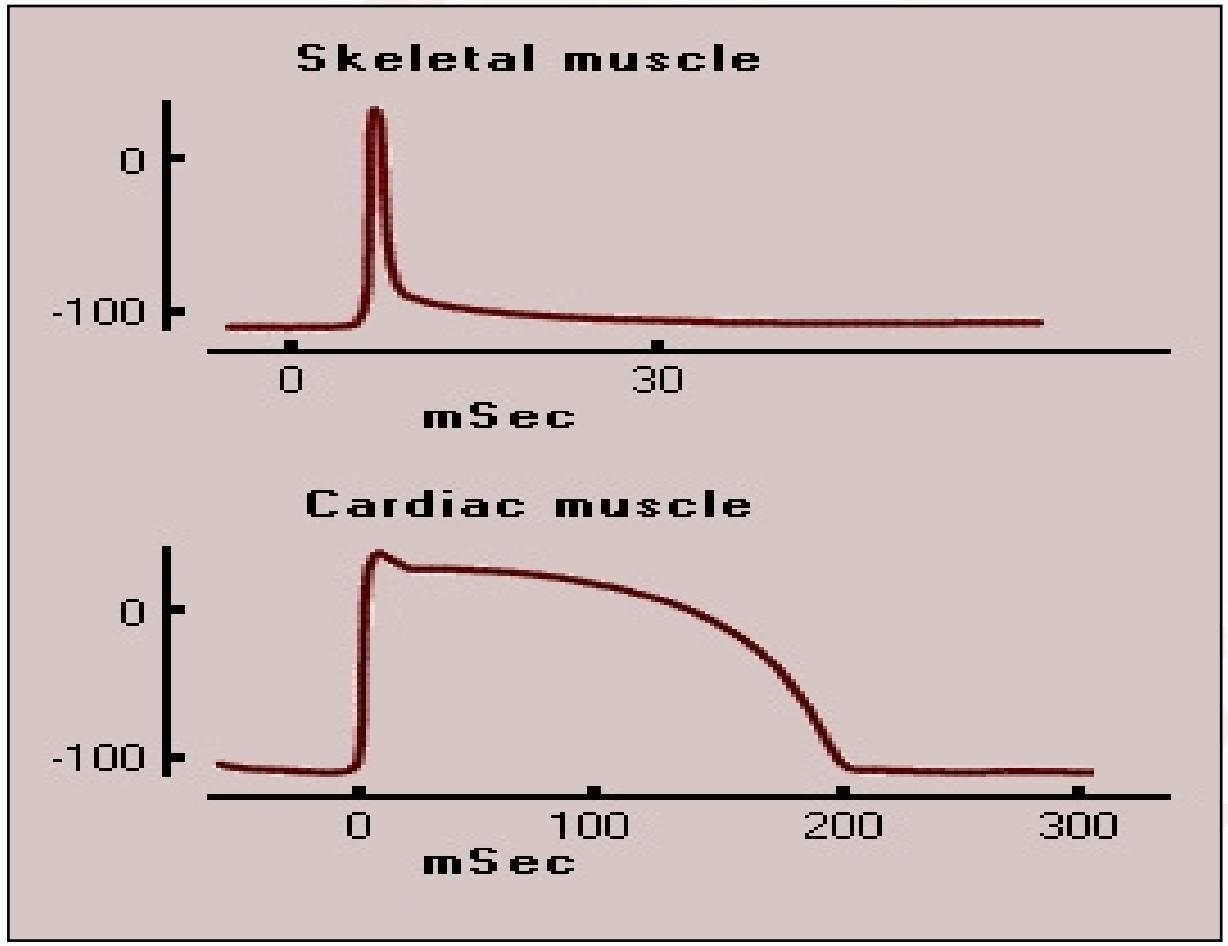
Electrophysiology of Heart

Disclaimer

All the content material provided here is only made for teaching purpose.

Action Potential

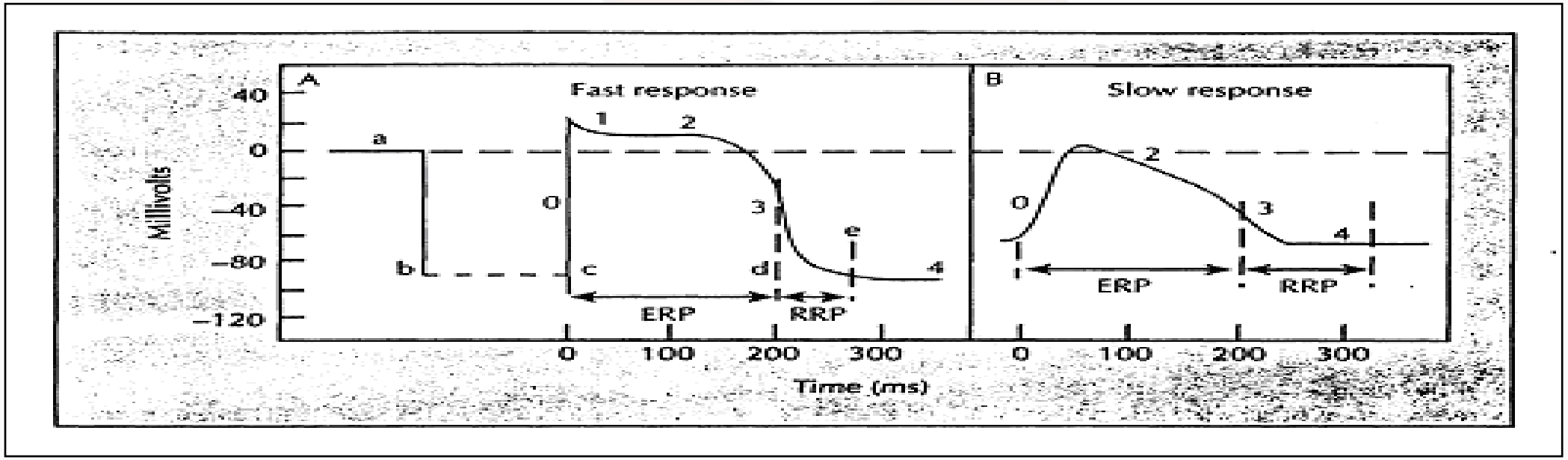
Skeletal



Cardiac

Myocyte Action Potentials

- Fast and Slow
  - Fast = non-pacemaker cells
  - Slow = pacemaker cells (SA and AV node)

