CVS

PHYSIOLOGY

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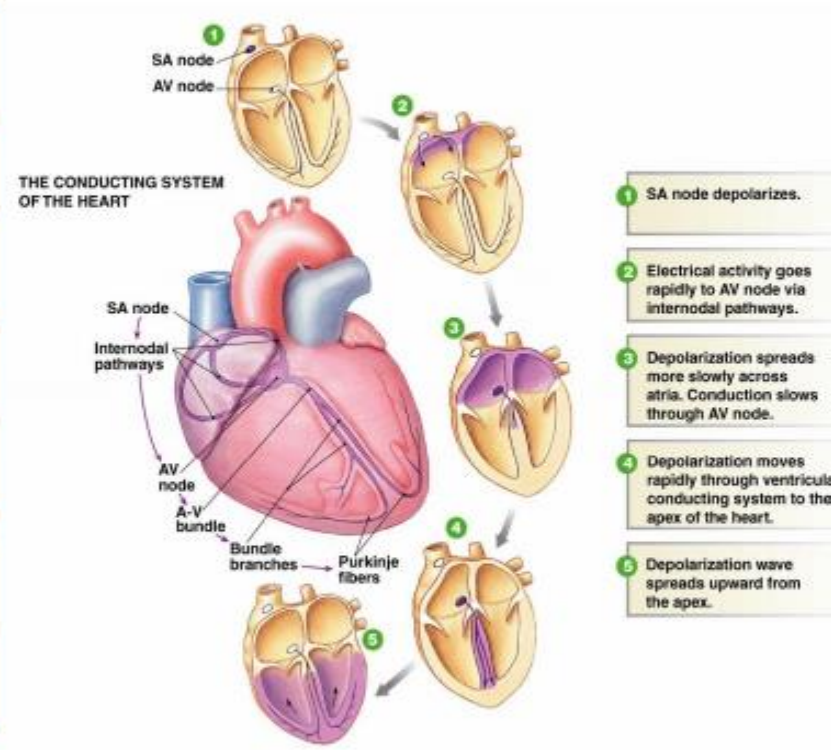
Tissue	Conduction rate (m/s)
Atrial muscle	0.3
Atrial pathways	1
AV node	0.05
Bundle of His	1
Purkinje system	4
Ventricular muscle	0.3-0.5



ECTOPIC PACEMAKER: REVISION

This is a portion of the heart with a more rapid discharge than the sinus node. It also occurs when transmission from sinus node to A-V node is blocked (A-V block). During sudden onset of A-V block, sinus node discharge does not get through, and the next fastest area of discharge becomes the pacemaker of the heartbeat (Purkinje system). A-V block results in a syndrome called "Stokes-Adams" syndrome. Usually, a new pacemaker (artificial) is implanted in A-V node, penetrating part of A-V bundle or in the right ventricular muscle.

"Stokes-Adams" syndrome refers to syncopal episodes that occur from cardiac arrhythmia

