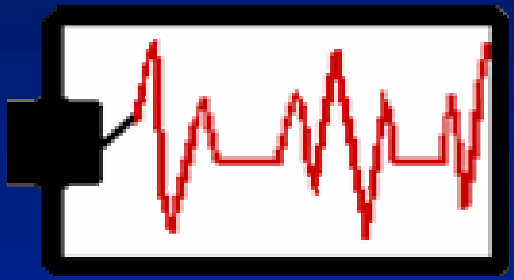


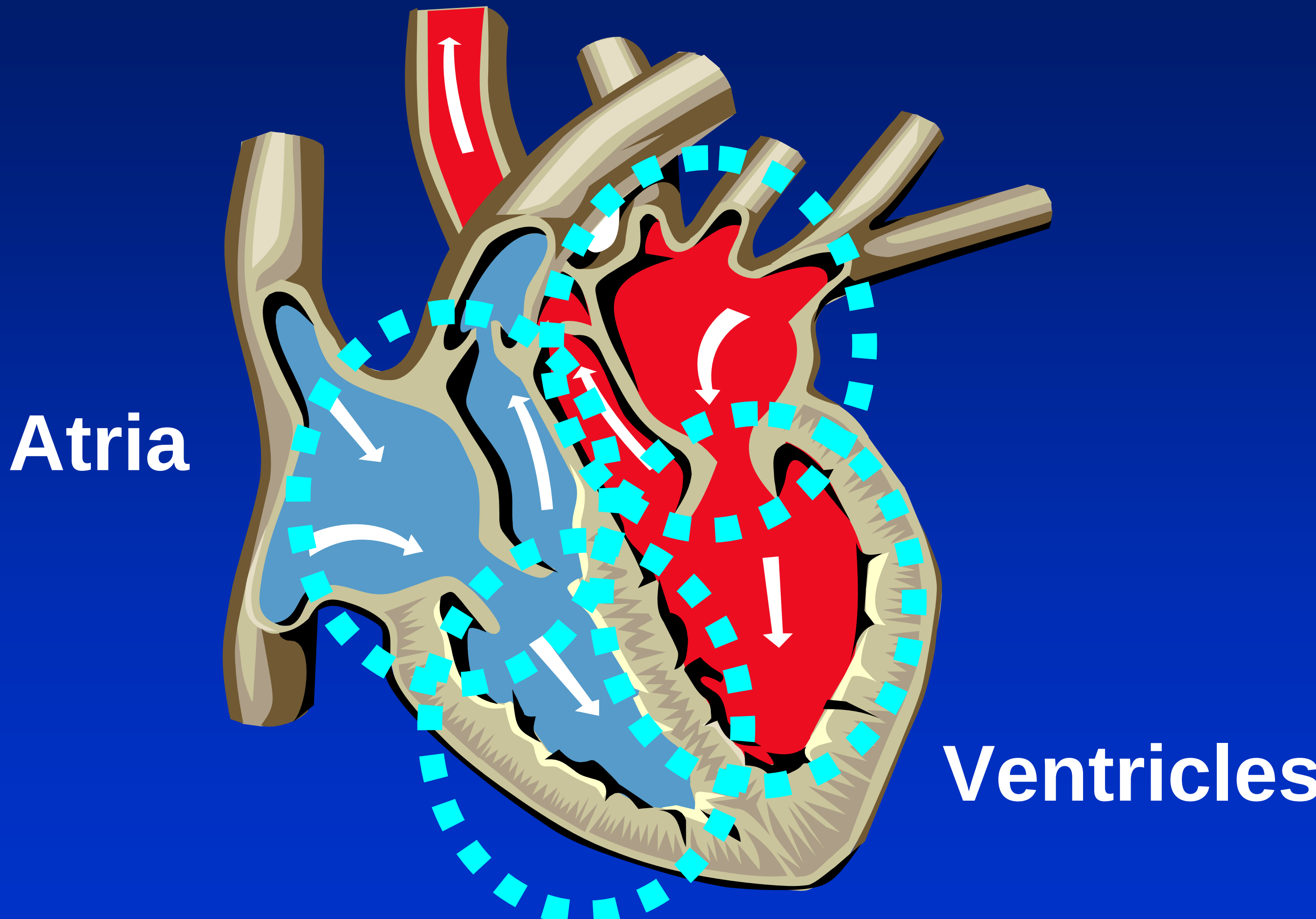
Electrophysiology and biomechanics of the cardiovascular system: an overview

Nasser-Eddin M, Ph.D

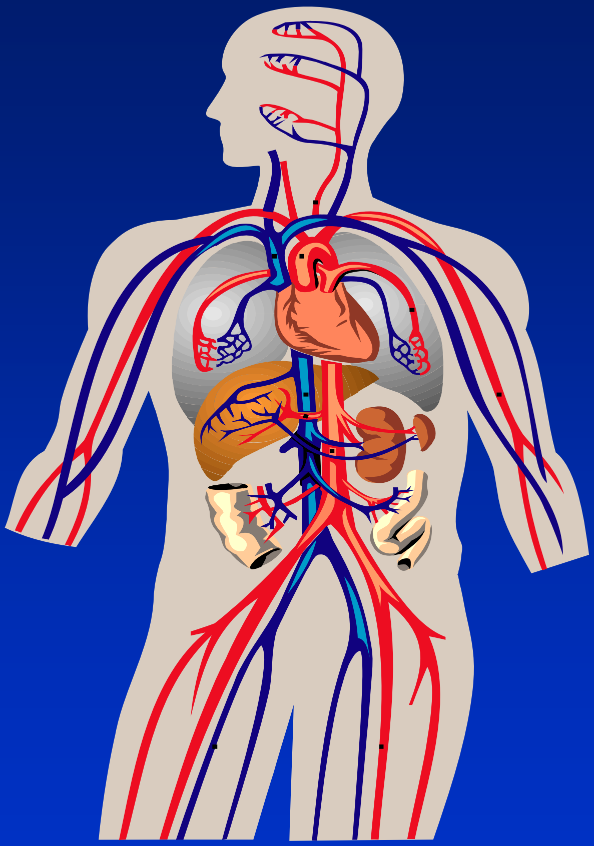
OVERVIEW

- Cardiovascular electrophysiology
- Cardiovascular biomechanics

Introduction



Introduction

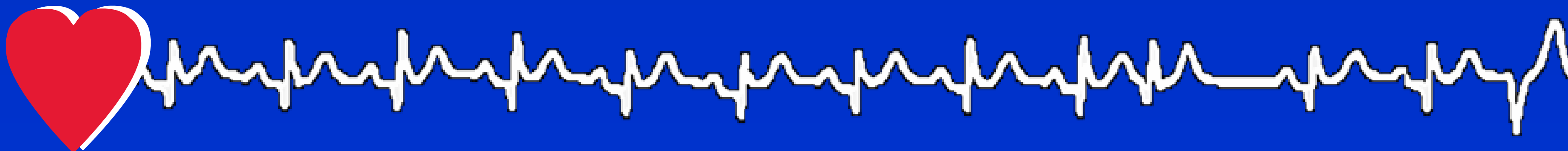


ARTERIES

distribute blood from the heart

VEINS

bring blood back to the heart



Electrophysiology	Biomechanics

Objectives:

1. Understand normal activation sequence, conduction velocities, and intrinsic pacemaker rates in the human heart

2. Understand the anatomical and physiological basis of the P wave, PR interval, QRS complex, ST segment, T waves, QT interval and U waves.

Electrophysiology	Biomechanics

- An inherent and rhythmic electrical activity is the reason for the heart’s lifelong beat.

- The primary function of cardiac myocytes is to contract. Electrical changes within the myocytes initiate this contraction.

- Cardiac cells, like all living cells in the body, have an electrical potential across the cell membrane. If measurements are taken with a resting ventricular myocyte, a membrane potential of about –90 mV will be recorded.

Concentrations of ions across the myocyte membrane:

Outside:

- **Positive ions = Na^{+} (+ a small [ ] of k+), Ca^{++}**
- **Negative ions = Cl^{-}**

Small over-quantity of positive ions

Inside:

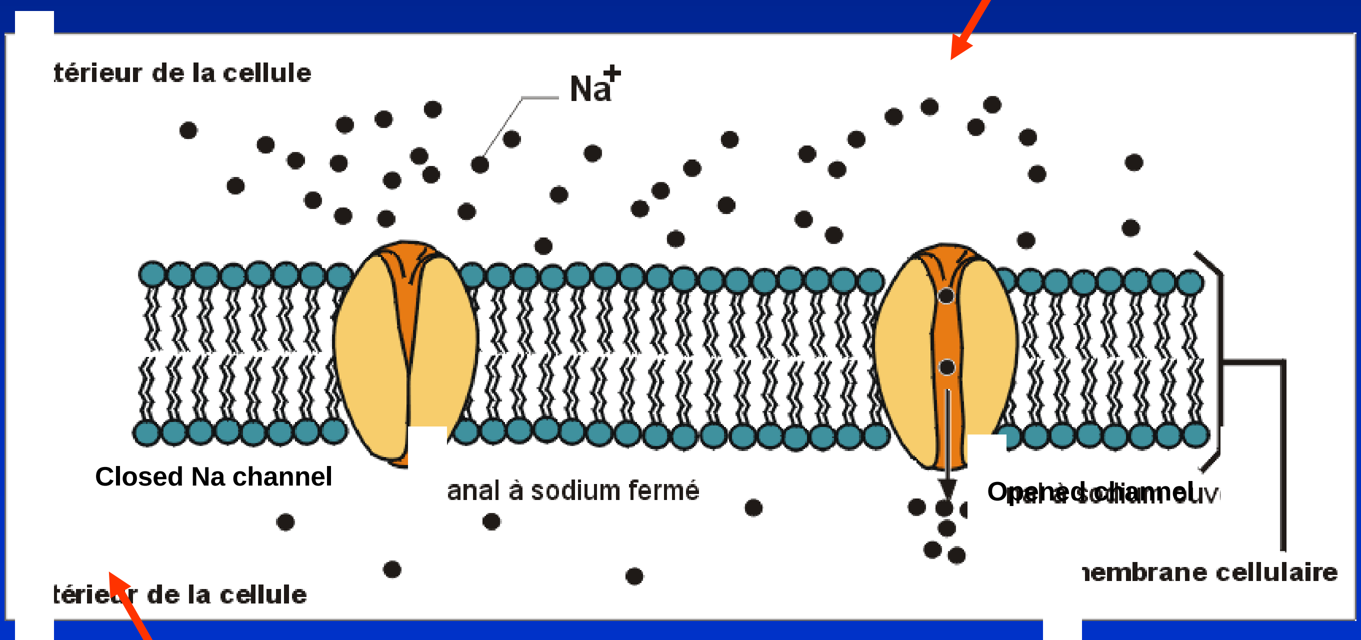
- **Positive ions = K^{+} (+ a small [ ] of Na^{+})**
- **Negative ions = Proteins and phosphates ions**

Small over-quantity of negative ions

Myocytes can answer to a stimulus (excitability).

