

# **Chapter 13**

## **Heart physiology**

# Lecture plan

Heart physiology

Blood path

Valves

Cardiac cycle

Heartbeat

EKG

Disease

## Blood path and valves

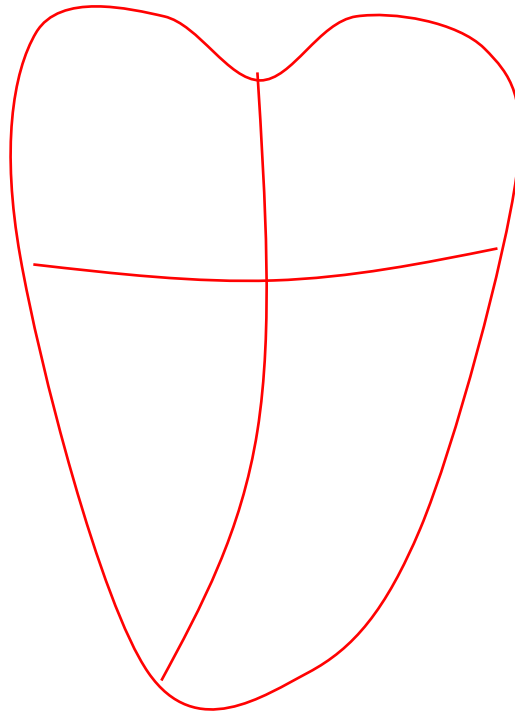
# Heart

R ATRIUM

L ATRIUM

R VENTRICLE

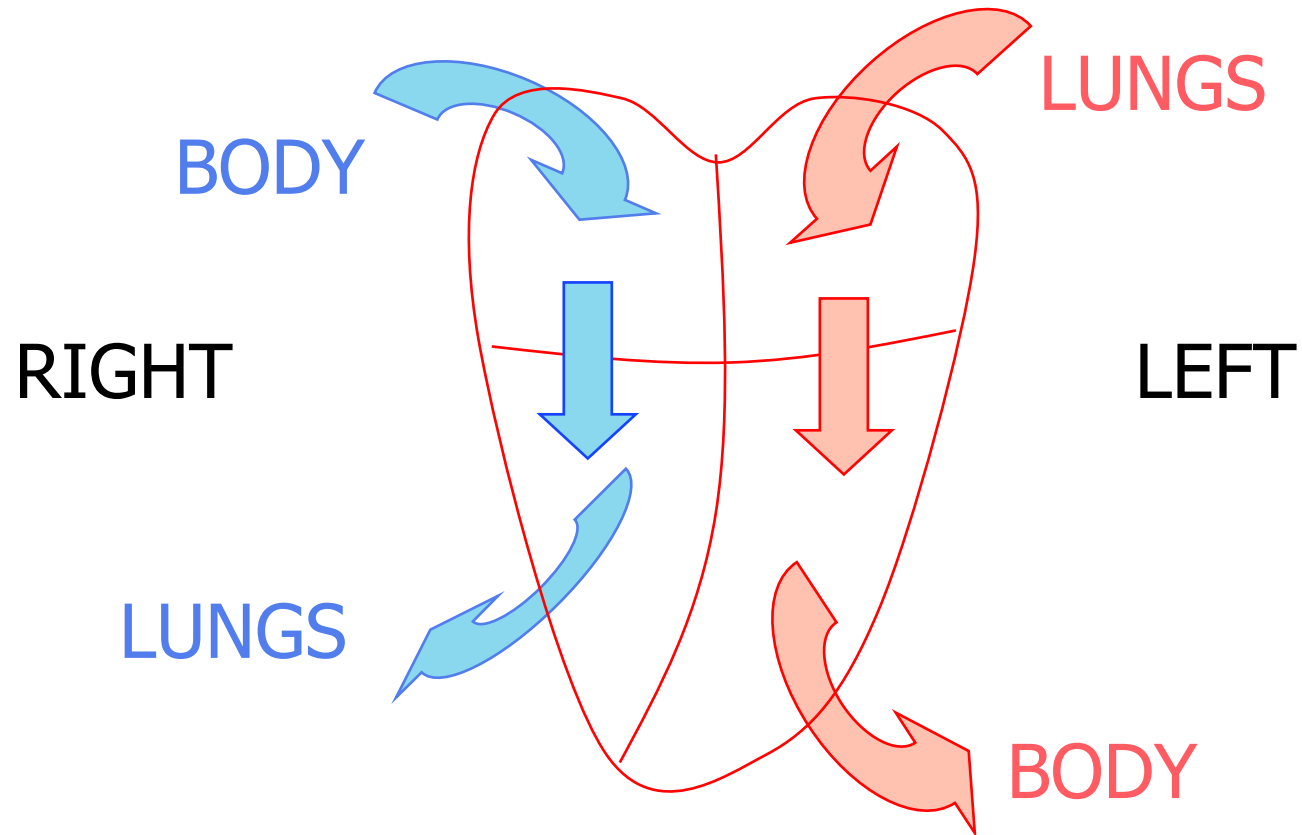
L VENTRICLE



# HEART

Body -> capillaries -> venules -> veins -> superior and inferior vena cava -> R atrium -> R ventricle -> pulmonary trunk -> pulmonary arteries -> lungs -> pulmonary veins -> L atrium -> L ventricle -> aorta -> arteries -> arterioles -> capillaries -> body

