

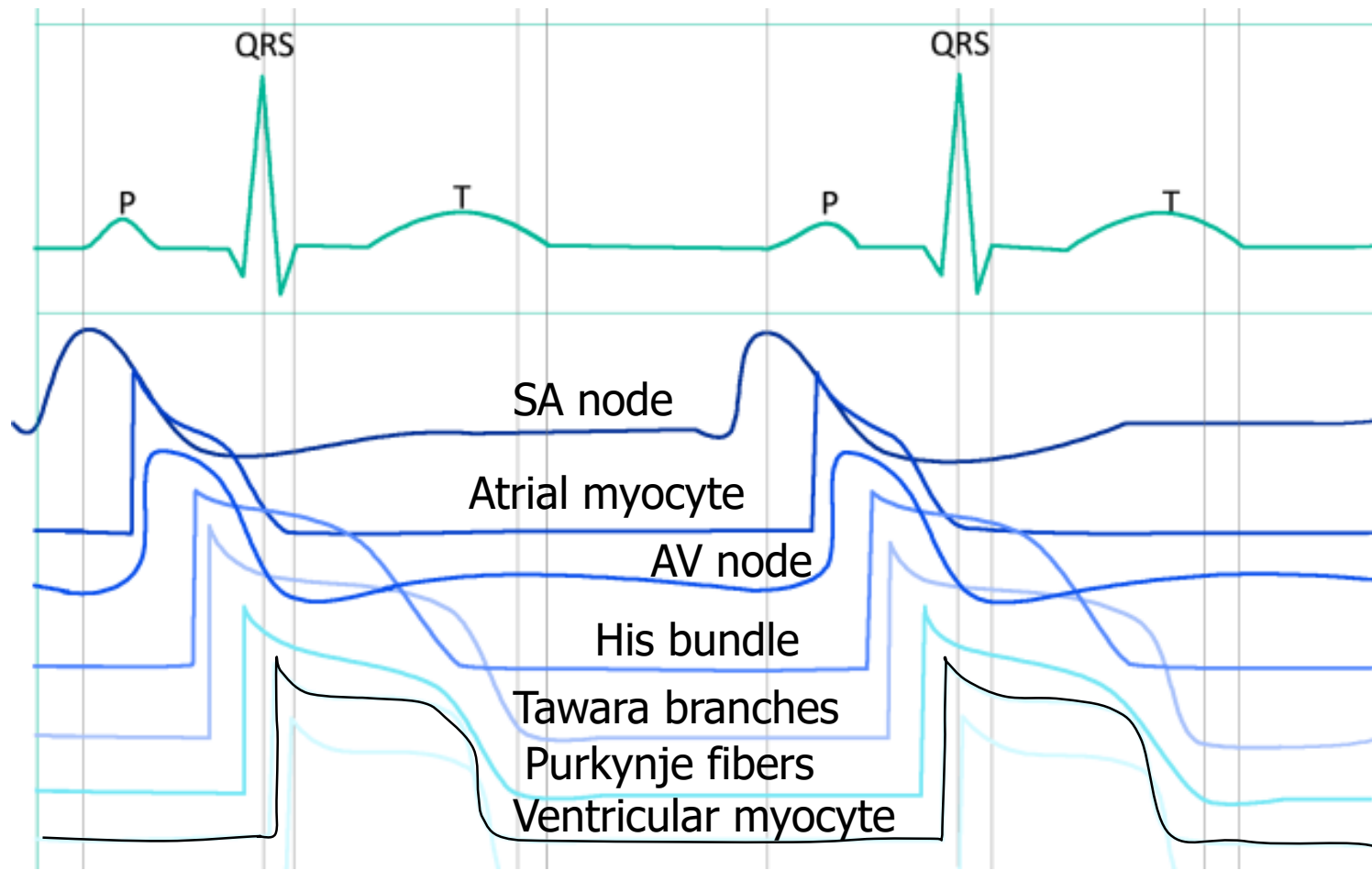
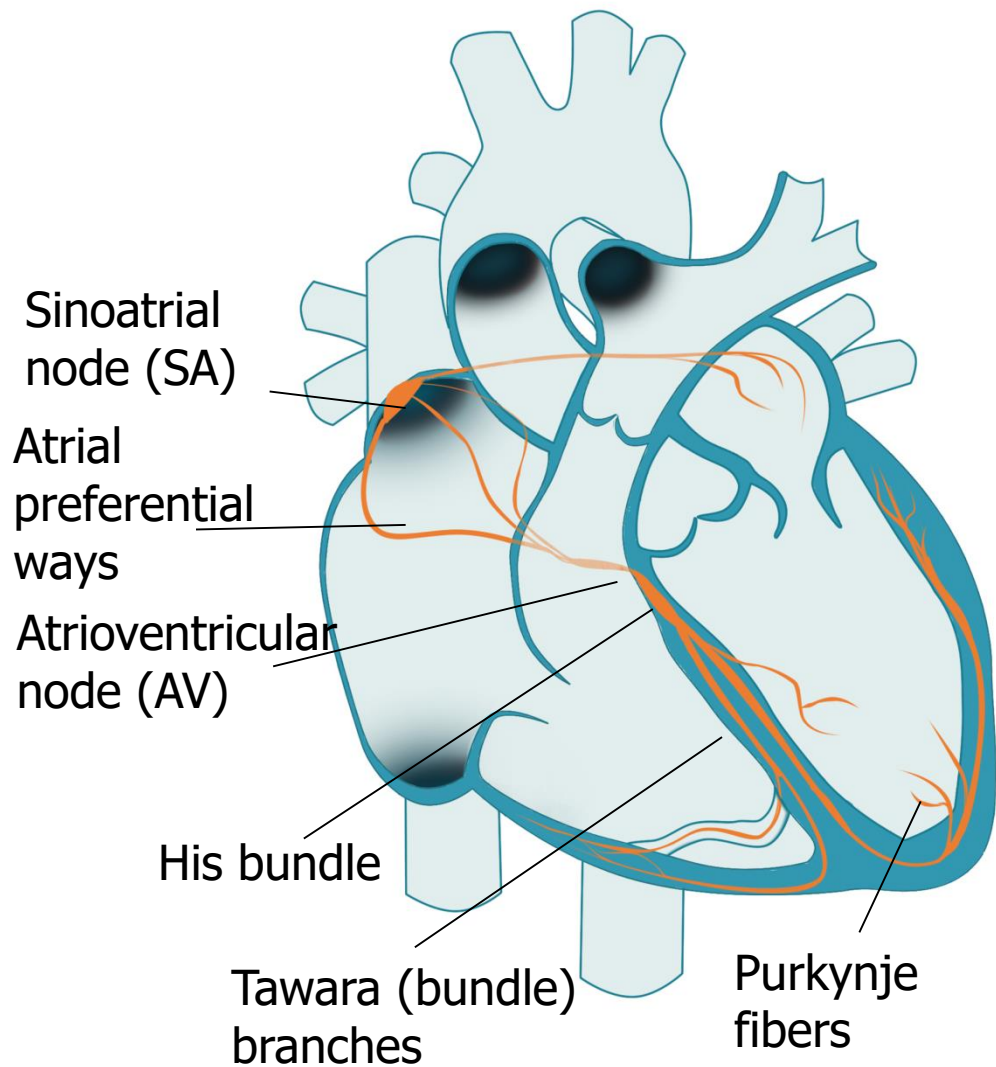
ECG – Electrocardiography

Practical Exercises in Physiology (Spring semester: 4th - 6th weeks)

Electrocardiography

- Definition: recording the cardiac electrical activity from the surface of the body
(el. heart activity can also be obtained from the esophageal leads or the heart surface itself, but these methods are used by other names)