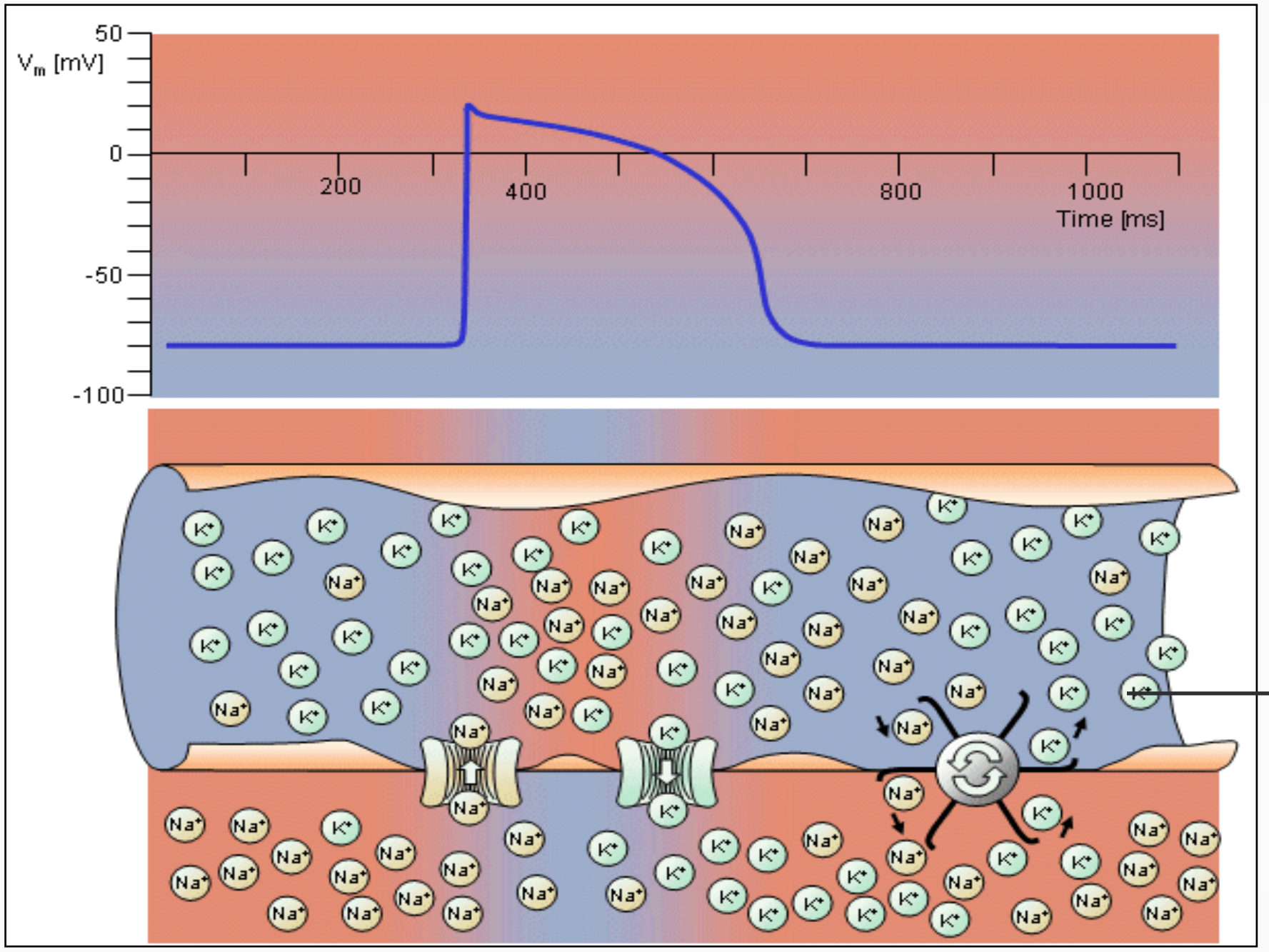


Ions

Ion	Extra-	Intra-
Na	140	10
K	4	135
Ca	2	0.1

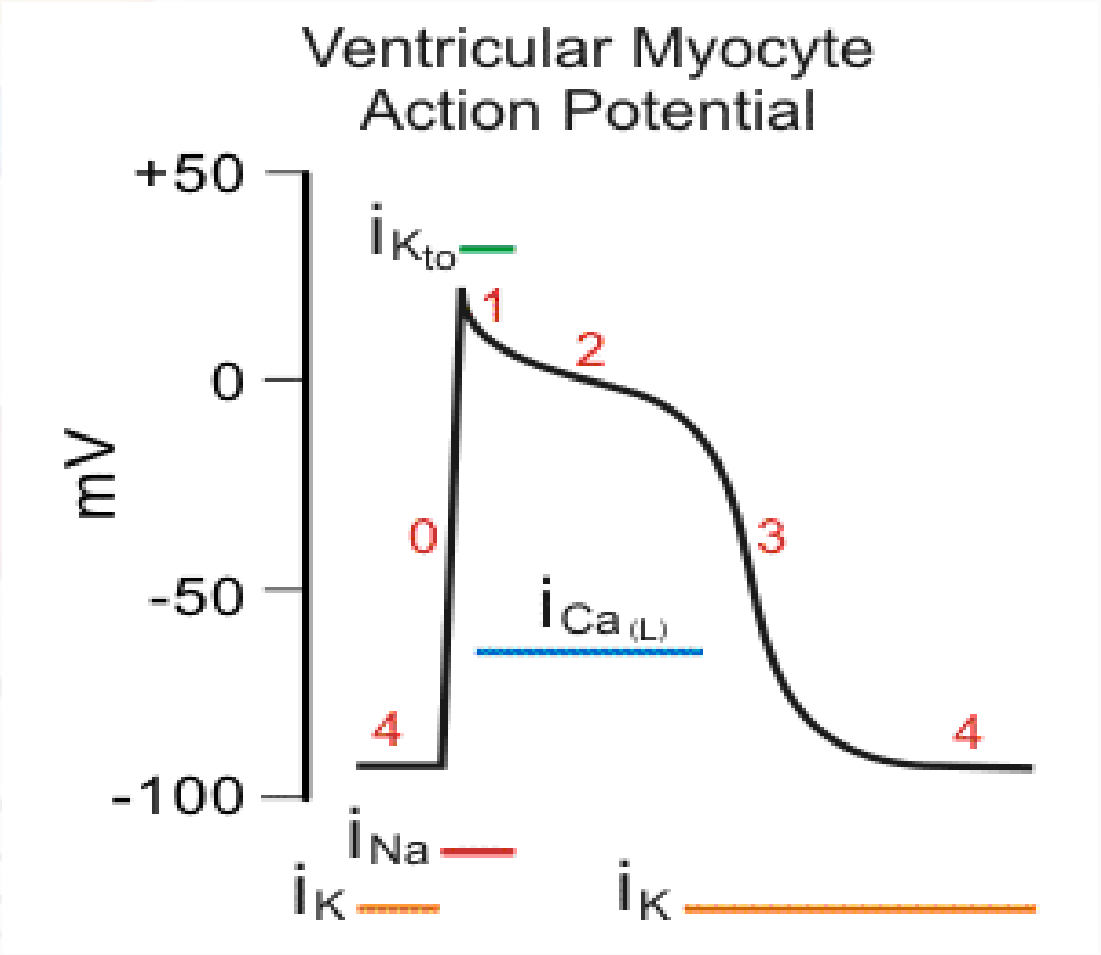
Action Potential

- Ion influx
    - Na channels (fast and slow)
    - K channels
    - Ca channels


50
V_m [mV]
0
-50
-100
200
400
800
1000
Time [ms]
Inside
Outside

Action Potential

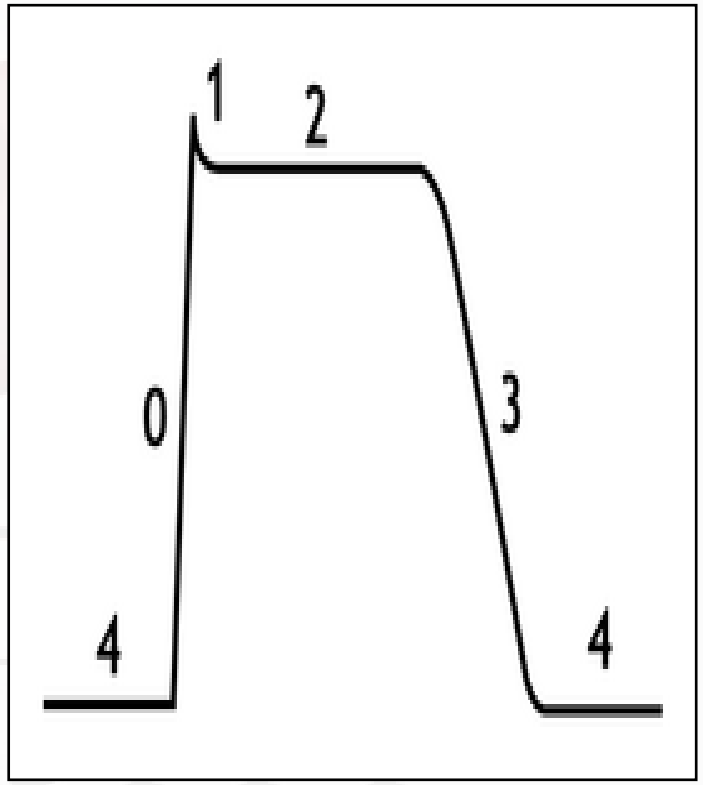
- Phase 0