# Heart



# Valves

Body -> capillaries -> venules -> veins -> superior and inferior vena cava -> R atrium -> **TRISCUSPID VALVE** -> R ventricle -> pulmonary trunk -> pulmonary arteries -> lungs -> pulmonary veins -> L atrium -> **MITRAL VALVE** -> L ventricle -> aorta -> arteries -> arterioles -> capillaries -> body

# Atrioventricular Valves (AV)

## TRISCUSPID VALVE

**Full atria: open**

**Ventricle contracts: closed**

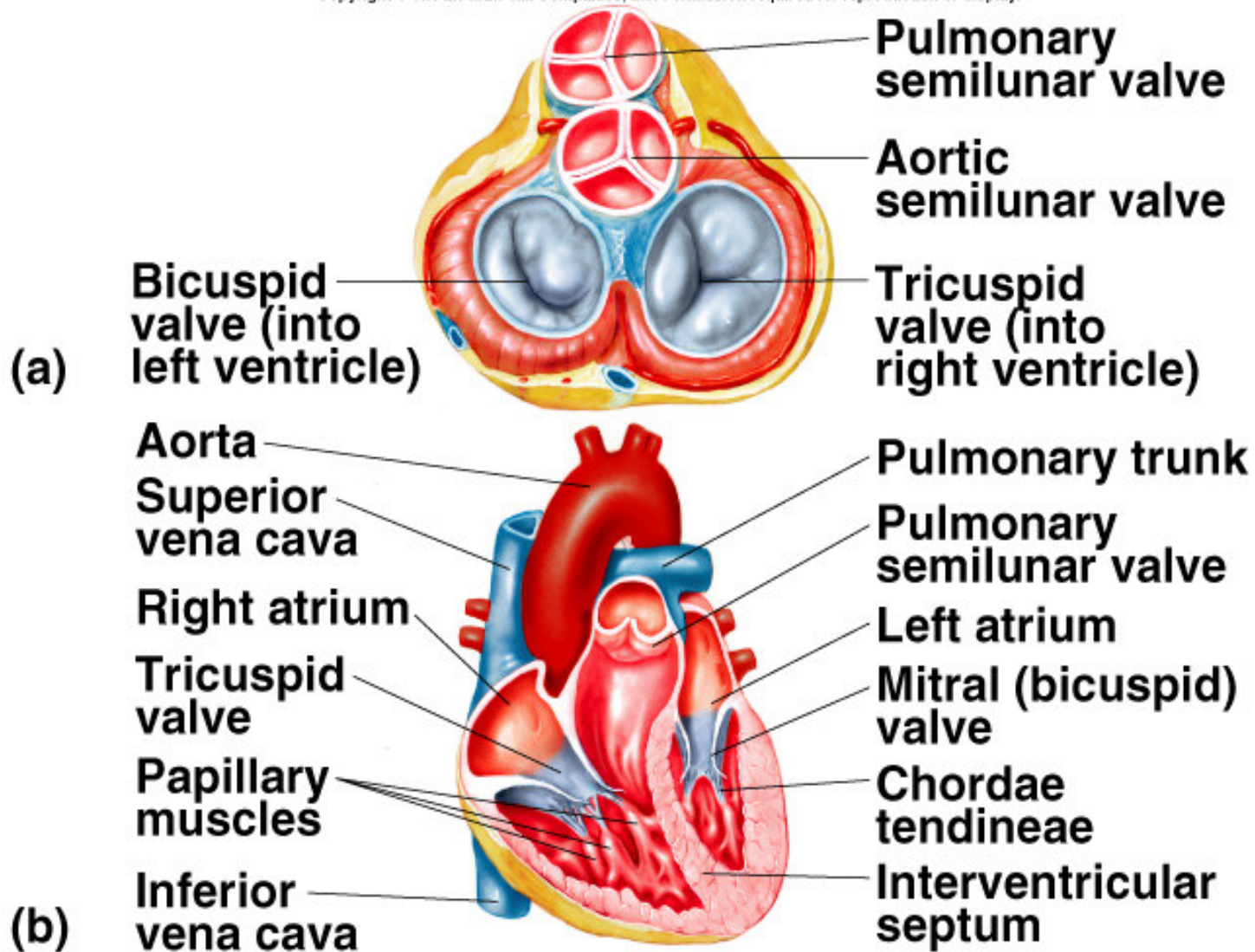
## MITRAL VALVE

**Full atria: open**

**Ventricle contracts: closed**

# Valves

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



# Valves

Body -> capillaries -> venules -> veins -  
> superior and inferior vena cava -> R  
atrium -> **TRISCUSPID VALVE** -> R  
ventricle -> **SEMILUNAR VALVES** ->  
pulmonary trunk -> pulmonary arteries -  
> lungs -> pulmonary veins -> L atrium  
-> **MITRAL VALVE** -> L ventricle ->  
**SEMILUNAR VALVES** -> aorta ->  
arteries -> arterioles -> capillaries ->  
body