Reaction = Opening of sodium channels of the membrane

Decrease of + outside



Increase of + inside

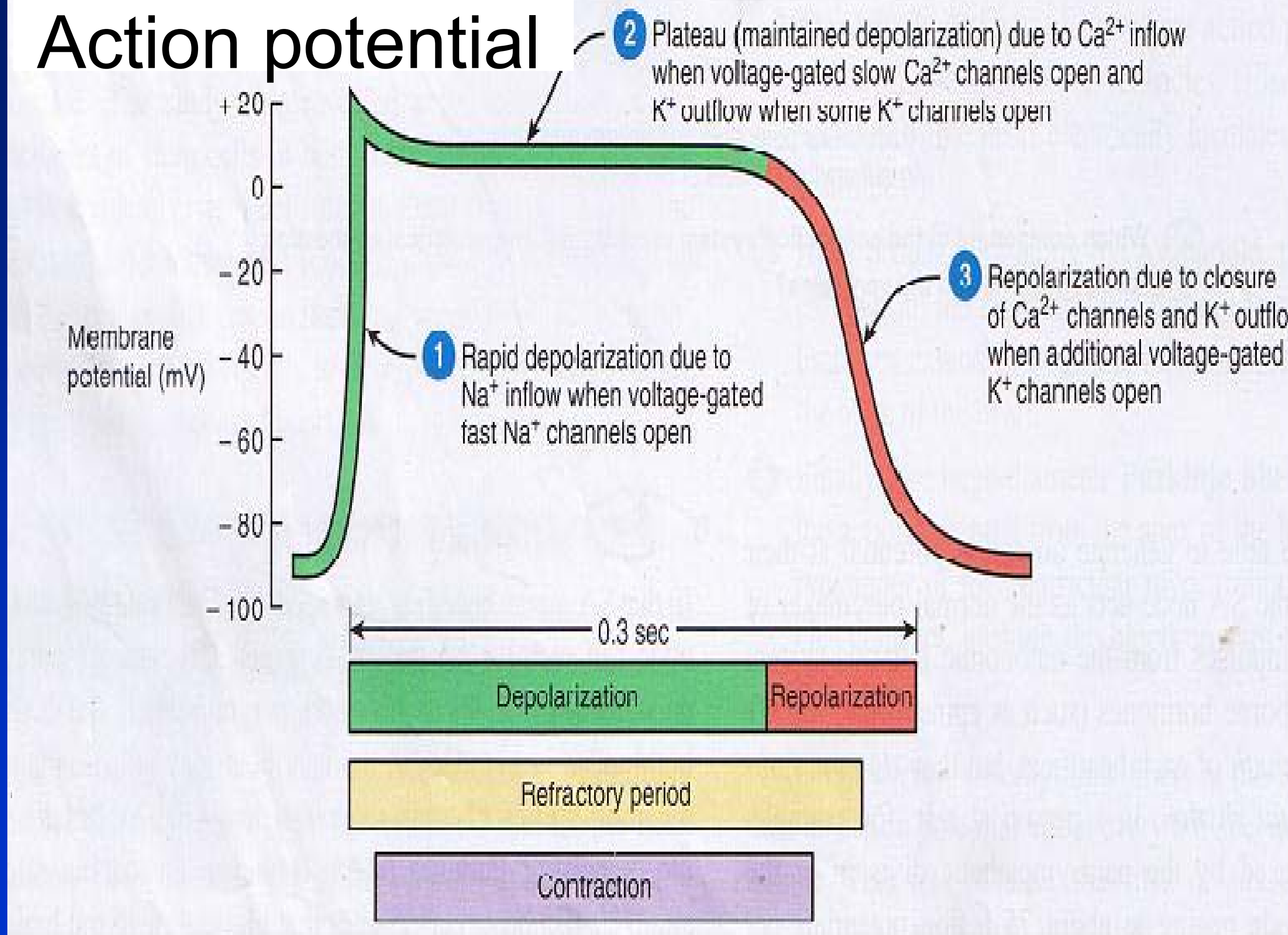
Massive entry of Na^+ ==> Depolarization

where the Na channels are opened

- 90mV → - 60mV → - 50 mV → ...

Electrophysiology | Biomechanics

Action potential



Electrophysiology	Biomechanics

Electrical activation sequence

SA NODE

Atrial Myocardium

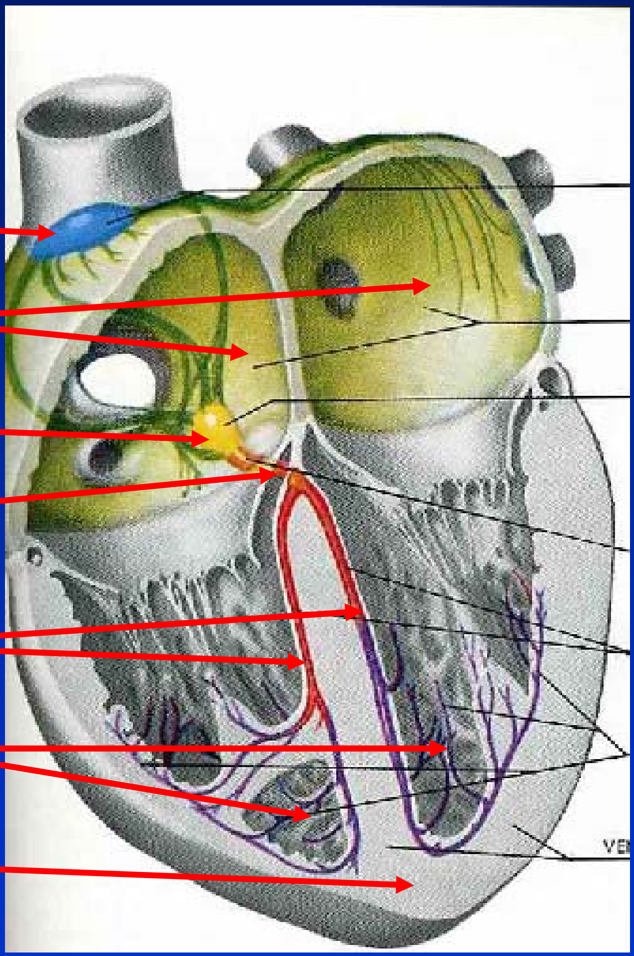
AV Node

AV Bundle

Bundle Branches

His-Purkinje System

Ventricular Myocardium



PACEMAKER + CONDUCTION SYSTEM

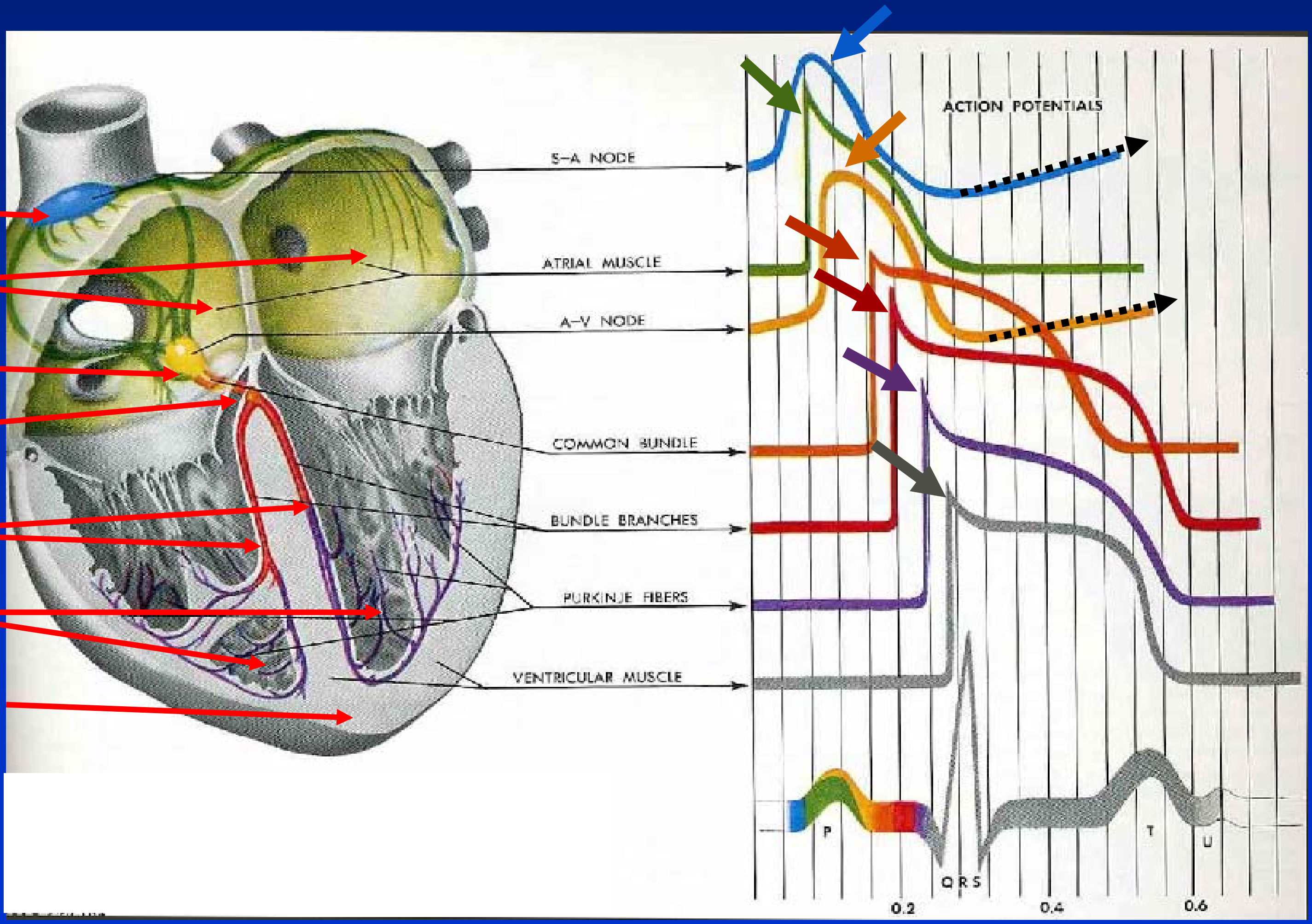
Electrophysiology | Biomechanics

The action potentials are not the same in all regions of the heart.

