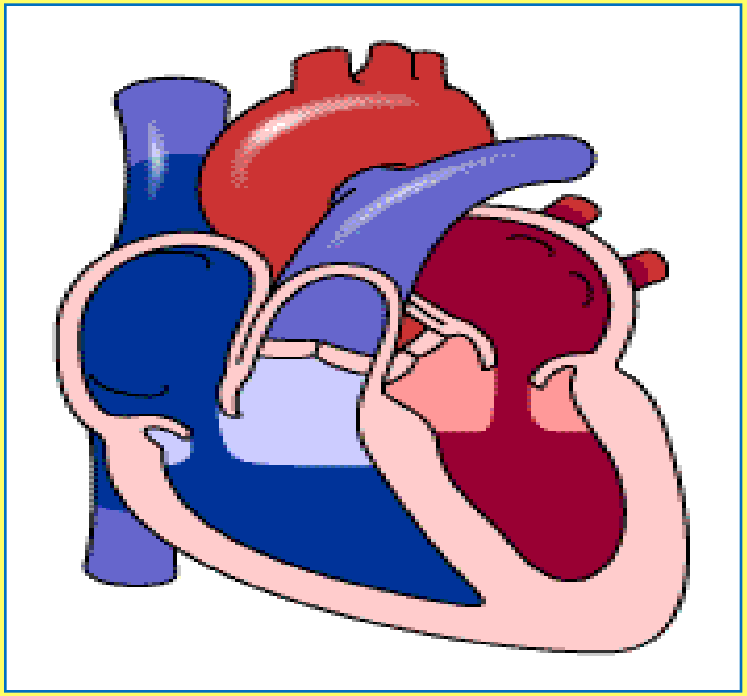
MEDICAL UNIVERSITY – PLEVEN
FACULTY OF MEDICINE
DISTANCE LEARNING CENTER

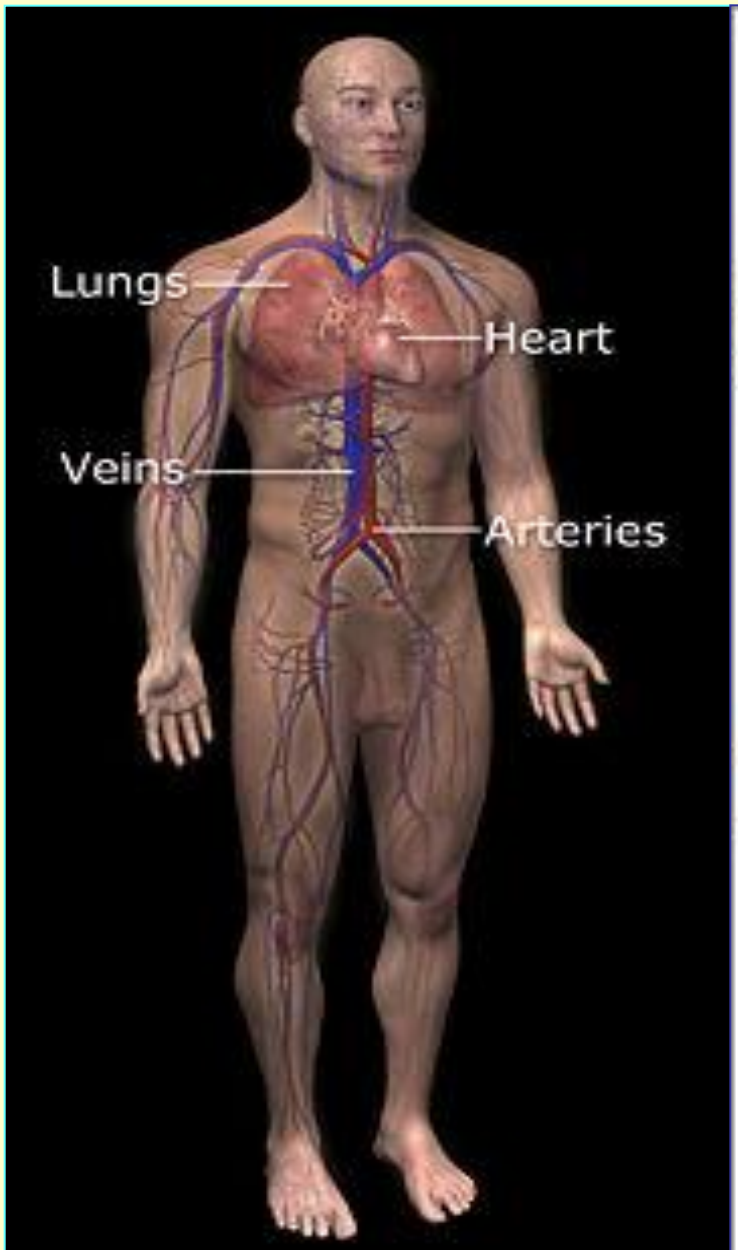
Lecture № 6

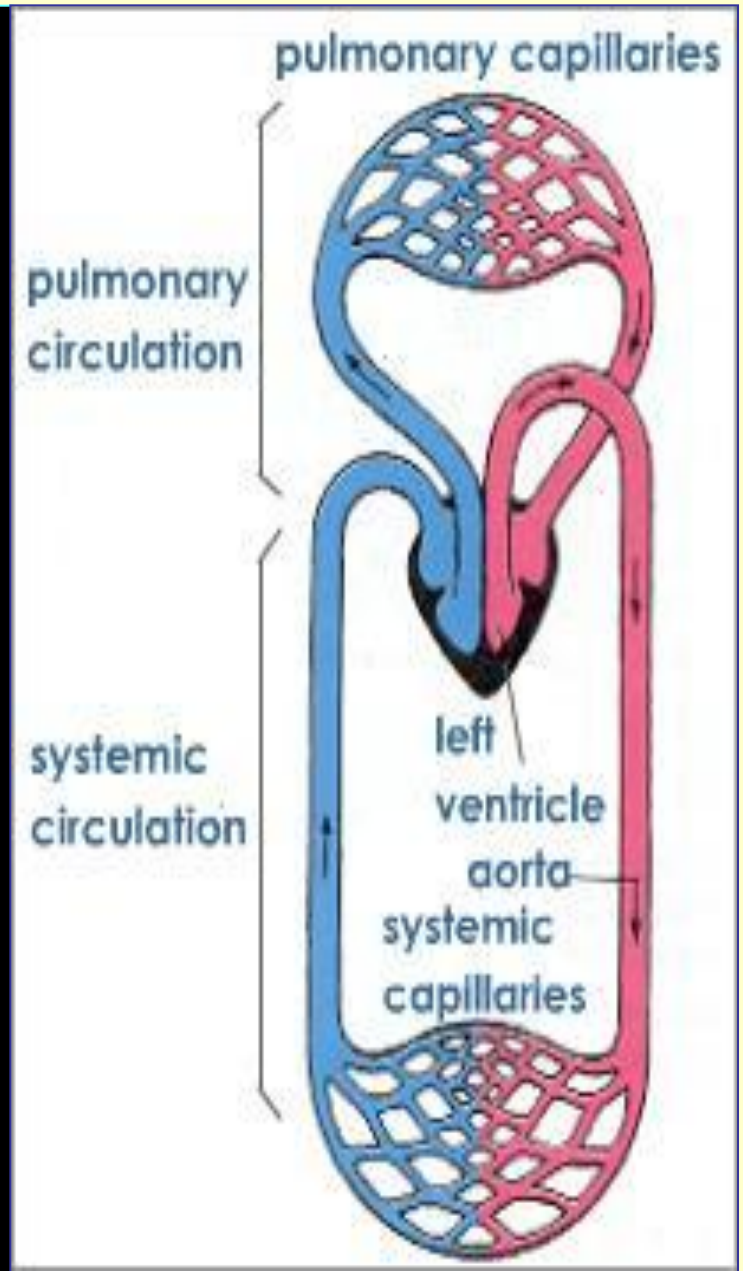
Morphology and function of cardiac muscle. Electrical activity of the heart. Electrocardiogram



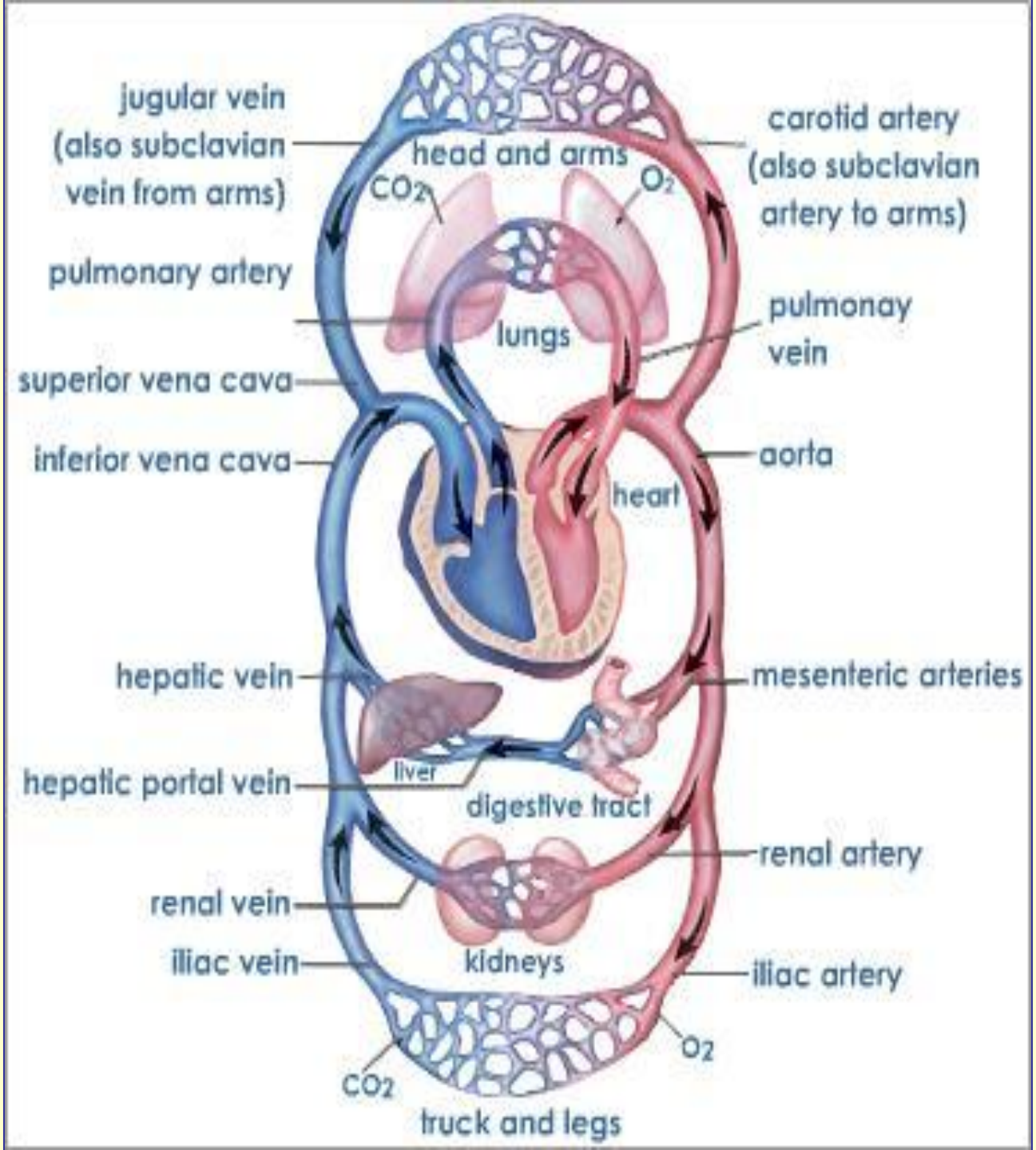
Assoc. prof. Boryana Ruseva, MD, PhD
Department of Physiology
Medical University - Pleven

Cardiovascular system

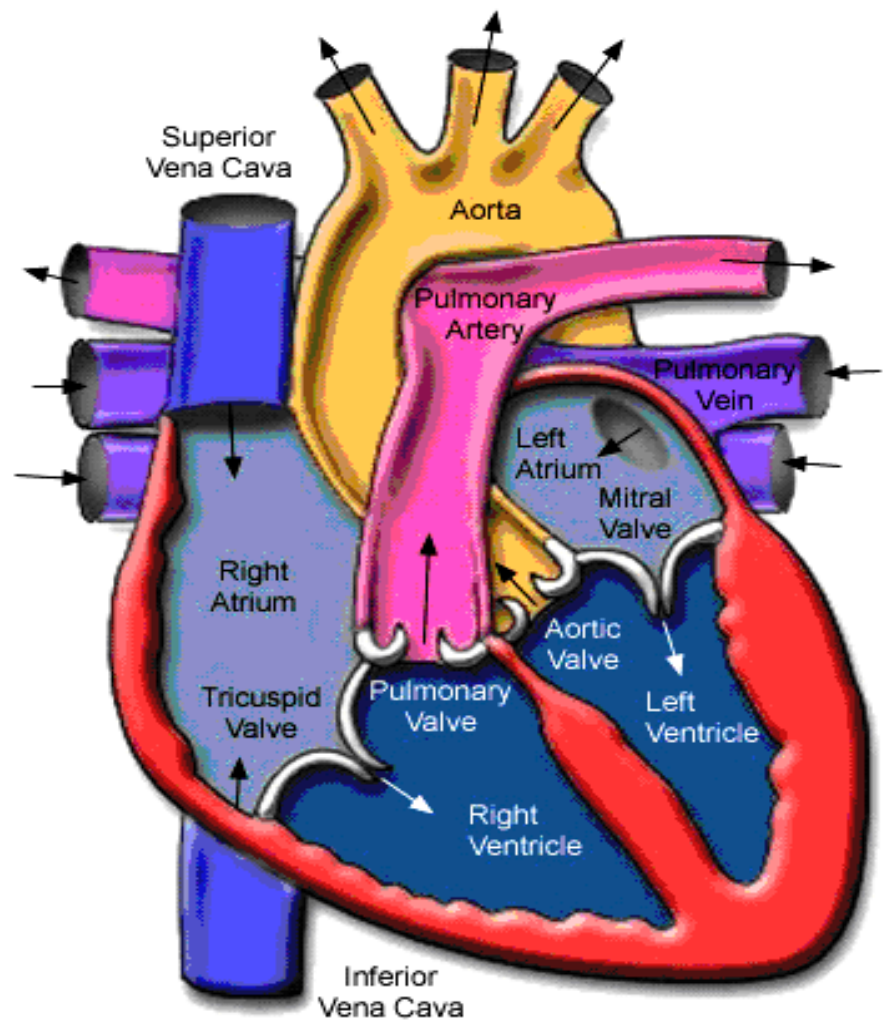


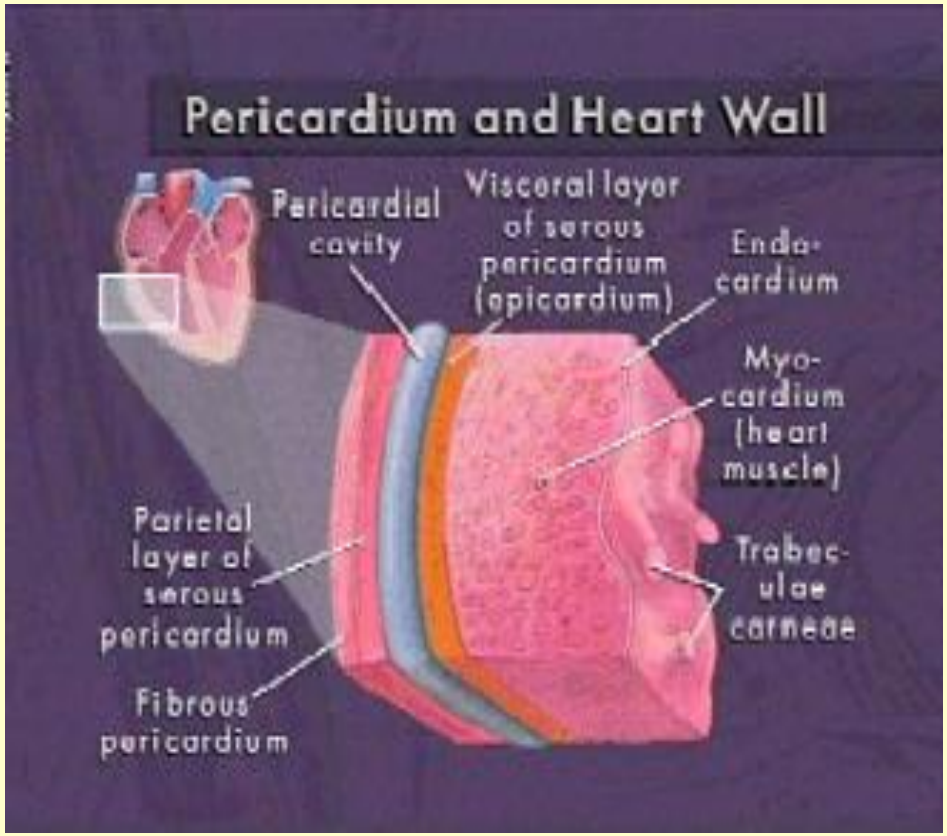


The heart works as a pump that periodically pumps the blood into two rings of circulation.