  - Stimulation of the myocardial cell
  - Influx of sodium
  - The cell becomes depolarize
  - Inside the cell = +20 mV



Action Potential

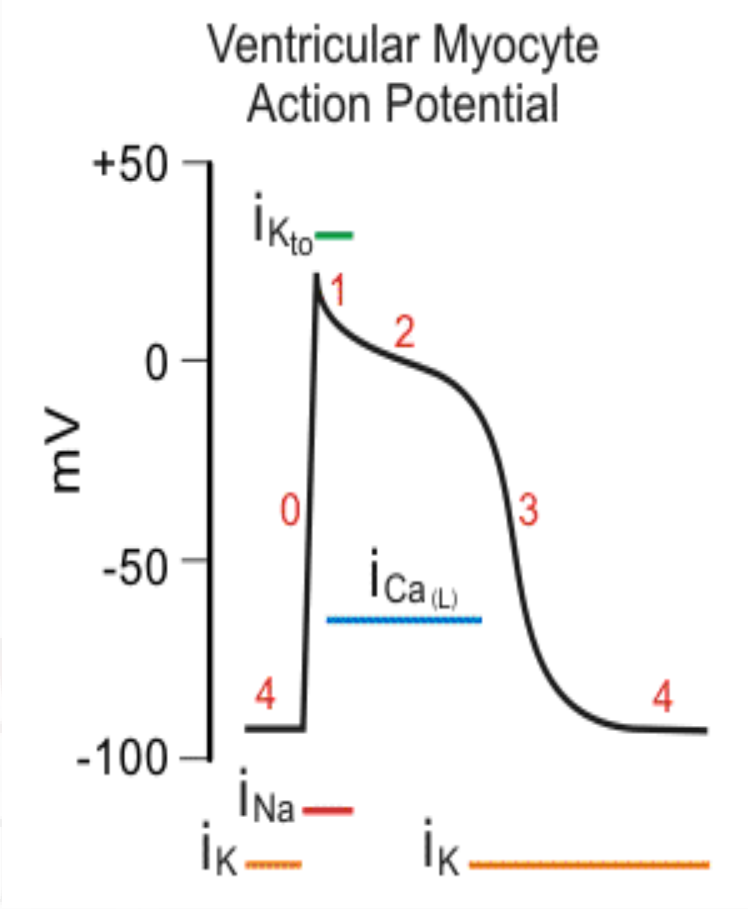
- Phase 1
    - Ions
        - Influx of sodium
        - Efflux of potassium
    - Partial repolarization

- Phase 2
    - Ions
        - Sodium
        - Efflux of potassium
        - Influx of calcium
    - Plateau