- ∑action potentials= ECG

Structure

SA Node
↓
Atrial Myocardium
↓
AV Node
↓
AV Bundle
↓
Bundle branches
↓
His-Purkinje system
↓
Ventricular Myocardium

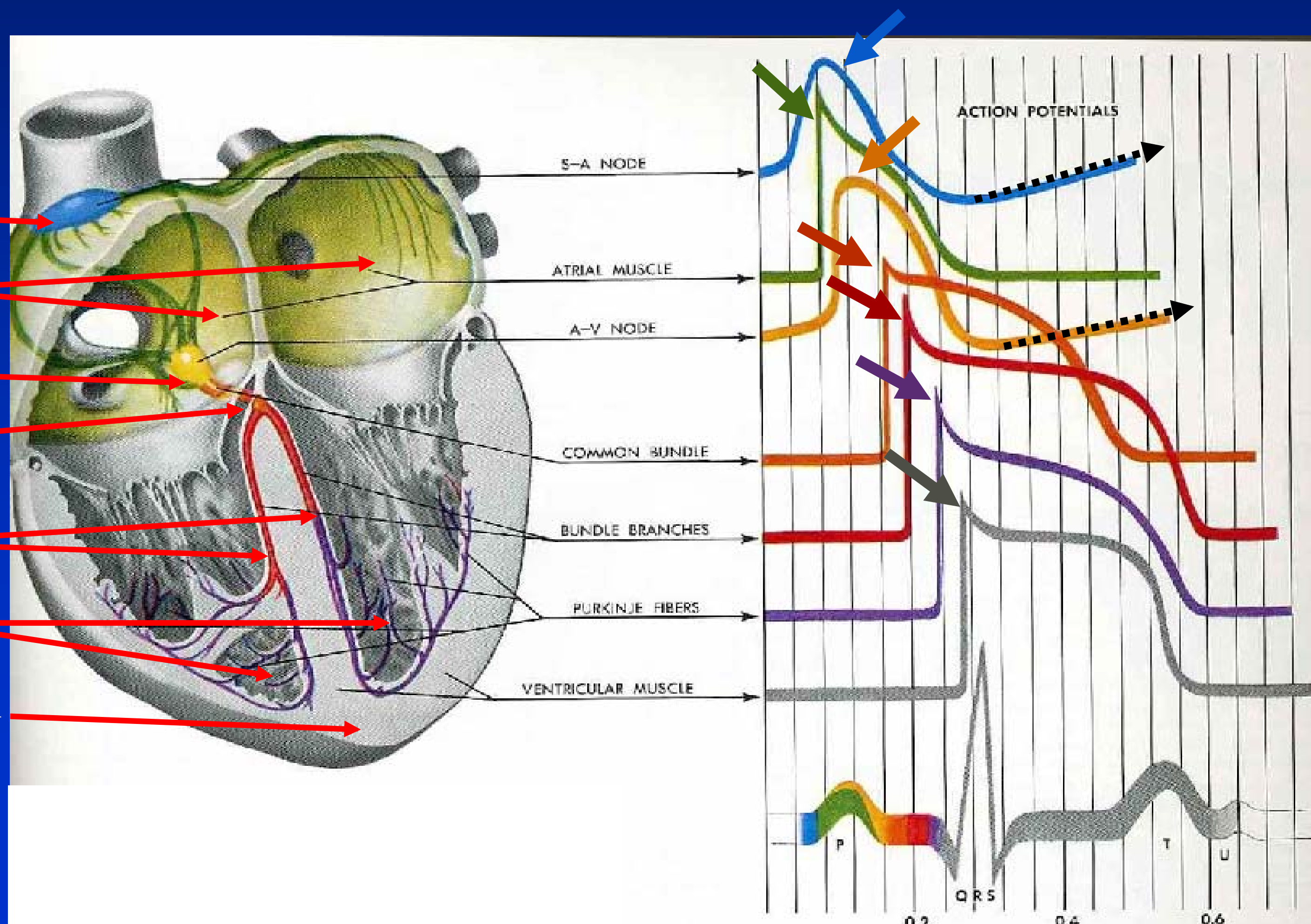


Electrophysiology | Biomechanics

Action potentials in the SA and AV Nodes are small, slowly rising, so they propagate slowly. Action potentials in the atria, AV bundle, bundle branches, His-Purkinje system, and ventricles are large, rapidly rising, so they propagate rapidly.

Structure

SA Node
↓
Atrial Myocardium
↓
AV Node
↓
AV Bundle
↓
Bundle branches
↓
His-Purkinje system
↓
Ventricular Myocardium



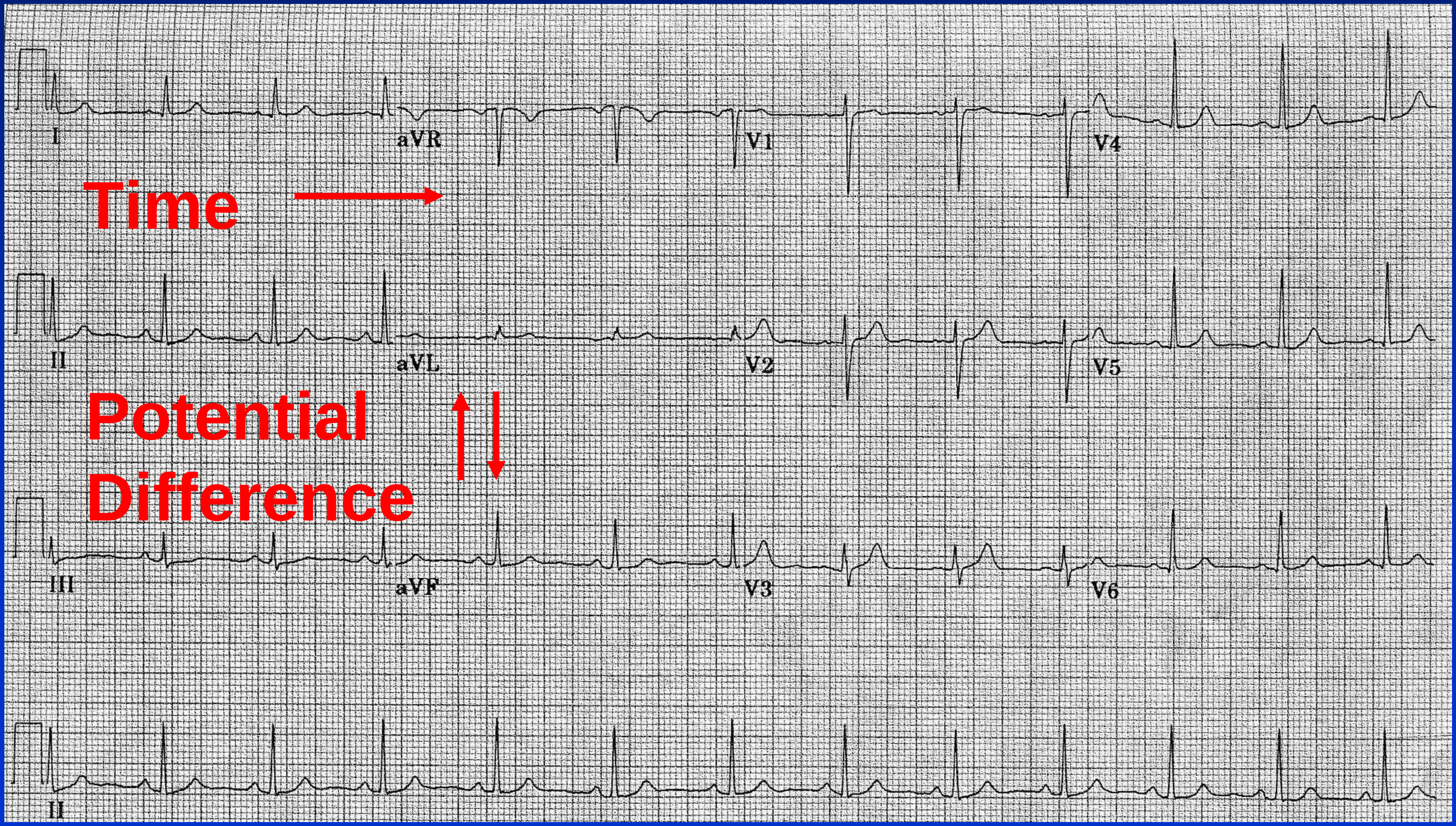
Electrophysiology	**Biomechanics**

Structure	Conduction Velocity	Rate of Pacemaker Firing (/min)
SA Node ↓	Very slow	60-100
Atrial Myocardium ↓	Fast	None
AV Node ↓	Very slow	40-55
AV Bundle ↓	Very fast	25-40
Bundle branches ↓	Very, very fast	25-40
His-Purkinje system ↓	Very, very fast	25-40
Ventricular Myocardium.	Moderate	None

Pacemaker activity is the fastest in the SA Node; slow in the AV Node; and very slow and unreliable in the AV bundle, bundle branches, and His-Purkinje system.

Electrophysiology	Biomechanics

The Electrocardiogram (ECG): A record of potential *differences* generated during depolarization and repolarization of the heart recorded from the body surface.



Electrophysiology | Biomechanics

The resulting tracing of voltage difference at any two sites due to electrical activity of the heart is called a LEAD.

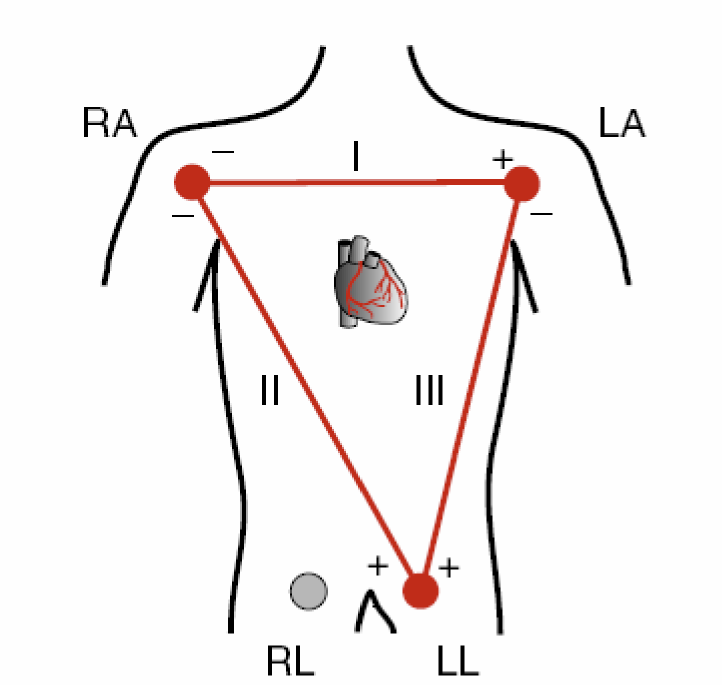
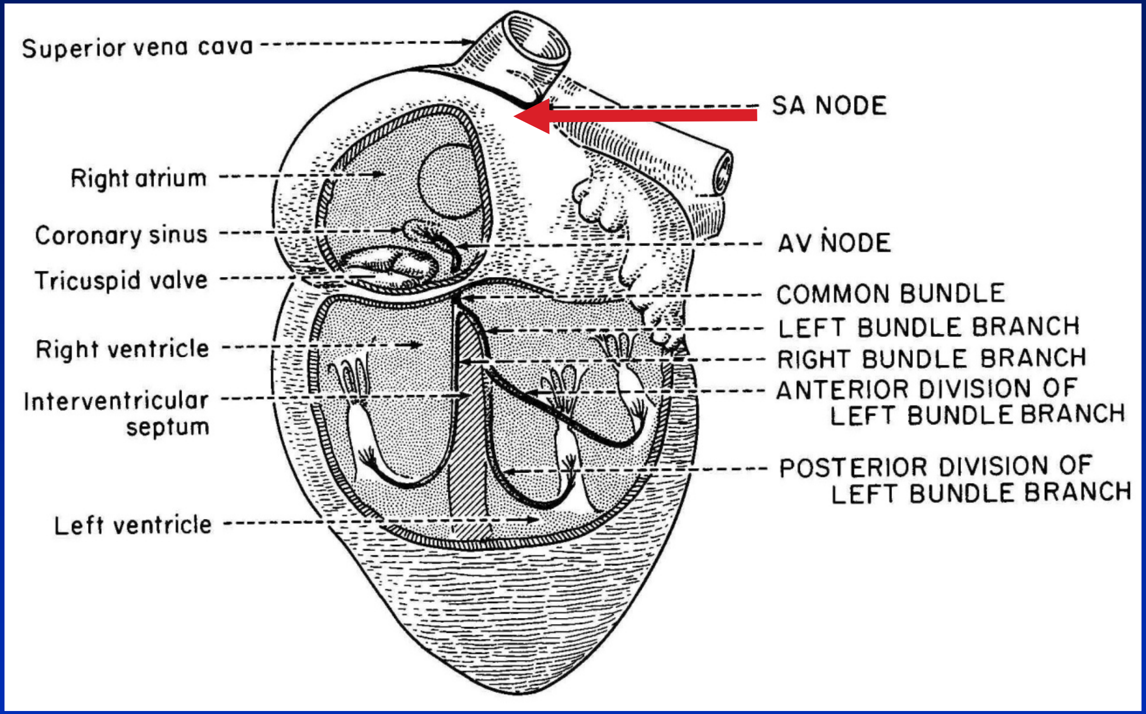


FIGURE 2-18 Placement of the standard ECG limb leads (leads I, II, and III) and the location of the positive and negative recording electrodes for each of the three leads. *RA*, right arm; *LA*, left arm; *RL*, right leg; *LL*, left leg.