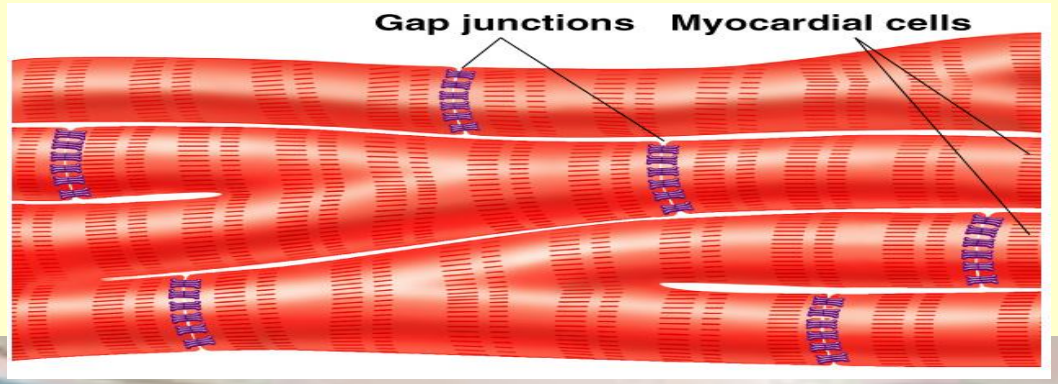

jugular vein
(also subclavian
vein from arms)
head and arms
CO_2
O_2
carotid artery
(also subclavian
artery to arms)
pulmonary artery
lungs
pulmonay
vein
superior vena cava
inferior vena cava
aorta
heart
hepatic vein
mesenteric arteries
liver
hepatic portal vein
digestive tract
renal artery
renal vein
kidneys
iliac vein
iliac artery
O_2
CO_2
truck and legs

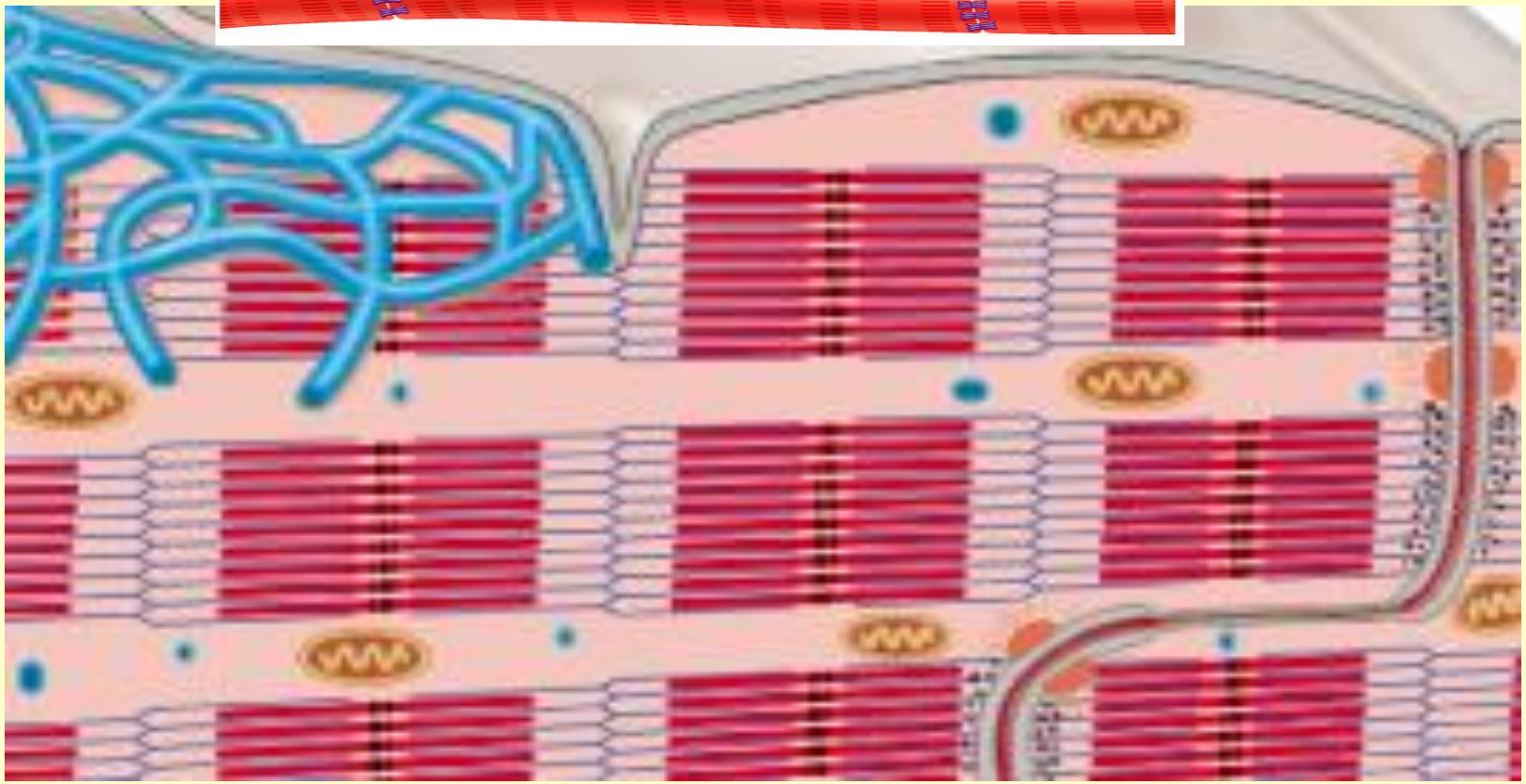
Anatomy of the heart





Myocardium



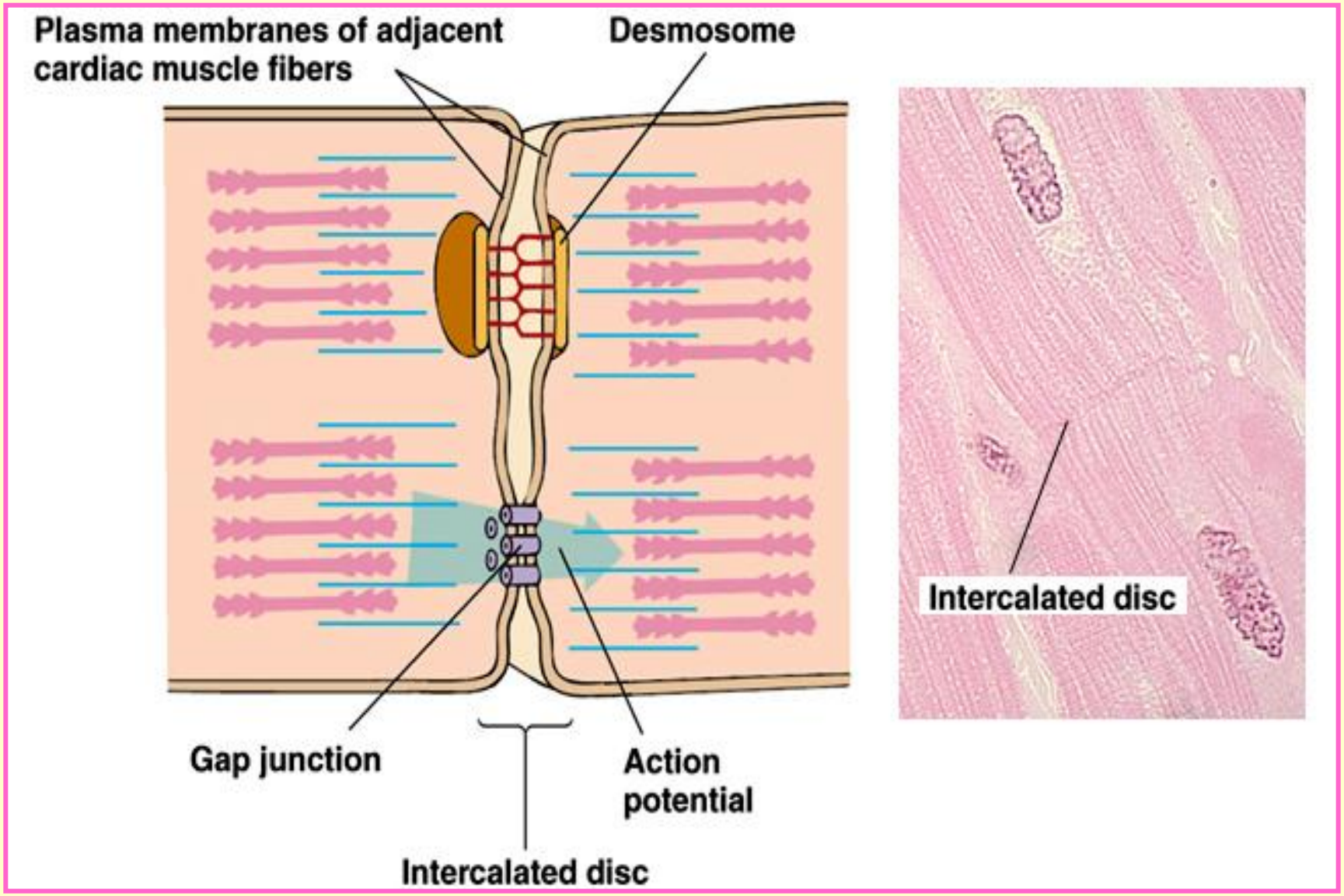


Myocardium

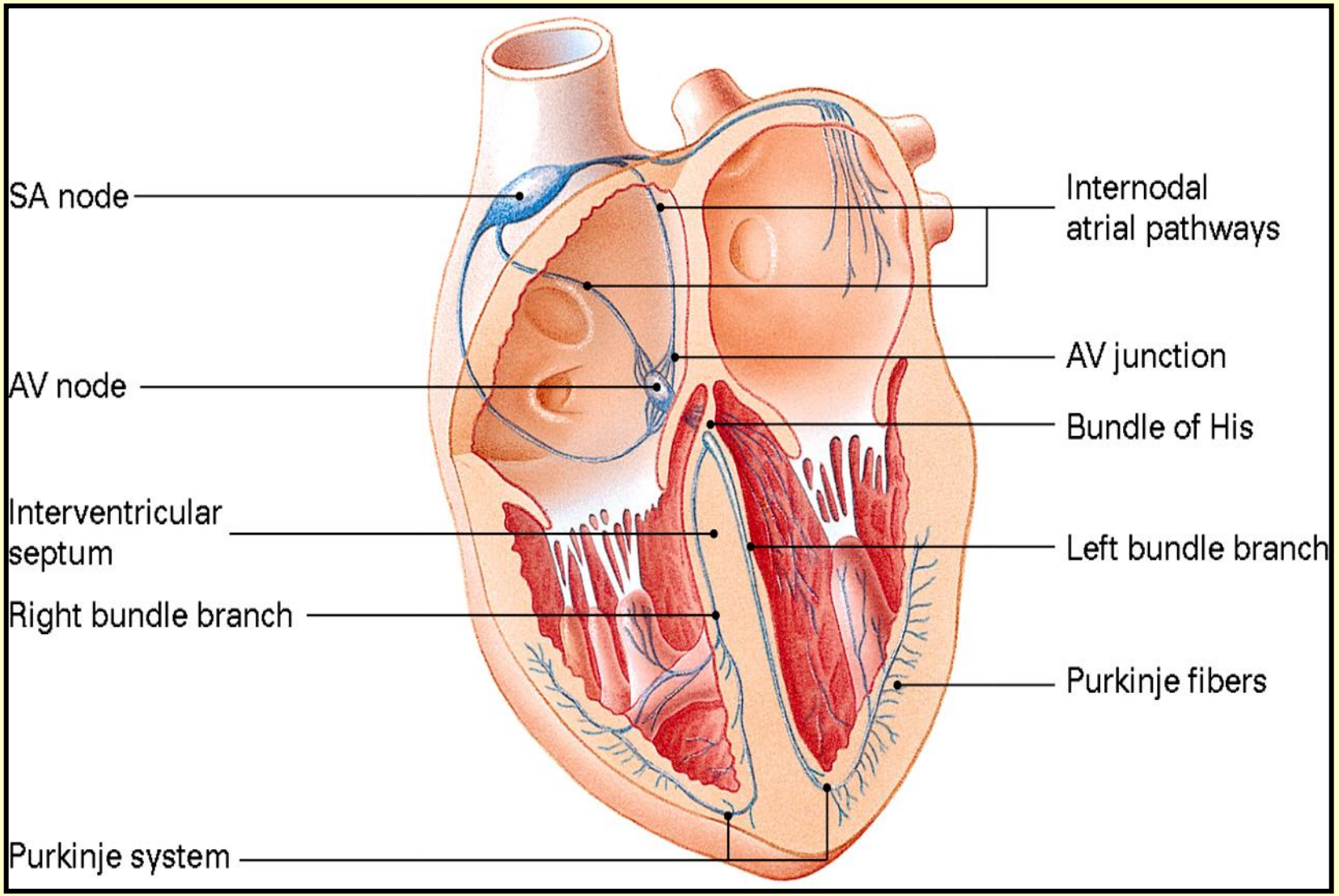
Intercalated discs contain two type of connections:

*electrical – gap junctions

*mechanical – desmosomes



Excitatory and conductive system of the heart



❑ S-A node is a pacemaker of the heart performance. Itself automatic rhythm is 100-115 /min.

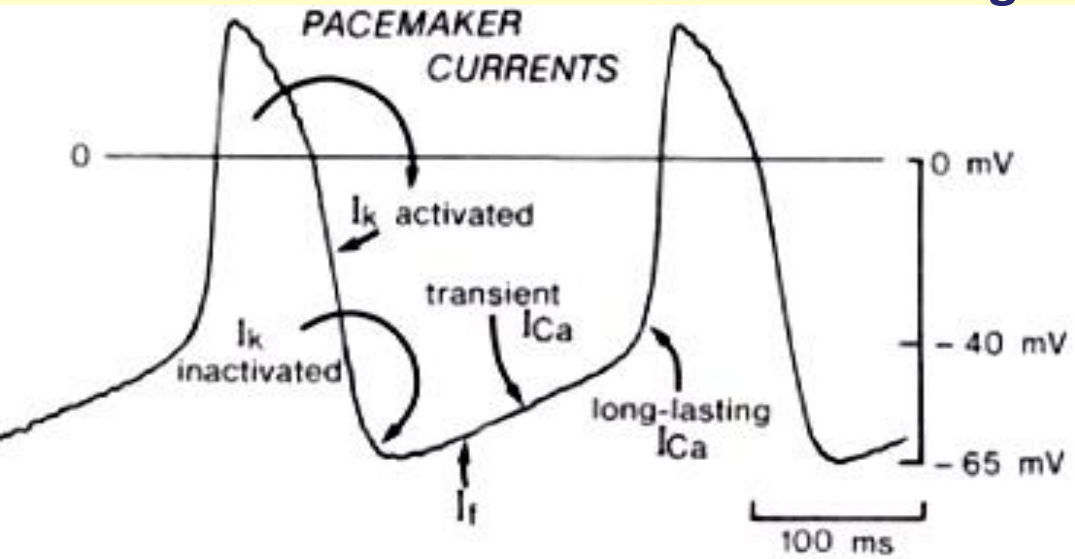
❑ Under the influence of the vagus nerve the frequency of heart beats is 60-80/min in adults at rest .