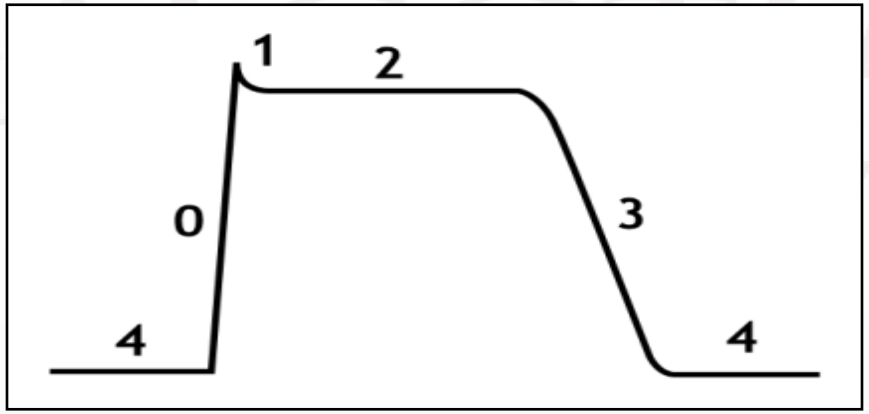


Action Potential

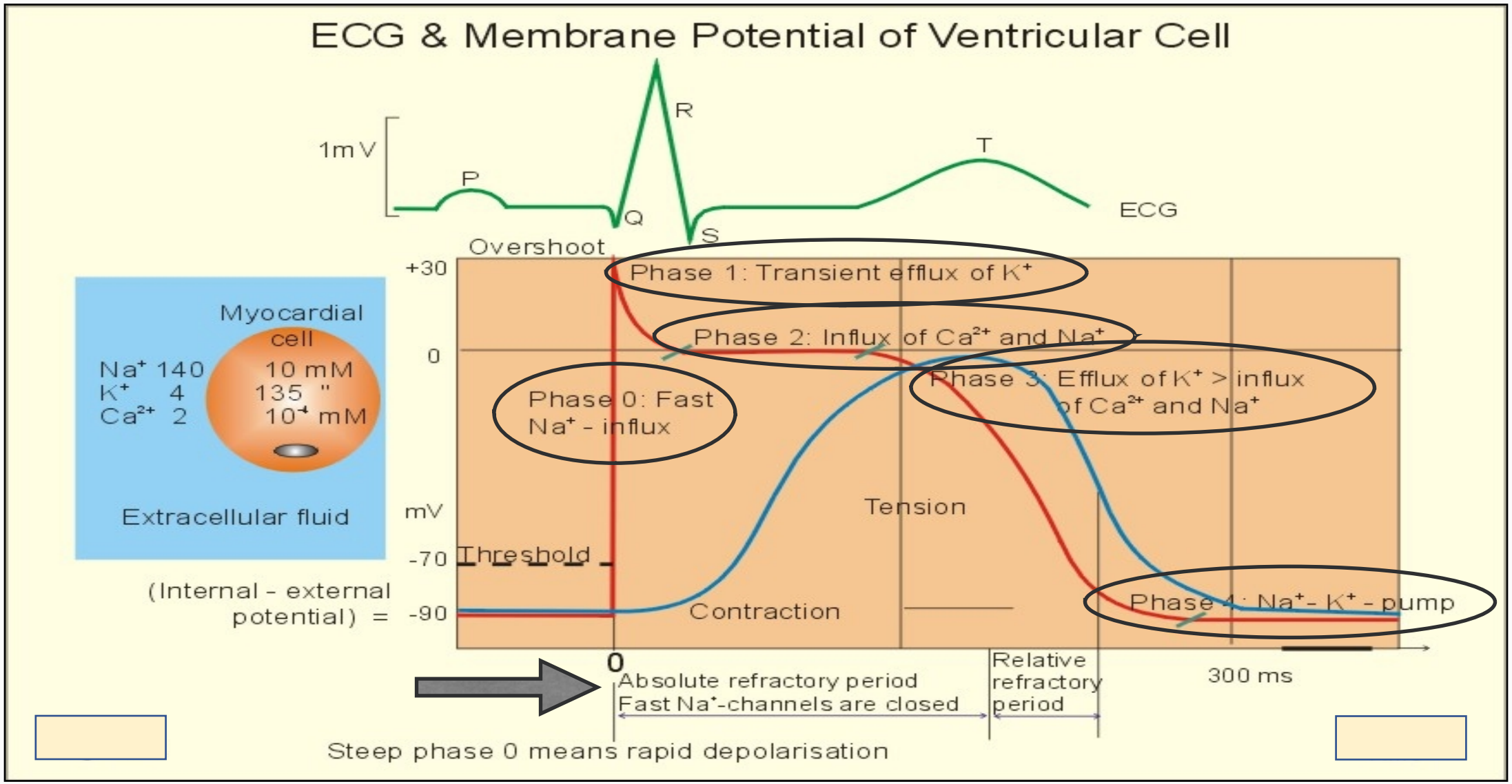
- Phase 3
  - Ions
    - Efflux of potassium*
    - Influx of calcium
  - Repolarization (slower process than depolarization)
- Phase 4
  - Interval between repolarization to the next action potential
  - Pumps restore ionic concentrations



Ion	0	1	2	3	4
Na	influx	influx			pump
K		efflux	efflux	efflux	pump
Ca			influx	influx	pump