Potential difference between right arm and left arm (Lead I)

Einthoven: Nobel Prize

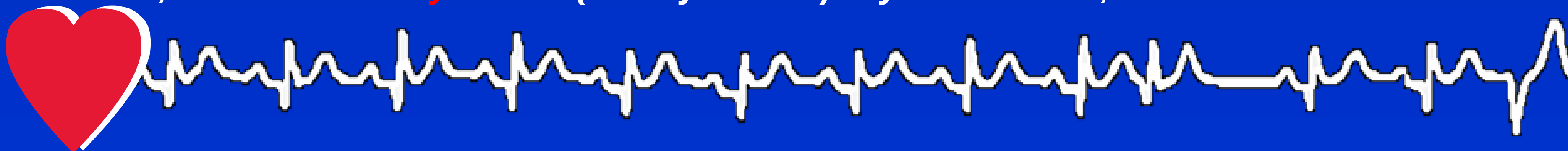
Electrophysiology | Biomechanics

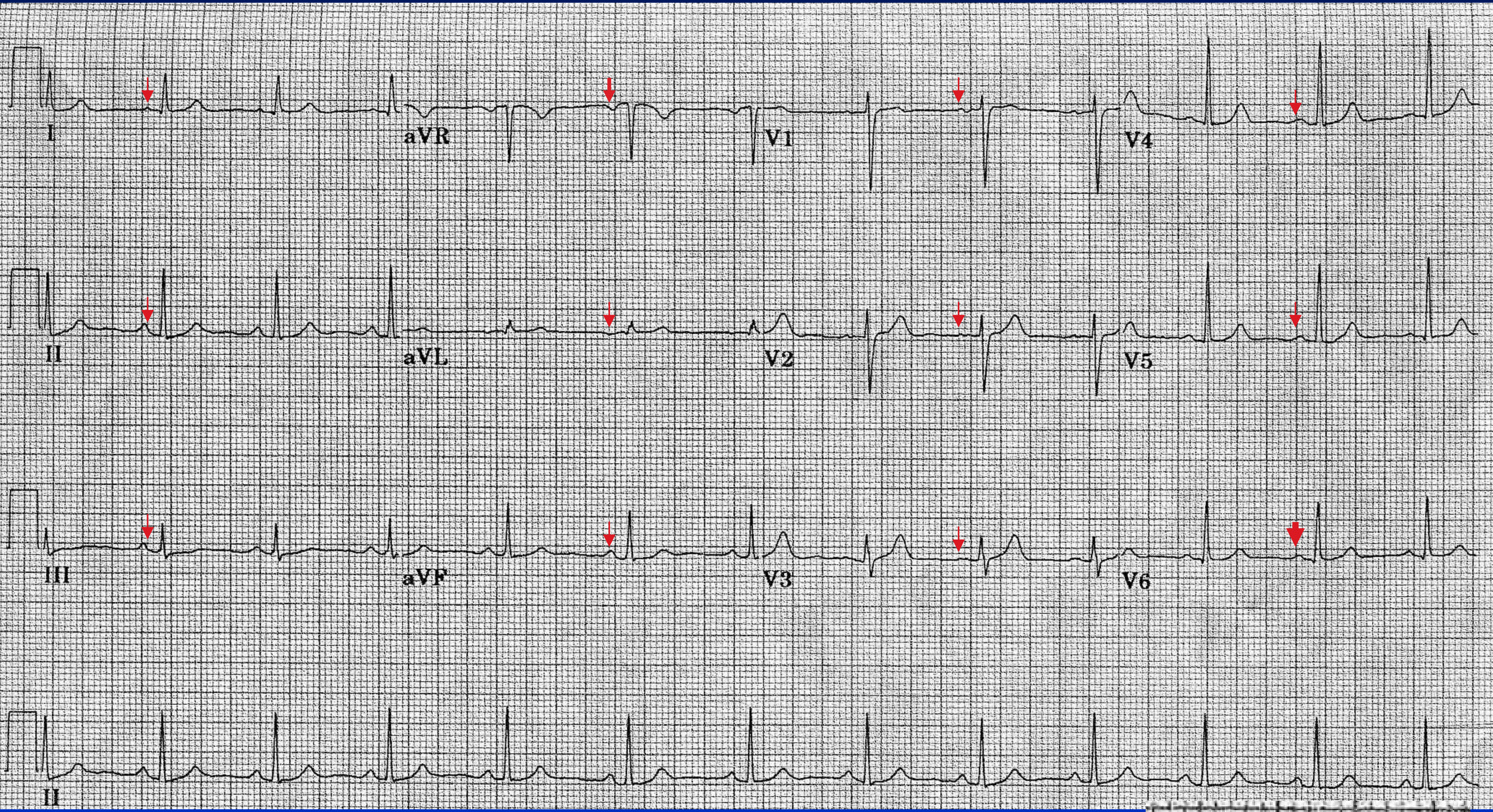


P wave

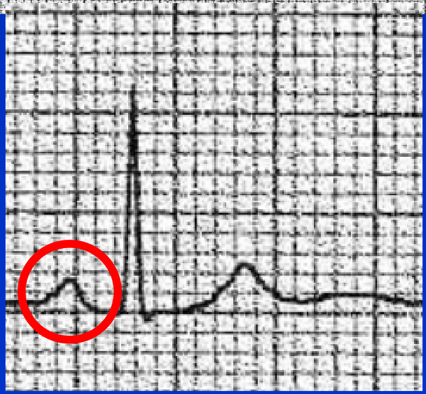
SA Node: Rate of depolarization faster than in any other region of the normal human heart (normally 60-100/min) so that the rate of SA Node depolarization normally determines the heart rate.

If too slow, sinus bradycardia ("brady" = slow). By convention, rate <60/min
If too, fast sinus tachycardia ("tachy" = fast). By convention, rate >100/min

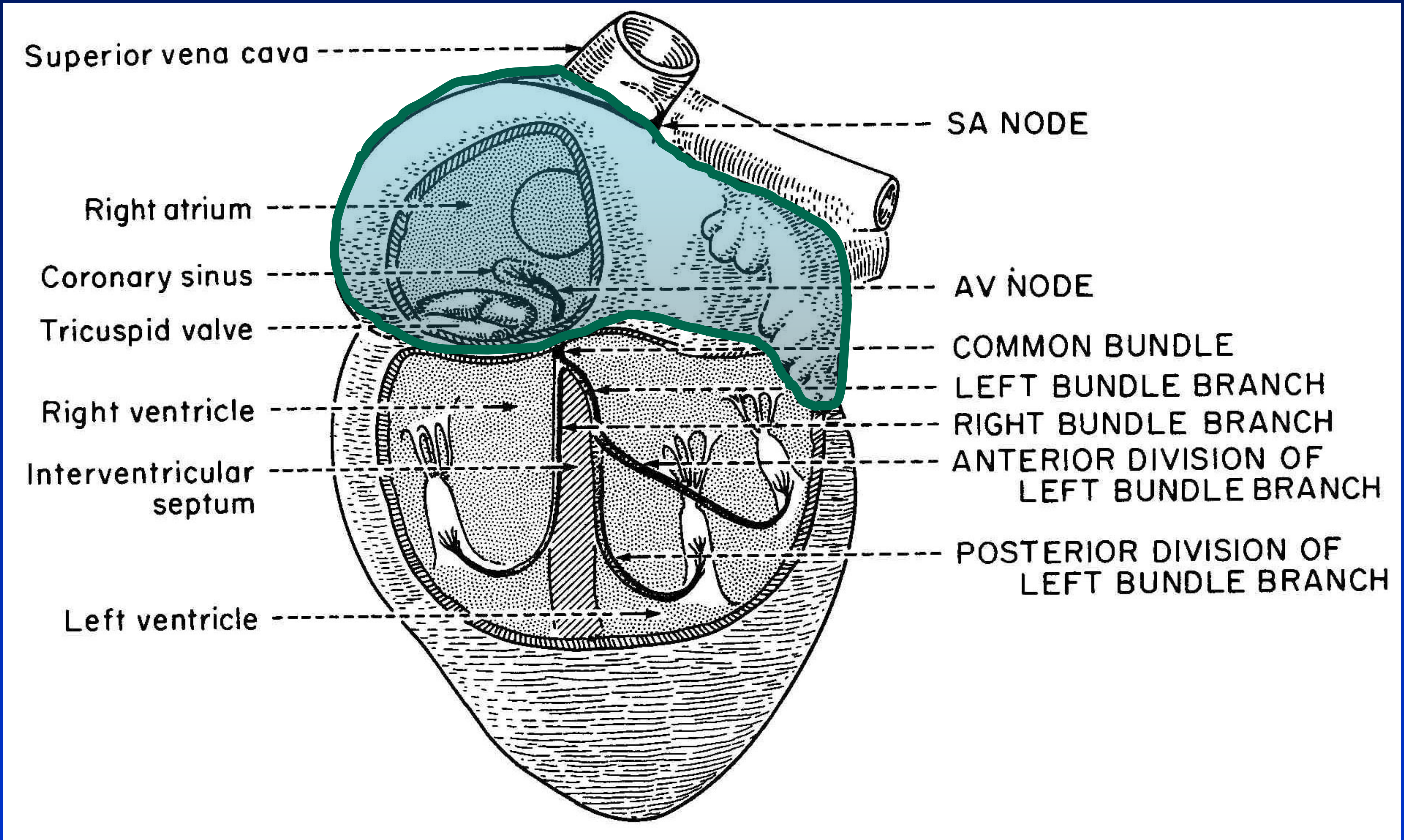




Atrial Depolarization: Gives rise to each P wave, the first electrical event recorded on the ECG.