Cardiac conduction system

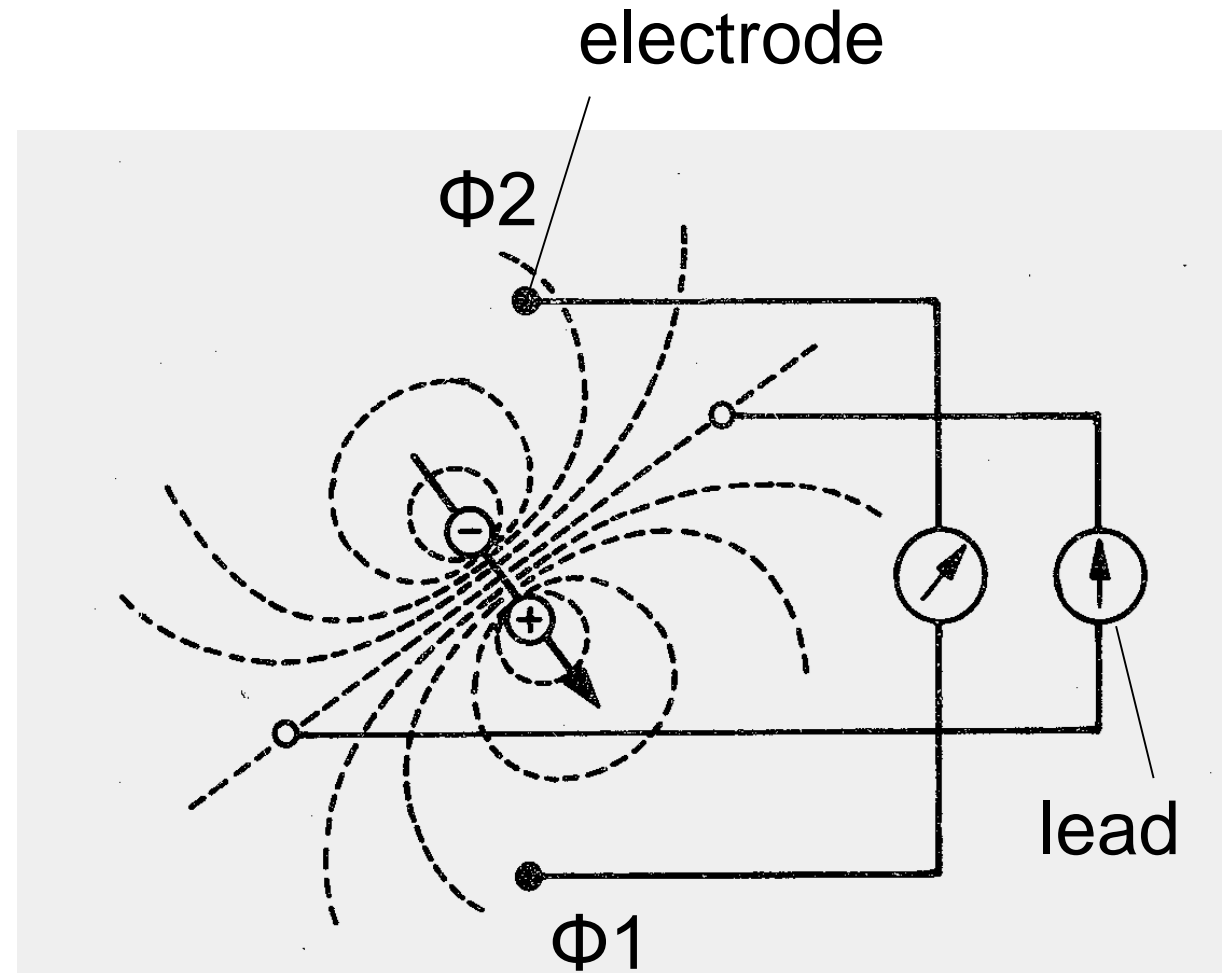


Cardiac conduction system

- Function: AP formation and preferential conduction
 - The atriums are separated from the chambers by a non-conductive fibrous septum - the only way is through the AV
 - Sinoatrial node (SA) - natural frequency 100 bpm (mostly under parasympathetic damping effect), conduction velocity 0.05 m/s
 - Preferred internodal atrial ways - conduction velocity 0.8 - 1 m / s
 - Atrioventricular node - single conductive connection between atria and ventricles, natural frequency 40 - 55 bpm, conduction velocity only 0.05 m / s (nodal delay)
 - His bundle – conduction velocity 1–1,5 m/s
 - Tawara (bundle) branches – conduction velocity 1–1,5 m/s
 - Purkynje fibers – conduction velocity 3–3,5 m/s
- } natural frequencies of 20 - 40 bpm, they have slow spontaneous depolarization
- Sinus rhythm - AP starts at the SA node
 - Junction rhythm - AP is formed in the AV node or His bundle
 - Tertiary (ventricular) rhythm - AP is formed in bundle branches or Purkynje fiber
 - Ventricular myocardial activation - from inside to outside, markedly synchronized, determined by the onset of excitement
 - Repolarization of ventricular myocardium - in the opposite direction, less sharp, repolarization isles
 - Note: natural frequency is the frequency of AP formation unaffected by neural and hormonal control

Electric dipole

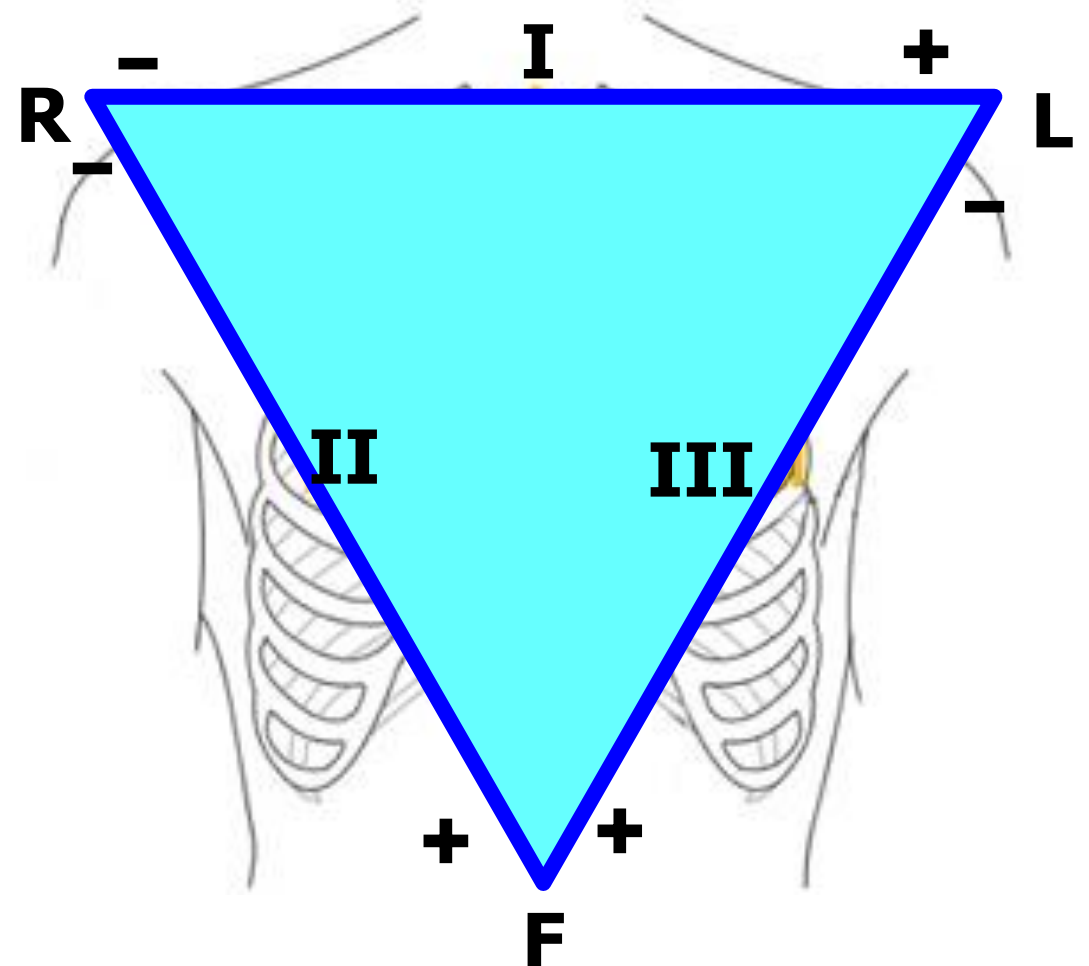
- Electrode: records electrical potential (Φ)
- Electrical lead: connection of two electrodes
 - It records the voltage between the electrodes
 - Voltage: difference of el. potentials ($V = \Phi_1 - \Phi_2$)



Einthoven triangle

(standard, limb, bipolar leads)

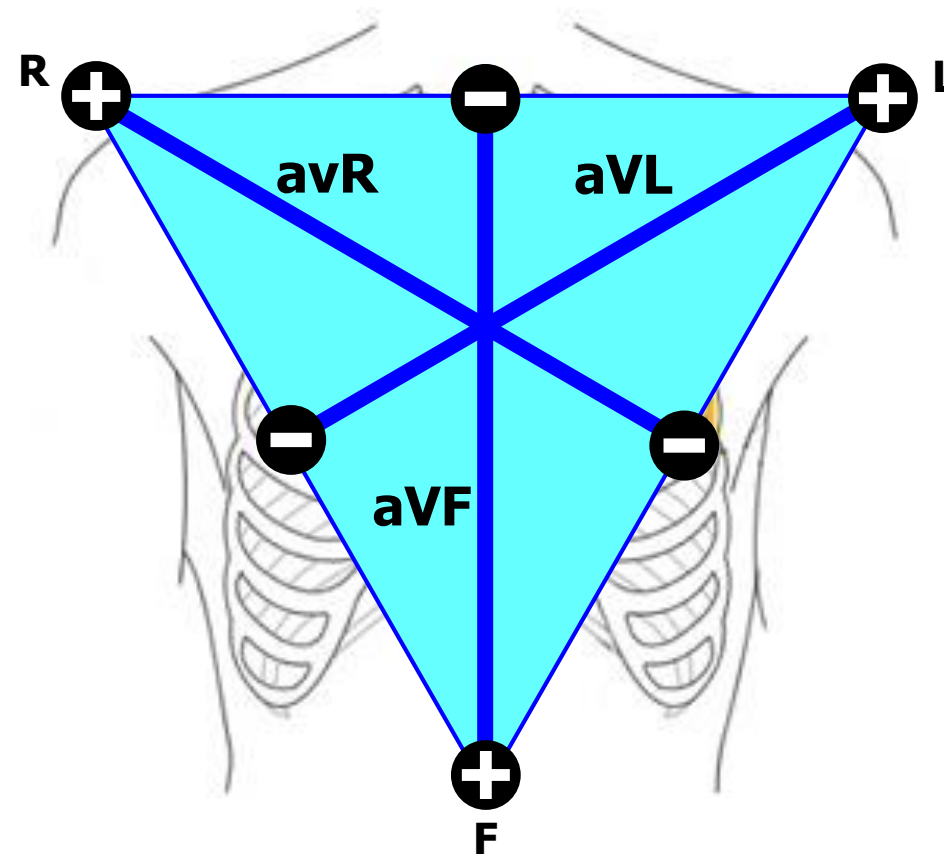
- Bipolar leads: both electrodes are active (variable electrical potential)
- Electrode colors:
R: red, L: yellow, F: green