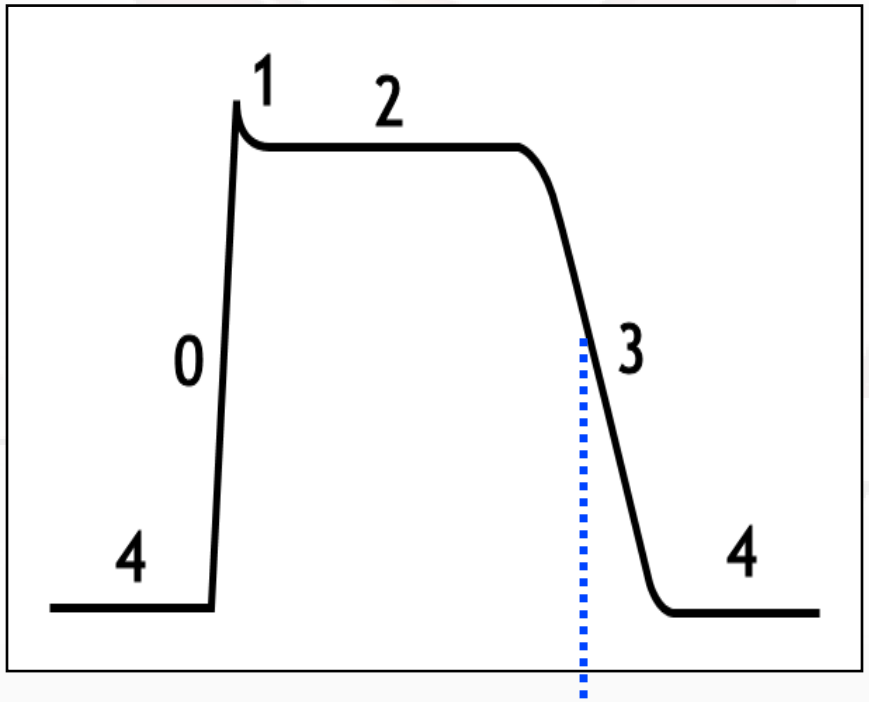


ECG & Membrane Potential of Ventricular Cell



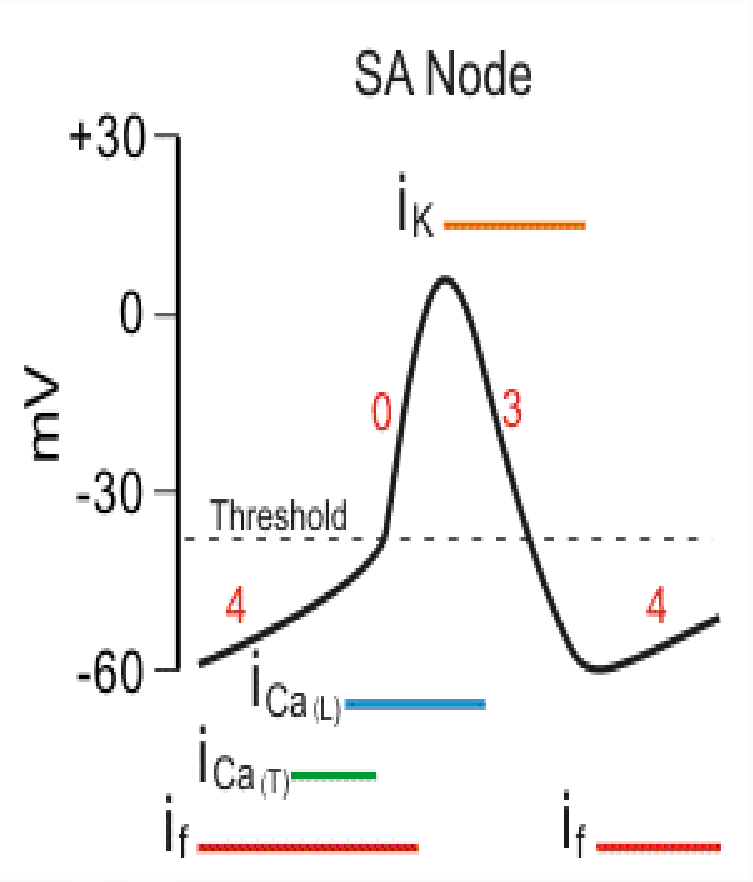
Refractory Periods

- Absolute refractory period - phase 1 - midway through phase 3
- Relative refractory period - midway through phase 3 - end of phase 3



SA Node Action Potential

- "Funny" currents (phase 4); slow Na channels that initiate spontaneous depolarization
- No fast sodium channels
- Calcium channels (slow)
    - Long-lasting, L-type
    - Transient, T-type
- Potassium channels



