MDEXPO
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Essential Cardiology for Biomeds

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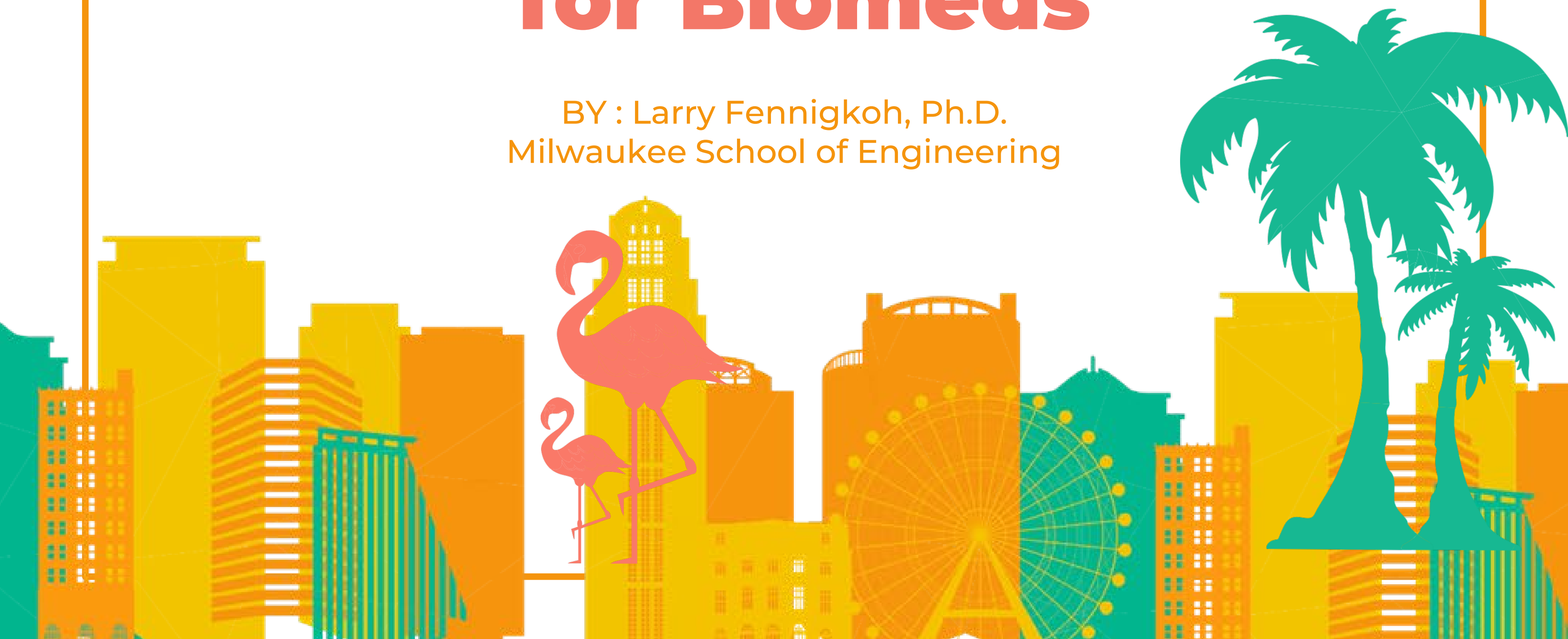
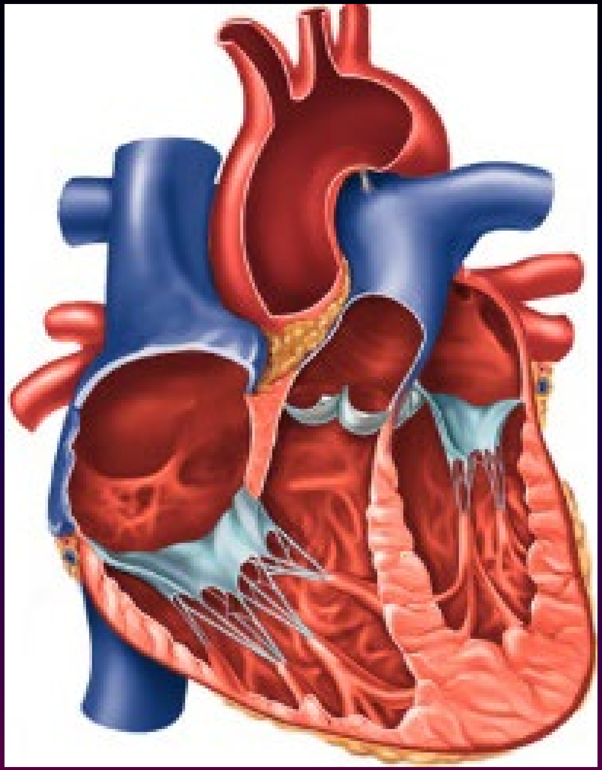
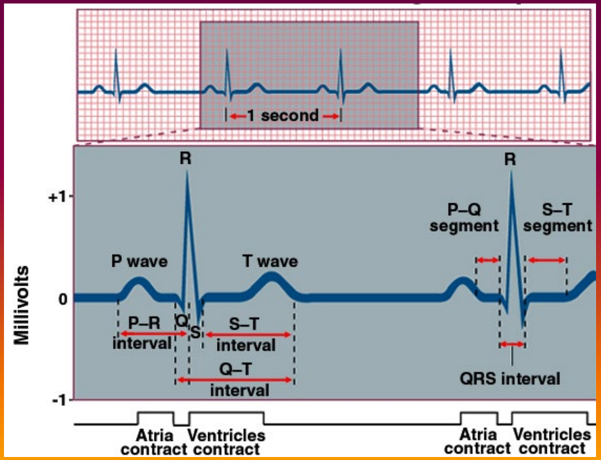


Topics:

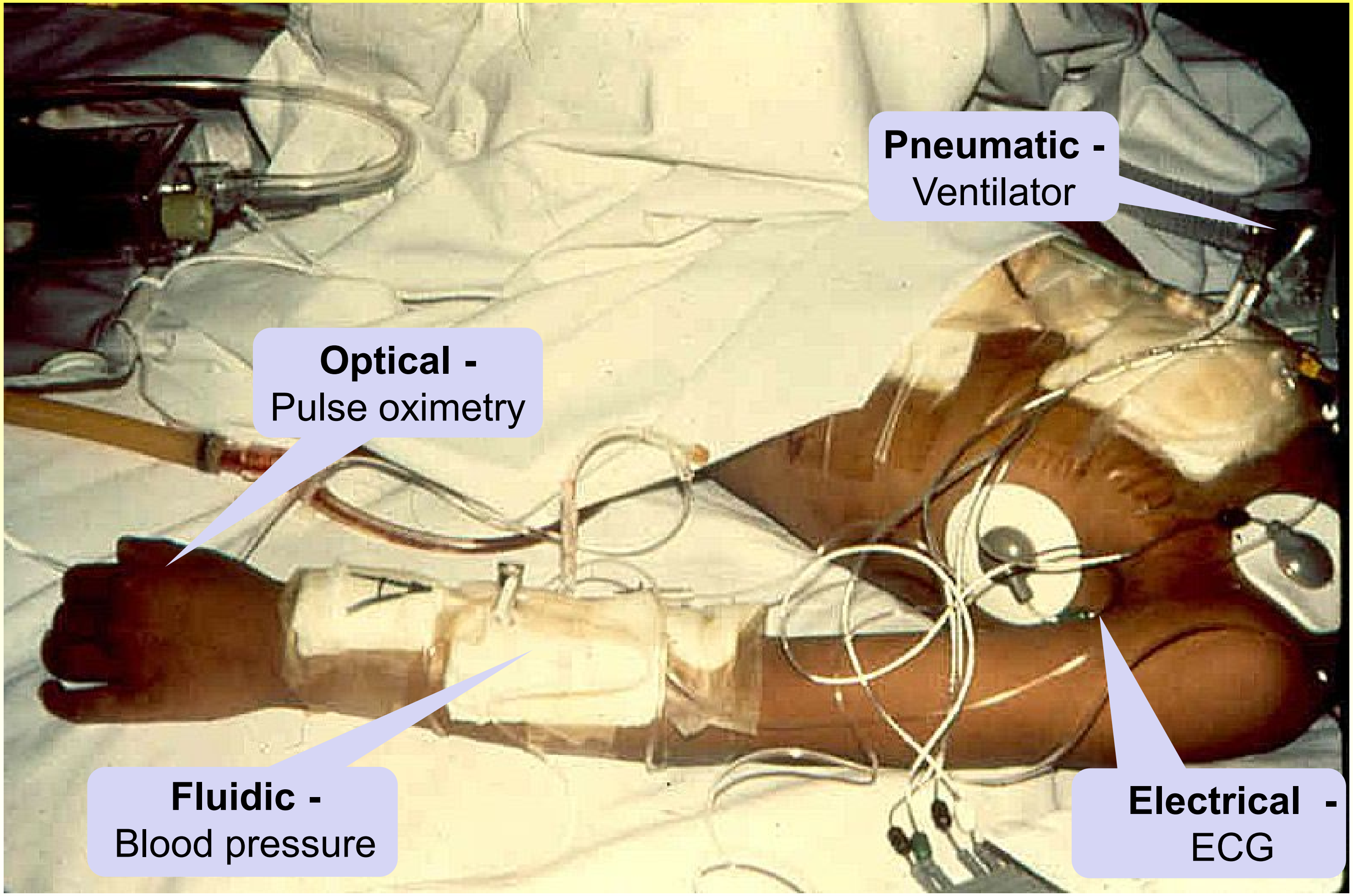
- Anatomy: great vessels, chambers, valves
- Cardiac muscle
- Origin & conduction of cardiac action potentials (ECG)
- Electrodes, electrocardiography, arrhythmias
- Pressure – volume relationships





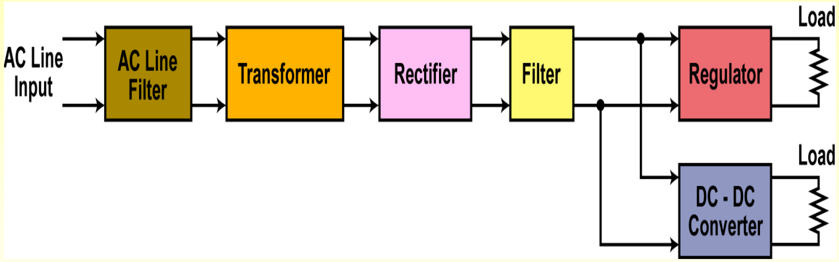
Adapted from K. Saladin, *Anatomy & Physiology: The Unity of Form and Function; D. Silverthorn, et al.*

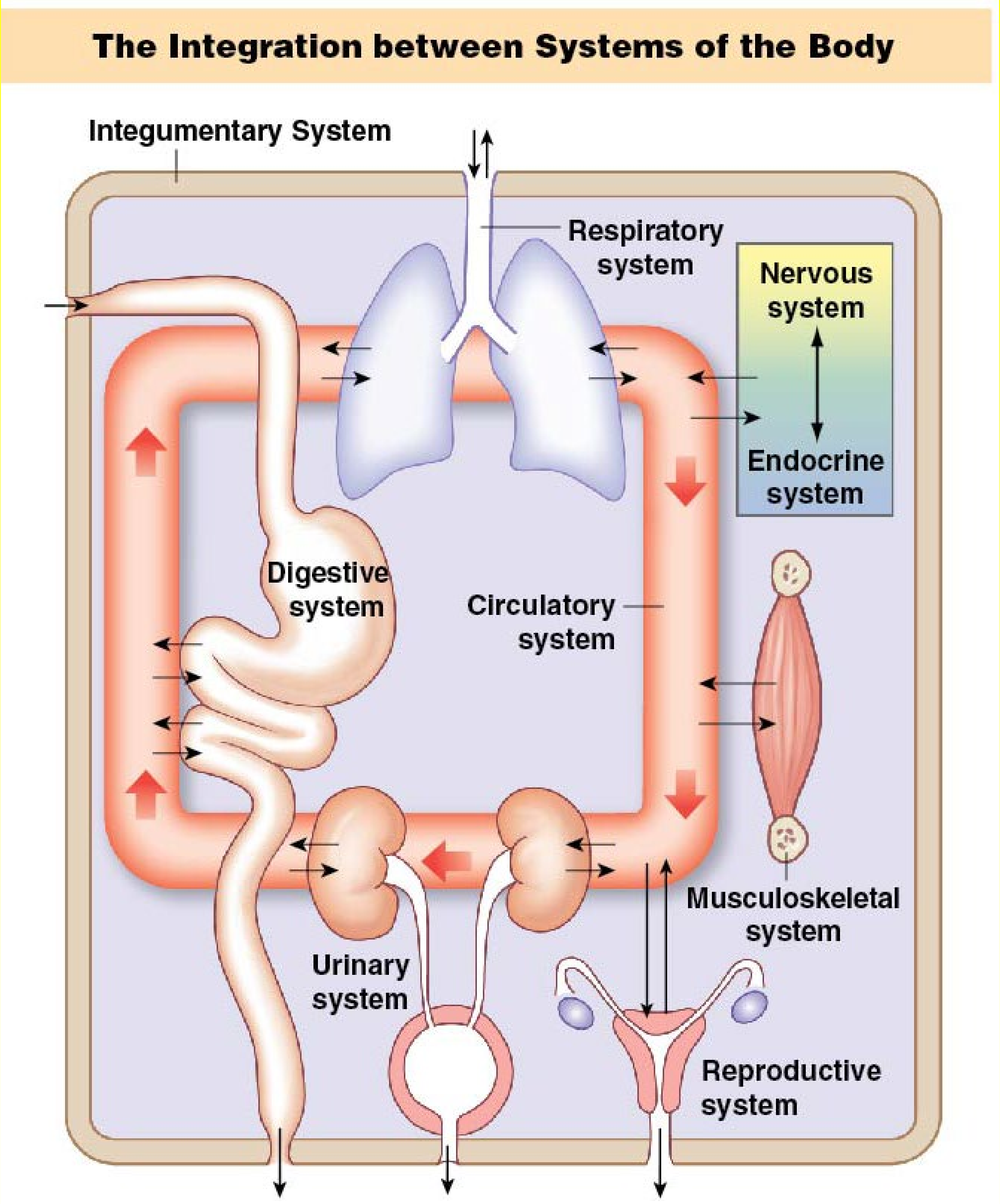
The *Reason* why an understanding of physiology, anatomy, and pathology is essential . . .



especially when patients become – literally – one with the machines.

The study of physiology is often done on a systems-by-systems level; like the learning of overall equipment function by studying its block diagram, e.g.,

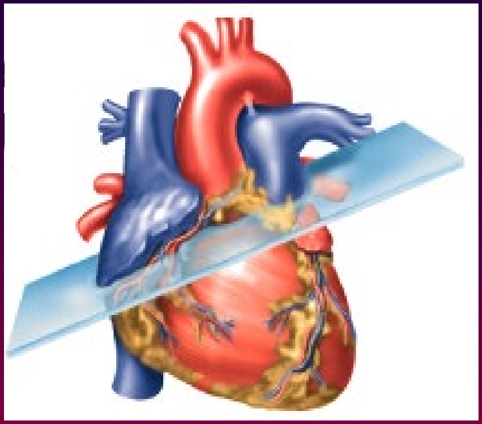




This schematic figure indicates relationships between systems of the human body. The interiors of some hollow organs (shown in white) are part of the external environment.

