Σύζευξη διέγερσης-συστολής στον καρδιακό μυ

ΗΚΓ

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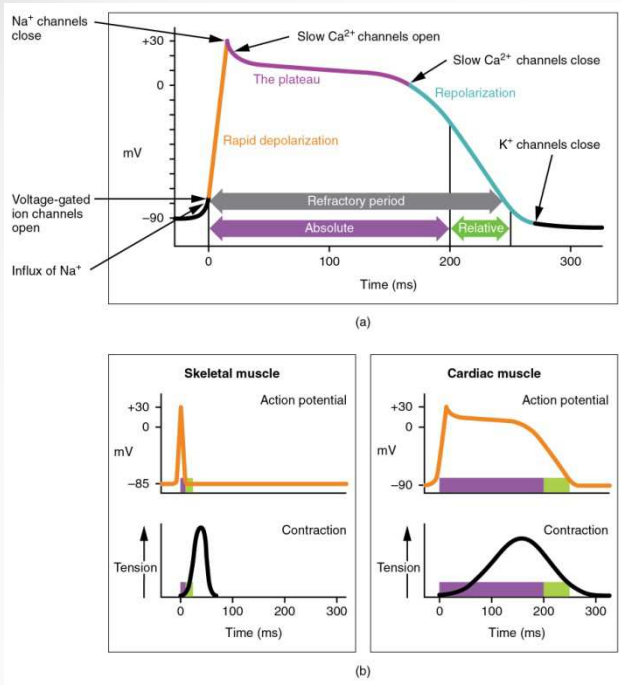
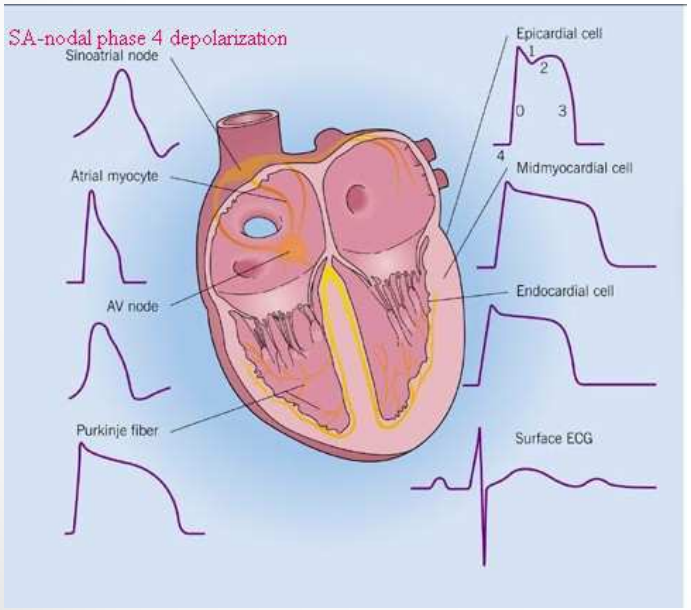
Λάρισα 21-11-2013





- Nerve and skeletal muscle APs are relative brief consisting of
  - A rapid depolarization phase
  - A rapid repolarization phase.
- The entire process of the nerve and skeletal muscle APs is largely complete within a few milliseconds.

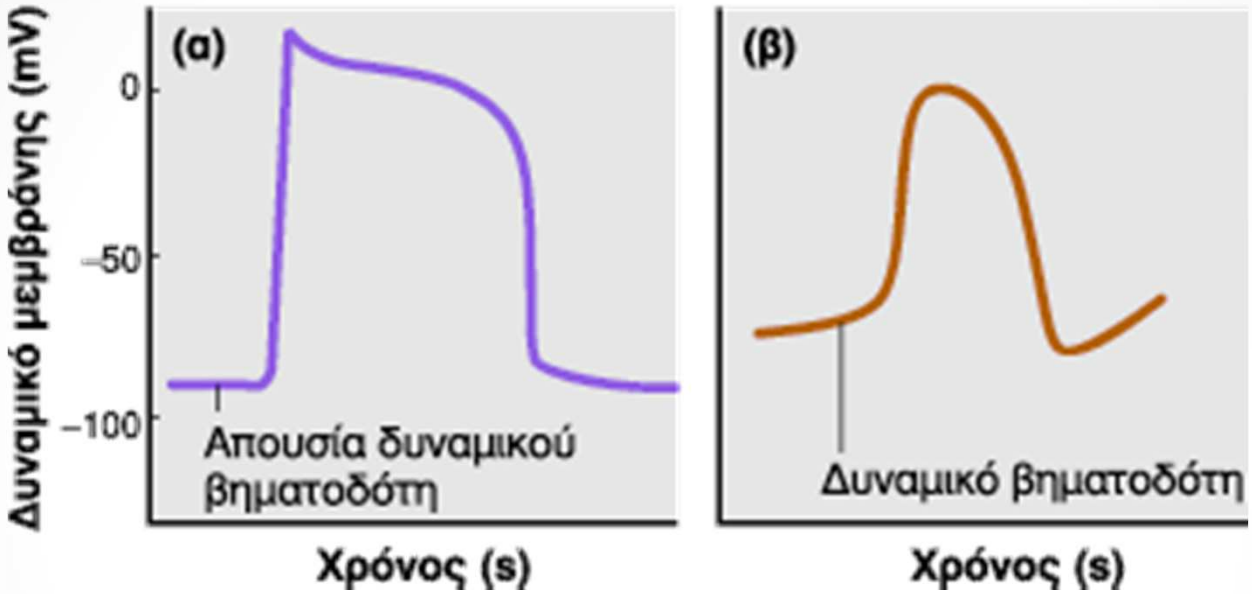
In cardiac cells,

✓ APs are more complex and generally much longer in duration.

✓ Thus for example a typical cardiac ventricular AP may be least 100-200 ms in duration.

✓ Unlike for nerve and skeletal muscle cells, APs from different regions of the heart **vary substantially in shape**.

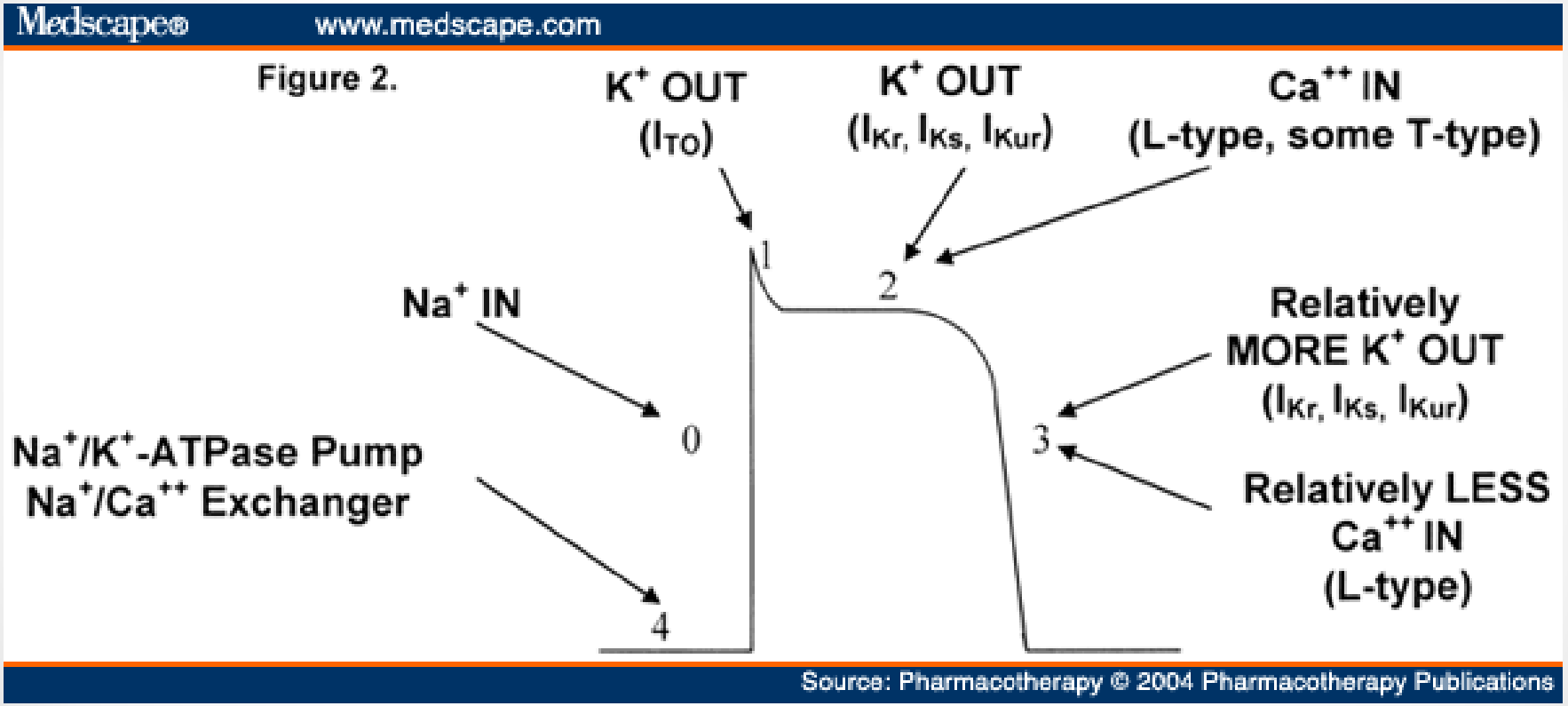
Types of cardiac cells



There are two primary types of cardiac cells.

- ✓ One cell type is found in the working cells of atria, ventricles, and the specialized conduction cells of the His-Purkinje network.
- ✓ The second type of cardiac cell is found in the sinoatrial and atrioventicular nodes

Phases of the venticular action potential and primary currents responsible



The L-type calcium current is central to many aspects of cardiac function

- Excitation contraction coupling

- Ca^{2+} influx stimulates Ca^{2+} release from internal stores

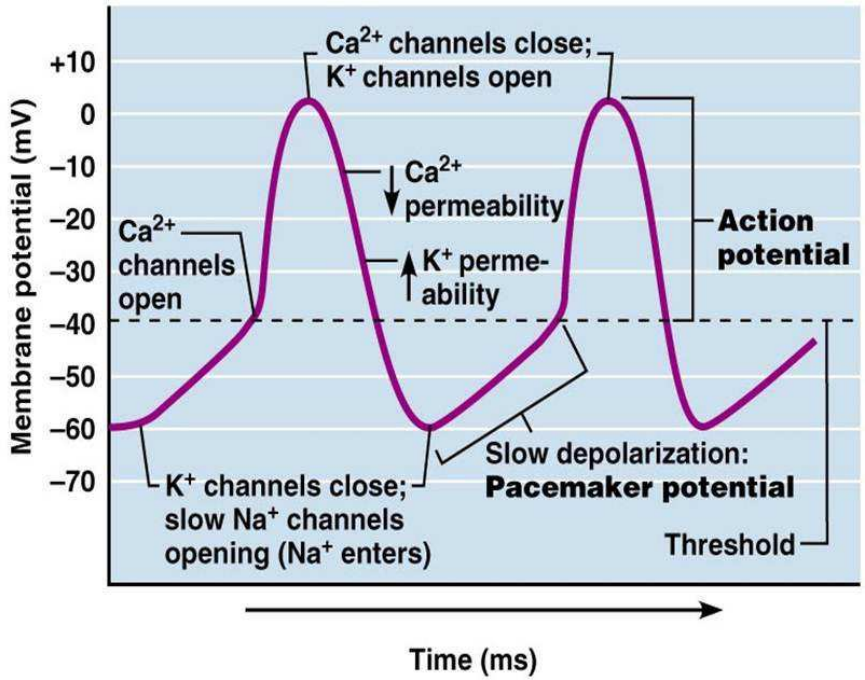
- Ca^{2+} current is important in automaticity and conduction (nodal AP)

- Is a major regulatory site in control of cardiac electrical activity and contraction by neurotransmitters, hormones, intracellular ions

e.g

Norepinephrine → production cAMP →
stimulation of cAMP-dependent protein kinase →
Phosphorylation of Ca^{2+} channels →
enhance of channel activity

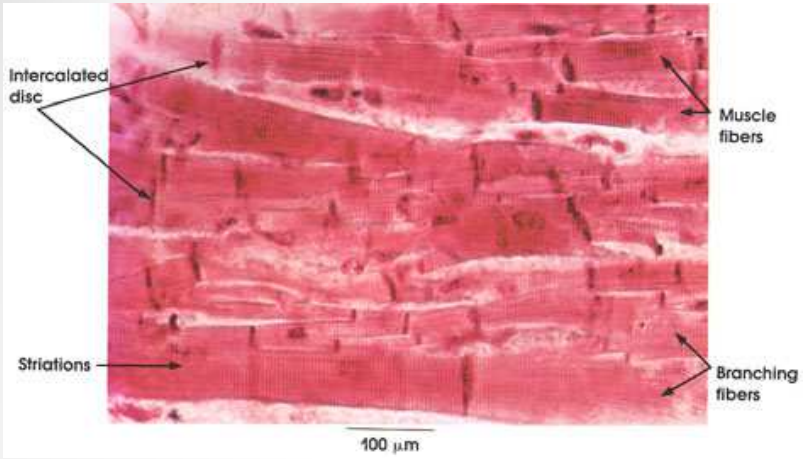
Automaticity: funny current (I_f)



- Automatic cells do not have a stable resting potential between APs, but rather have a maximum diastolic potential following by spontaneous phase 4 depolarization known as pacemaker potential.
- The slope of the pacemaker potential largely determines the rate of AP firing

- The primary current responsible for the pacemaker potential is funny current.
- Funny current is a slow activating inward depolarizing current activated by hyperpolarization, which is present in automatic cells.
- It is nonselective cation current (Na and K)
- In addition to funny current there may be a small contribution of T-type calcium current to the latter stages of the pacemaker potential.

Anatomy



- The anatomy of the heart muscle cell (cardiac myocyte) fits its physiology almost as well as the *intercalated discs* at the end of the cells fit one another! The extensive branching and interdigitation of the cells helps to provide mechanical cohesion of the cells, but more than this, it provides a substrate for electrical cohesion.

- Associated with the intercalated discs is a vast network of "gap junctions" linking the sides of the muscle fibres and providing a low resistance pathway for the rapid conduction of electrical current. Heart muscle functions as a syncitium, despite the fact that it is made up of discrete, individual cells

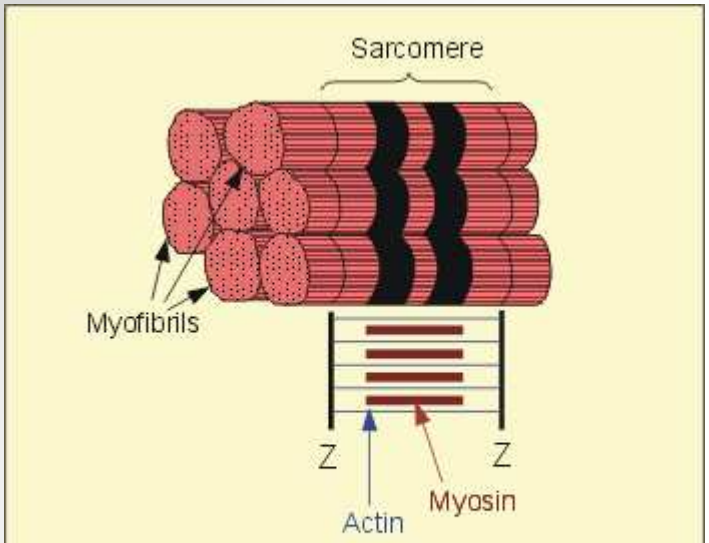


Figure 1. Cardiac myocyte composed of myofibrils, each of which contains myofilaments. The sarcomere lies between two Z-lines.

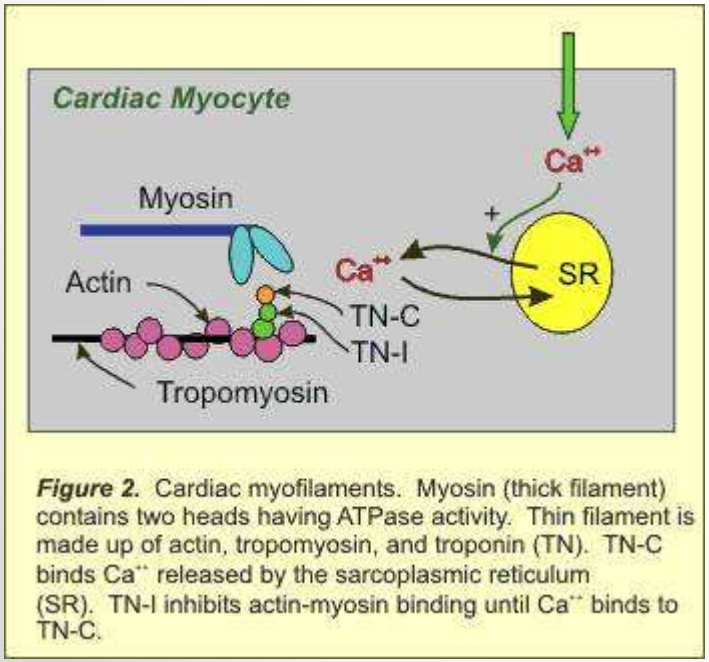


Figure 2. Cardiac myofilaments. Myosin (thick filament) contains two heads having ATPase activity. Thin filament is made up of actin, tropomyosin, and troponin (TN). TN-C binds Ca^{++} released by the sarcoplasmic reticulum (SR). TN-I inhibits actin-myosin binding until Ca^{++} binds to TN-C.

- The 'motor' inside the muscle cell is made up of interdigitating fibres of actin and myosin. This is true for both skeletal muscle and cardiac muscle, although several differences between the two exist.
  - Actin filaments are thin, myosin are thick.
  - The thick myosin fibres have many projecting heads, and it is these tiny heads that swivel backwards and forwards, moving along the actin fibres

- The **sarcomere** is the "fundamental unit" of the muscle cell.
  - It has a Z disk at each end, and the thin actin filaments extend from both Z disks in towards the centre of the cell.
  - The thick myosin filaments are found towards the centre of the sarcomere. We can see where all the microscopic complications arose: the Z band corresponds to the Z disk, a light I band is actually made up of actin filaments from two adjacent sarcomeres, cut in two by a Z disk, and the dark M band is made up of thick myosin filaments in the middle of a sarcomere

How does cardiac muscle differ from skeletal muscle?

