The Electrocardiography (ECG) I

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Lecture Objectives:

1. Describe the principles of voltage recording in a volume conductor and its application to recording from the heart.
2. Explain ECG waveforms and intervals in relation to the instantaneous pathway of waves of depolarization through the cardiac muscle.
3. Identify voltage and time calibration of the ECG.
4. Explain the normal ECG.

Definition

An electrocardiogram (ECG) is an amplified, timed recording of the electrical activity of the heart, as detected on the surface of the body.

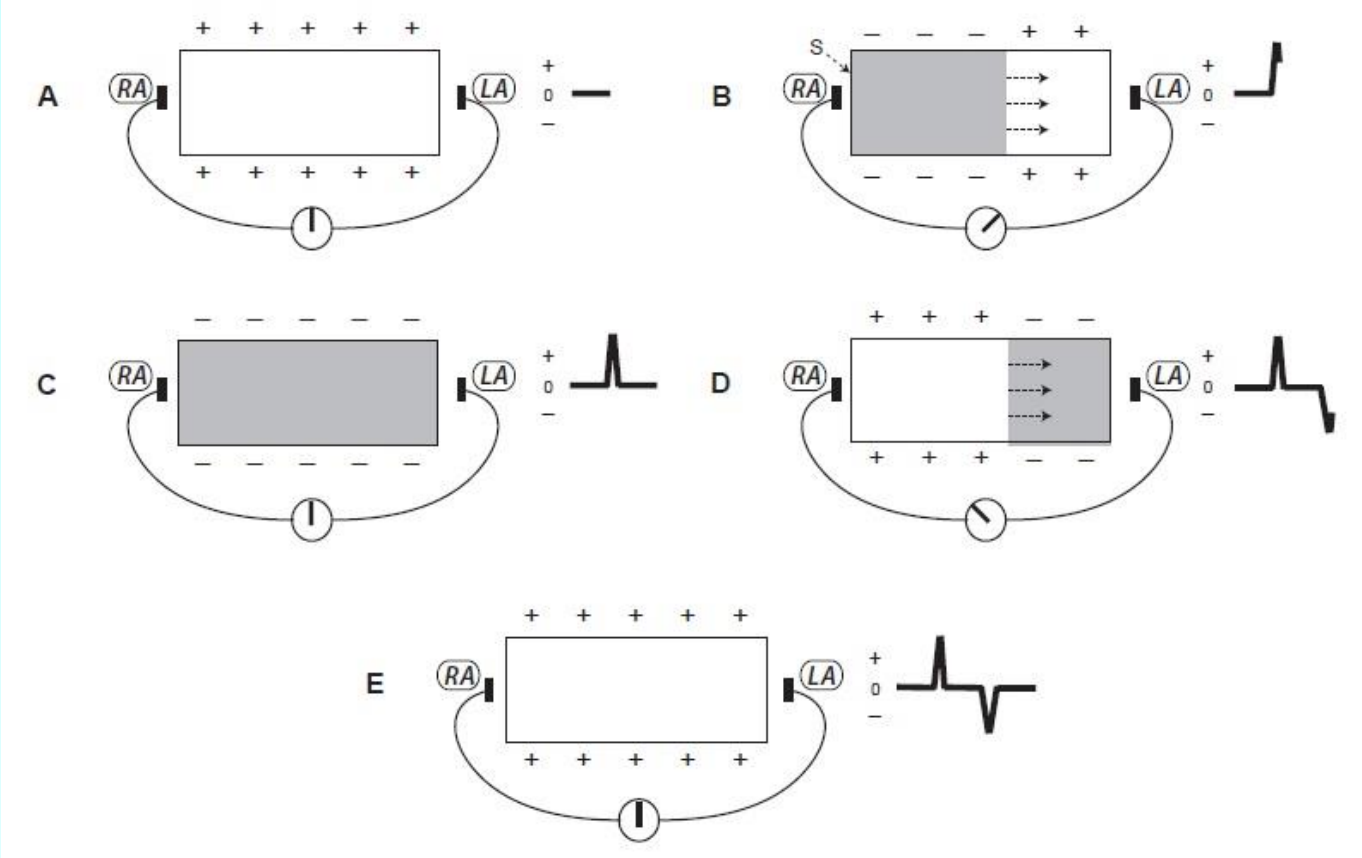
ECG is useful to determine:

1. The anatomical orientation of the heart.
2. The relative sizes of the heart chambers.
3. Various disturbances in rhythm and conduction.
4. The extent, location, and progress of ischemic damage to the myocardium.
5. The effects of altered electrolyte concentrations.
6. The influence of certain drugs (notably digitalis, antiarrhythmic agents, and calcium channel antagonists).