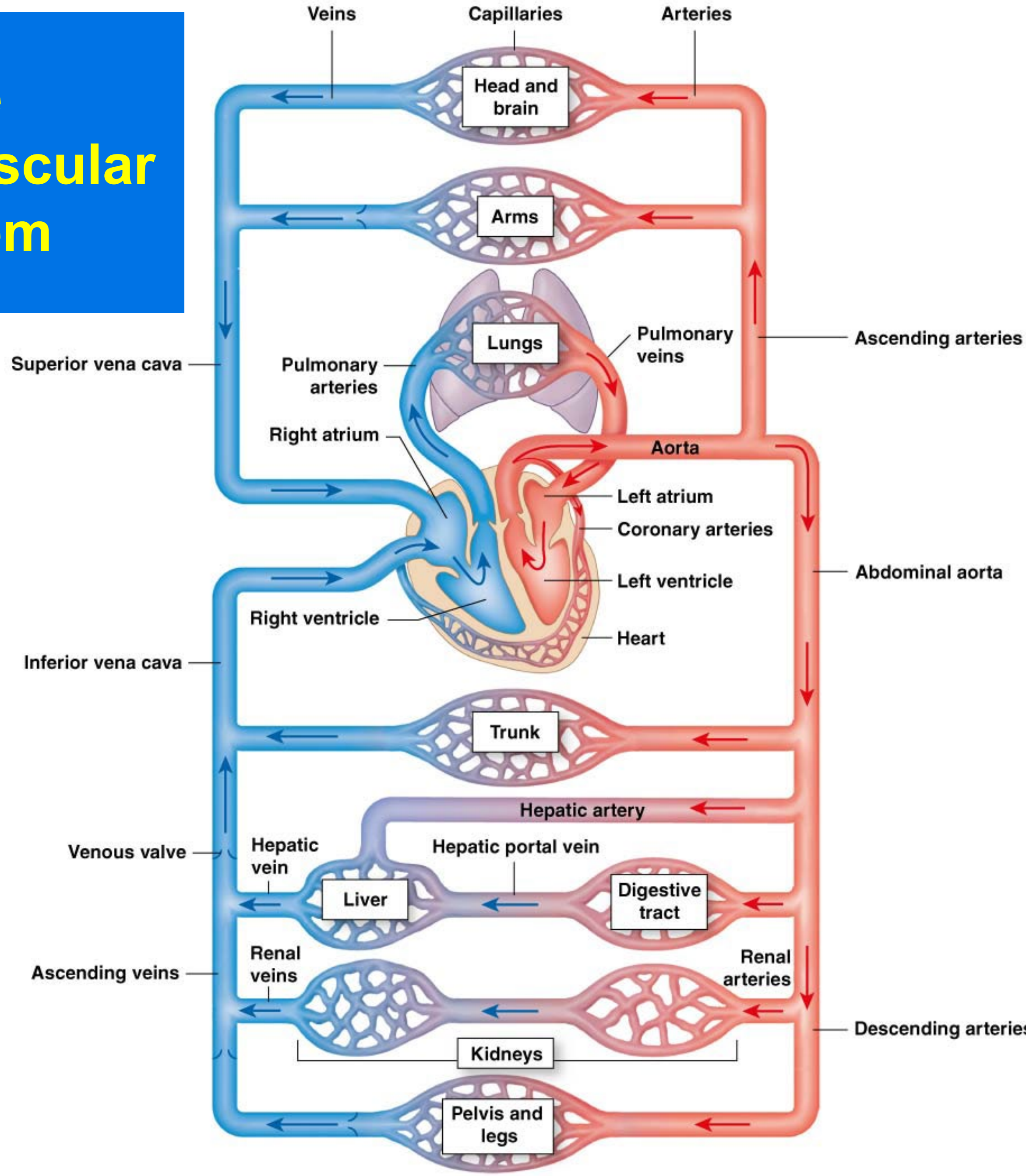
Cardiovascular System & Anatomy

- Primary functions include transport of:
  - O_2 & CO_2, nutrients, waste, hormones, heat
  - Defense against pathogens

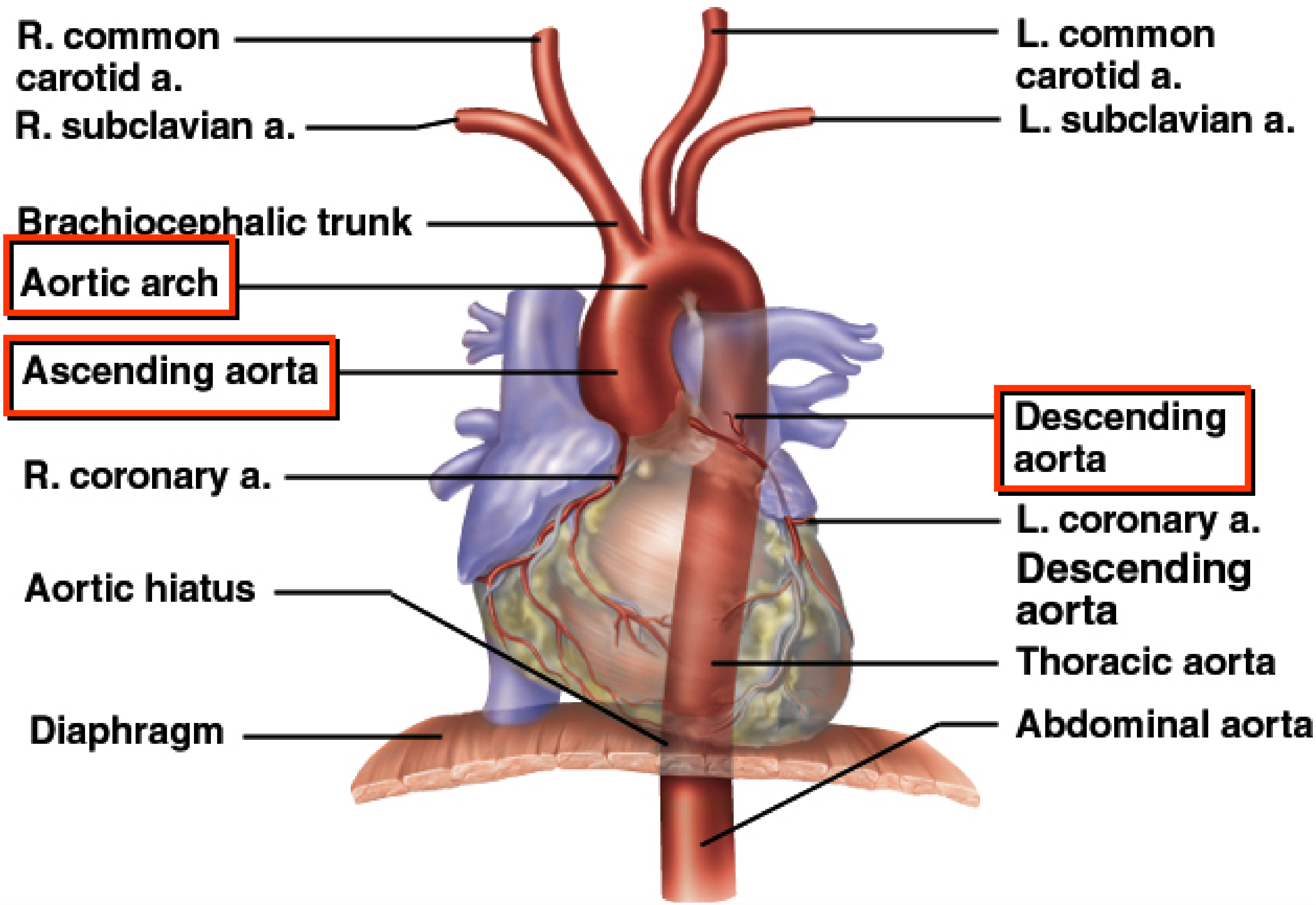


- Cardiovascular system:
  - heart, arteries, veins and capillaries; 2 major divisions:
- **Pulmonary circuit** - right side of heart
  - carries venous, deoxygenated blood to lungs for gas exchange
- **Systemic circuit** - left side of heart
  - supplies blood to all organs of the body

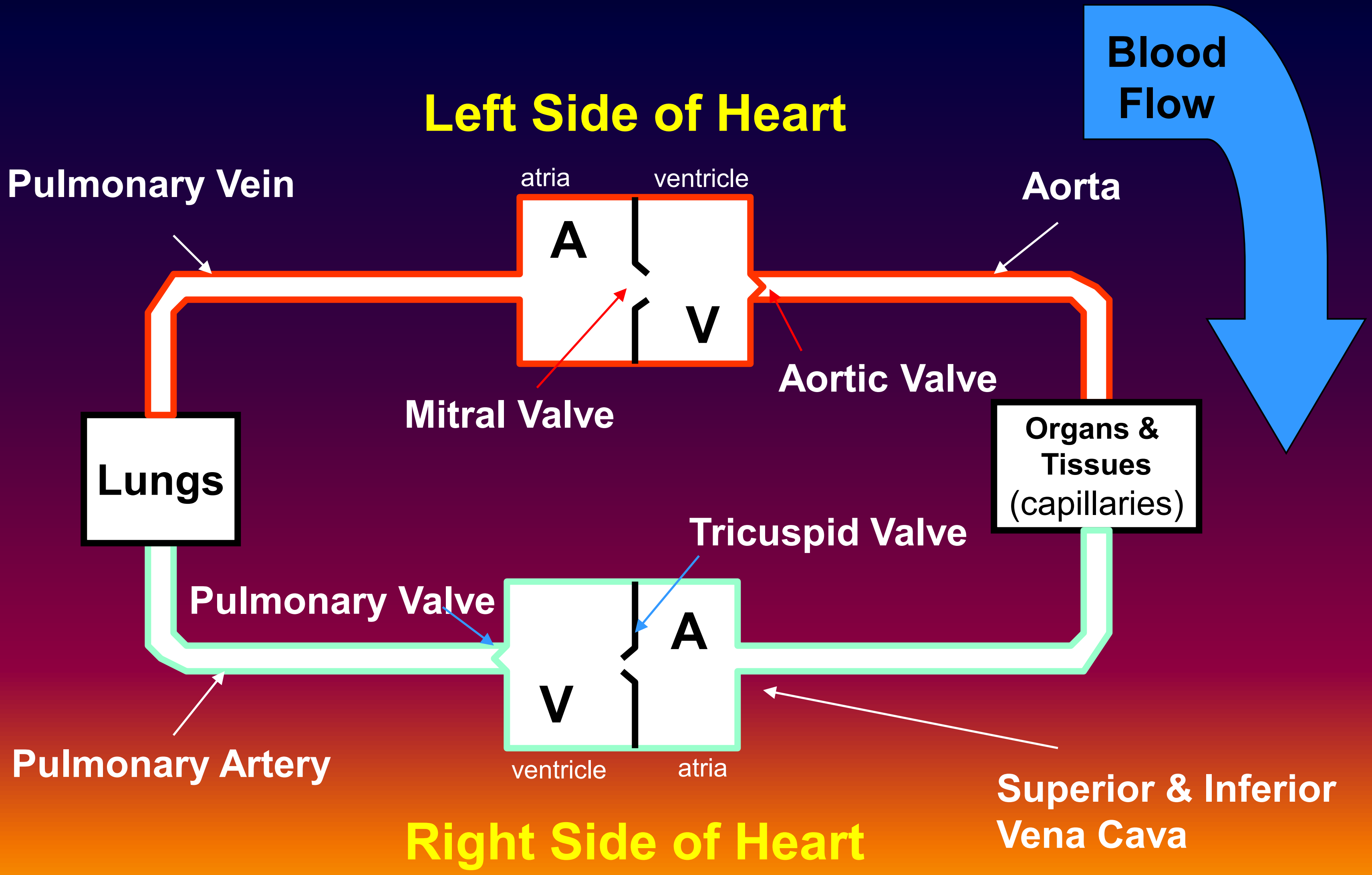
The Cardiovascular System



Major Branches of the Aorta

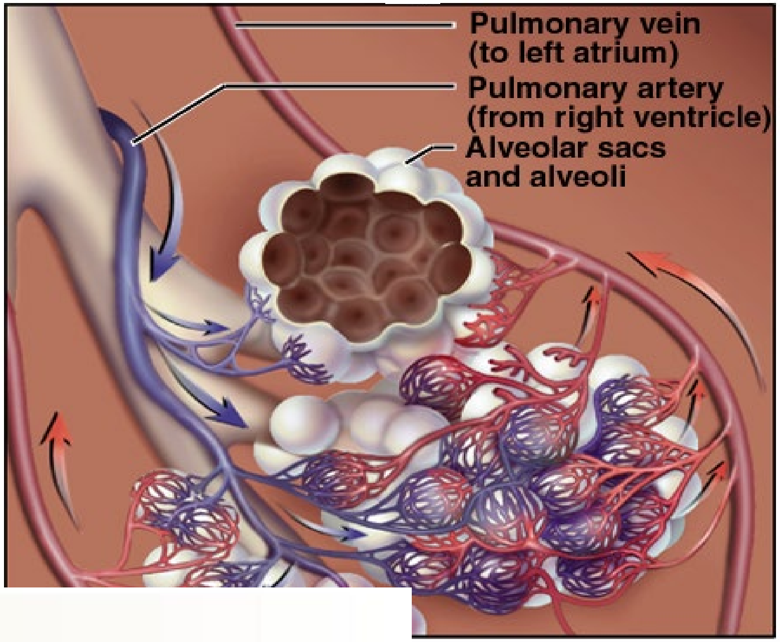


Circulation Schematic

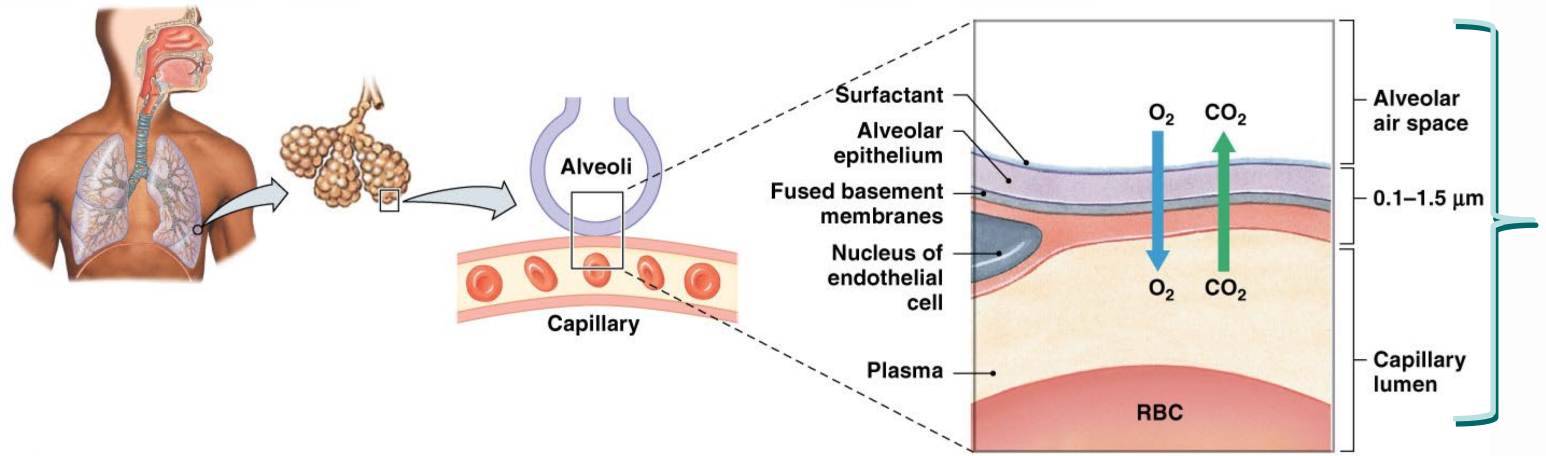


Pulmonary Capillaries Near Alveoli

- Basketlike capillary beds surround the alveoli
- Exchange of gases with air occur within the alveoli



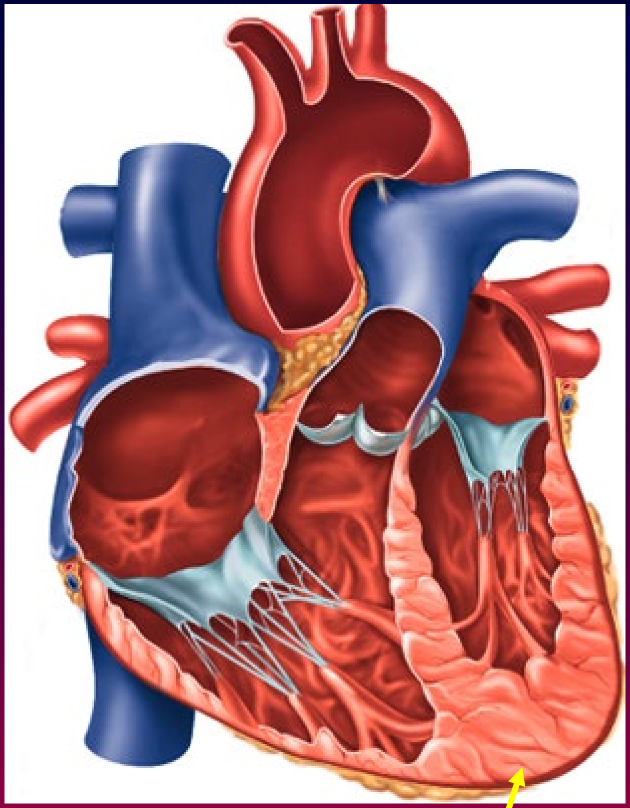
(b) Cells form a diffusion barrier between lung and blood.