- Differences are numerous, including:
  - Skeletal muscle cells have numerous peripherally located nuclei, in contrast to the single centrally located nuclei of cardiac muscle
  - Cardiac myocytes end in intercalated discs
  - Cardiac myocytes have abundant mitochondria
  - T-tubules ramify through the cytoplasm of cardiac myocytes near the Z line, and not (as in skeletal muscle) at the A-I junction

«Διέγερση»
(εκπόλωση της
κυτταροπλασματικής μεμβράνης)

Άνοιγμα των τασεοευαίσθητων διαύλων Ca^{2+} της κυτταροπλασματικής μεμβράνης στα σωληνάρια Τ

Εισροή Ca^{2+} μέσα στο κύτταρο

Πρόσδεση Ca^{2+} σε υποδοχείς Ca^{2+} στην εξωτερική επιφάνεια του σαρκοπλασματικού δικτύου

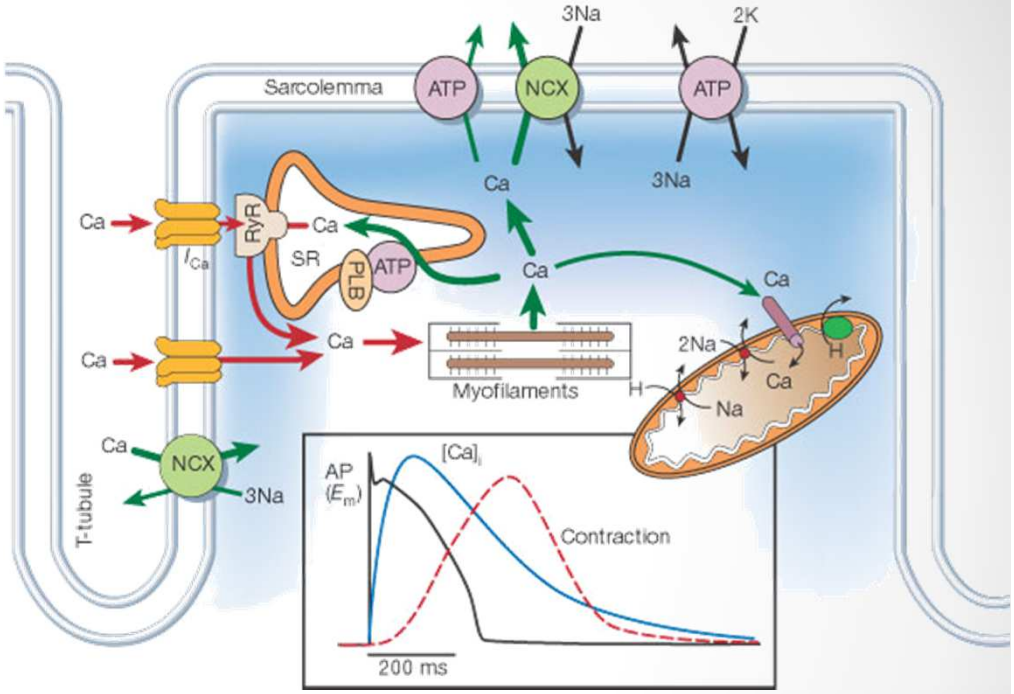
Άνοιγμα εσωτερικών διαύλων Ca^{2+} αυτών των υποδοχέων

Εισροή Ca^{2+} στο κυτοσόλιο

↑ Συγκέντρωσης κυτοσολικού Ca^{2+}

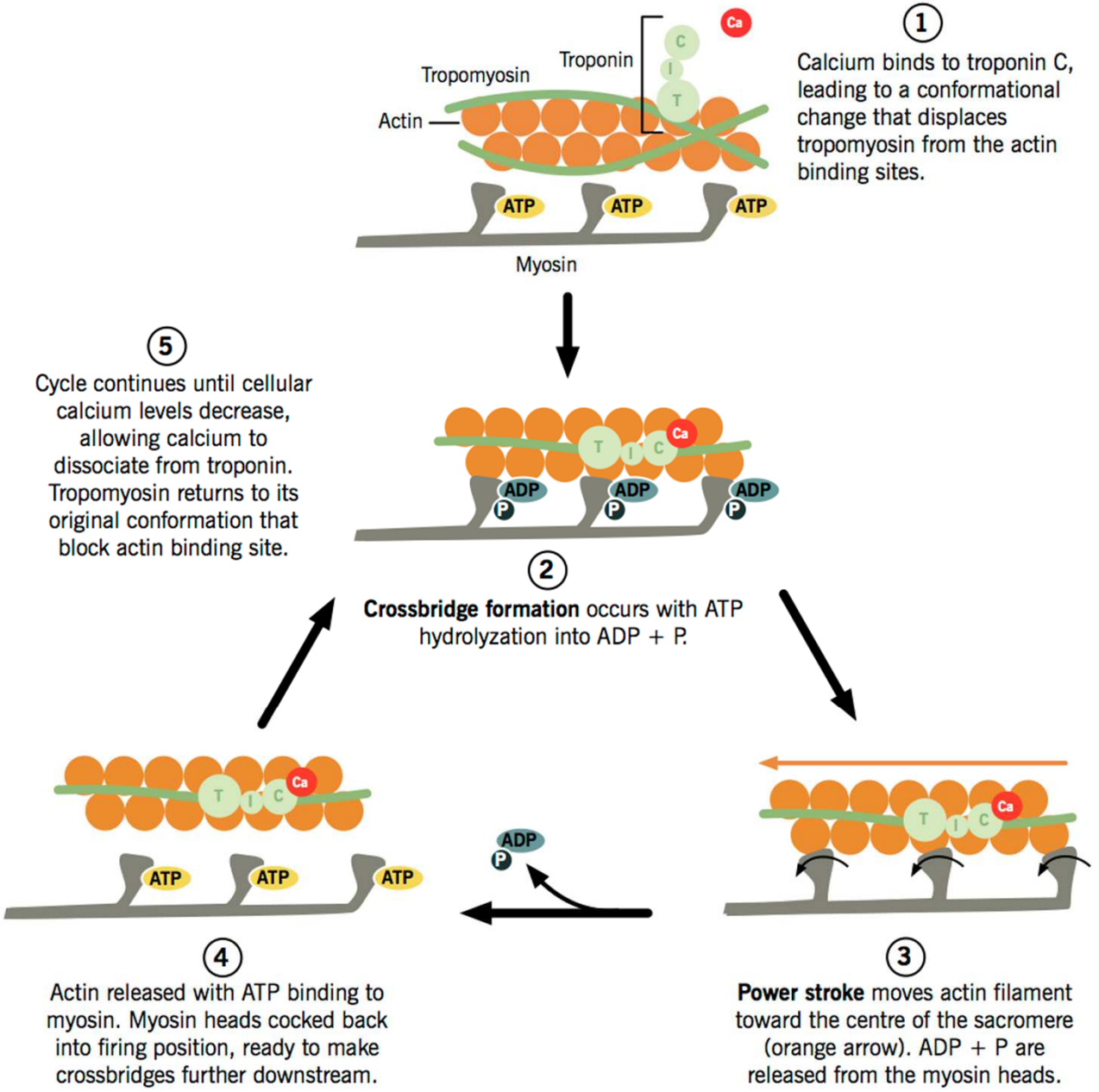
Πολλαπλά βήματα

Συστολή

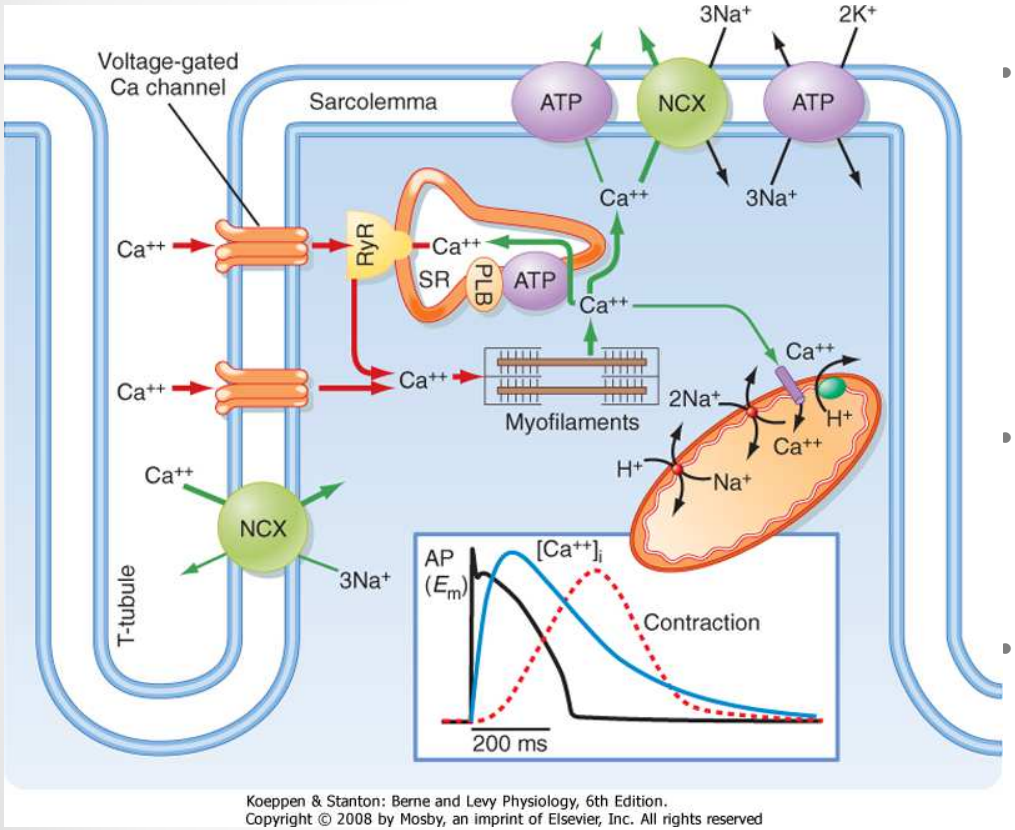


Cardiomyocyte contractile cycle

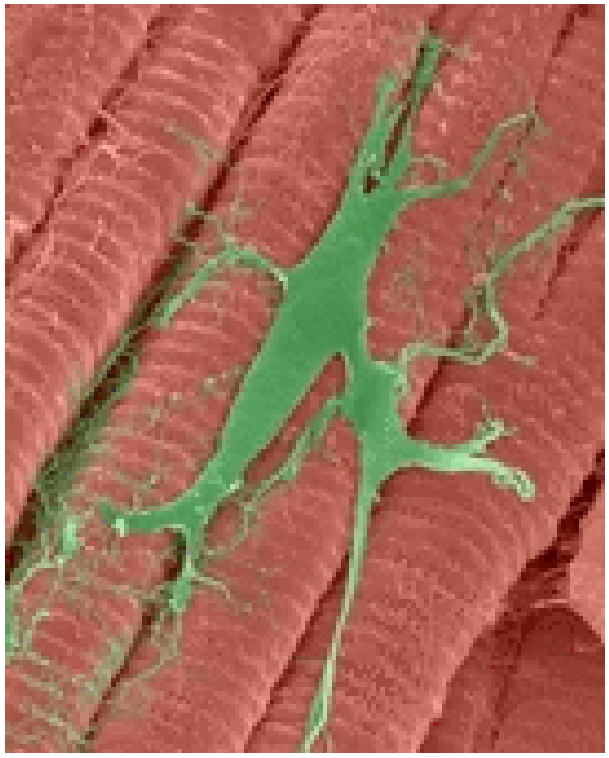
Grigoriy Ikonnikov and Eric Wong



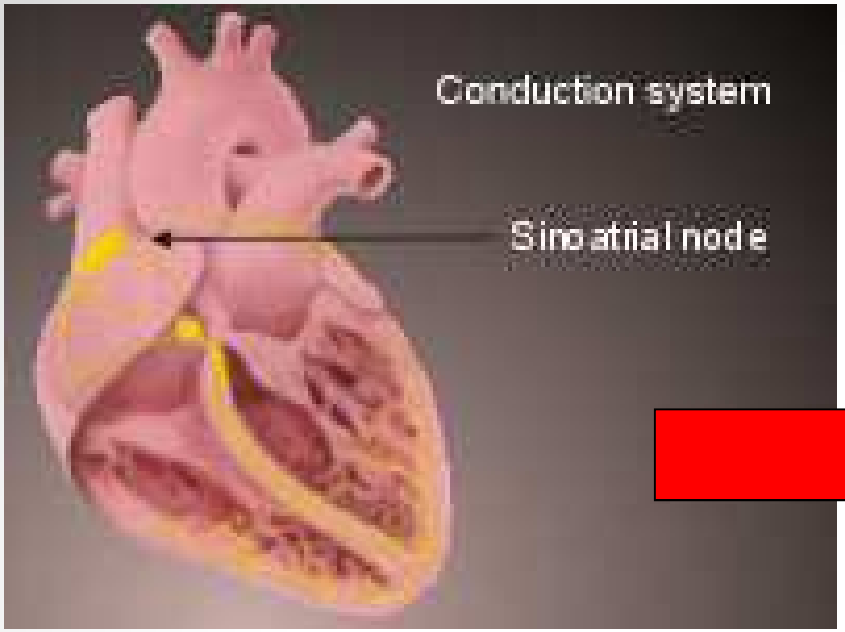
Cardiac Excitation-Contraction Coupling

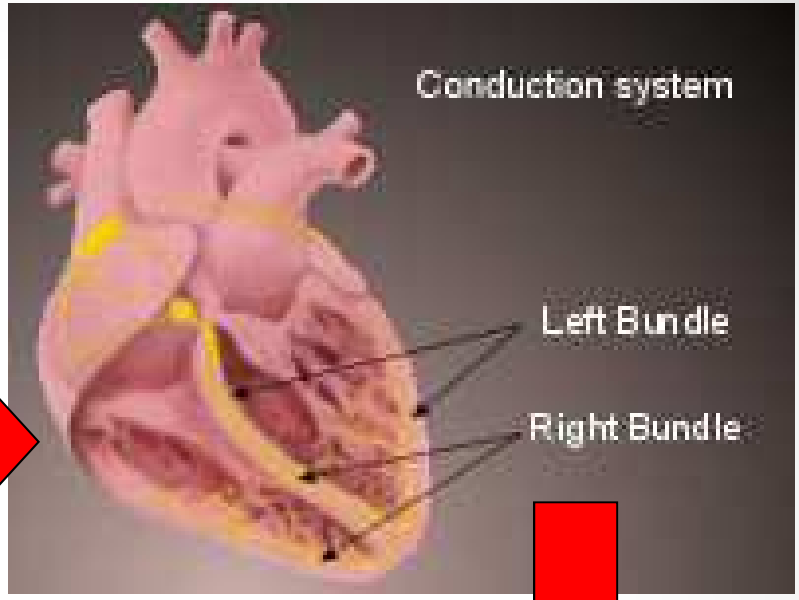


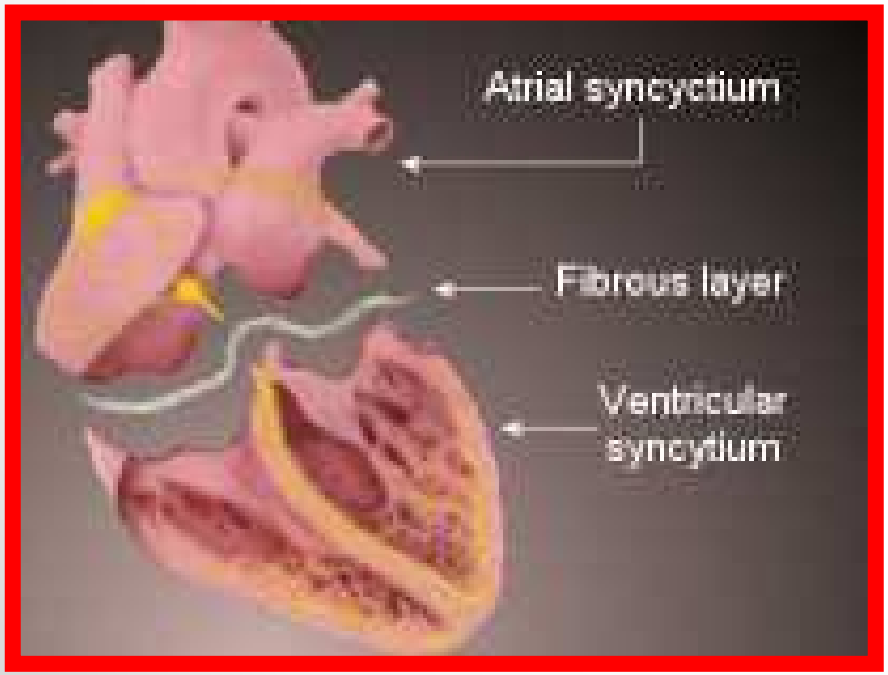
- Ratcheting cycles occur as long as the cytosolic Ca^{2+} remains elevated.
- At the end of phase 2 of AP, Ca^{2+} entry into the cell slows and calcium is sequestered by the SR by an ATP-dependent Ca^{2+} pump (**SERCA**, sarco-endoplasmic reticulum calcium-ATPase), thus lowering the cytosolic Ca^{2+} concentration and removing Ca^{2+} from the TN-C.
- A quantitatively smaller extent, cytosolic Ca^{2+} is transported out of the cell by the **sodium-calcium-exchange pump**.
- The reduced intracellular Ca^{2+} induces a conformational change in the troponin complex leading, once again, to TN-I inhibition of the actin binding site.