# Valves

## SEMILUNAR VALVES

**Ventricle contracts: open**

**Ventricle relaxes: closed**

Cardiac cycle

# Cardiac Cycle

**Systole:** contraction.

**Diastole:** relaxation.

# Heart Sounds

Lub (first sound):

closing of the AV valves  
contraction of ventricles.  
systole

Dub (second sound):

closing of the semilunar valves  
ventricles relax  
diastole

# Heart Murmurs

## Heart murmurs:

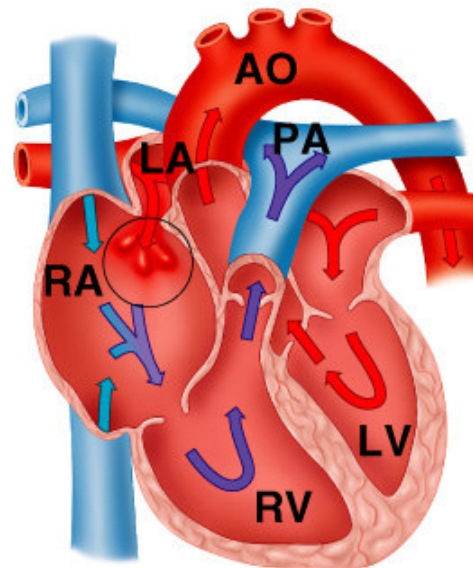
- abnormal heart sounds produced by abnormal patterns of blood flow.
- often due to defective heart valves
  - damaged by an infection, or congenital defects.

# Heart Murmurs

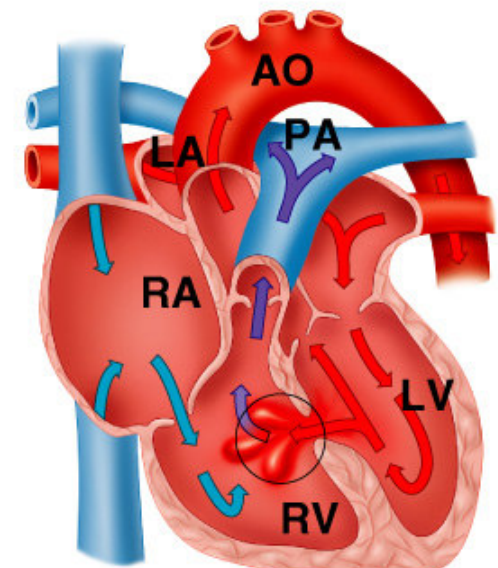
## Septal defects

Usually congenital.  
Holes in septum.  
Blood passes from  
left to right.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



Septal defect  
in atria



Septal defect  
in ventricles

Heartbeat

# Heart

## SA node:

Sinoatrial node

Top of R atrium

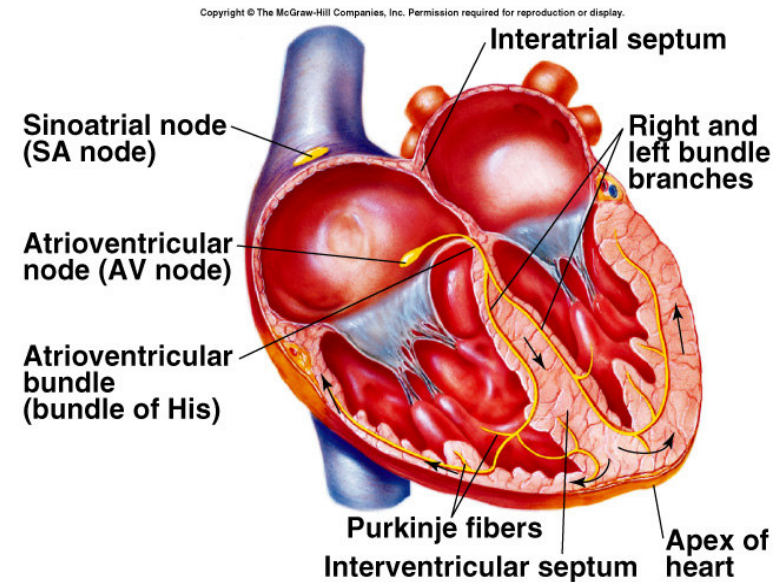
pacemaker

Spontaneous, cyclic depolarization

Slow  $\text{Ca}^{2+}$  channels.

No RMP

Ectopic pacemakers (around SA node).



# SA node AP

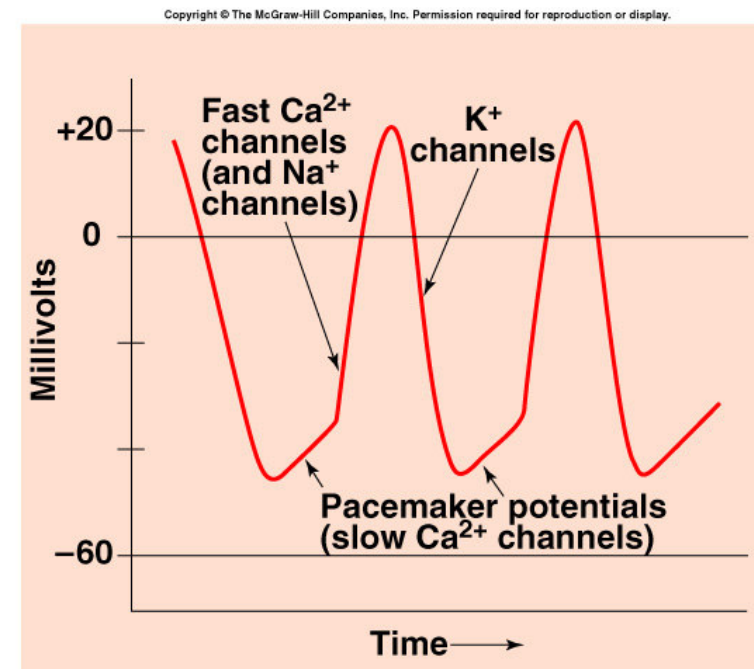
Unique, rhythmic action potentials (AP) at the SA node.

