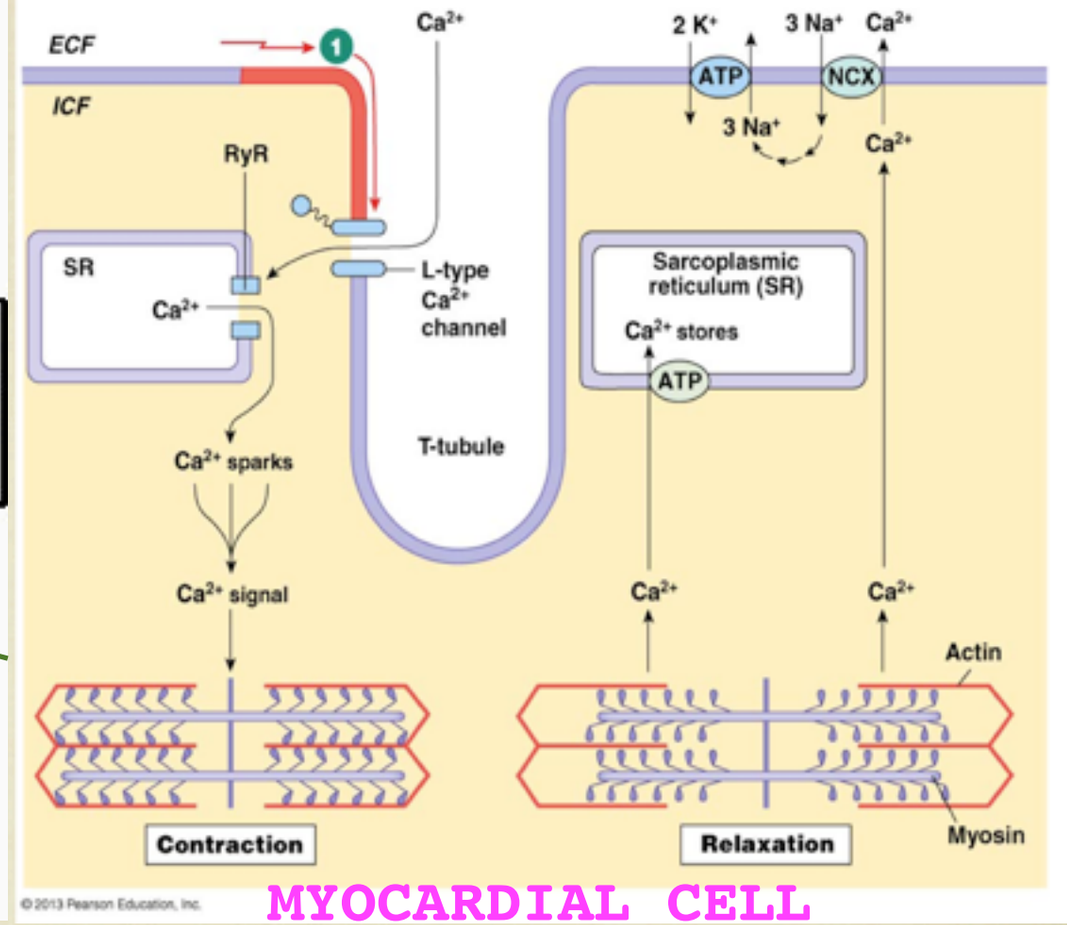
4) Cocked Myosin Head

Ca^{+2}

Myosin is in a strong binding state

(ATP is used to bend myosin head = "cocked")

RELAXATION
(under the green line)



MYOCARDIAL CELL

AP plateau (Ca in) → activate voltage gated K channels

ATP depletion → activate receptor gated K channels (ATP, Ach)

Acetylcholine (Ach) → activate receptor gated K channels (ATP, Ach)

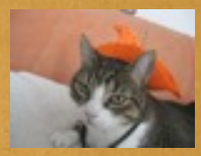
K ↑ extracellular

Ca back to SR → due to ATPase

Ca out of the cell → due to Ca/Na pump driven by the energy from Na/K ATP pump

Ca ↓ intracellular

RELAXATION



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NORMAL EKG

- EKG: 10 electrodes, machine and paper

- 12 Leads EKG: 6 limb and 6 chest leads

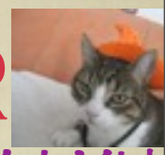
- EKG at rest

- Intervals

- Waves

- Segments

EKG:10 Electrodes and Paper



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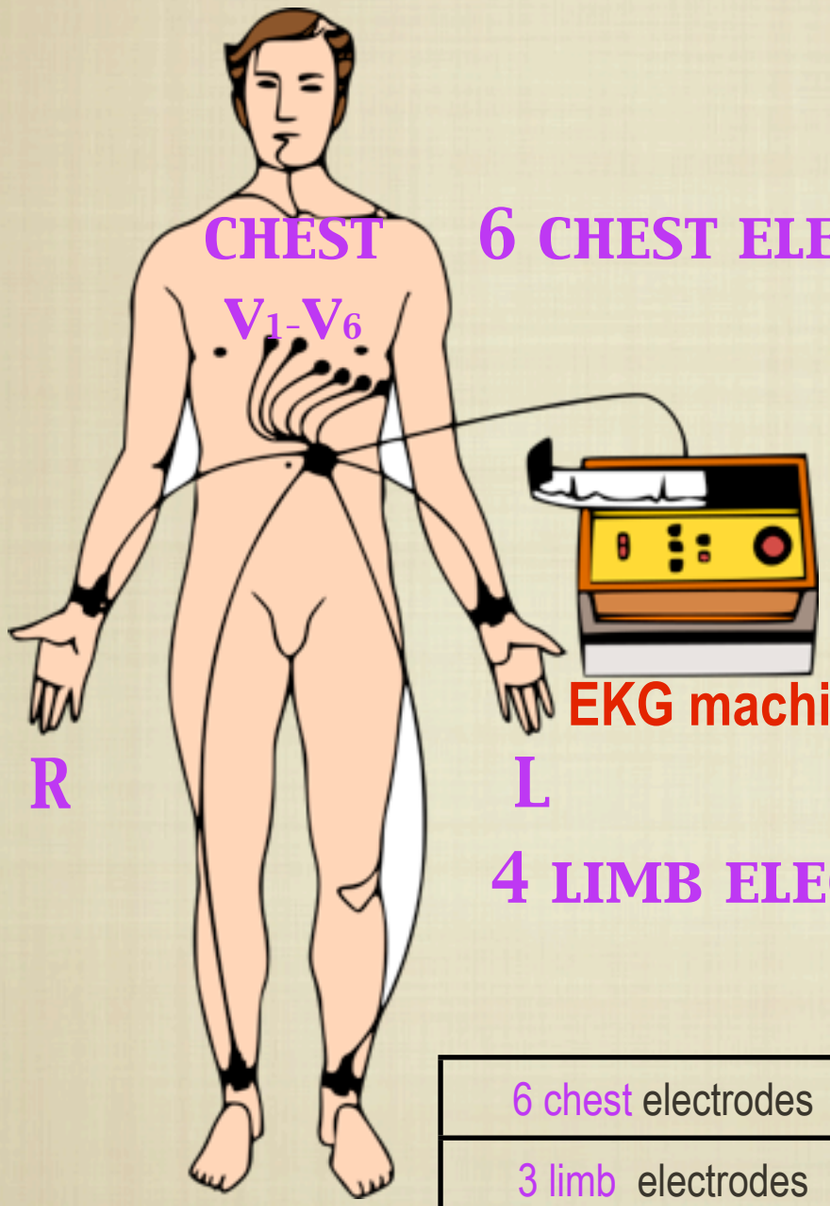
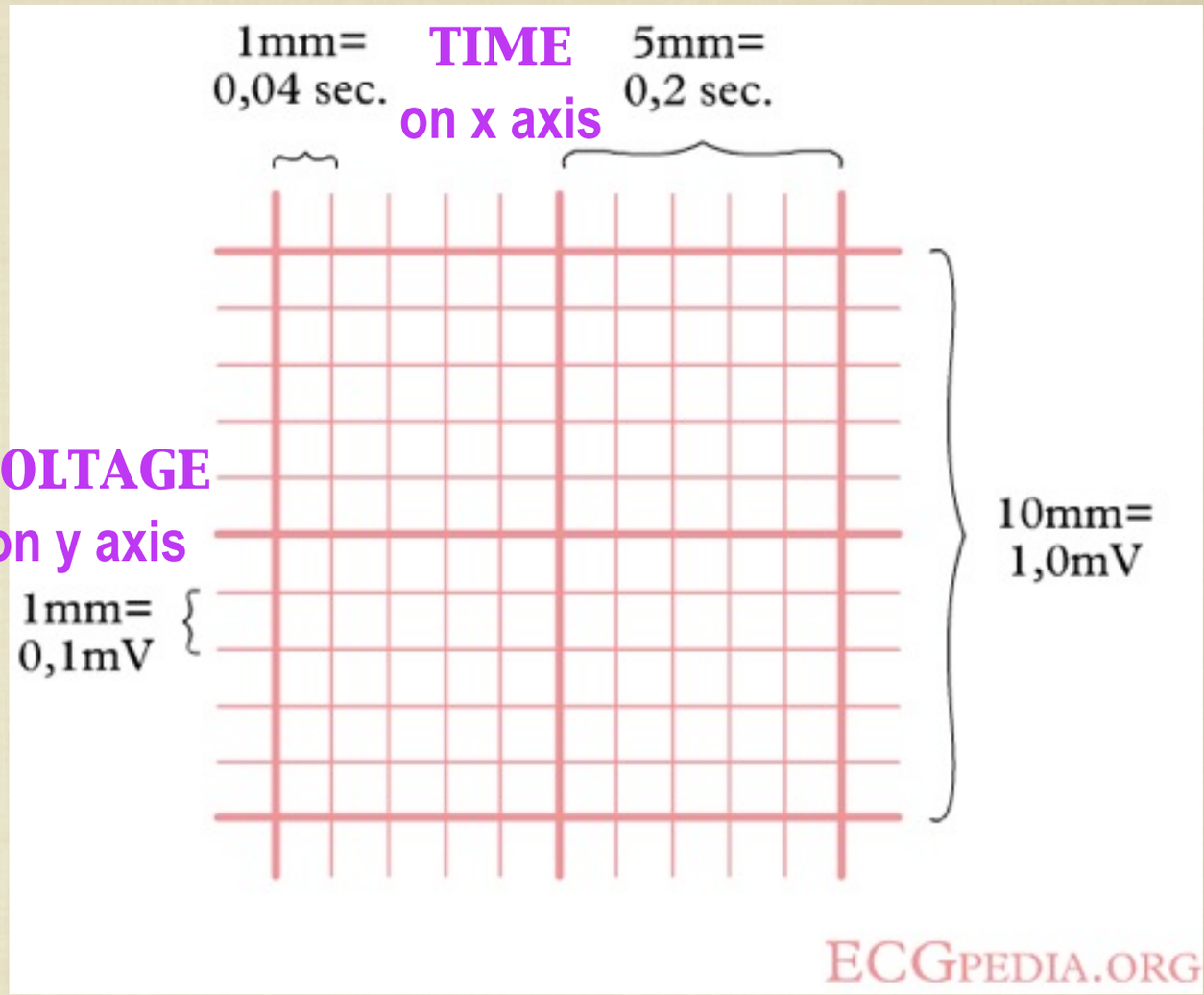
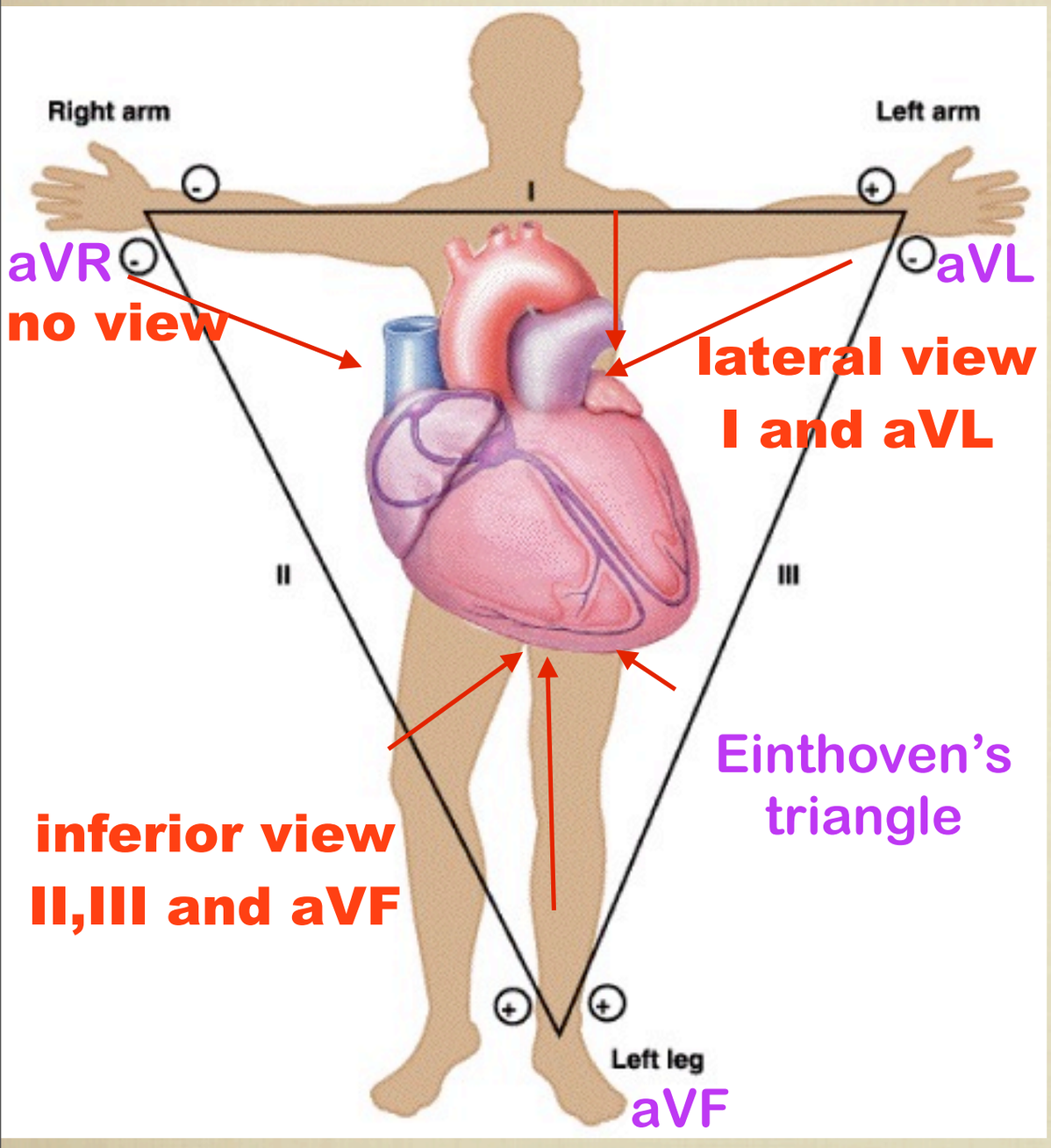