Goldberger leads

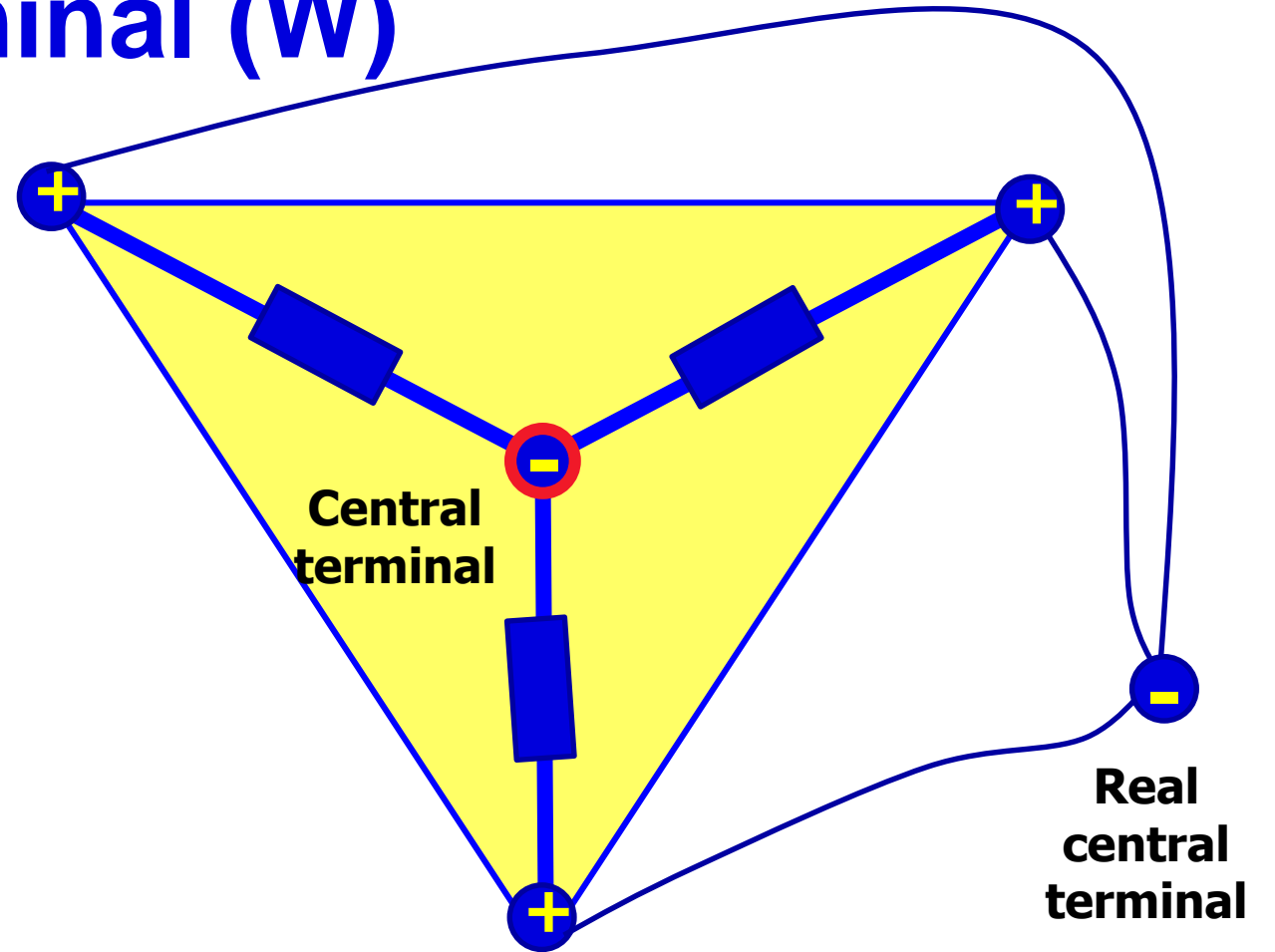
(augmented, limb, unipolar leads)

- Unipolar leads: one electrode is active (variable electric potential) and the other is inactive (constant electric potential, usually 0 mV)
- The active electrode is always positive



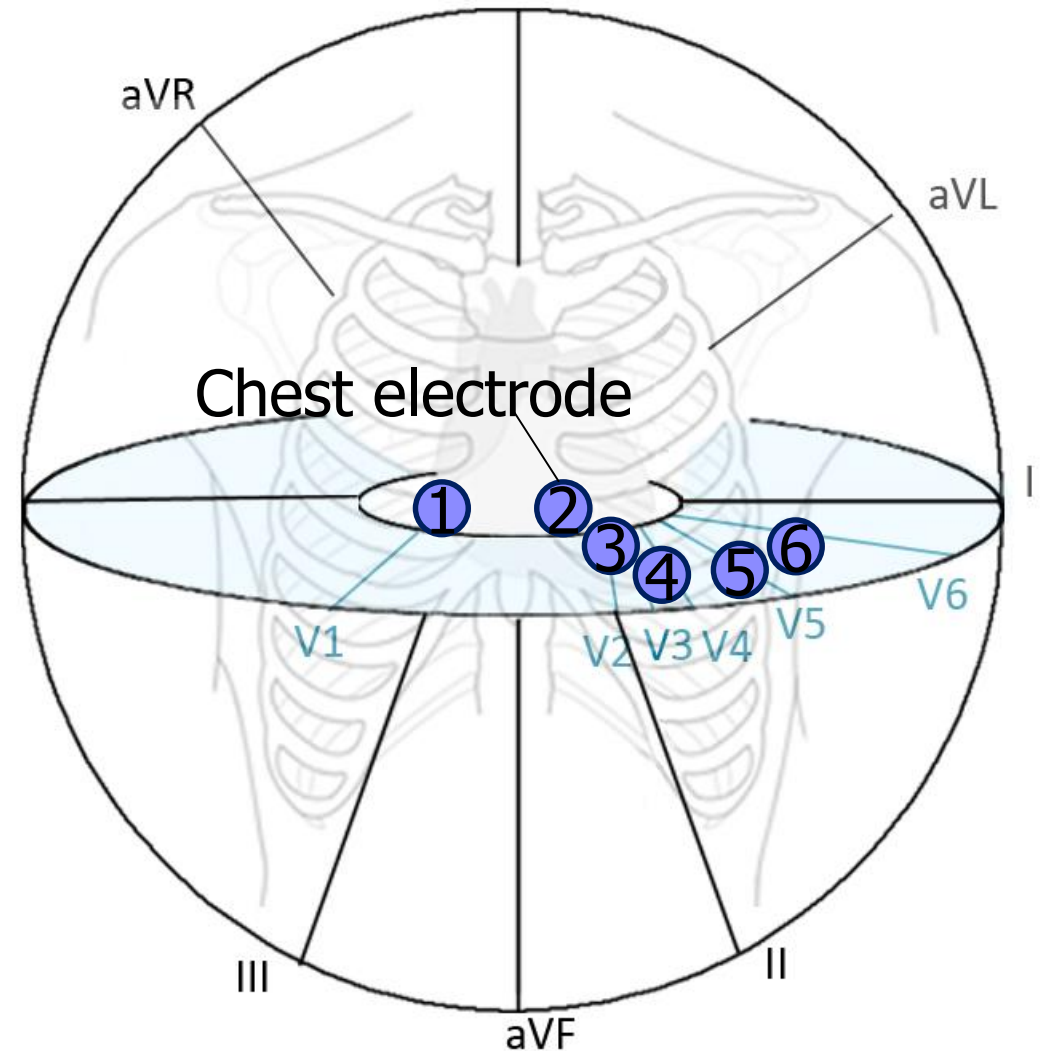
Wilson's central terminal (W)

- It is formed by the connection of limb electrodes through resistors
- electrically represents the center of the heart (it is actually led out or it is calculated)
- Inactive electrode (constant potential)