Depolarization:

VG fast  $\text{Ca}^{2+}$  channels

Repolarization:

VG  $\text{K}^+$  channels.



# Myocardial APs

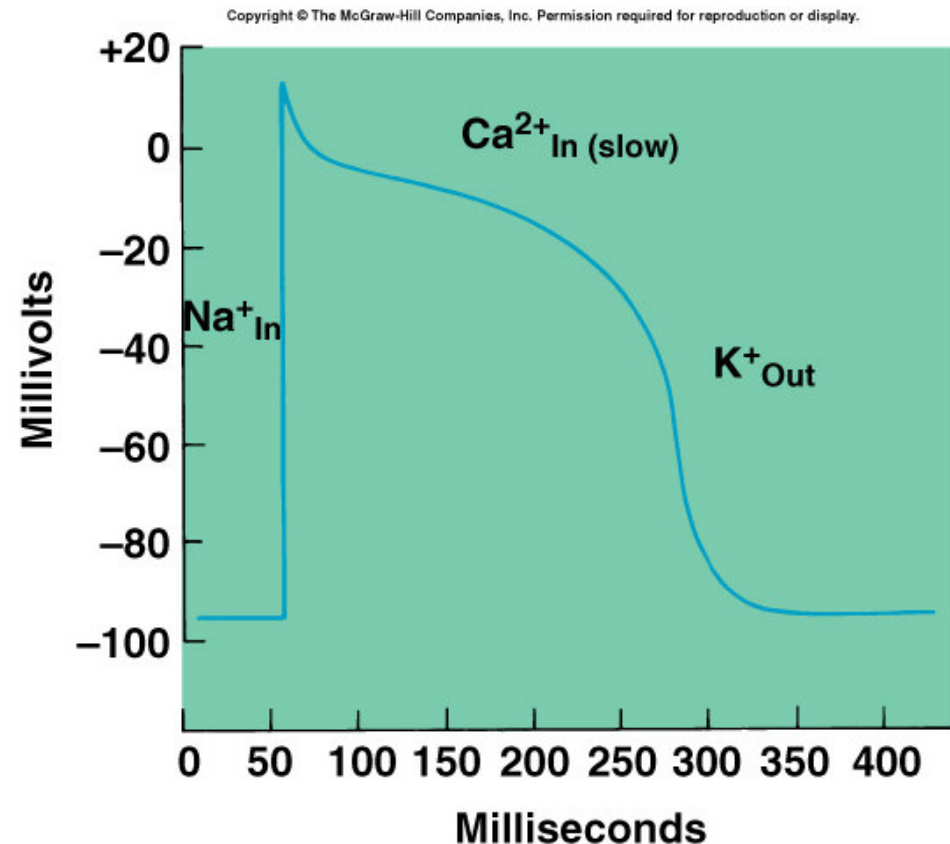
SA node spreads APs to myocardial cells.

Depolarization: VG  $\text{Na}^+$  channels

Plateau phase: VG slow  $\text{Ca}^{2+}$  channels open.

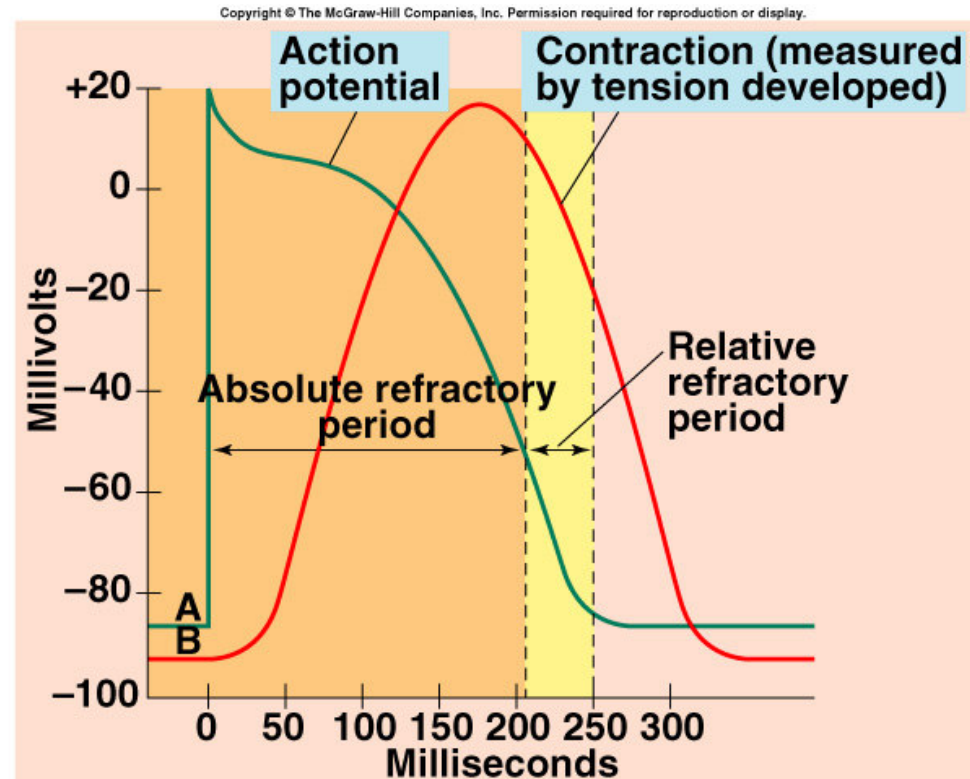
Slow inward  $\text{Ca}^{2+}$  balances outflow of  $\text{K}^+$ .