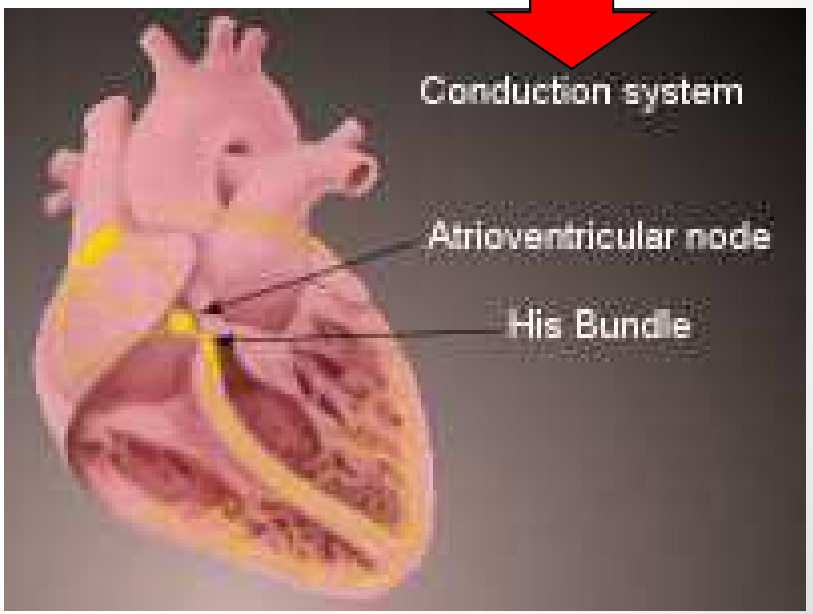


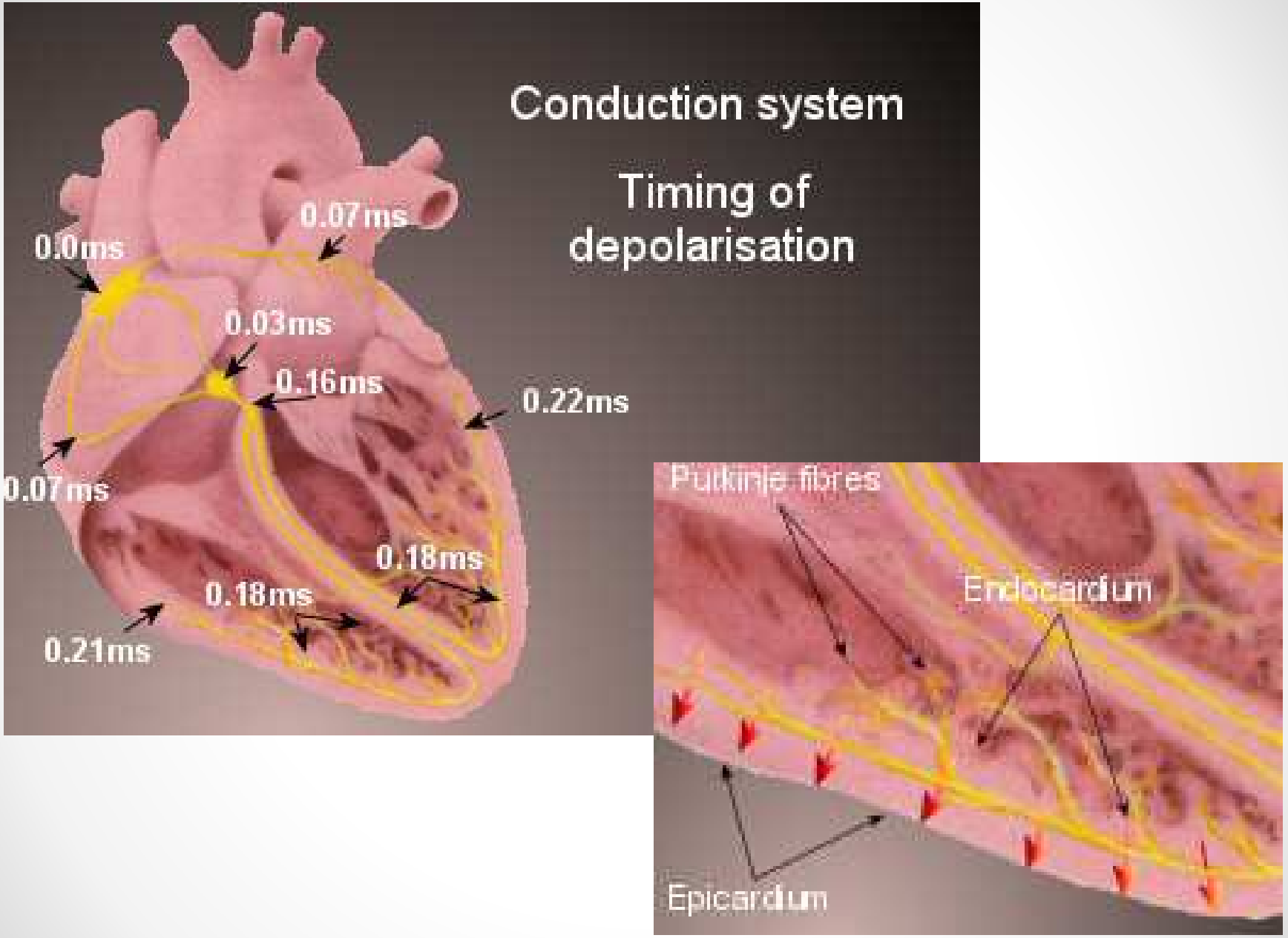
Μεταξύ ινών Purkinje και μυοκυττάρων υπάρχουν ηλεκτρικές συνάψεις

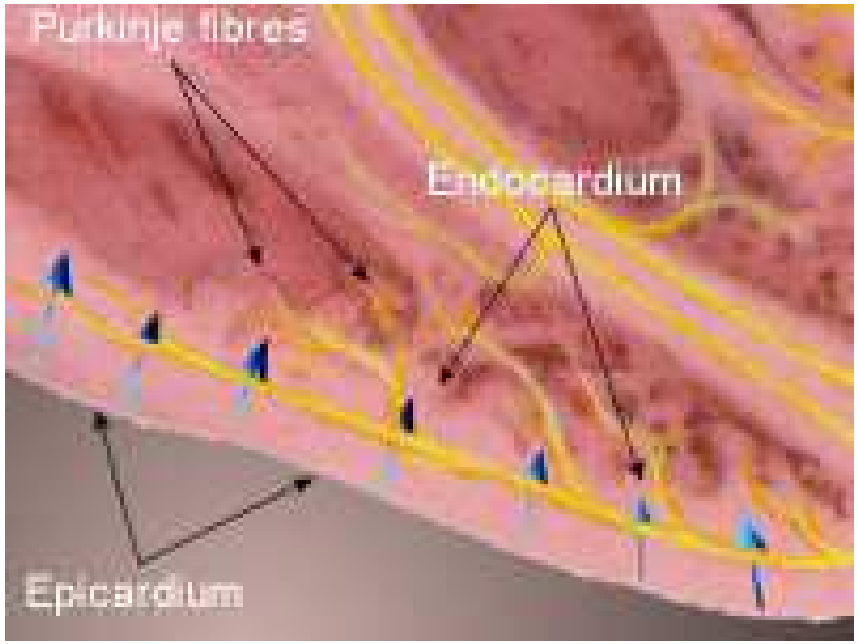

Conduction system
Sino atrial node


Conduction system
Left Bundle
Right Bundle

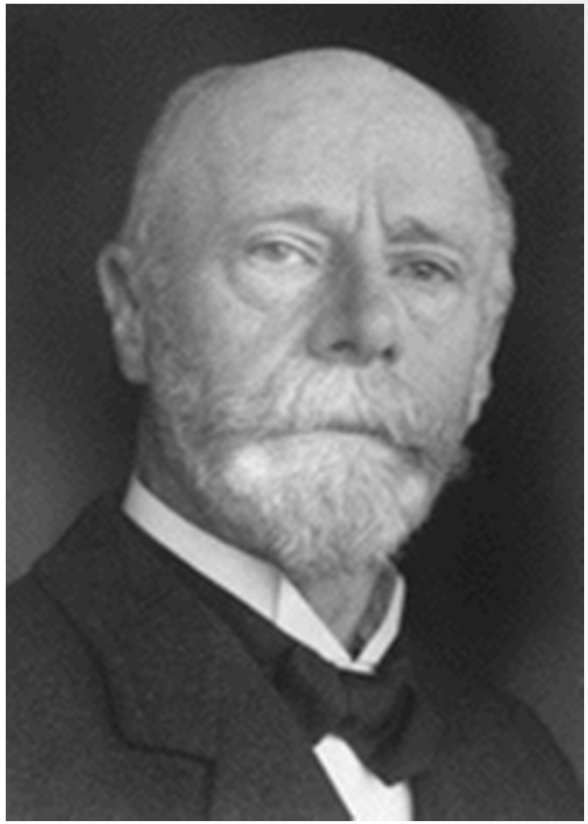

Atrial syncytium
Fibrous layer
Ventricular syncytium


Conduction system
Atrioventricular node
His Bundle


Conduction system
Timing of depolarisation
0.0ms
0.07ms
0.03ms
0.16ms
0.22ms
0.07ms
0.18ms
0.18ms
0.21ms
Purkinje fibres
Endocardium
Epicardium

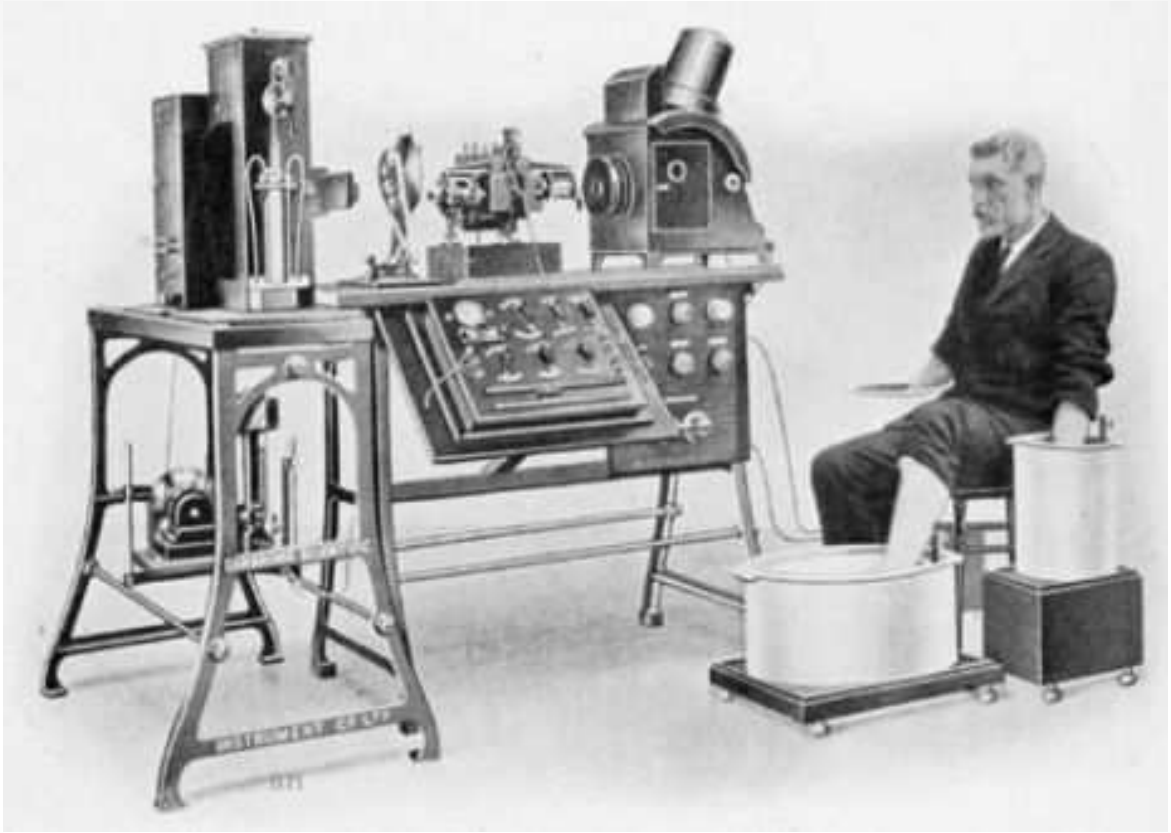

Purkinje fibres
Endocardium
Epicardium

Ηλεκτροκαρδιογράφημα



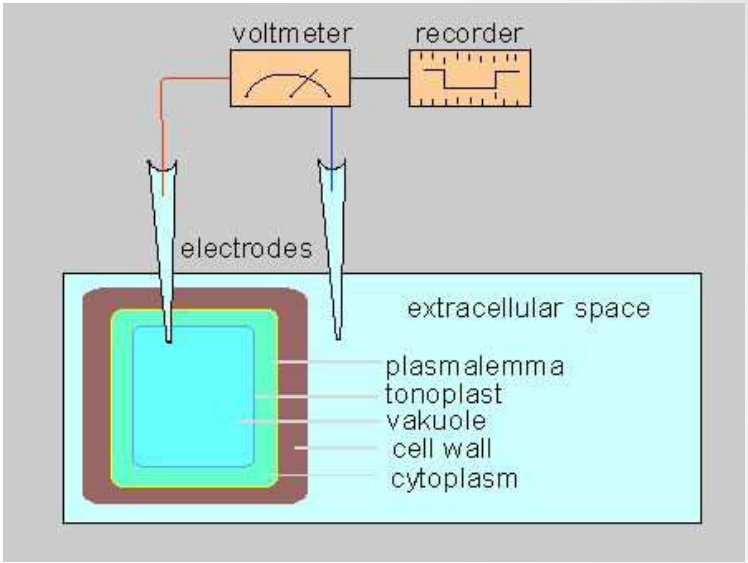
Willem Einthoven

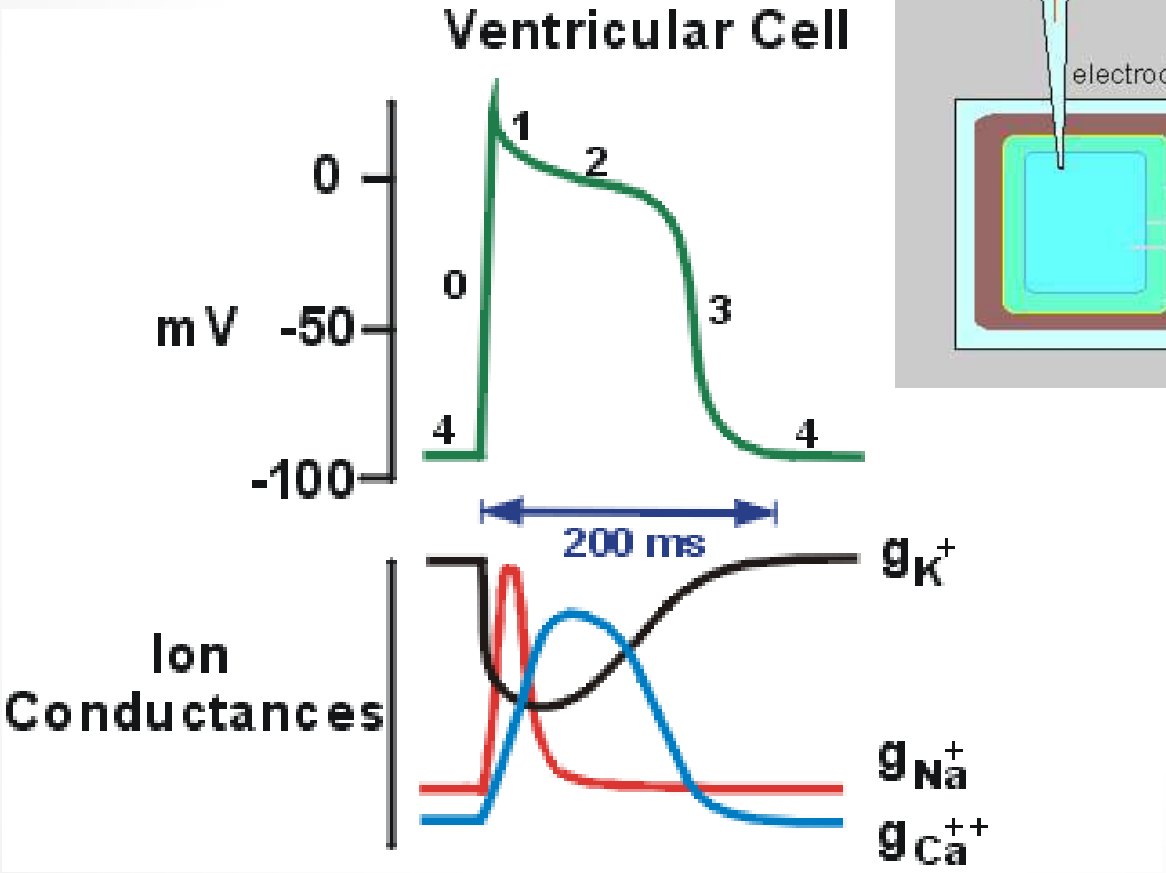
Βραβείο Nobel Ιατρικής
1924



Photograph of a complete electrocardiograph showing the manner in which the electrodes were attached to the patient; the hands and one foot were immersed in jars of salt solution.