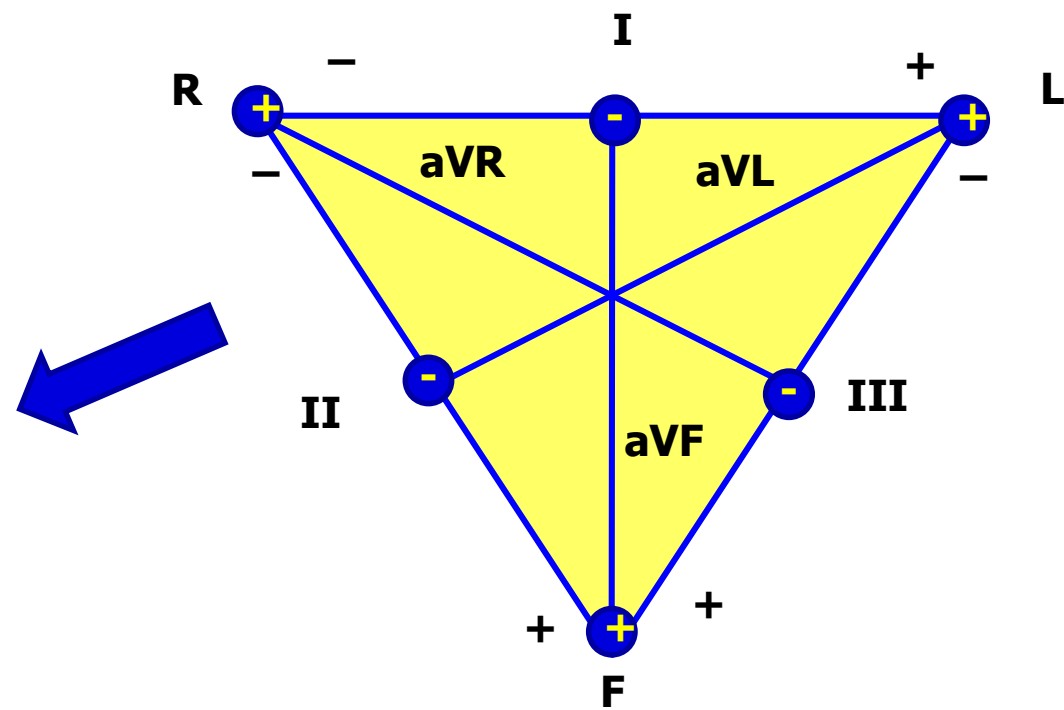
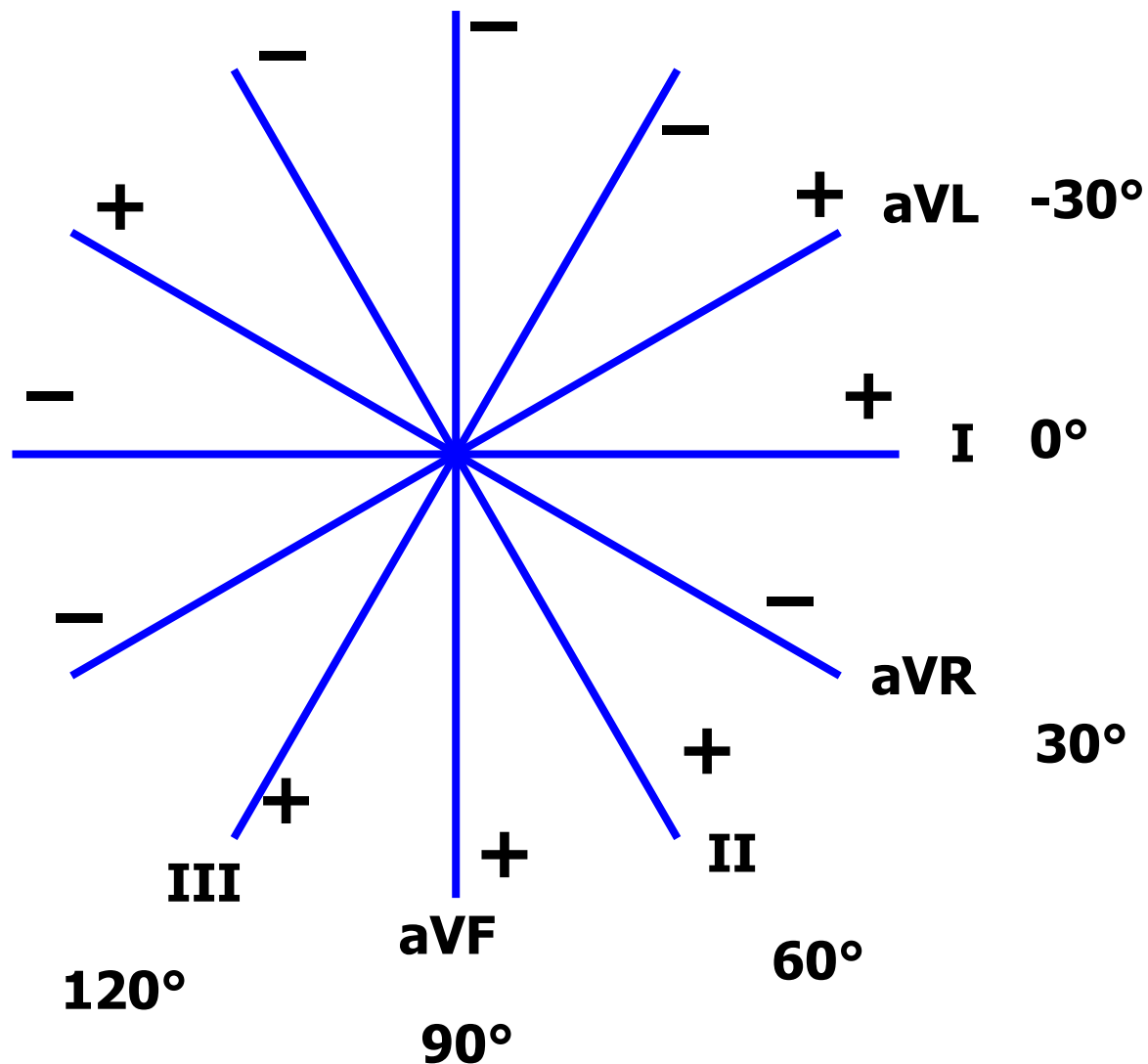


Chest leads

- Chest lead: connection of chest electrode and central terminal
- Unipolar leads: chest electrode is active (positive) and central terminal is inactive (0 mV potential)

