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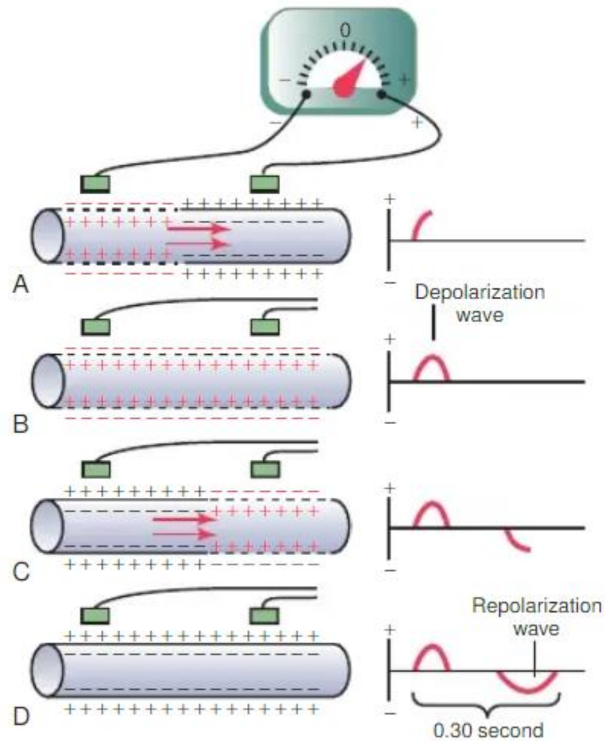
Electrocardiogram (ECG) Basics

- An electrocardiogram (**ECG**) is a simple test that can be used to check your **heart's rhythm** and **electrical activity**. Sensors attached to the **skin** are used to detect the electrical signals produced by your heart each time it beats.

- **Further explanation:** when cardiac impulses pass through the heart, electrical current is spread into the adjacent tissues surrounding the heart. A **small** portion of the current spreads over the **surface** of the body. **Electrodes** of a galvanometer are placed on the **skin** on **opposite** sites of the heart records electrical potentials; this recording is known as ECG.
  - ⇨ Since small portions reach the skin, a galvanometer with **amplifiers** is used.
- There is **no difference** between an ECG and an EKG. ECG stands for electrocardiogram, and EKG is the **German** spelling for elektrokardiographie.

Depolarization versus Repolarization Waves: *'understand'*

- The figure below shows a single cardiac muscle fiber in the stages of depolarization and repolarization. Two electrodes are placed at the surface recording the **potential difference**:



A- The first half of the fiber is under **Depolarization**, demonstrated by red positive charges inside and red negative charges outside, traveling from left to right. The **other** half is still **polarized**.

The **left** electrode is in an area of **negativity**, and the **right** electrode is in an area of **positivity**, which causes the meter to record a **positive** potential difference.

B- Complete depolarization of the fiber. The recording has returned to the **zero** baseline because **both** electrodes are now in areas of equal **negativity** (no potential difference).

C- Repolarization starts, where positive charges return to the outside of the fiber in the first half. At this point, the **left** electrode is in an area of **positivity**, and the **right** electrode is in an area of **negativity**. Consequently, the recording, as shown, **becomes negative.**

D- Complete repolarization of the fiber. **Both** electrodes are now in areas of **positivity** so that no potential difference is recorded between them. Thus, the recording returns once more to **zero**.

⇨ At the stages where **complete** polarization and depolarization occurs, there is **no** potential difference since the electrodes are in areas of **equal** charges. The **zero baseline** they reach in the recording is called the **'isoelectric line'**.

The Standardized Electrocardiogram:

- The normal ECG is composed of a P-wave, a QRS complex, and a T-wave:

  1- **P-wave:** is caused by **atrial depolarization** before their contraction begins.

  2- **QRS complex:** caused by **ventricle depolarization** before their contraction via the bundle of His and Purkinje fibers. The **normal** duration of the QRS complex is **less than 0.12s**. If it becomes **more** than that, it may indicate a **bundle branch block**. It is important to know that not every QRS complex will contain all Q, R, and S waves.

  3- **T-wave:** caused by **ventricles repolarization**. Although the T-wave is repolarization, its wave is **upright** because:

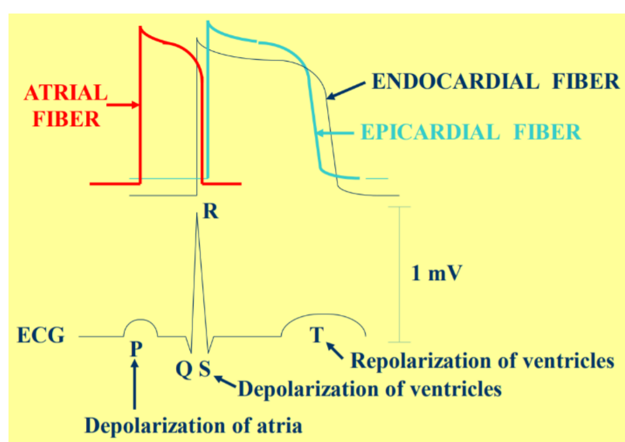
  Usually, the depolarization current of the ventricles starts from the base towards the apex and from the endothelium to the pericardium.
  Whereas its repolarization current happens in the opposite direction; from the apex to the base and from the pericardium to the endothelium.