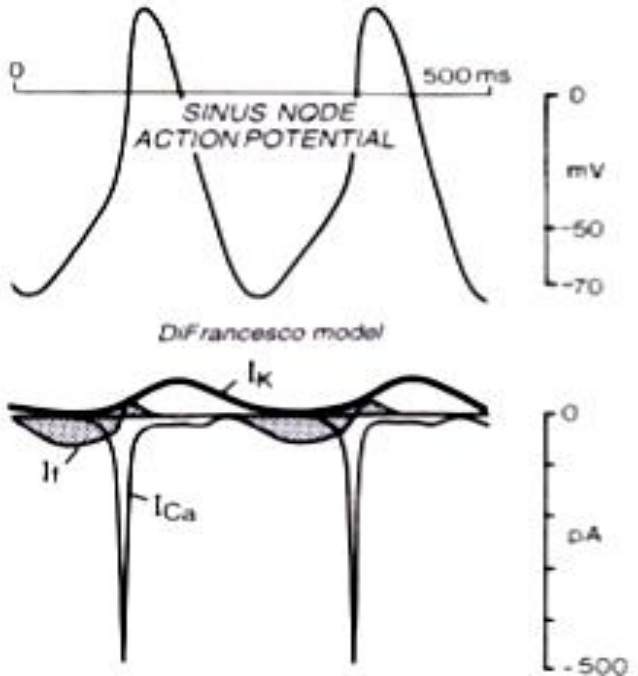
❖ spontaneous diastolic depolarization consists of 3 ion currents:

✓ If (Ih) –current of Na^+ and K^+ ions – it is activated during hyperpolarization of cellular membrane

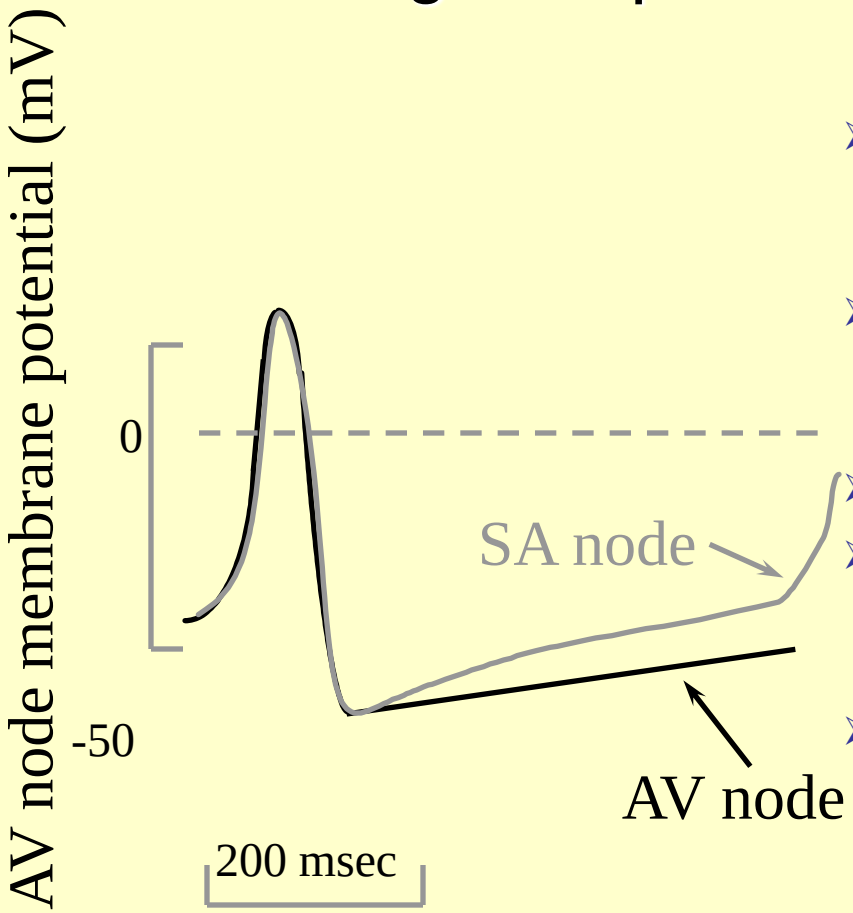
✓ ICa^{2+} -opening of long-lasting Ca^{2+} during depolarization

✓ IK^+ - slow decrease of K^+ current during diastole





Changes of potential of the cells of A-V node



- Less spontaneous frequency than this of S-A (40-60/min, because slower diastolic depolarization
- It is latent pacemaker – its automatic rhythm is inhibited by the signals from S-A
- Slow AP looks like this of S-A node
- Slow velocity of spreading, because of small size of the cells and low number of gap junctions
- This delay lasts 0.1 s – it is necessary for completion of atrial contraction

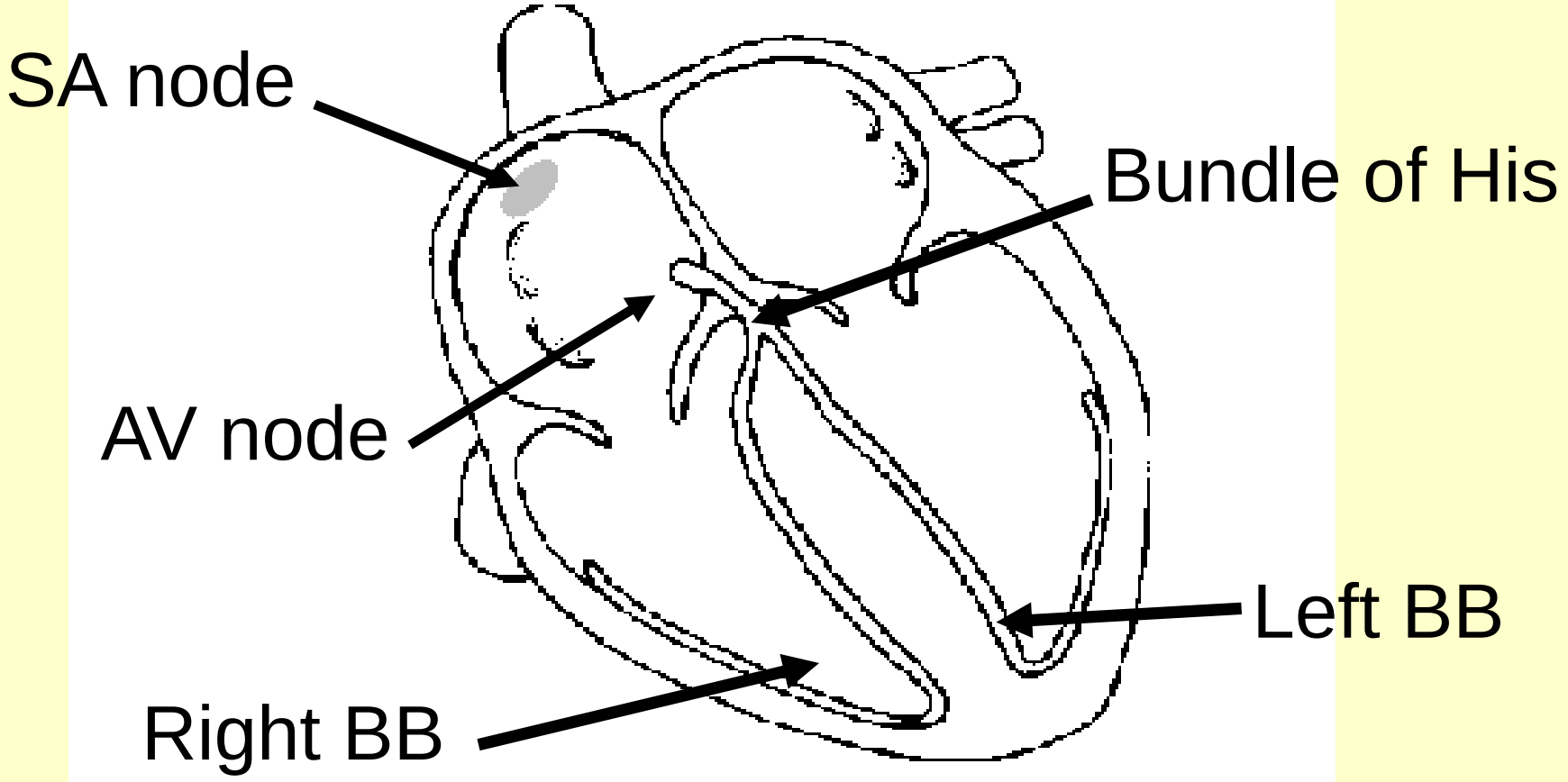
❖ Automatic Electrical Rhythmicity of the other structures of excitatory and conductive system of the heart may manifest when:

✓automatic electrical rhythmicity of the S-A node is inhibited

✓presence of block of traveling of excitation from basic pacemaker

✓pathological increase of itself automatic frequency of generation of AP than this of basic pacemaker