EXTRINSIC INNERVATION OF THE HEART

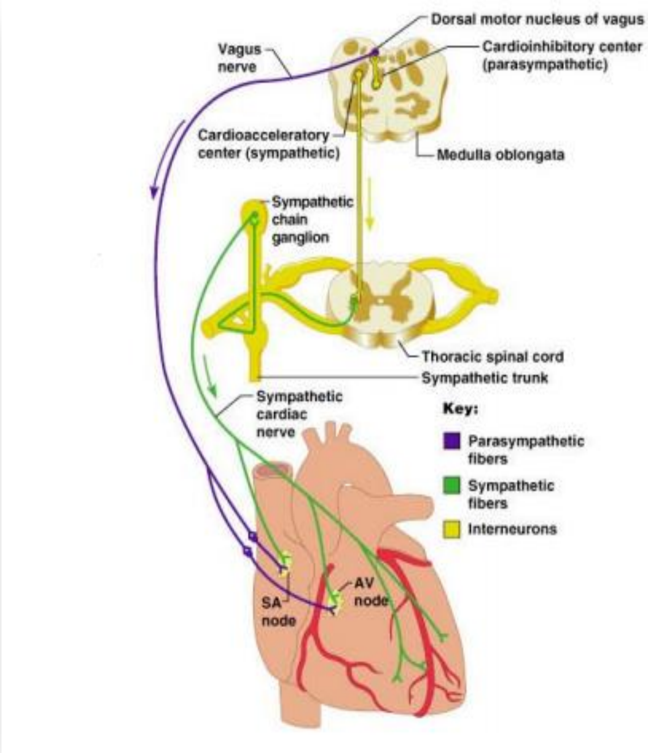
The heart is supplied with both sympathetic and parasympathetic nerves. The parasympathetic nerves are distributed mainly to the SA and AV nodes, and, to a lesser extent, to the muscle of the two atria, and slightly directly to the ventricular muscle. The sympathetic nerves, conversely, are distributed to all parts of the heart, with strong representation to the ventricular muscle, as well as to all the other areas.

-**Parasympathetic fibers:** Vagus (X) nerve → supply only the atria, SA & AV node.
-**Sympathetic fibers:** sympathetic ganglia (cervical ganglia & superior thoracic ganglia T1-T4). → supply all parts of the heart.

***Cardiac centers:**

- Cardioaccelerator center: Activates sympathetic neurons that increase HR.
- Cardioinhibitory center: Activates parasympathetic neurons that decrease HR.

→ Cardiac center receives input from higher centers (hypothalamus), monitoring blood pressure and dissolved gas concentrations.



-To understand the effect of sympathetic and parasympathetic on the heart, you should be familiar with these terms:

1- **Chronotropic effect**: produce changes in heart rate.
2- **Dromotropic effect**: produce changes in conduction velocity.
3- **Inotropic effect**: intrinsic ability of cardiac muscle to develop force at a given muscle length (contractility).

PARASYMPATHETIC INNERVATION TO THE HEART:

Increase the permeability of the cardiac cells to K^+ and decrease its permeability to Na^+ and Ca^{2+} in response to ACH, which causes hyperpolarization (mainly because of increased K+ permeability). This causes decreased transmission of impulses, maybe temporarily, stopping the heart rate.

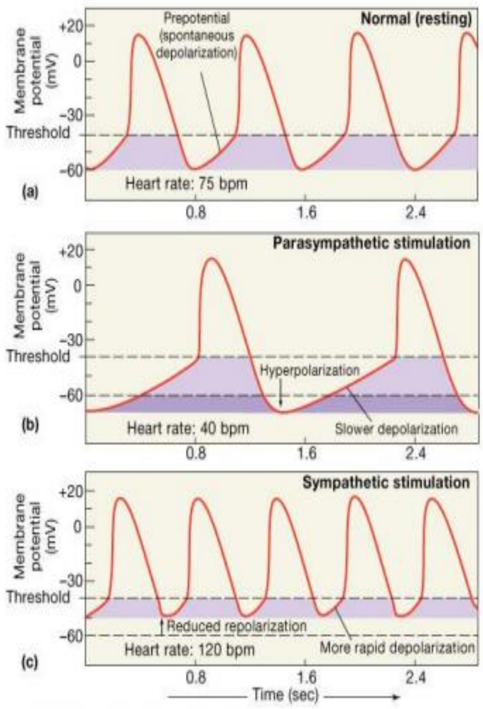
Parasympathetic effects:

- ✓ **Decreases the heart rate** (negative chronotropic effect): Due to increasing the permeability for potassium (efflux) and decreasing it for sodium and calcium, the resting membrane potential becomes more negative→the slow depolarization occurs slower (decreasing the slope of phase 4) →takes more time to reach threshold→ the heart rate decreases.
- ✓ **Negative inotropic and dromotropic** effects on the ***atria*** only.
- ✓ **Has no effect on the contractility of ventricles**. As vagus nerve does not supply ventricles only atria, so only atrial contractility is affected.

