Essentials of Human Anatomy & Physiology

Seventh Edition

Elaine N. Marieb

Adapted by H. Goon, North HS, Phoenix, AZ

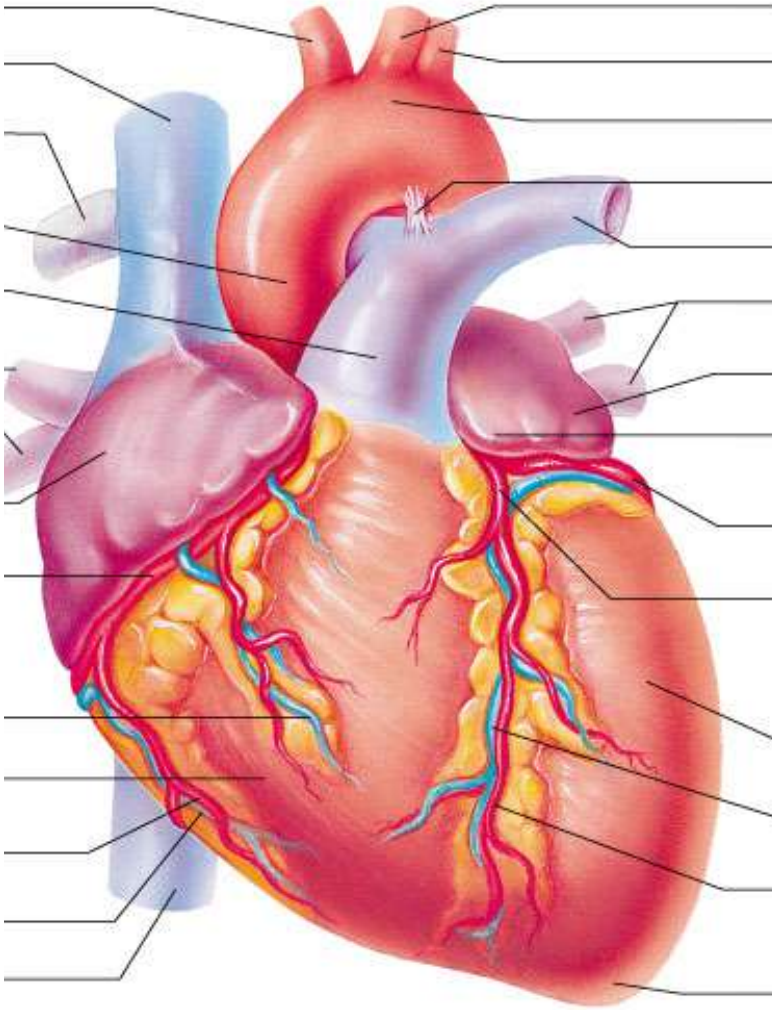
The Cardiovascular System

(Chapter 15)

Overview of the Cardiovascular System

- The cardiovascular system is a closed system of the heart and blood vessels
  - the heart pumps blood into blood vessels
  - blood vessels circulate the blood to all parts of the body, to ALL cells
- Functions: to deliver oxygen and nutrients to all body cells, transport enzymes and hormones, and to remove carbon dioxide and other waste products from the cells

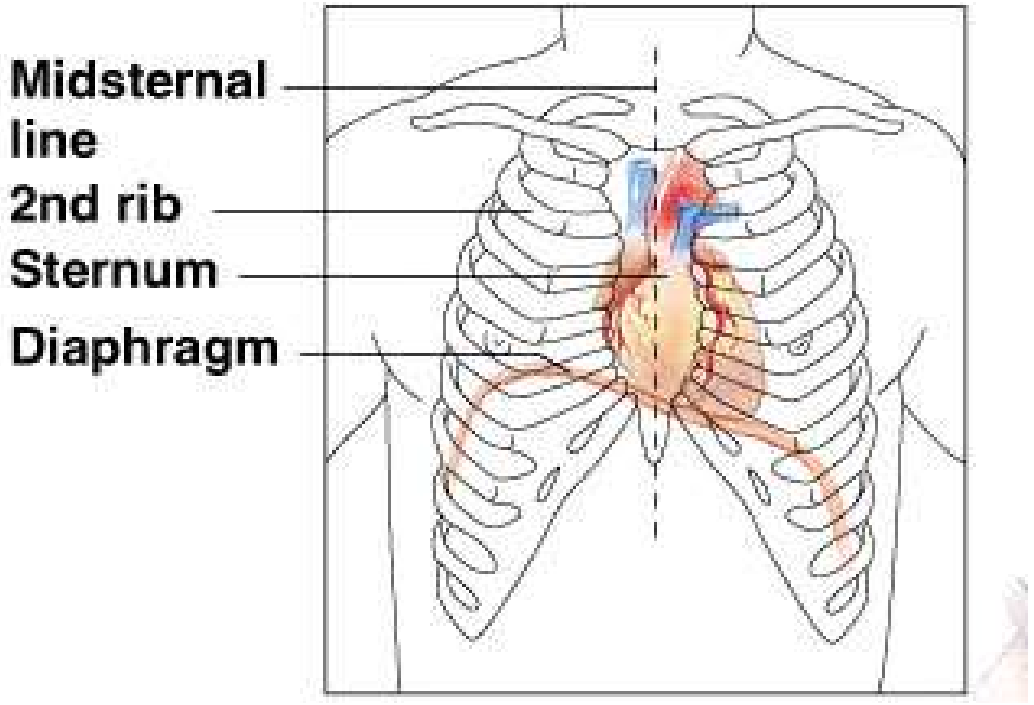
External Heart Anatomy



A) Anatomy of the Heart

1. Location

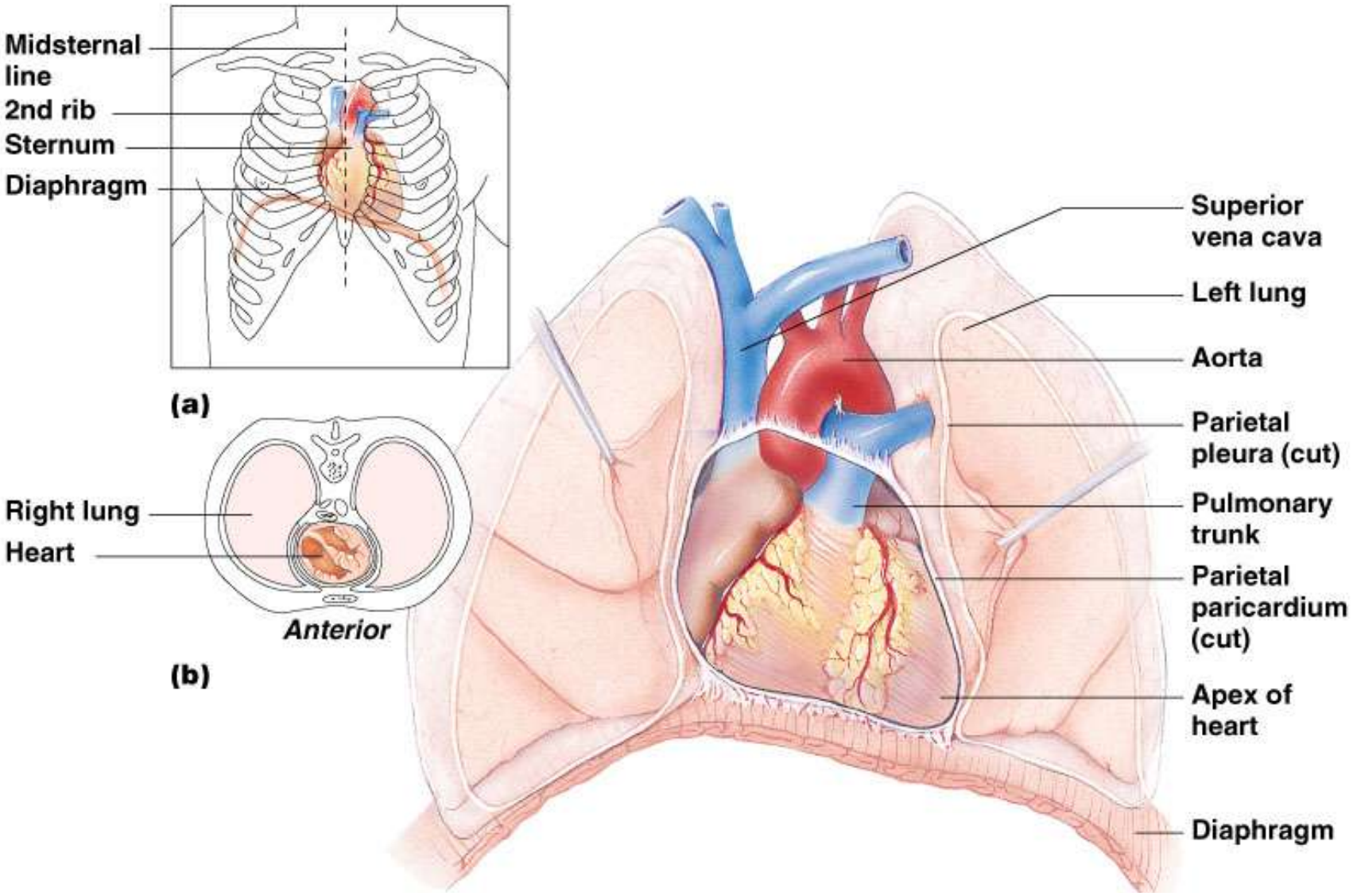
- thoracic cavity
- in the mediastinum, between the lungs



Can you describe the location of the heart?

- The heart is _____ to the lungs, _____ to the sternum, _____ to the vertebral column, and _____ to the diaphragm.
- Its _____ end, the apex, points to the left, terminating at the level of the 5th intercostal space.

- The heart is **medial** to the lungs, **posterior** to the sternum, **anterior** to the vertebral column, and **superior** to the diaphragm.
- Its **distal** end, the apex, points to the left, terminating at the level of the 5^{th} intercostal space.