Note:

The ECG, however, cannot give **direct** information about the contractile performance of the heart. Other tools must be used for such an evaluation.

Recording from a single cardiac fiber



1. Shows depolarization and repolarization waves.
2. The two waves are in opposite direction.
3. No potential is recorded when fiber is either completely polarized or completely depolarized.

Recording from the whole heart

The normal electrocardiogram is composed of the following;

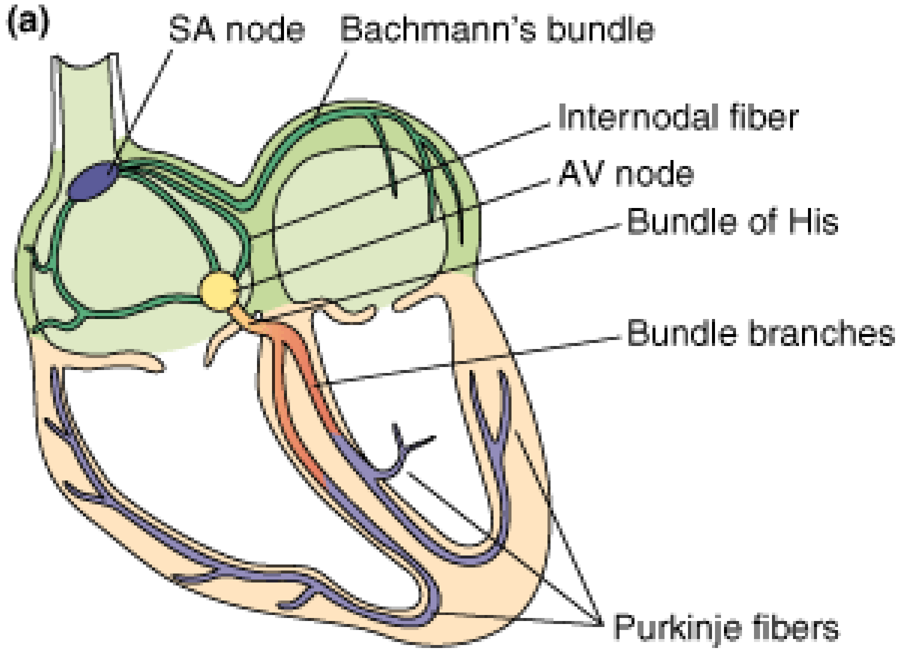
P wave – atrial depolarization wave (appears just before the beginning of atrial contraction).

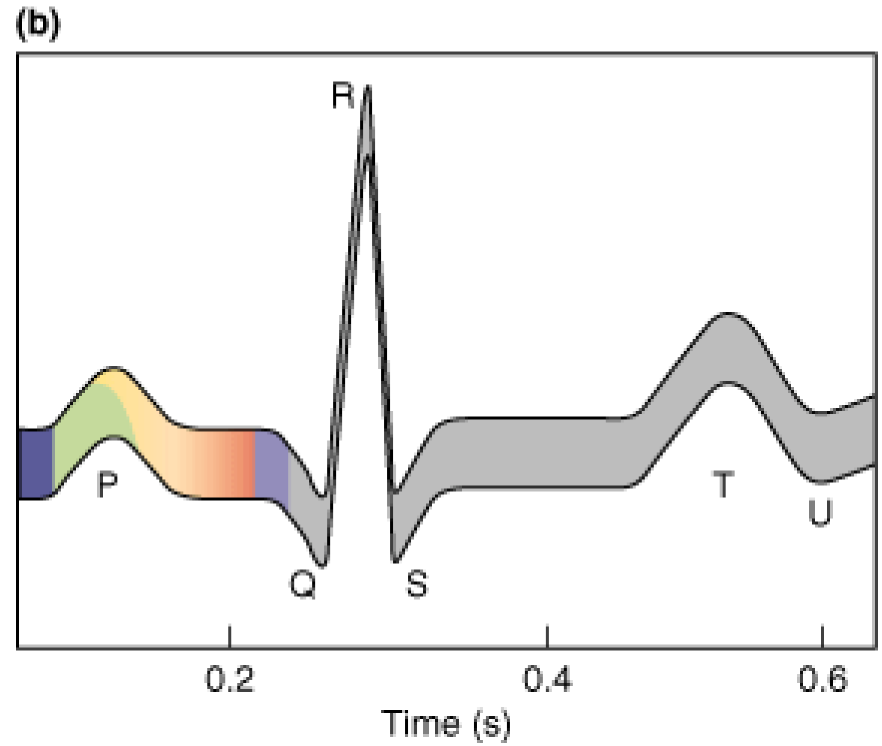
QRS complex – ventricular depolarization wave (appears just before the beginning of ventricular contraction). It coincides with phase 0 of cardiac action potential.