  Theory: this phenomenon may be attributed to the intrinsic property of the ventricles' fibers. In which ventricular depolarization is followed by contraction (ventricular systole) increasing the pressure in the ventricles. This presses the endothelium in the ventricles changing its ionic composition causing repolarization to start from the pericardium delaying it from the endocardium.

  Current moving in the **opposite** direction between electrodes causes the readings to **flip**, which explains why the repolarizing T-wave is upright.

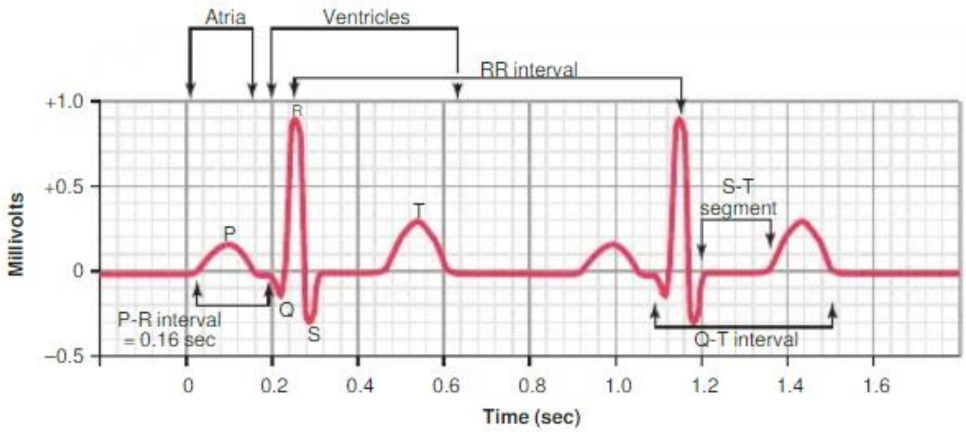
- As mentioned, both the P-wave and the QRS complex represent atrial and ventricular depolarizations respectively, and the T-wave represents the repolarization of the ventricles.

  There is **no** distinctly **visible** wave representing **atrial repolarization** in the ECG because it occurs **during** ventricular depolarization. The wave of atrial repolarization is relatively **small** in amplitude *(i.e., has low voltage)*, thus it is **masked** by the much larger ventricular depolarization.



- The **cardiac cycle** comprises a complete relaxation and contraction of both the atria and ventricles which lasts approximately **0.8 seconds**. When cardiac cycles are **irregular** *(i.e. not equal in duration)* the heart's rhythm is said to be **irregular** (arrhythmia).

- ECG paper is a grid where time is measured along the horizontal axis. It is divided into multiple squares:
  - ➔ Each **small** square is **1 mm** in length and represents **0.04** seconds.
  - ➔ Each **larger** square (5 small squares) is **5 mm** in length and represents **0.2** seconds.



- The ECG paper moves at a standard speed of **25mm/sec**. It has a heat-sensitive coating which is marked by a heated stylus for the recording. The stylus is attached to a moving coil galvanometer and movement of the stylus corresponds to the voltage detected by the galvanometer.

- In ECG, there are intervals and segments: *'follow on the figure above'*

1- **Interval**: it is a period measured in milliseconds starting from one wave to the other. Thus, an interval **contains waves**.

   a- **PR interval:** it reflects conduction through the **AV node**. The normal PR interval is between **0.12 - 0.2s** in duration (3-5 small squares). If the PR interval is >0.2s, **first-degree heart block** is said to be present.

   b- **RR interval:** it reflects the **time** between **heartbeats**. The normal RR interval is **0.6 – 1 s** → Therefore, per minute (60s), normal heartbeats ≈ 60 beats.

   c- **QT interval:** it represents the time taken for **ventricular depolarization** and **repolarization**. The normal QT interval **shouldn't** exceed **half** the cardiac cycle; around **0.4 s**.

Interval	Time (s)	Small squares (0.04s)
PR	0.12 - 0.2	3 - 5 (1 large square)
RR	0.6 - 1	15 - 25 (4 large squares)
QT	0.4	10 (2 large square)

2- **Segment:** it is the **isoelectric** (flat) line between the end of a wave and the start of another. Thus, a segment **doesn't contain waves**. The following segments correspond to **phase 2** 'plateau' in the cardiac muscle action potential:

a- **ST segment:** represent **complete ventricular depolarization**. The most important cause of ST segment abnormality *(elevation or depression around the isoelectric line)* is **decreased blood flow** which may cause myocardial ischemia or infarction.

b- **PR segment:** represent **complete atrial depolarization**.

ECG component	Abnormality	Indicates:
PR	>0.2s	First degree heart block
ST	Elevated or depressed	Decreased blood flow
QRS	>0.12s	Bundle branch block
Cardiac cycle	Irregular intervals	Arrhythmia

Questions:

Recall: we said that the RR interval can represent the time between beats.

1- If the RR interval = **15 small squares**, what is the heart rate per minute?

1 small square = 0.04s

15 x 0.04s = 0.6s →1 beat every 0.6s

Per minute: 60 / 0.06 = 100 beat/min

2- If the RR interval = **25 small squares** (1 second), what is the heart rate?

Per minute: 60/1 = 60 beat/min

3- If the RR interval = **20 small squares**, what is the heart rate?

20 x 0.04s = 0.8s

Per minute: 60 / 0.8 = 75 beat/min

Good Luck

Sorry for any mistake, reach me if there is.