***In either type of stimulation (sympathetic or parasympathetic), the peak doesn't change.**

SYMPATHETIC INNERVATION TO THE HEART:

Increase the permeability of the cardiac cells to Na^+ and Ca^{2+}, mediated by epinephrine and norepinephrine results in:



- ✓ Increase the heart rate **(positive chronotropic effect)**: Due to increasing the permeability to sodium (influx) and calcium, the resting membrane potential become less negative→the slow depolarization occurs faster (increasing the slope of phase 4) →reaching threshold faster→ the heart rate increases.
- ✓ Increase the strength of contraction **(positive inotropic effect)**: Increasing the permeability to calcium. (note: calcium is not important for conduction system but it is important for contractile cells (ex. ventricular cells)). Force of contraction increases in atria and ventricles.
- ✓ Increase the rate of conduction of impulse **(positive dromotropic effect)**.

We said that the parasympathetic innervation to the heart is via the vagus nerve. Sometimes, if the vagus nerve is over stimulated (in most cases by the carotid abnormalities which compress the nerve), it may stop the heart rate and the person falls down. But after 15-30 seconds, the heart resumes its pumping because the vagus nerve does NOT innervate the ventricles and the Purkinje fibers, thus they will resume their intrinsic rate, this is called the **ventricular escape**.

Few pages to go

Normal Electrography

When the cardiac impulse passes through the heart, electrical currents generated during depolarization and repolarization also spreads from the heart into the adjacent tissues surrounding the heart. A small portion of the current spreads all the way to the surface of the body. If electrodes are placed on the skin on opposite sides of the heart, electrical potentials generated by the current can be recorded; the recording is known as an electrocardiogram (ECG). Before we start talking about ECG, let's first understand the principal of recording potential difference.

❈ Depolarization Waves Versus Repolarization Waves

- The following figure shows a single cardiac muscle fiber in four stages of depolarization and repolarization, being recorded using a galvanometer. The electrodes are put on the **surface** of the muscle fiber. Let's define some concepts to understand the graph:

✓ The color red designates depolarization in which during, the normal negative potential inside the fiber reverses and becomes slightly positive inside and negative outside.

✓ Depolarization is demonstrated as an upward deflection (+), and repolarization as a downward deflection (-).

✓ The potential difference between the two electrodes increase as the impulse moves from left to right until it reaches the halfway mark. When it reaches the halfway mark, the membrane potential difference between the two sides is maximum. When it exceeds the halfway mark, the potential difference decreases until the muscle fiber is either completely depolarized or repolarized → no potential difference **(isoelectric line).**

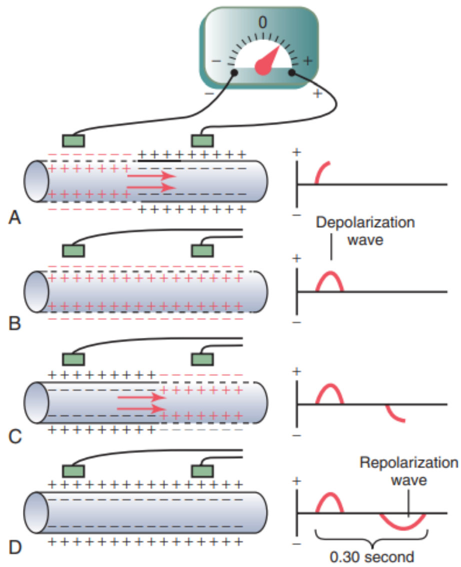


Figure 11-2. Recording the depolarization wave (**A** and **B**) and the repolarization wave (**C** and **D**) from a cardiac muscle fiber.