Alveolar surface area within both lungs is about 70 - 80 square meters !

Heart Chambers

- 4 chambers
- Right and left atria
  - 2 superior, posterior chambers
  - receive blood returning to heart
- Right and left ventricles
  - 2 inferior chambers
  - pump blood into arteries



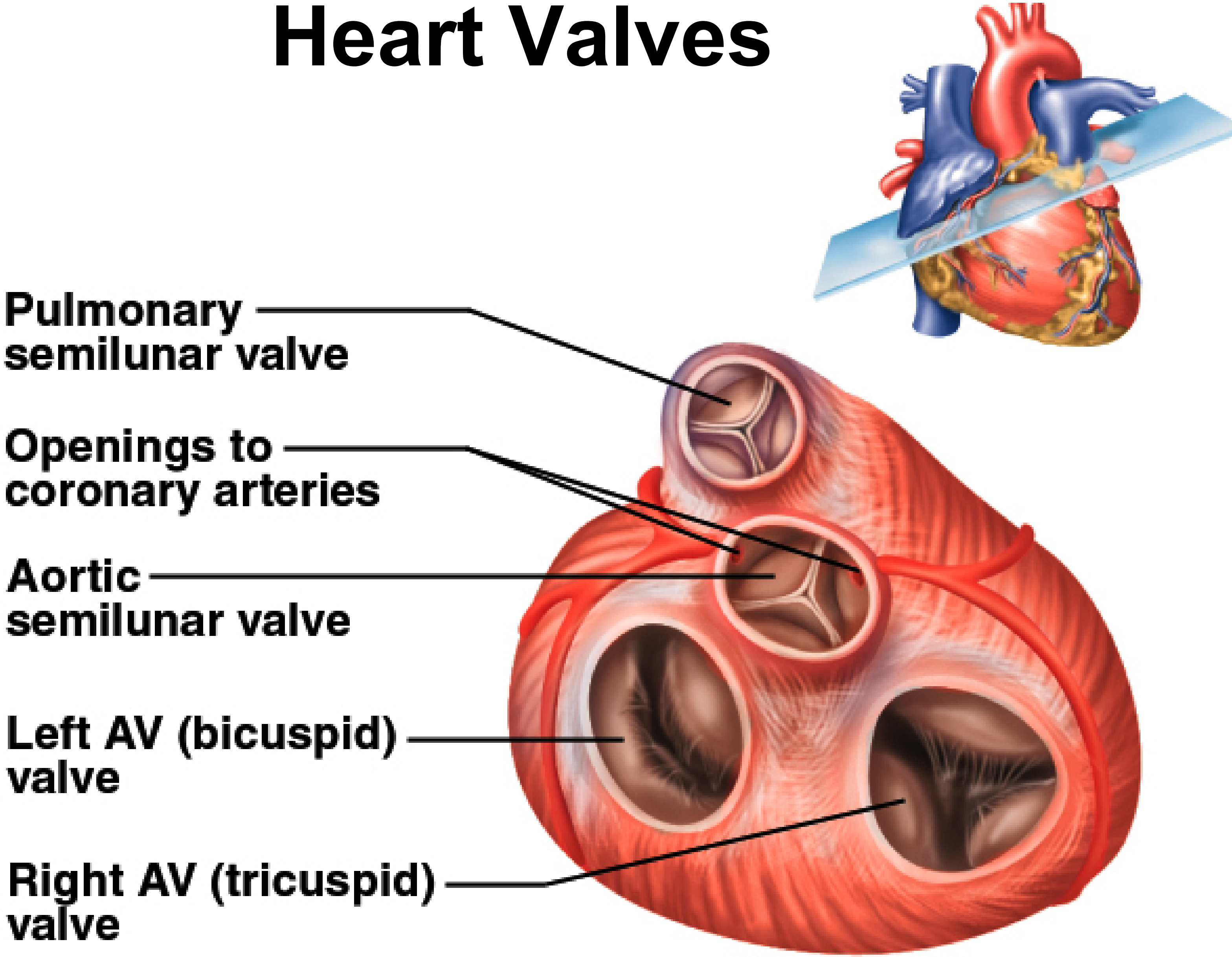
Left ventricle is more muscular

Heart Valves

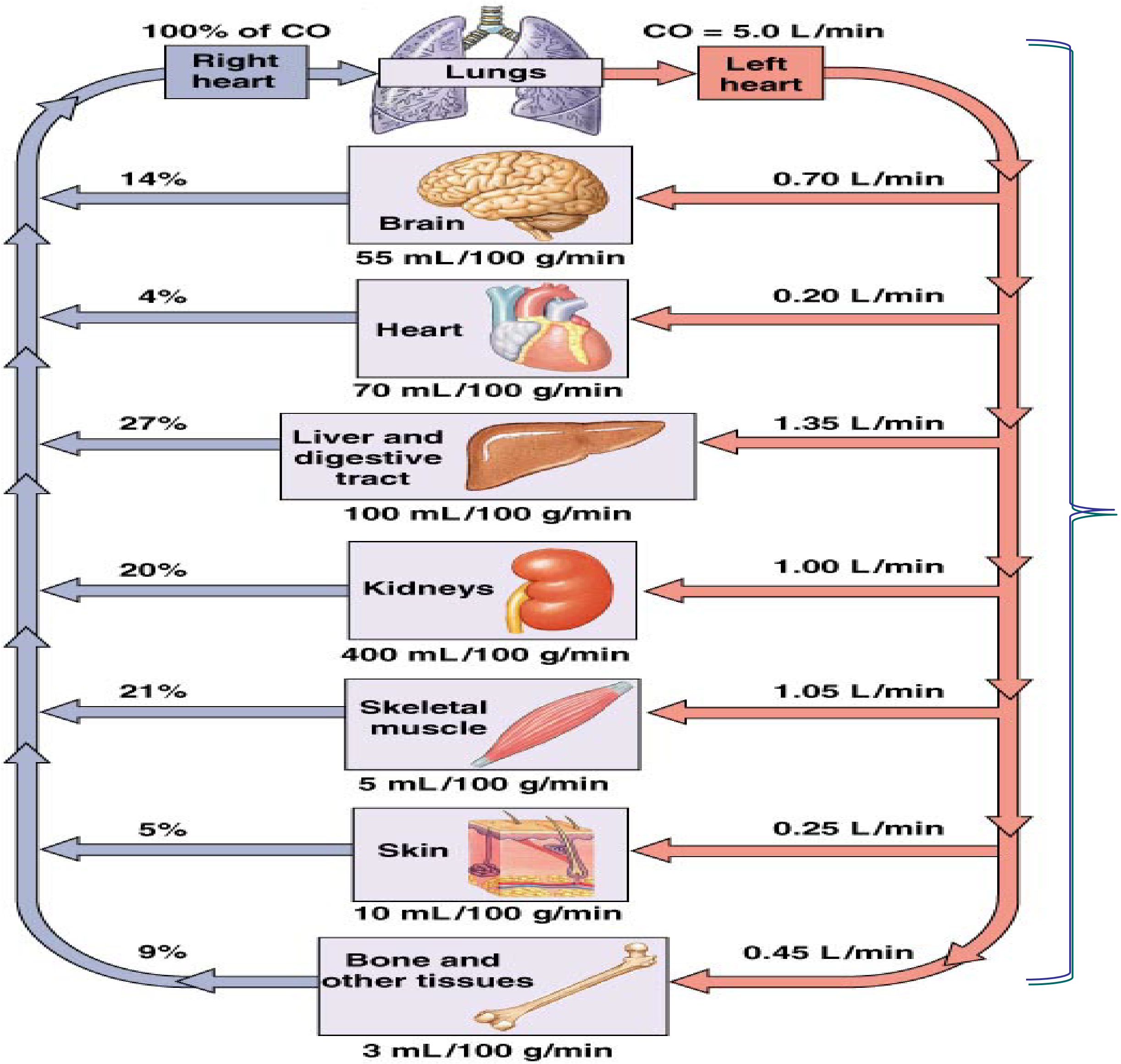
Artificial valve

- Ensure one-way blood flow
  - (analogous to a check valve or diode)
- Atrioventricular (AV) valves
  - right AV, or <u>tricuspid</u>, valve has 3 cusps
  - left AV, or <u>mitral</u>, bicuspid, valve has 2 cusps
- Semilunar valves - control flow into great arteries
  - <u>pulmonary</u>: from right ventricle into pulmonary trunk
  - <u>aortic</u>: from left ventricle into aorta

Heart Valves



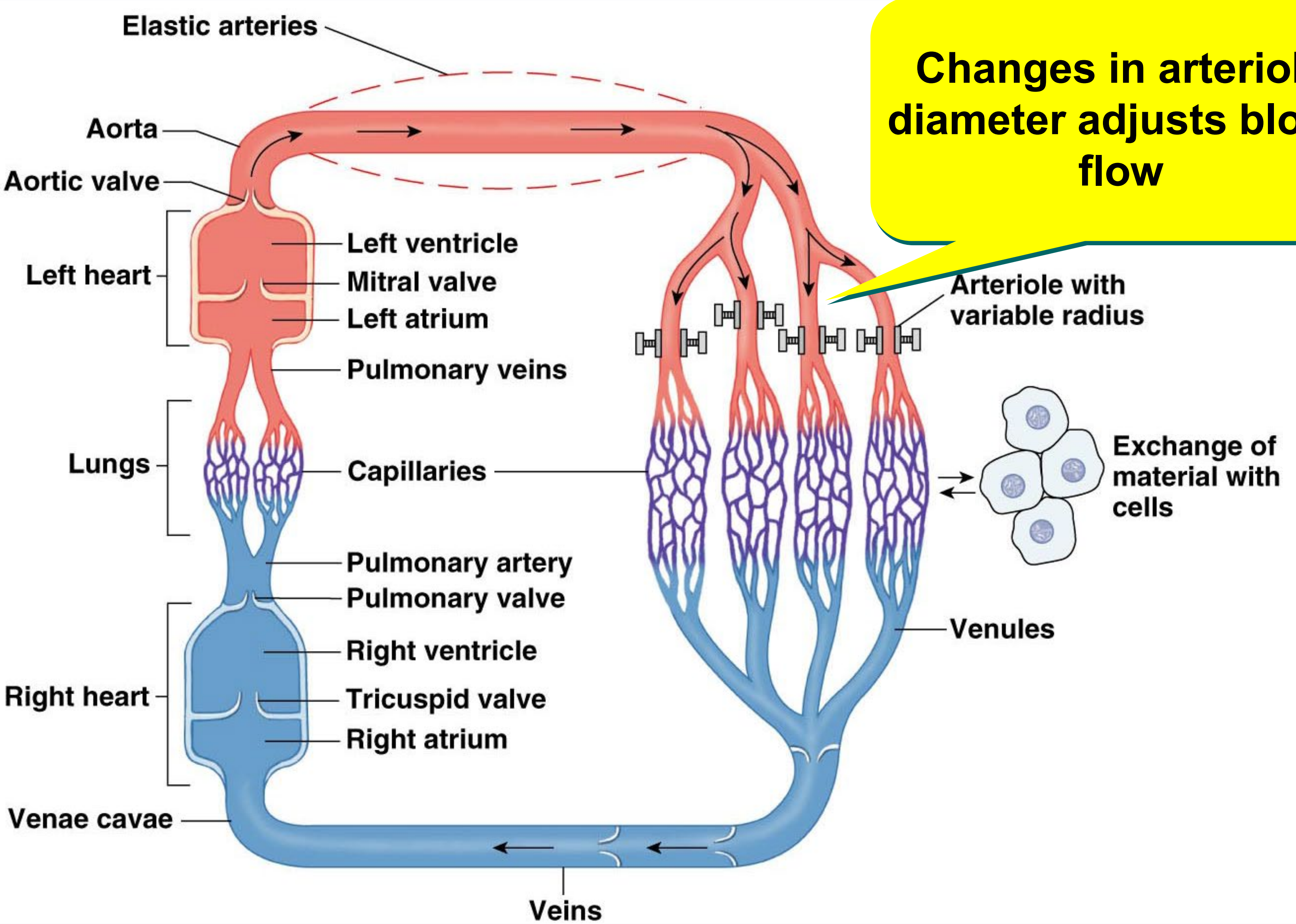
Distribution of blood in the body at rest



The body automatically adjusts blood flow to its various organs based upon their metabolic need. Total blood flow leaving the heart (cardiac output) also increases accordingly.