Midsternal line
2nd rib
Sternum
Diaphragm
(a)
Right lung
Heart
Anterior
(b)
Superior vena cava
Left lung
Aorta
Parietal pleura (cut)
Pulmonary trunk
Parietal paricardium (cut)
Apex of heart
Diaphragm

2. Size

- approximately the size of a person's fist & less than 1 pound

~ 14 cm long; 9 cm wide

3. Coverings of the heart

a) pericardium (or pericardial sac)

1) fibrous pericardium—sac made of tough connective tissue

2) double layered serous membrane:

a. parietal pericardium

b. visceral pericardium (a.k.a. epicardium)--covers the heart

b) serous fluid fills the pericardial cavity between parietal & visceral layers

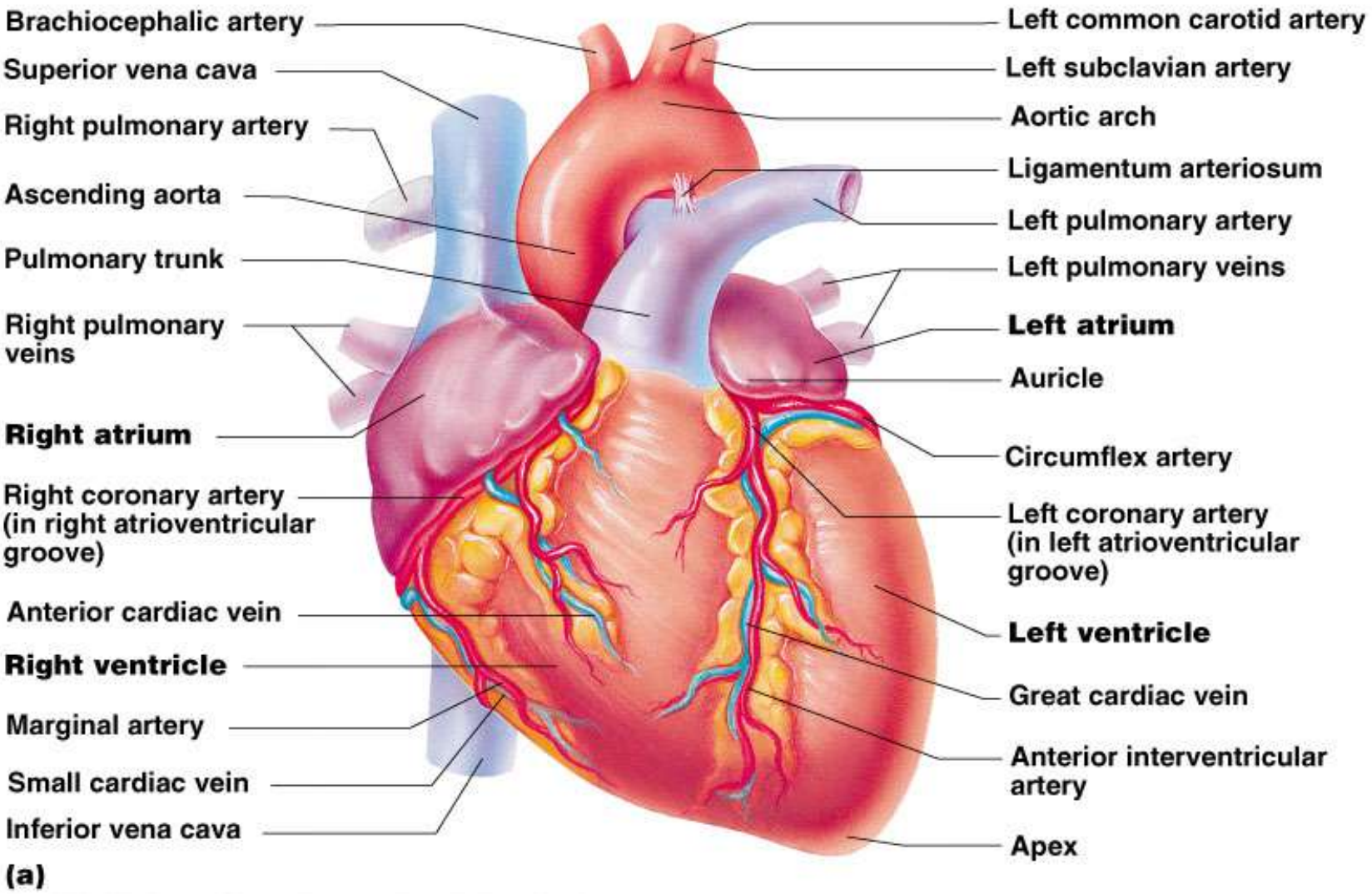
4. Heart wall

a) **epicardium** (aka visceral pericardium) outside layer of connective tissue on surface of the heart
b) **myocardium** = thick wall of cardiac muscle
c) **endocardium**—inner epithelial & connective tissue lining of heart and valves

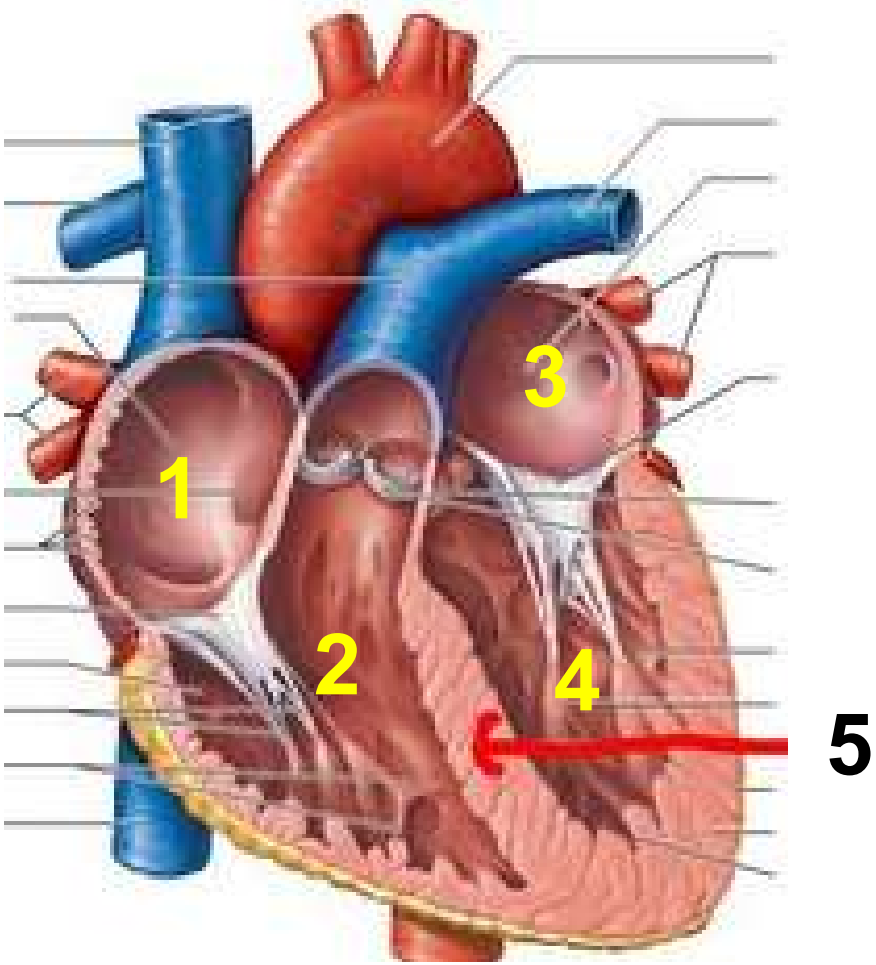
5. Chambers of the heart (4)

- **atrium** (R & L)—receive blood
  - each atria extends into a smaller, external chamber called an **auricle**
- **ventricle** (R & L)—inferior to the atria; expel blood out of the heart
- The chambers on the left are separated from the chambers on the right by a septum (wall of cardiac muscle)
  - interatrial septum
  - interventricular septum

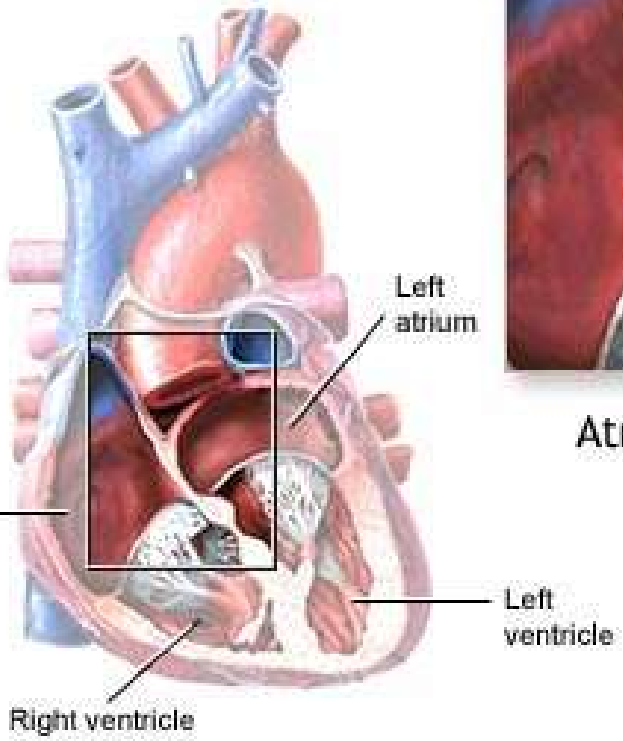
External Heart Anatomy



Can you name each numbered part of the heart?