6 chest electrodes	$V_1, V_2, V_3, V_4, V_5.V_6$	detect action potentials from antero-posterior plan of the heart
3 limb electrodes	L and R arm, L leg	detect action potentials from frontal plan of the heart
1 limb electrode	R leg	non-detector, represents the ground

12 Leads EKG: 6 Limb Leads

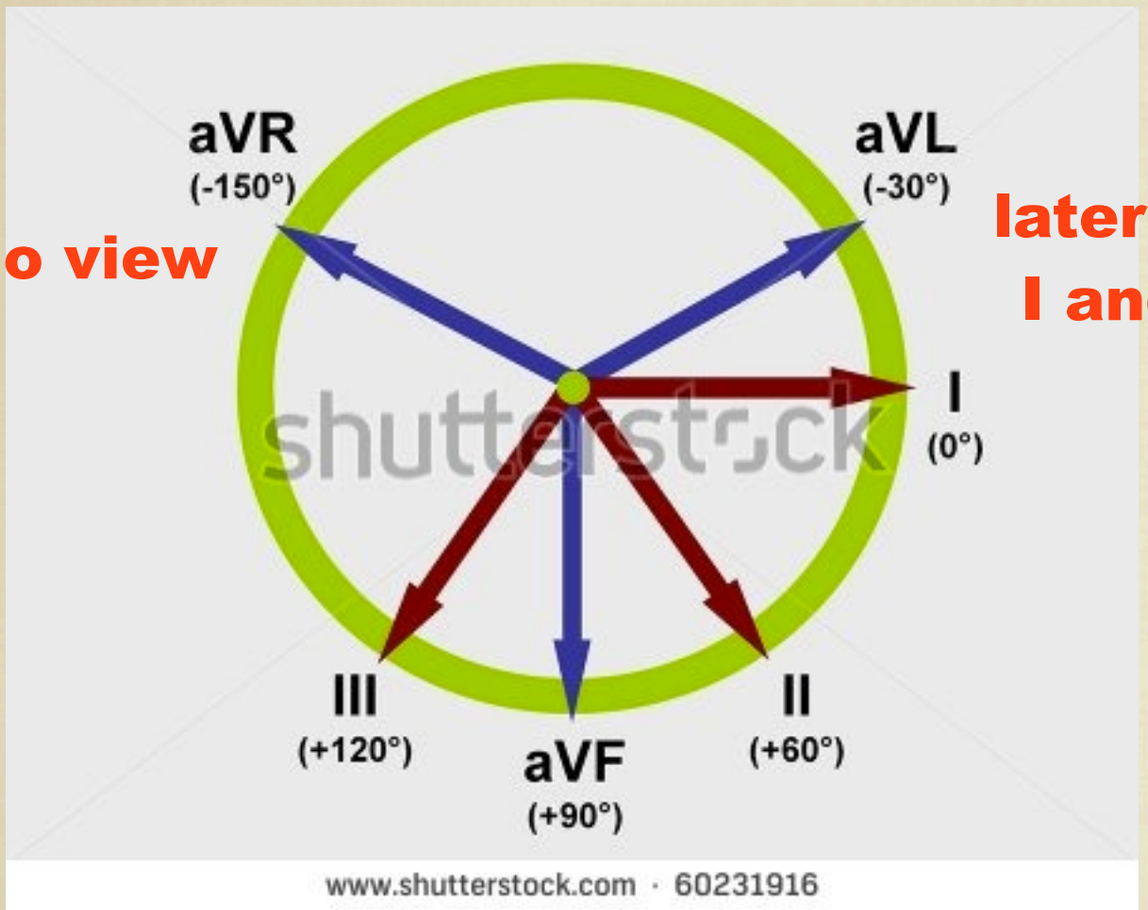
Ask Mish



LEADS (12) 6 limb + 6 chest	12 views of different anatomic parts of the heart obtained from 9 detectors (electrodes)
LIMB LEADS (6) red arrows	6 views of different anatomic part of the heart from 3 limb electrodes; possible by adding lead I, II, and III obtained by 3 imaginary lines through electrodes (Einthoven's triangle)
LEAD I bipolar	machine combines information from 2 poles: L and R arms
LEAD II bipolar	machine combines information from 2 poles:R arm and L leg
LEAD III bipolar	machine combines information from 2 poles: L arm and L leg
LEAD aVL unipolar	aV =augmented voltage; voltage coming only from one arm (L in this case) needs to be boosted cos it's far from heart
LEAD aVR unipolar	information comes from the R arm
LEAD aVF unipolar	information comes from the L leg