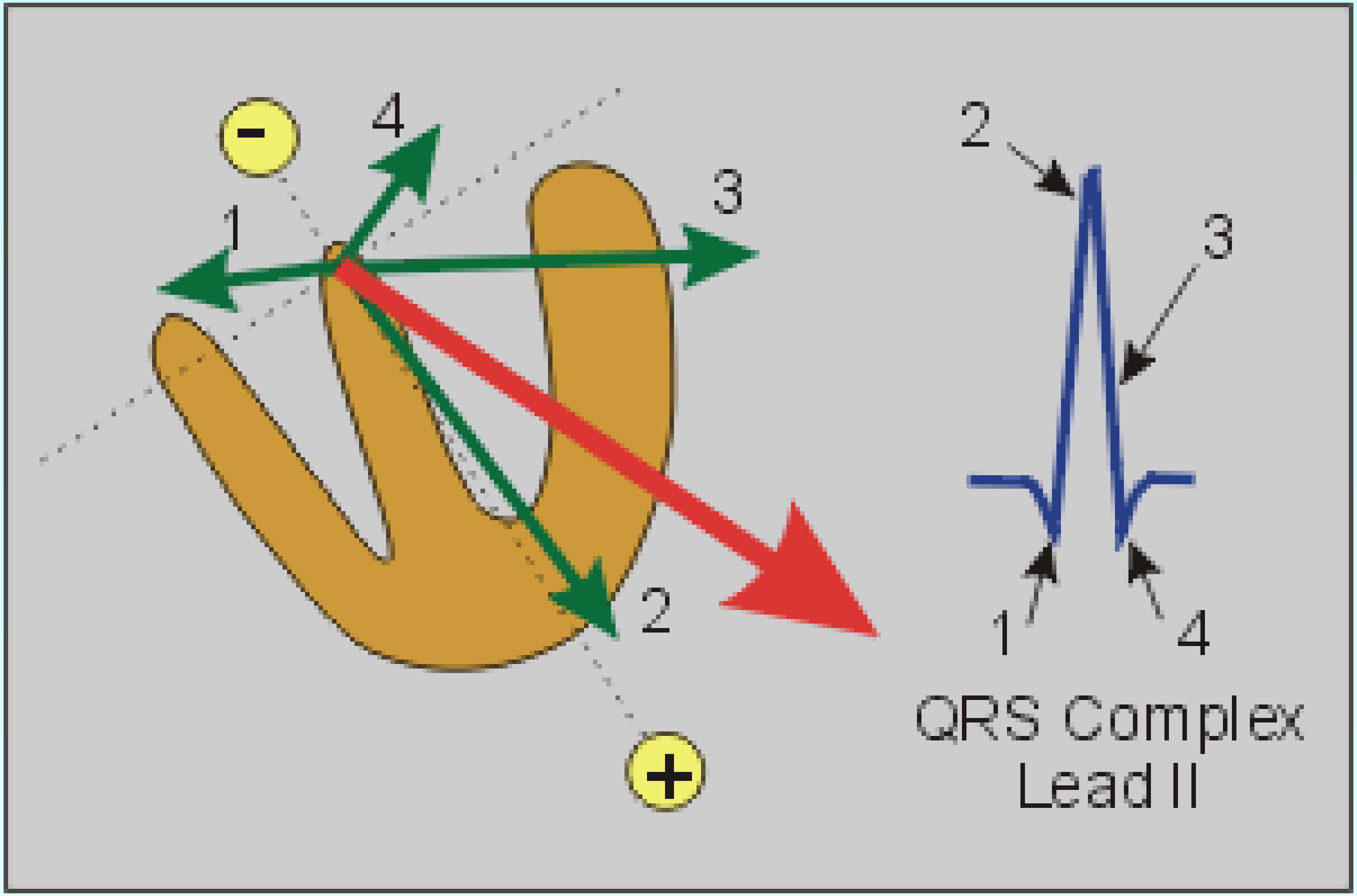
T wave - ventricular repolarization wave. It coincides with the end of repolarization phase (phase 3) of cardiac action potential. T waves that are abnormal either in direction or in amplitude may indicate myocardial damage, electrolyte disturbances, or cardiac hypertrophy.