Spread of the excitation



The spread of excitation

S-A node

↓

Atrial myocardium

↓

A-V node

↓

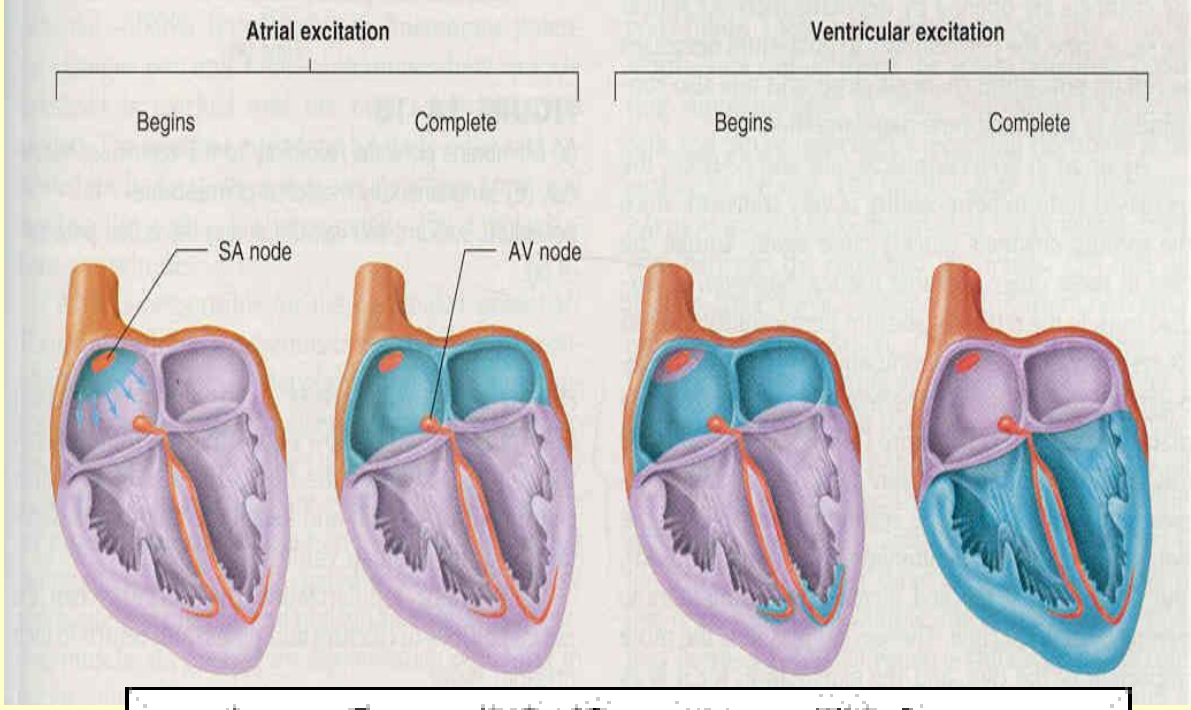
Bundle of His

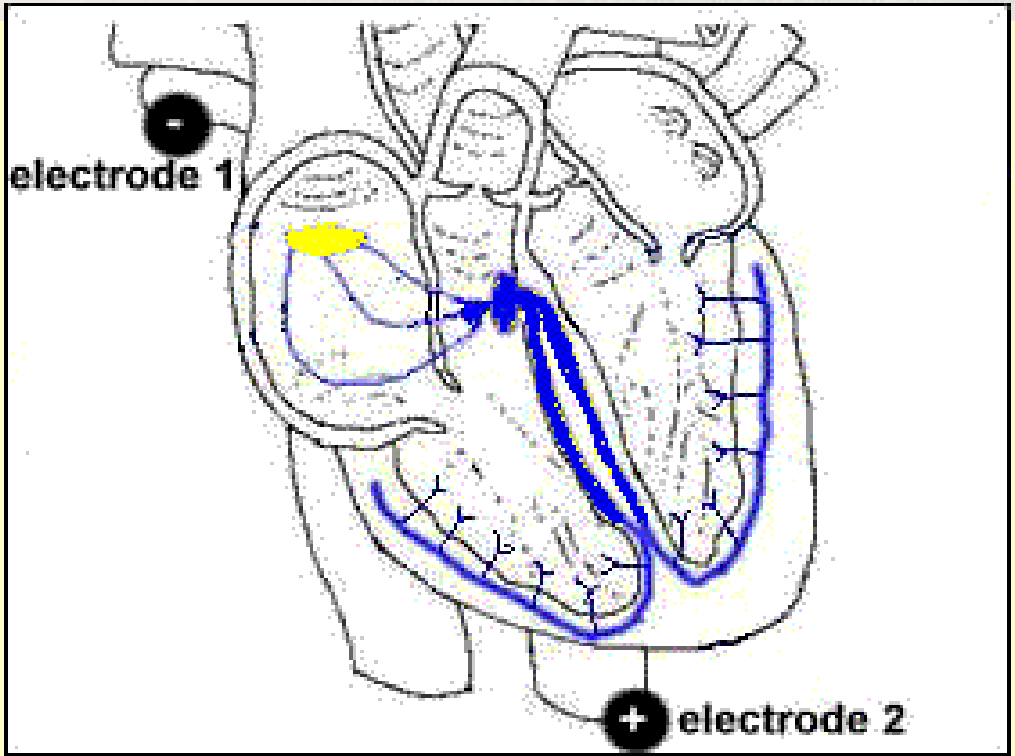
↓

Purkinje fibers

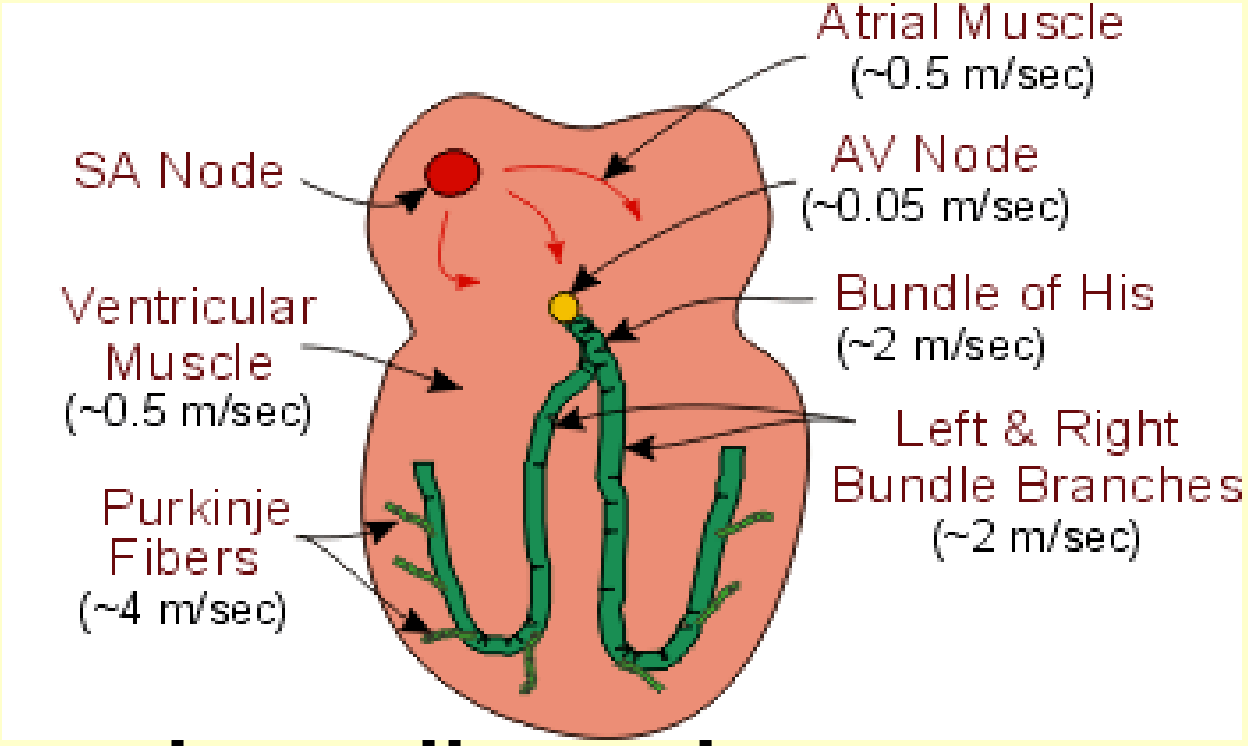
↓

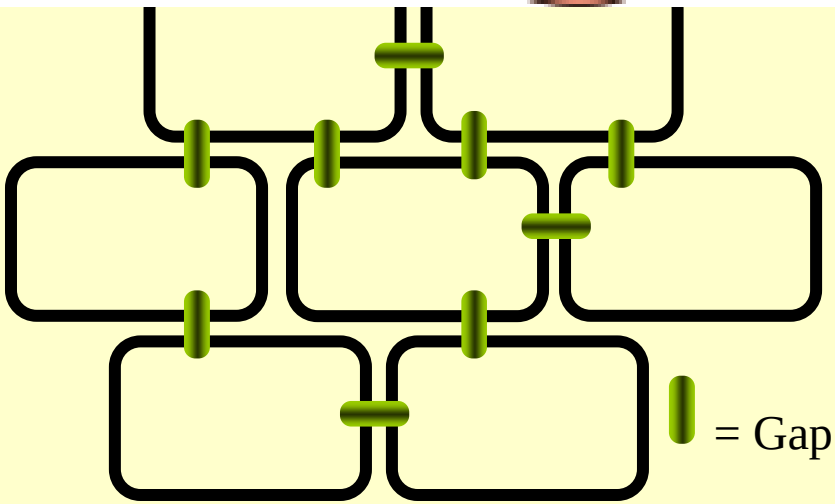
Ventricular myocardium





Velocity of traveling of AP



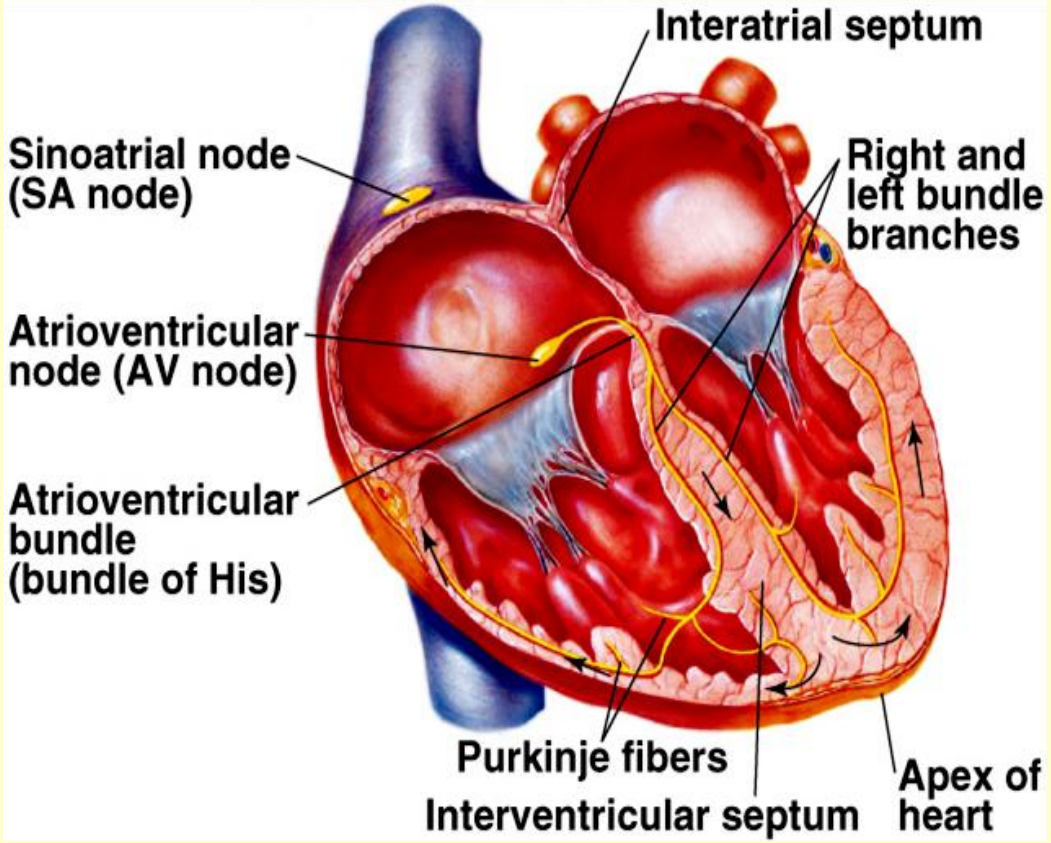


= Gap Junction Channel

❖ The bundle of His

✓the single connection

between atria and ventricles



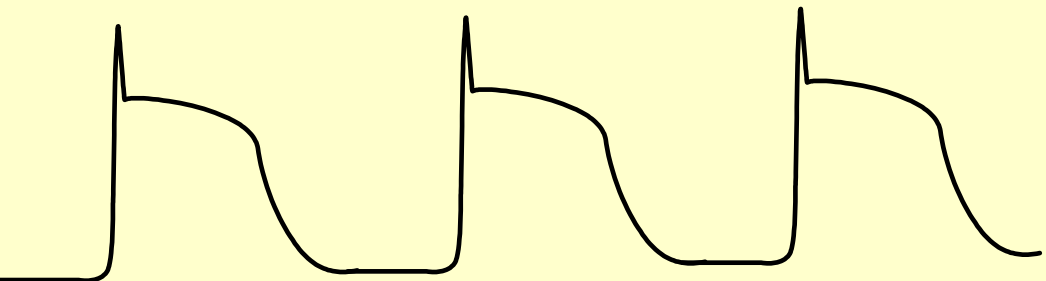
❖ Purkinje fibers

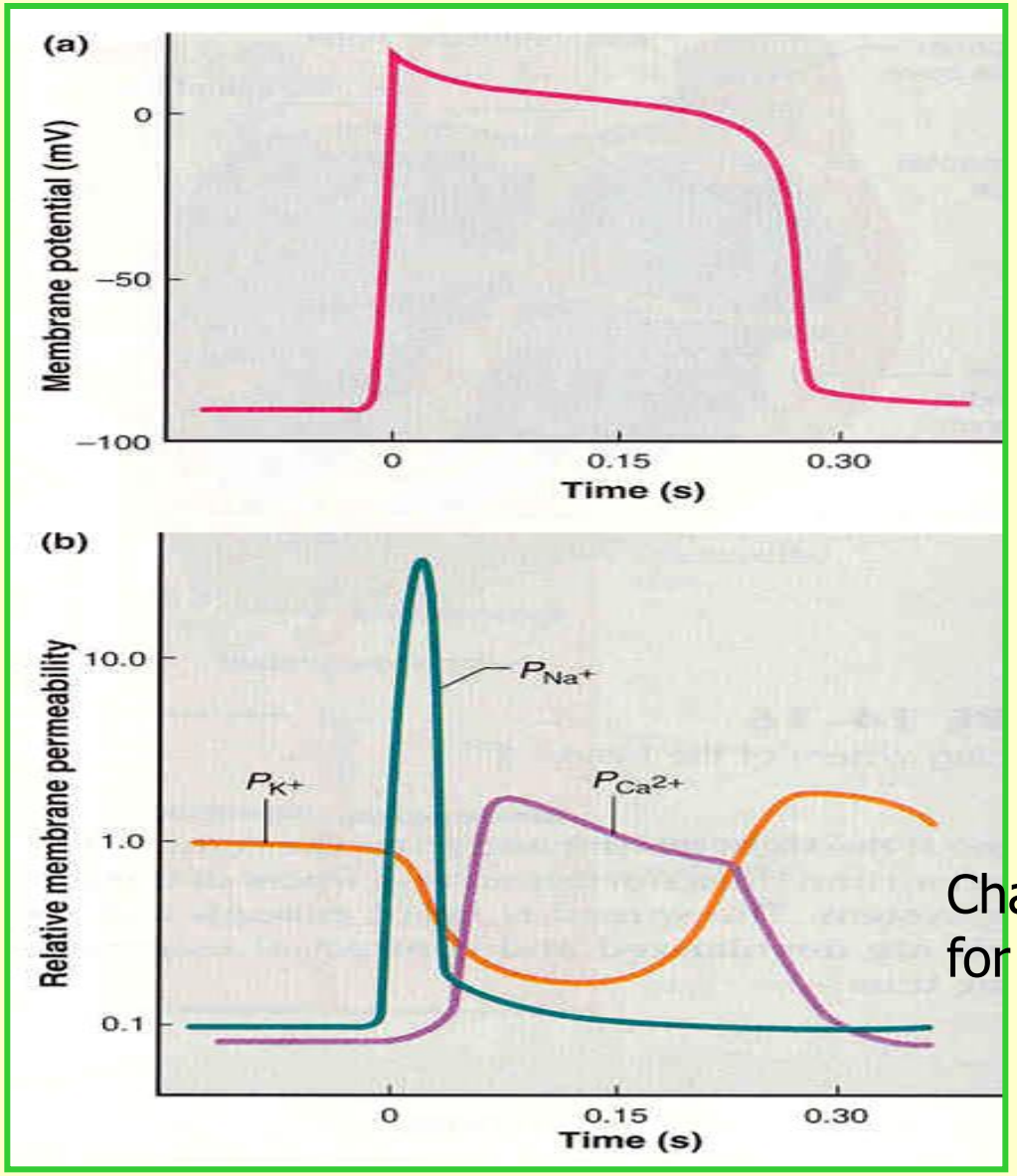
✓ the thickest fibers

✓ the greatest velocity of conduction (4-5 m/s)

✓ low automatic rhythm 20-30/min

✓ prolonged AP

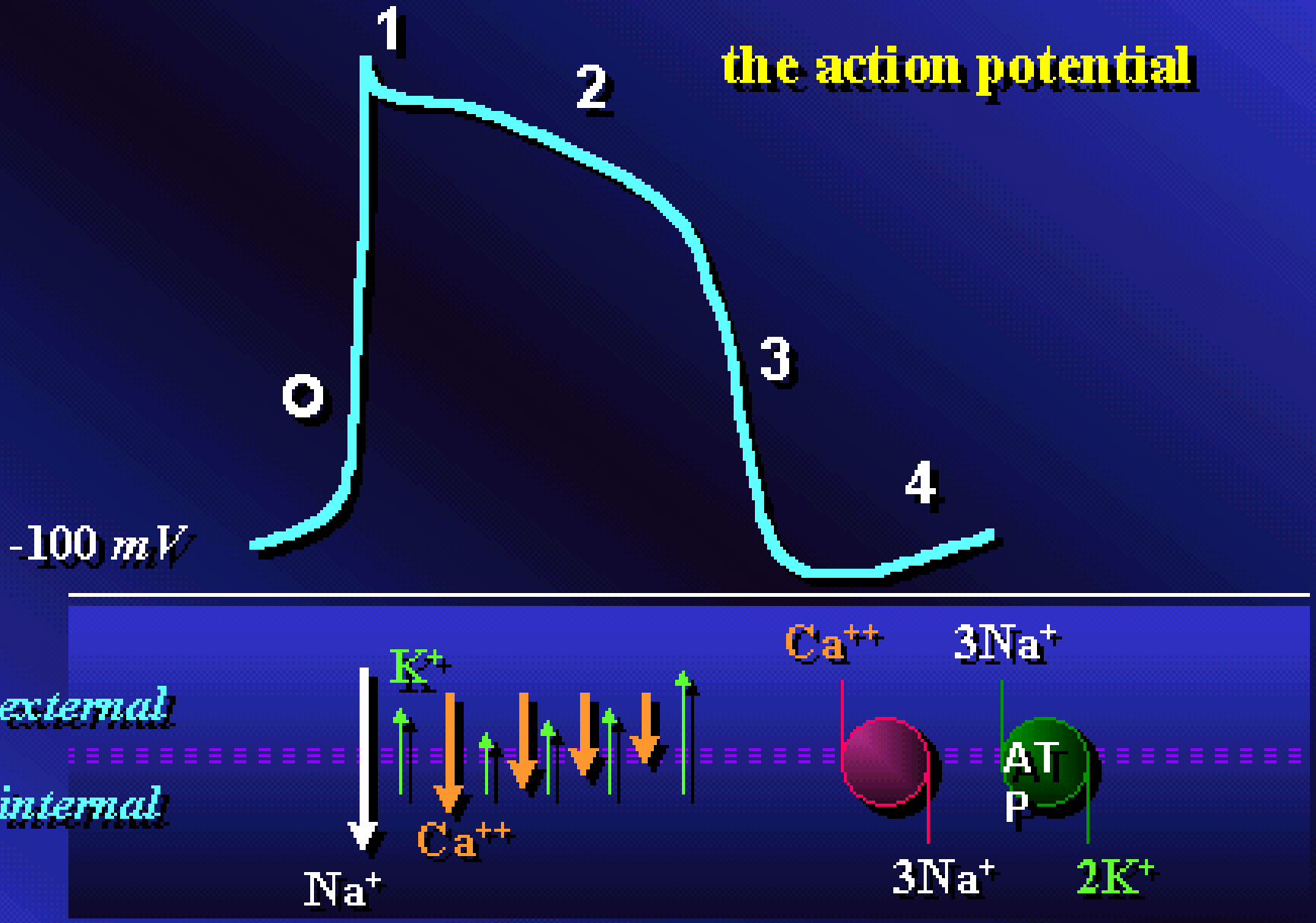




AP of ventricular muscle cell

Changes of membrane permeability for different ions during AP

AP of working ventricular myocardium



Electromechanical coupling in the myocardium

1. The AP is spread over the membrane

2. Depolarization opens L-type voltage-gated **Ca^{2+}** channels

3. Entered **Ca^{2+}** ions interact with ryanodine receptors and open **Ca^{2+}** channels on the membrane of SR

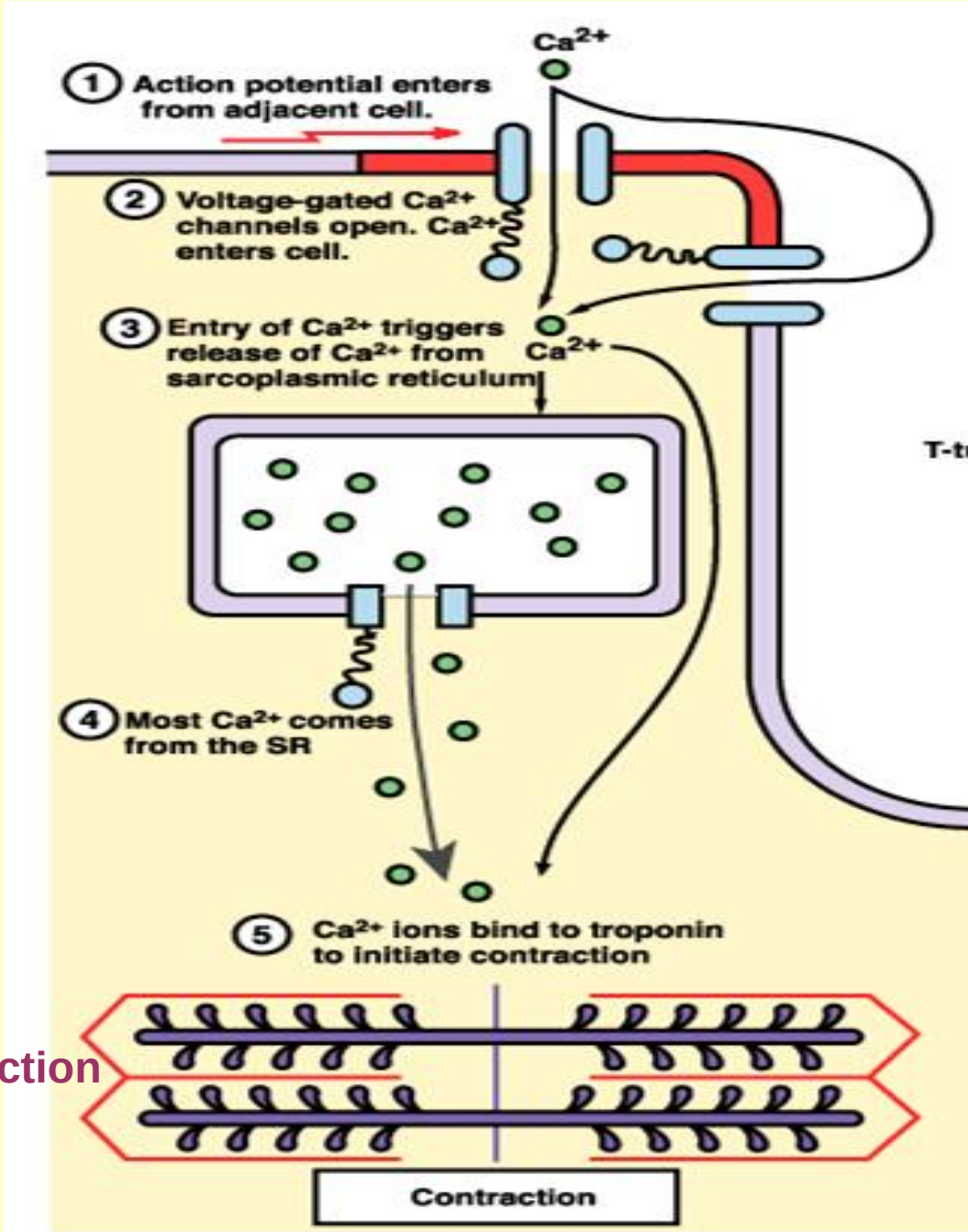
4. Ca^{2+} release from SR

5. Ca^{2+} bind to troponin C

6. Removal of the inhibitory action of troponin I on the actin occurs

7. Tropomiozin moves and the active centers of actin are discovered

8. Myosin heads bind to actin → **contraction**



Comparison of excitation-contraction coupling in skeletal muscle and cardiac muscle