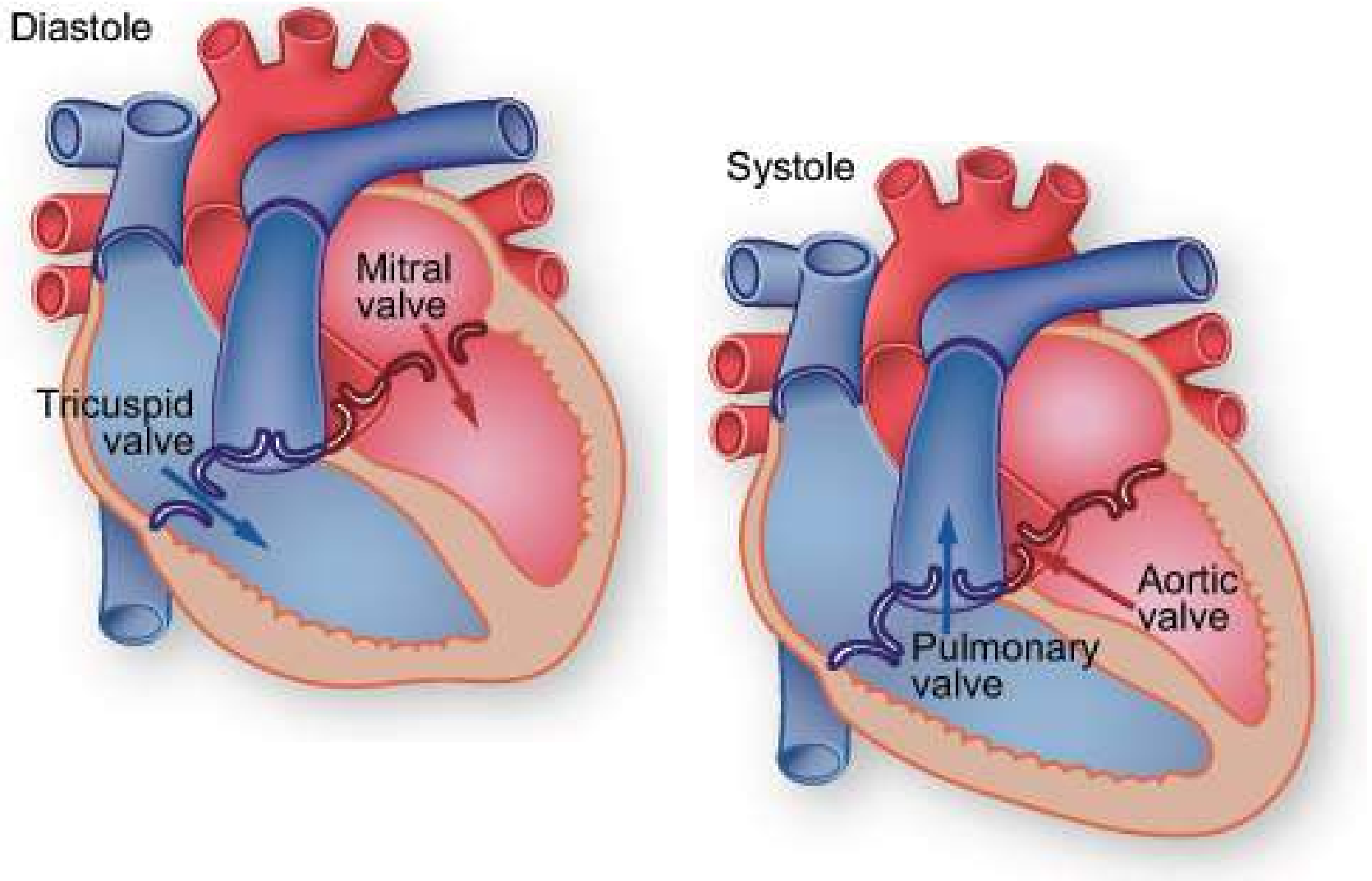
An atrial septal defect is a hole between the two atria



Atrial septal defect

6. Heart Valves

a) are flaps that allow blood to flow in only one direction


Diastole
Mitral valve
Tricuspid valve
Systole
Aortic valve
Pulmonary valve

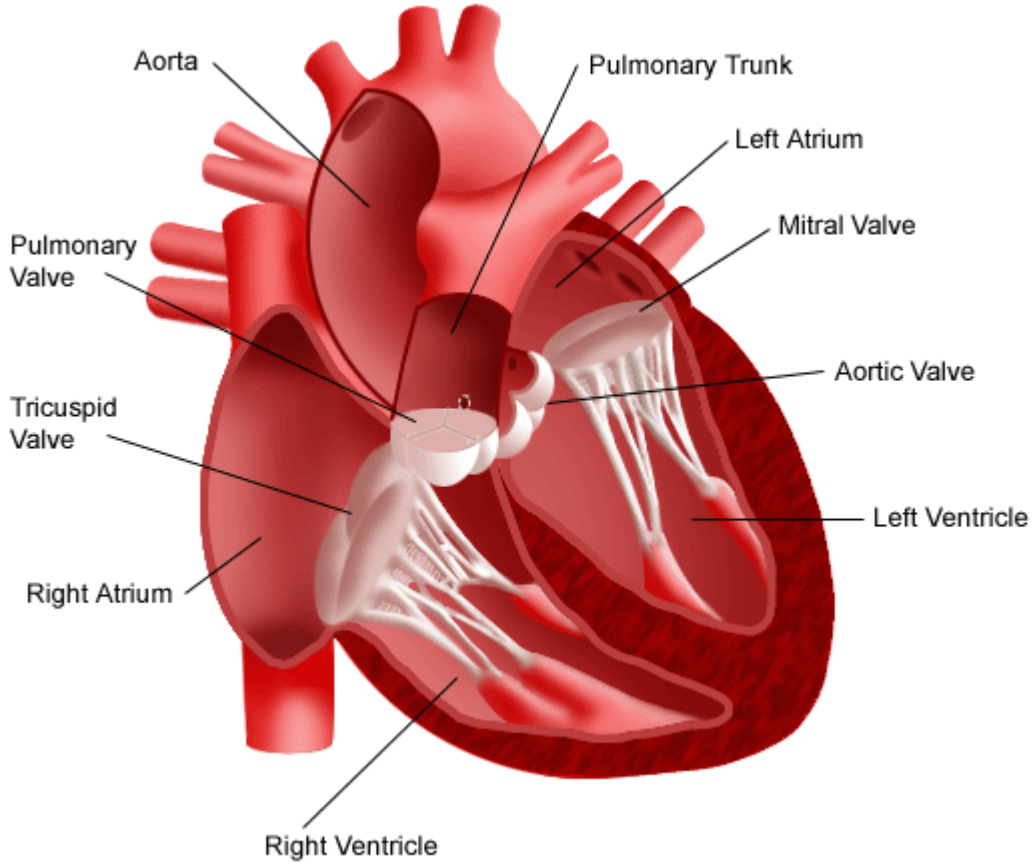
b) **atrioventricular (AV) valves** – between each atrium and ventricle; allow blood flow from each atrium down into the ventricle

- **bicuspid/mitral valve** (left side)
- **tricuspid valve** (right side)

c) **semilunar valves** - between ventricle and major heart artery; allow blood flow out of each ventricle through one of the major heart arteries; 3 cusps

- **pulmonary valve** (R ventricle & pulmonary trunk)
- **aortic valve** (L ventricle & aorta)

d) The valve cusps are held in place by chordae tendineae (“heart strings”) which originate from papillary muscles protruding from the inside of the ventricle wall