U wave – can appear occasionally. It could be due to slow repolarization of the papillary muscles.

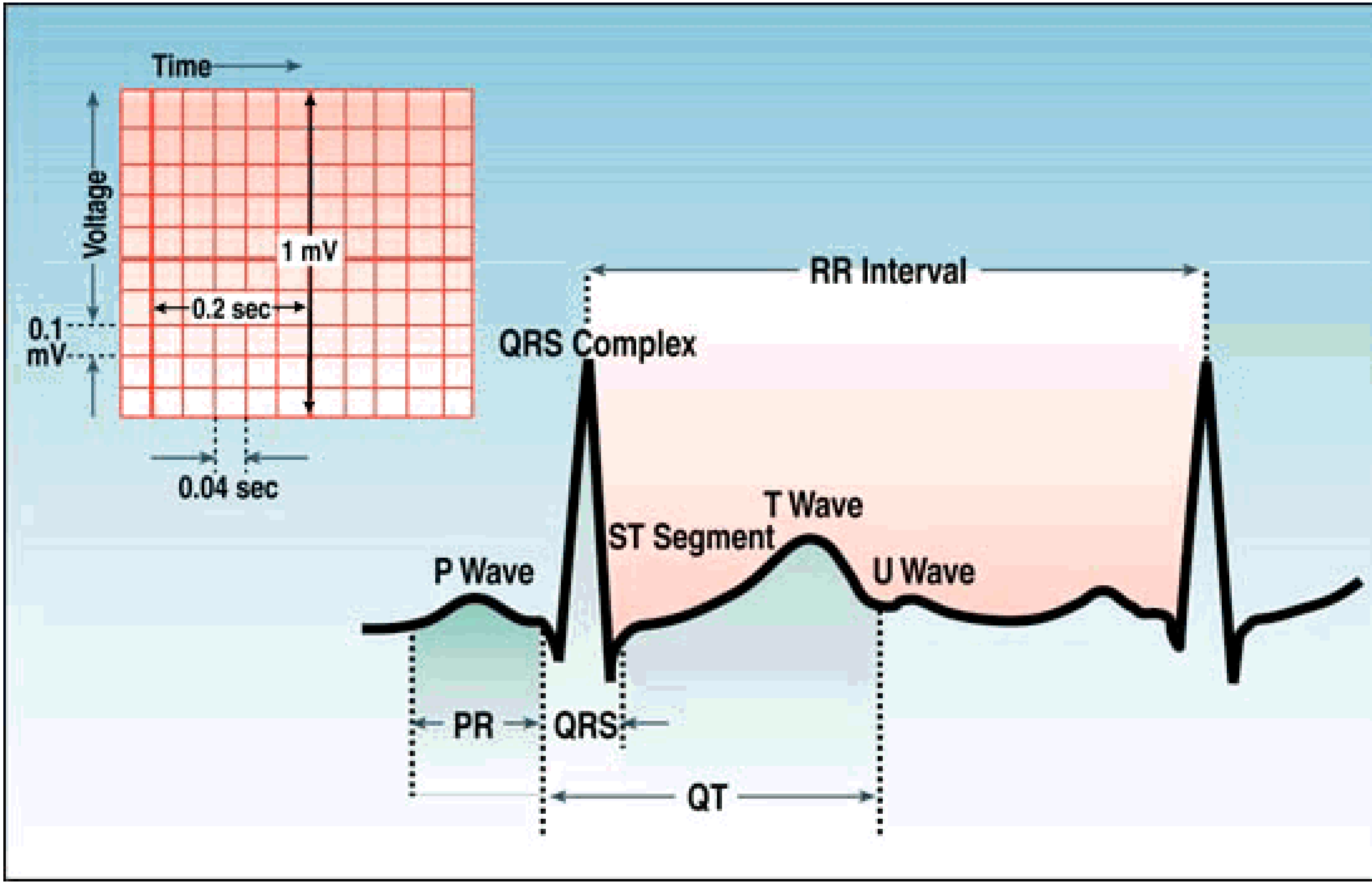
► Conduction System of the Heart







4
3
1
2
2
3
1
4
QRS Complex
Lead II



Time
Voltage
1 mV
0.2 sec
0.1 mV
0.04 sec
RR Interval
QRS Complex
T Wave
ST Segment
P Wave
U Wave
PR
QRS
QT