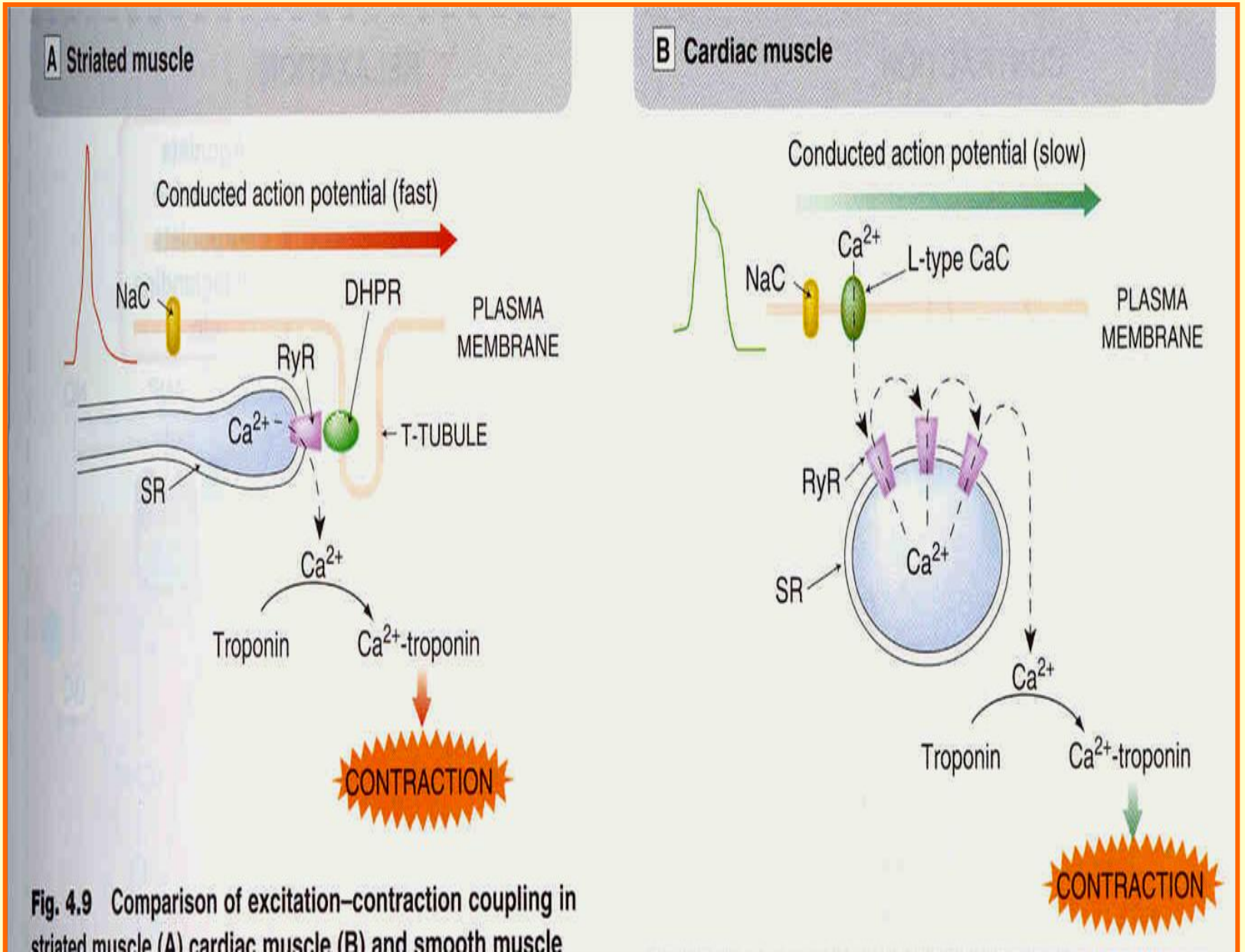
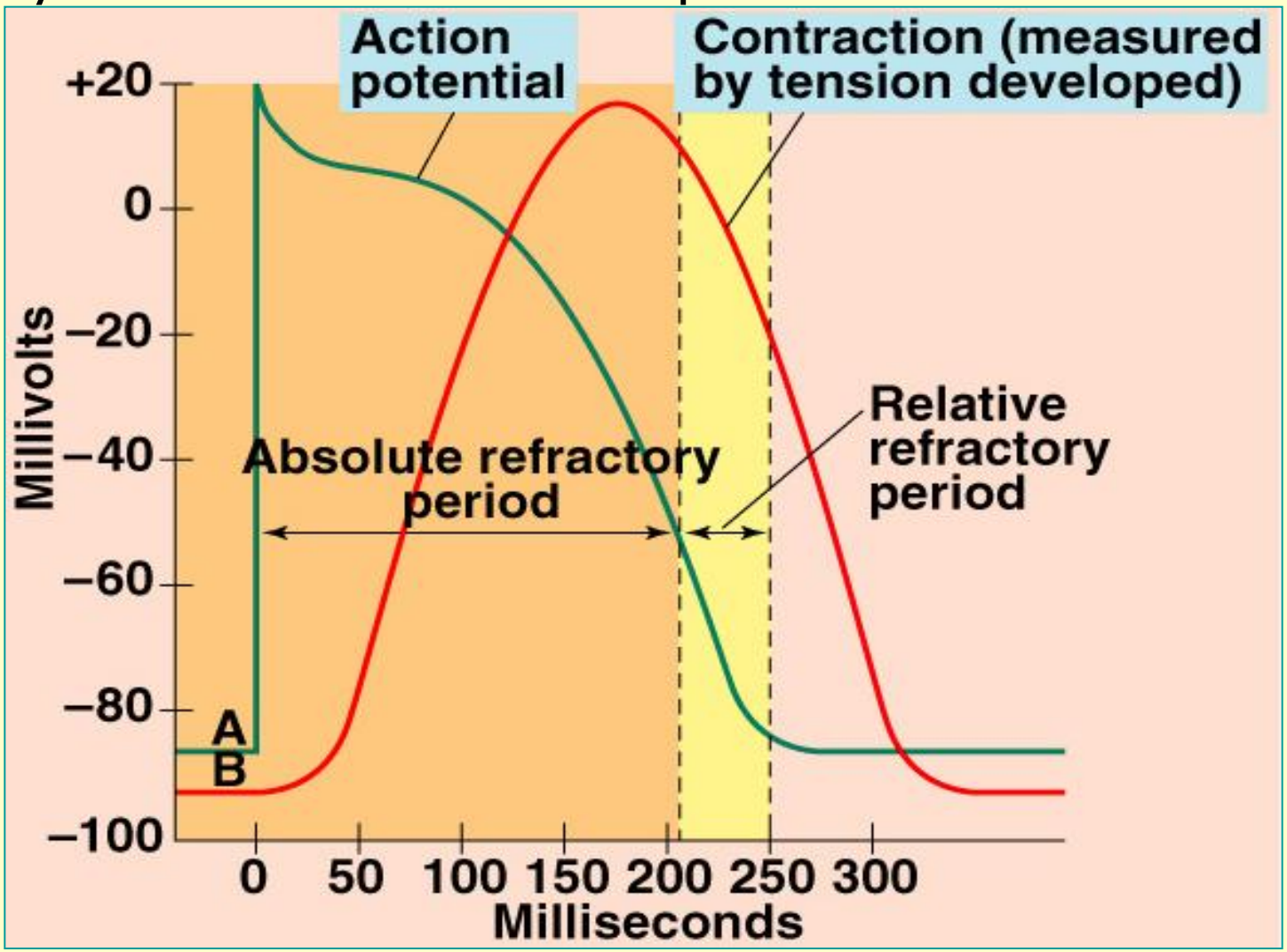


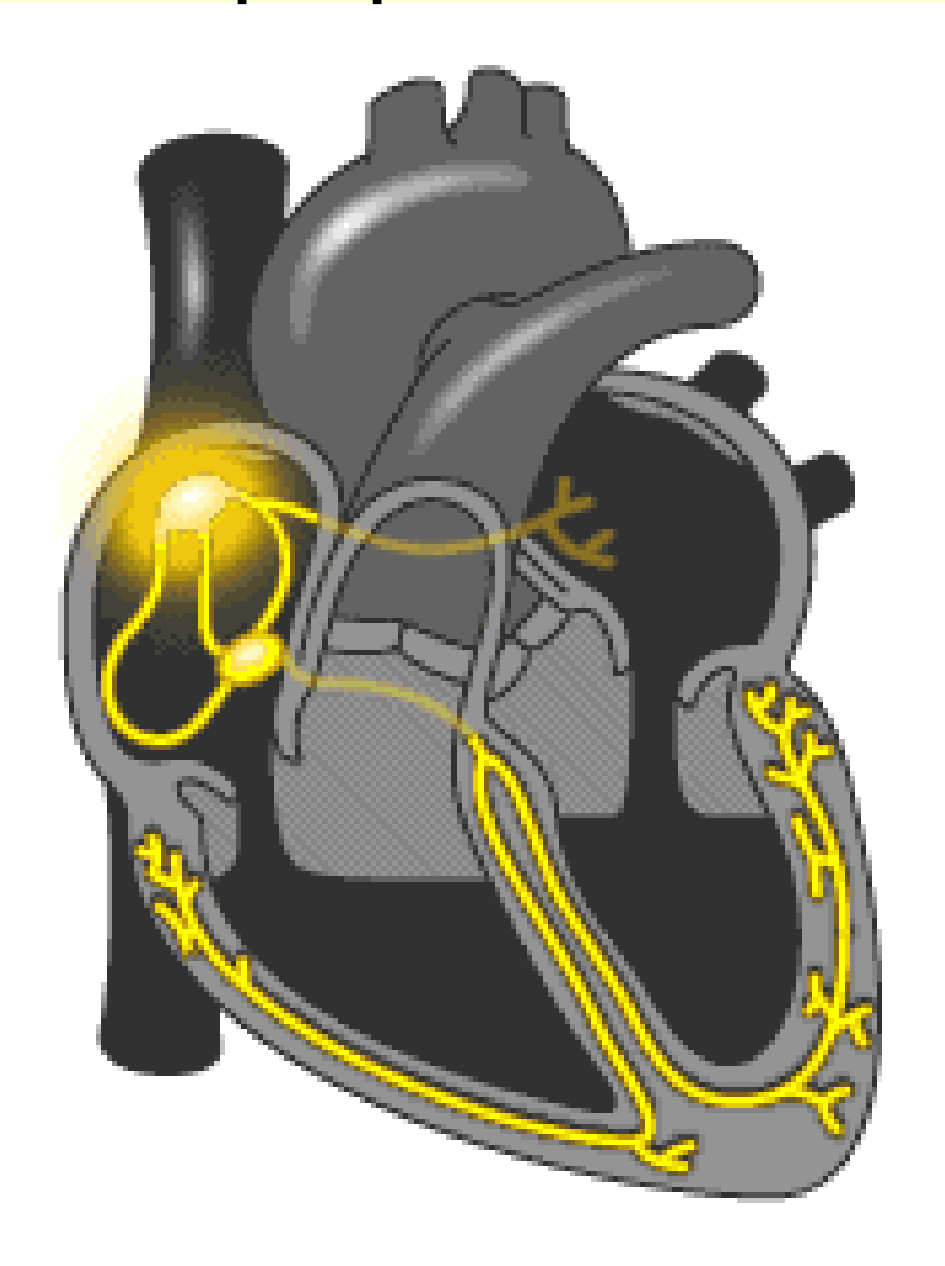
Fig. 4.9 Comparison of excitation–contraction coupling in striated muscle (A) cardiac muscle (B) and smooth muscle

Excitation and contraction

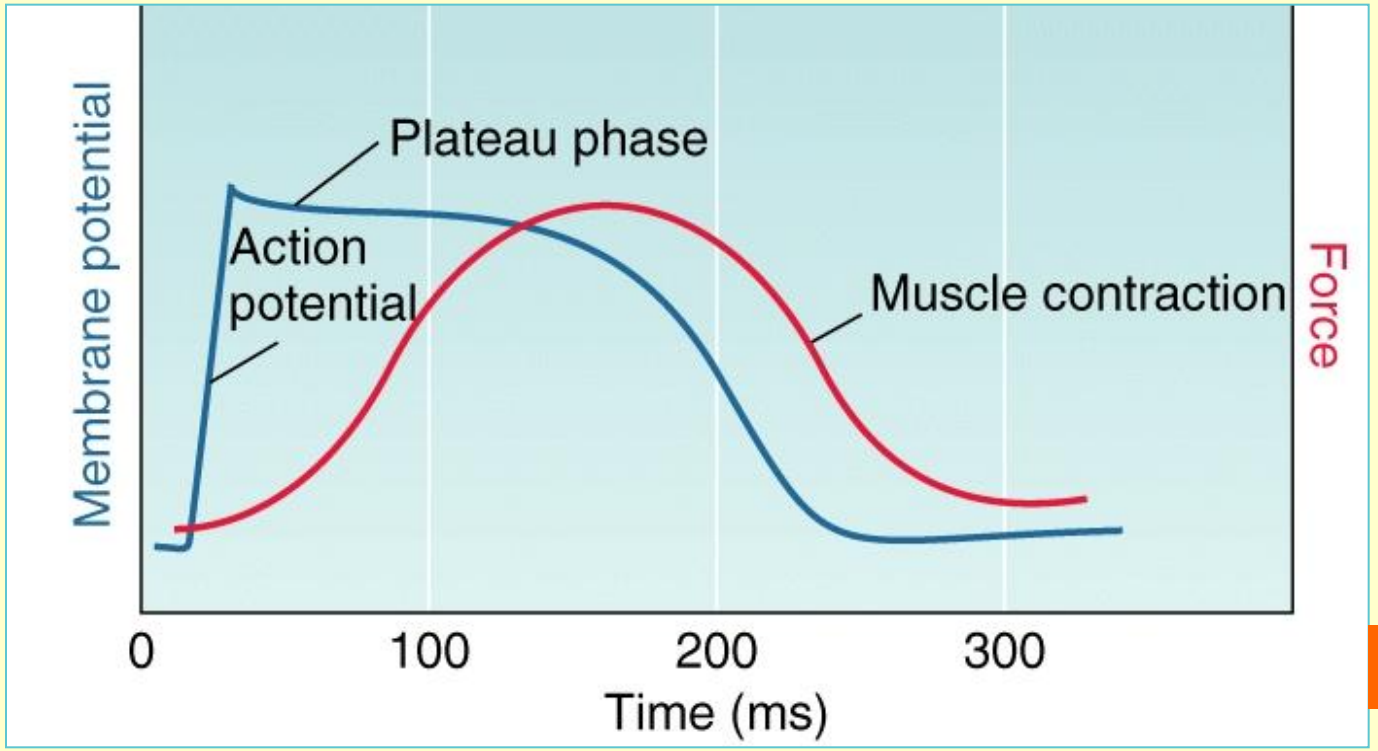
Absolute refractory period of AP of working ventricular myocardium coincides with period of contraction.



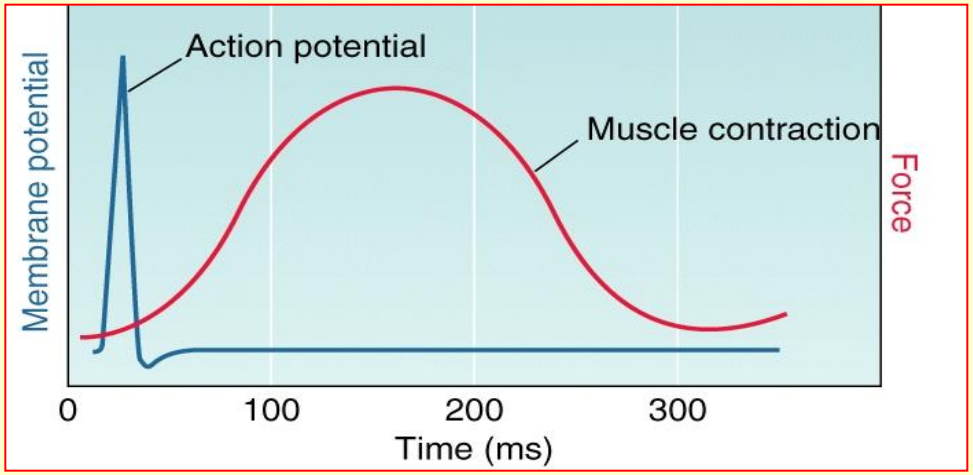
Excitation and contraction of myocardium ensures its pump function



Functional differences between cardiac and skeletal muscles



Cardiac muscle



Skeletal muscle

Willem Einthoven (1860-1927) and Thomas Lewis (1881-1945)

*While **Einthoven** must be looked upon as the inventor of electrocardiography, **Lewis** should be remembered as the promoter of its clinical application and the father of clinical cardiac electrophysiology.*

Early ECG apparatus developed by *Cambridge Scientific*

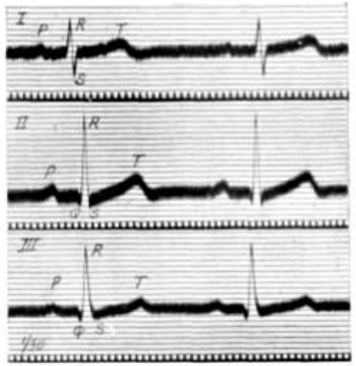


Fig. 22. Three electrocardiograms from a healthy young man.

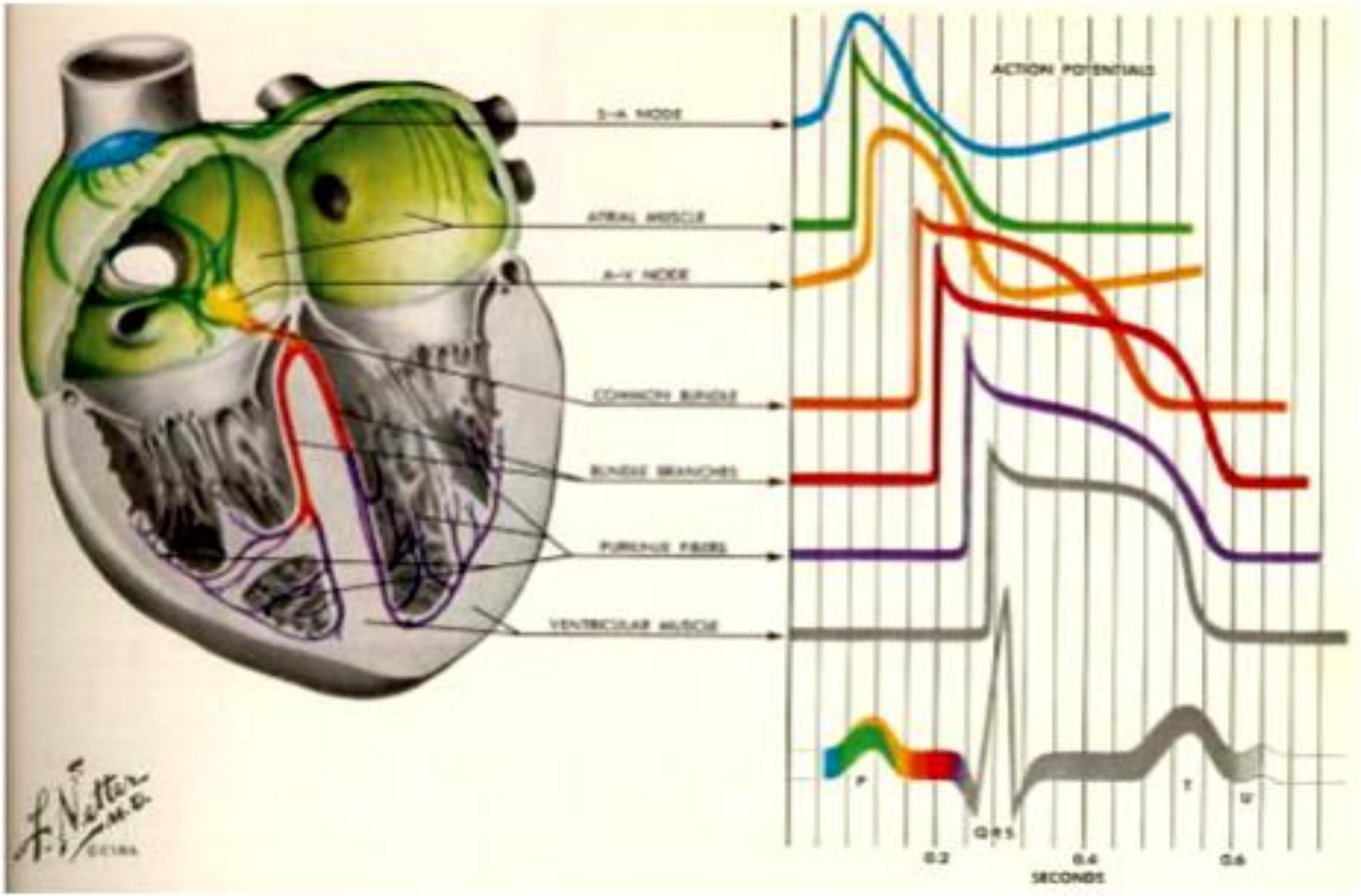
I. Leading from the right arm to the left arm.
II. Leading from the right arm to the left leg.
III. Leading from the left arm to the left leg.