12 Leads EKG: 6 Limb Leads

Ask Mish



no view

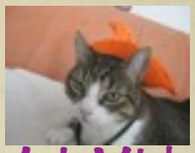
lateral view
I and aVL

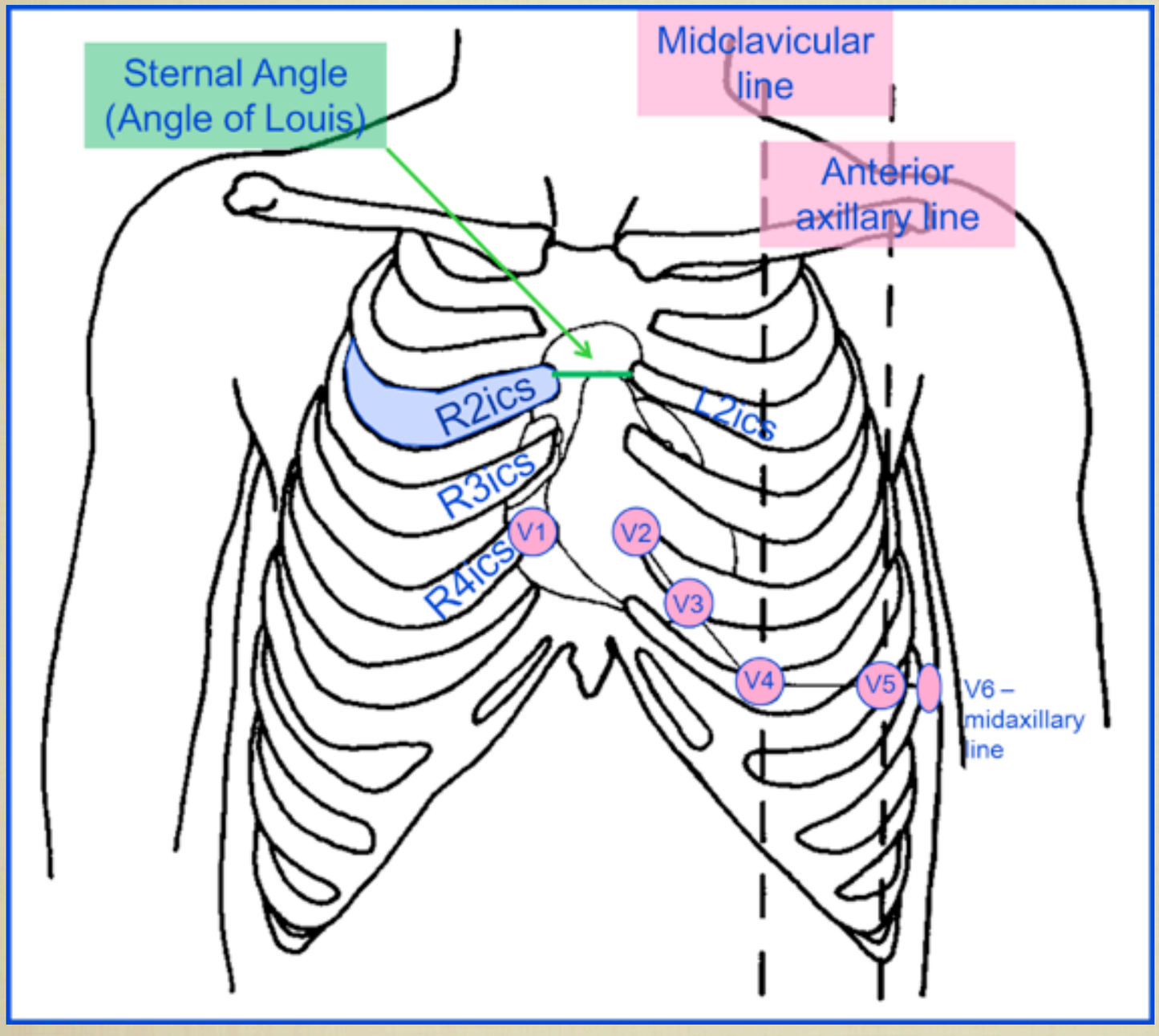
inferior view
II,III and aVF

- Moving the limb leads to a center we obtain the angles btw frontal heart views

- By convention, + is the direction of AP propagation(up to down) in the heart; negative is the opposite

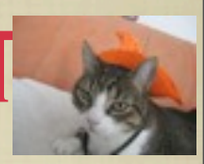
12 Leads EKG: 6 Chest Leads





- Position of chest (precordial) leads:
- V1 and V2 on R and L sternal border at level of the 4th rib
- V4, V5 and V6 on the level of the 5th rib as follows
- V4 : midclavicular line
- V6 : midaxillary line
- V5 : midway V4-V6 or anterior axillary line
- V3 : midway V2 - V4

12 Leads EKG: Views of Heart



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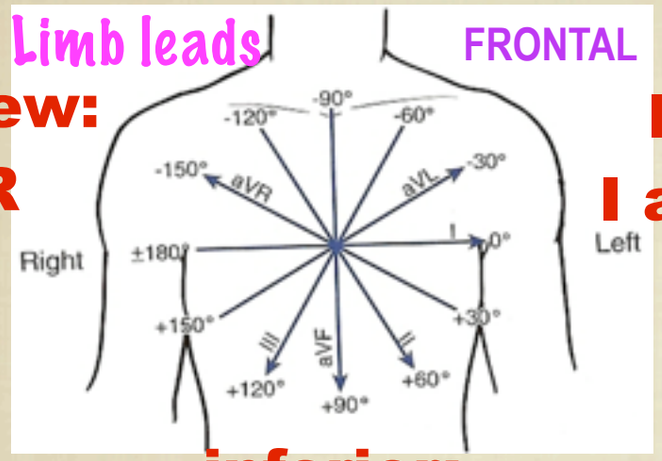
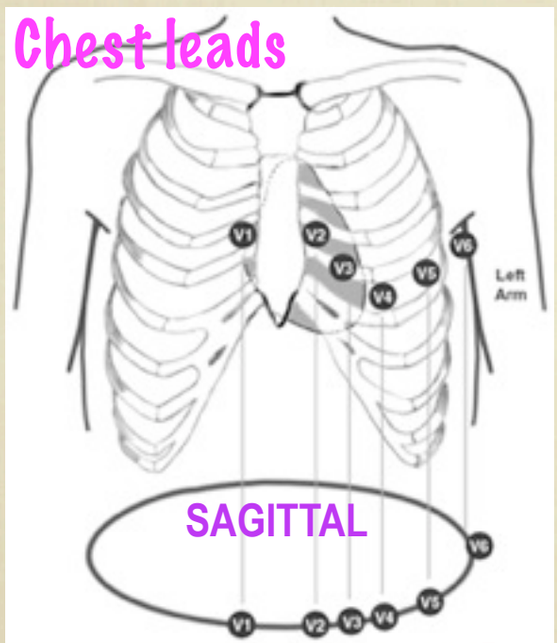


no view: aVR

lateral: I and aVL

inferior: II,III and aVF



lateral: V_5, V_6

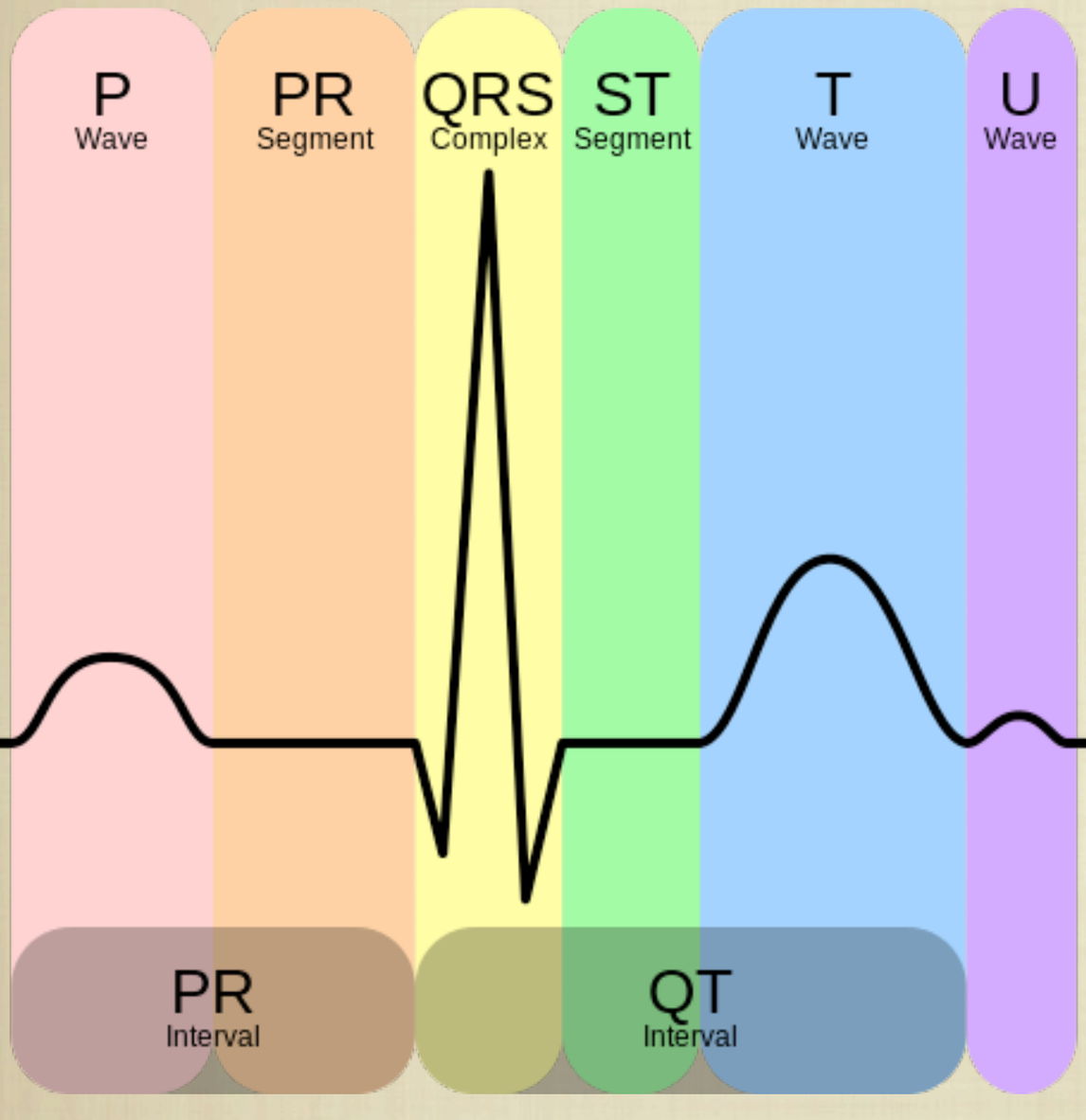
anterior: V_3, V_4

septal: V_1, V_2

Leads: name, view and standard color

I Lateral	aVR	V1 Septal	V4 Anterior
II Inferior	aVL Lateral	V2 Septal	V5 Lateral
III Inferior	aVF Inferior	V3 Anterior	V6 Lateral