Repolarization: VG  $\text{K}^+$  channels.



# Myocardial APs

Long AP due to plateau phase leads to refractory period and periodic beating of heart!

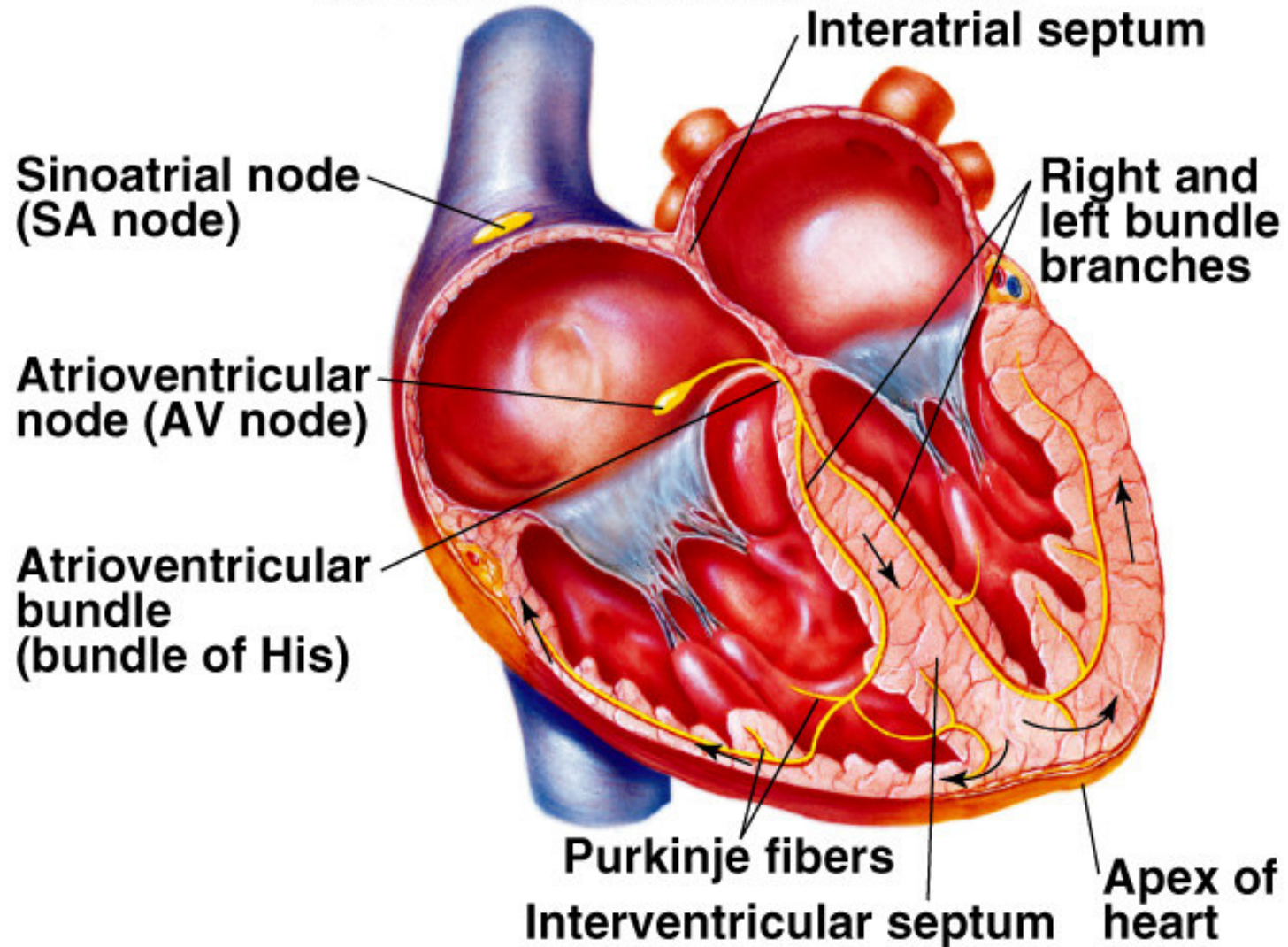


# Heart

- APs spread from cell to cell through through gap junctions (intercalated discs).
- myocardial cells contract as syncytium (one giant, multinucleate cell).
- contraction lasts almost 300 msec.
- Lifelong periodic beating!

# Heart

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



# Contraction

- SA directly causes atria to contract but...
- Impulses cannot spread to ventricles directly because of fibrous tissue.
- Special myocardial cells (AV node, bundle of His) and Purkinje fibers cause both ventricles to contract simultaneously (but slightly after atrial contraction).

# Contraction

Striated muscle!

Contraction

- similar to skeletal muscle
- except that calcium comes from internal stores
  
- sarcomeres, with actin filaments sliding over myosin filaments
- calcium releases troponin/tropomyosin block

# Contraction

$\text{Ca}^{2+}$  stimulated  $\text{Ca}^{2+}$  release (Crac!)

VG  $\text{Ca}^{2+}$  channels in sarcolemma lead to opening of  $\text{Ca}^{2+}$ -release channels in sarcoplasmic reticulum.