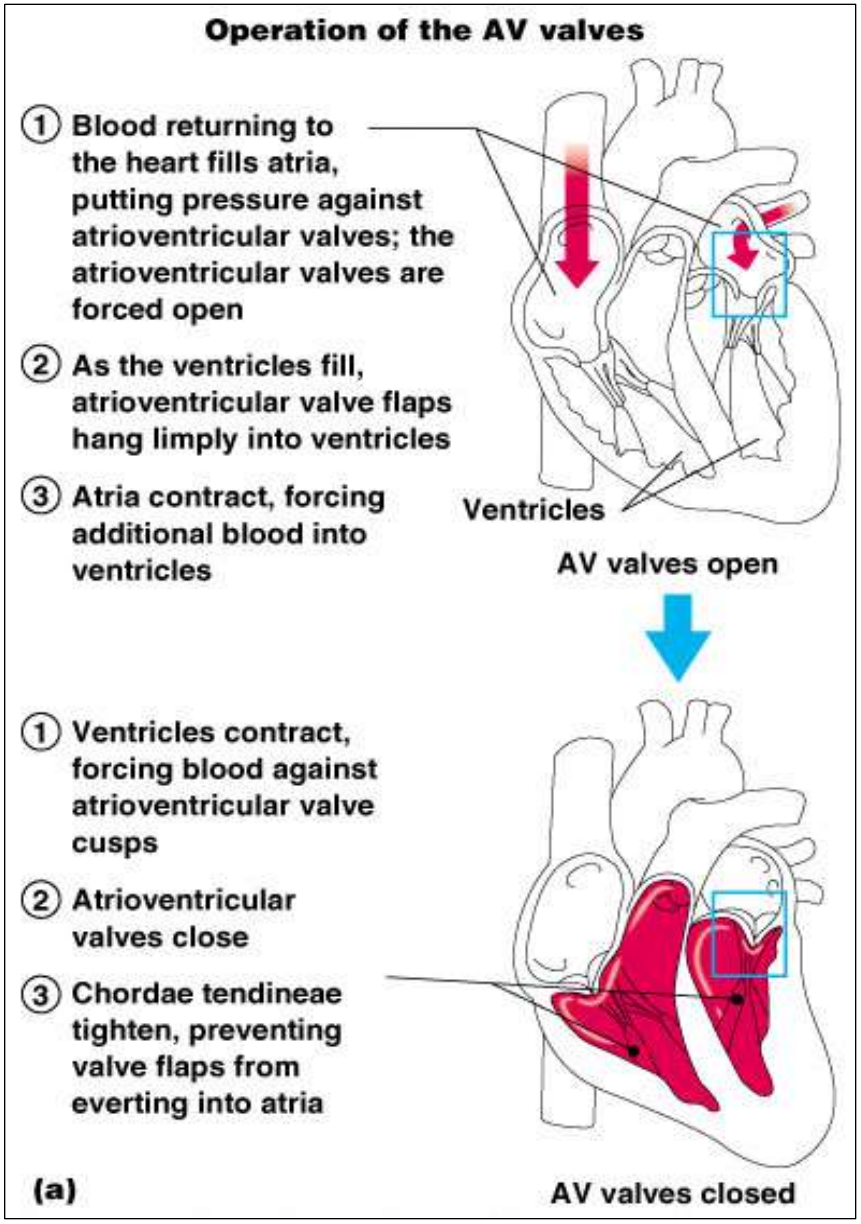
e) valve function

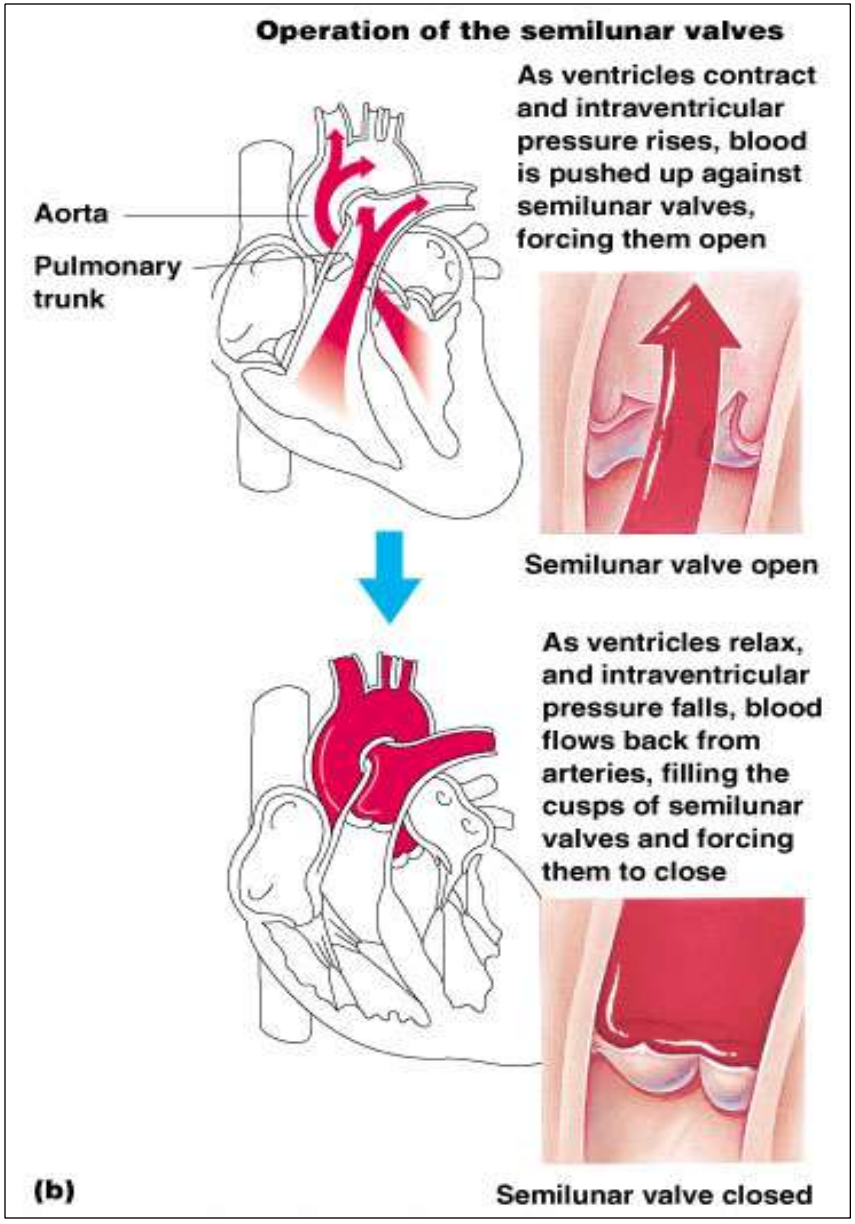
- when a chamber wall contracts blood is pumped through a valve
- any backflow increases pressure on the cusps and closes the valves
- AV valves close during ventricular contraction; papillary muscles also contract pulling the chordae tendineae which keep the valve cusps from prolapsing back into the atrium

f) heartbeat sound

"lub" = when AV valves close

"dup" = when semilunar valves close


Operation of the AV valves
1 Blood returning to the heart fills atria, putting pressure against atrioventricular valves; the atrioventricular valves are forced open
2 As the ventricles fill, atrioventricular valve flaps hang limply into ventricles
3 Atria contract, forcing additional blood into ventricles
Ventricles
AV valves open
1 Ventricles contract, forcing blood against atrioventricular valve cusps
2 Atrioventricular valves close
3 Chordae tendineae tighten, preventing valve flaps from everting into atria
(a)
AV valves closed


Operation of the semilunar valves
As ventricles contract and intraventricular pressure rises, blood is pushed up against semilunar valves, forcing them open
Aorta
Pulmonary trunk
Semilunar valve open
As ventricles relax, and intraventricular pressure falls, blood flows back from arteries, filling the cusps of semilunar valves and forcing them to close
(b)
Semilunar valve closed

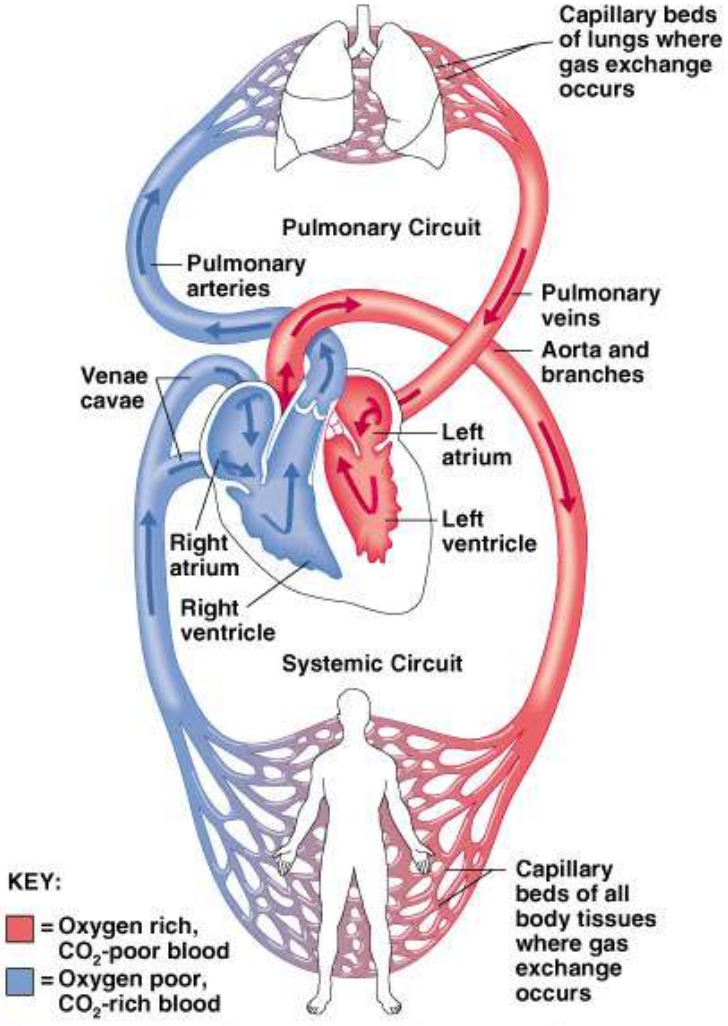
g) valve pathology

- an incompetent valve can lead to backflow, heard as a “heart murmur” and repumping (regurgitation) of the same blood
- stenosis = narrowing of valve increases workload on heart to pump out blood
- Treatment: valve repair or replacement

Video clip Overview of Circulation

http://www.bing.com/videos/search?q=blood+circulation&FORM=HDRSC3#view=detail&mid=D7FC584D7C3259E0686DD7FC584D7C3259E0686D