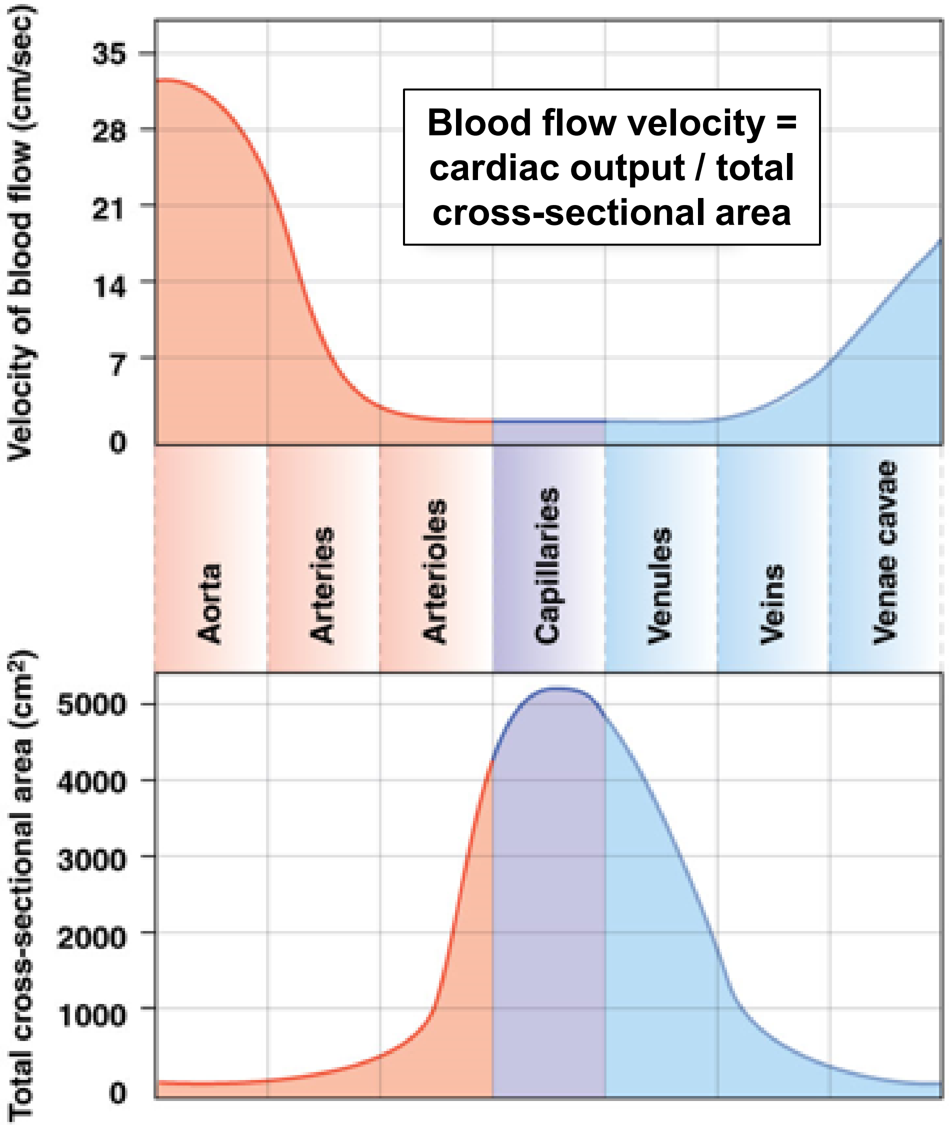
Functional Model of the Cardiovascular System

Changes in arteriole diameter adjusts blood flow

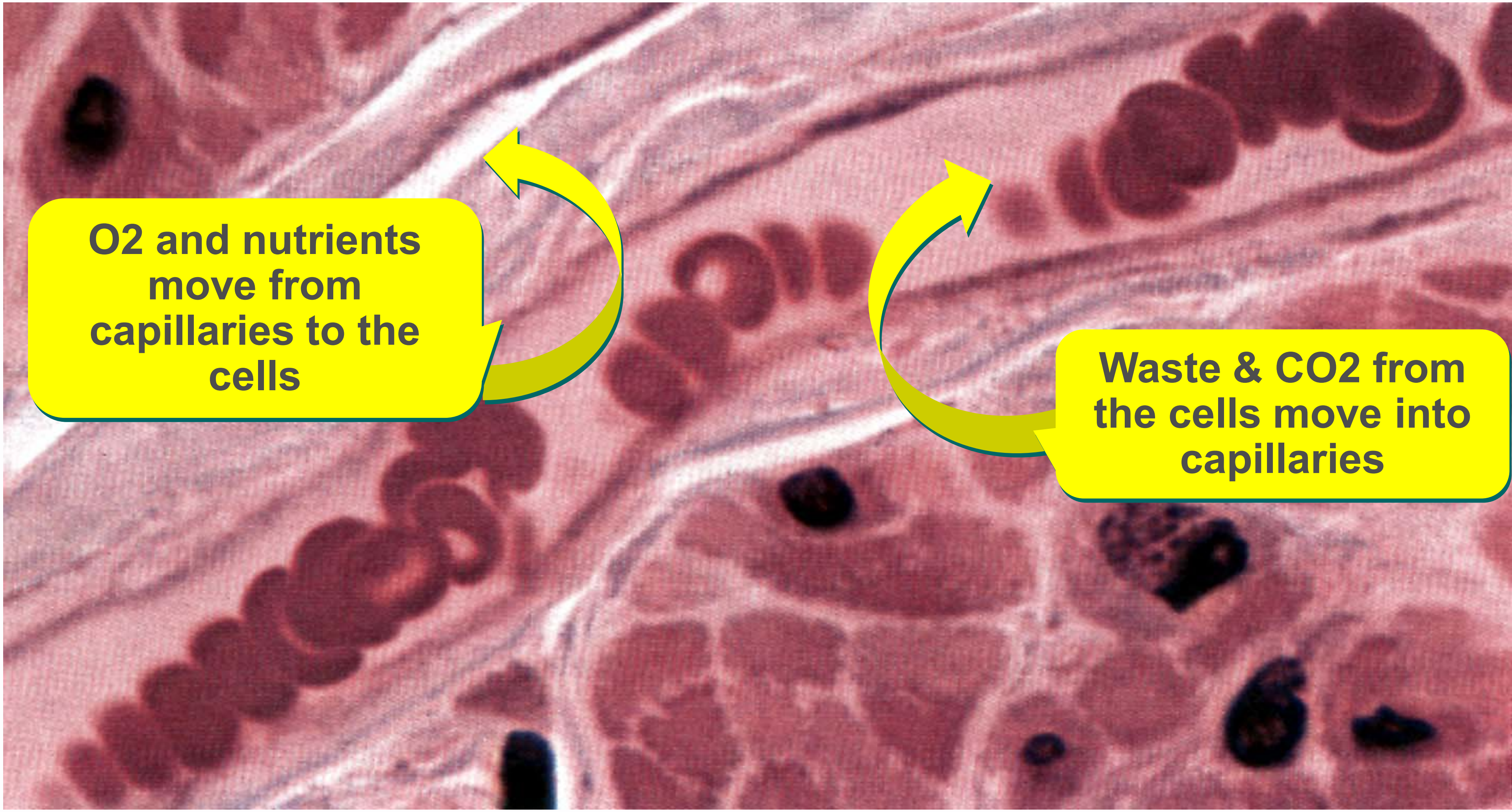


Circulatory system design

- The arterial system is characterized by successive branching down to the level of the capillaries.
- Capillaries coalesce into larger (and fewer) veins.
- Velocity of flow depends on cardiac output and total cross-sectional area of the vessels.



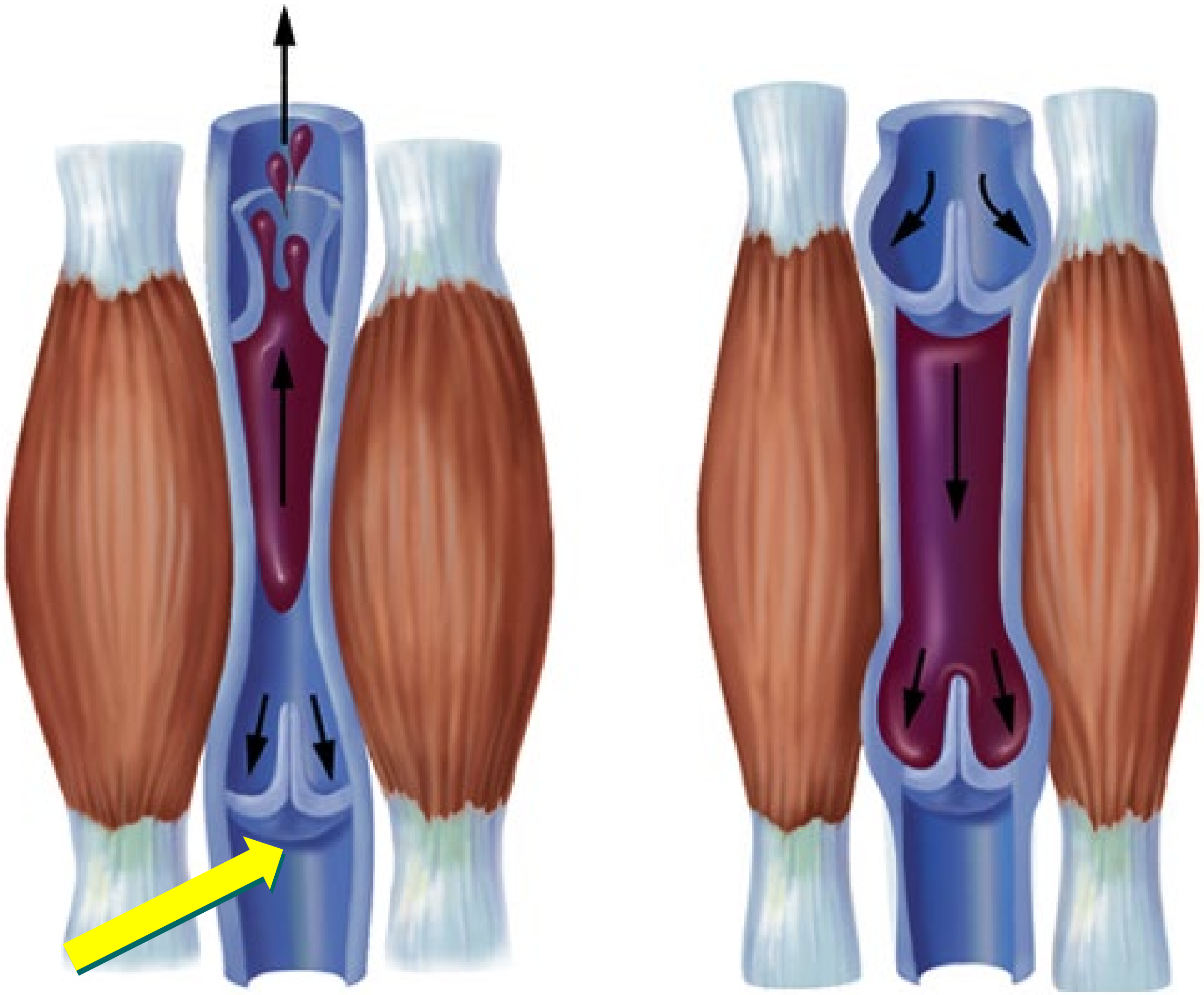
Blood flow in capillaries



- Red blood cells moving single file through a capillary
- It is where the exchange of gases, nutrients, fluids, wastes occur

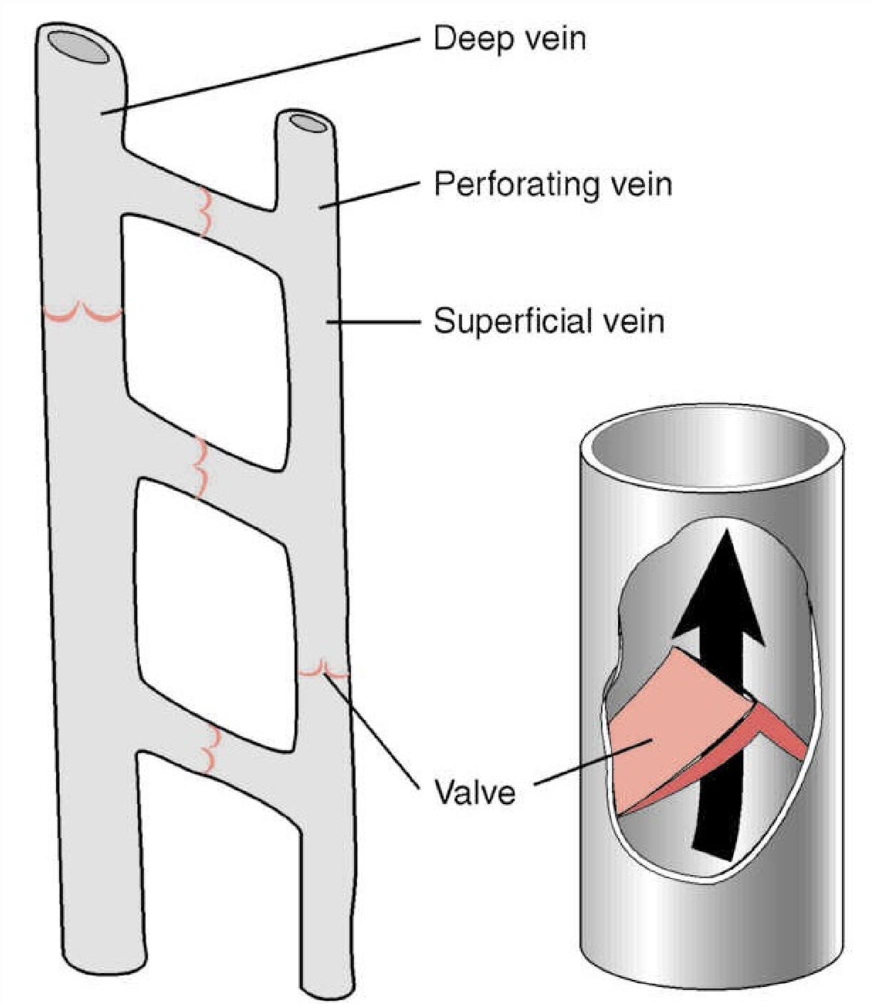
Skeletal Muscle Pump

Passively assists in returning venous blood to the heart

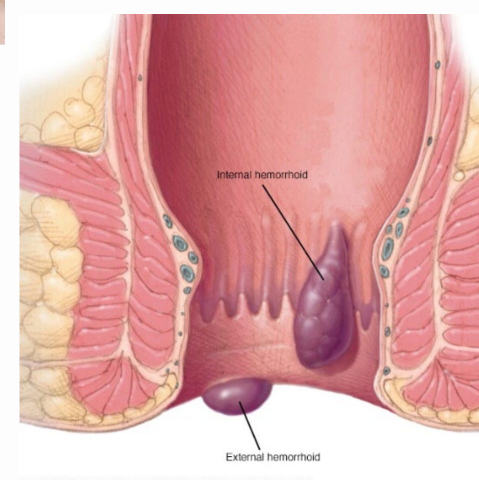


Most veins contain a series of ‘check valves’ that prevent backflow on the blood’s return to the right heart.