Recording from the whole heart

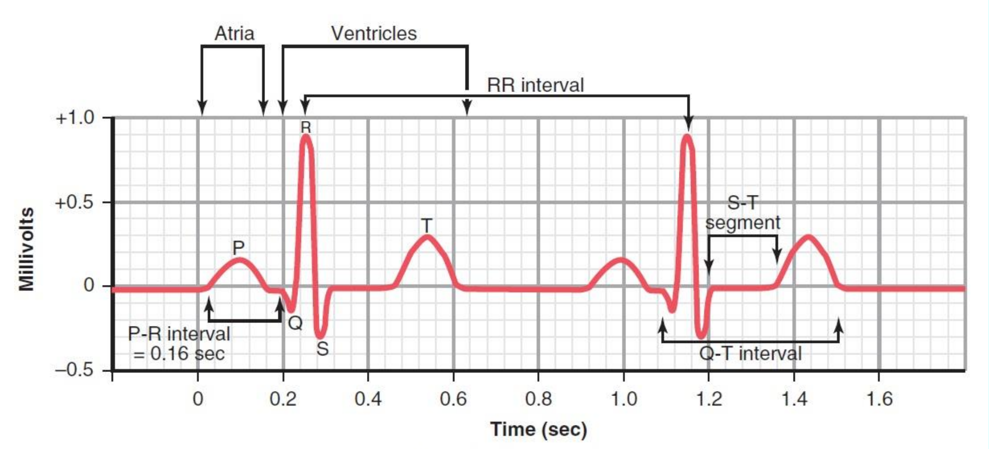
PQ or PR interval – measured from the *beginning* of P wave to the *beginning* of the QRS complex. It measures about 0.12-0.20 sec. This interval represents the delay of the depolarization wave at the AV node. The PR interval shortens as heart rate increases.

QT interval – represents the contraction interval of the ventricle (electrical systole). This interval lasts from the *beginning* of the Q wave to the *end* of the T wave. It measures about 0.35-0.43 sec. The QT interval shortens as heart rate increases (i.e. it varies inversely with the heart rate).

QRS duration – It measures about 0.06-0.10 sec. If longer, it indicates longer time is needed for the depolarization wave to finish its propagation in the myocardium.

ST segment – It corresponds to the plateau phase of the non-pacemaker action potential. It extends from the end of the S wave to the onset of the T wave. Its average is 0.08 sec. This segment should be on the iso-electric line (zero line). The normal ST segment has a slight upward concavity. Up or down deviation of this segment indicates the presence of **current of injury** (ischemic damage to the myocardium).

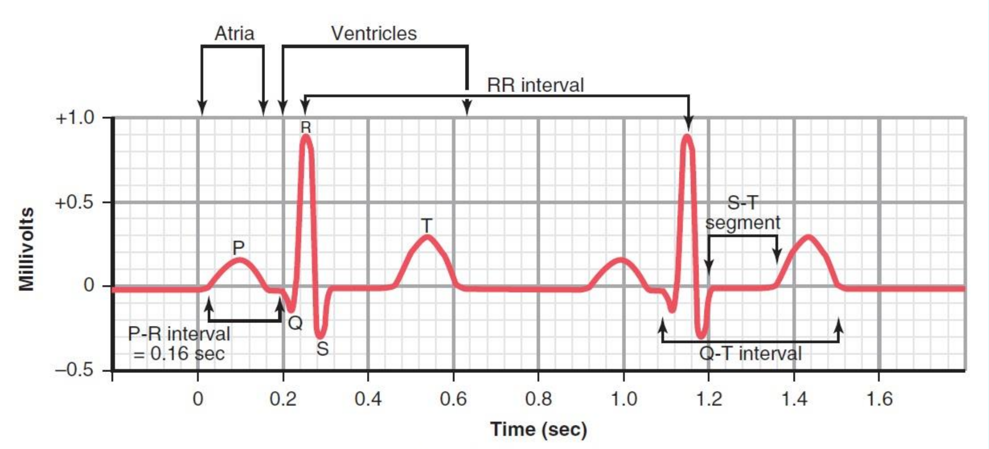
Voltage and Time Calibration of the Electrocardiogram