EKG: components & description



wave	deflection up/down
segments	horizontal lines btw waves
interval	wave(s) + segment(s)
P wave	atrial depolarization
QRS complex	ventricular depolarization
T wave	ventricular repolarization
U wave	not known; after repolarization
PR segment	short AP block at AV node
ST segment	time btw ventricular depol. and repolarization

EKG: related Electrical & mechanical events

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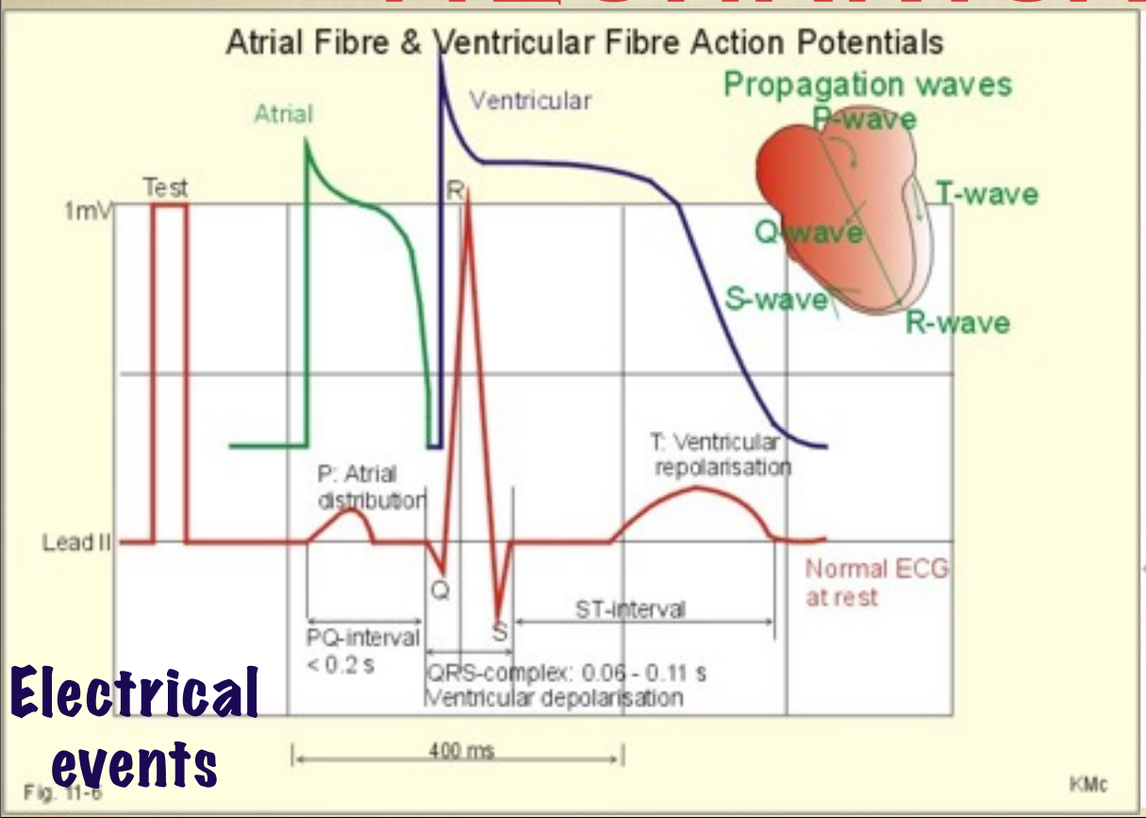
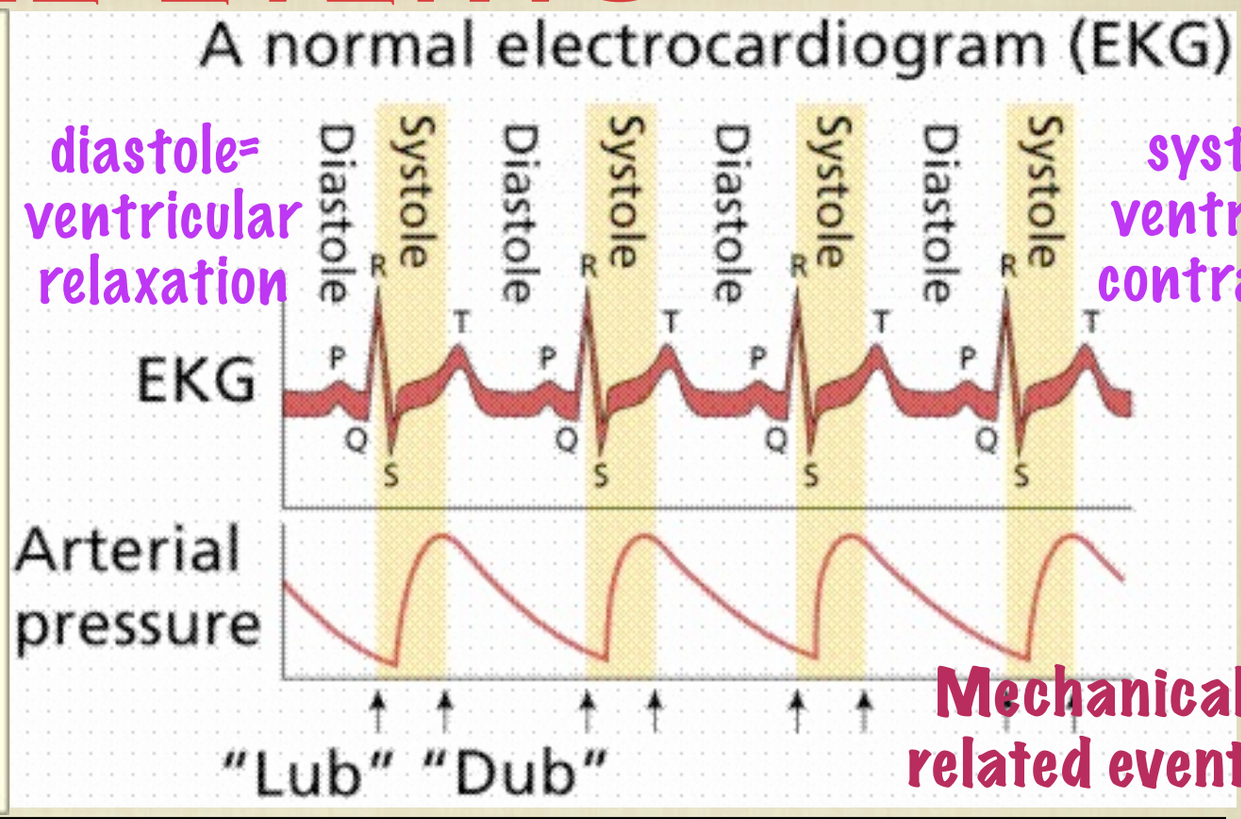