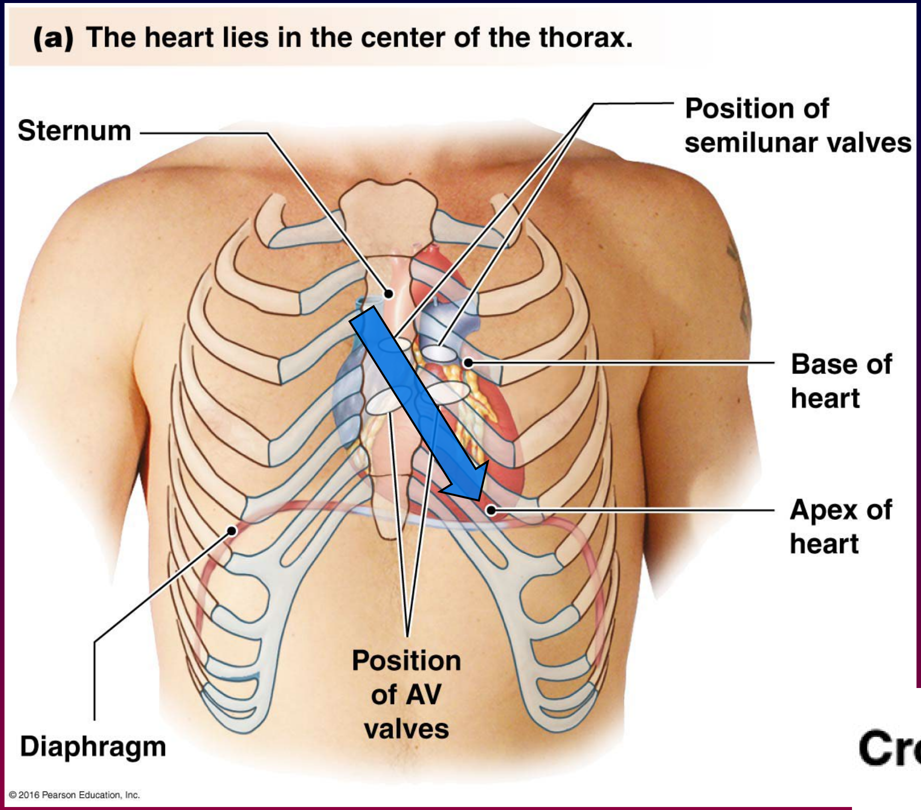
Venous valves of the leg

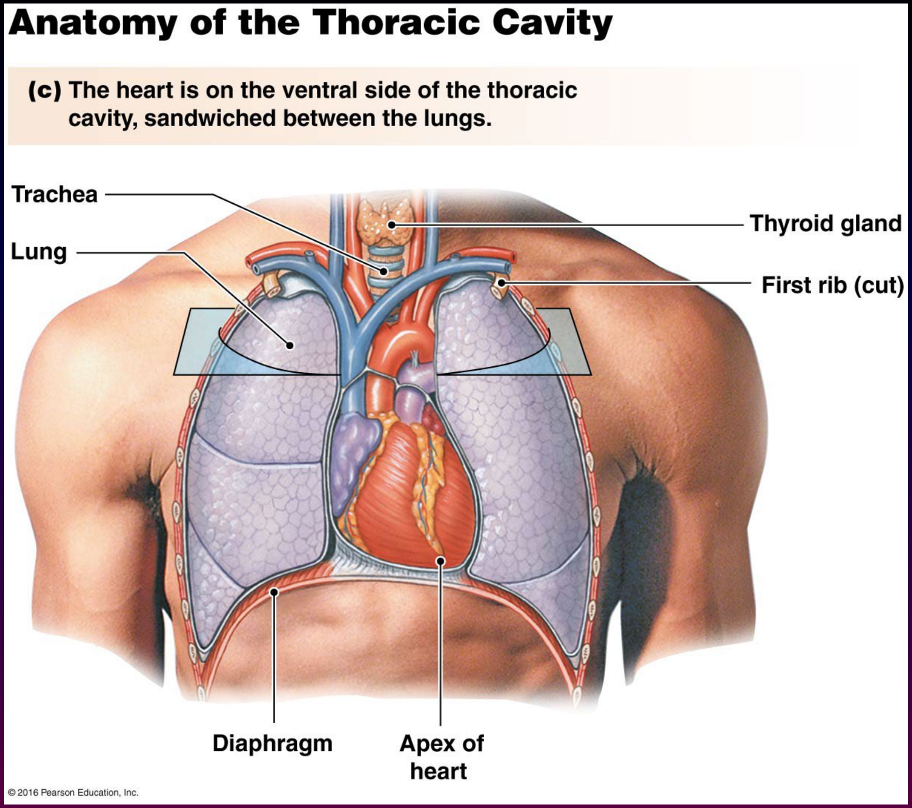


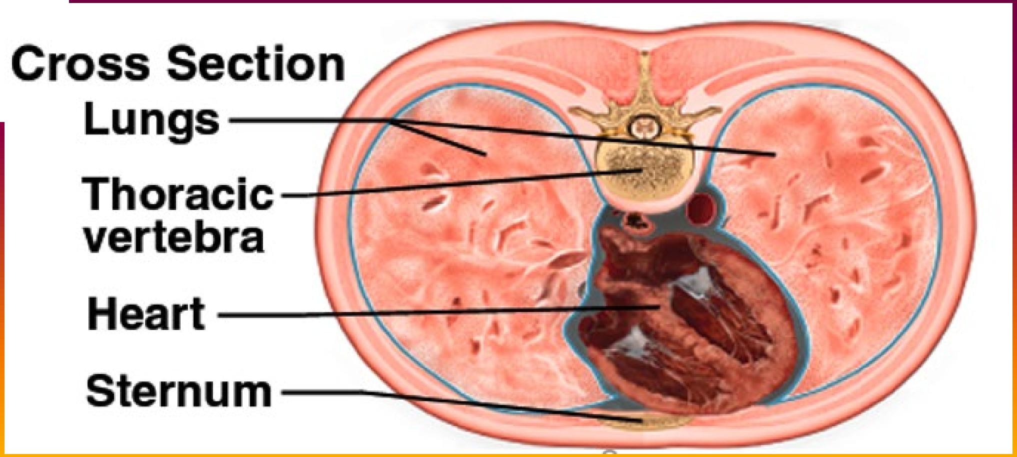
Failure or prolapse of these valves results in varicose veins and hemorrhoids



Position of the Heart





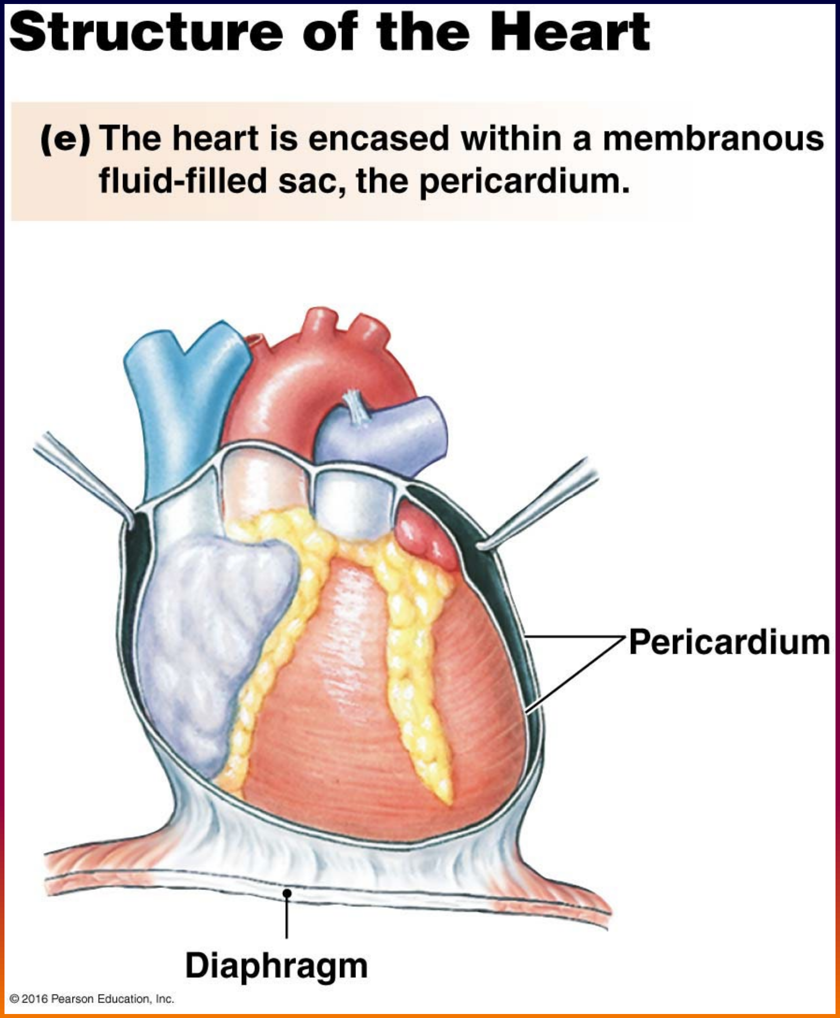


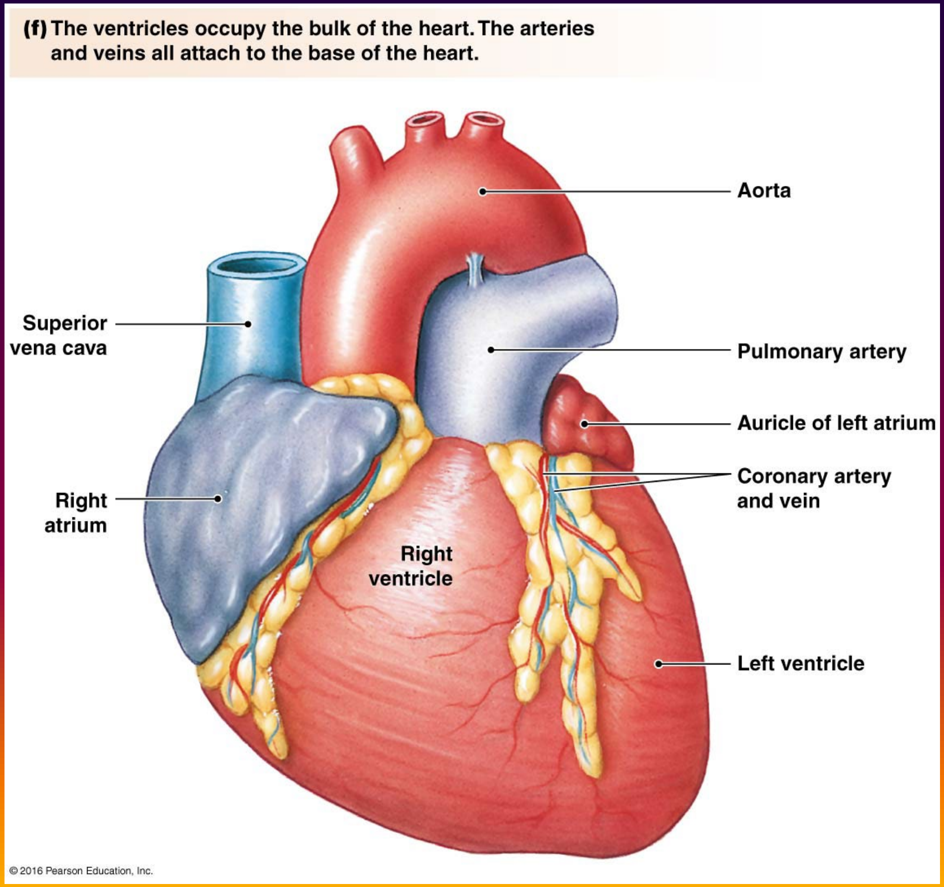
Basis for the placement of ECG electrodes and defibrillator paddles.

Structure of the Heart

- The heart is composed mostly of myocardium

(Cardiac muscle)



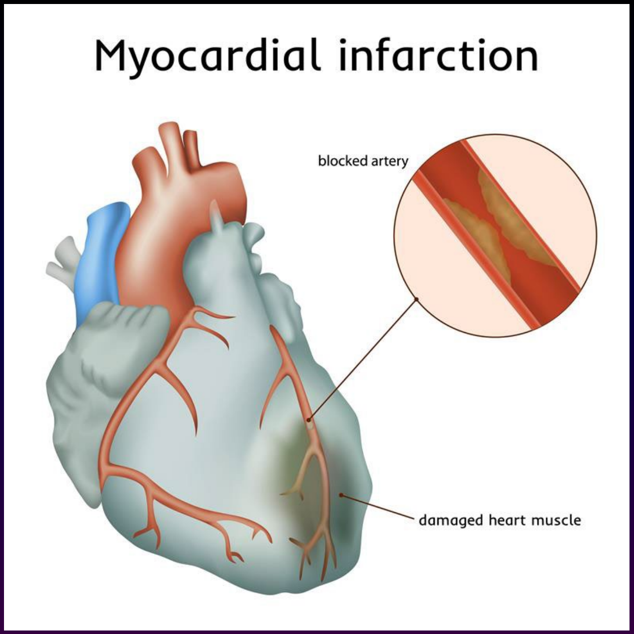


Pericardial fluid dramatically reduces the friction of the beating heart.

Coronary Circulation

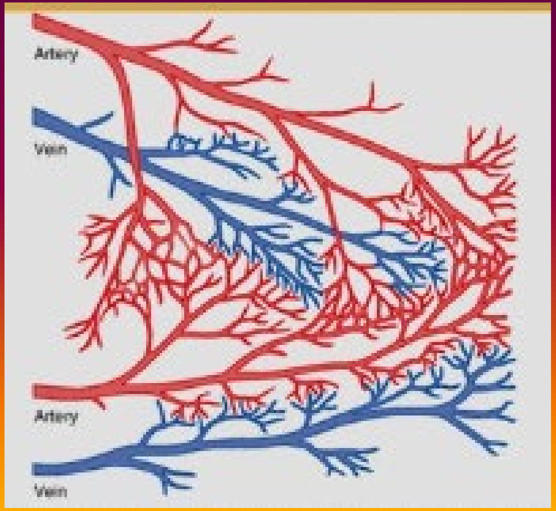
- Blood vessels of heart wall nourish cardiac muscle
- Left coronary artery - under left auricle, 2 branches
  - anterior interventricular artery
    - supplies interventricular septum + anterior walls of ventricles
  - circumflex artery
    - passes around left side of heart in coronary sulcus, supplies left atrium and posterior wall of left ventricle
- Right coronary artery - supplies right atrium
  - passes under right auricle in coronary sulcus, divides:
  - marginal artery and posterior interventricular artery
    - supplies posterior walls of ventricles

Myocardial Infarction

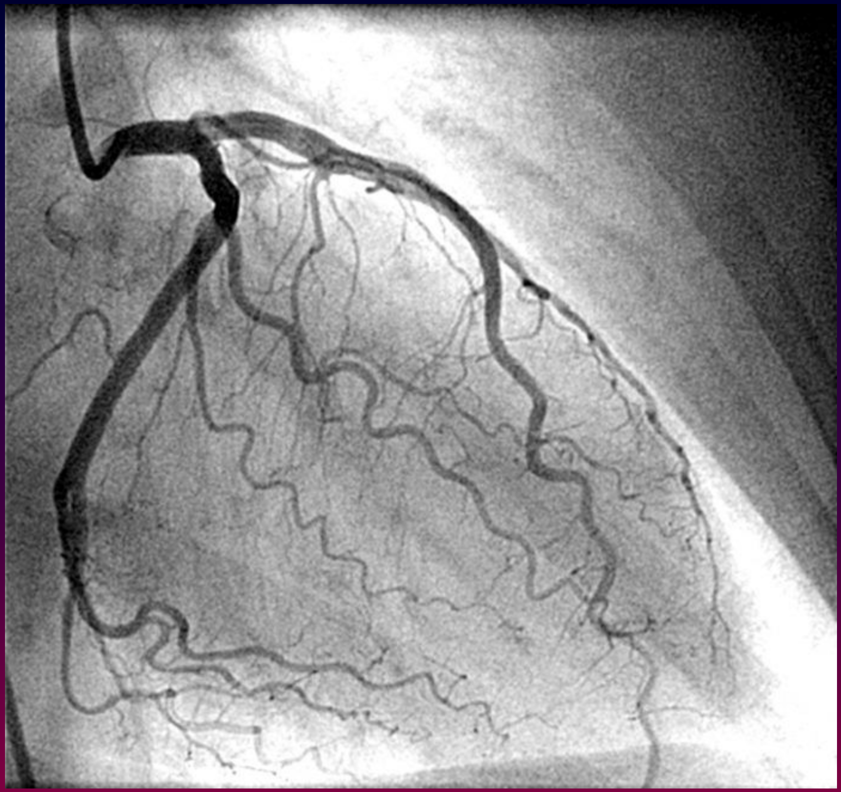


- Sudden death of heart tissue caused by interruption of blood flow from vessel narrowing or occlusion