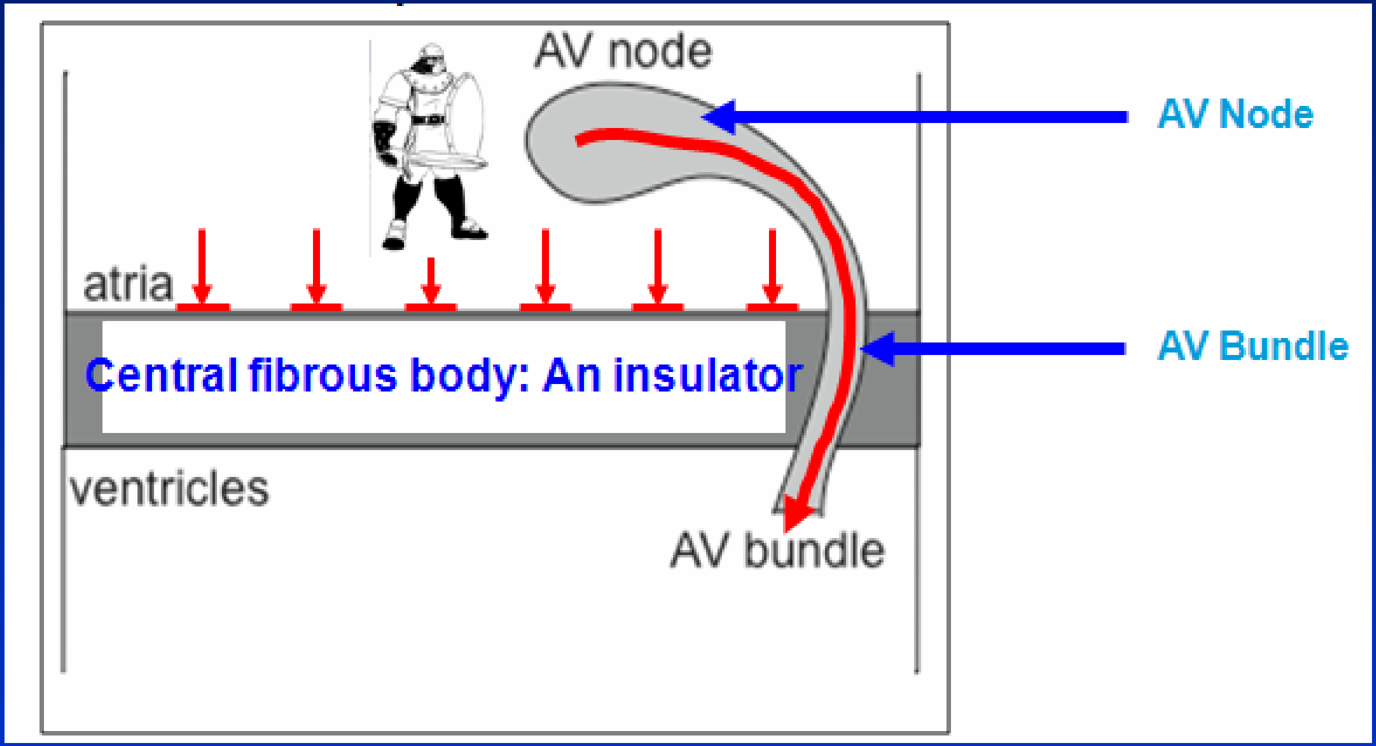
Electrophysiology | Biomechanics



Atrioventricular (AV) Conduction:

Conduction of the wave of depolarization from atria to ventricles.

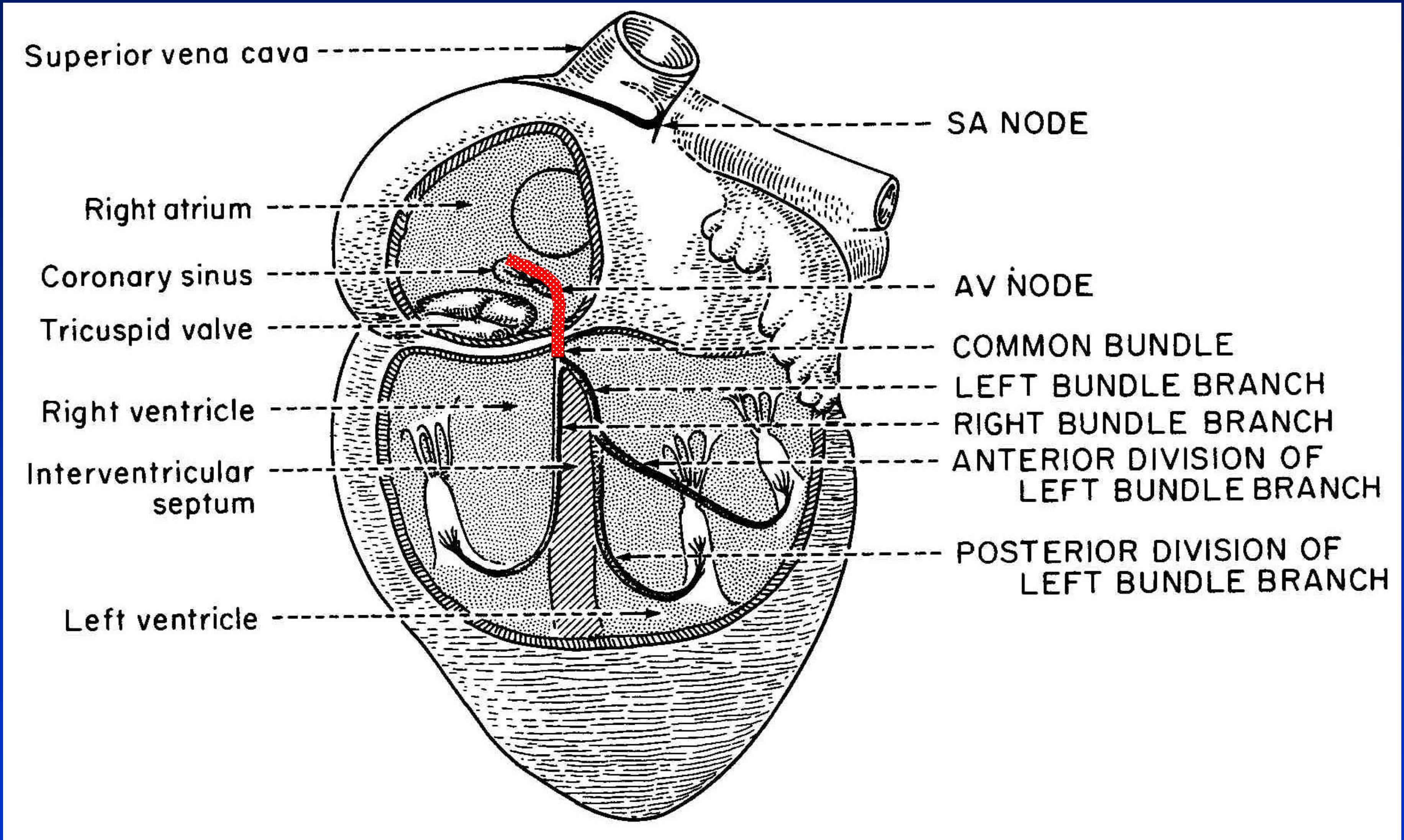
the atria's and ventricles are isolated from each other by a connective tissue structure called the *central fibrous body*.



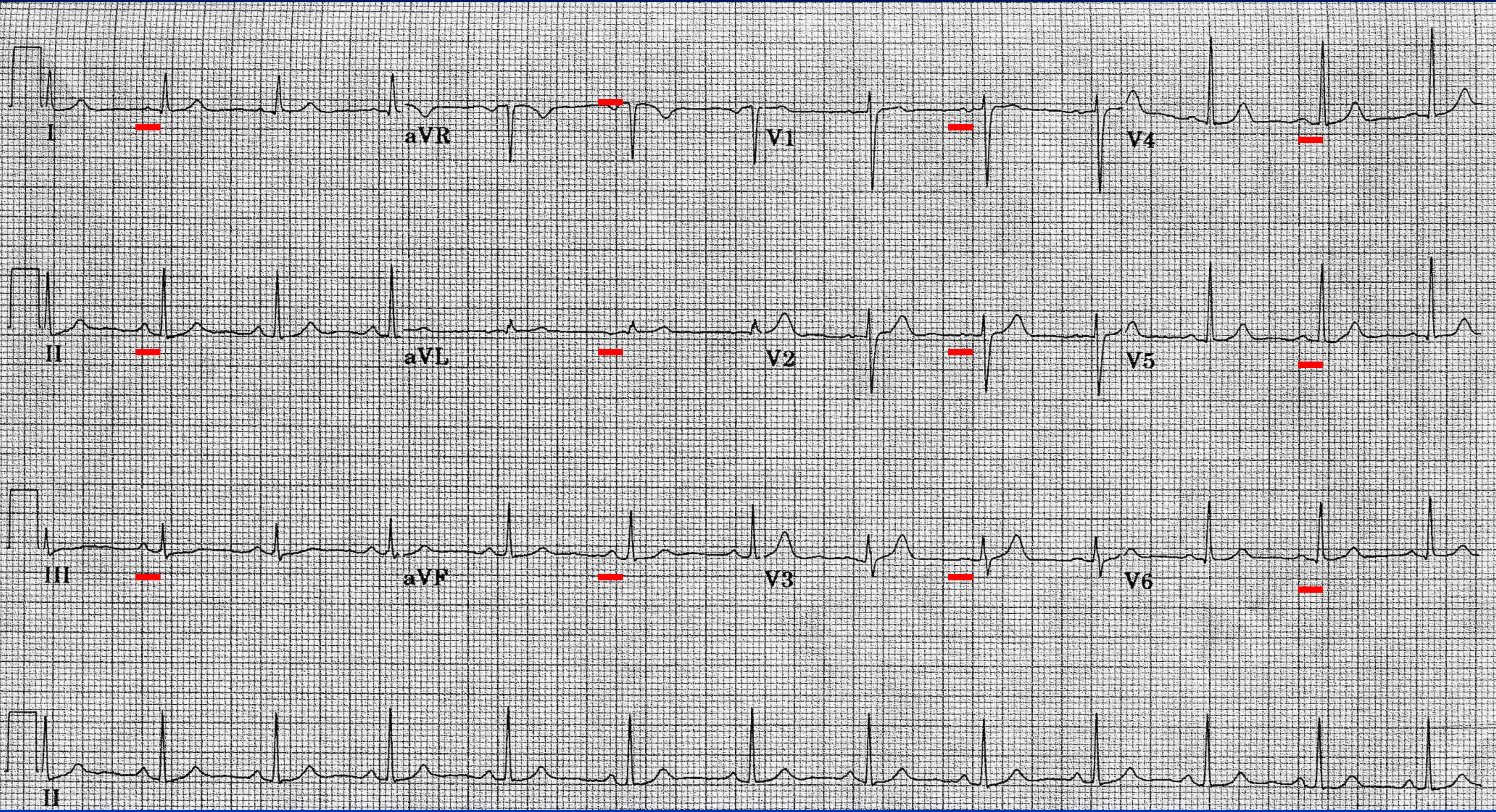
The only structure that normally conducts a wave of depolarization through the central fibrous body is the AV Bundle .

Access to the AV Bundle is controlled by a small structure called the AV (Atrioventricular) Node.

Electrophysiology | Biomechanics

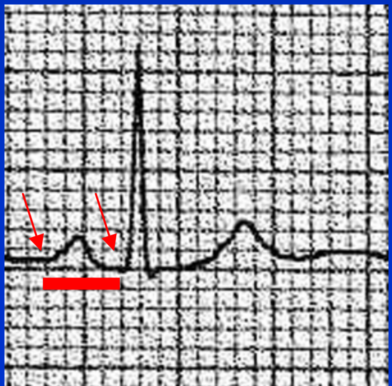


Atrioventricular (AV) Conduction:
Conduction of the wave of depolarization from atria to ventricles.



Atrioventricular (AV) Conduction:
Conduction of the wave of depolarization from atria to ventricles.