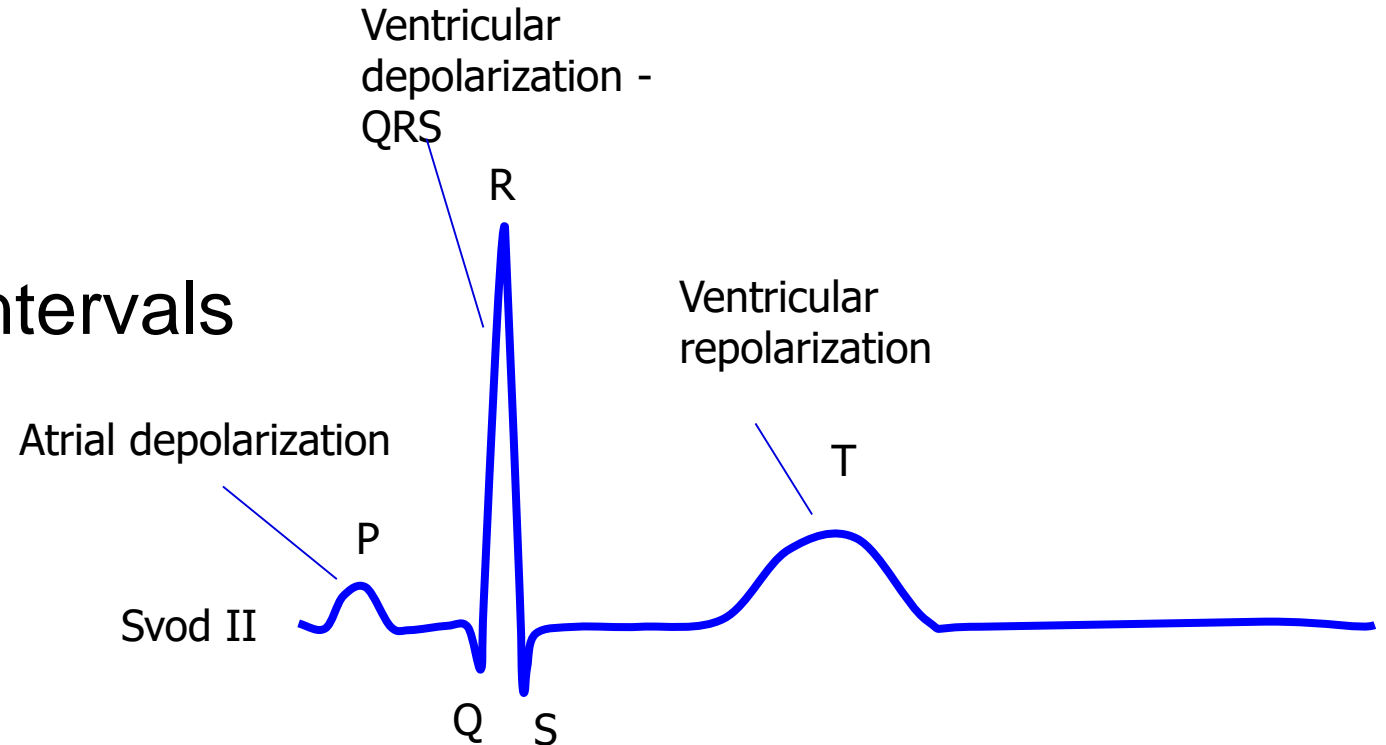


Leads according to Cabrera



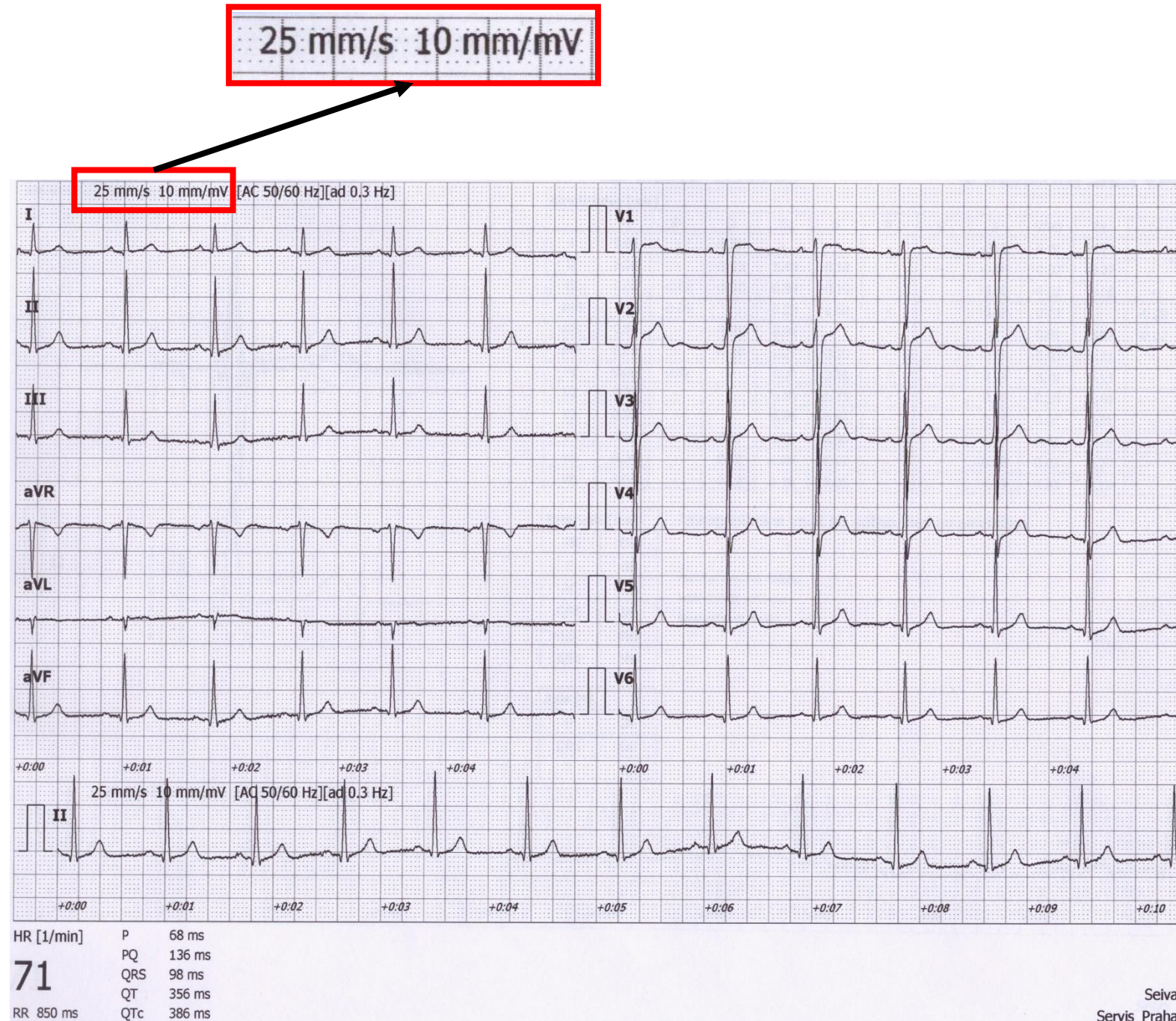
Analysis of ECG

1. Heart action
2. Heart rhythm
3. Heart rate
4. Waves, segments and intervals
 - P wave
 - PQ interval
 - QRS complex
 - ST segment
 - T wave
 - QT interval
5. Electrical heart axis



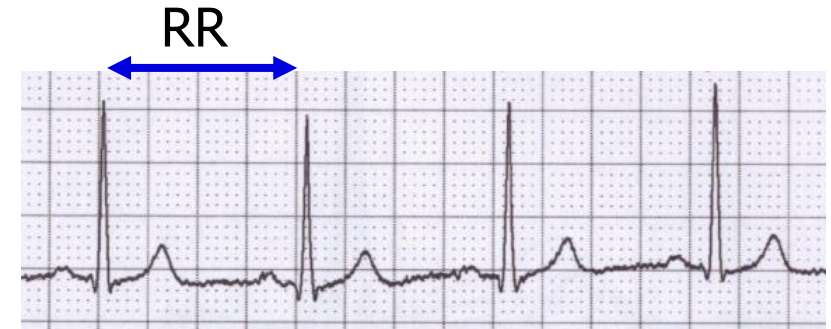
Analysis of ECG

- A millimetre grid of paper will help in fast analysis
- See the paper speed (here 25 mm / s)v
 - How many ms is one mm?
 - It is good to know how much mV is one mm



1) Heart action

- Regularity of distances between QRS complexes - RR intervals
- Calculate difference: $RR - \text{mean } RR$
(you only need to choose the shortest and longest RR in the record)
- Regular action: difference $< 0,16 \text{ s}$
- Irregular action: difference $> 0,16 \text{ s}$
 - Usually pathological
 - Beware of significant sinus respiratory arrhythmia - it is very physiological. If you are unsure, ask the patient to hold their breath during recording
- Note: if one extrasystole is present, but otherwise the action is regular, it is called regular



2) Heart rhythm

- Heart rhythm is determined by the source of action potentials that lead to ventricular depolarization

ventricular depolarization is crucial, because it determines cardiac output

- **Sinus rhythm**

- AP begins in SA node
- On ECG: present P wave (atrial depolarization) before QRS

- **Junction rhythm**

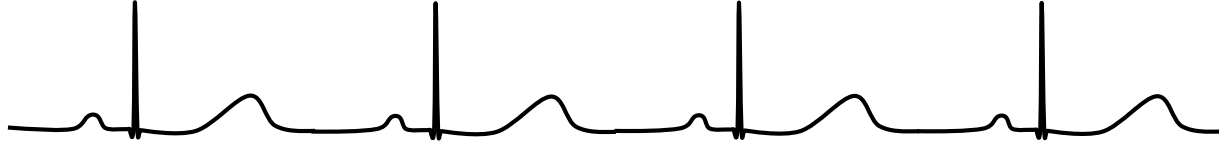
- AP begins in AV node or His bundle, the frequency is usually 40-60 bpm
- P wave is not before QRS, QRS is normal (narrow)
- Heart rate is low (40-60 bpm)
- Atrial depolarization can be present in the ECG if the ventricular impulses are transferred to the atria - wave is after QRS and has opposite polarity because it runs in opposite direction

- **Tertial (ventricular) rhythm**

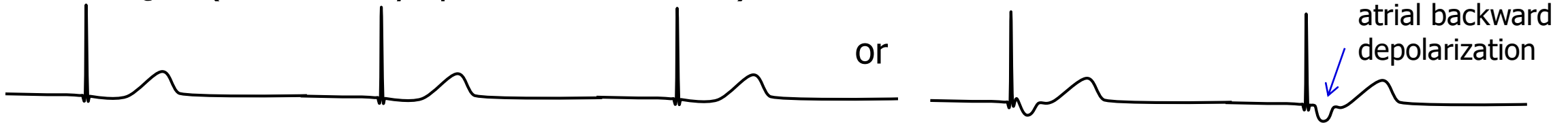
- AP begins in other parts of the conduction system, frequency 30-40 bpm
- QRS has a strange shape (wider), because it spreads in a non-standard direction in the ventricles

2) Heart rhythm

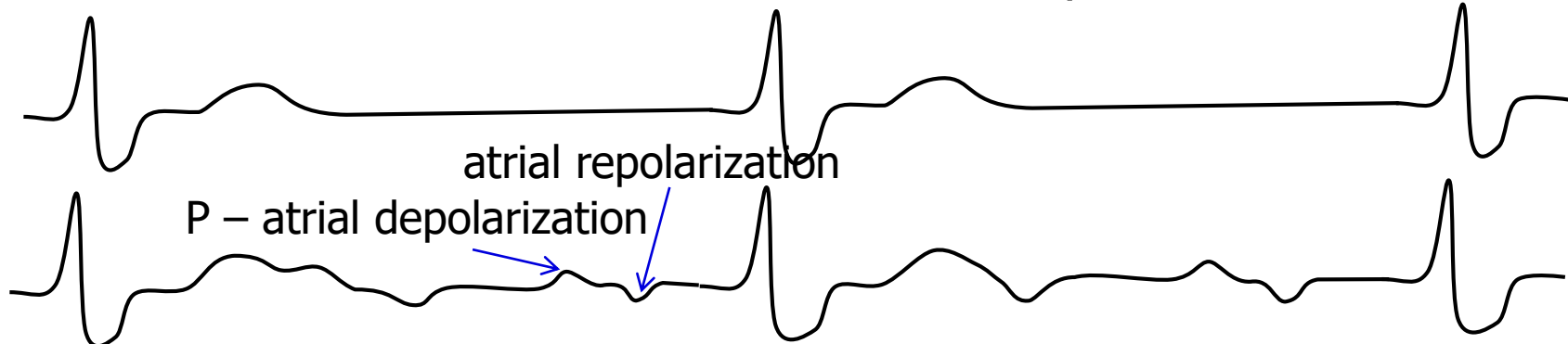
Sinus rhythm – before each QRS there is a P wave - the excitement begins in the SA node, followed by depolarization of the ventricles