- In (A), depolarization, demonstrated by red positive charges inside and red negative charges outside, is traveling from left to right. The first half of the fiber has already depolarized, while the remaining half is still polarized. Therefore, the left electrode on the outside of the fiber is in an area of negativity, and the right electrode is in an area of positivity, which causes the meter to record **positively**. To the right of the muscle fiber is shown a record of changes in potential between the two electrodes, as recorded by the galvanometer. Note that when depolarization has reached the halfway mark, the record has risen to a maximum positive value (upward deflection).

- In (B), depolarization has extended over the entire muscle fiber, and the recording to the right has returned to the zero baseline because both electrodes are now in areas of equal negativity (**isoelectric line**). The completed wave is **a depolarization wave** because it results from spread of depolarization along the muscle fiber membrane.

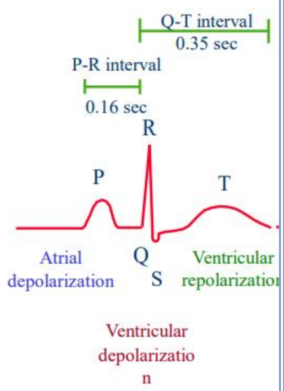
- (C) shows halfway repolarization of the same muscle fiber, with positivity returning to the outside of the fiber. At this point, the left electrode is in an area of positivity, and the right electrode is in an area of negativity. This polarity is opposite to the polarity in (A). →Consequently, the recording, as shown to the right, becomes negative.

- In (D), the muscle fiber has completely repolarized, and both electrodes are now in areas of positivity so that no potential difference is recorded between them (**isoelectric line**). Thus, in the recording to the right, the potential returns once more to zero. This completed negative wave is a repolarization wave because it results from spread of repolarization along the muscle fiber membrane.

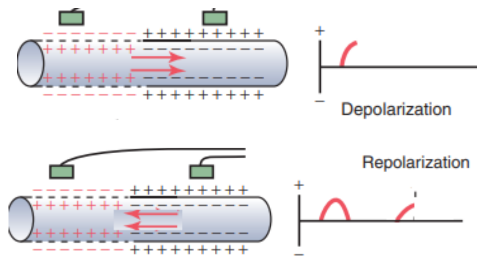
❈ Characteristics of the Normal Electrocardiogram (ECG)

- The electrograph is a machine composed of a galvanometer with amplifiers.
- To record the electrical potentials generated by the cardiac impulse (ECG), the electrodes of the galvanometer are placed on the skin on opposites sides of the heart; one on the left arm, the other on the right arm.
- The potential difference during the cardiac action potential (the difference between the electrical potential in depolarization **+20mv** and repolarization **-90mv**) is nearly110 mv.
- However, the potential difference that is recorded in the arms is much less than that of the heart, so in order to record the potential difference in the heart (110mv), we add amplifiers to amplify the potential difference between depolarization and repolarization.

- The normal ECG is composed of **a P wave, a QRS complex, and a T wave**. The QRS complex is often, but not always, three separate waves: the Q wave, the R wave, and the S wave.
- The **P wave** is caused by electrical potentials generated when the **atria depolarize** before atrial contraction begins. The **QRS complex** is caused by potentials generated when the **ventricles depolarize** before contraction, that is, as the depolarization wave spreads through the ventricles. → Therefore, both the P wave and the components of the QRS complex are **depolarization waves.**
- The T wave is caused by potentials generated as the ventricles recover from the state of depolarization. The **T wave** is known as **a repolarization wave.**