This is a slow process, which explains the long interval from the *beginning of the P wave* to the *beginning of the QRS complex*, called the P-R Interval



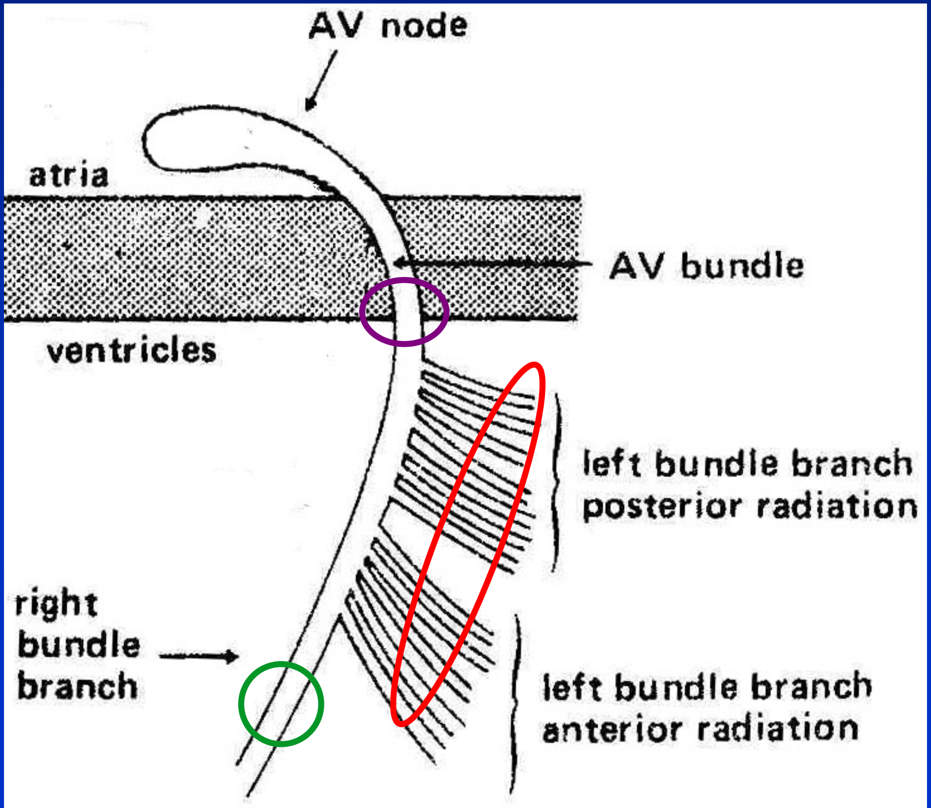
Bundle Branches and His-Purkinje System: Very fast conduction.

Some potential pacemaker activity but intrinsic rates are very slow (25-40/min).

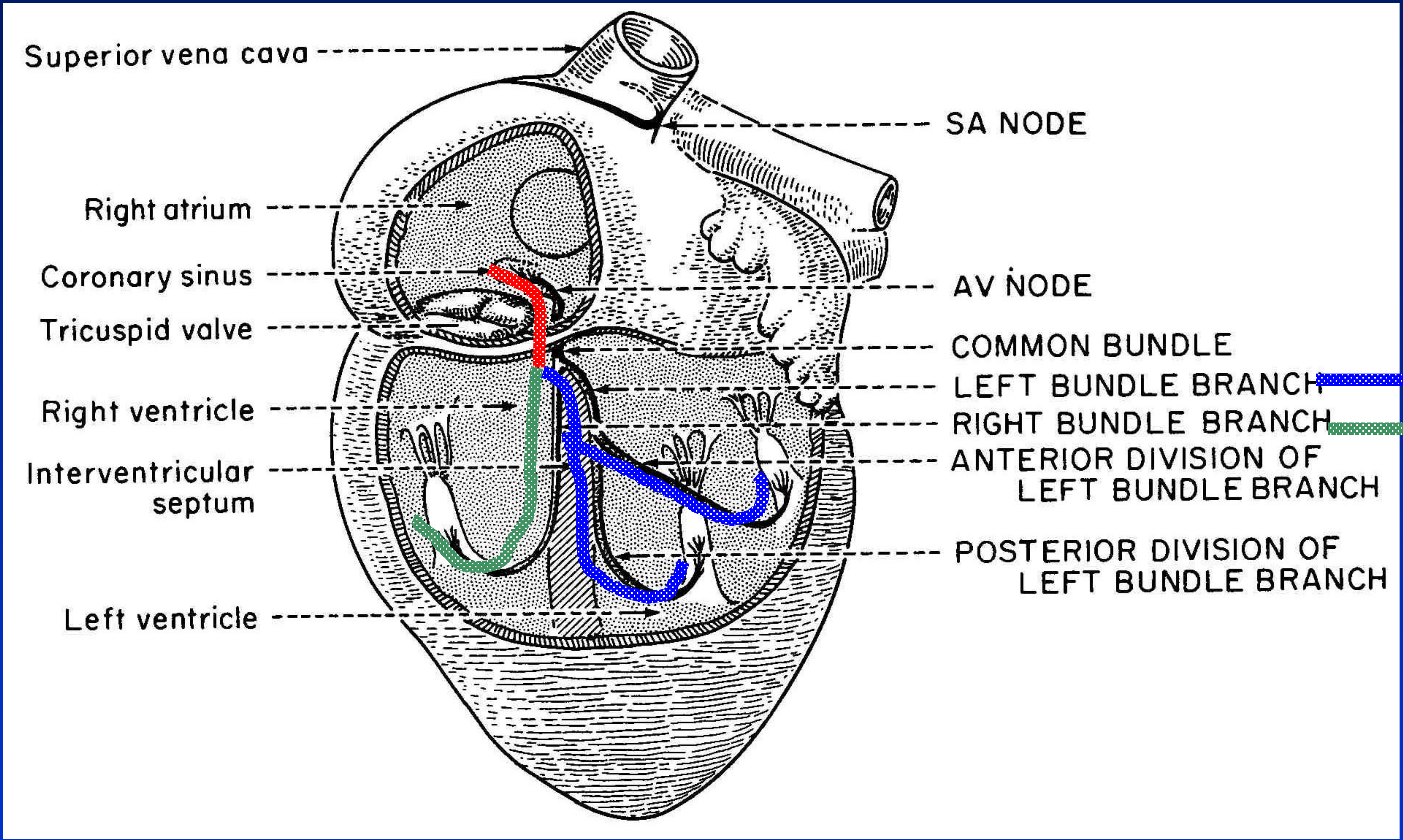
The AV bundle ( ) divides into two branches.

Right bundle branch (RBB) - conducts wave of depolarization into the right ventricle.

Left bundle branch (LBB) - conducts wave of depolarization into the left ventricle.