Electrical events

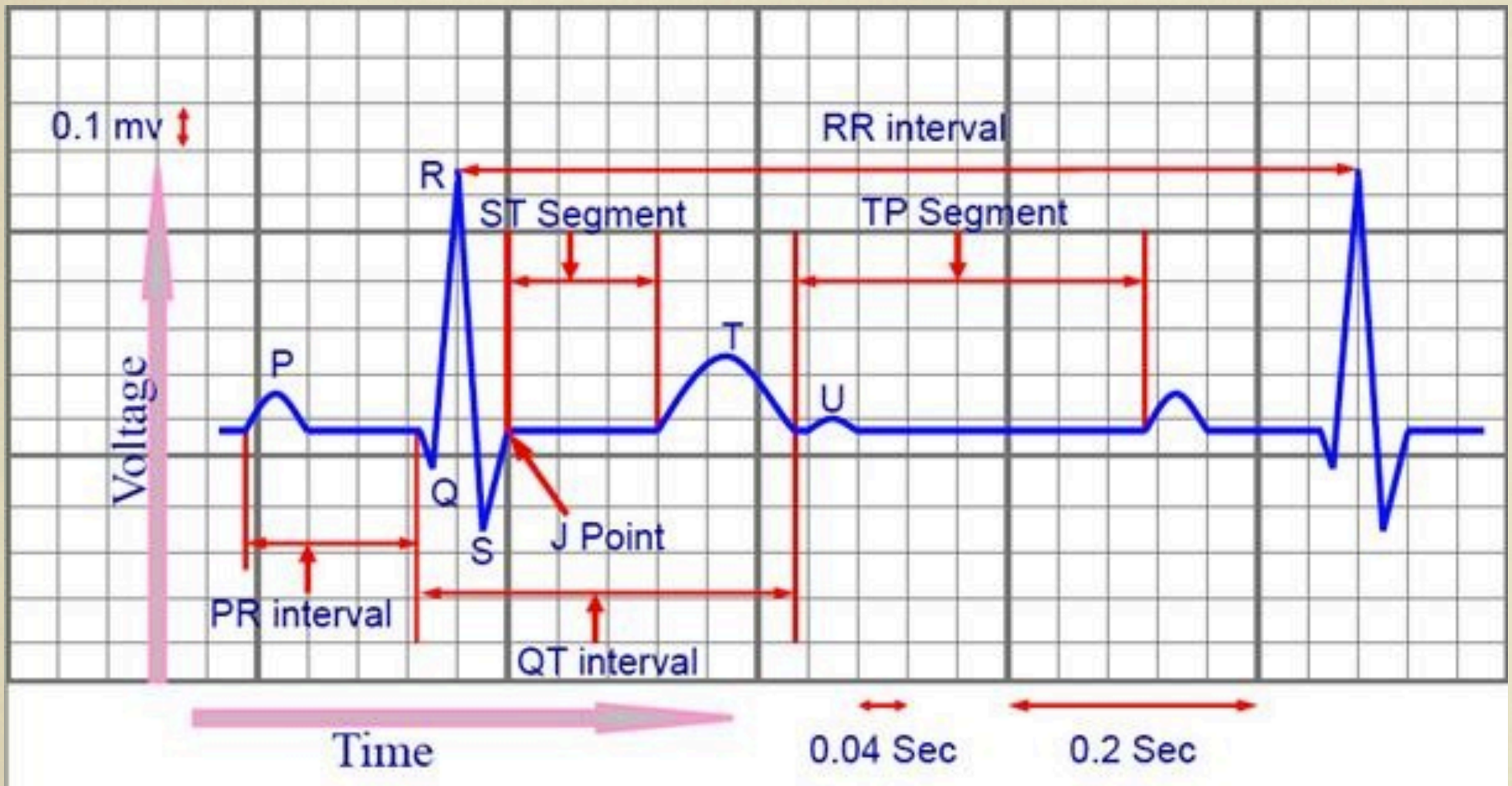


Mechanical related events

EKG	ELECTRICAL EVENTS	MECHANICAL related EVENTS
P wave	ATRIAL depolarization	ATRIAL contraction; VENTRICULAR relaxation
QRS complex	VENTRICULAR depolarization	VENTRICULAR contraction
T wave	VENTRICULAR repolarization	VENTRICULAR relaxation

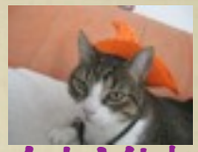
EKG at Rest:Intervals

Duration of the EKG main intervals and QRS complex

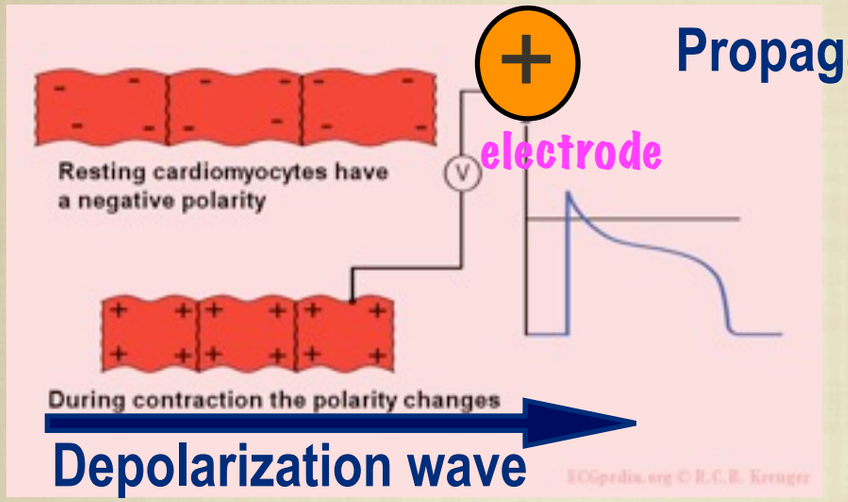


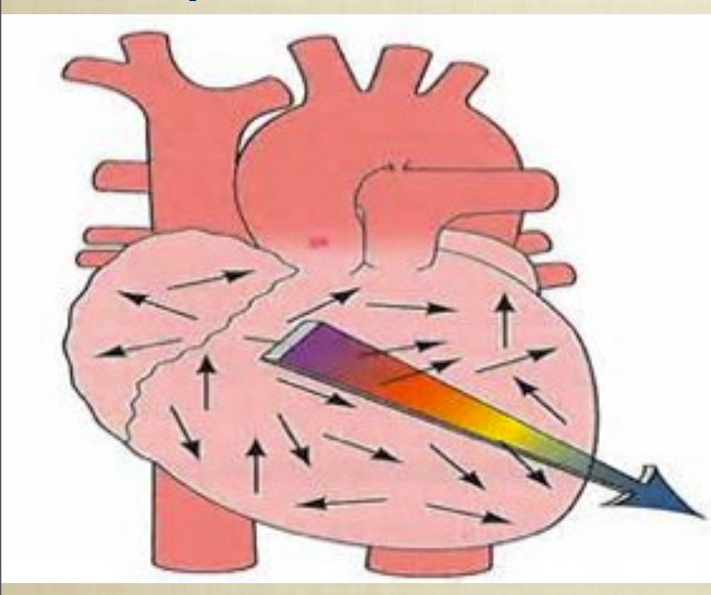
• PR interval	0.12 – 0.20 sec	• QT interval	0.4 – 0.43 sec
• QRS duration	0.08 – 0.10 sec	• RR interval	0.6 – 1.0 sec

EKG: Depolarization Waves

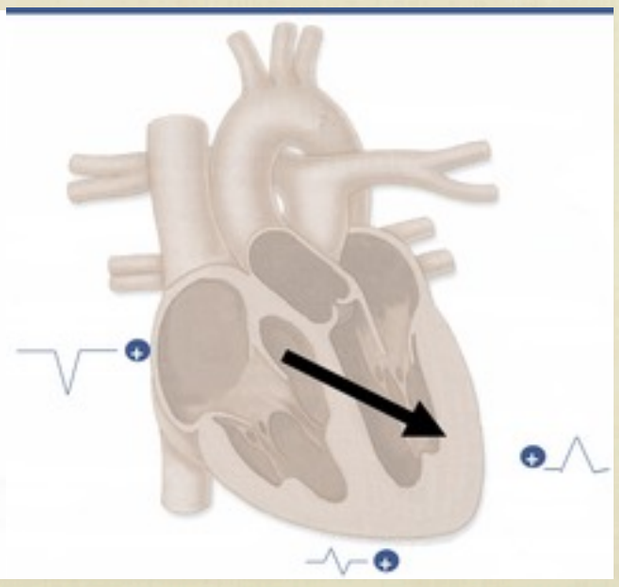


Depolarized cell





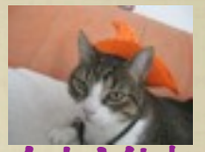
Summation vector

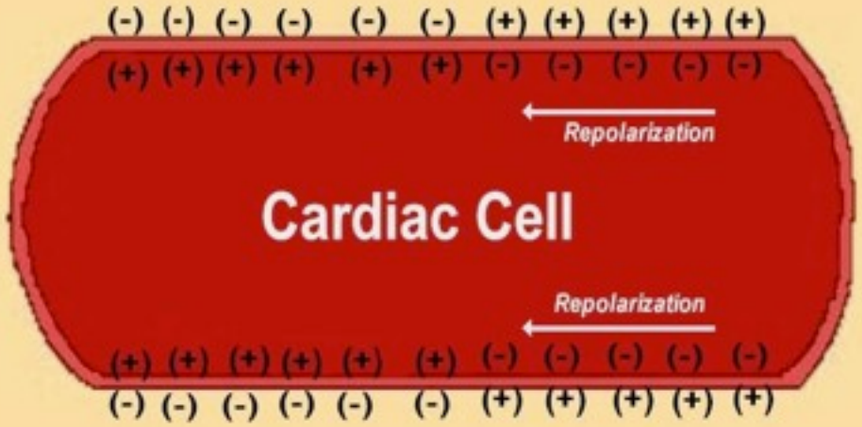


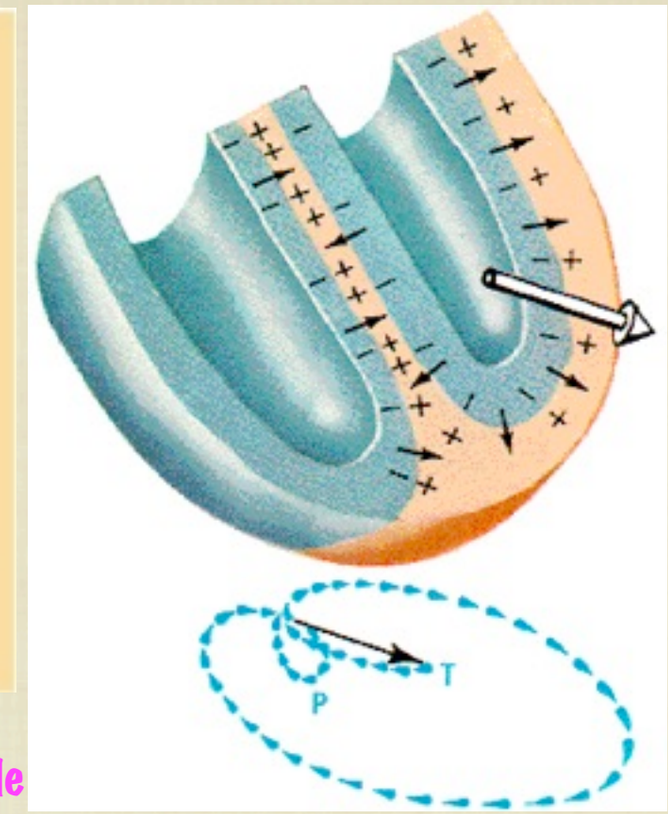
Waves up, down, biphasic

- Depolarization: cell more positive inside than outside.
- Negative charges propagate toward positive electrode.
- Summing up all the individual directions of depolarization we obtain a summation (integral) vector of depolarization.
- If the vector is toward the electrode, the wave registered on EKG is up, if away from the electrode , the wave is down and if perpendicular to the electrode the wave is biphasic
- the peak of the wave= tissue fully depolarized and the isoelectric line= all charges reached the electrode and were neutralized.