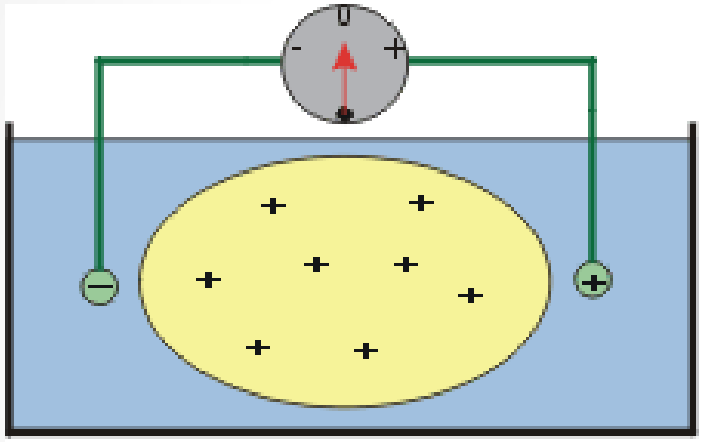
ΕΝΔΟΚΥΤΤΑΡΙΕΣ ΚΑΤΑΓΡΑΦΕΣ



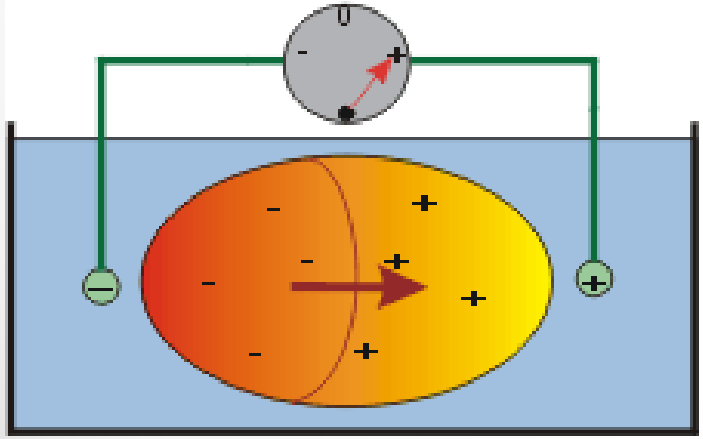


ΕΞΩΚΥΤΤΑΡΙΕΣ ΚΑΤΑΓΡΑΦΕΣ

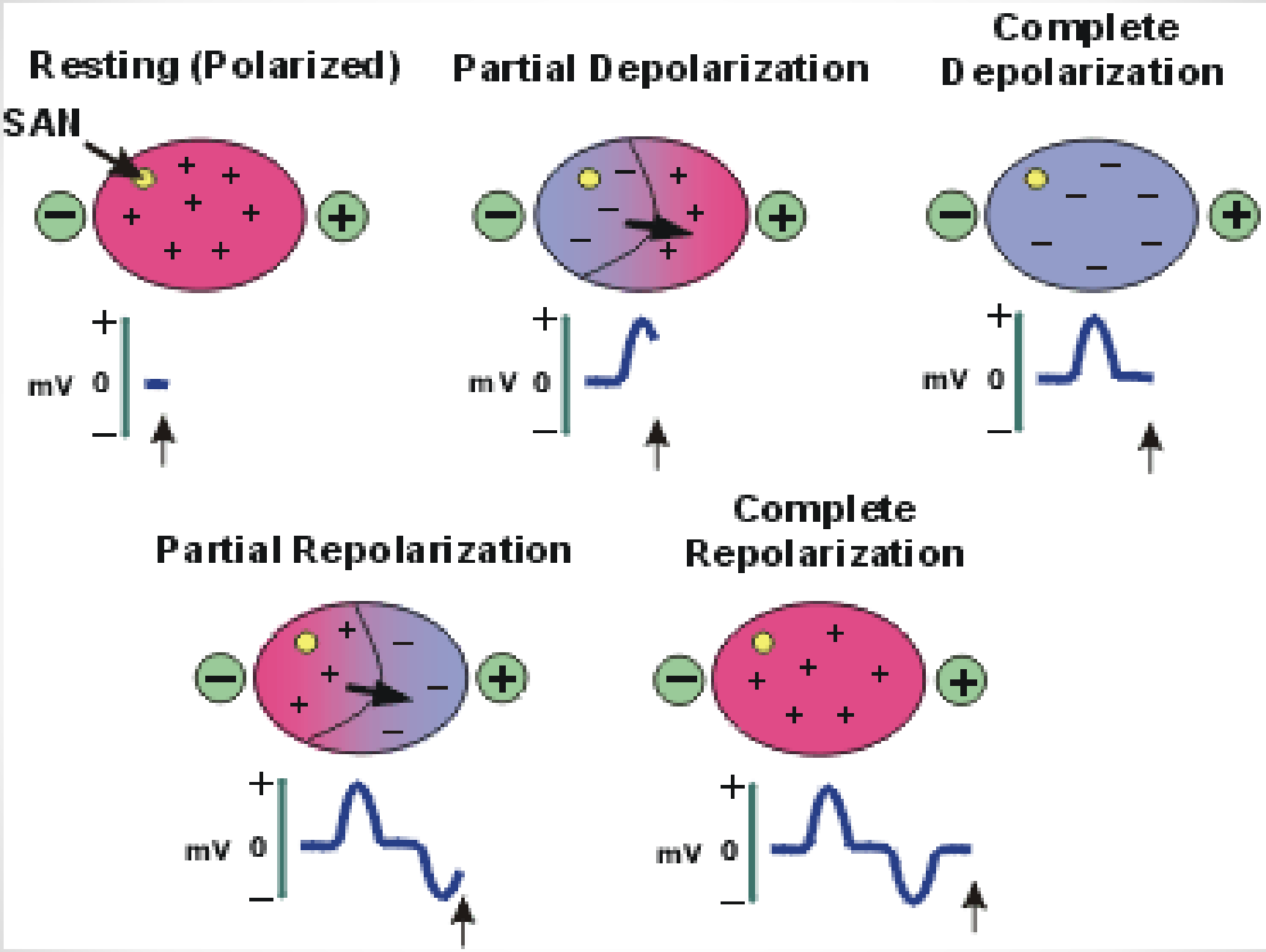
Μυοκάρδιο κοιλιών σε αλατούχο διάλυμα



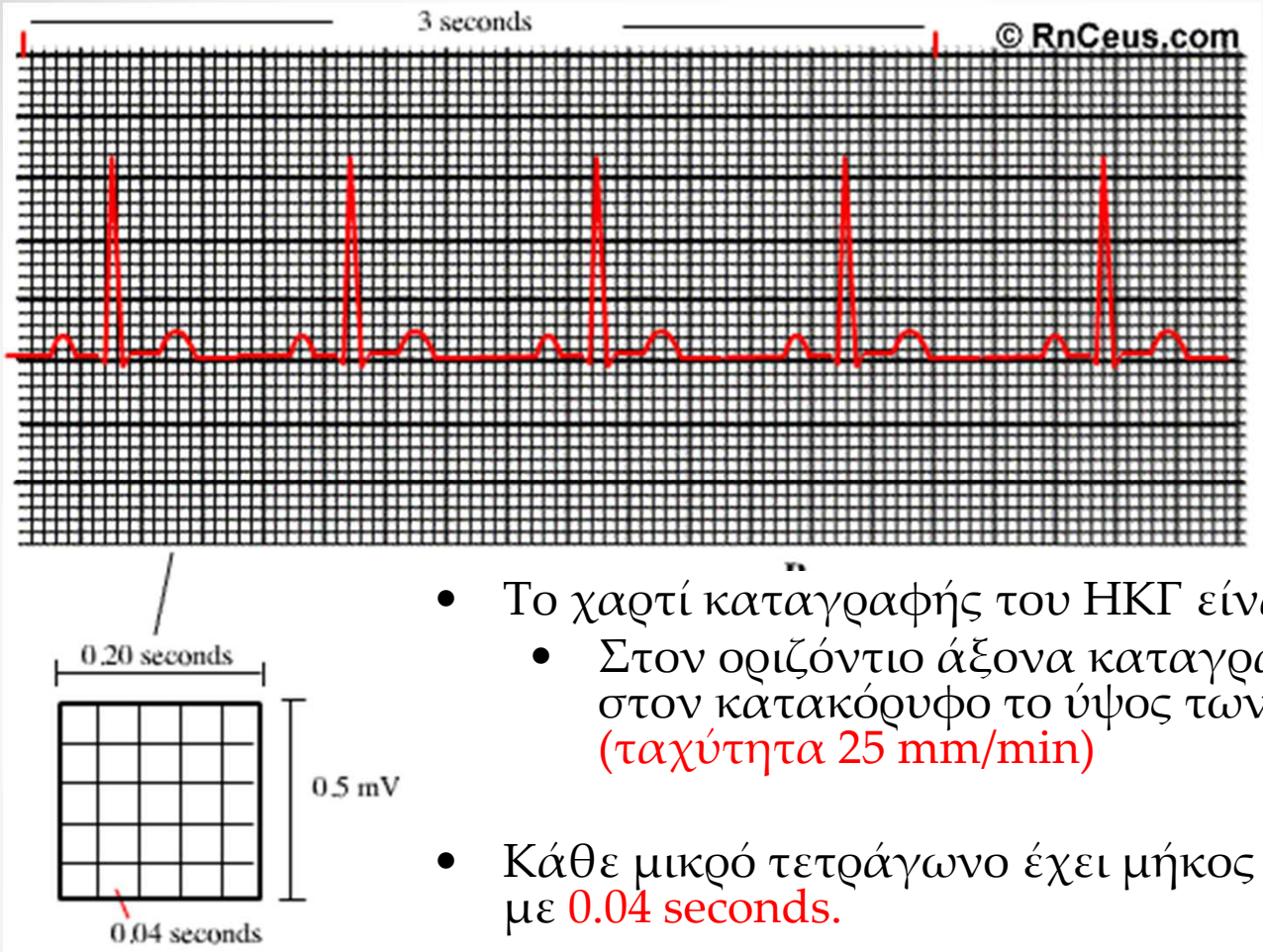
Κατάσταση ηρεμίας (δεν καταγράφεται δυναμικό)



Ηλεκτρική διέγερση ενός άκρου του ιστού και εκπόλωση του (καταγραφή δυναμικών)


Resting (Polarized)
SAN
mV 0
Partial Depolarization
mV 0
Complete Depolarization
mV 0
Partial Repolarization
mV 0
Complete Repolarization
mV 0

- Στο ΗΚΓ χρησιμοποιούμε ηλεκτρόδια που τοποθετούνται στην επιφάνεια του σώματος και μετρούν την ηλεκτρική δραστηριότητα της καρδιάς. Αυτό είναι δυνατό γιατί το σώμα λειτουργεί ως αγωγός του ηλεκτρικού ρεύματος που παράγεται στην καρδιά.



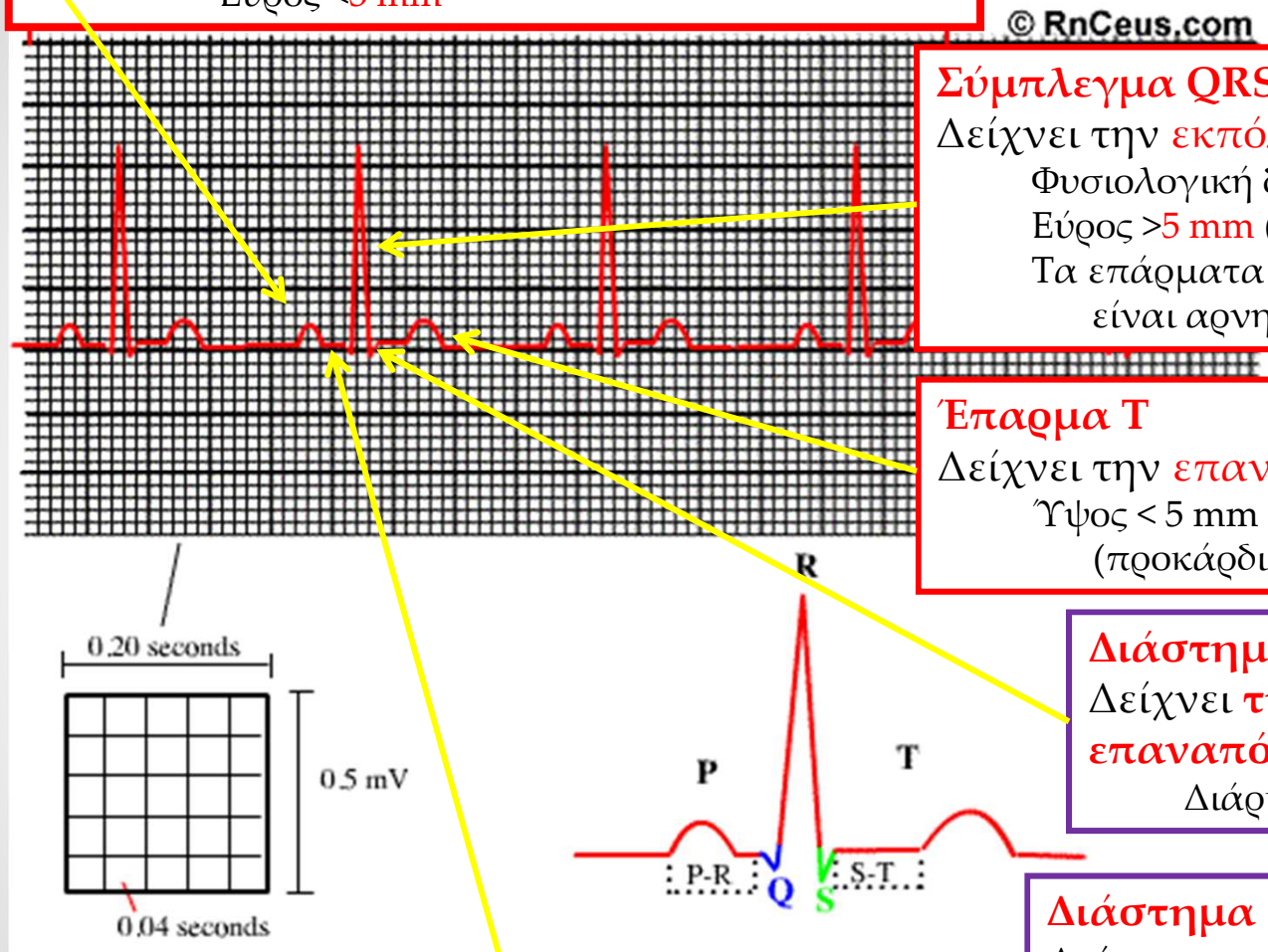
- Το χαρτί καταγραφής του ΗΚΓ είναι διαβαθμισμένο.
  - Στον οριζόντιο άξονα καταγράφεται ο χρόνος και στον κατακόρυφο το ύψος των δυναμικών (ταχύτητα 25 mm/min)
- Κάθε μικρό τετράγωνο έχει μήκος 1 mm και ισοδυναμεί με 0.04 seconds.
- Κάθε μεγάλο τετράγωνο έχει μήκος 5 mm και ισοδυναμεί με 0.2 seconds.
- Το δυναμικό μετράται στον κατακόρυφο άξονα. 10 mm ισοδυναμούν με 1mV

Έπαρμα P

Δείχνει την εκπόλωση ή συστολή των κόλπων.

Φυσιολογική διάρκεια < 0.11s (< 3 mm)

Εύρος <3 mm



Σύμπλεγμα QRS

Δείχνει την εκπόλωση ή συστολή των κοιλιών.

Φυσιολογική διάρκεια < 0.1s

Εύρος >5 mm (απαγωγή II) ή >9 mm (V3 και V4)

Τα επάρματα R είναι θετικά ενώ τα Q και S είναι αρνητικά

Έπαρμα T

Δείχνει την επαναπόλωση των κοιλιών

Ύψος < 5 mm (απαγωγές άκρων) ή 10 mm (προκάρδιες απαγωγές)