B) Paths of Blood Circulation

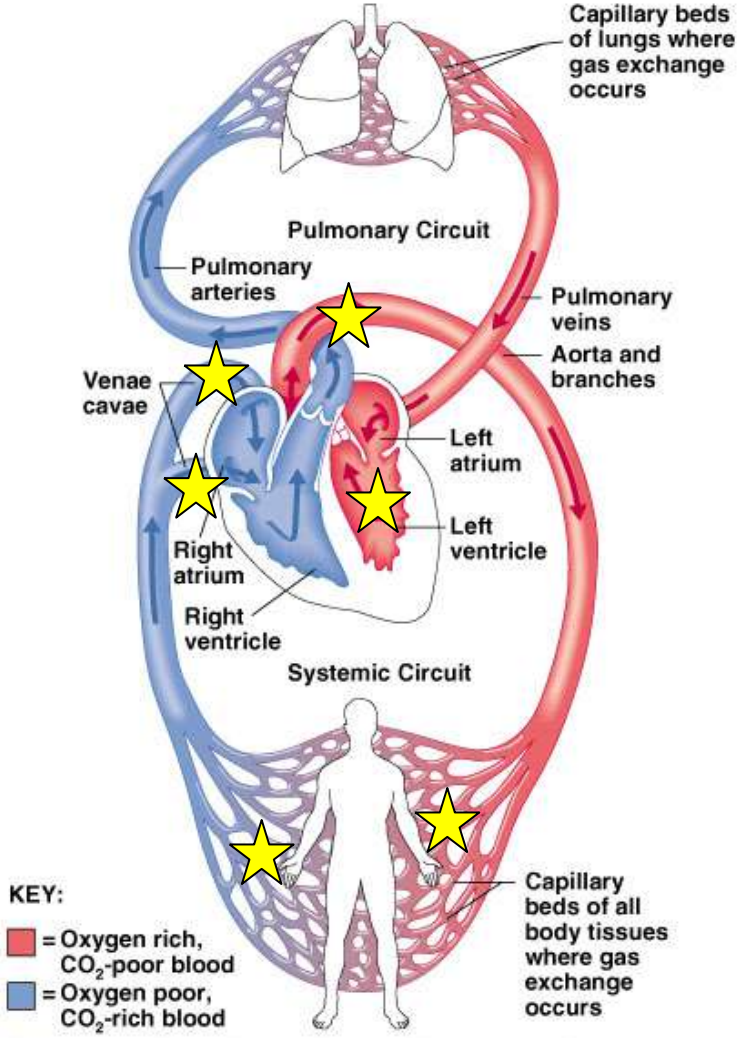


1. Major Blood Vessels of the Heart

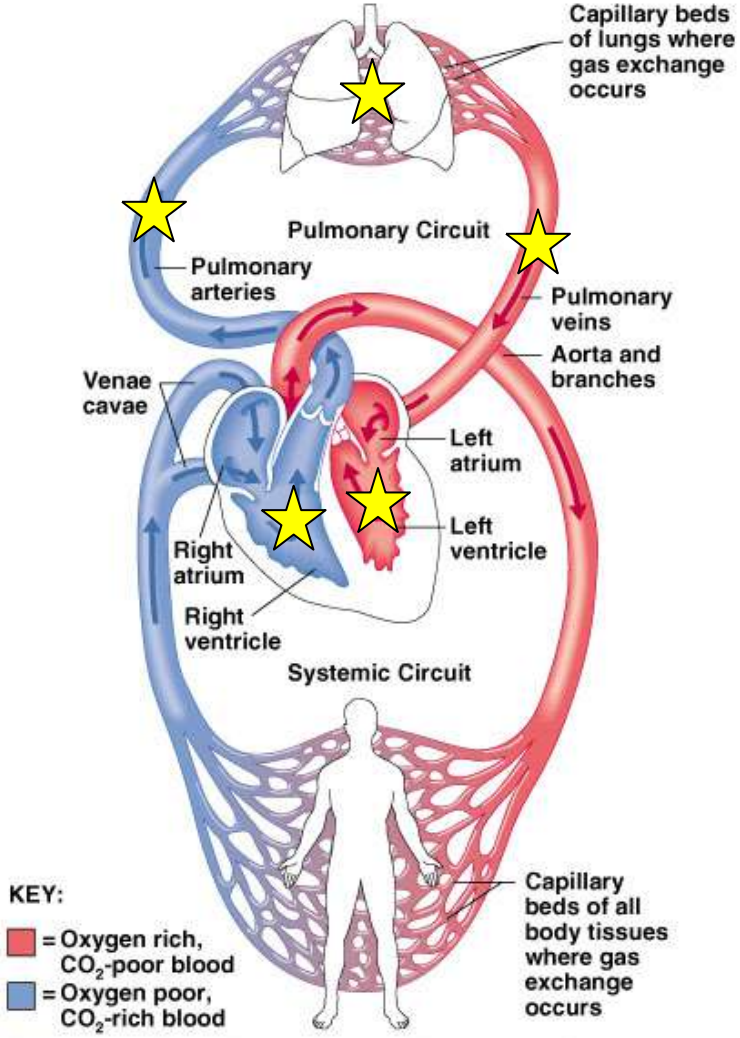
- **aorta** carries _____ blood from the left ventricle to upper & lower body
- **pulmonary arteries** (L & R): carries _____ blood from right ventricle to lungs
- **vena cava** (superior & inferior): carries _____ blood from upper & lower body into right atria
- **pulmonary veins** (2 pairs, L & R): carry _____ blood from lungs into left atria

- **aorta** carries **oxygenated** blood from the left ventricle *to upper & lower body*
- **pulmonary arteries** : carries **deoxygenated** blood from right ventricle *to lungs*
- **vena cava**: carries **deoxygenated** blood *from upper & lower body* into right atria
- **pulmonary veins**: carry **oxygenated** blood *from lungs* into left atria

2. Systemic circuit

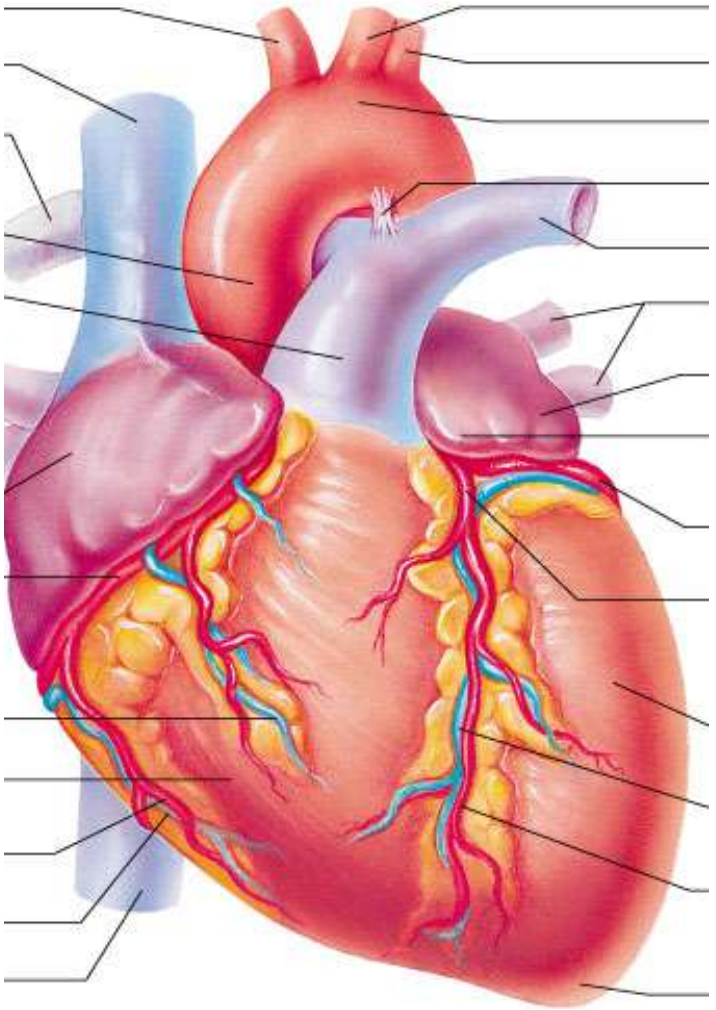


3. Pulmonary circuit



3. Coronary circuit

- The heart has its own network of blood vessels to supply the cardiac muscle cells
  - coronary arteries & veins, capillaries
- NOTE: The blood flowing *through the heart chambers* does NOT nourish the myocardium



Video clip Coronary Heart Bypass surgery

http://www.bing.com/videos/search?q=video+of+coronary+circulation&view=detail&mid=8B64DE6E57407A5A5E1B8B64DE6E57407A5A5E1B&first=0&FORM=LKVR&adlt=strict#view=detail&mid=7B67DD929983076406EC7B67DD929983076406EC

* Video clip of mitral valve disease

http://www.medmovie.com/mmdatabase/MediaPlayer.aspx?ClientID=65&TopicID=773

Heart Physiology

How does the heart function?