Junction rhythm – no P waves before QRS - AP starts in AV node or His bundle, low heart rate, but normal QRS (AP normally spreads in chamber)



Tertial (ventricular) rhythm – there are no normal P waves associated to QRS, the AP begins somewhere in the ventricles - deformed QRS, very low heart rate, for example AV block III. degree



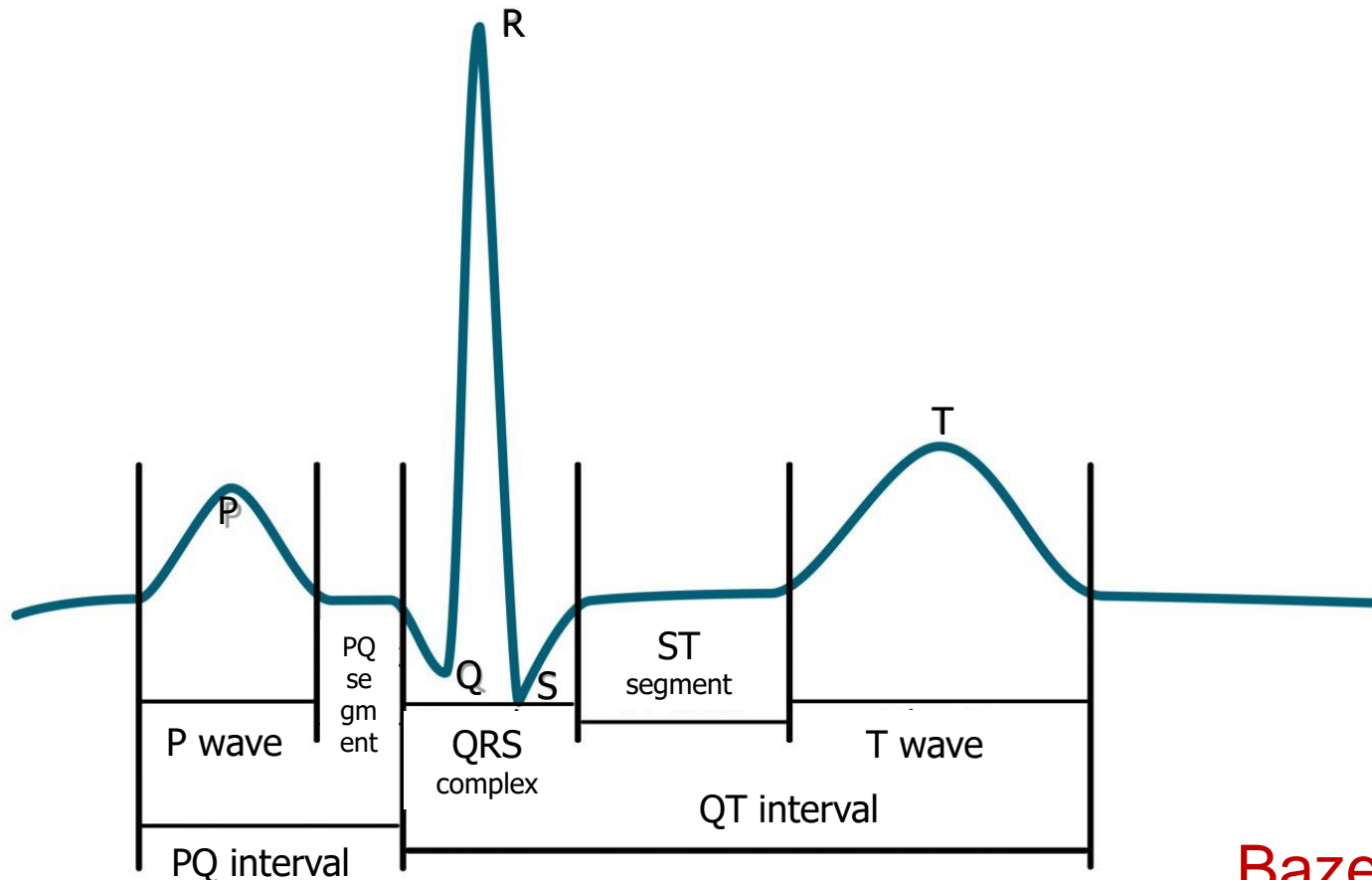
AV block III. - the ventricles follow a tertiary rhythm, the atria have its faster rhythm determined by the SA node, but AP is not transferred to the ventricles

3) Heart rate (HR)

- Frequency of ventricular contraction (because it determines cardiac output); on ECG - frequency of ventricular depolarizations
- $HR = 1 / RR$ bpm
- Physiological: 60 - 90 bpm at rest

- Tachycardia: > 90 bpm in rest
 - Can be sinus (increase sympathetic activity, medication, ...)
 - Tachyarrhythmias: rhythm is not sinus
- Bradycardia: < 60 bpm
 - Can be sinus (increase sympathetic activity, sport heart - physiological)
 - $HR < 50$ bpm, rhythm probably is not sinus

4) Waves, segments, intervals



Name	Norm
wave P	80 ms
interval PQ (PR)	120-200 ms
segment PQ (PR)	50-120 ms
Q	-
complex QRS	80-100ms
R	-
S	-
segment ST	80-120 ms
interval QT	< 420ms
wave T	160 ms

Bazett's formula: $QT_c = \frac{QT}{\sqrt{RR}}$

QT depends on RR interval – correction of QT on RR

4) Waves, segments, intervals

name	Place and description	Physiological background	Norm
wave P	First round wave (negative or positive)	Atrial depolarization	80 ms
Interval PQ (PR)	Interval from beginning of P to beginning of Q (or R, if Q is not present)	Time interval from SA node activation to the Purkynje fibers activation	120-200 ms
segment PQ (PR)	From P wave end to beginning of Q (or R, if Q is not present)	Complete atrial depolarization, AP transfer from AV to ventricles	50-120 ms
Q	First negative deflection	Depolarization of septum and papilar muscles	-
complex QRS	From beginning of R to end of S	Ventricular depolarization	80-100ms
R	Positive deflection	Main ventricular depolarization	-
S	Negative deflection after positive deflection.		-
segment ST	Interval of isoelectric line between end of QRS and beginning of T wave	Complete depolarization of ventricles	80-120 ms
Interval QT	From beginning of Q (or R) to the end of wave T	Electrical systole	< 420ms
wave T	Second round wave (negative or positive)	Ventricular repolarization	160 ms

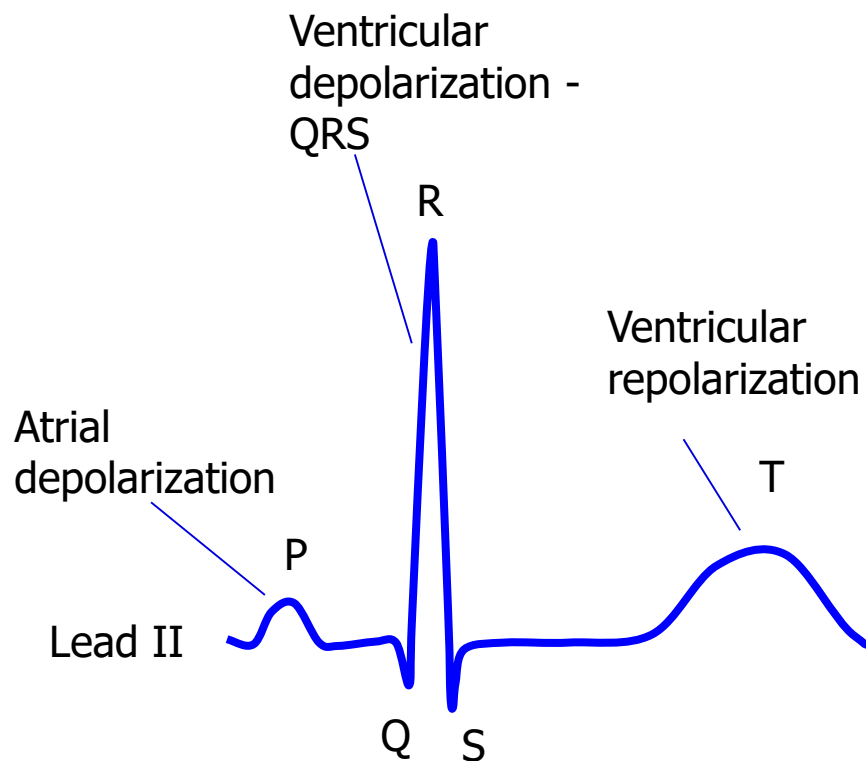
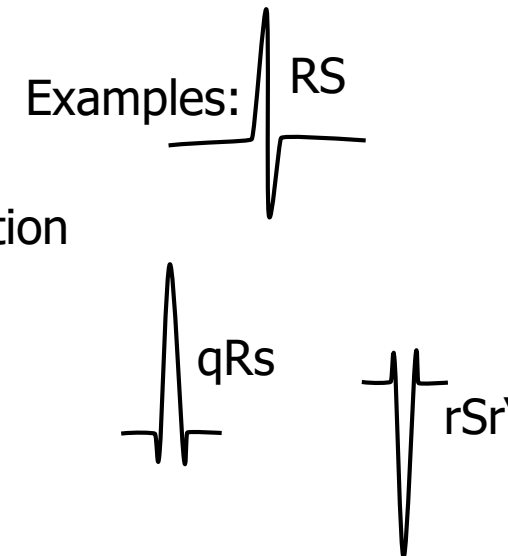
4) Waves

Wave P:

- Is present?
- Is positive/negative, one-peak/two-peak, high(>0,25mV)/normal/low?