Διάστημα ST

Δείχνει **την αρχική φάση της επαναπόλωσης των κοιλιών**

Διάρκεια <5 mm

Διάστημα QT

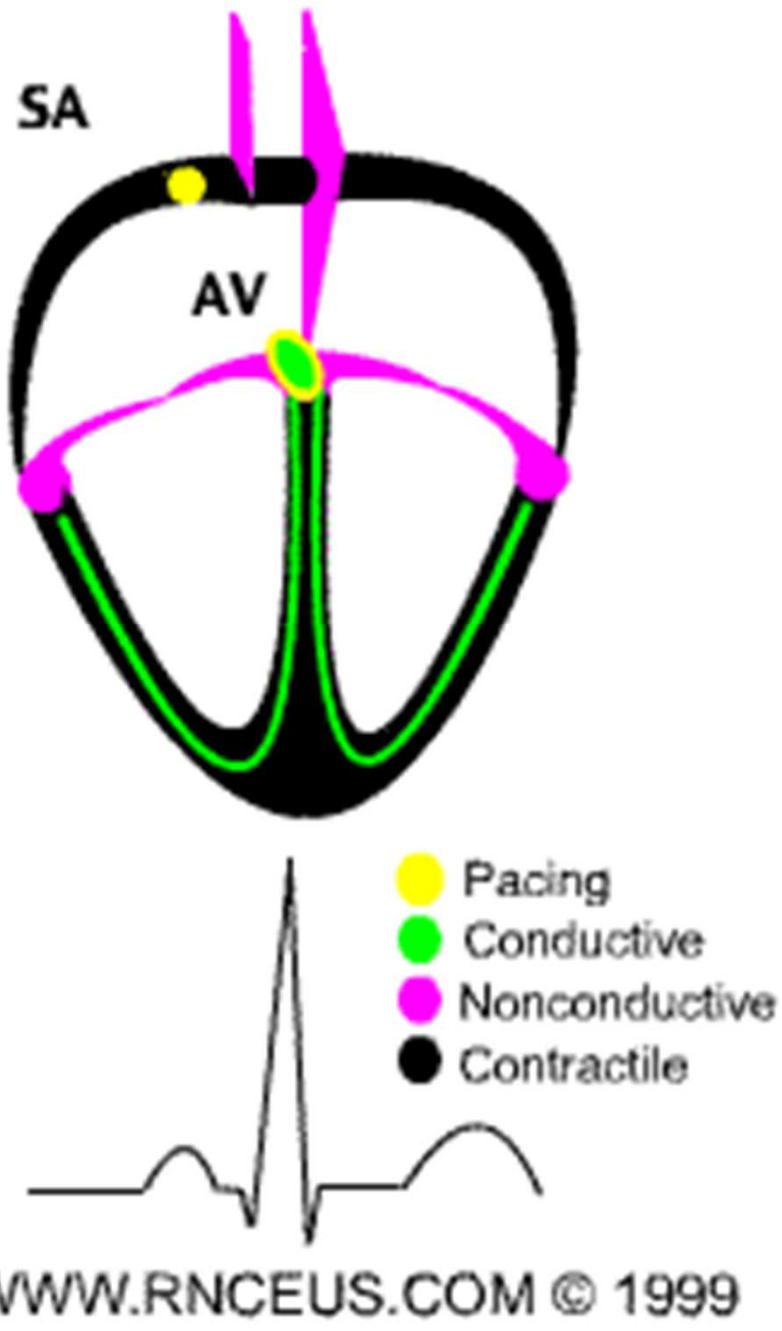
Δείχνει τον χρόνο επαναπόλωσης

Γενικός κανόνας: Διάρκεια μικρότερη από το 50% του προηγούμενου R-R διαστήματος

Διάστημα PR

Δείχνει **τον χρόνο αγωγής του ερεθίσματος από τους κόλπους στις κοιλίες**

Διάρκεια 0.12 έως 0.20 seconds


SA
AV
Pacing
Conductive
Nonconductive
Contractile
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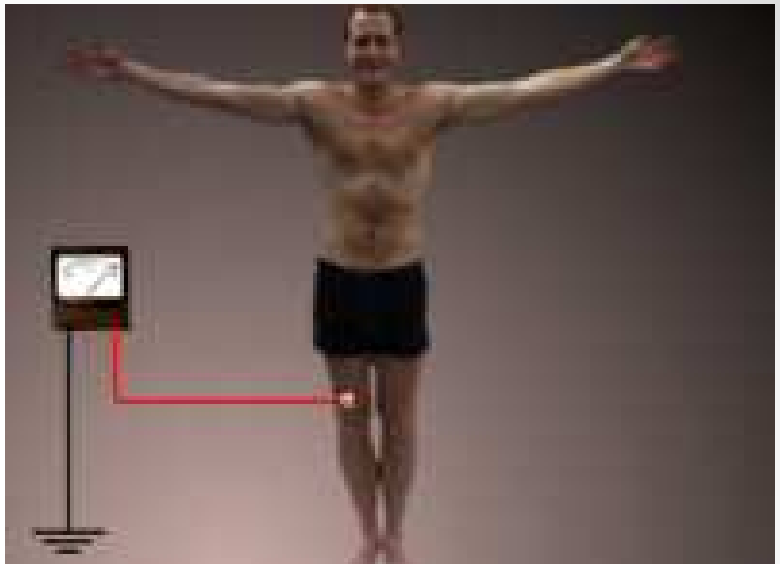
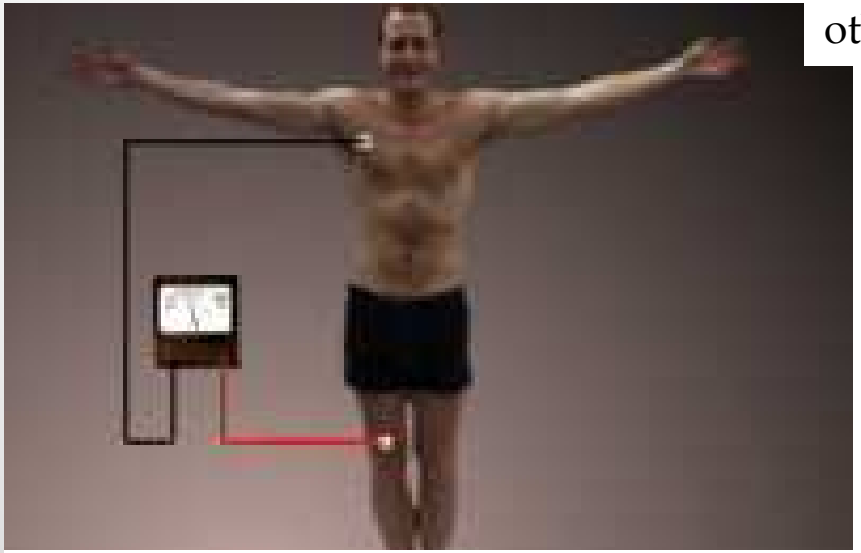
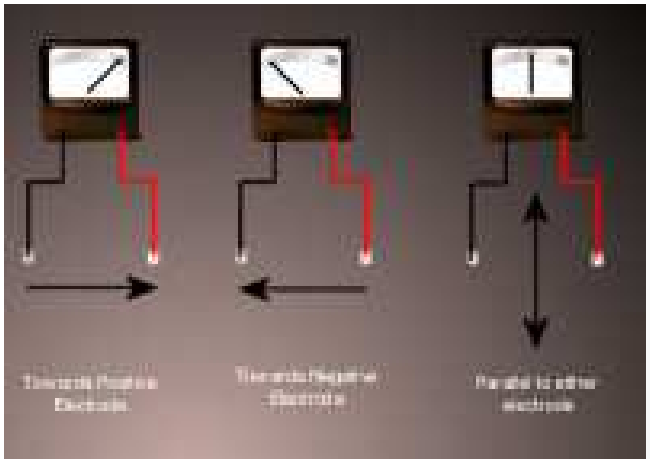
ΑΠΑΓΩΓΕΣ



Unipolar electrodes are used when only one 'positive' electrode is receiving an electrical signal, and the other is a 'ground' electrode and detects zero voltage

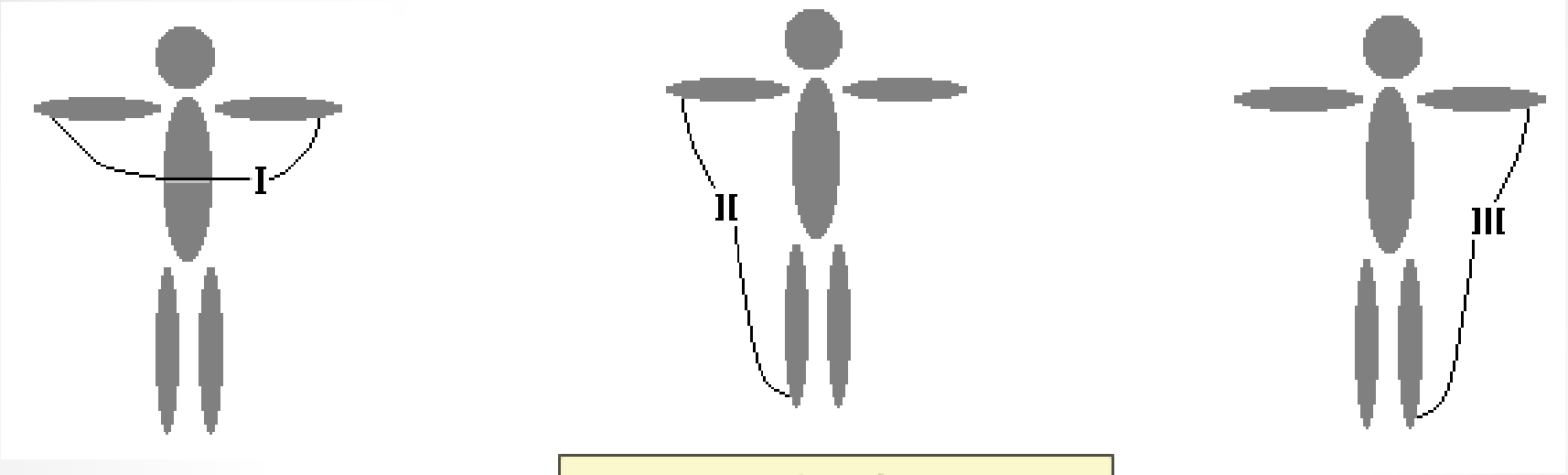


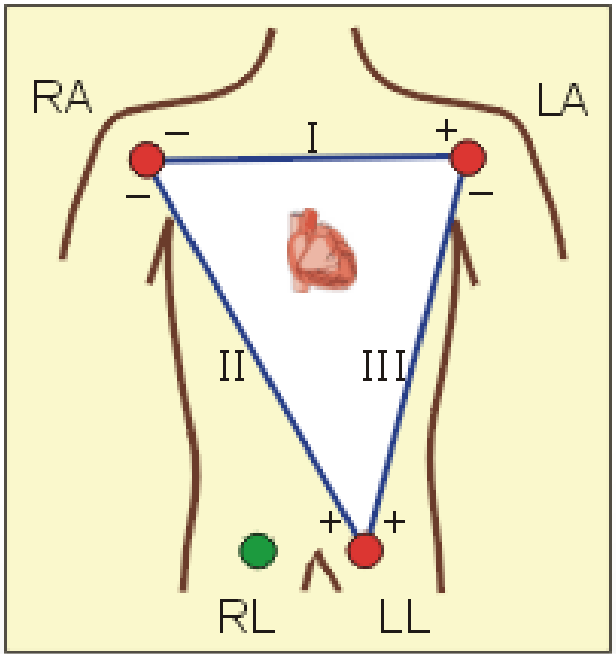


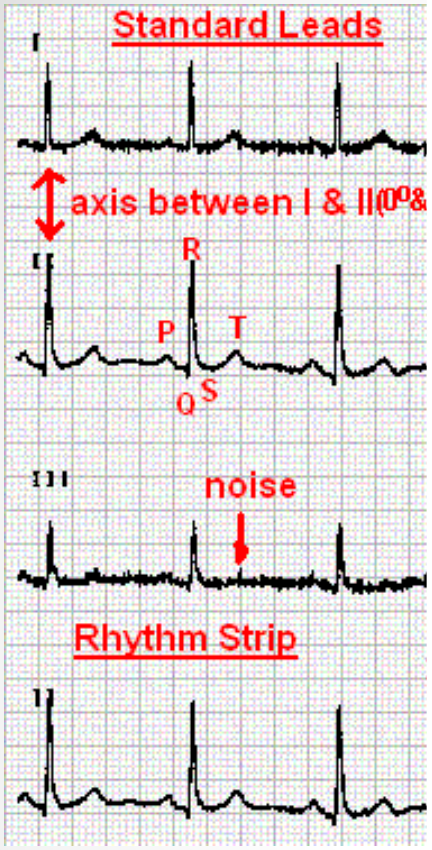
Bipolar electrodes

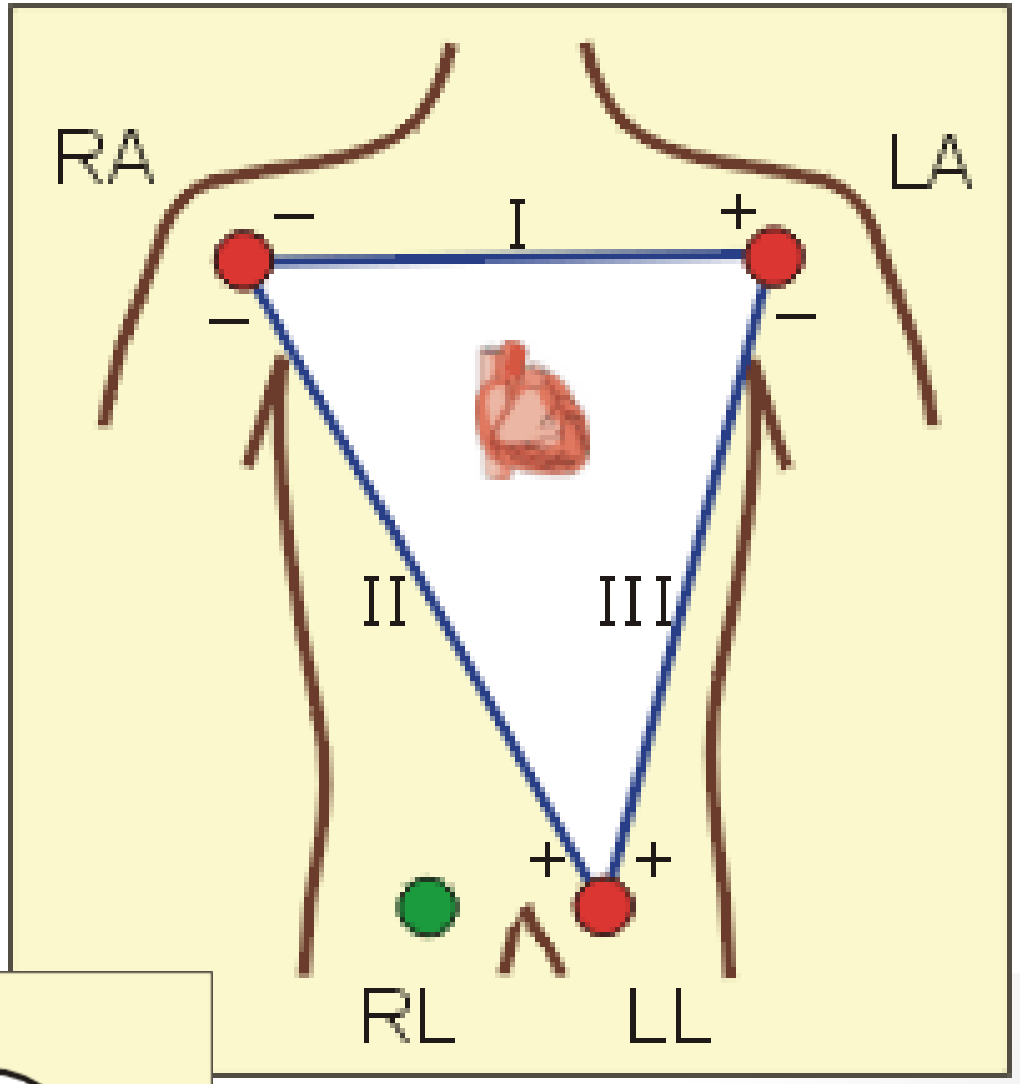
A bipolar electrode system is one where both electrodes detect an electrical signal, and we then record the difference between the two.

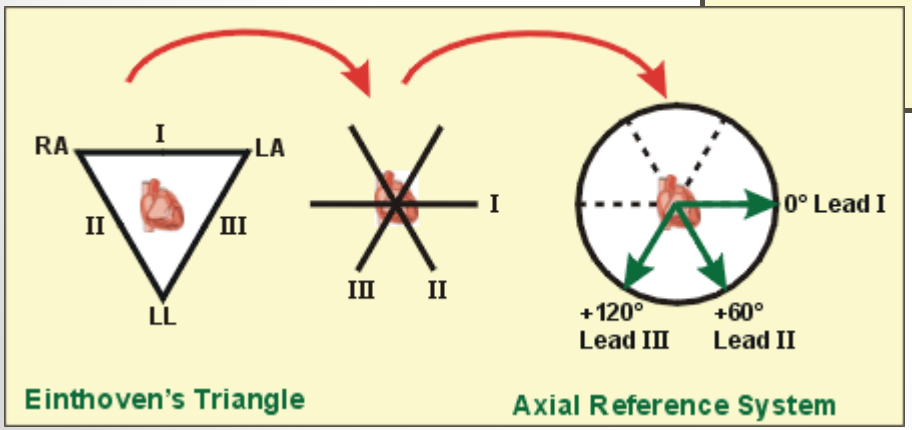
Διπολικές απαγωγές των άκρων (I, II, III)



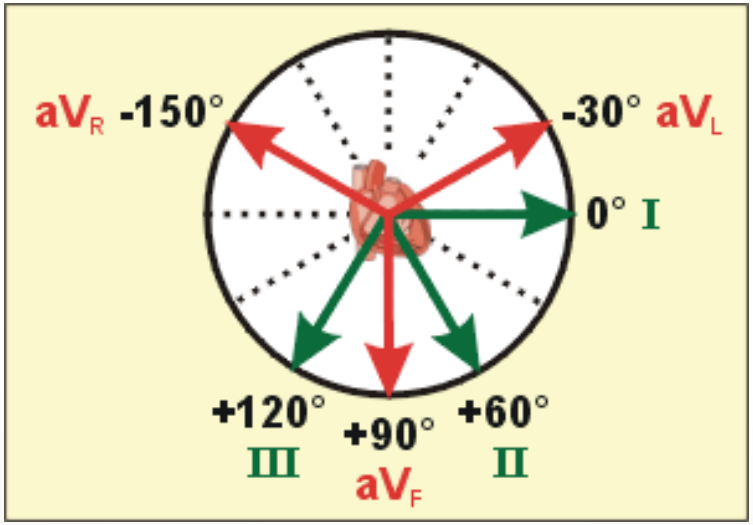



Standard Leads
I
axis between I & II(0°&
R
P
T
Q
S
III
noise
Rhythm Strip
II

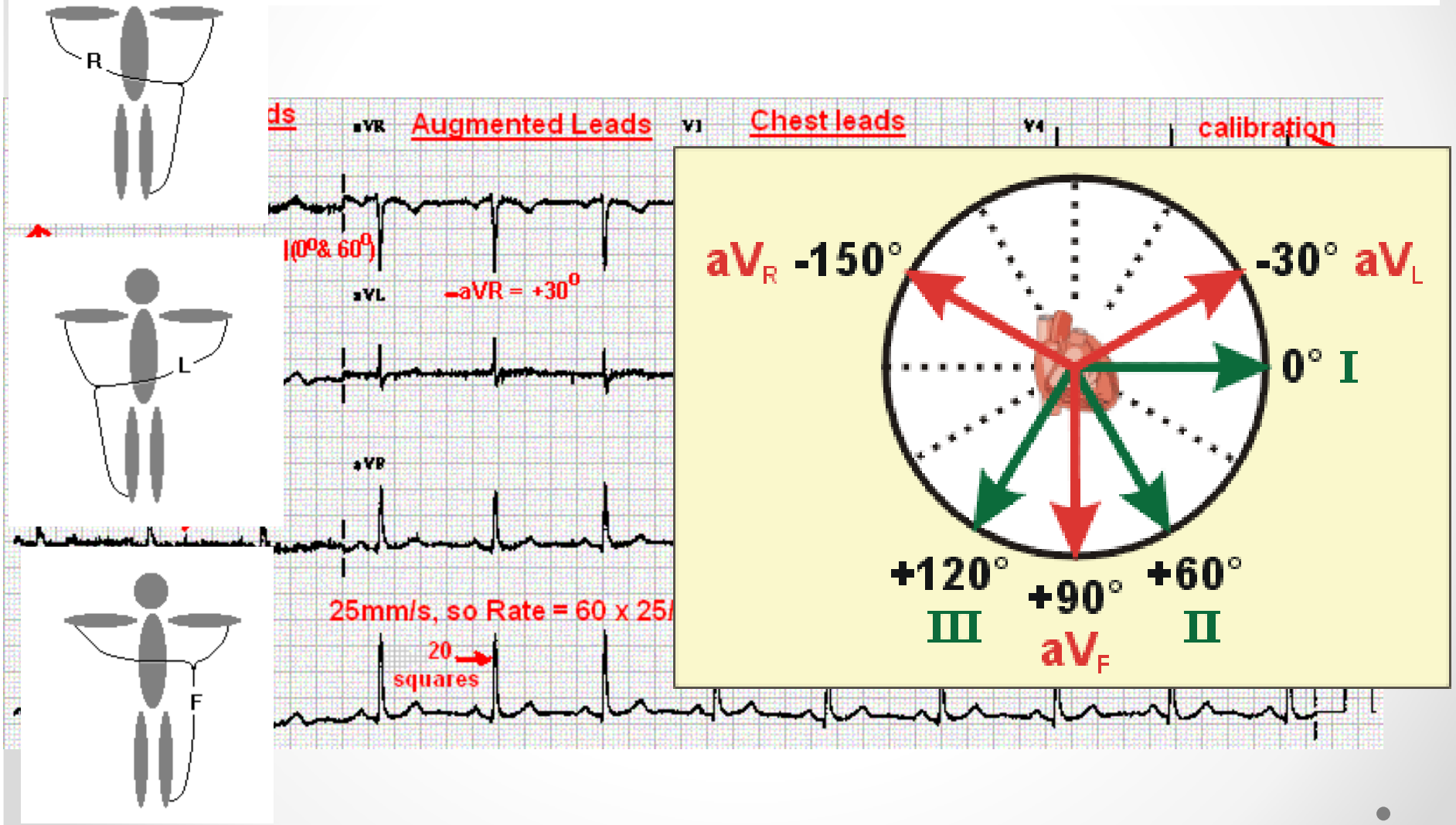

RA
LA
I
II
III
RL
LL


RA
I
LA
II
III
LL
I
III
II
0° Lead I
+120°
Lead III
+60°
Lead II
Einthoven's Triangle
Axial Reference System