A) The Cardiac Cycle

1. A cardiac cycle refers to the series of contractions & relaxations of the heart to produce a complete heartbeat

systole = contraction

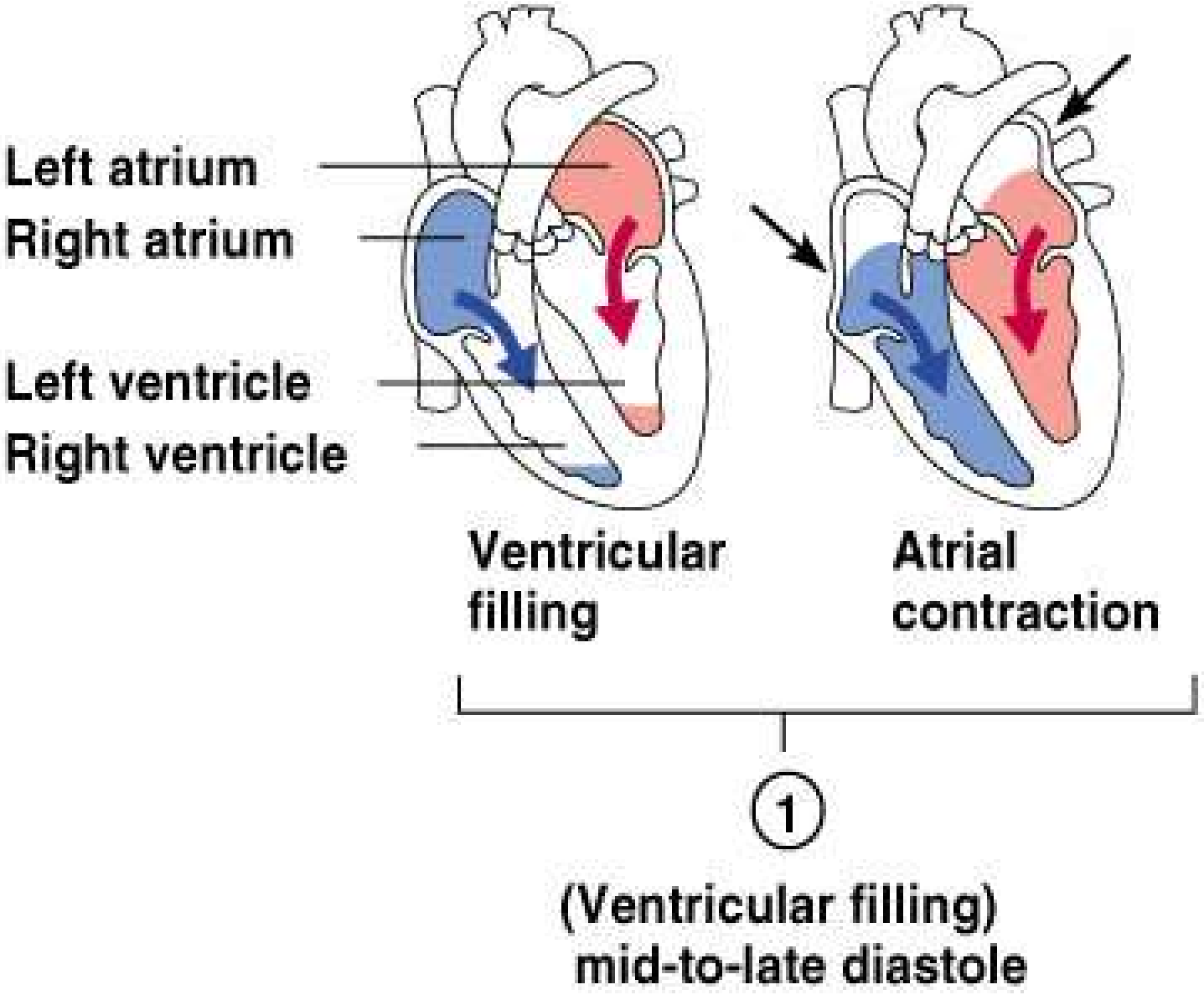
diastole = relaxation

2. Events of the cardiac cycle

Diastole

I. Atria and ventricles **fill** with blood

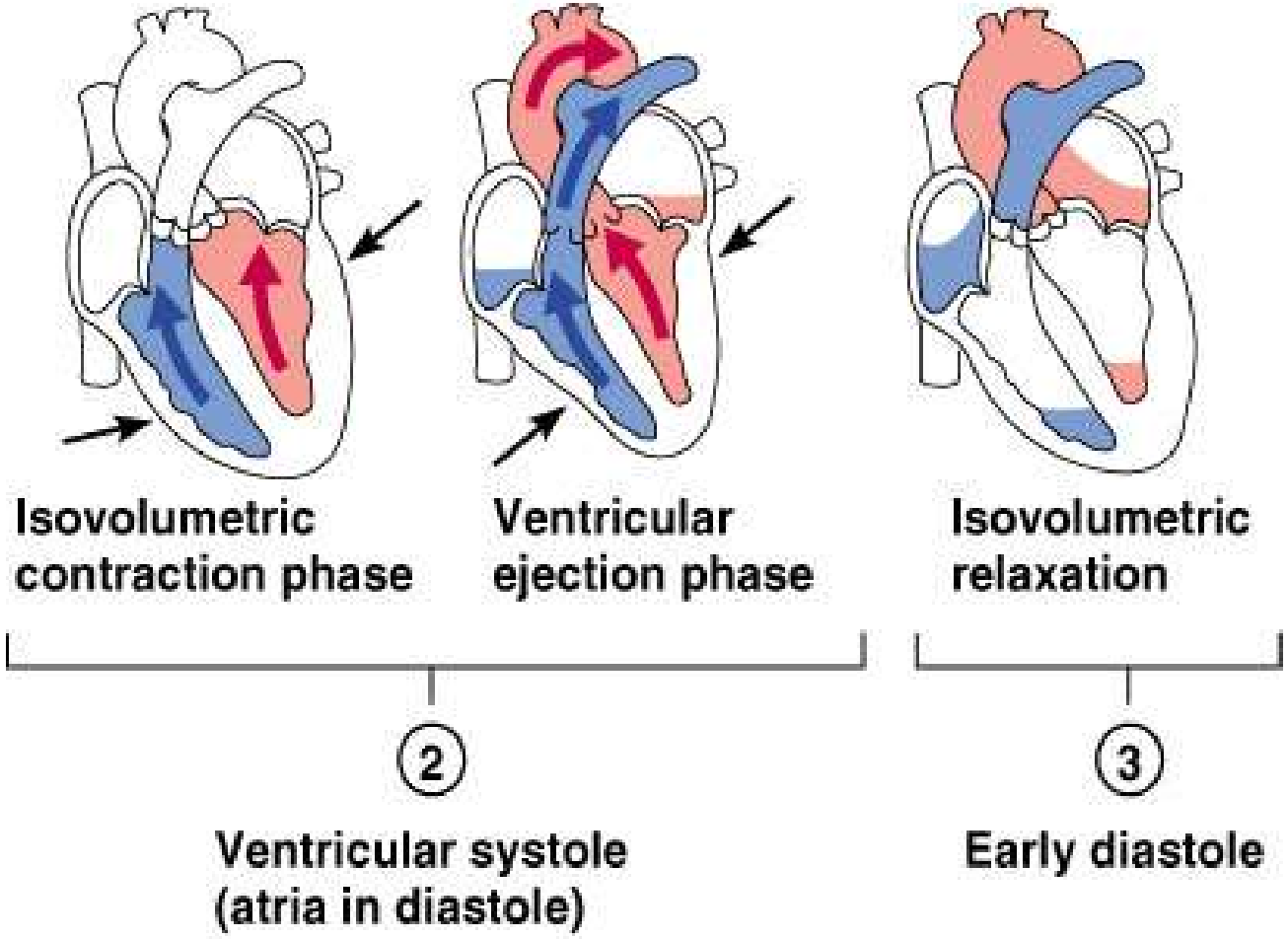
II. Atria contract (simultaneously) to complete the filling of ventricles; **ventricles are relaxed**


Left atrium
Right atrium
Left ventricle
Right ventricle
Ventricular filling
Atrial contraction
1
(Ventricular filling)
mid-to-late diastole

Systole

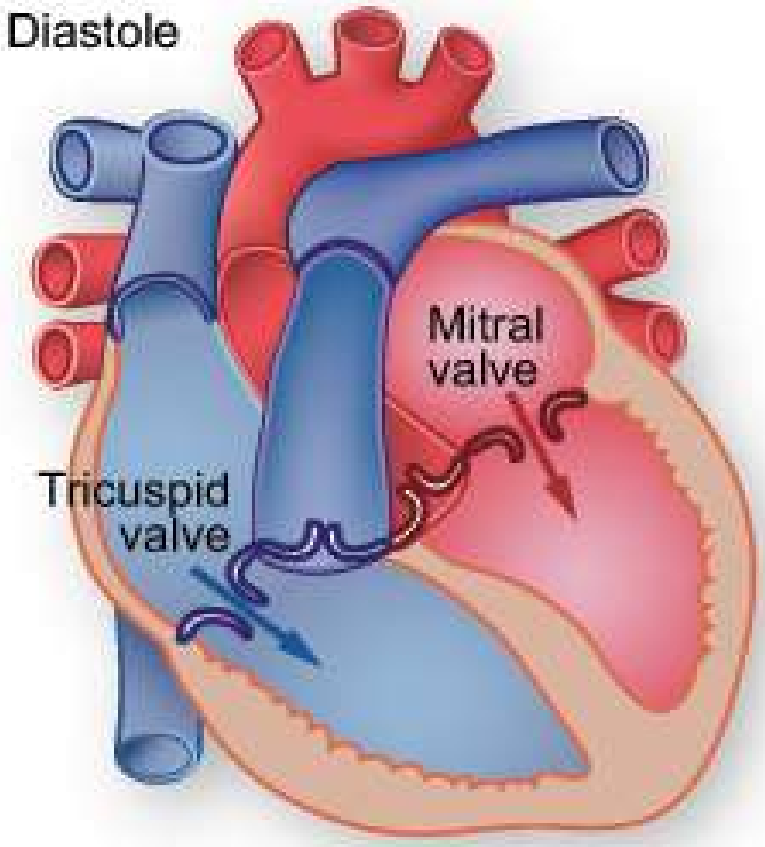
III. **Ventricles contract** **forcing blood up and out** of the heart arteries; AV valves shut (“lup”)

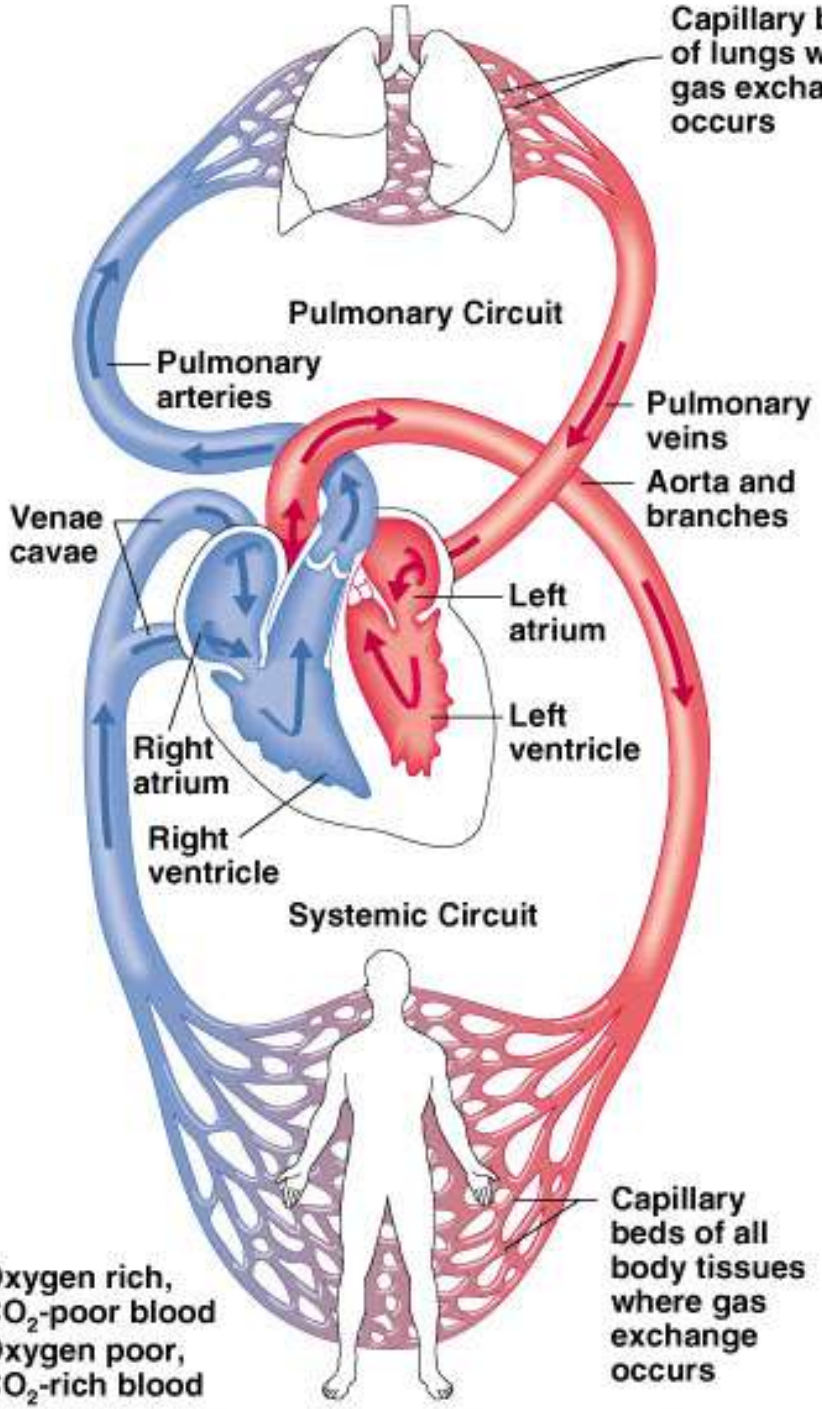
IV. Backflow in the aorta & pulmonary arteries cause semilunar valves to shut (“dup”)


Isovolumetric contraction phase
Ventricular ejection phase
Isovolumetric relaxation
2
Ventricular systole (atria in diastole)
3
Early diastole

Video: systole & diastole

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter22/animation__the_cardiac_cycle__quiz_2_.html


Diastole
Mitral valve
Tricuspid valve


Capillary beds of lungs where gas exchange occurs
Pulmonary Circuit
Pulmonary arteries
Pulmonary veins
Aorta and branches
Venae cavae
Left atrium
Left ventricle
Right atrium
Right ventricle
Systemic Circuit
Capillary beds of all body tissues where gas exchange occurs
KEY:
= Oxygen rich, CO_2-poor blood
= Oxygen poor, CO_2-rich blood

B) Conduction System

- is an intrinsic, nodal conduction system that regulates heart wall contractions via electrical impulses
- Specialized muscle tissue regulates contractions by carrying nerve impulses