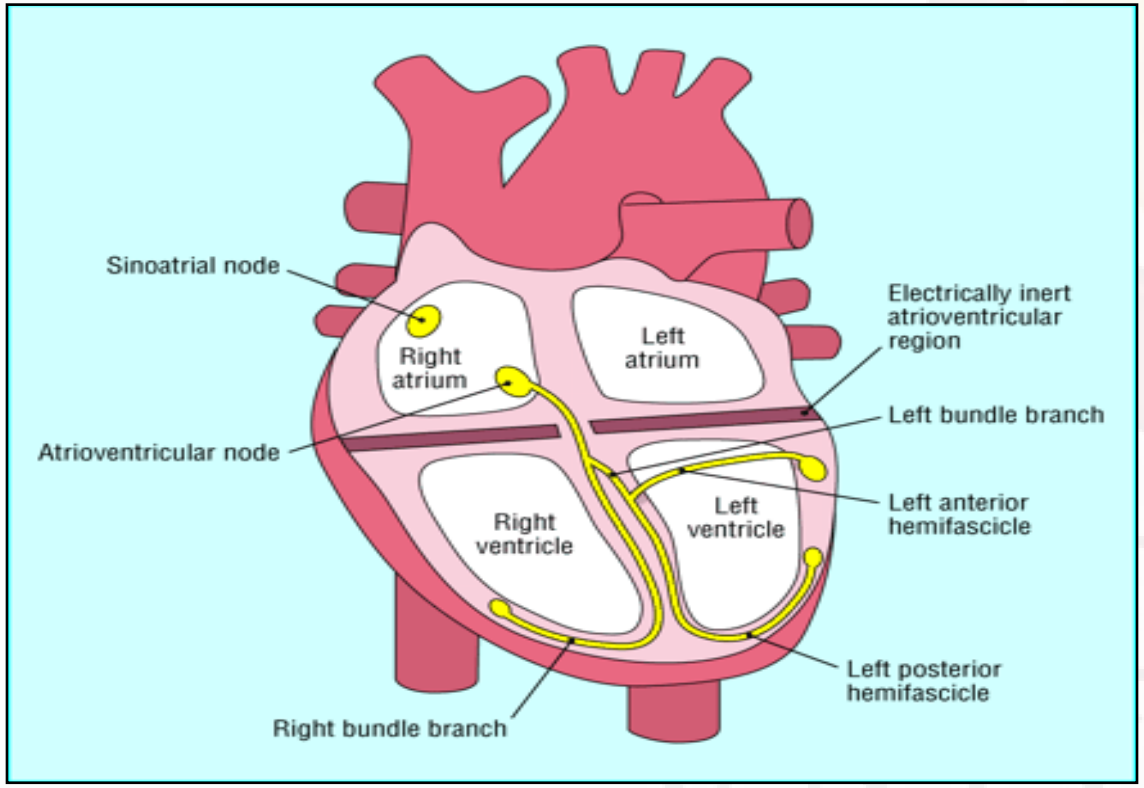
Action Potentials

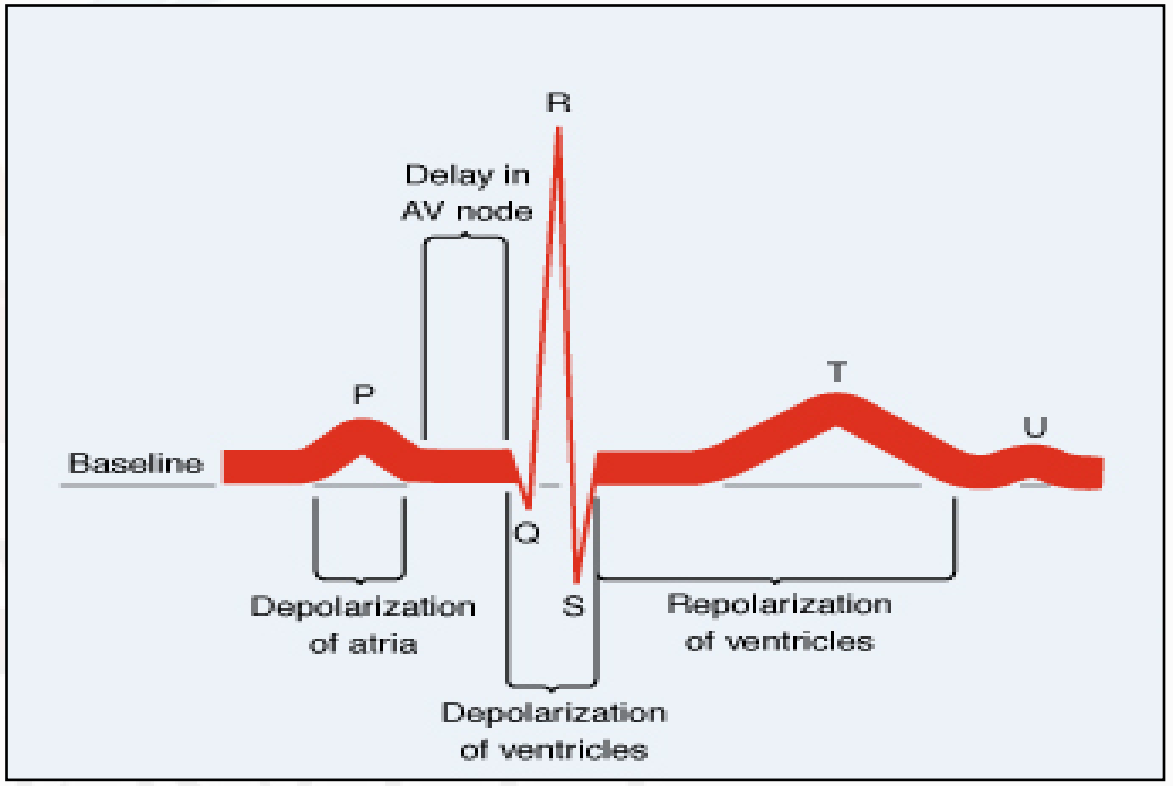
It is important to note that non-pacemaker action potentials can change into pacemaker cells under certain conditions. For example, if a cell becomes hypoxic, the membrane depolarizes, which closes fast Na^+ channels. At a membrane potential of about –50mV, all the fast Na^+ channels are inactivated. When this occurs, action potentials can still be elicited; however, the inward current are carried by Ca^{++} (slow inward channels) exclusively. These action potentials resemble those found in pacemaker cells located in the SA node,and can sometimes display spontaneous depolarization and automaticity. This mechanism may serve as the electrophysiological mechanism behind certain types of ectopic beats and arrhythmias, particularly in ischemic heart disease and following myocardial infarction.

Action Potential

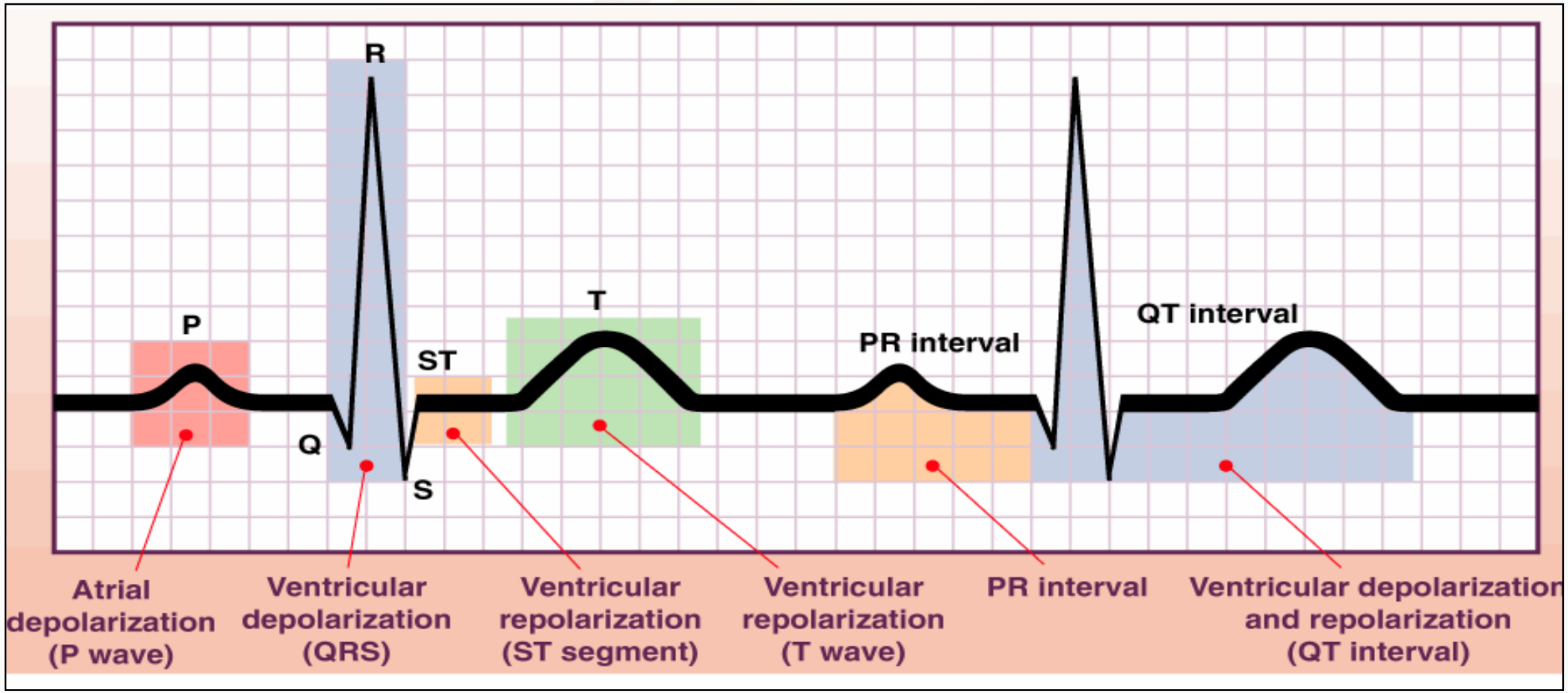
- ECG records depolarization and repolarization
    - Atrial depolarization
    - Ventricular depolarization
        - Atrial repolarization
    - Ventricular repolarization