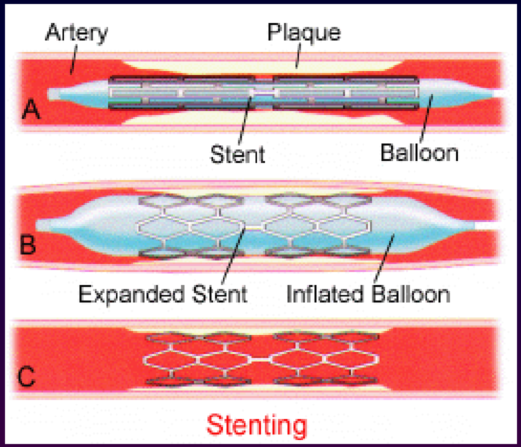
- Anastomoses defend against interruption by providing alternate blood pathways



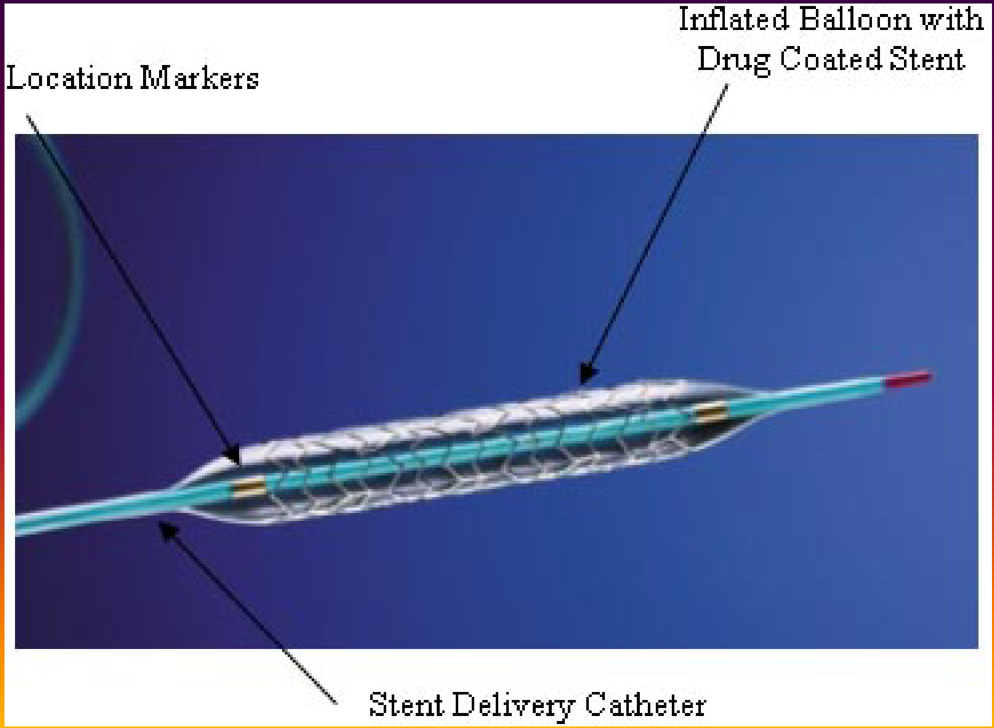
Balloon Angioplasty and Stents



Coronary angiogram



Contrast injector



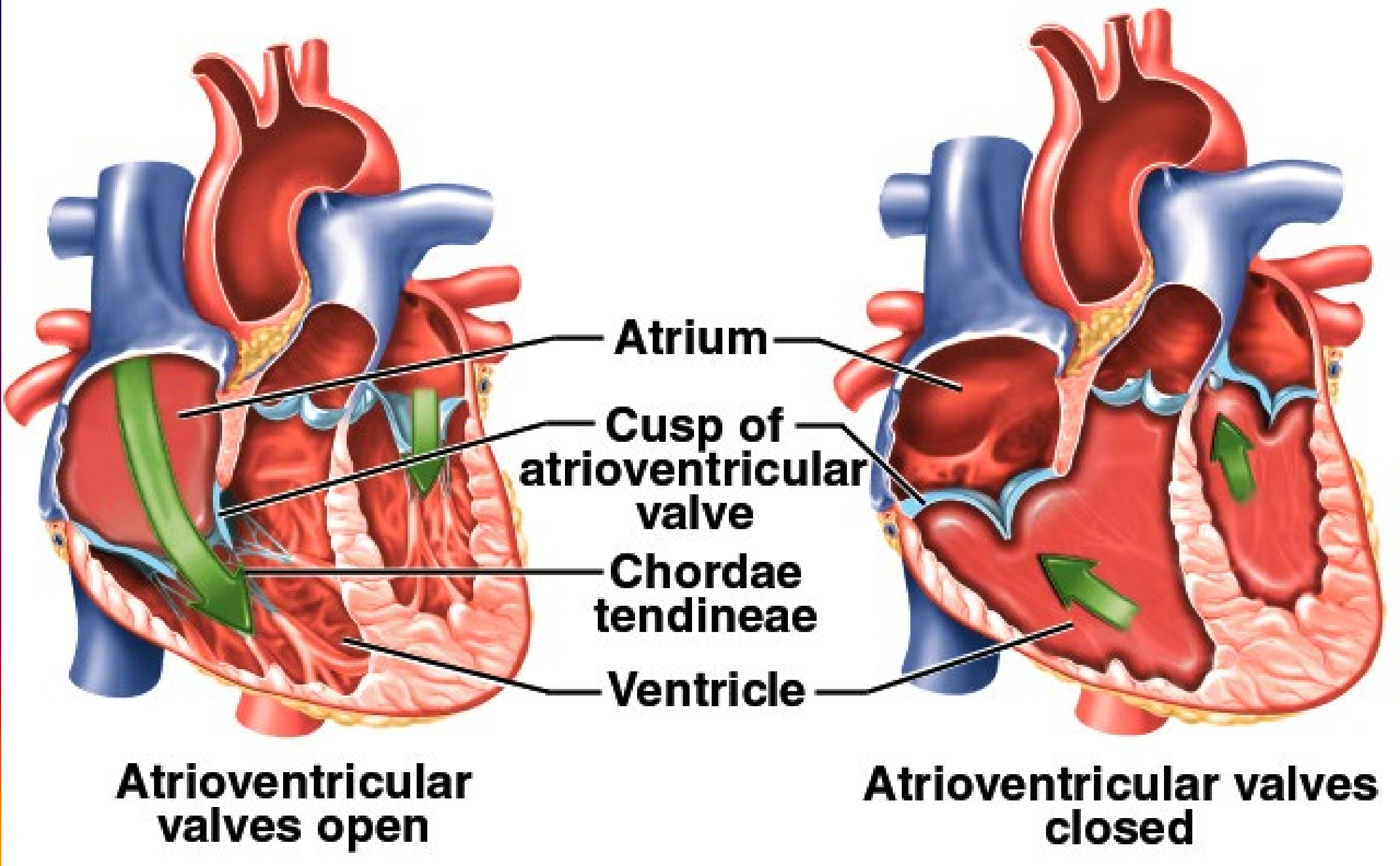
AV Valve Mechanics

- **Ventricles relax, *pressure drops*, semilunar valves close, AV valves open, blood flows from atria to ventricles**

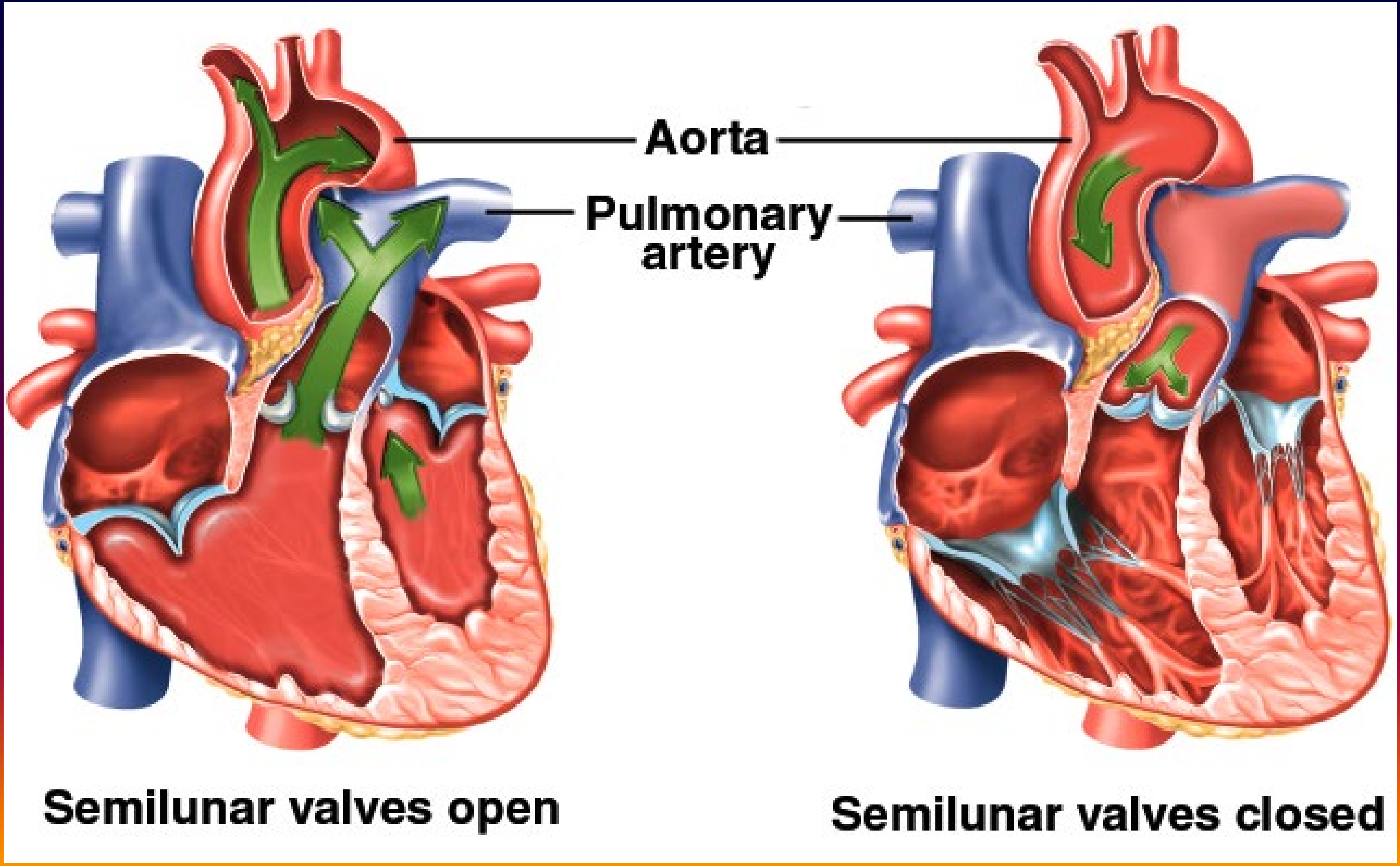
- **Ventricles contract, *pressure rises*, AV valves close, (papillary m. contracts and pulls on chordae tendineae to prevent prolapse) *pressure rises* and semilunar valves open, blood flows into arteries**

Heart valves open and close due to pressure drops and changes during the cardiac cycle.