Thomas Lewis,
The Mechanism and Graphic Registration of the Heart Beat,
3rd ed.
Shaw & Sons Ltd.,
London, 1925

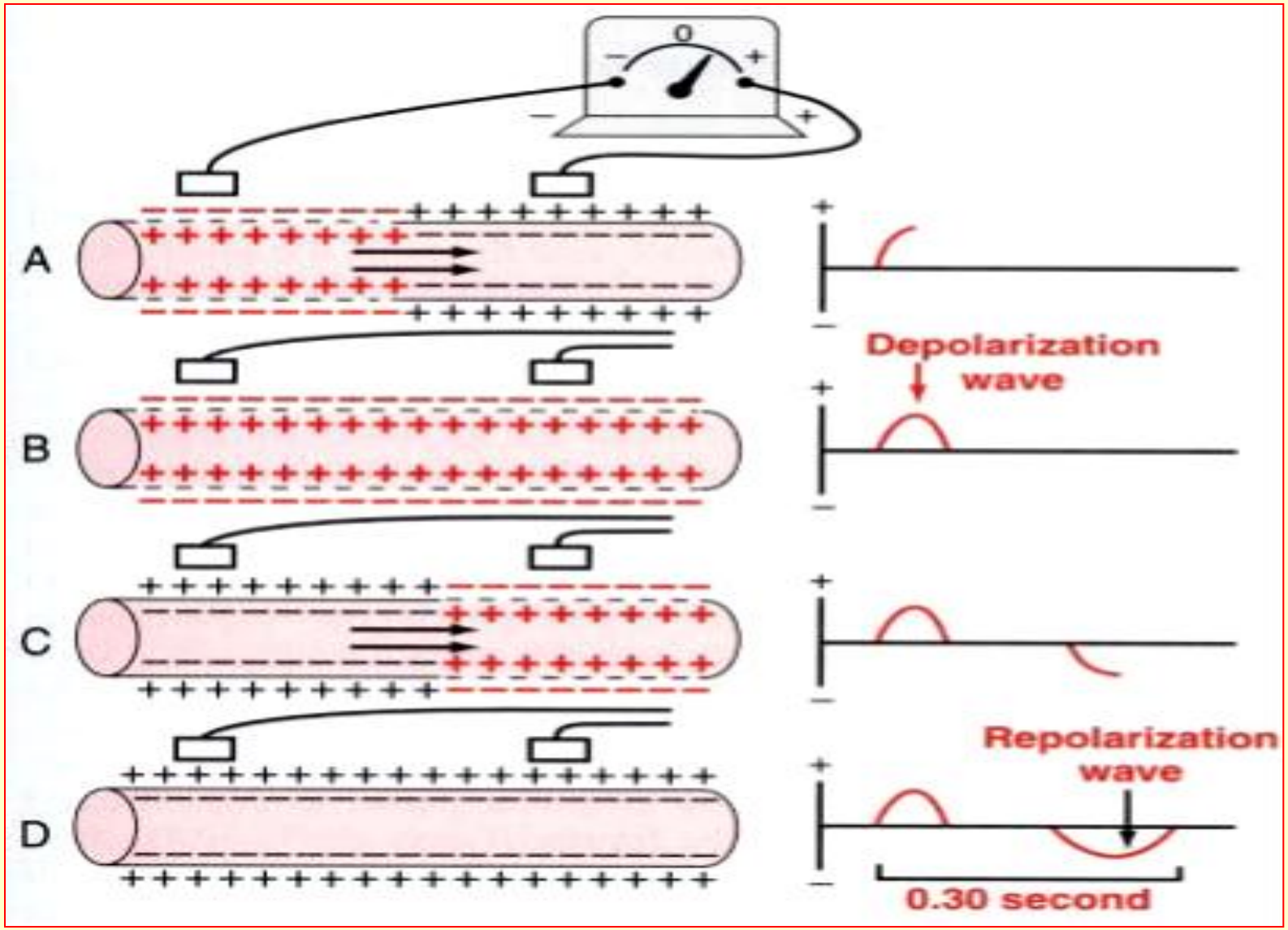
Electrocardiogram (ECG)

The ECG is a record of the total potential difference arising during the de- and the repolarization of the heart taken away from the surface of the body.