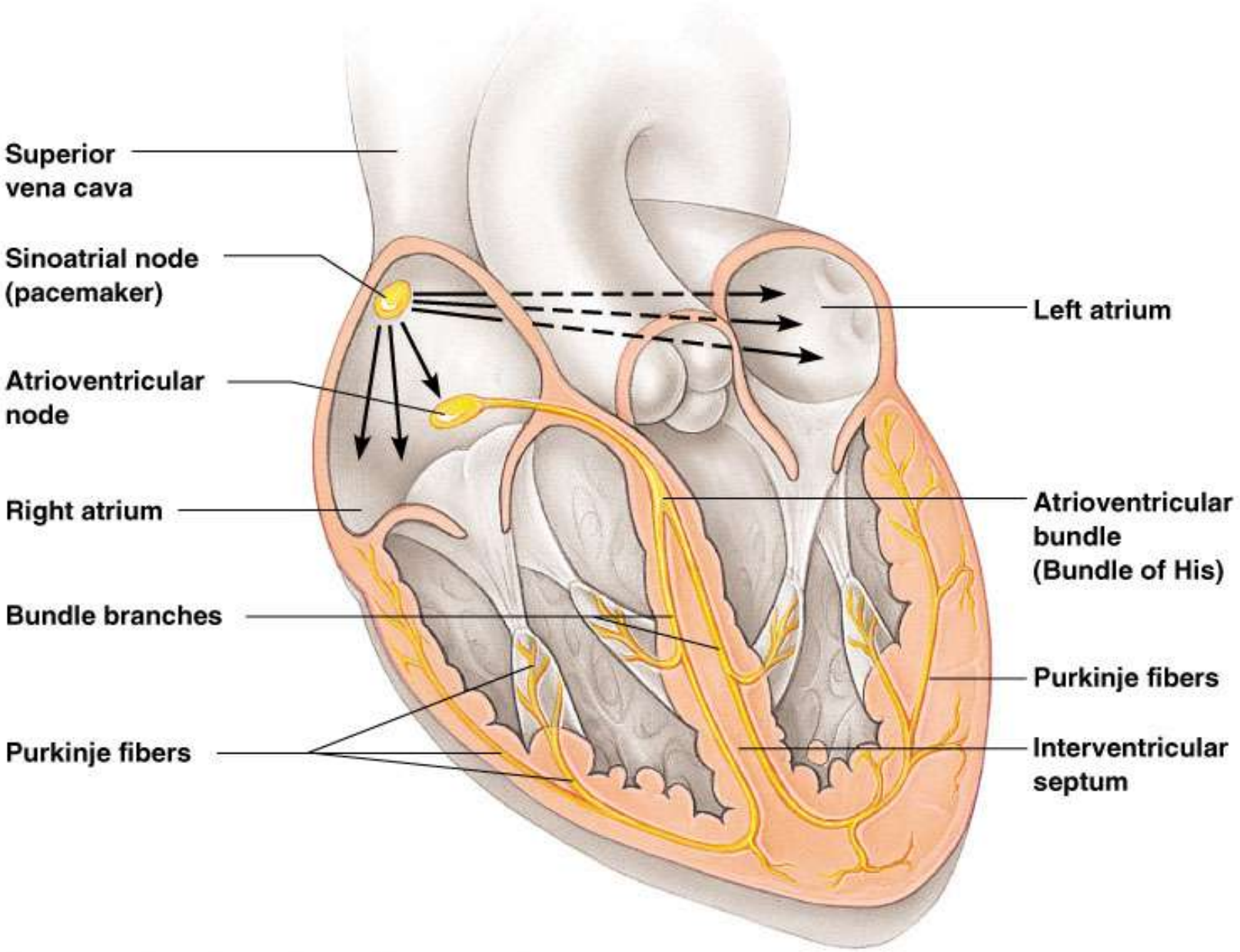
i. **sinoatrial (SA) node** = “pacemaker” (located in the wall of the right atrium)

ii. **atrioventricular (AV) node** (in septum at the junction of the R & L atria)

iii. **atrioventricular bundle** or Bundle of His (in the interventricular septum)

iv. **bundle branches** (right and left)

v. **Purkinje fibers** (in the myocardium wall)

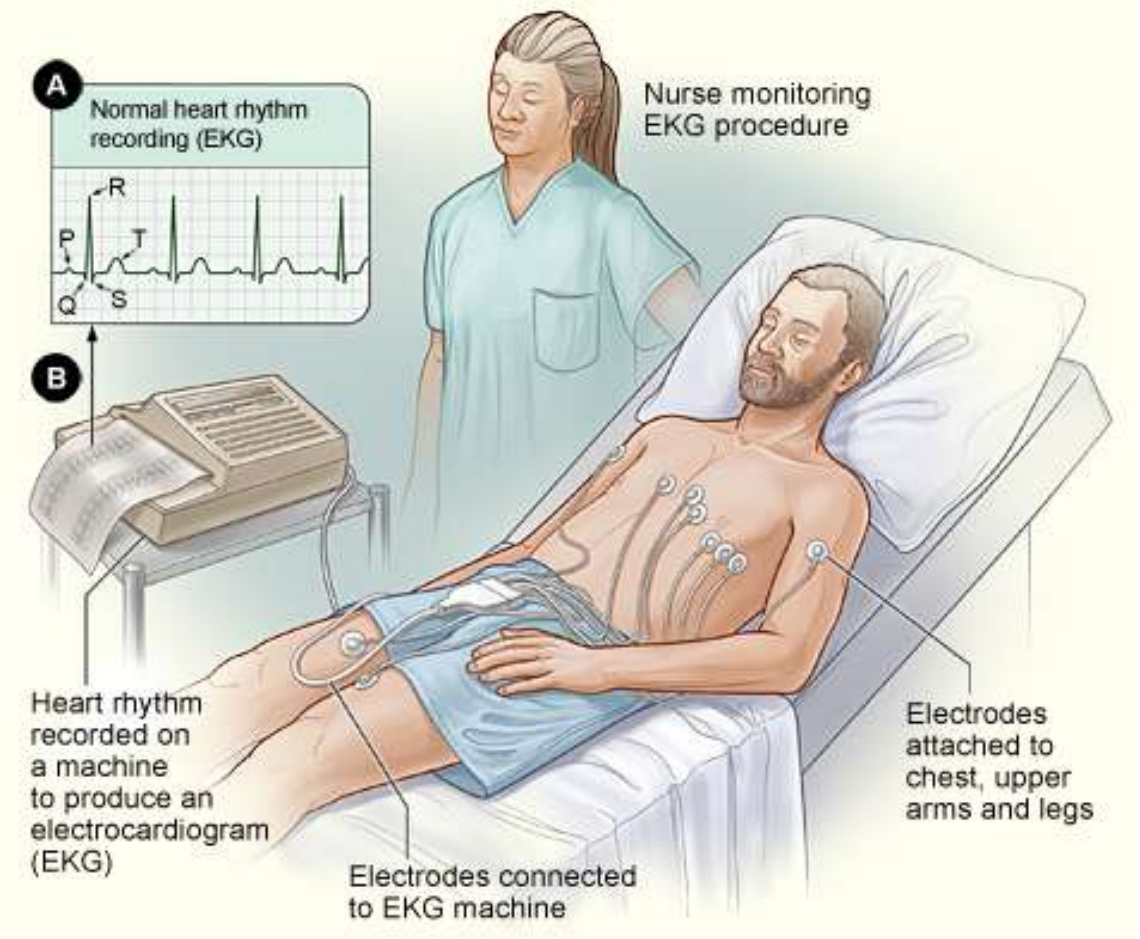


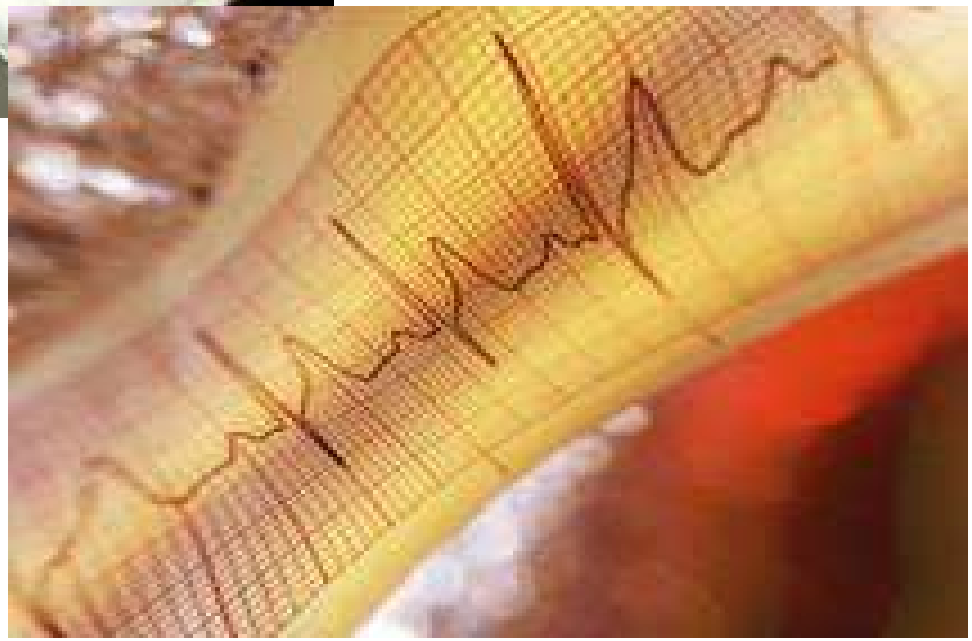
Video: Conduction

http://highered.mcgraw-hill.com/sites/0072495855/student_view0/chapter22/animation__conducting_system_of_the_heart.html

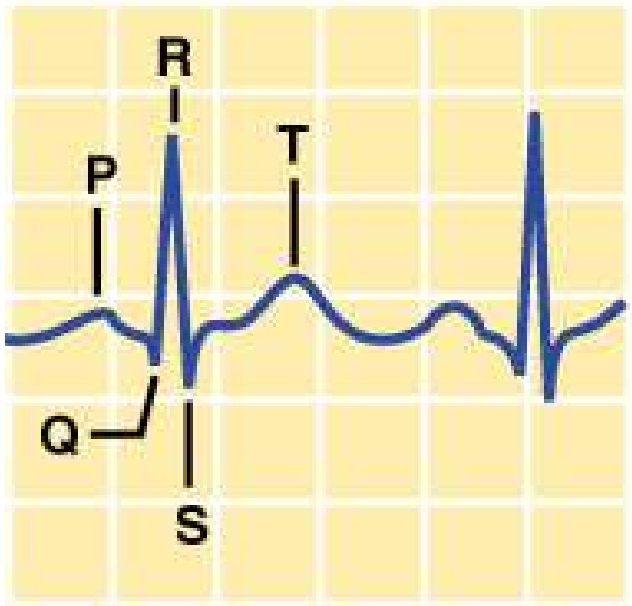
C) electrocardiogram (ECG or EKG)

is a recording of the electrical changes in the myocardium during a cardiac cycle