Normal electrocardiogram

- All recordings of ECGs are made with appropriate calibration lines on the recording paper.
- Electrocardiograph machine is calibrated so that 10 of the small line divisions (=10 mm) upward or downward ECG represent 1 mV, with positivity in the upward direction and negativity in the downward direction.
- A typical ECG is run at a paper speed of **25 mm** per second, although faster speeds are sometimes used. Therefore, each 1 mm in the horizontal direction is **0.04 second**
- Each 5 mm segment is indicated by a dark vertical lines and represents 0.20 second.

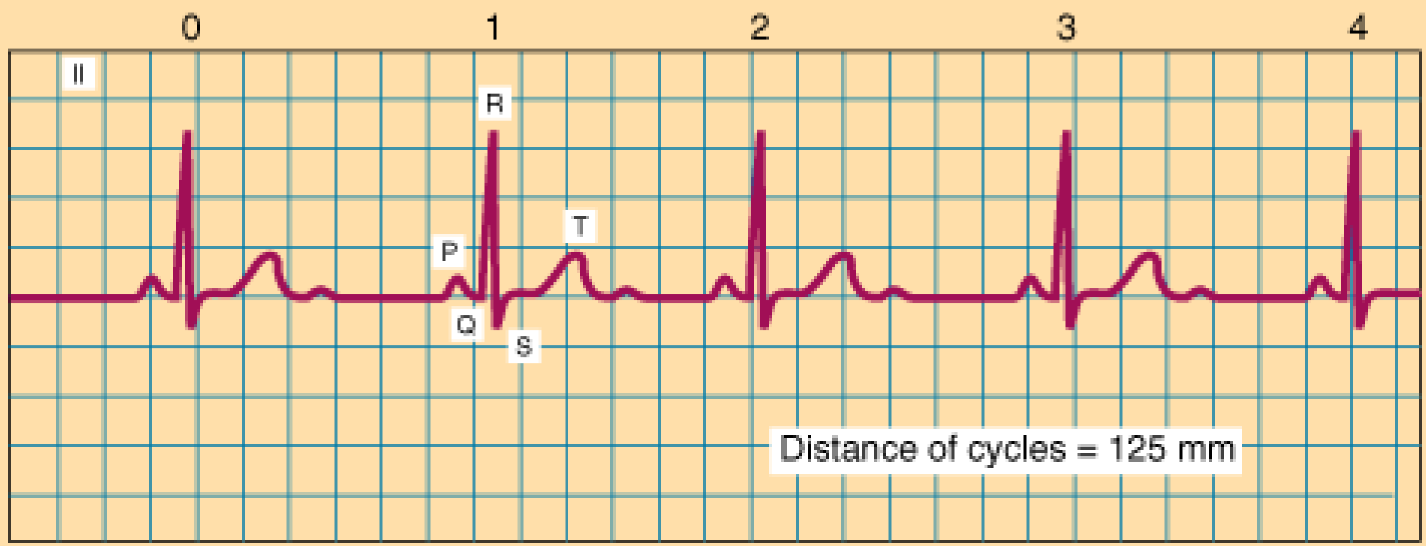
Voltage and Time Calibration of the Electrocardiogram (cont.)



Normal electrocardiogram

- The recorded voltages of the waves in the normal ECG depend on;
  1. The manner in which the electrodes are applied to the surface of the body.
  2. How close the electrodes are to the heart. The closer the electrode the greater the recorded voltage.
  3. The mass of myocardium from which the voltage it is generated
- The QRS complex voltage may be as great as 3 to 4 mV (average 1.0 to 1.5 mV) from the top of the R wave to the bottom of the S wave.
- The voltage of the P wave is between 0.1 and 0.3 mV.
- The voltage of the T wave is between 0.2 and 0.3 mV.