EKG: Repolarization Waves







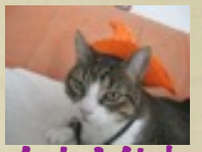
Repolarization summation vector

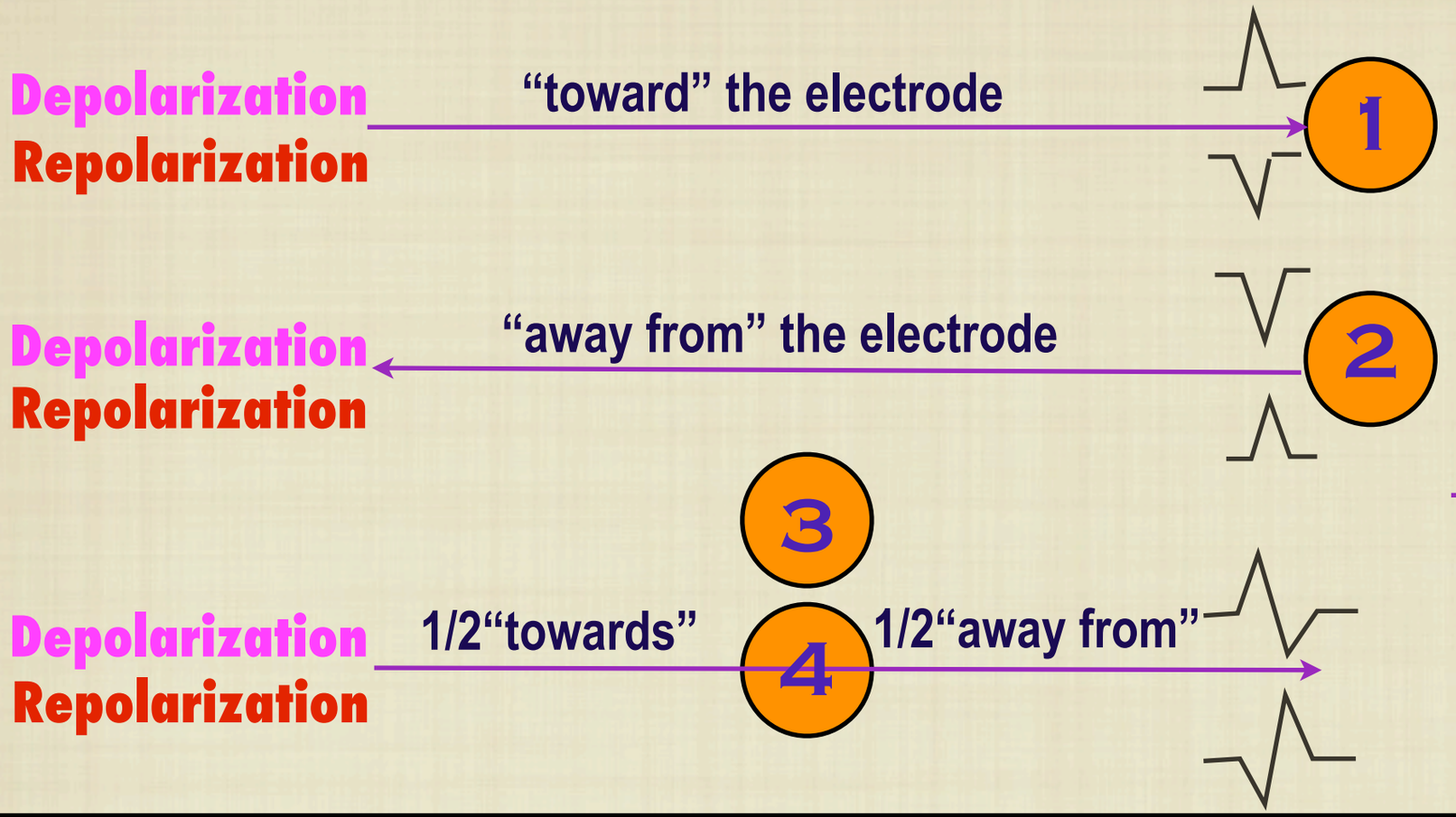
electrode

Repolarized cell

- Repolarization: comes after depolarization and cell turns negative inside from positive.
- Repolarization begins where the depolarization ends up and goes all the way back until all the tissue(cells) is fully repolarized.
- Despite reverse polarity during repolarization, the summation vector points the same direction as the depolarization one, so the repolarization wave (T wave) points in the same direction as the depolarization one(R wave).

EKG at Rest: All Waves(1)


Ask Mish



1, 2 electrodes at the end of propagation way

3, 4 electrodes perpendicular on the propagation way

propagation direction

wave up

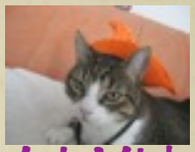
wave down

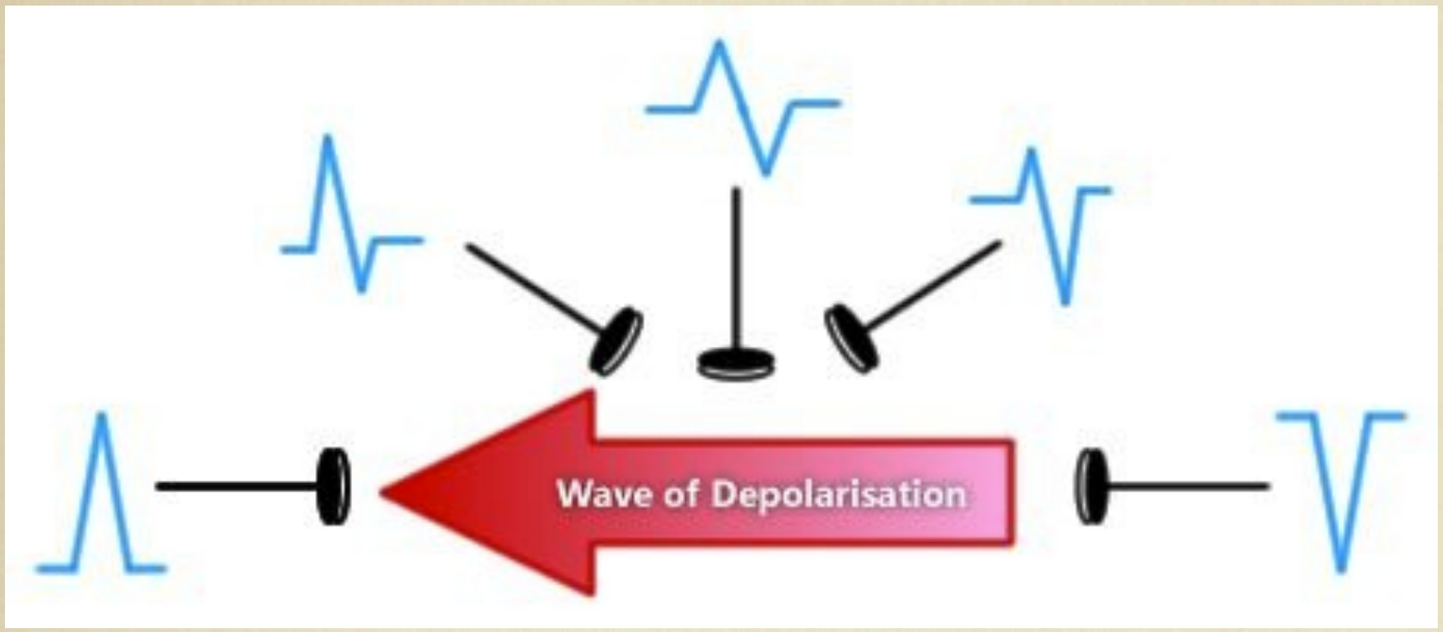
biphasic, 1st +

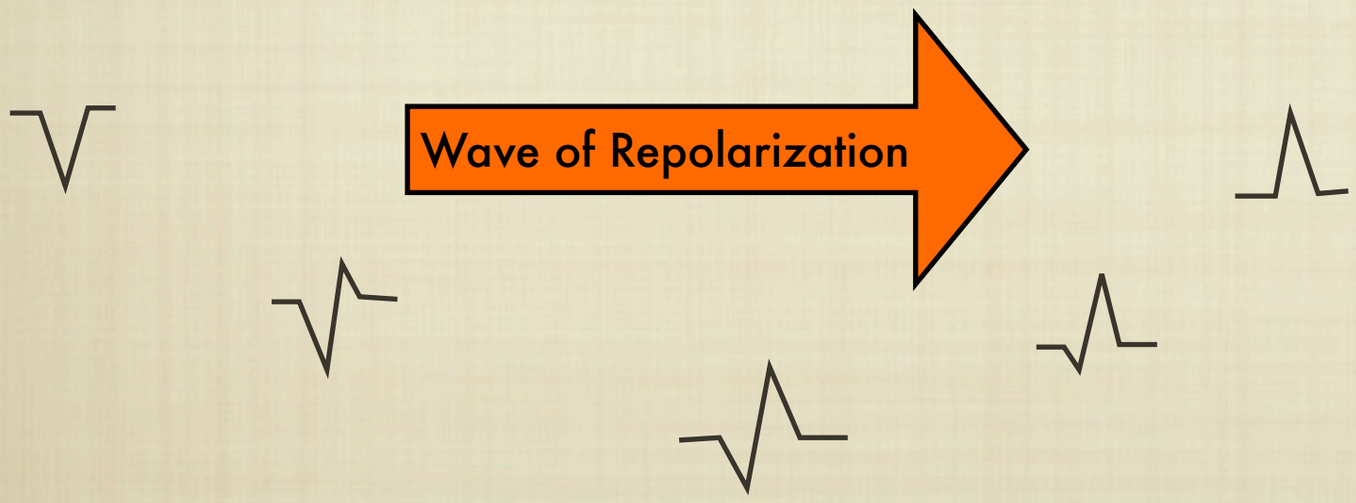
biphasic, 1st -

EKG waves	Depolarization wave	Repolarization wave
toward the electrode	UP (positive deflection)	DOWN
away from electrode	DOWN (negative deflection)	UP
reaching electrode	isoelectric line	isoelectric line
electrode perpendicular	biphasic	biphasic