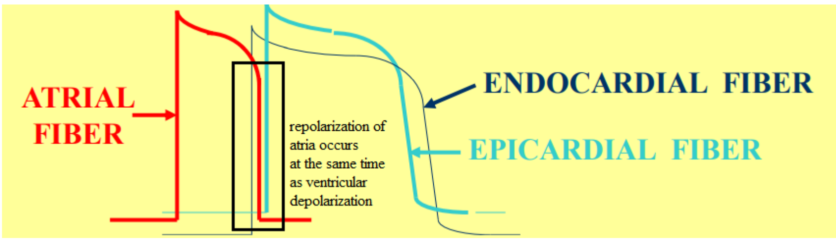
- Note that even though it's a repolarization wave, the T wave exhibits a positive deflection. The reason for this is that the last cells to depolarize in the ventricles are the first to repolarize (direction of repolarization is **opposite** of that in figure 11-2C).
- This occurs because the depolarization of ventricles starts from the endocardial part of the muscle to the epicardial part (base of the heart → apex), but repolarization starts from the epicardial part to the endocardial part (apex → base). This might be due to intrinsic properties of the cardiac action potential.
- Therefore, repolarization waves of the ventricles generally are oriented opposite of depolarization waves, and since the left is area of negativity and the right is area of positivity, the meter records **positively** (just like in figure 11-2A).



- In conclusion, the **ECG** is composed of both **depolarization and repolarization waves**.

**ECG can be called EKG as well, EKG is the German spelling for elektrokardiographie, which is the word electrocardiogram translated into the German language.*

- During each cardiac cycle, we record atrial depolarization, ventricular depolarization and ventricular repolarization. But what about atrial repolarization? Atrial repolarization occurs at the same time as ventricular depolarization, and since the depolarization of the ventricles is strong, it masks the repolarization of atria and that's why it doesn't show in the record.



- The recording of ECG shows repeated cycles of P, QRS and T waves. The interval between 1 R and the following one represents a cardiac cycle. The same applies to each of the intervals between (P-P, T-T, S-S and Q-Q) but the R-R interval is the most definite one with significant sharp peaks.
- The number of electrical cardiac cycles per minute is equal to the number of heart beats per minute (normally ranges from 60 to 100 BPM). Which means that we can calculate the heart rate using ECG.

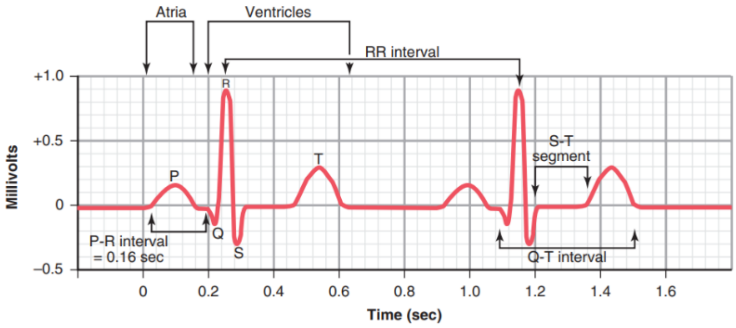


Figure 11-1. Normal electrocardiogram.

Standardized (ECG):

- Time and voltage calibrations are standardized by putting a heat-sensitive vapor under the pointer of the electrocardiograph. Underneath this pointer, is a paper that is squared.
- The horizontal calibration lines (**Y-axis**) are arranged so that each 10 small squares upward or downward in the standard ECG represent 1 millivolt, with positivity in the upward direction and negativity in the downward direction.
- The vertical lines (**X-axis**) are time calibration lines. A typical ECG is run at a paper speed of 25 millimeters per second. Therefore, each 25 millimeters in the horizontal direction is 1 second, and each 5-millimeter segment (big square), indicated by the **dark** vertical lines, represents 0.20 second. The 0.20-second intervals are then broken into five smaller intervals by thin lines (5 small squares), and each small square represents 0.04 second.

- Now let's discuss the intervals and segments that are recorded in normal ECG:

1. Intervals:

- The term interval refers to a period that contains a wave

a) The P-Q or P-R Interval:

- The first interval that shows in normal ECG is the P-Q interval (often this interval is called the P-R interval because the Q wave is likely to be absent).
- The normal P-R interval is about 0.16 second and it represents the time between the beginning of electrical excitation of the atria and the beginning of excitation of the ventricles.