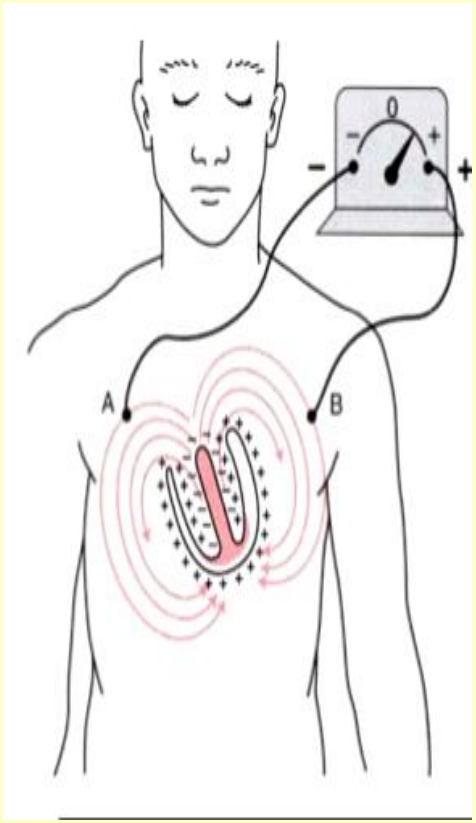
Cellular basis of ECG

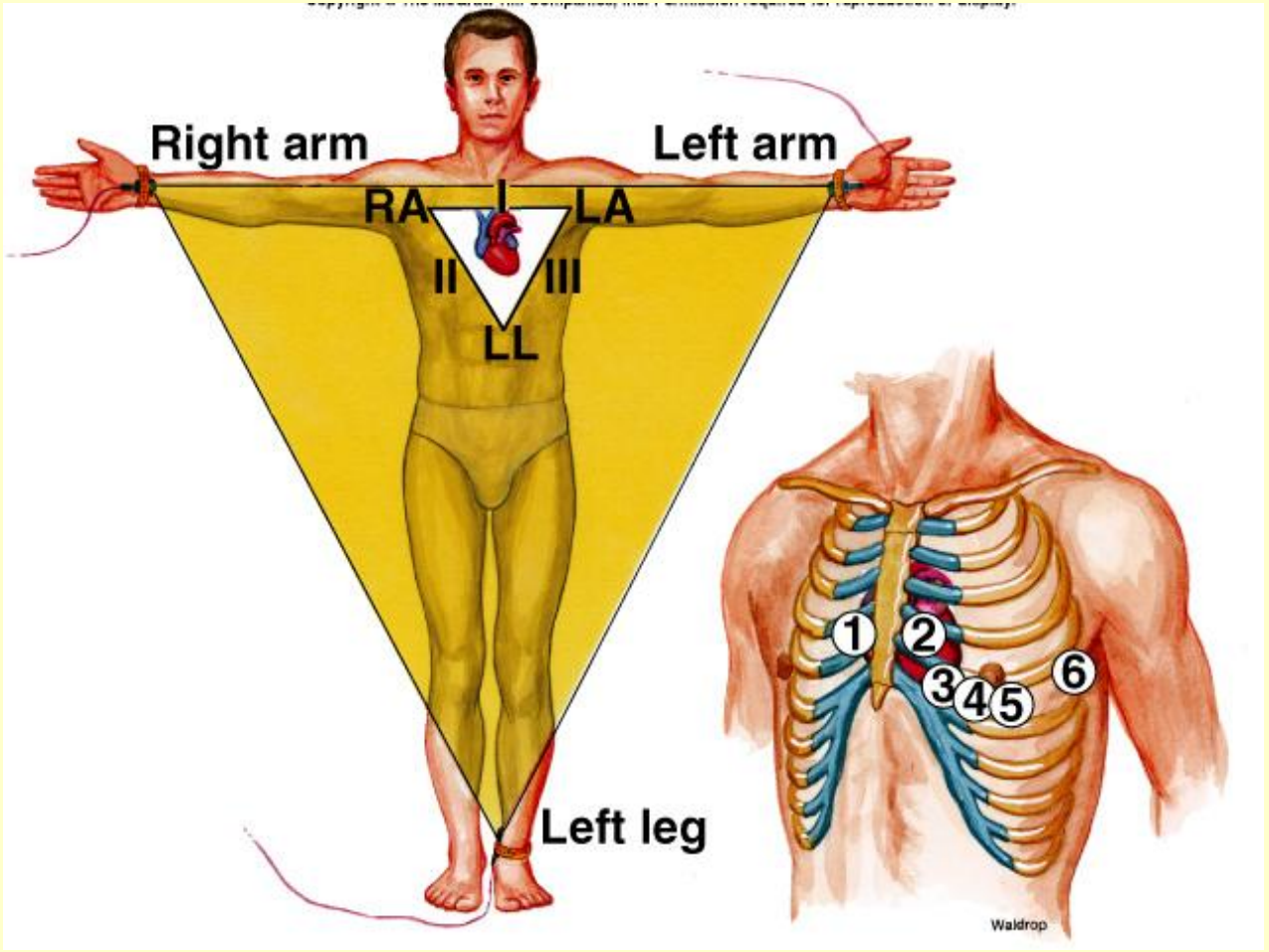


Registration of electrical currents

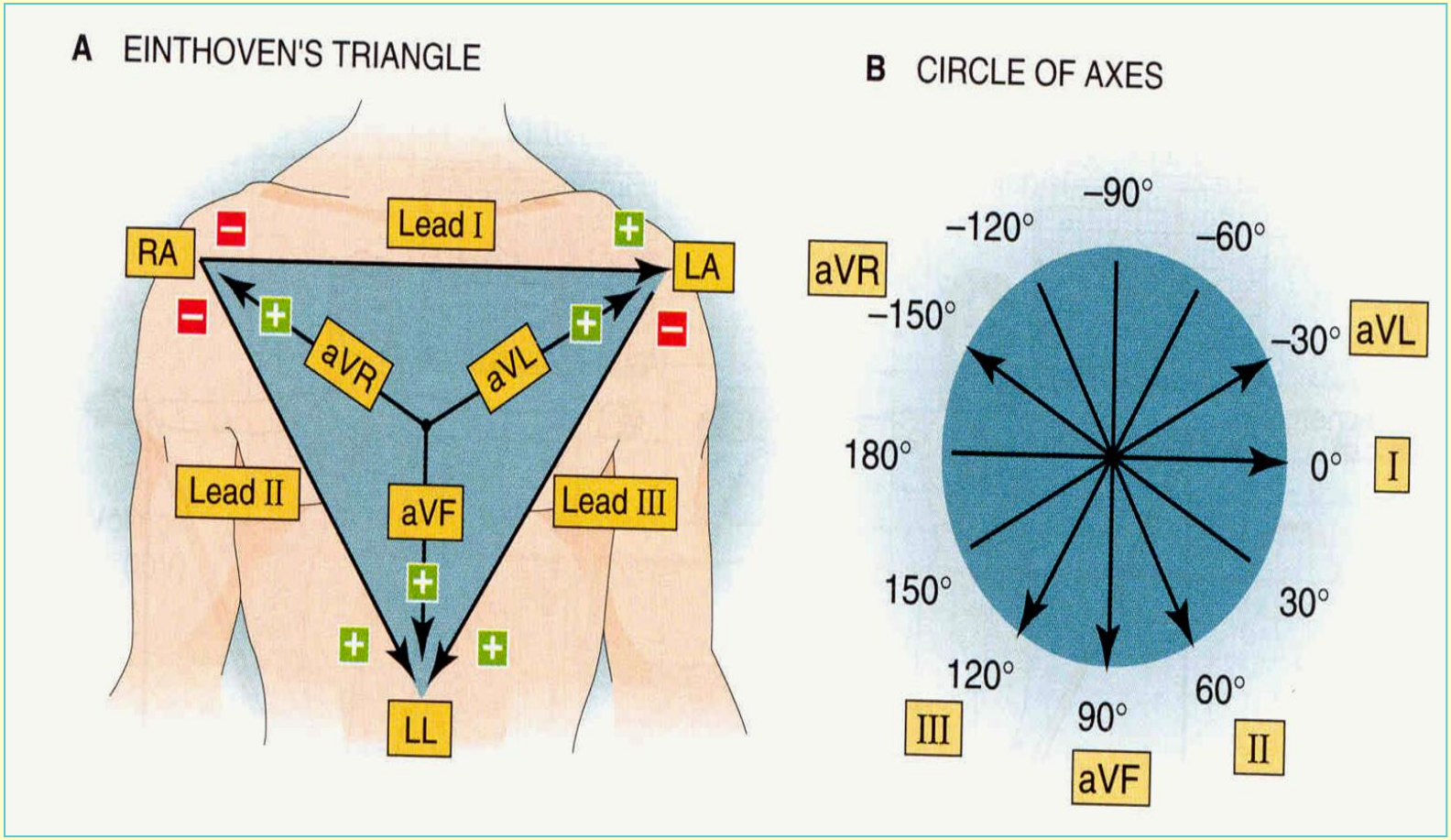


ECG

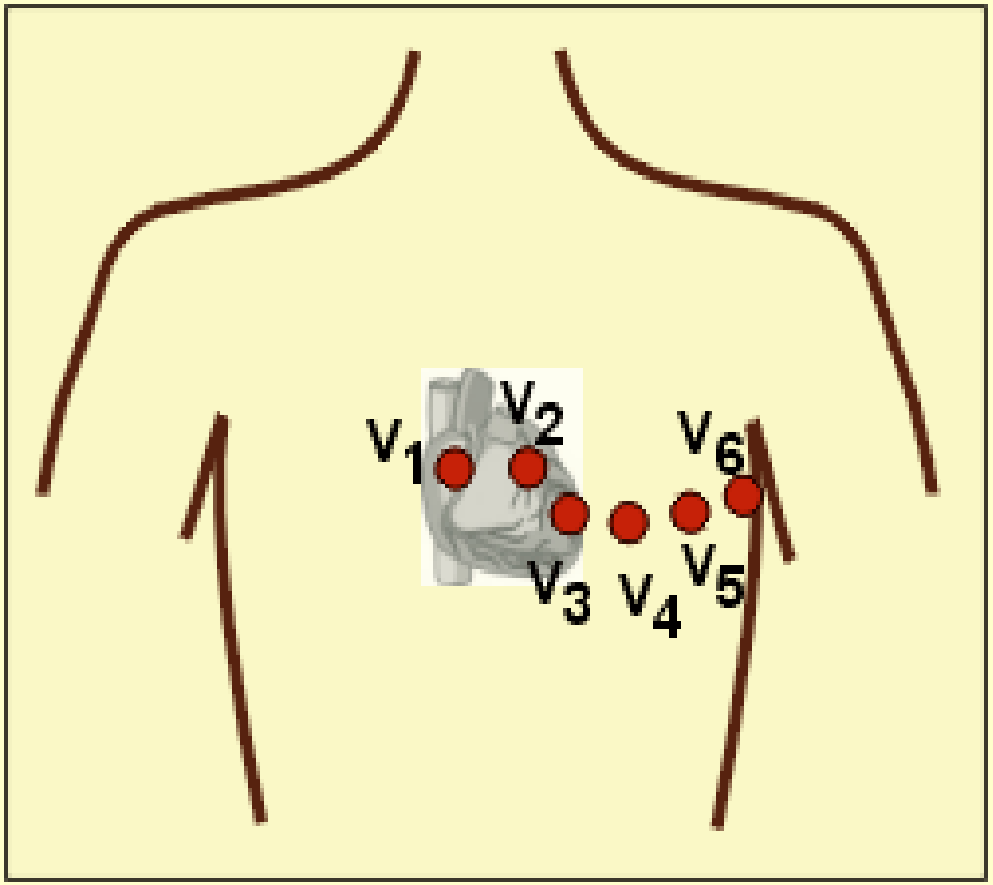




Electrical axes of peripheral ECG leads



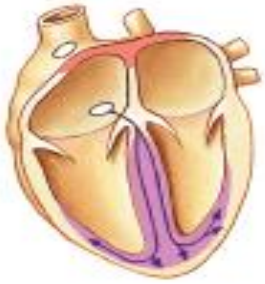
Precordial leads



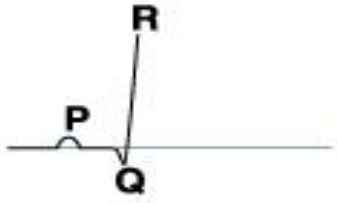
P wave

PQ segment

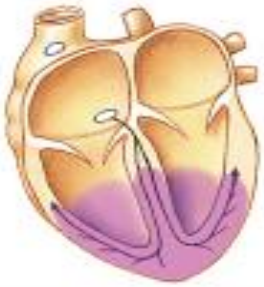
Q wave



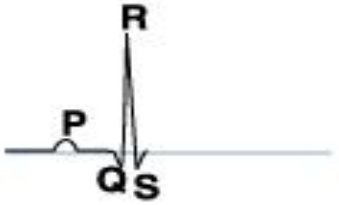
R wave



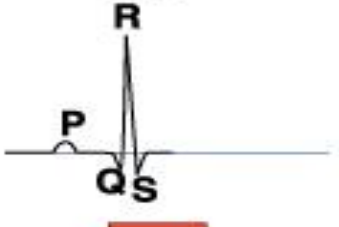
sys



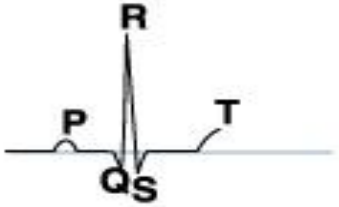
S wave



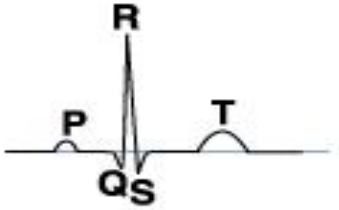
ST segment

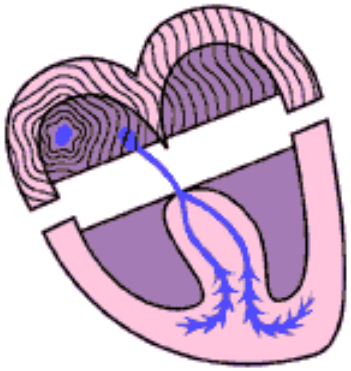


T wave



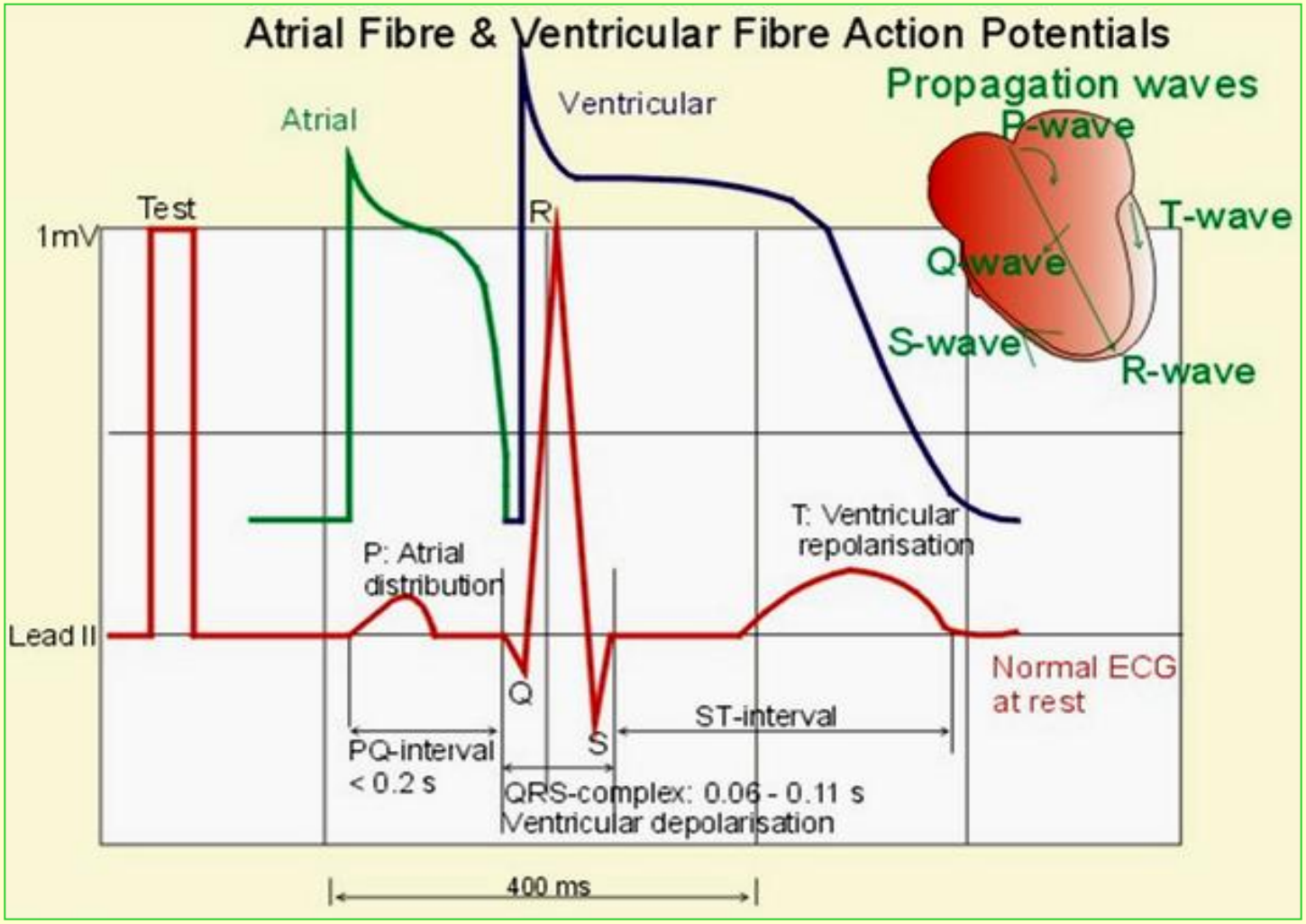
The end



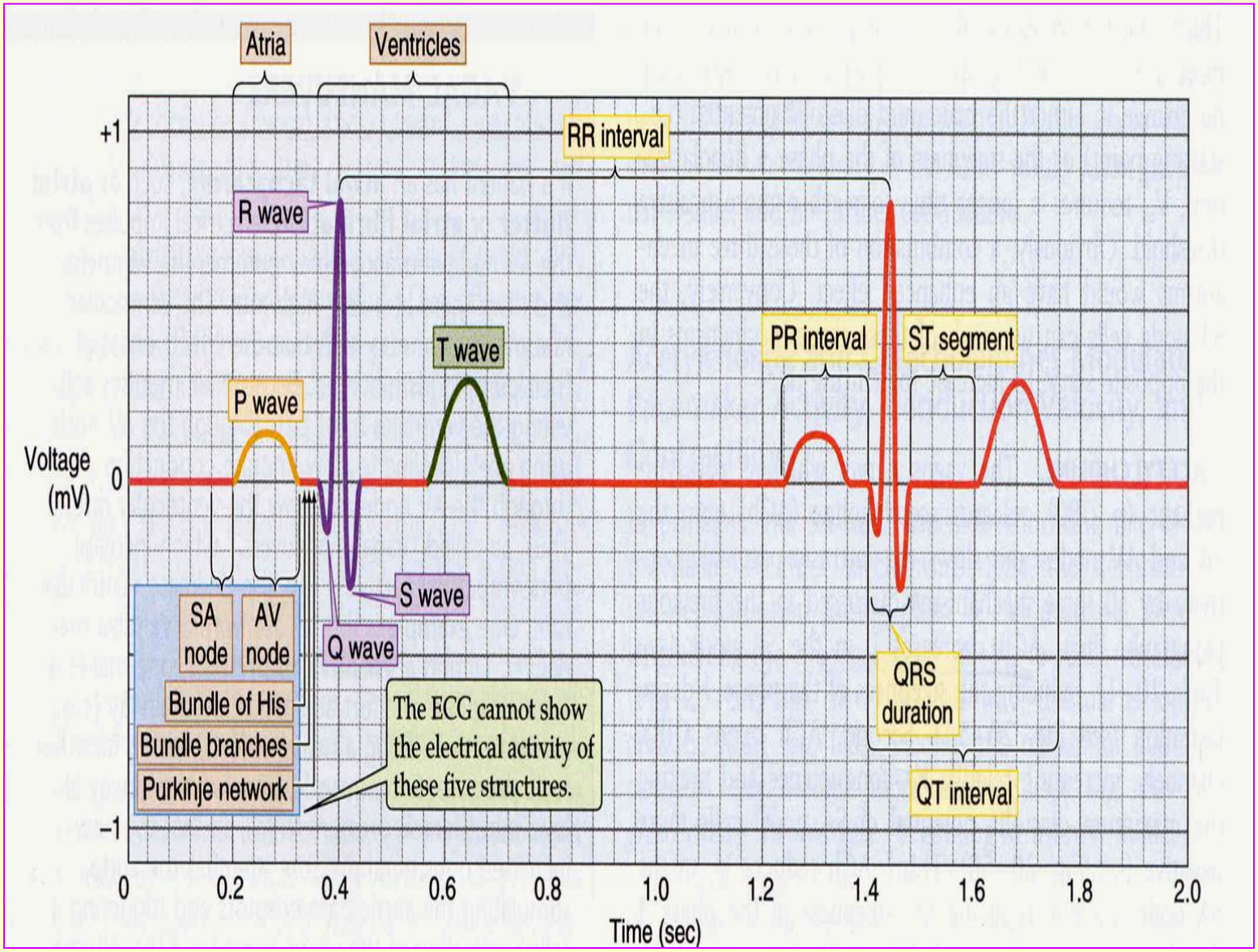


P wave

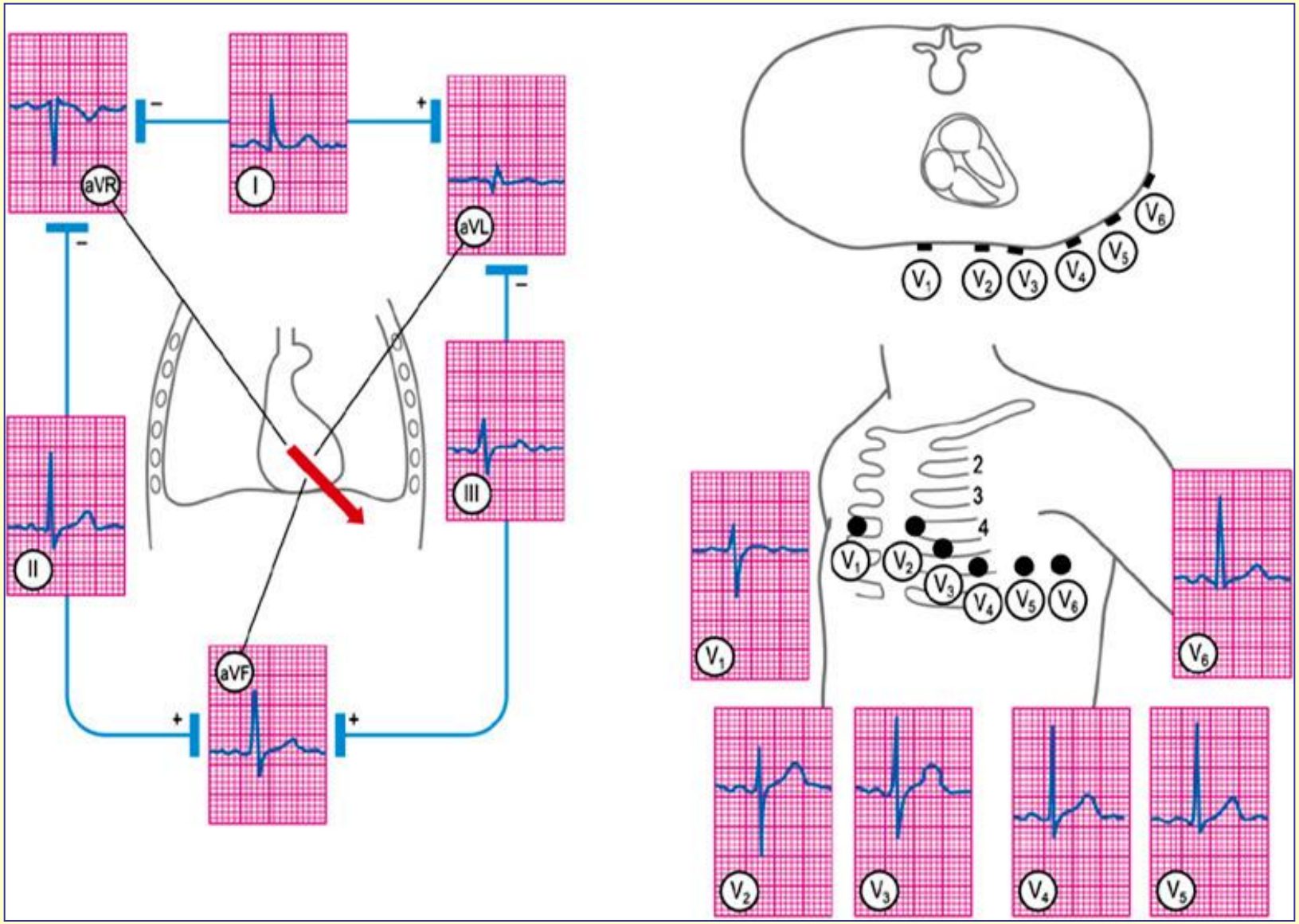
The origin of the elements of ECG

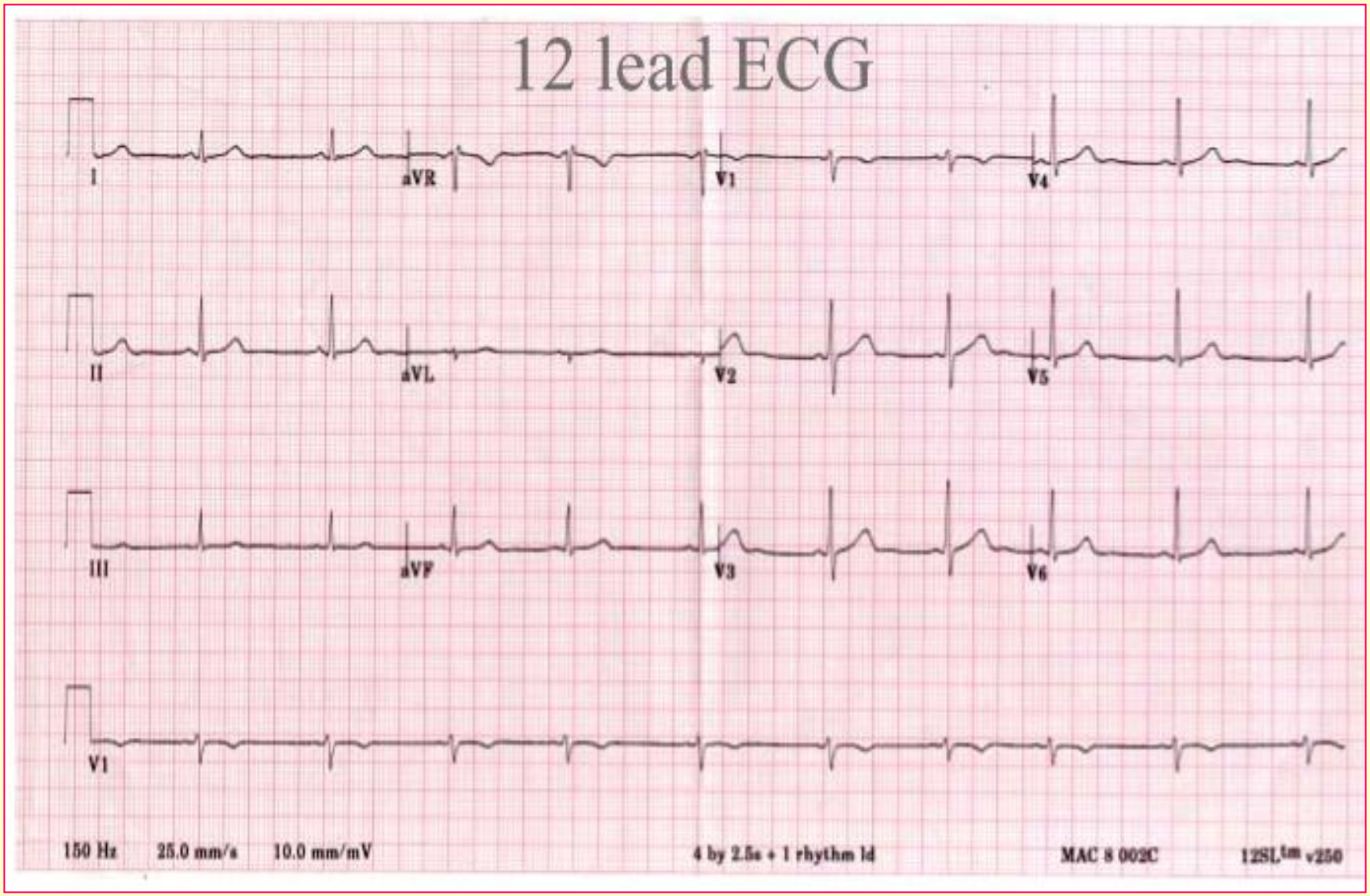


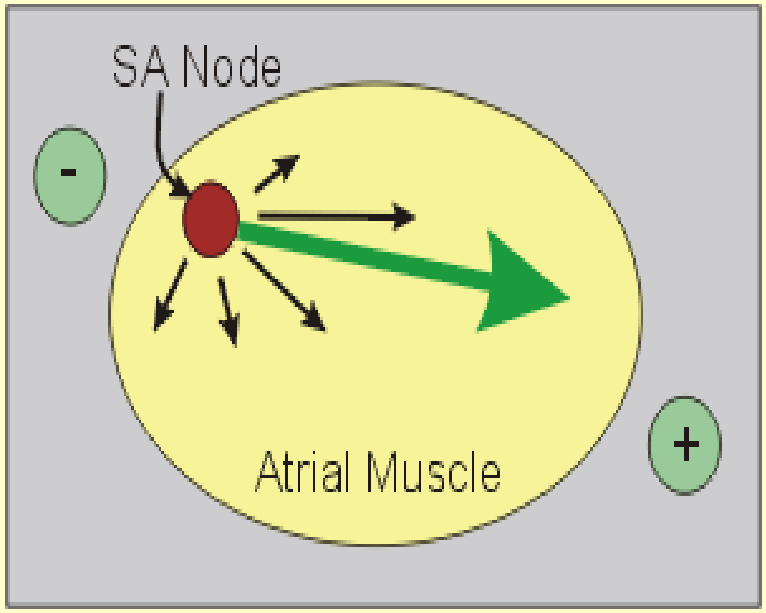
ECG


Atria
Ventricles
RR interval
R wave
T wave
PR interval
ST segment
P wave
+1
0
−1
Voltage (mV)
S wave
Q wave
SA node
AV node
Bundle of His
Bundle branches
Purkinje network
The ECG cannot show the electrical activity of these five structures.
QRS duration
QT interval
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
Time (sec)