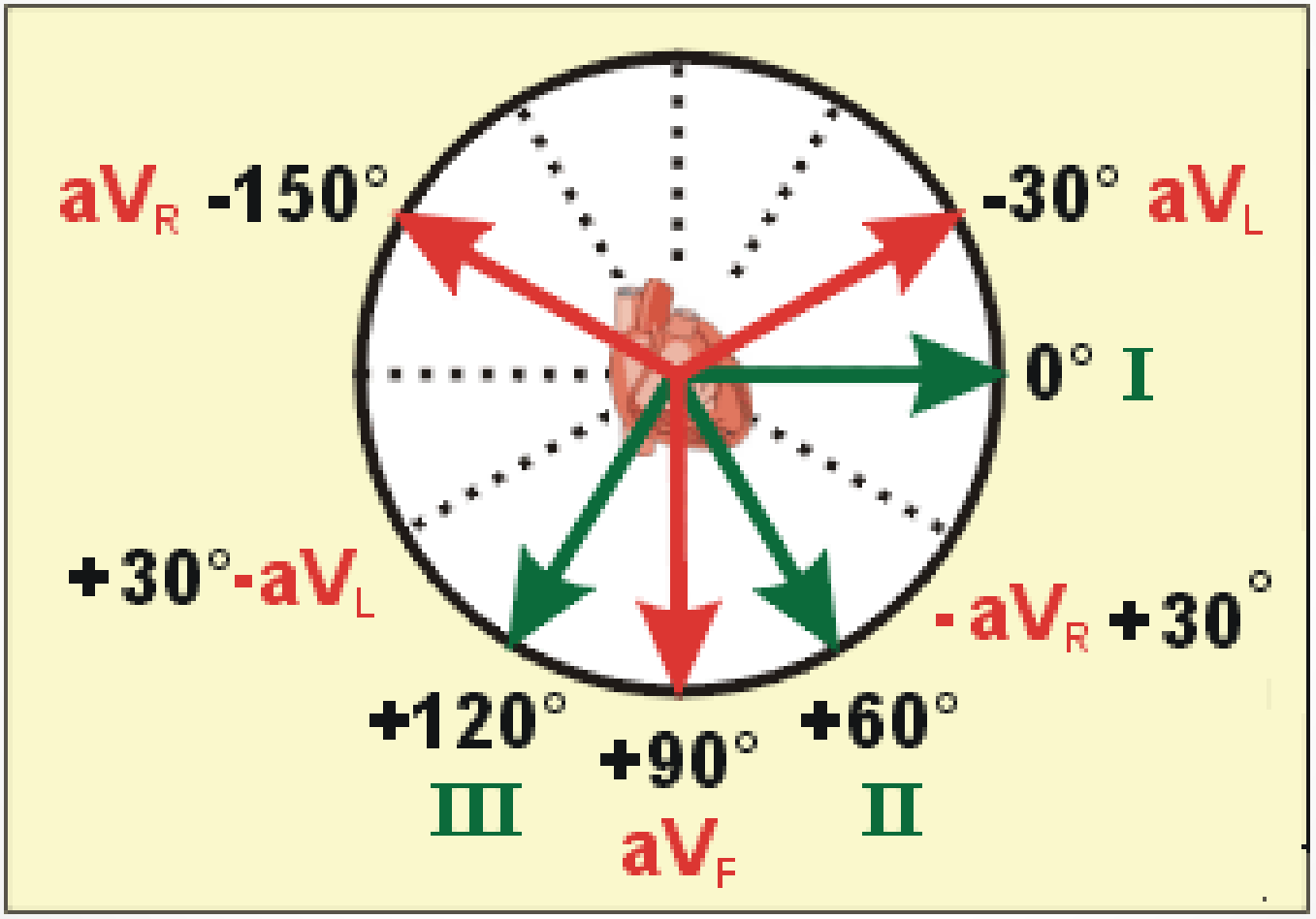
Ενισχυμένες απαγωγές των άκρων aV_R, aV_L, aV_F



Ενισχυμένες απαγωγές των άκρων aV_R, aV_L, aV_F

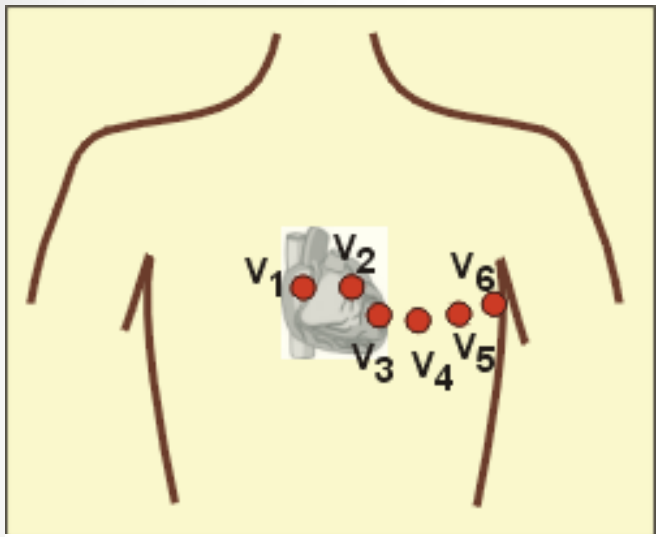


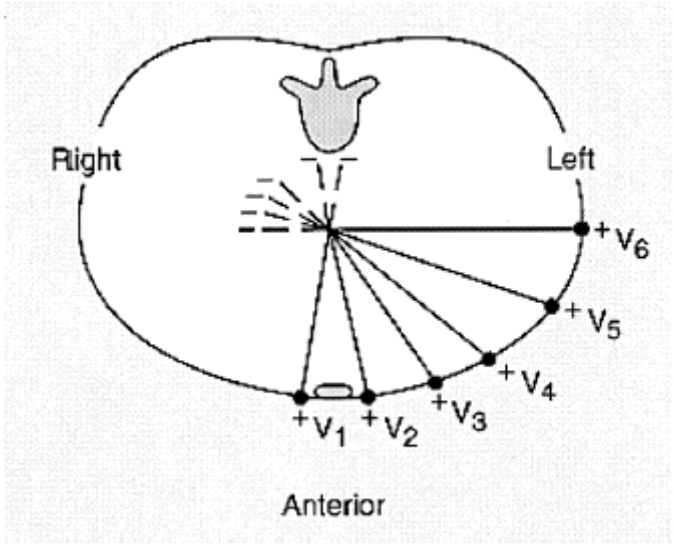
These leads effectively measure the EKG potential at 30º angle about the heart. The R waves of the leads whose axes most closely aligned with the axis of the heart are larger in amplitude, providing a means to quickly assess the patient for hypertrophy of the left (hypertension) or right (lung disease) ventricle

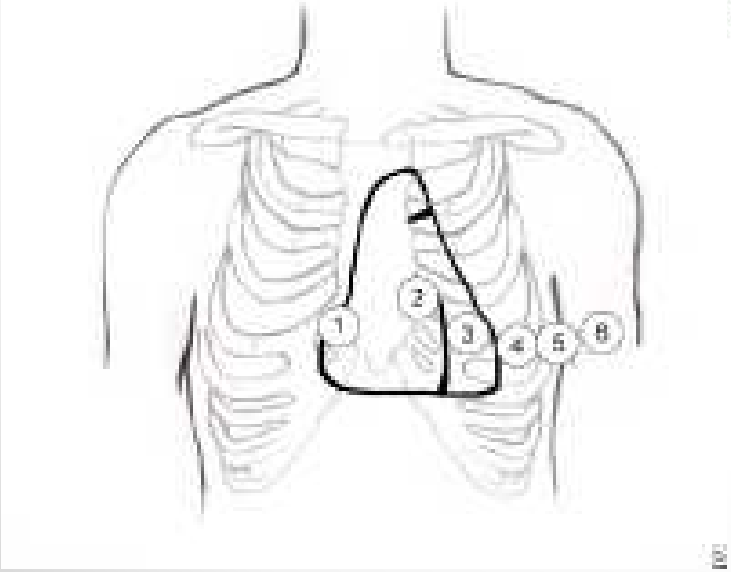


Note that the R wave is negative in aVR, aVL so they are reversed to calculate the axis

Προκάρδιες απαγωγές (V1-6)

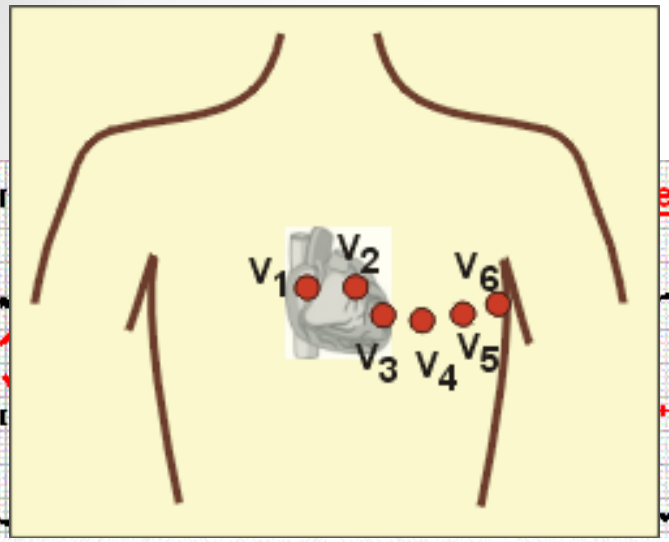


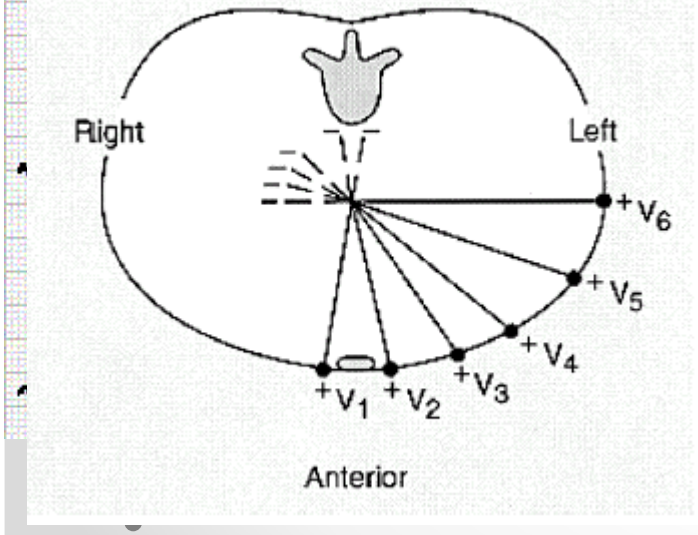




The chest leads look at the transverse plane

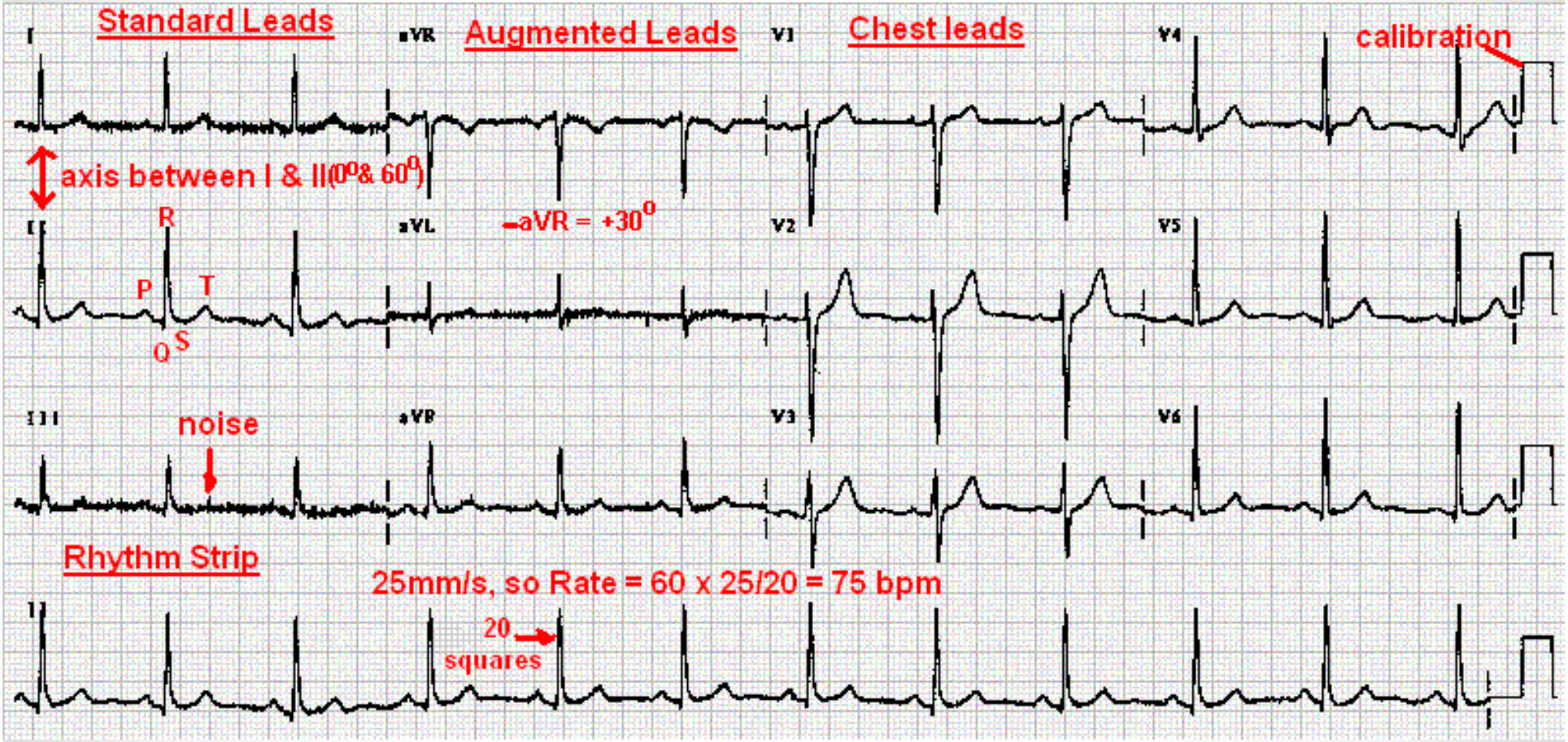
Προκάρδιες απαγωγές (V1-6)