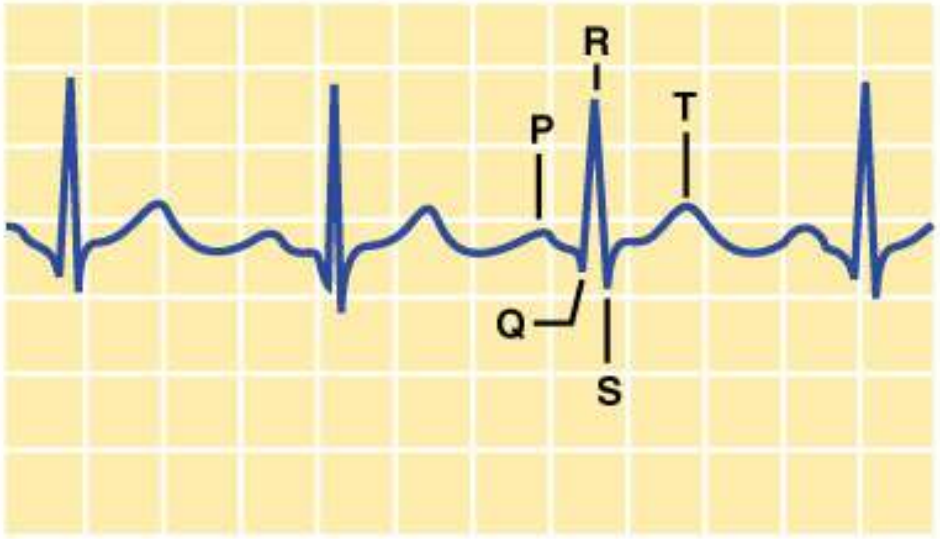




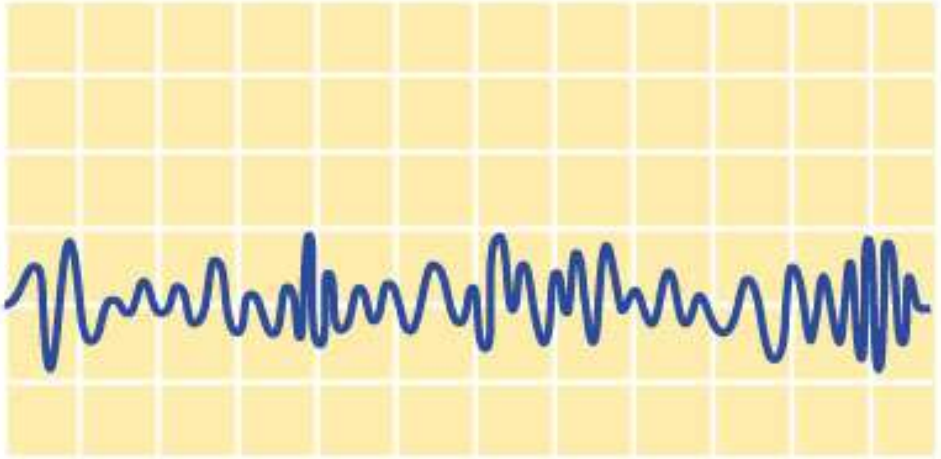
A normal ECG recording



P wave: atria depolarize
QRS complex: ventricles depolarize
T wave: end of electrical activity in ventricles; repolarization of ventricular muscles



(b) A normal ECG recording



(c) Ventricular fibrillation

Figure 8.15B, C

D) Pathology of the Conduction System

- **fibrillation** =an irregular & often rapid heart rate; decreases blood flow
- **tachycardia** = more than 100 beats/min
- **bradycardia** = less than 60 beats/min

Possible causes of atrial fibrillation

Abnormalities /damage to the heart's structure due to:

- High blood pressure or Heart attacks
- Abnormal heart valves
- Congenital heart defects (you're born with)
- An overactive thyroid gland
- Stimulants (medications, caffeine, tobacco, alcohol)
- improper functioning of SA node
- Emphysema or other lung diseases
- Viral infections
- Stress due to pneumonia, surgery
- Sleep apnea

E) Cardiac Output

1. is the amount of blood pumped by the ventricle in one minute

2. Formula for cardiac output

= (heart rate) x (stroke volume*)

*** volume of blood pumped by a ventricle in one contraction**

3. Normal cardiac output

= (75 beats/min) x (70 mL/beat)

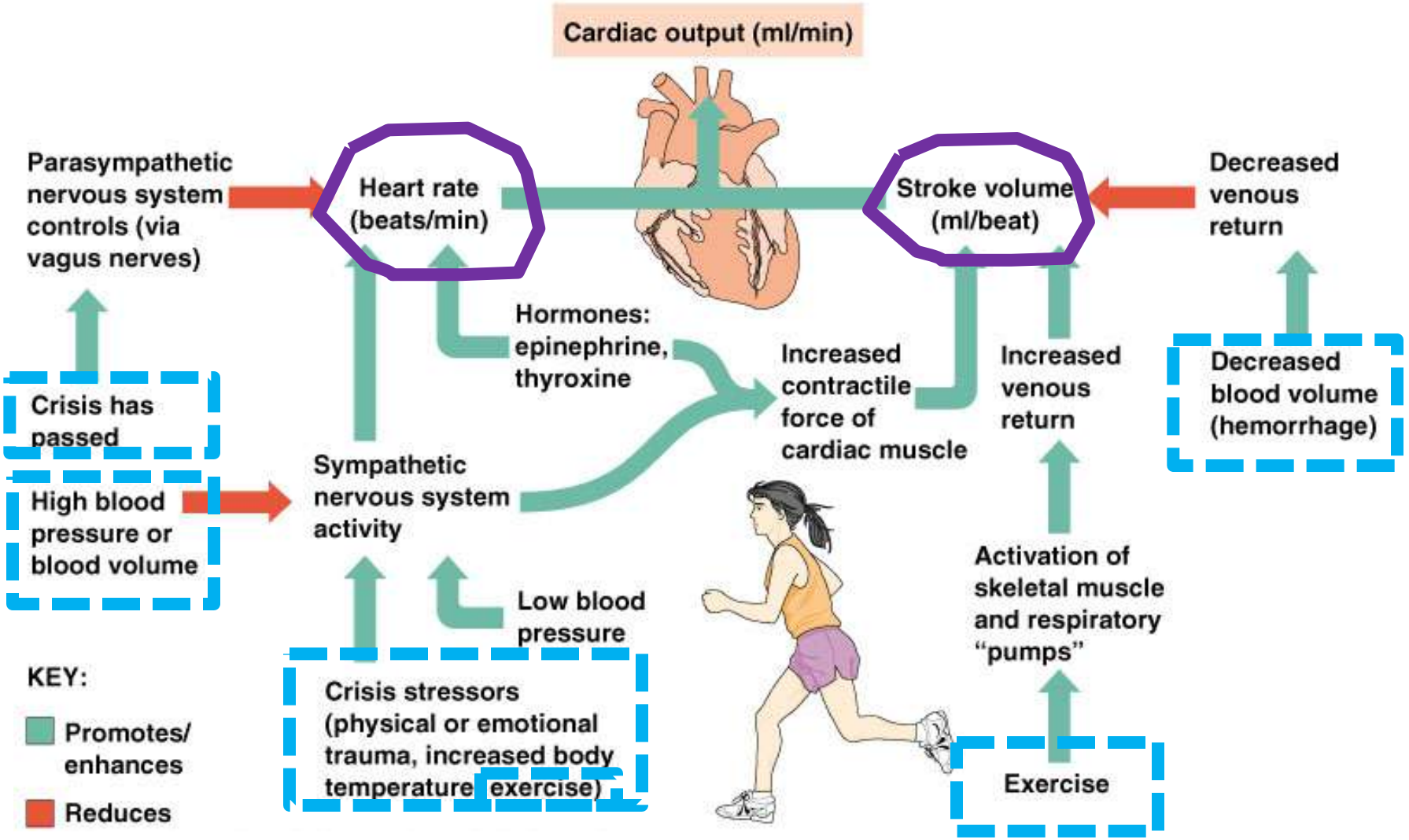
= 5000 mL/min

= 5 L/min

4. Cardiac output varies with demands of the body

e.g.

Cardiac Output Regulation

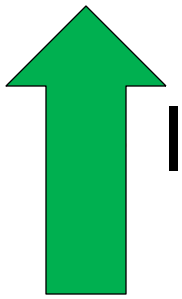


Q. How long does it take for a RBC to make a roundtrip through the body (via systemic circuit)?

5. The entire blood supply passes through body once every **minute**.

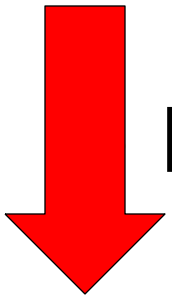
F) Regulation of Heart Rate

1. Stroke volume usually remains relatively constant
2. The most common way the body changes cardiac output is by changing the heart rate.



Increases heart rate

- Sympathetic nervous system
  - ✓Crisis
  - ✓Low blood pressure
- Hormones
  - ✓Epinephrine
  - ✓Thyroxine
- Exercise
- Decreased blood volume



Decreases heart rate

- Parasympathetic nervous system
- High blood pressure or blood volume
- Decreased venous return
- In congestive heart failure the heart is worn out and pumps weakly. Digitalis works to provide a slow, steady, but stronger beat.

Cardiac Pathology

- Rapid heart beat
- = Inadequate blood
- = Angina Pectoris

Congestive Heart Failure (CHF)

- Decline in pumping efficiency of heart
- Inadequate circulation
- Progressive, also coronary atherosclerosis, high blood pressure and history of multiple Myocardial Infarctions
- Left side fails = pulmonary congestion and suffocation
- Right side fails = peripheral congestion and edema