$\text{Ca}^{2+}$  binds to troponin and stimulates contraction of sarcomeres (as in skeletal muscle).

During repolarization  $\text{Ca}^{2+}$  actively transported via a  $\text{Na}^{+}$ - $\text{Ca}^{2+}$  exchanger.

A thick orange rectangular border is centered on the page, enclosing the text 'EKG'.

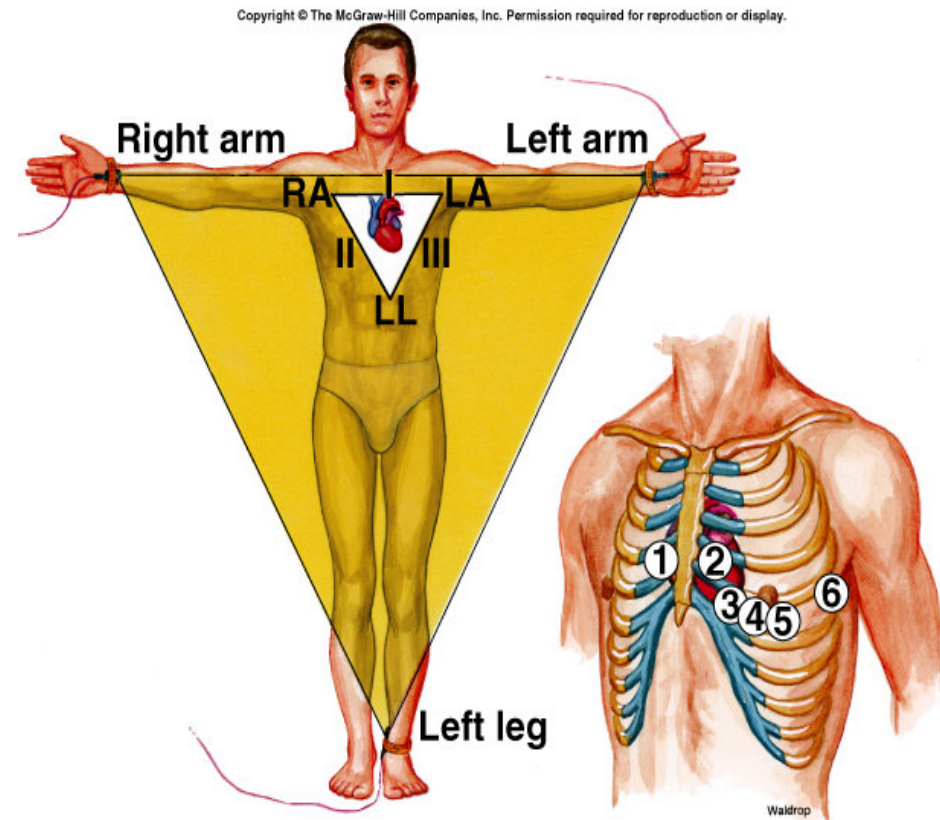
EKG

# Electrocardiogram (ECG/EKG)

Note: Tissue fluids conduct electricity.

## EKG:

Measure of the electrical activity of the heart.



# ECG

## P wave:

Atrial depolarization,  
contraction.

## QRS complex:

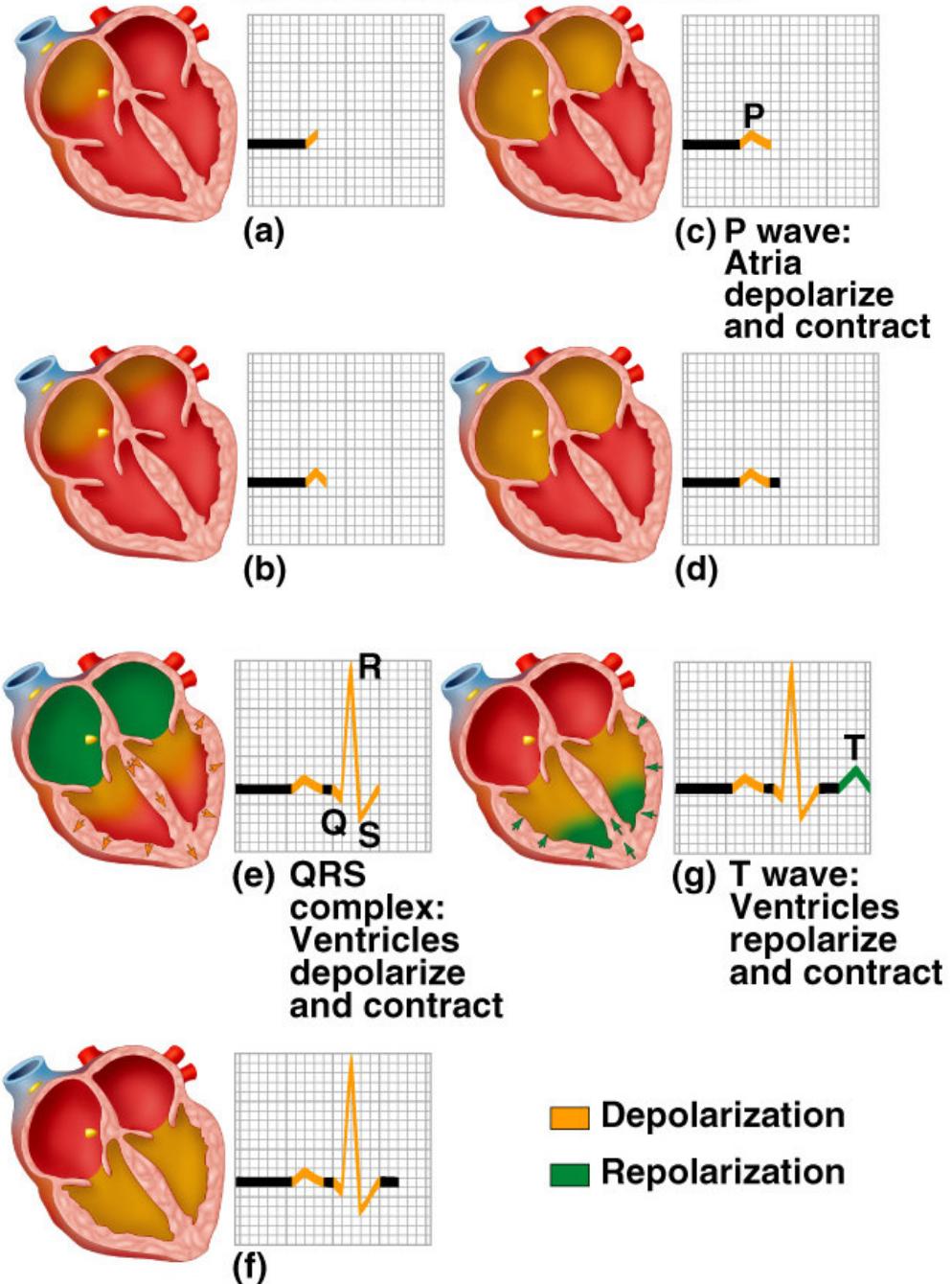
Ventricular  
depolarization,  
contraction