ECG Complexes



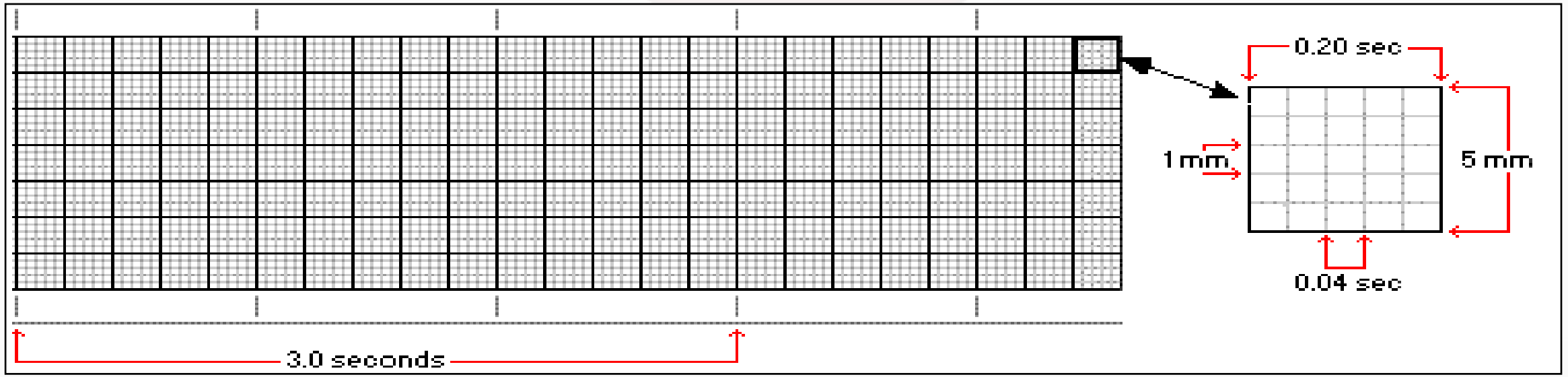


ECG Complexes



ECG Paper

- Small boxes = 1 mm
- Large boxes = 5 mm
- Small boxes = 0.04 seconds
- Large boxes = 0.20 seconds
- 5 large boxes = 1.0 second
- Paper speed = 25 mm / sec

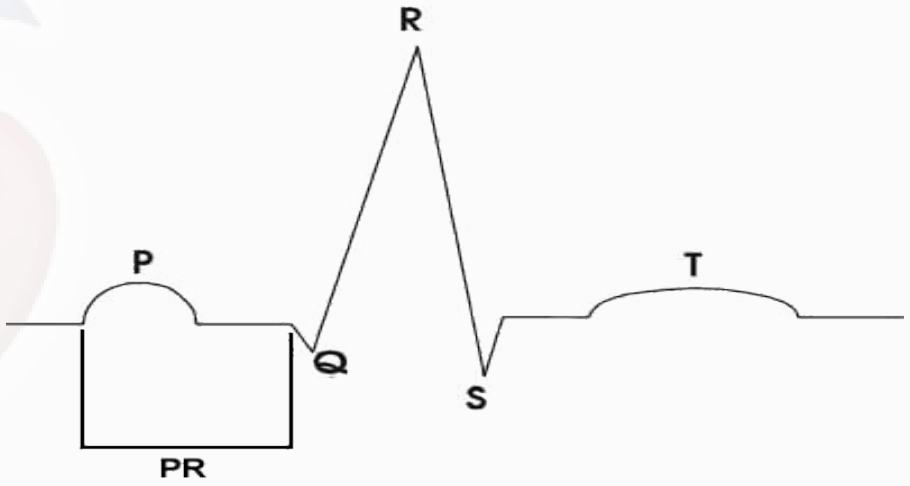


ECG Waves

- Upward wave is described as positive
- Downward wave is described as negative
- A flat wave is said to be isoelectric
    - Isoelectric as describes the baseline
- A deflection that is partially positive and negative is referred to as biphasic

ECG Waves

- <u>P wave</u>
  - atrial depolarization
    - ≤ 2.5 mm in amplitude
    - < 0.12 sec in width
- <u>PR interval</u> (0.12 - 0.20 sec.)
  - time of stimulus through atria and AV node
    - *e.g. prolonged interval = first-degree heart block*

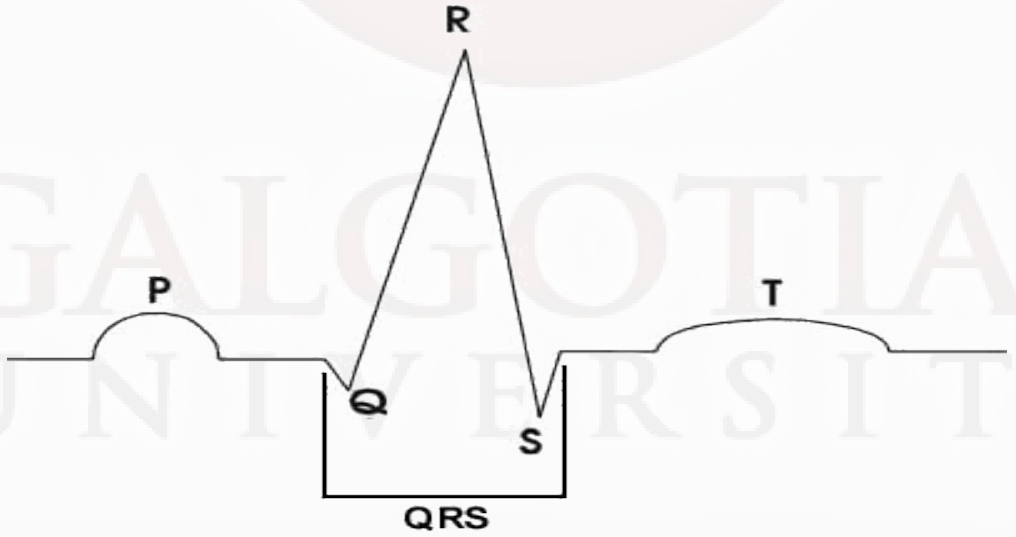


ECG Waves

- <u>QRS wave</u>
  - Ventricle depolarization
    - Q wave: when initial deflection is negative
    - R wave: first positive deflection
    - S wave: negative deflection after the R wave