QRS:

- Q: first negative deflection
- R: first positive deflection
- S: negative deflection after positive deflection
- small deflection (pod 0,5 mV) – small letter
- Strong deflection – capital letter
- Second positive deflection (')



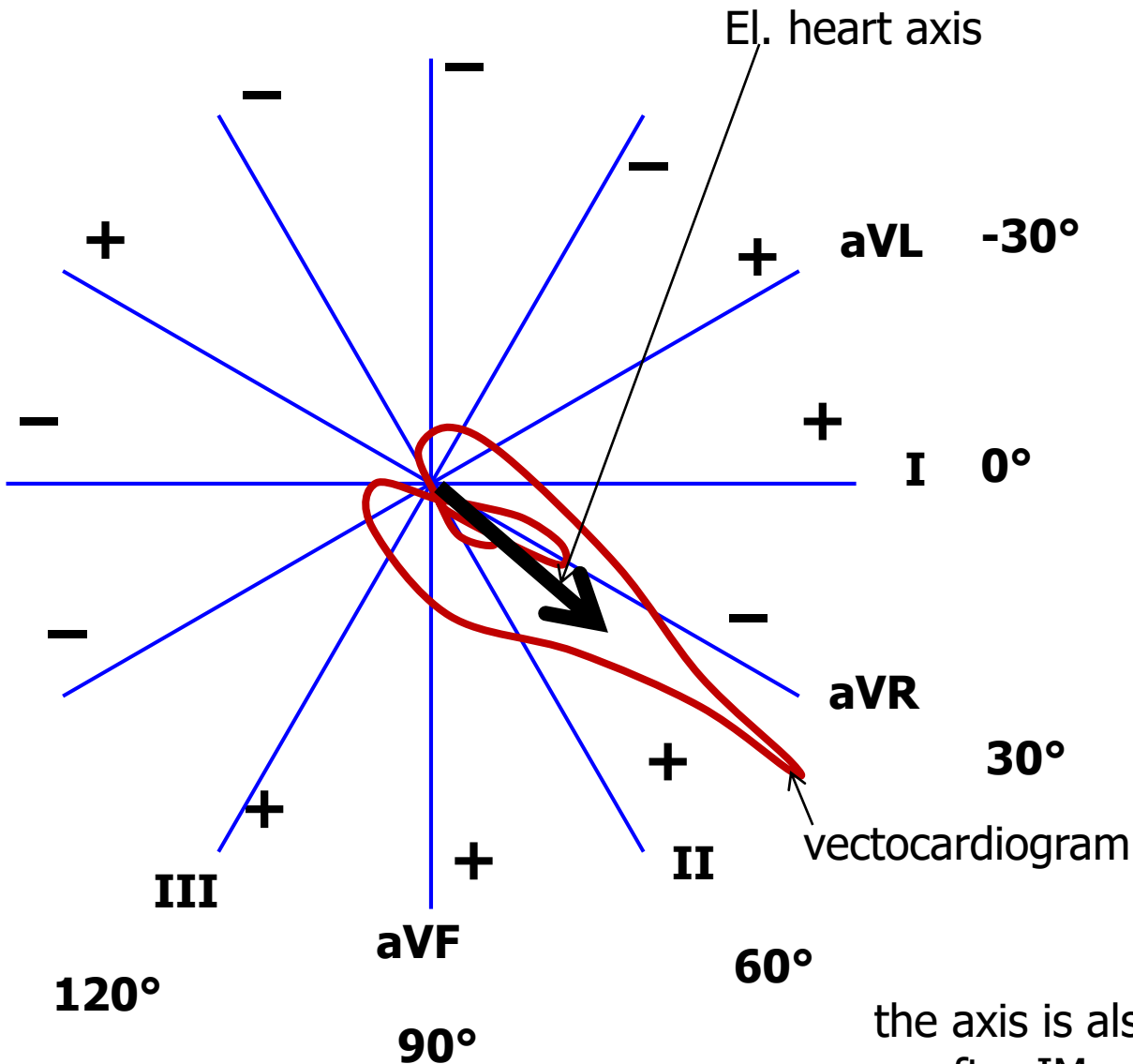
Wave T:

- Is positive/negative/bipolar?
- Does it have the same polarity as the strongest QRS deflection?
 - Yes: concordant (ok), No: discordant (pathology)
- Bipolar T:
 - Preterminal negative (-/+)
 - Terminal negative (+/-)

5) Electrical heart axis

Electrical heart axis: average direction of the electric heart vector during ventricular depolarization (QRS complex)

(can also be determined for atrial depolarization: P, or ventricular repolarization: T, but in practice we will analyse ventricular depolarization)



Heart axis is physiologically directed down, left, back - refers to the real placement of the heart in the chest.
- Here we solve only the frontal plane (limb leads)

Physiological range:

Middle type $0^{\circ} - 90^{\circ}$

Left type $-30^{\circ} - 0^{\circ}$

Right type $90^{\circ} - 120^{\circ}$

Pathological range:

Right deviation: $> 120^{\circ}$ (P ventricular hypertrophy, dextrocardia)

Left deviation: $< -30^{\circ}$ (L ventricular hypertrophy, pregnancy, obesity)

the axis is also changed when Tawara branches are blocked or after IM, missing el. activity of part of chambers

Electrical heart axis - evaluation

- Because the el. axis is related to ventricular depolarization in the frontal plane, use QRS in limb leads: I, II, III.
- Calculate the sum of QRS oscillations in leads I, II, III.

When the oscillation is down, it is negative. When the oscillation is up, it is positive. Use a millimeter grid

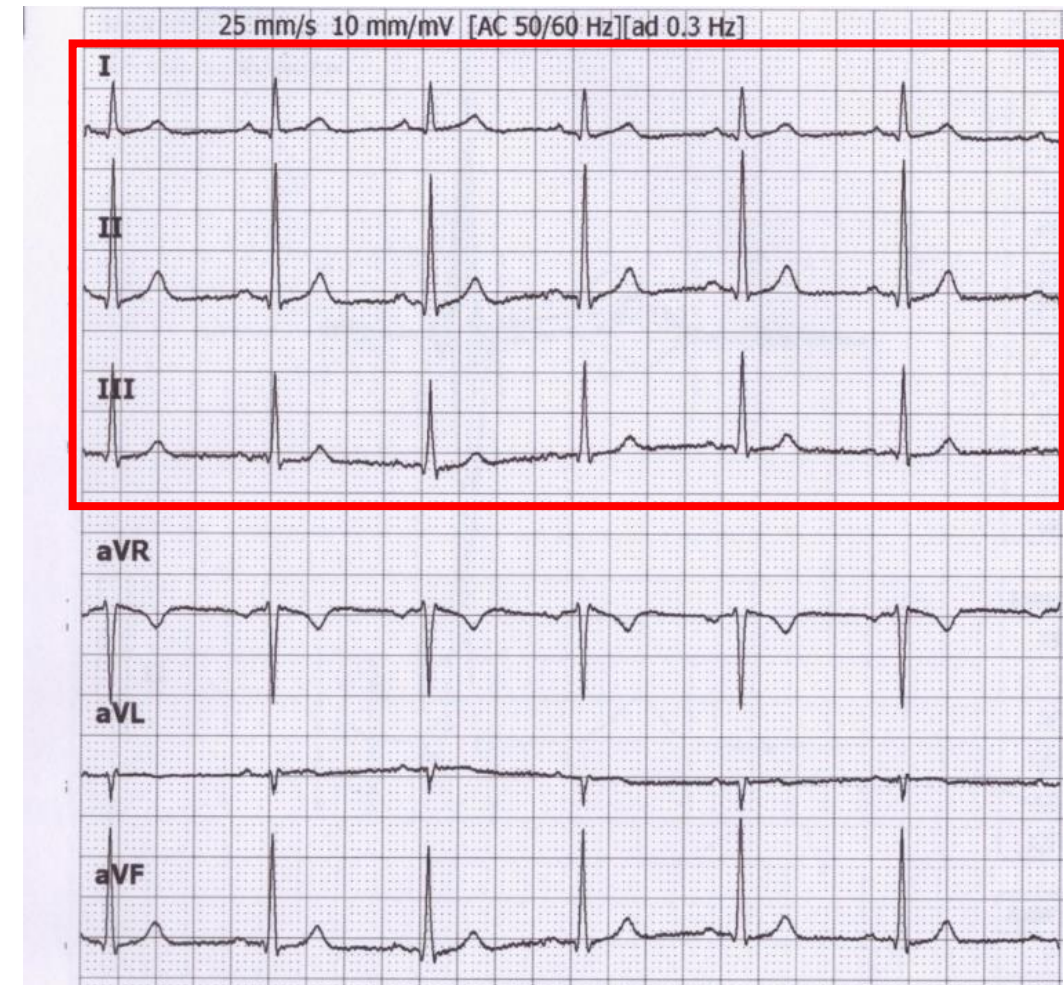
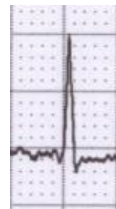
- Lead I: $Q_I = -1$; $R_I = 6$; $S_I = 0$;
 $QRS_I = 5$