Atrial repolarization.

## T wave:

Ventricular  
repolarization.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



# Summary

## Systole

Lub (AV closes)

~ QRS to T

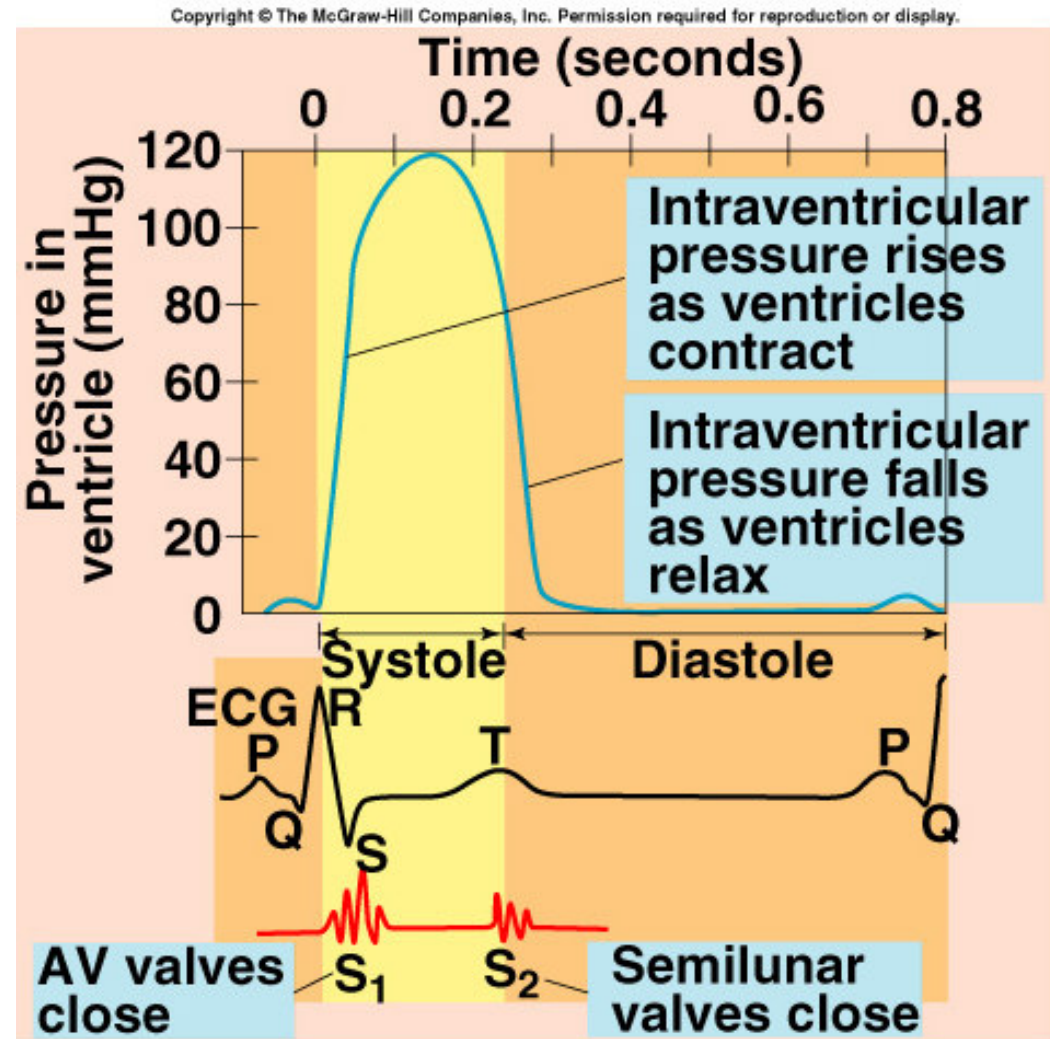
Ventricles contract

## Diastole

Dub (semilunar close)