Electrophysiology | Biomechanics

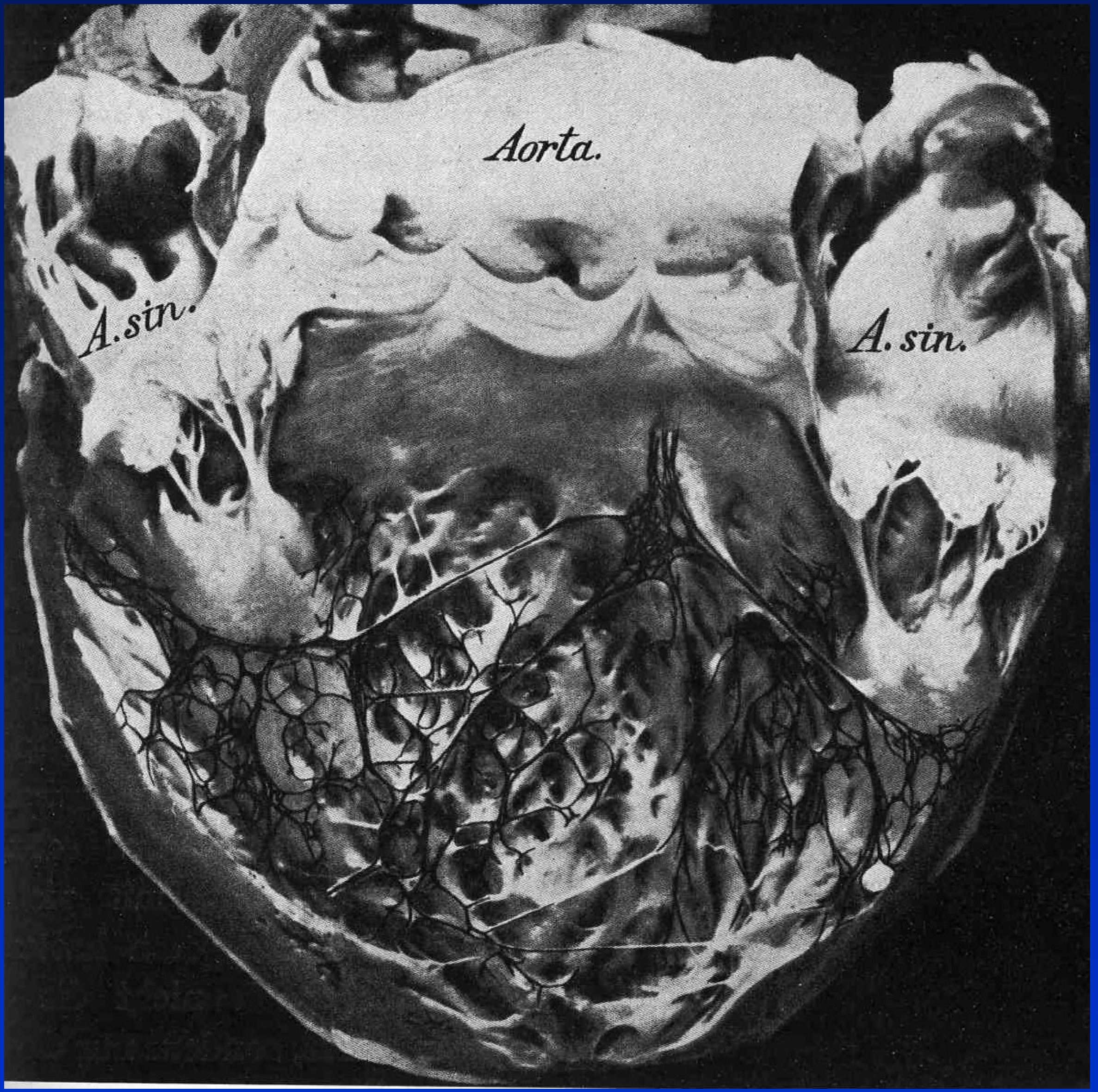


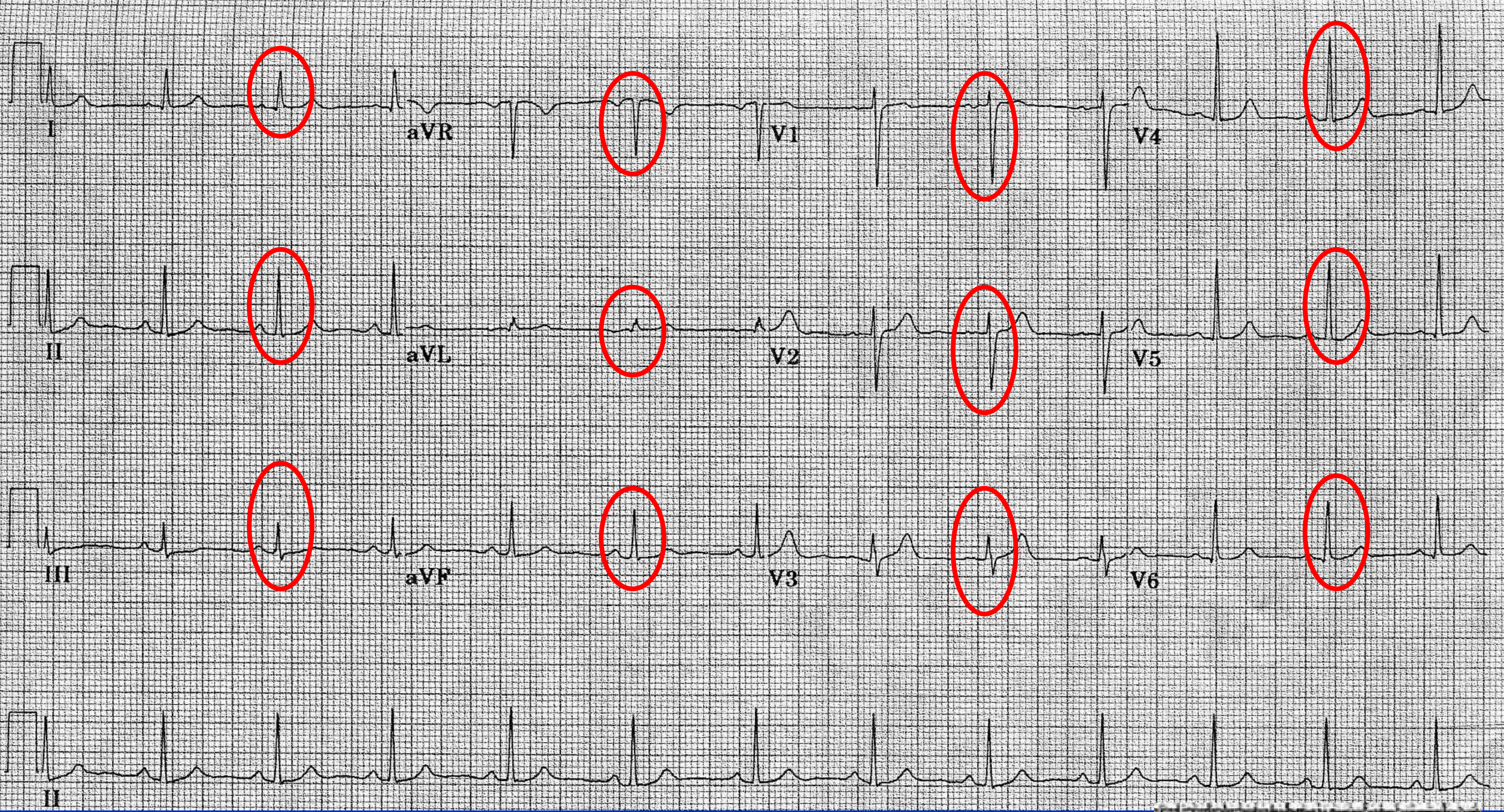
Bundle Branches and His-Purkinje System

The His-Purkinje System

Fast-conducting fibers that run along the surfaces of the ventricles. Some pacemaker activity but slow (intrinsic rates 25-40/min) and unreliable.

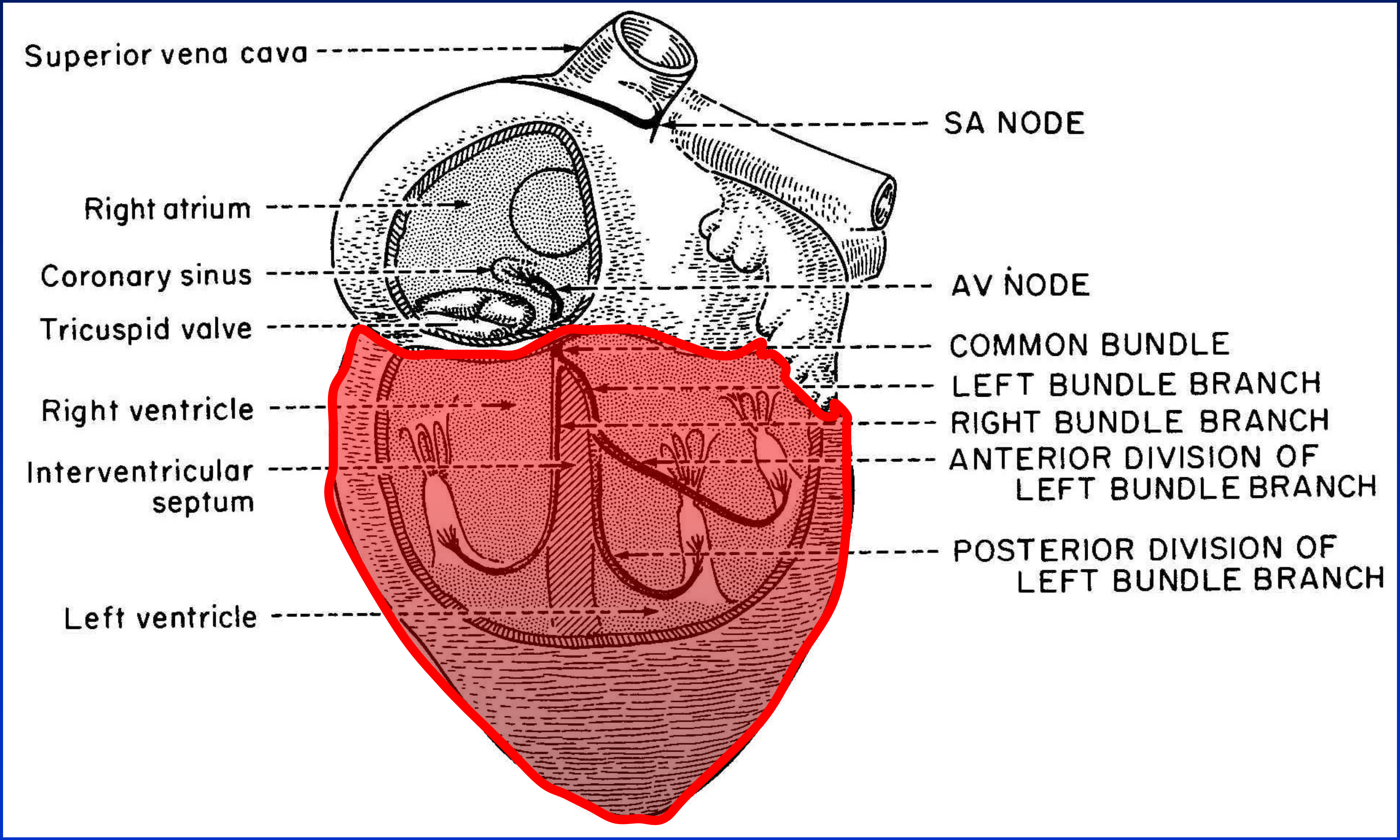
Major function: synchronize ventricular contraction, which minimizes waste of energy that occur if some regions of the ventricle were able to contract while other regions were still relaxed.





Ventricular Depolarization: Gives rise to the QRS Complexes. The high amplitude of the QRS complex reflects the large mass of ventricular myocardium; its brief duration is due to the rapidity of the spread of the wave of depolarization which, because of very rapid impulse conduction by the His-Purkinje system, activates the ventricular mass in a very short time.

Electrophysiology | Biomechanics



Ventricular Depolarization: Gives rise to the **QRS Complexes.**

Electrophysiology	**Biomechanics**

Relationship Between Ventricular Action Potential and the ECG

QRS Complex: Depolarization: Upstrokes (phase 0) of all of the action potentials generated as the wave of depolarization spreads over the ventricles.