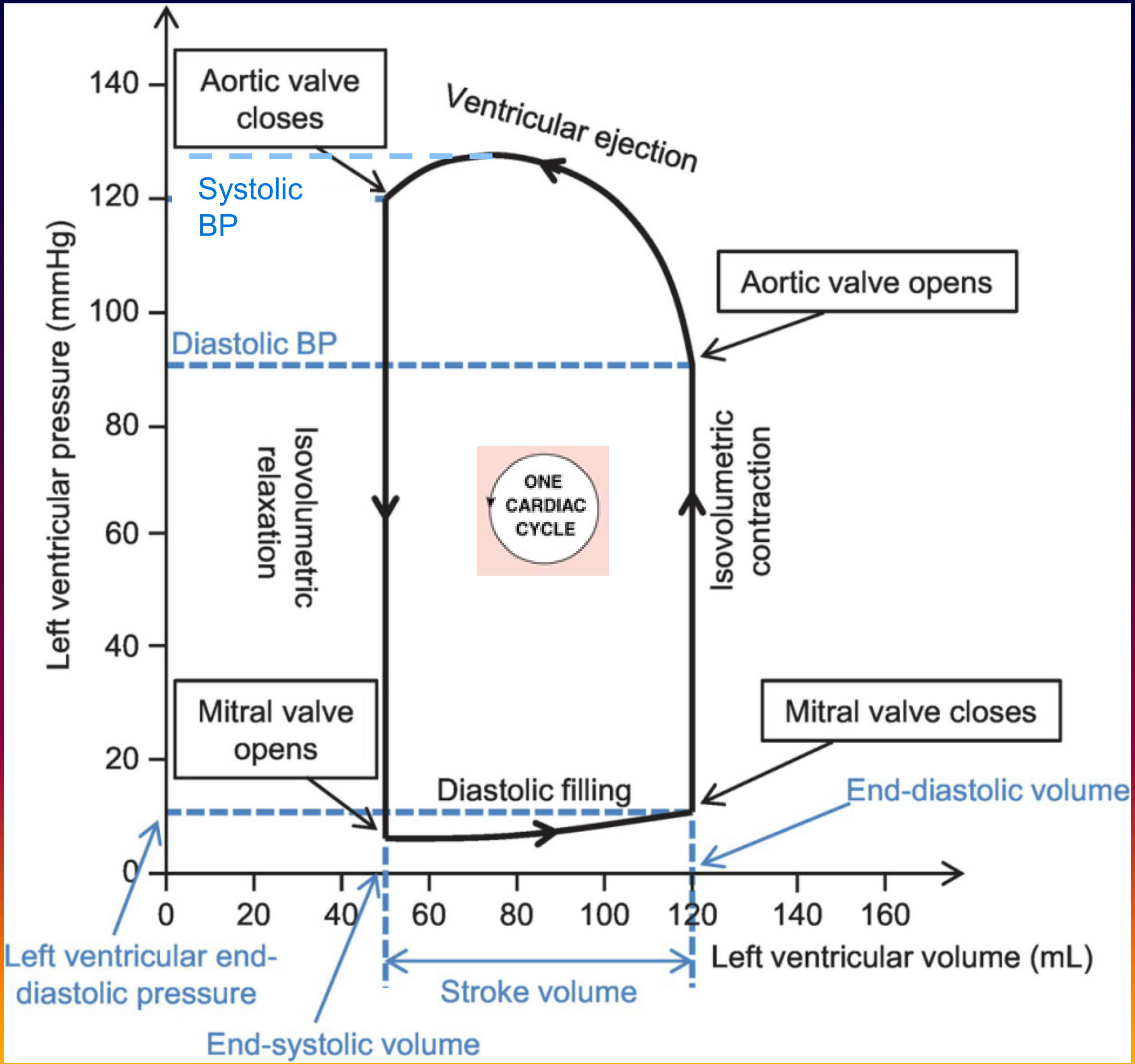
Operation of Atrioventricular Valves



Operation of Semilunar Valves



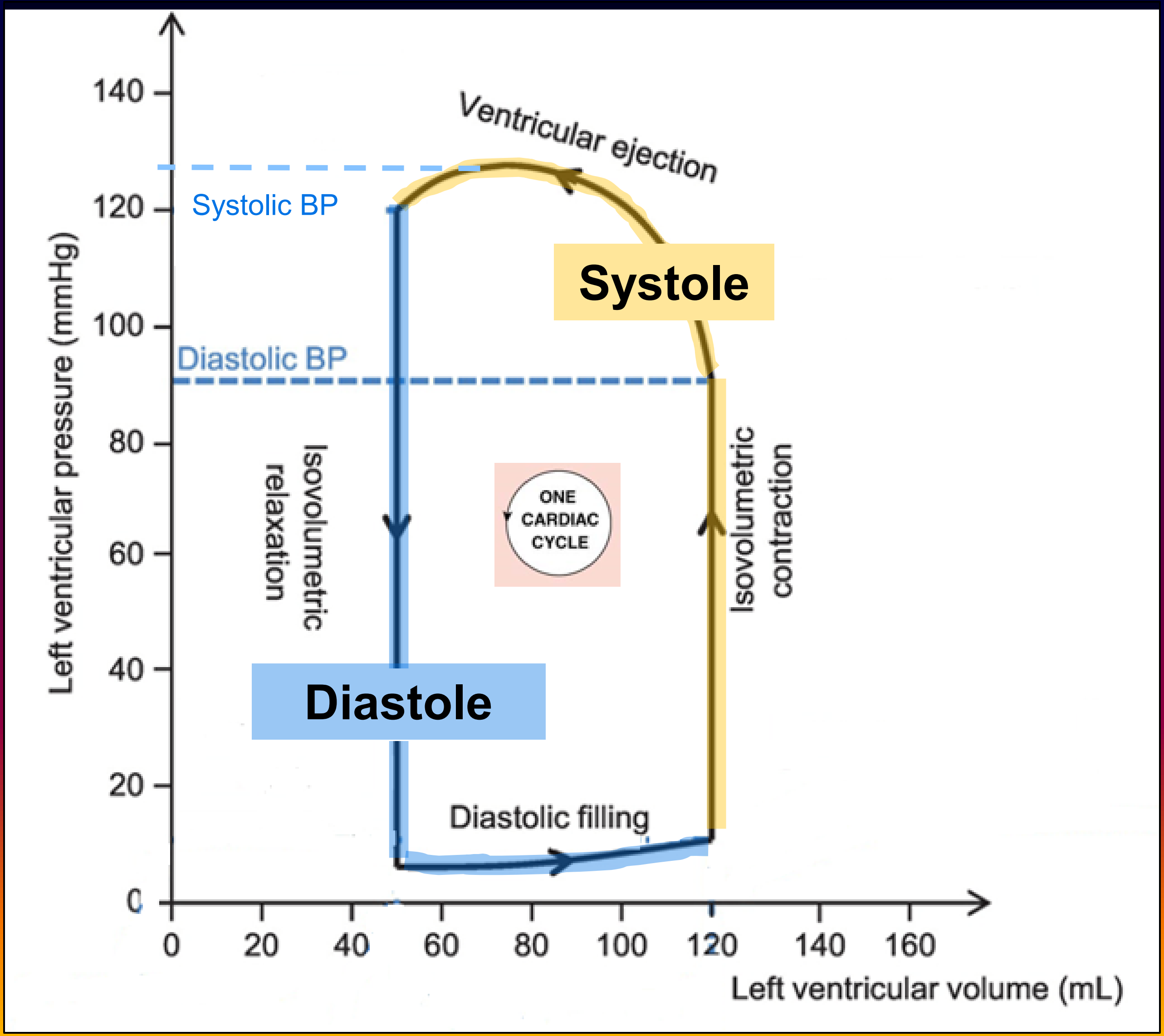
Pressure – volume relationships
(left ventricle)



Ejection fraction:

- Is the ratio of the stroke volume to end diastolic volume
- Is a measure of heart health
- Normally ranges from 55-70%

Pressure – volume relationships
(left ventricle)



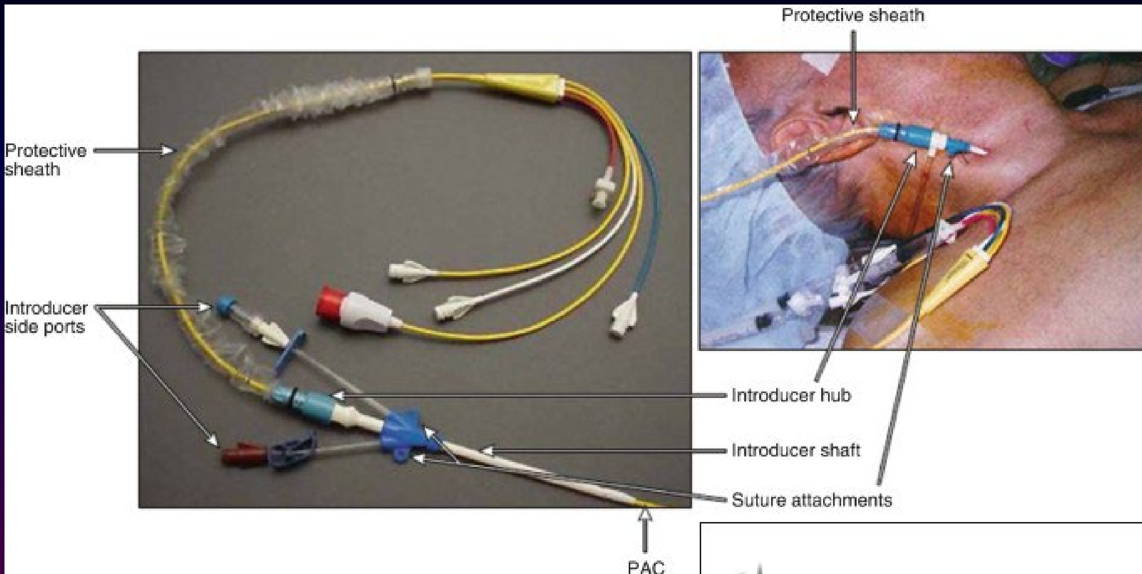
Systole = contractile, working phase of cardiac cycle.

Diastole = relaxation, filling phase. The heart spends about 2/3 of its time in diastole. This is when the heart is being perfused.

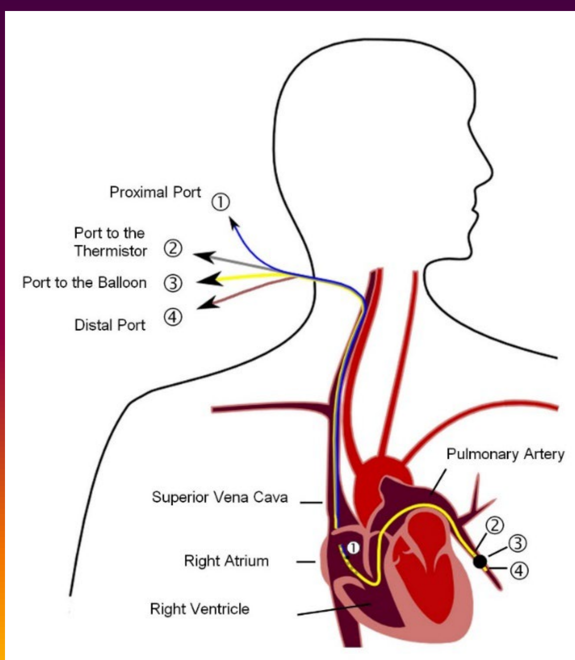
Cardiac Output (CO)

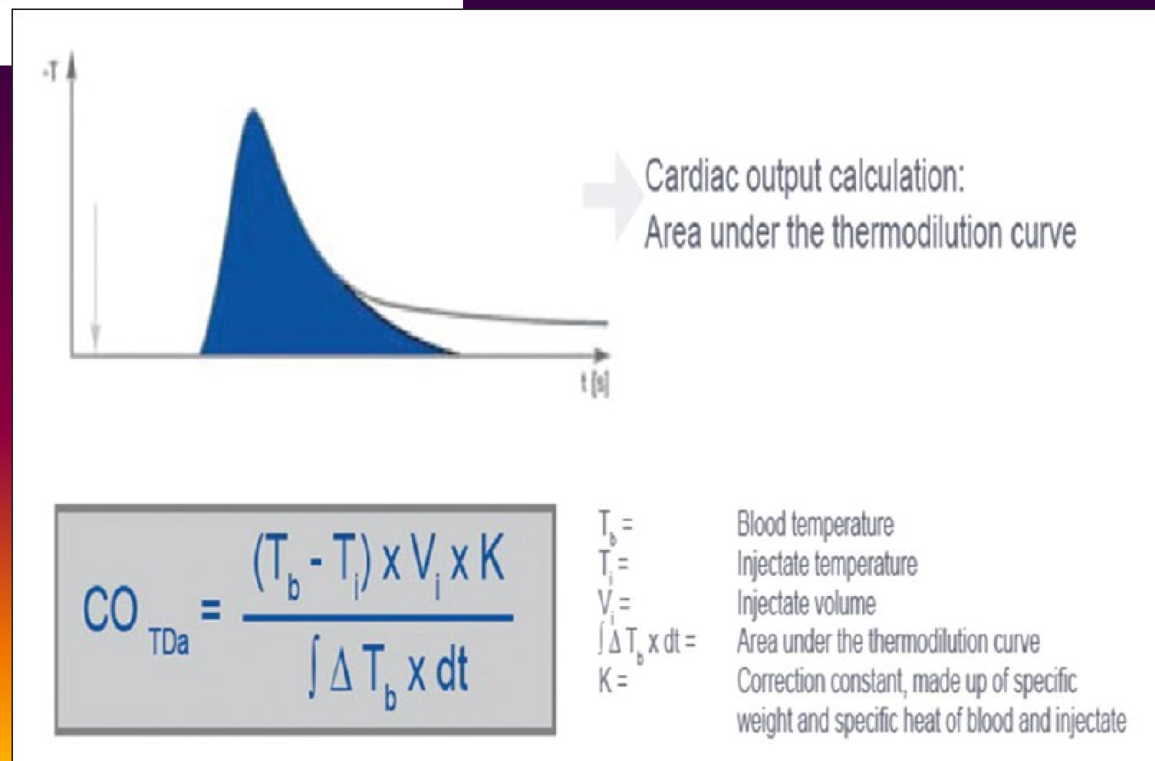
- Volume of blood ejected by each ventricle in 1 minute
- Cardiac Output = Heart Rate x Stroke Volume
- Resting values, CO = 75 beats/min x70 ml/beat = 5,250 ml/min, usually about 4 to 6L/min
- Vigorous exercise ↑ CO to 21 L/min for fit person and up to 35 L/min for world class athlete
- Cardiac reserve: difference between maximum and resting CO

Measurement of cardiac output



by thermodilution



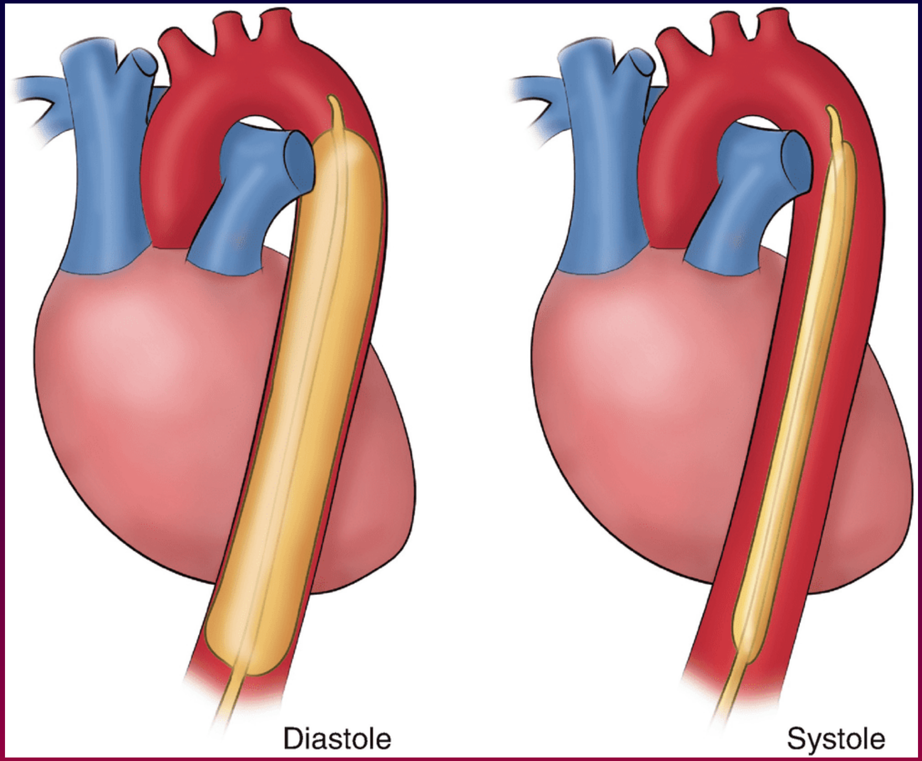


Afterload

- Pressure in arteries above semilunar valves which opposes opening of valves
- ↑ afterload, ↓ SV
  - any impedance in arterial circulation ↑ afterload
- Continuous ↑ in afterload (lung disease, atherosclerosis, etc.) causes hypertrophy of myocardium, may lead it to weaken and fail

Intra-aortic Balloon Pump

A therapeutic ventricular assist device that improves blood flow to the coronary arteries and reduces afterload.