T to ~ QRS

Ventricles relax

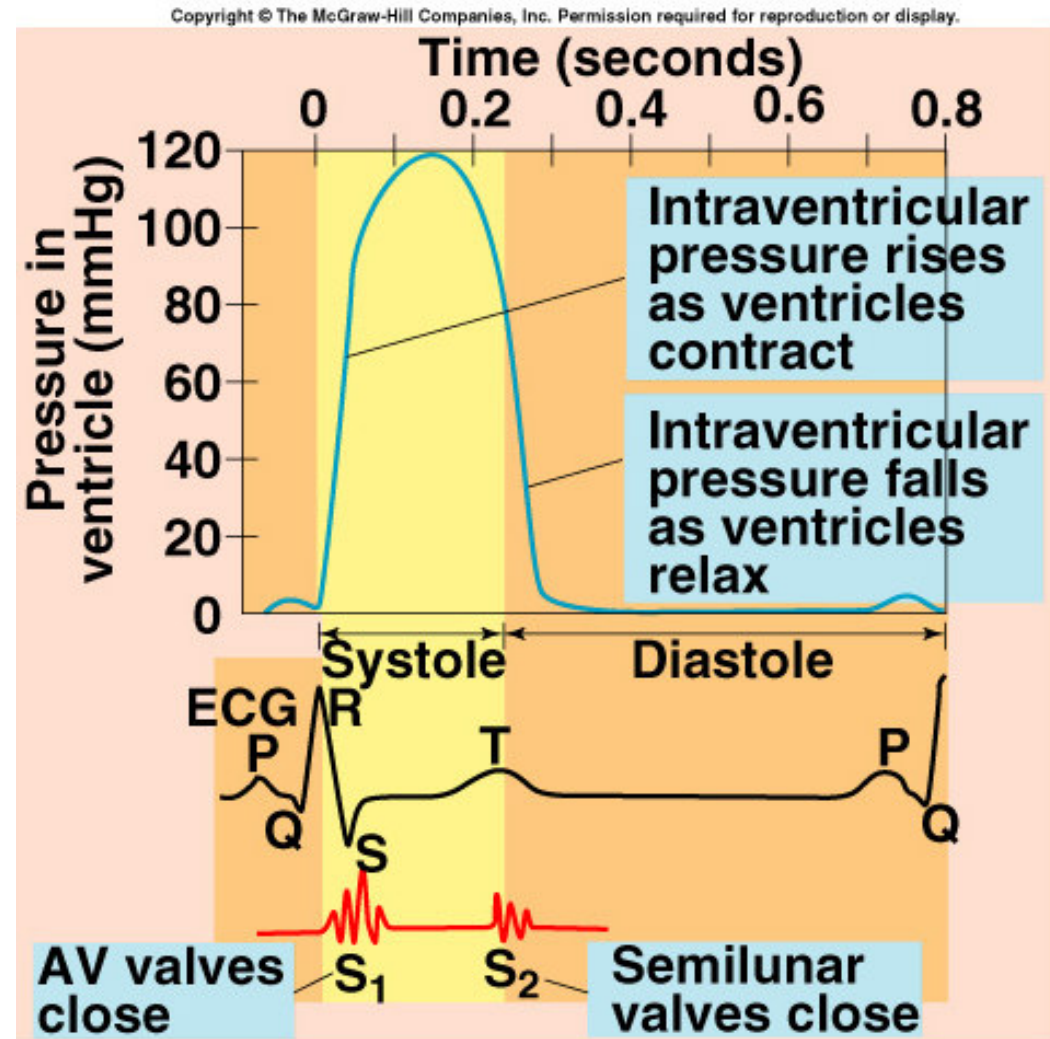


# Note

Heart contracting:  
P-T (300 ms)

Heart not  
contracting:  
T-P

- can change



Heart disease

# Heart Disease

Arrhythmias = abnormal heart rhythms.

Bradycardia = slower

Tachycardia = faster (exercise!)

Flutter: extremely rapid

Fibrillation:

Contractions of different groups of myocardial cells at different times.

Ventricular fibrillation is life-threatening.

Copyright © The McGraw-Hill Companies, Inc. Permission required for reproduction or display.



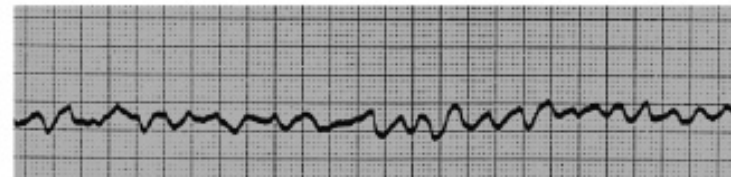
**Sinus bradycardia**



**(a) Sinus tachycardia**



**Ventricular tachycardia**



**(b) Ventricular fibrillation**

# Heart Disease solutions

Electrical defibrillation: depolarize all myocardial cells (stops them!) so they start up in sync again.

Amazing devices:

Artificial pacemakers (always set the pace)

ICD (Implantable cardioverter devices)

- monitor and record heartbeat
- administer electrical defibrillation if needed
- size of a pack of cards, 1 hour surgery
- portable paramedics!

Nutrition, exercise, no smoking!