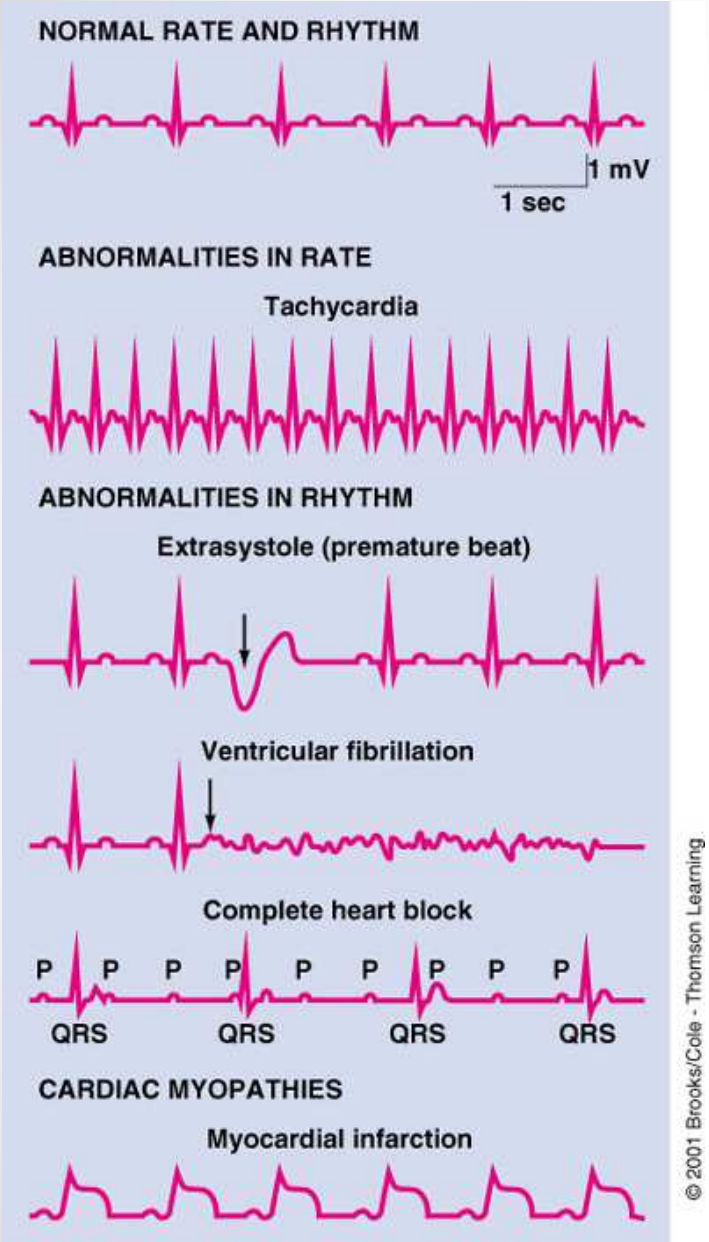




Normal EKG

Φυσιολογικό ΗΚΓ



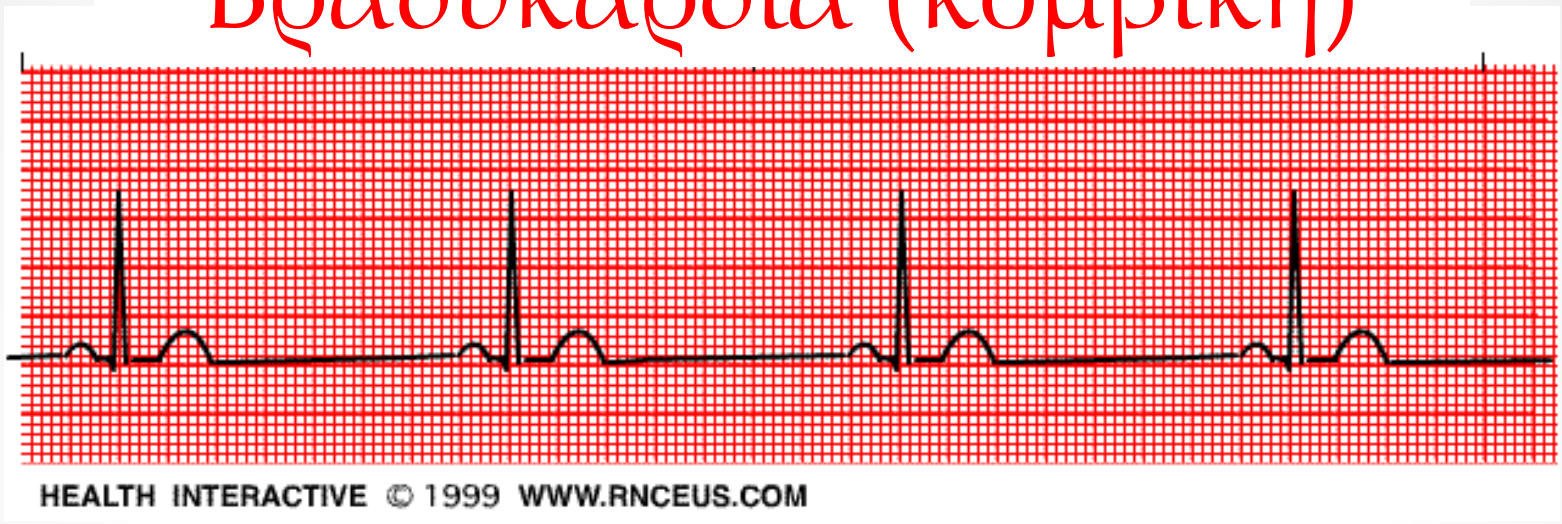


Χρήσεις ΗΚΓ

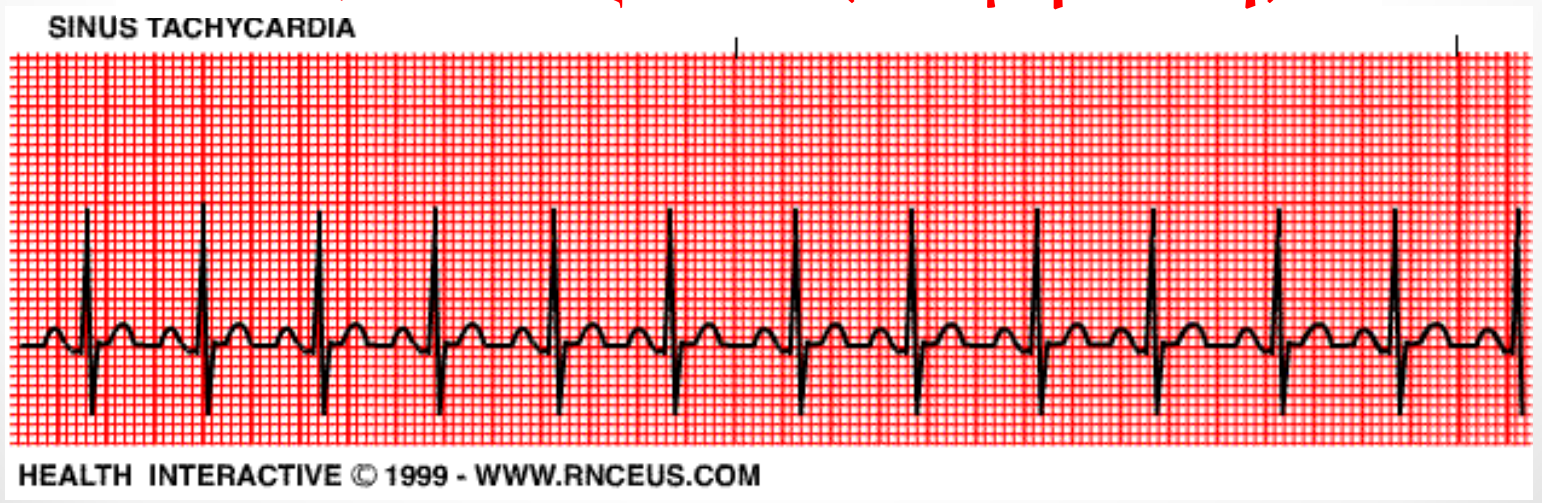
Το ΗΚΓ είναι χρήσιμο στην κλινική πράξη. Χρησιμοποιείται:

1. Συχνότητα και ρυθμός (ταχυκαρδία-βραδυκαρδία)
2. Υπολογισμός μέσου ηλεκτρικού άξονα (πχ υπερτροφία λόγω υπέρτασης)
3. Εκτίμηση κατάστασης μυοκαρδίου (πχ ισχαιμία)

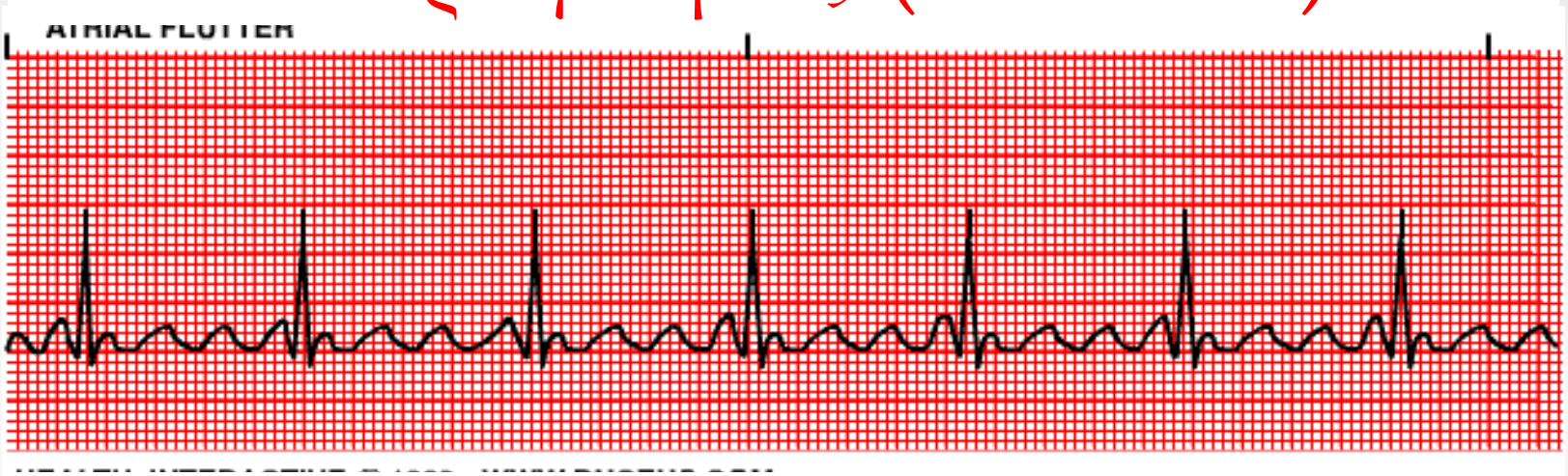
Βραδυκαρδία (κομβική)



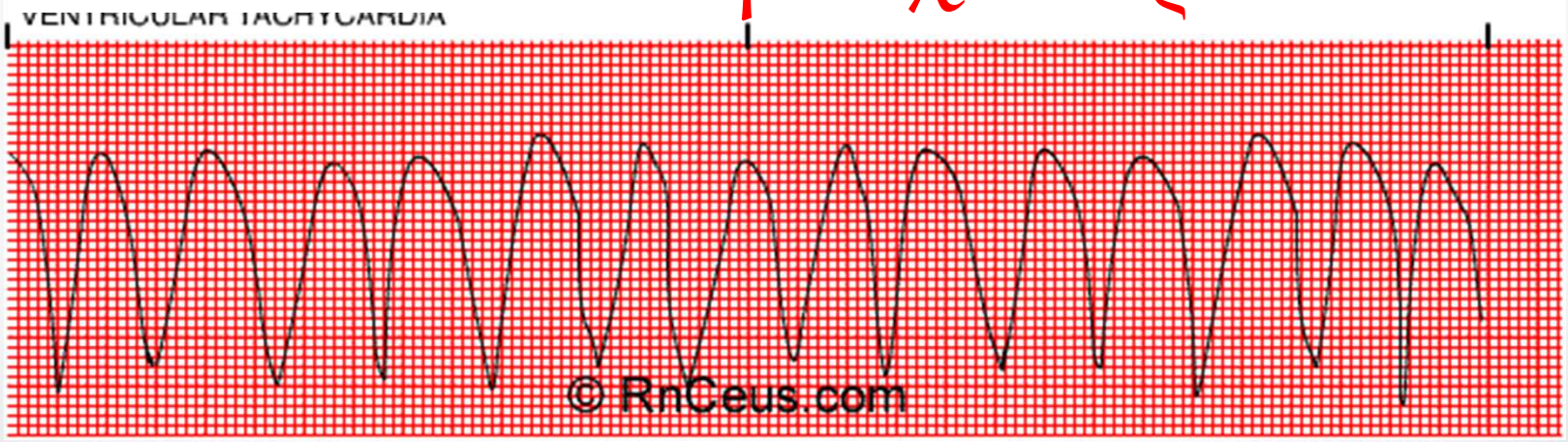
Ταχυκαρδία (κομβική)



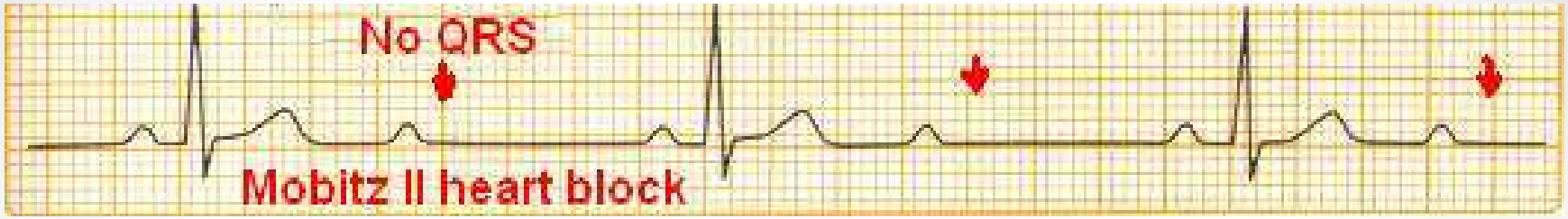
Πτερυγισμός (κόλπων)