EKG at Rest: All Waves(2)

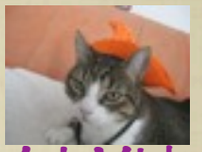


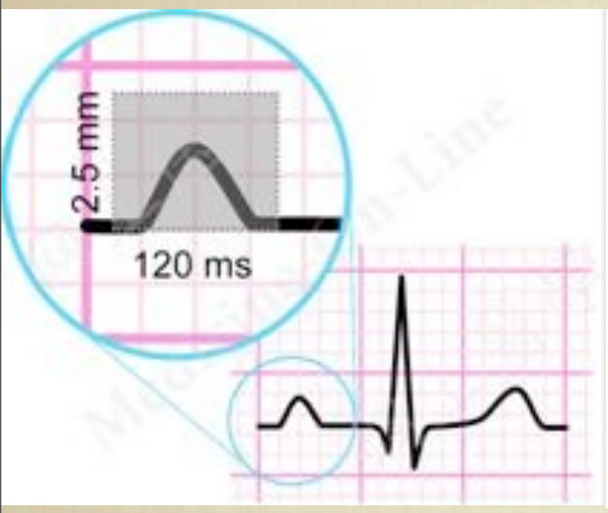


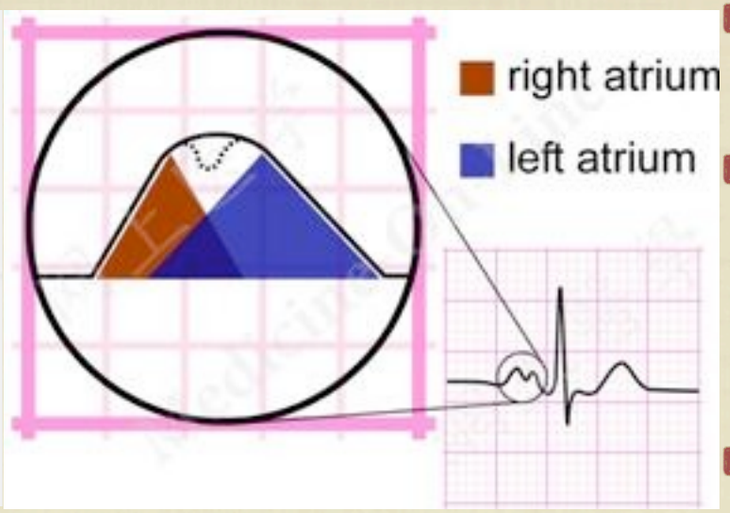


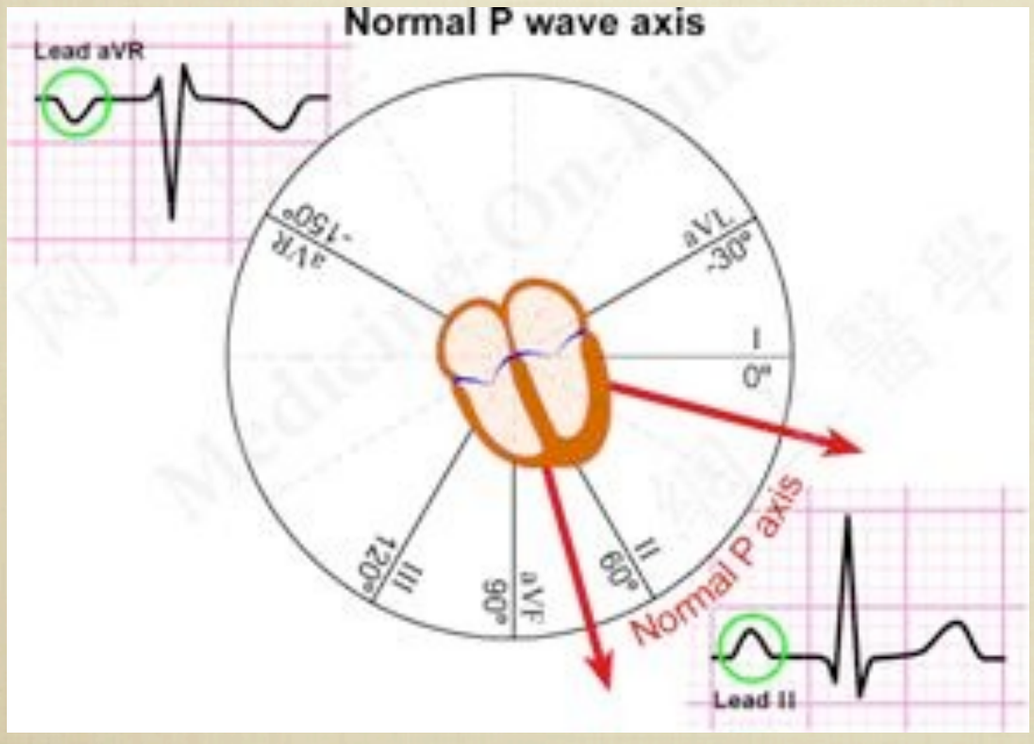
- Electrodes placed in btw those situated on the propagation wave and perpendicular on the propagation wave produce various shaped waves related to the location of the electrode: on the direction of depolarization/ repolarization or away from it.

EKG at Rest: P wave



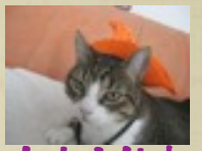


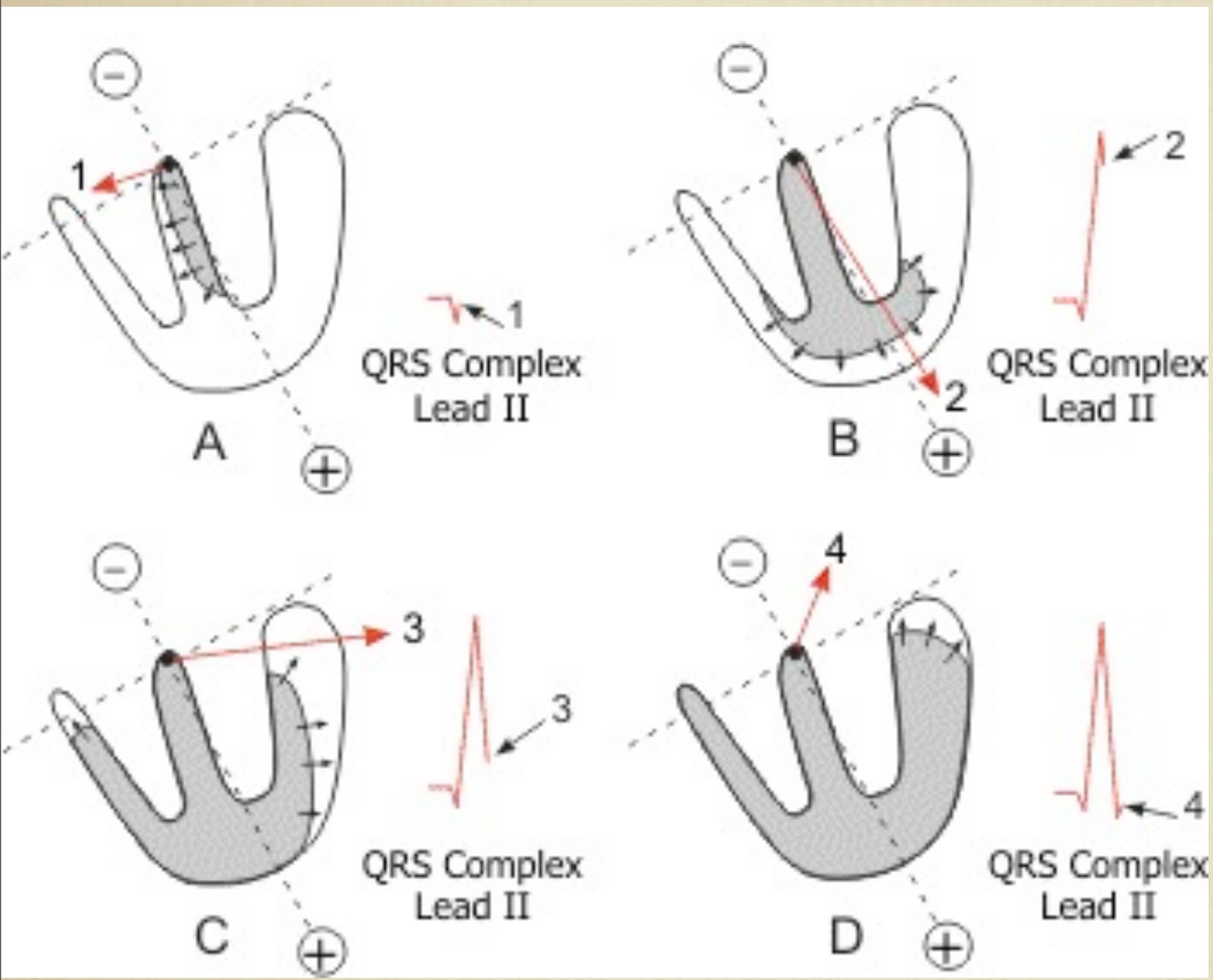




- P wave= atrial depolarization
- Amplitude of P wave < 2.5 mV (2.5 mV = 2.5 small squares); Duration of the P wave < 120 ms
- Since right atrium depolarizes before left atrium, P wave first half is right atrial depolarization and second half is left atrium depolarization
- Atrial depolarization vector normal range is 30-75 degrees.
- P wave is normally + in lead II, - in lead aVR and biphasic or negative in lead III