12 ECG leads




12 lead ECG
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
V1
150 Hz
25.0 mm/s
10.0 mm/mV
4 by 2.5s + 1 rhythm ld
MAC 8 002C
12SL[tm] v250



Electrical axis of the heart

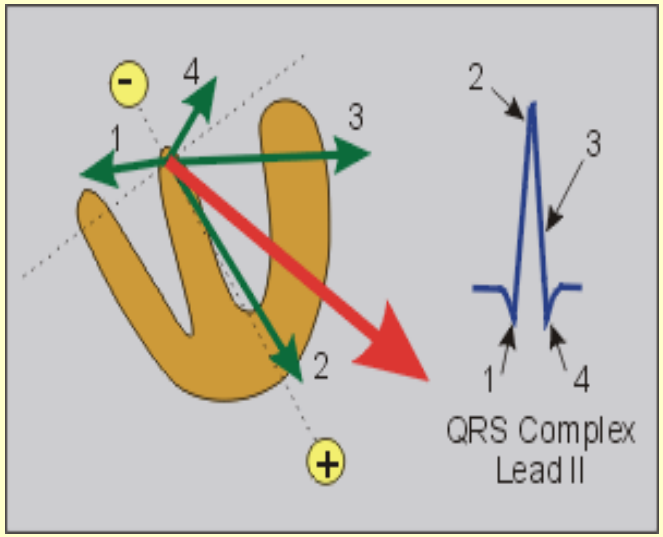
– the axis that connects the points with the greatest potential differences in the heart during cardiac cycle.

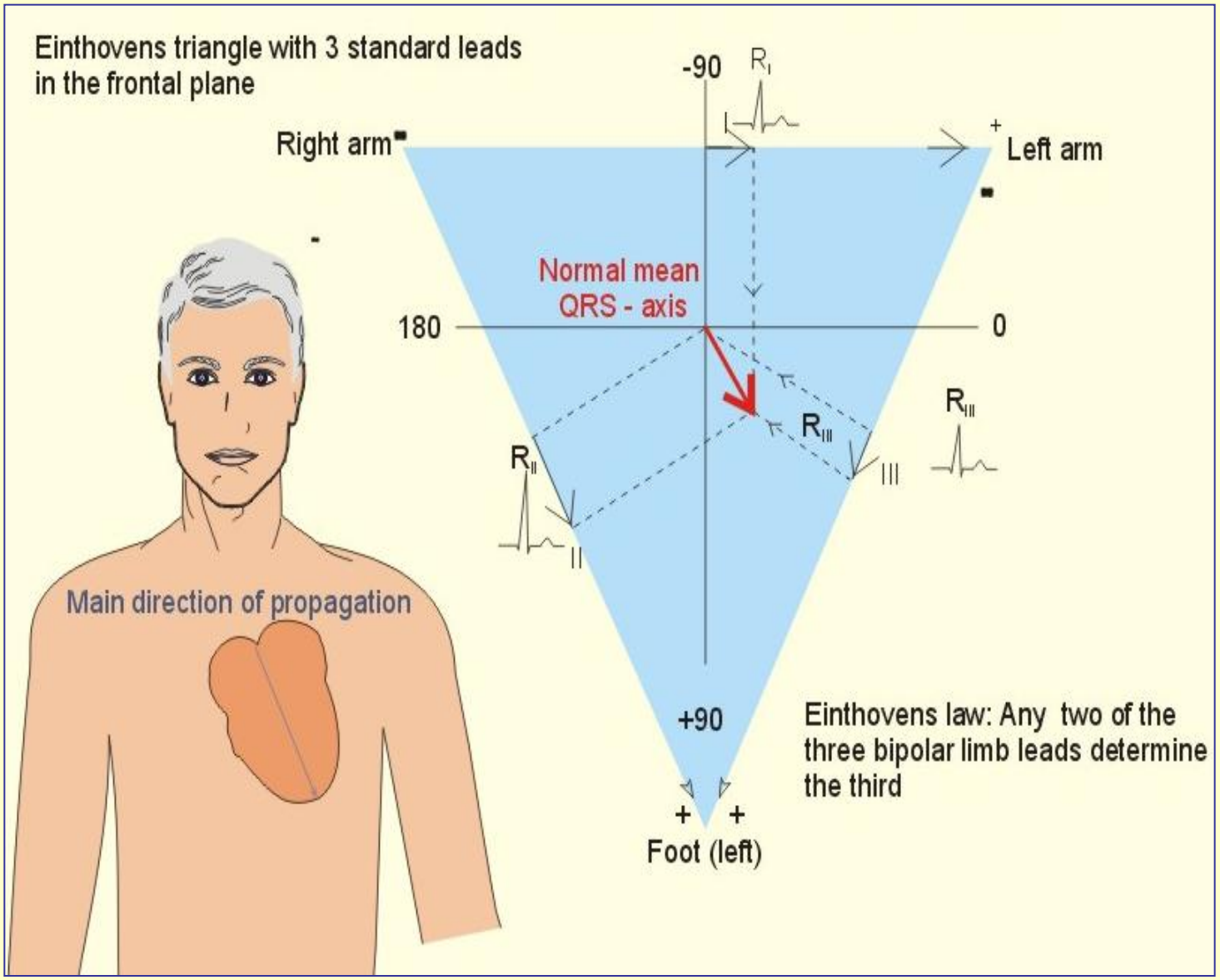
Mean electrical axis of the heart

– the dominant direction of electrical axis of the heart during ventricular depolarization.

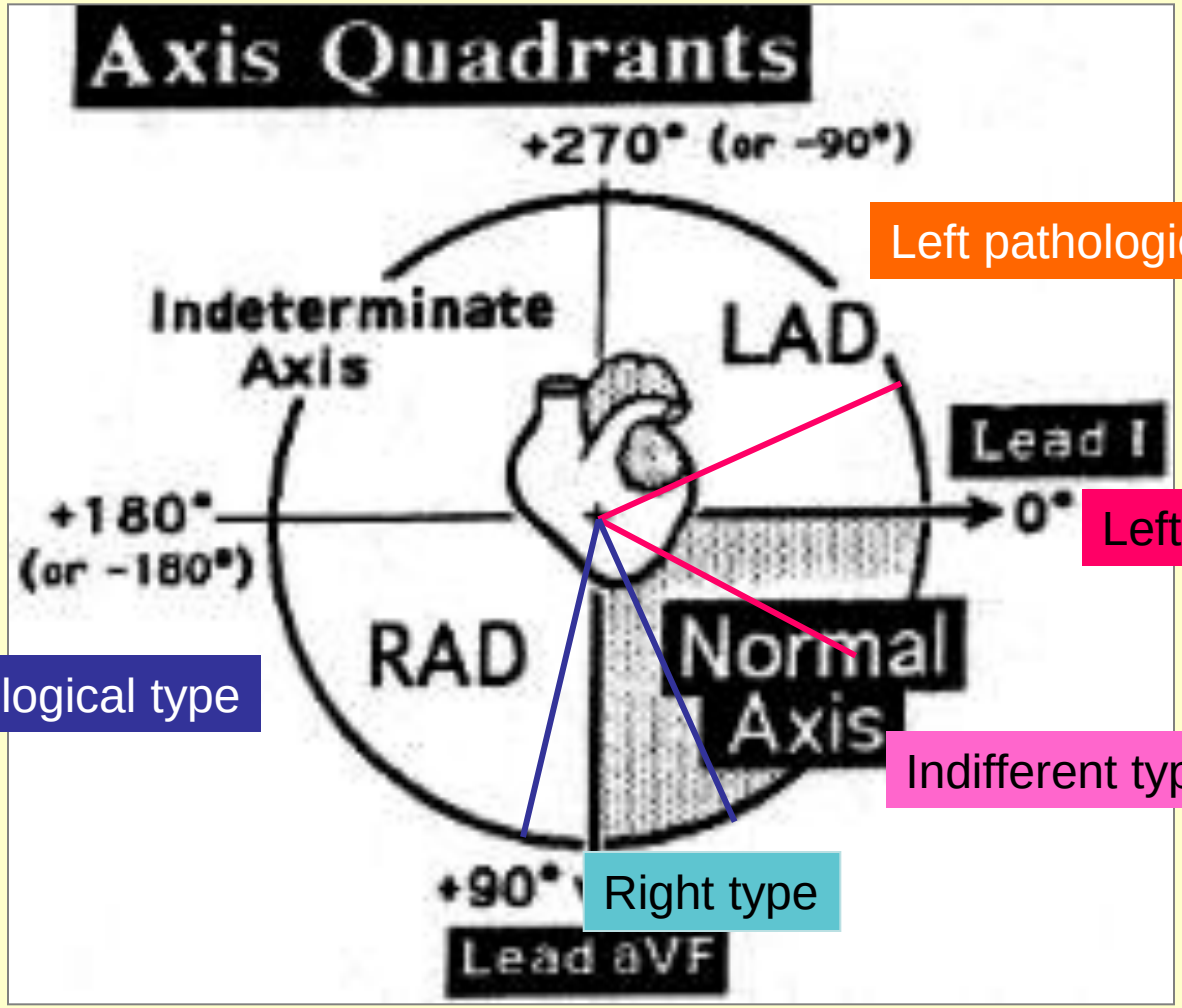
Its direction depends on:

- anatomical axis of the heart
- the mass of ventricular myocardial cells
- the time for propagation of excitation in ventricles




Einthovens triangle with 3 standard leads in the frontal plane
-90
R_I
Right arm
Left arm
Normal mean QRS - axis
180
0
R_{III}
R_{II}
III
II
Main direction of propagation
+90
Einthovens law: Any two of the three bipolar limb leads determine the third
Foot (left)

The types of mean electrical axis of the heart (electrical position of the heart)



Left pathological type

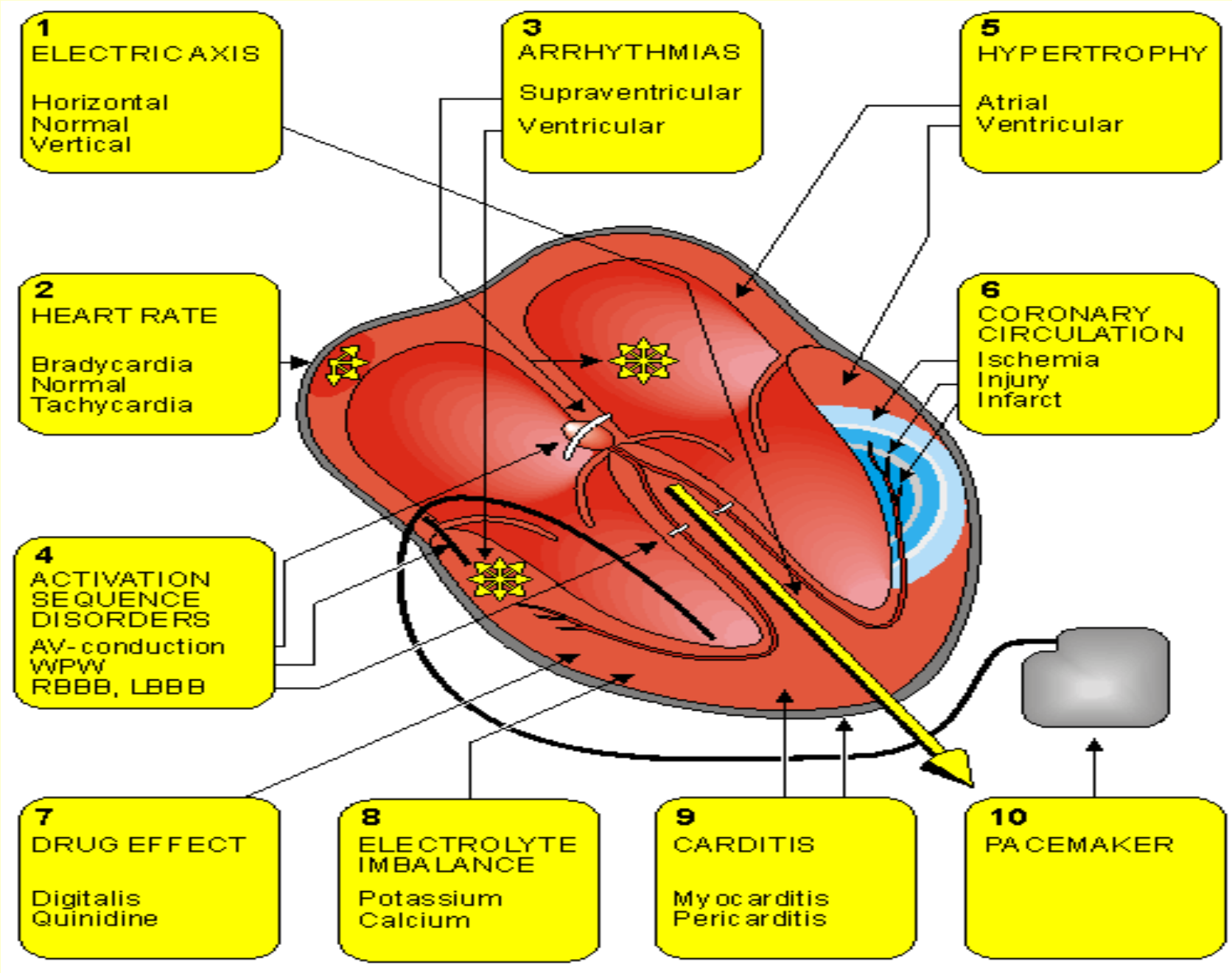
Left type

Right pathological type

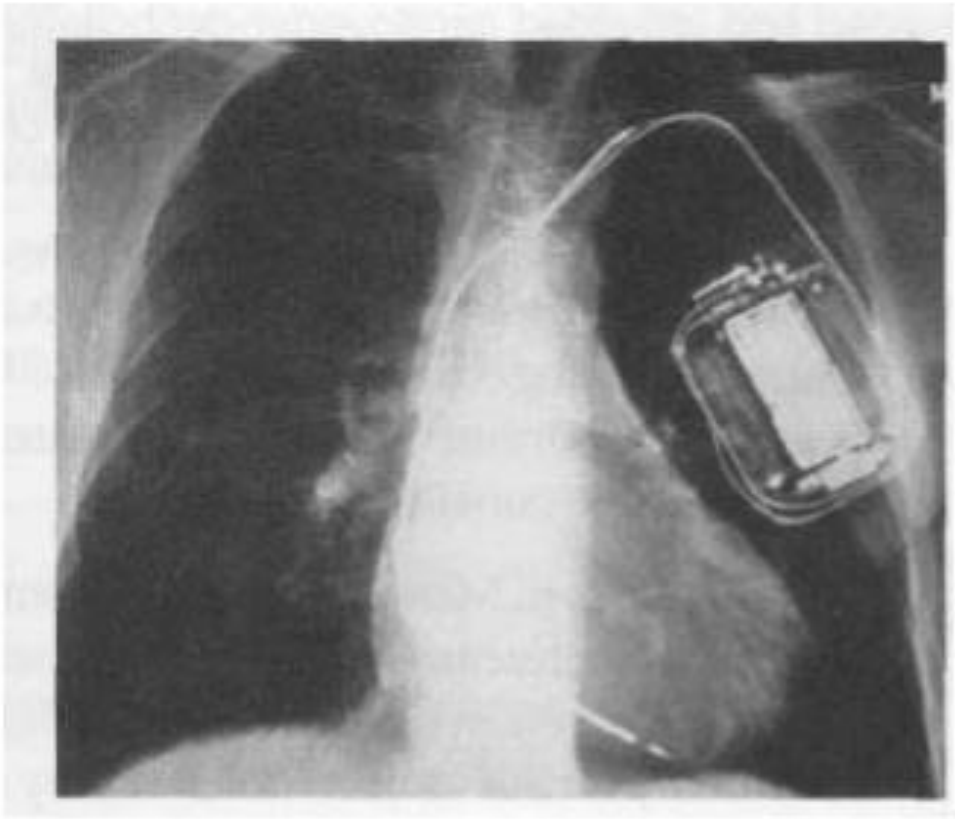
Indifferent type

Right type

Clinical application of ECG for:



Implantable device therapy



Automatic external defibrillator

Thanks for your attention!