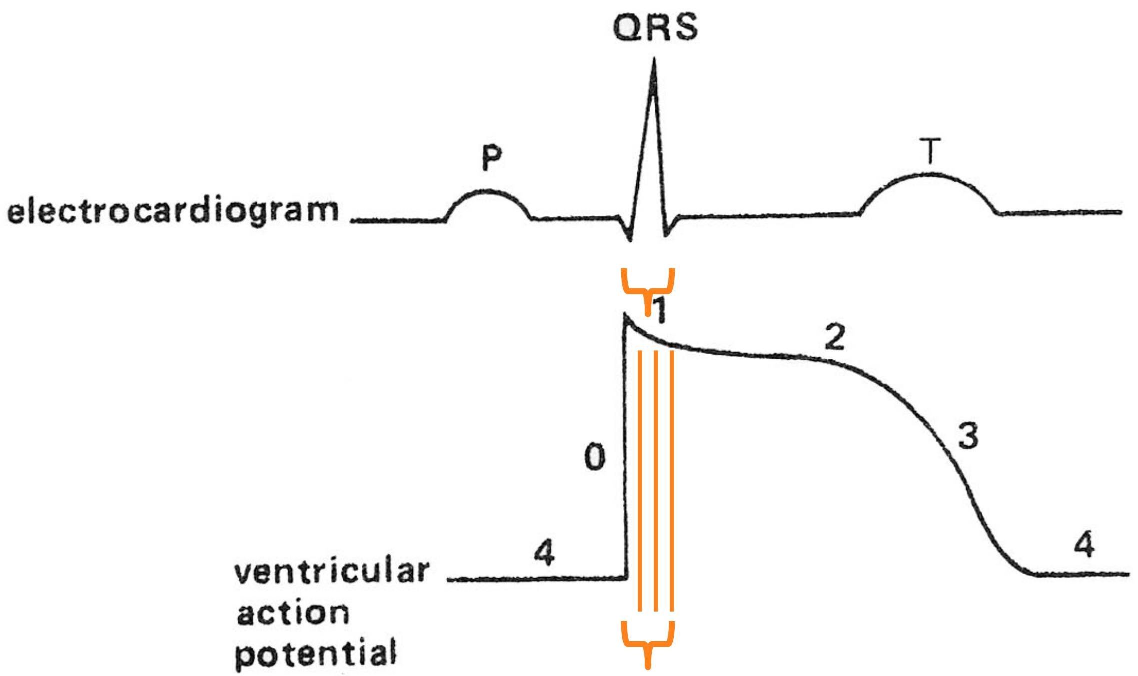
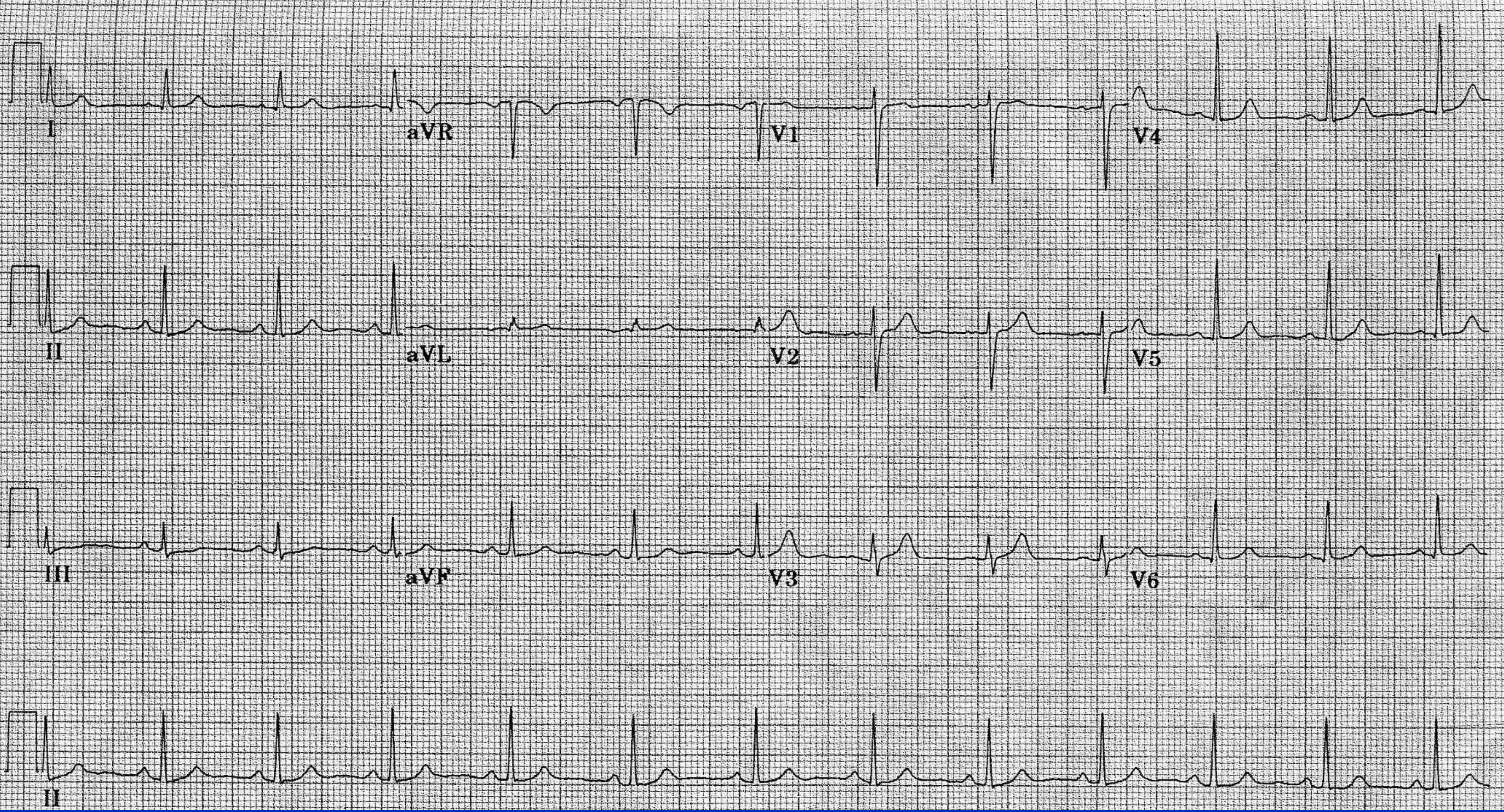
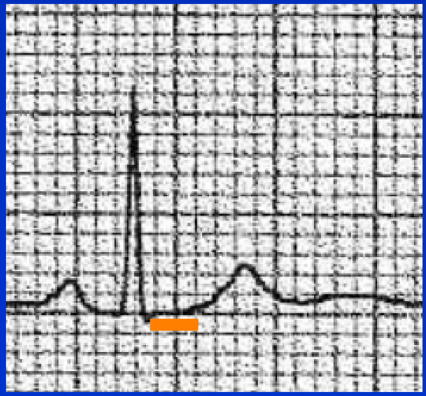
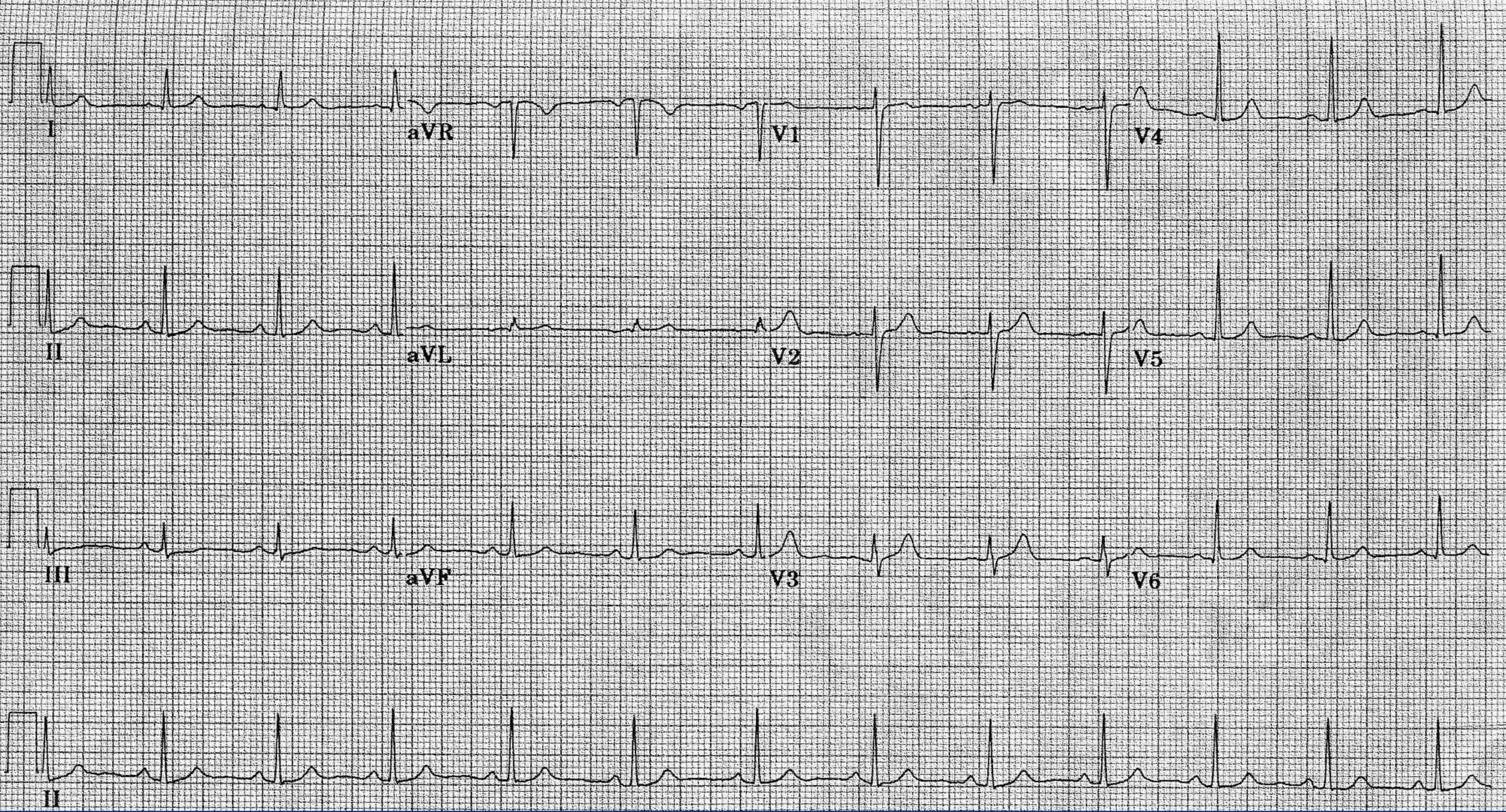


FIG. 20-12. Temporal relationships between the ECG **(top)** and a representative cardiac action potential **(bottom).** The QRS complex is produced by the upstrokes (phase 0) of all of the action potentials in the ventricles; the isoelectric S–T segment corresponds to the plateau (phase 2), and the T wave is inscribed during repolarization (phase 3) of the ventricular mass. The isoelectric segment that follows the T wave, called the T–P segment, is inscribed during ventricular diastole (phase 4).



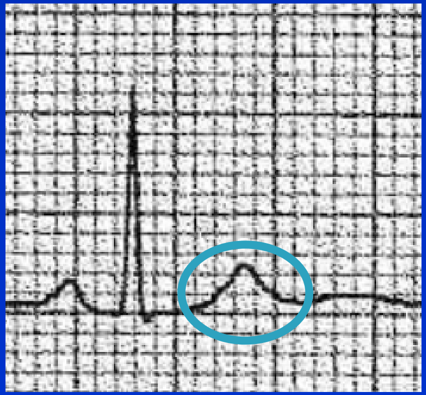
The ST Segment: The segment between the end of the QRS complex and the beginning of the T wave. Occurs when all regions of the ventricles are depolarized, during the plateau of the cardiac action potential.





T waves: Repolarization of the ventricles.

The T waves are smaller, and rise and fall more slowly than the QRS complexes, because repolarization, unlike depolarization, is *not* a rapidly propagated wave.



Electrophysiology | Biomechanics

Relationship Between Ventricular Action Potential and the ECG

T wave: Ventricular repolarization (phase 3)

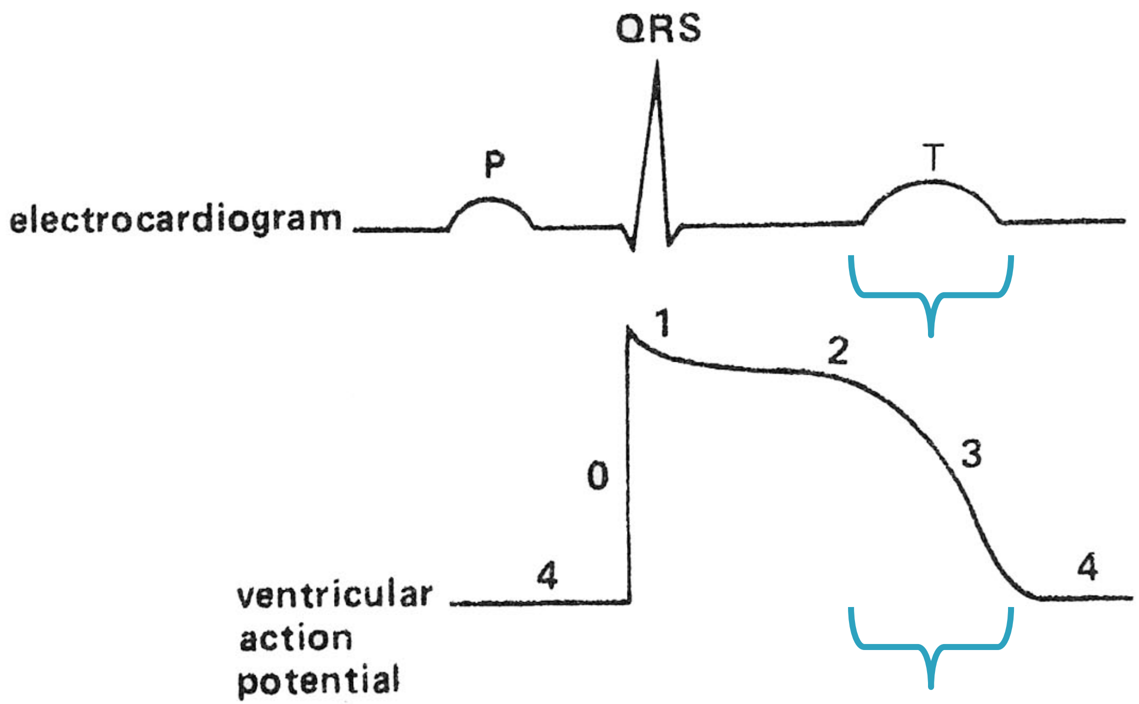


FIG. 20-12. Temporal relationships between the ECG **(top)** and a representative cardiac action potential **(bottom).** The QRS complex is produced by the upstrokes (phase 0) of all of the action potentials in the ventricles; the isoelectric S–T segment corresponds to the plateau (phase 2), and the T wave is inscribed during repolarization (phase 3) of the ventricular mass. The isoelectric segment that follows the T wave, called the T–P segment, is inscribed during ventricular diastole (phase 4).