- Lead II: $Q_{II} = -1$; $R_{II} = 17$; $S_{II} = -1$;
 $QRS_{II} = 15$

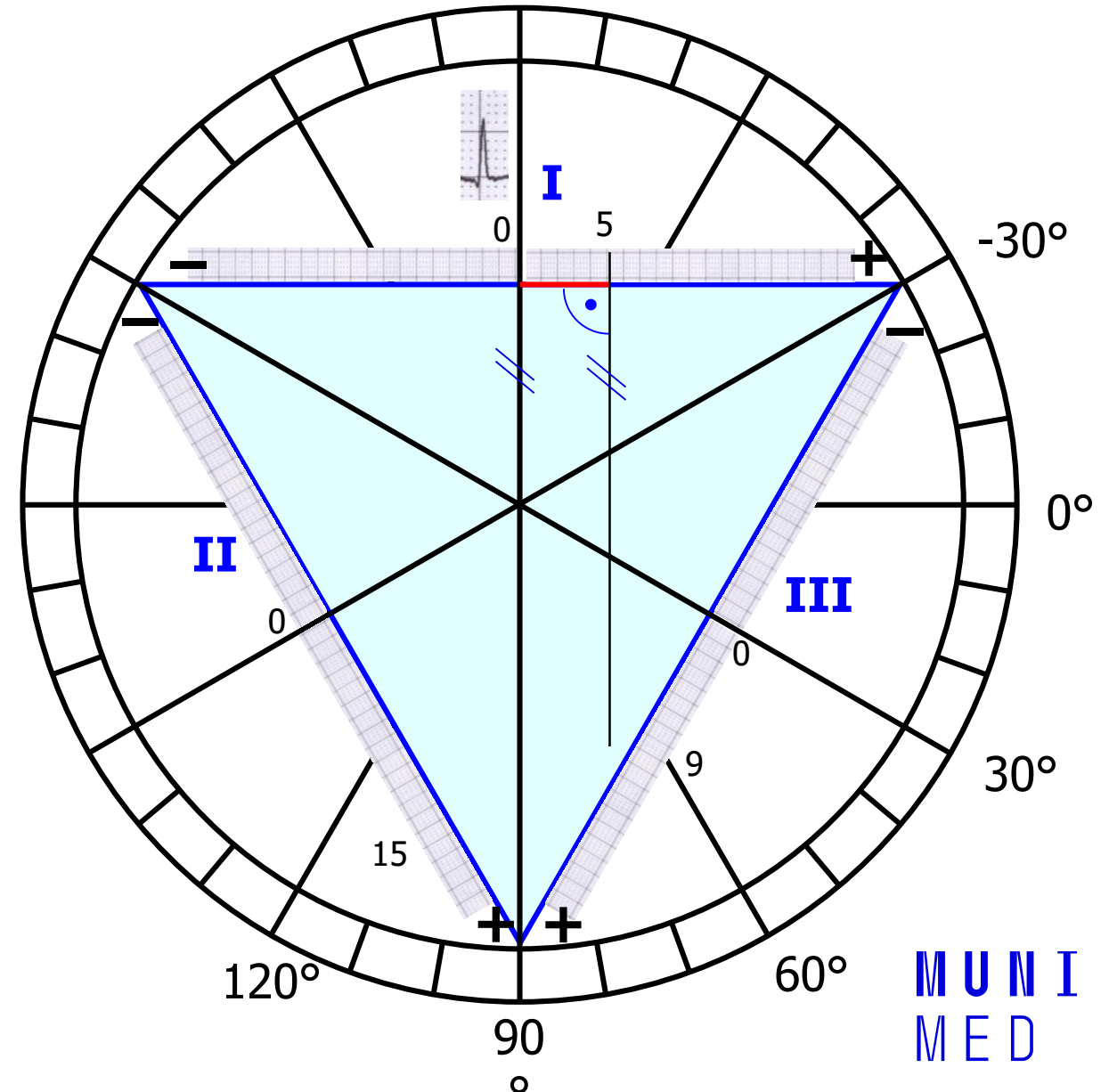


- Lead III: $Q_{III} = 0$; $R_{III} = 10$; $S_{III} = -1$;
 $QRS_{III} = 9$



Electrical heart axis - evaluation

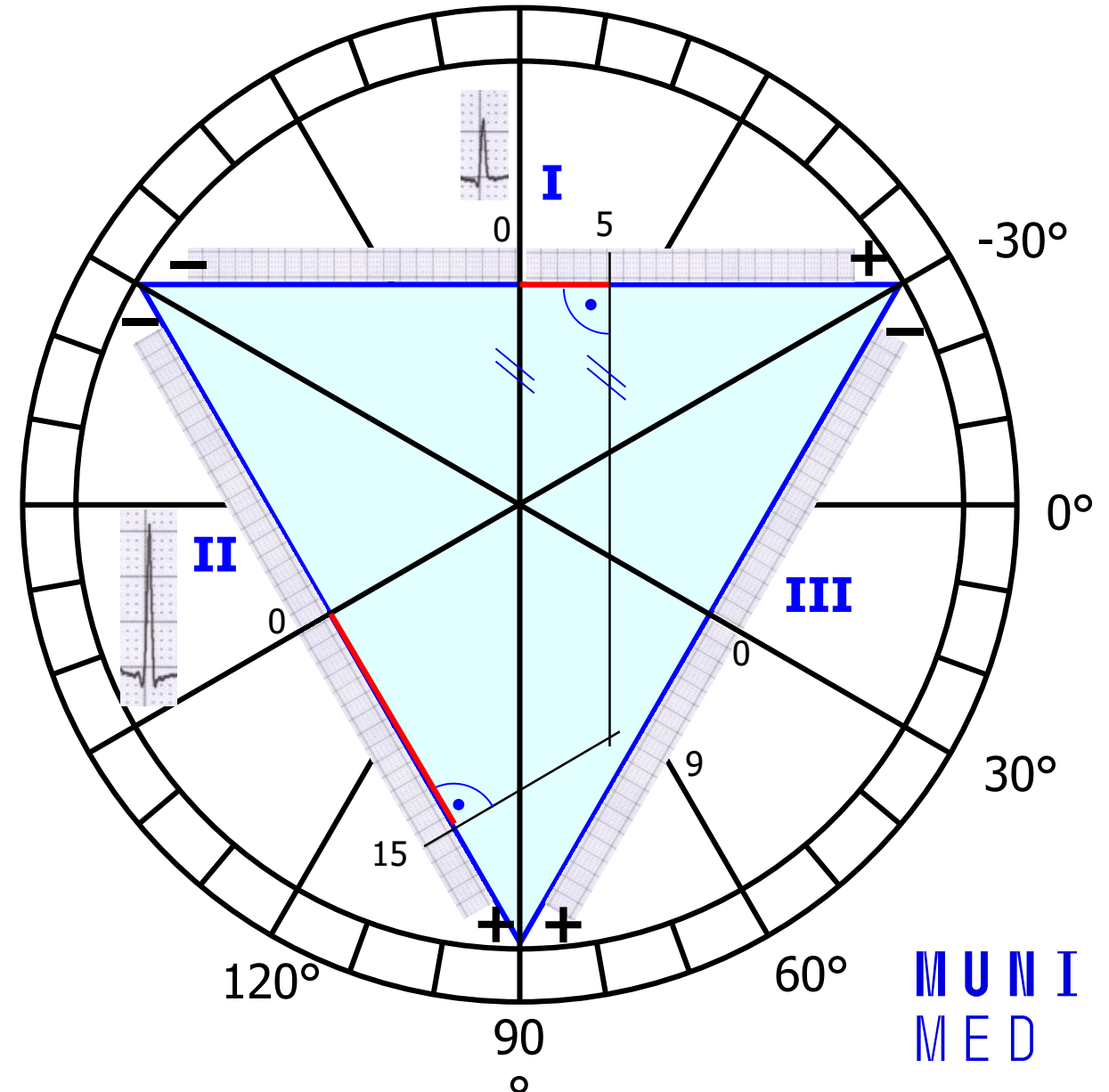
- Draw the Einthoven Triangle with Goldberger augmented Leads
- Mark the angles around the triangle (in the circle)
- Lead I:
 - 0 at lead I is in the center of lead
 - $QRS_I = 5$, so from 0, measure 5mm towards the positive electrode, make a mark (or any other units, ratio is important)
 - If the sum of QRS is negative, you will go towards the negative electrode
 - Run a line from the mark perpendicular to the I lead (parallel to the aVF lead)



Electrical heart axis - evaluation

– Lead II:

- 0 at lead II is again in the centre of lead
- $QRS_{II} = 15$, so from 0, measure 15 mm towards the positive electrode, make a mark (again, if the sum of QRS is negative, you will go towards the negative electrode)
- Run a line from the mark perpendicular to the II lead (parallel to the aVL lead)



Electrical heart axis - evaluation

- Lead III:
 - The same way draw line for $QRS_{III} = 9$
- Draw an arrow that starts at the centre of the triangle and passes the cross of the drawn lines
- This arrow shows the direction of the cardiac electrical axis in the frontal plane
- Note. logically, only lines from two leads are sufficient

The cardiac electrical axis for ventricular depolarization in the frontal plane is 70°