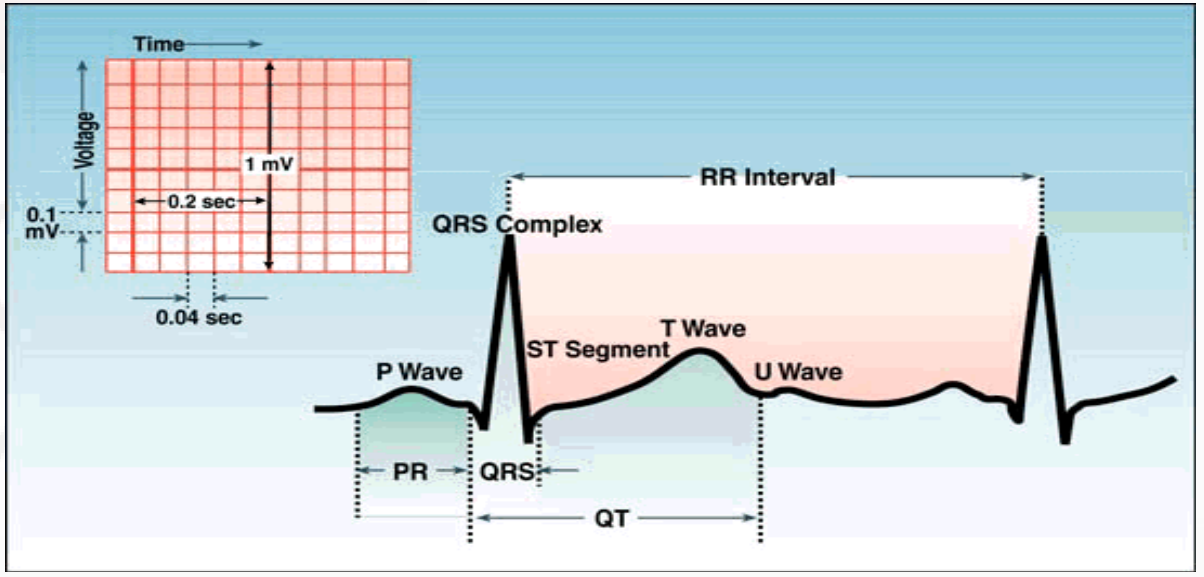
ECG Waves

- QRS
  - width usually 0.10 second or less



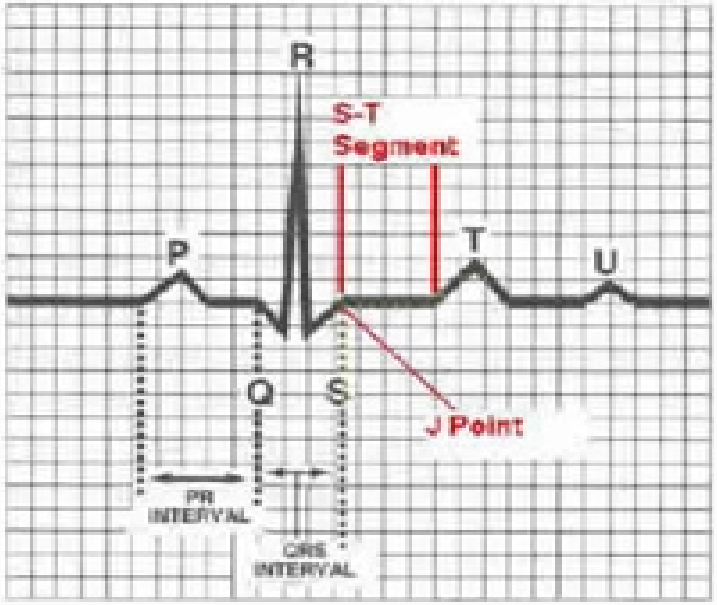
ECG Waves

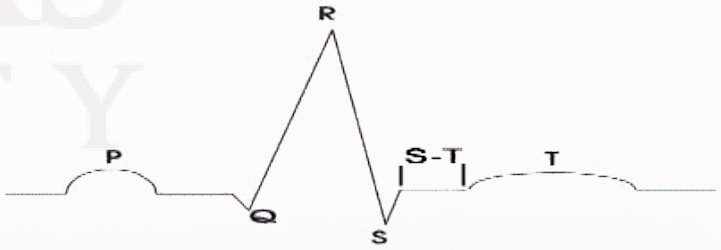
- <u>RR interval</u>
    - interval between two consecutive QRS complexes



ECG Waves

- J point
  - end of QRS wave and
  - beginning of ST segment
- ST segment
  - beginning of ventricular repolarization
  - normally *isoelectric* (flat)
  - changes-elevation or depression-may indicate a pathological condition





ECG Waves

- T wave
  - part of ventricular repolarization
  - asymmetrical shape
  - usually not measured

ECG Waves

- <u>QT interval</u>
  - from beginning of QRS to the end of the T wave
  - ventricular depolarization & repolarization
  - length varies with heart rate (table 2.1)
  - long QT intervals occur with ischemia, infarction, and hemorrhage
  - short QT intervals occur with certain medications and hypercalcemia

ECG Waves

- Long QT interval
  - certain drugs
  - electrolyte distrubances
  - hypothermia
  - ischemia
  - infarction
  - subarachnoid hemorrhage
- Short QT interval
  - drugs or hypercalcemia

ECG Waves

- U Wave
  - last phase of repolarization
  - small wave after the T wave
  - not always seen
  - significance is not known
  - prominent U waves are seen with hypokalemia

The ECG as a Combination of Atrial and Ventricular Parts

- Atrial ECG = P wave
- Ventricular ECG = QRS-T waves
- Normally, sinus node paces the heart and P wave precedes QRS
    - P-QRS-T
- Sometimes, atria and ventricles paced separately (e.g. complete heart block)

References

1. Guyton, A. C. and Hall, J. E. 2006. Textbook of Medical Physiology. 11th Edition. Saunders, Philadelphia.

2. Martini, F.H. and Nath, J. L. 2009. Fundamentals of Anatomy & Physiology. Pearson Benjamin Cummings.

3. Specter P. 2016. Understanding Clinical Cardiac Electrophysiology: A Conceptually Guided Approach.