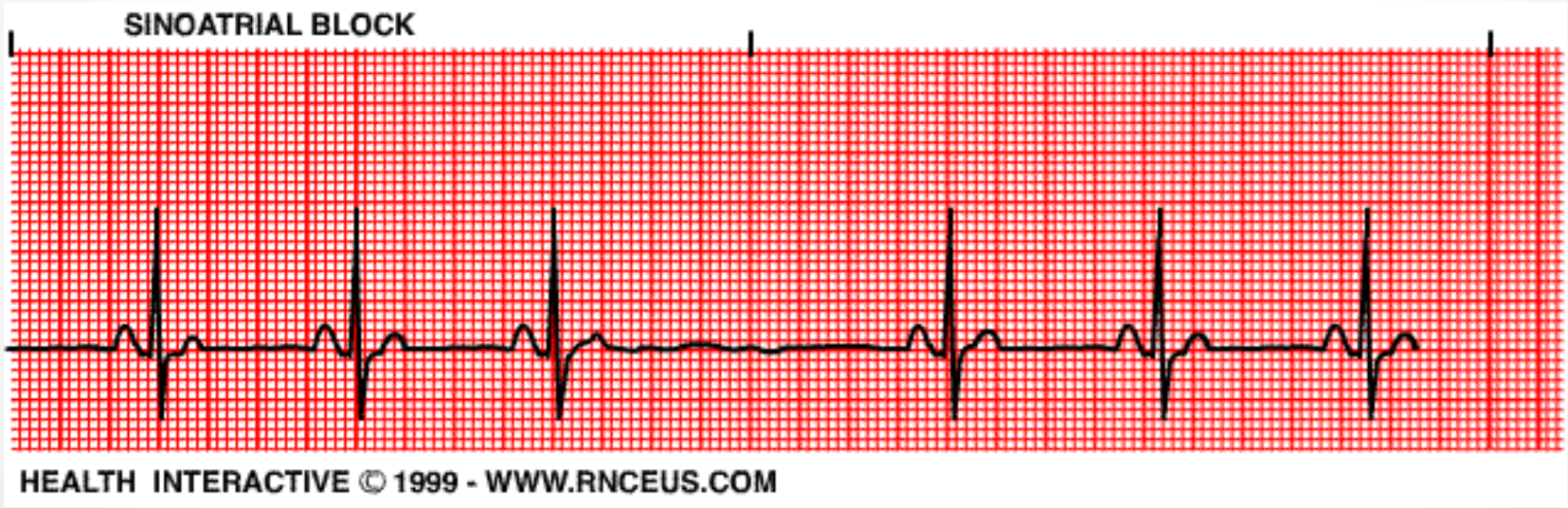


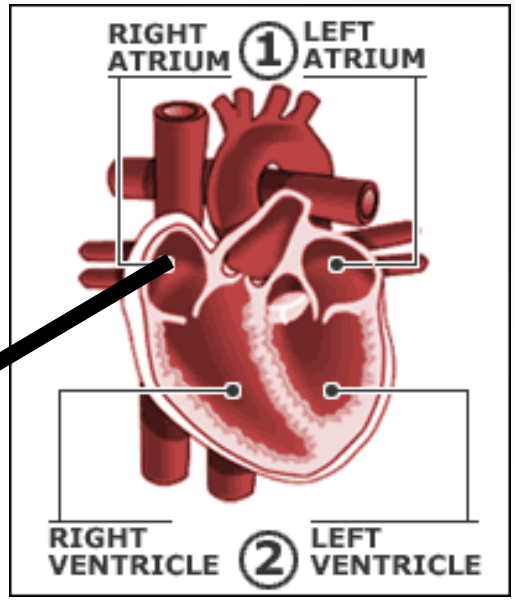
Κοιλιακή ταχυκαρδία

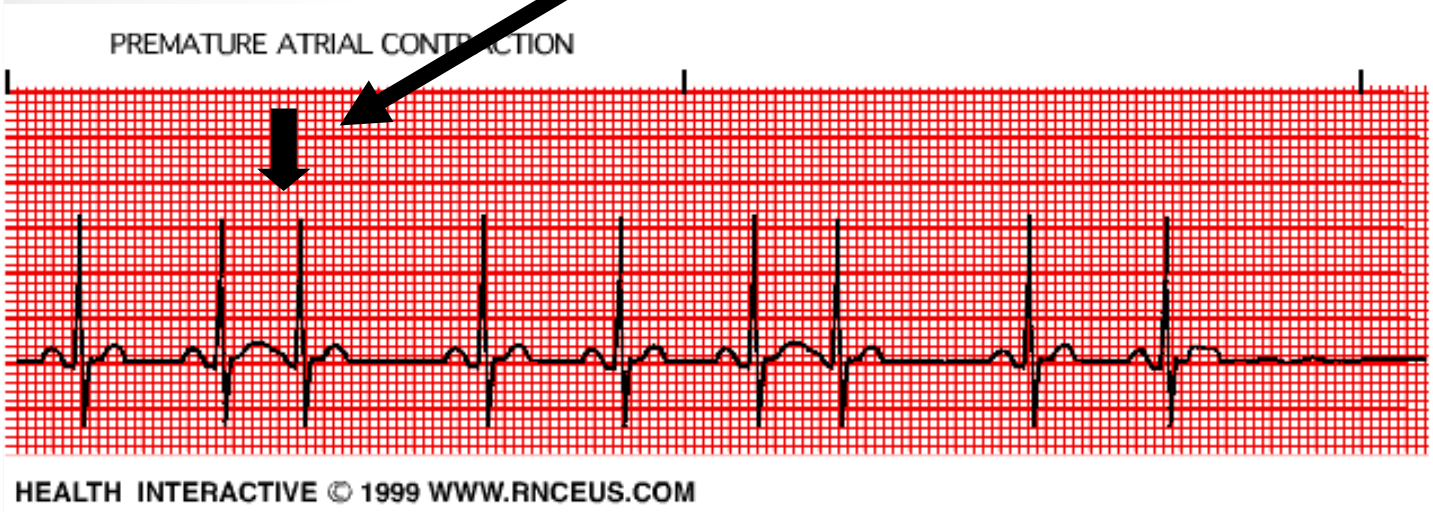


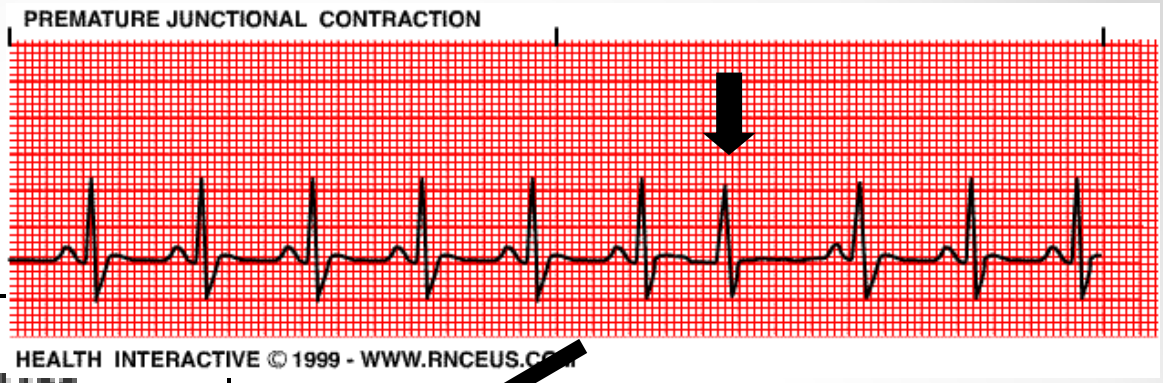
heart block

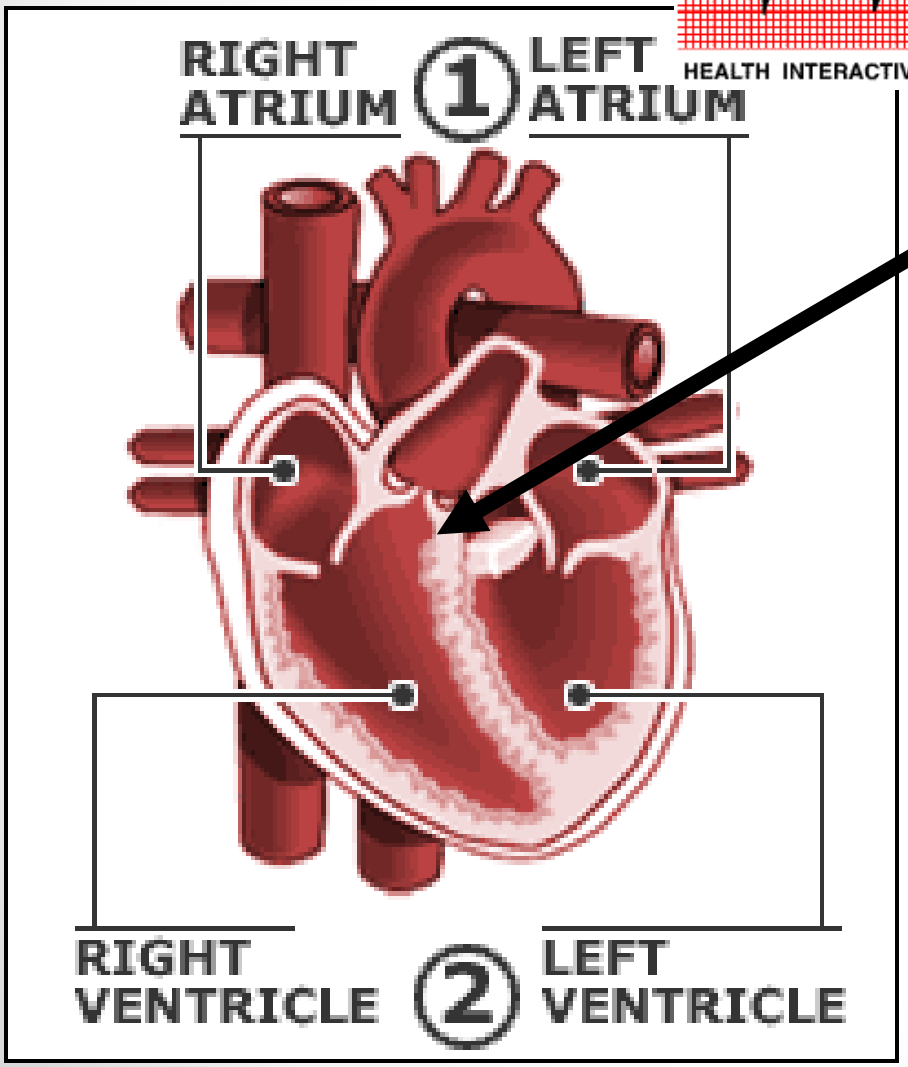

No QRS
Mobitz II heart block

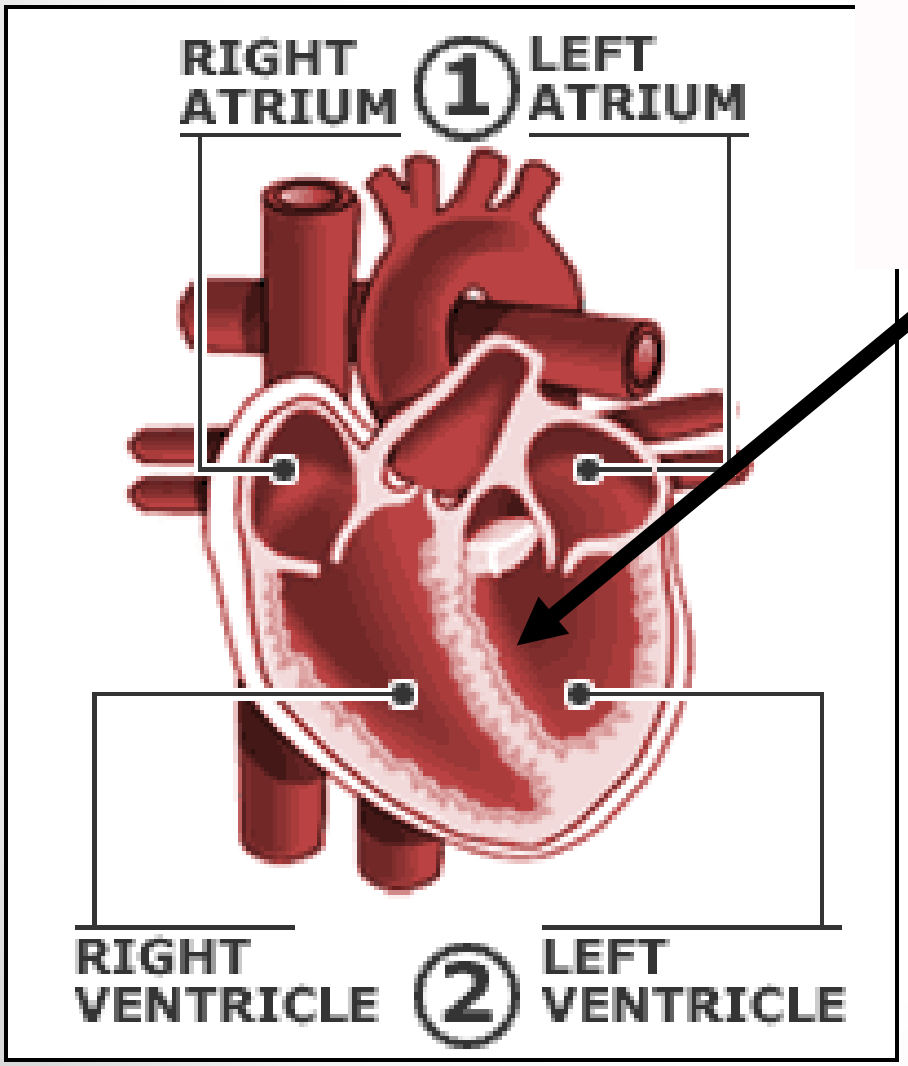

SINOATRIAL BLOCK
HEALTH INTERACTIVE © 1999 - WWW.RNCEUS.COM

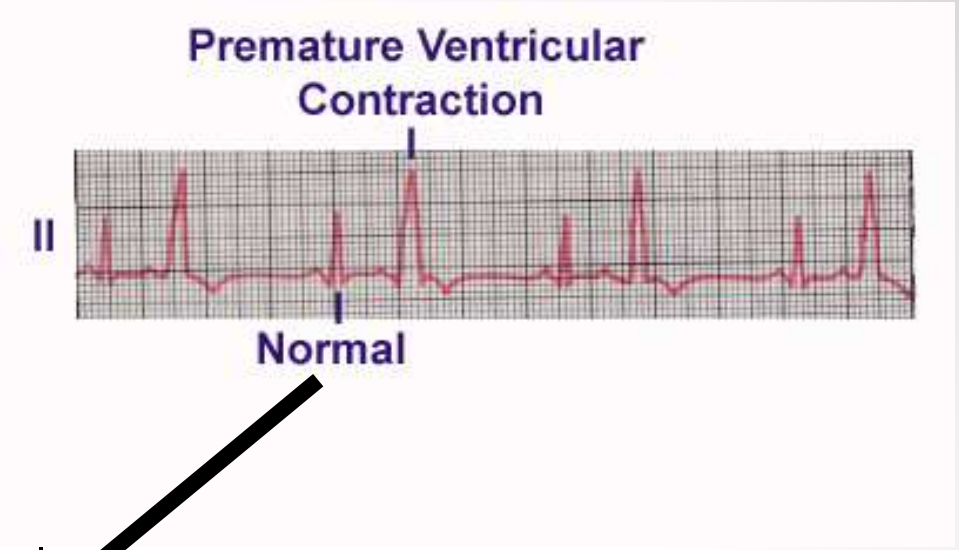

RIGHT ATRIUM
1
LEFT ATRIUM
RIGHT VENTRICLE
2
LEFT VENTRICLE


PREMATURE ATRIAL CONTRACTION
HEALTH INTERACTIVE © 1999 WWW.RNCEUS.COM

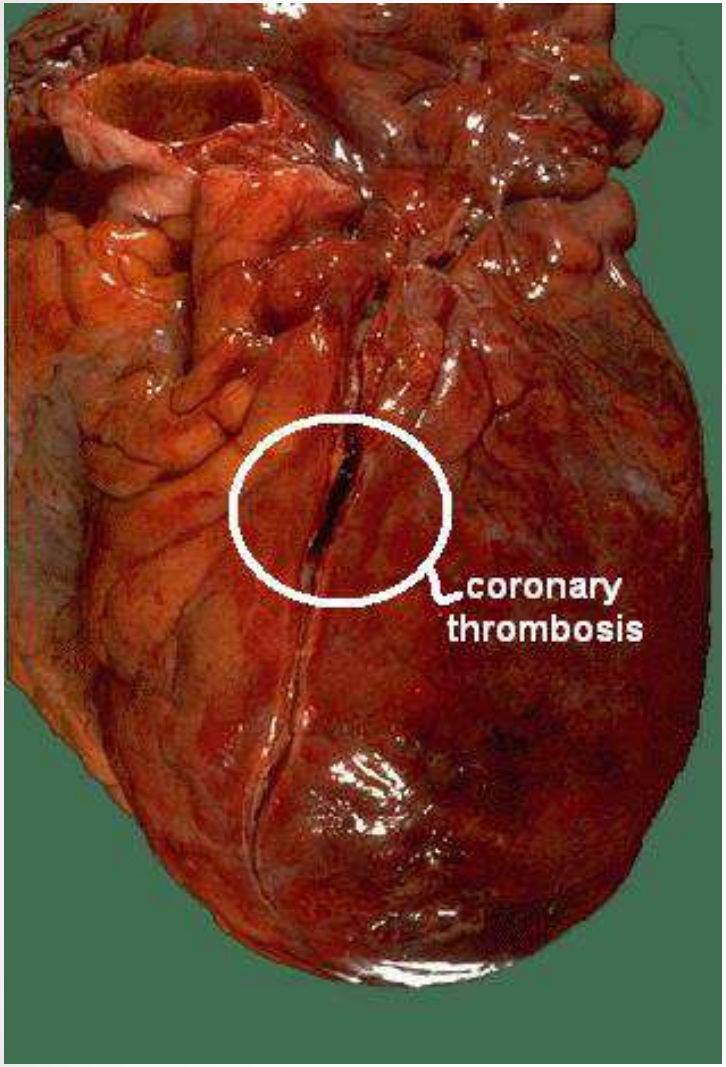

PREMATURE JUNCTIONAL CONTRACTION
HEALTH INTERACTIVE © 1999 - WWW.RNCEUS.COM

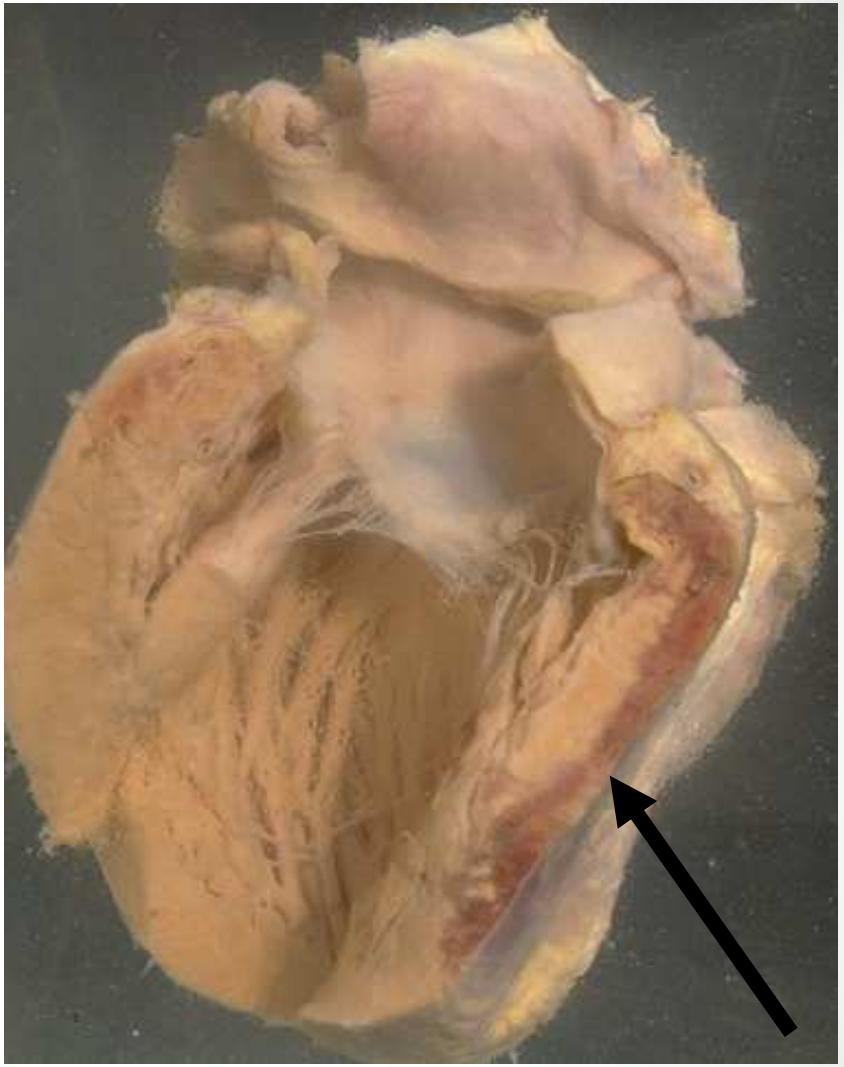

RIGHT ATRIUM
1
LEFT ATRIUM
RIGHT VENTRICLE
2
LEFT VENTRICLE

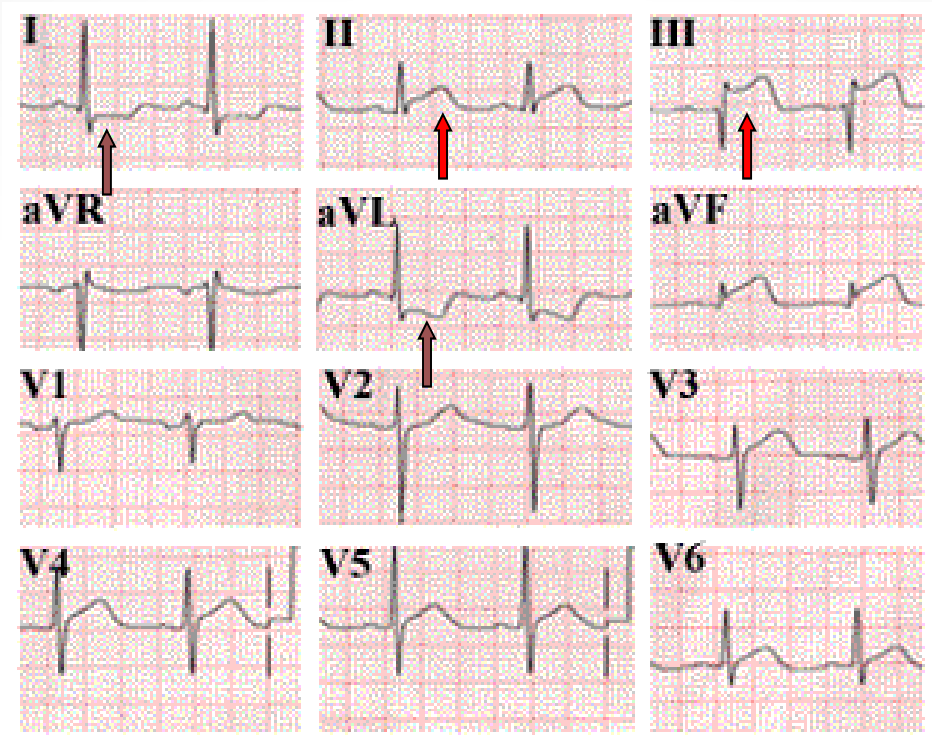

RIGHT ATRIUM
1
LEFT ATRIUM
RIGHT VENTRICLE
2
LEFT VENTRICLE


Premature Ventricular Contraction
II
Normal

Ισχαιμία μυοκαρδίου


coronary
thrombosis





Ανάσπαση ST στις απαγωγές II & III

(έμφραγμα μυοκαρδίου)

Κατάσπαση ST στις απαγωγές I, AVL

(ισχαιμία)

Έμφραγμα μυοκαρδίου

Κατάσπαση ST ?