▶ ECG Used to Calculate Heart Rate



$$\text{Heart Rate} = \frac{1500}{\text{R–R interval}}$$

Effects of Changes in The Ionic Composition of The Blood on ECG Recording

Note:

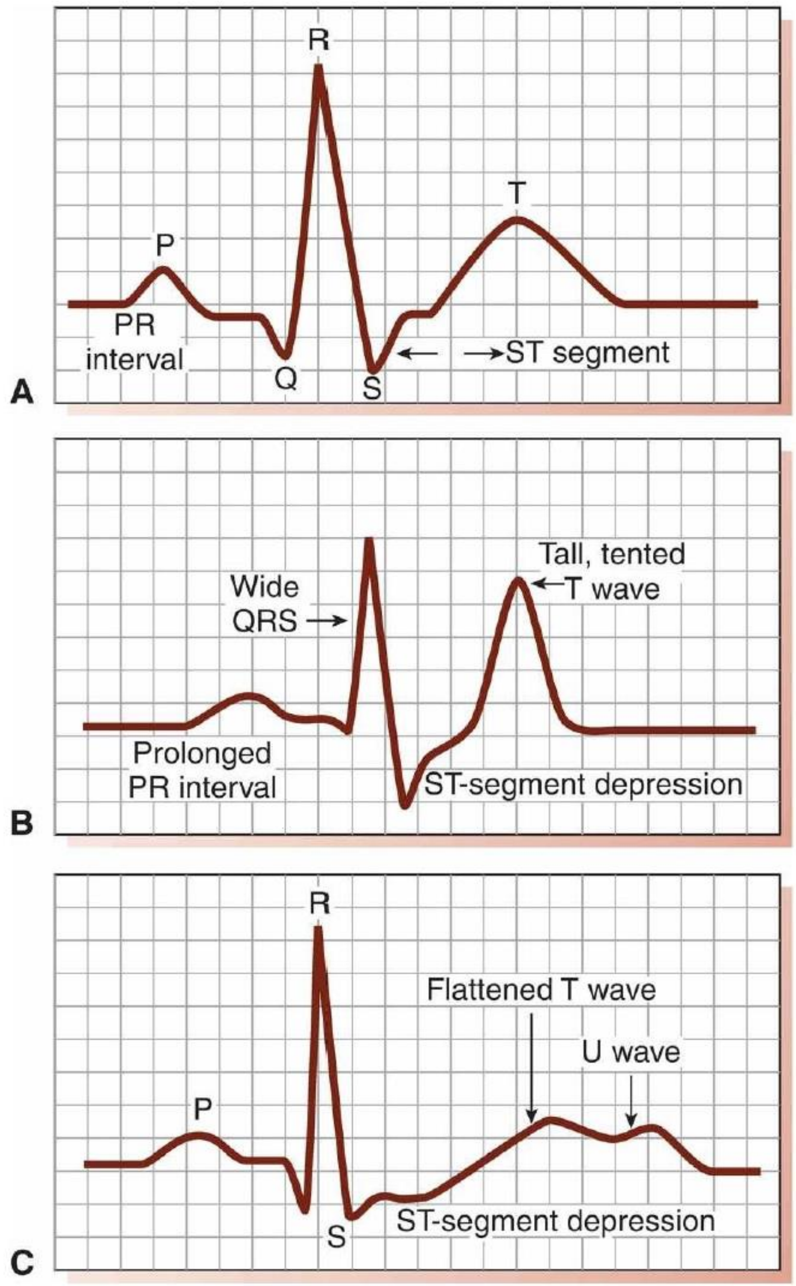
Clinically, a fall in the plasma level of Na^+ may be associated with low-voltage electrocardiographic complexes. Changes in the plasma K^+ level produce severe cardiac abnormalities.

Hyperkalemia → prolongation of the PR interval + appearance of tall peaked T waves.

Hypokalemia → flattened T wave + ST-segment depression + prominent U waves frequently superimposed upon T waves.

Hypocalcemia → prolongation of the QT interval.

(Calcium increases potassium conductance during phase 3. Therefore, low serum Ca^{2+} levels can thus delay the repolarization of the ventricles, and this is revealed on the ECG as an abnormally long QT interval)



Normal

Effect of hyperkalemia

Effect of hypokalemia

Test Question:

Q. The PR interval of ECG corresponds to?

A. Ventricular repolarization.

B. Ventricular depolarization.

C. Conduction through AV node.

D. Repolarization of AV node and bundle of His.

E. Timing of second heart sound.