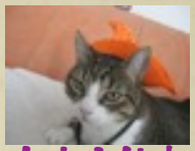
EKG at Rest: QRS complex(1)

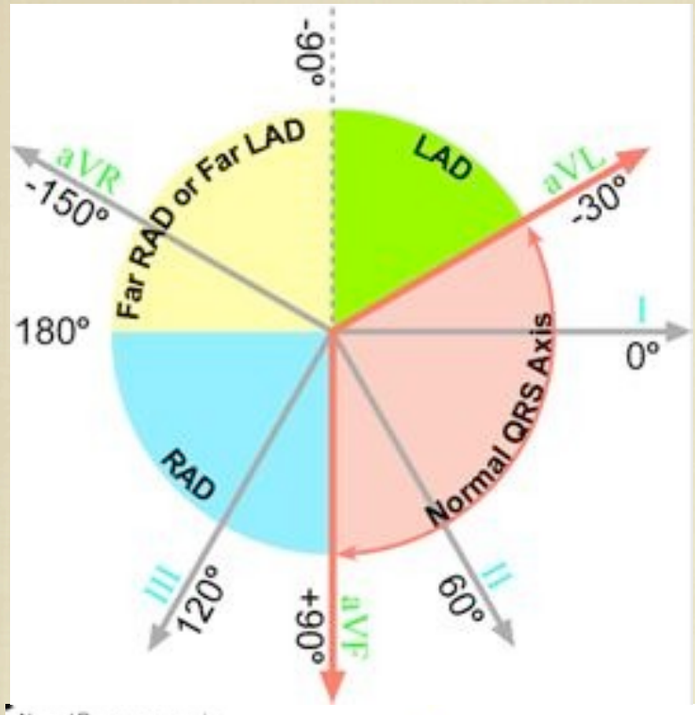


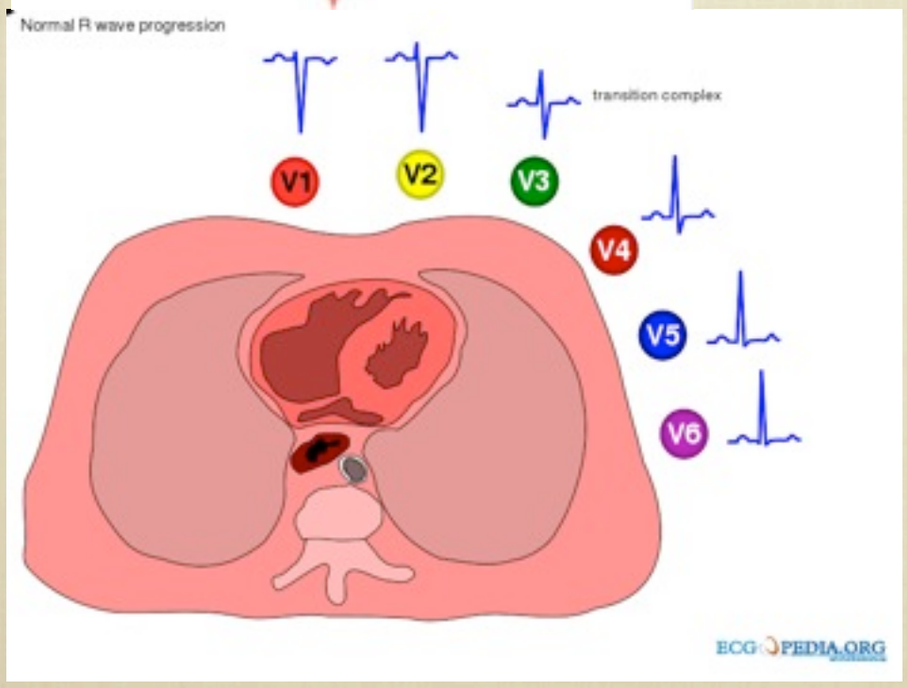


- Q wave represents septal (wall btw R & L ventricles) depolarization. This is the beginning of ventricular depolarization.(1)
- It is propagated from left to right.
- The septal depolarization is initiated by the action potential arrived at the septal fascicle of left bundle branch (LBB)
- Q wave appears as a negative deflection in lateral, inferior and anterior leads with an amplitude < 0.1 mV
- Sometimes Q wave is not visible on a normal EKG

EKG at Rest: QRS complex(2)

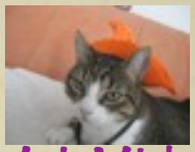


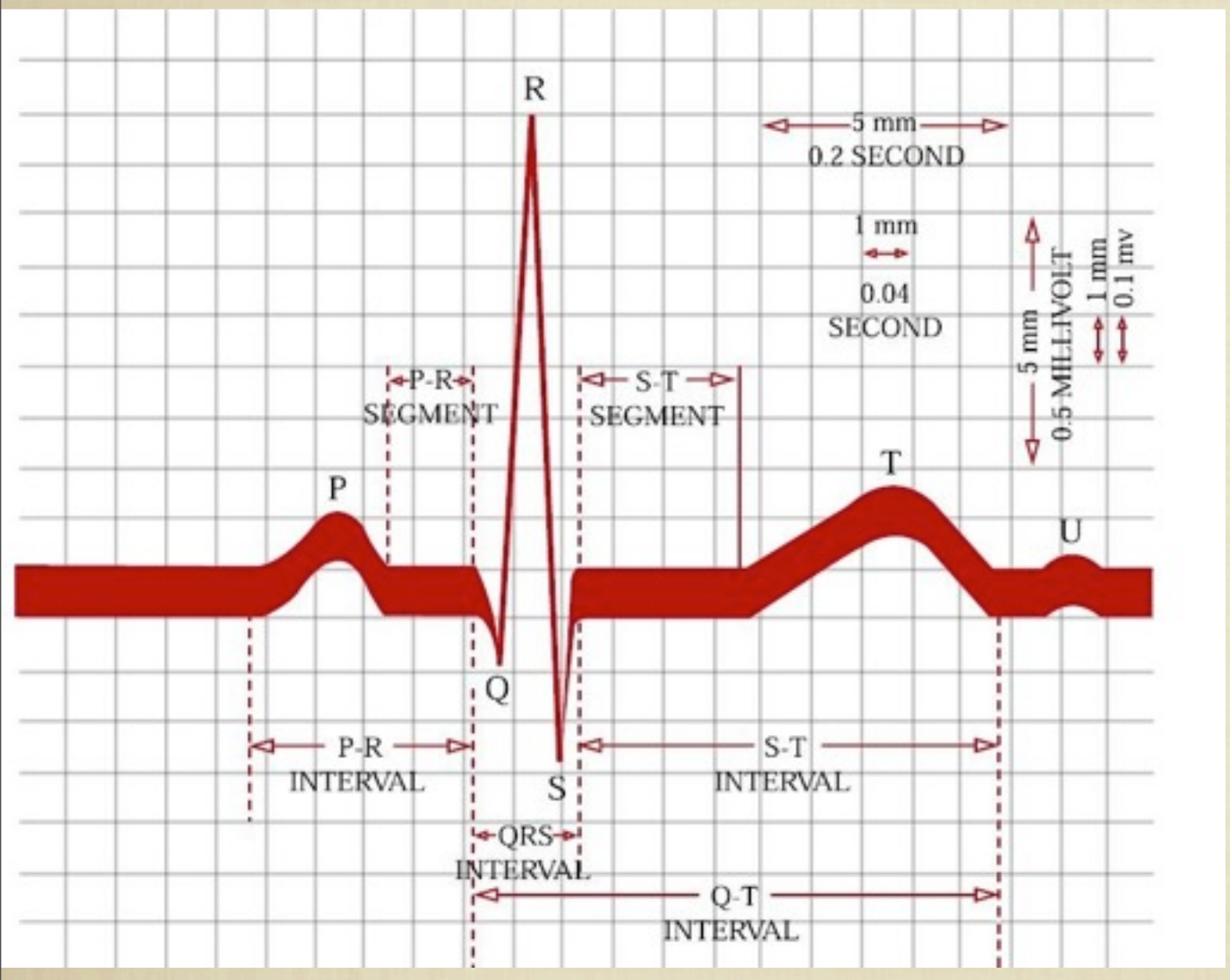




- RS represents VENTRICULAR MUSCLE depolarization. R is the positive deflection and S the negative one.
- Left Ventricle is more massive than the right one and the average vector points left, anywhere from -30 to +90 degrees. So R (positive) waves will be found in the inferior and lateral leads while S(negative wave)in aVR for ex.
- In sagittal plan: V1 and V2 covers the R ventricle while V5 and V6 the L ventricle. So an S wave will appear in the first 2 V leads and an R in the last 2 V leads. V3 and V4 are biphasic and called transition zone.
- The progressively increasing R wave from right to left in the precordial leads is known as R-wave progression
- QRS amplitude >> P wave amplitude due to much more muscle mass of the ventricles in comparison with the atria generating a greater action potential

EKG at Rest: Segments





- PR segment represents the time from the end of atrial depolarization and the beginning of ventricular depolarization.
- Normal PR: 0.12-0.2s.
- ST segment represents the time from the end of ventricular depolarization and the beginning of the ventricular repolarization.

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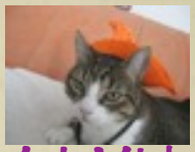

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