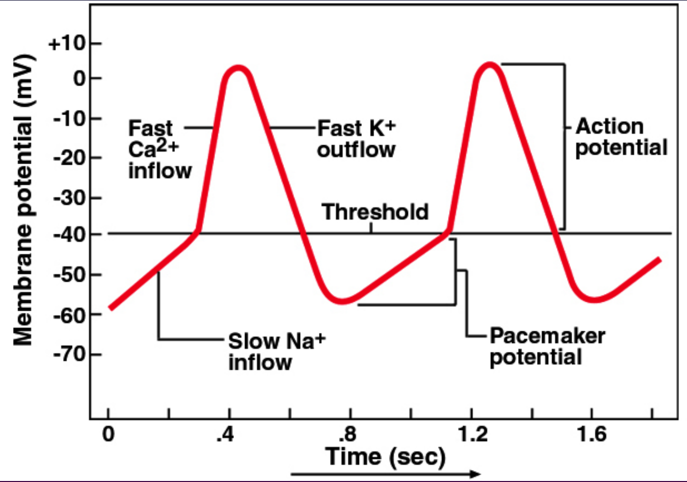
Rapid inflation of helium-filled balloon during diastole increases blood flow to coronary arteries

Rapid deflation at the onset of systole reduces afterload making it easier for heart to eject blood

Cardiac Conduction System

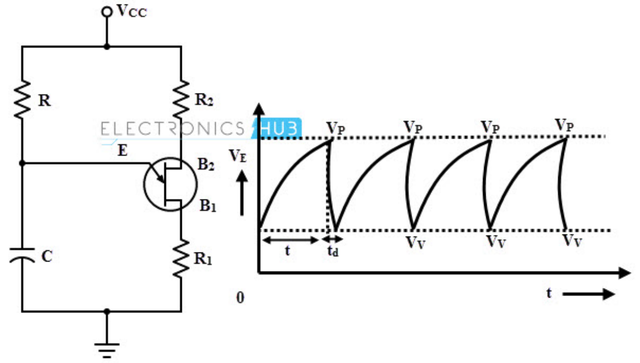
- **Myogenic** - heartbeat originates within heart
- **Autorhythmic** - depolarize spontaneously regularly
- Conduction system
  - **Sinoatrial (SA) node**: pacemaker, initiates heartbeat, sets heart rate
  - *fibrous skeleton insulates atria from ventricles*
  - **Atriventricular (AV) node**: electrical gateway to ventricles
  - **AV bundle**: pathway for signals from AV node
  - Right and left bundle branches: divisions of AV bundle that enter interventricular septum and descend to apex
  - **Purkinje fibers**: upward from apex spread throughout ventricular myocardium

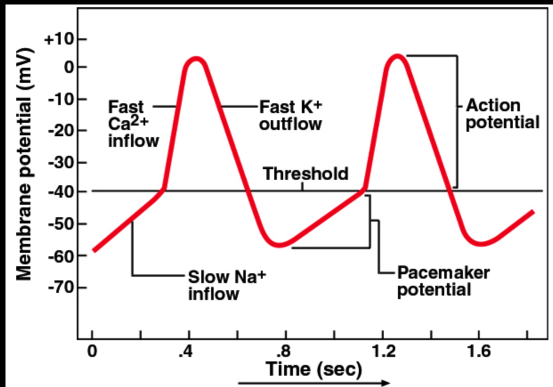
SA Node Potentials



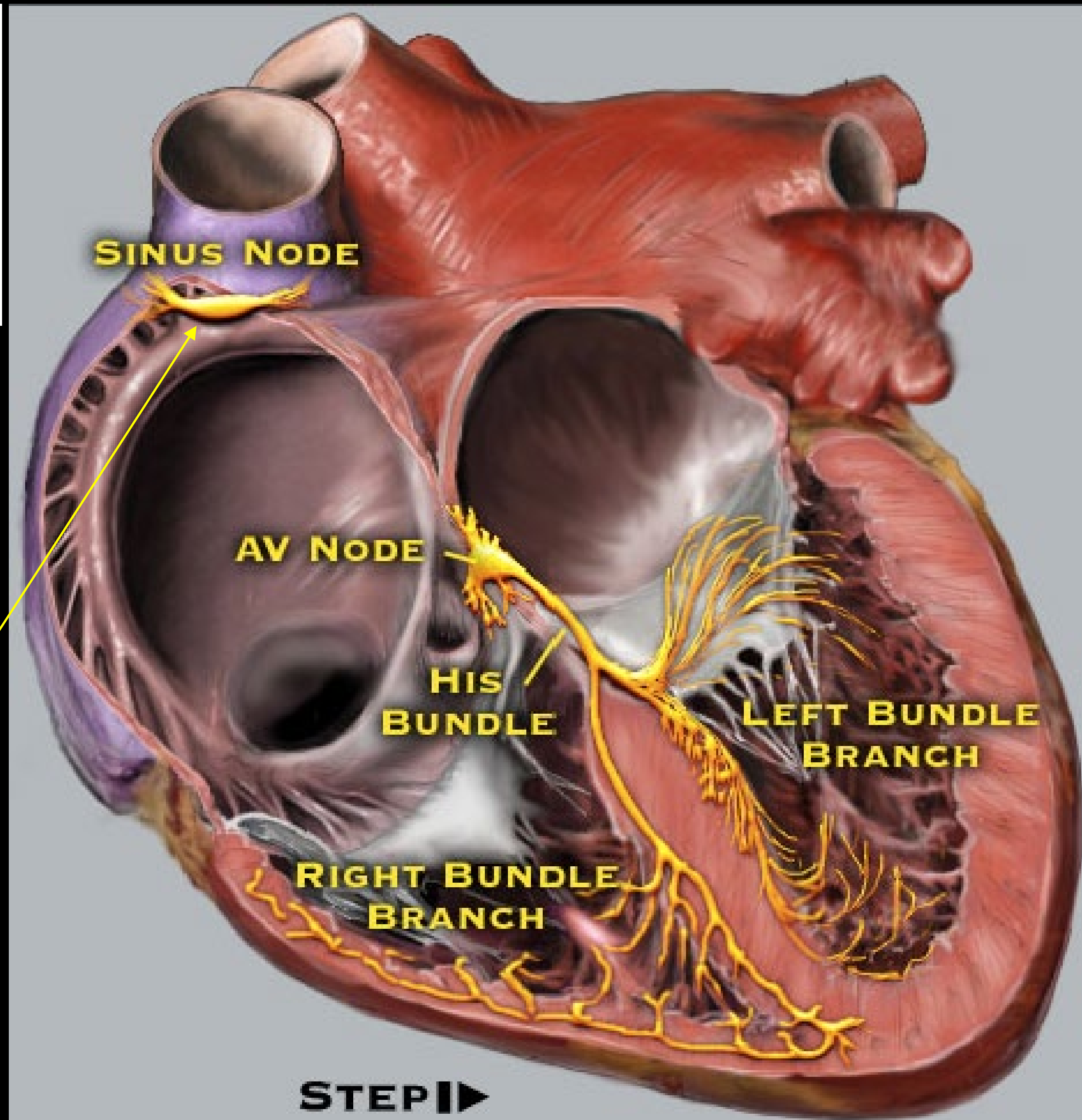
Spontaneously depolarize or 'fire' which triggers a heartbeat; electrically analogous to the output of a relaxation oscillator.

- SA node – has no stable resting membrane potential
- Action potential:
  - at threshold *-40 mV*, fast Ca^{+2} channels open, (Ca^{+2} in)
  - depolarizing phase *to 0 mV*, K^+ channels open, (K^+ out)
  - repolarizing phase *back to -60 mV*, K^+ channels close
- Each depolarization creates one heartbeat
  - SA node at rest fires at about 90 bpm but is reduced to about 75 bpm by autonomic nervous system

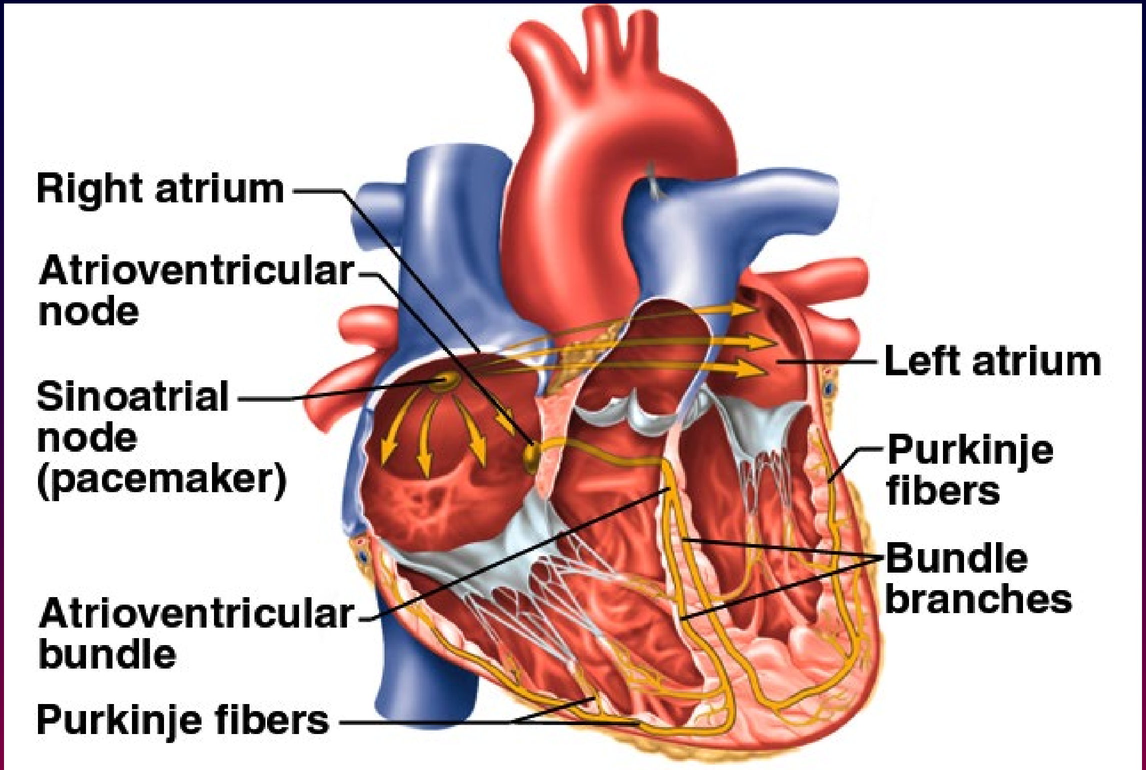


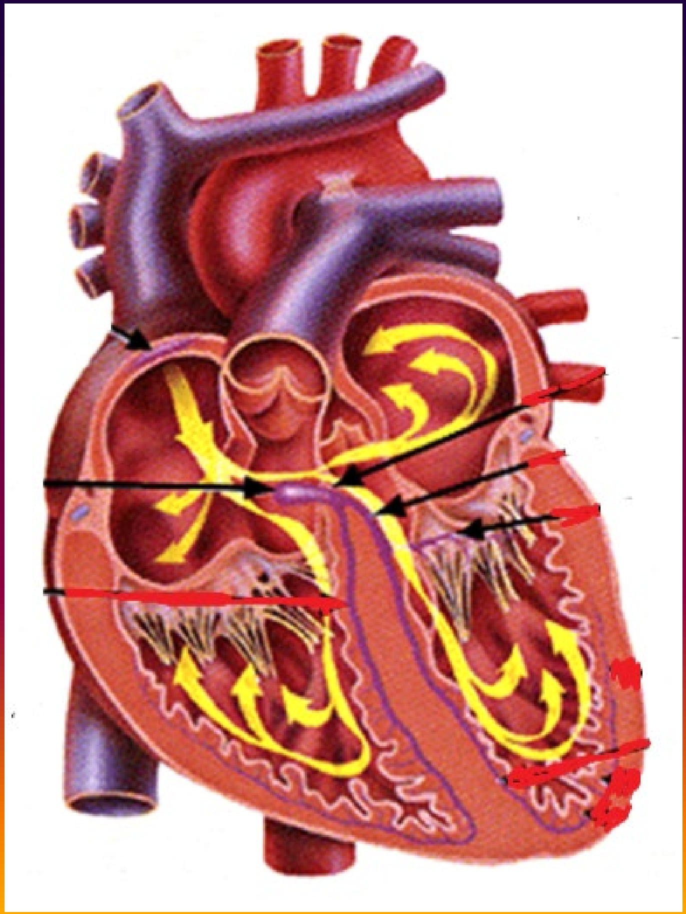


Cardiac action potential originates in SA node and then spreads throughout the heart in a (normally) very repeatable manner.



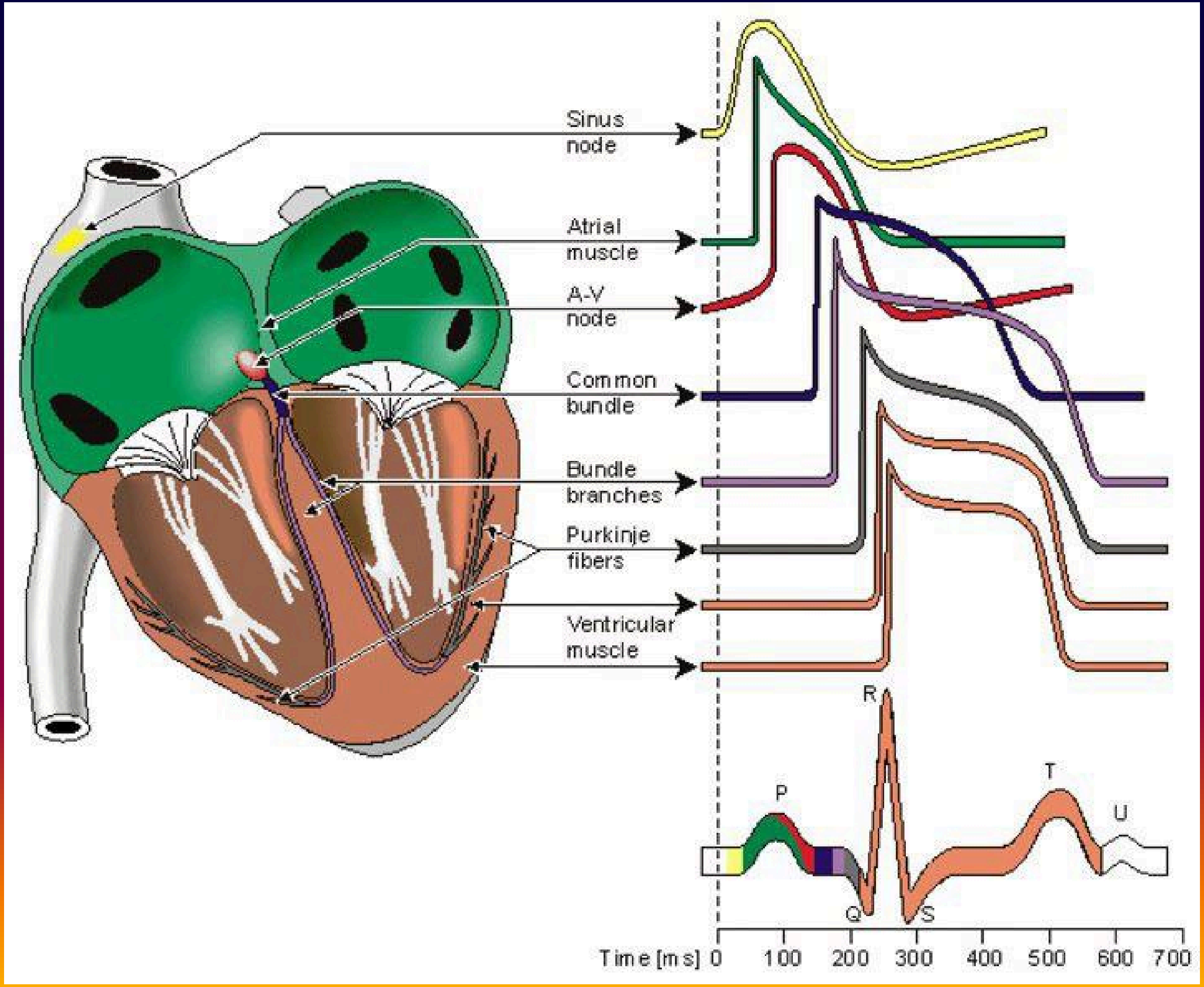
Cardiac Conduction System





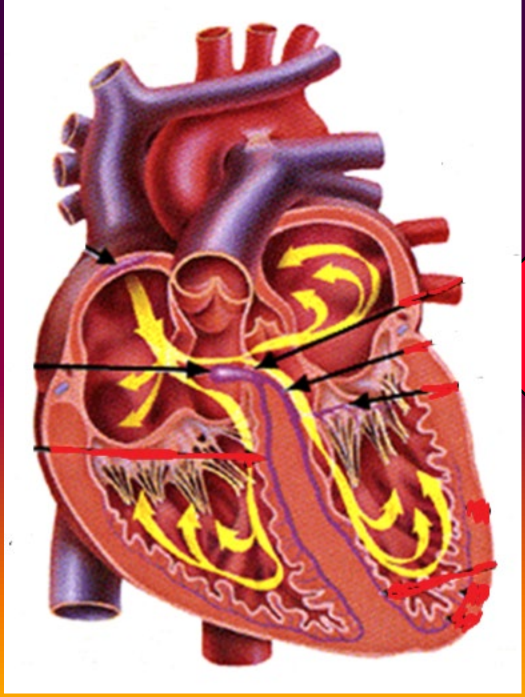
The temporal and spatial movement of cardiac action potentials throughout the heart is what produces the ECG.

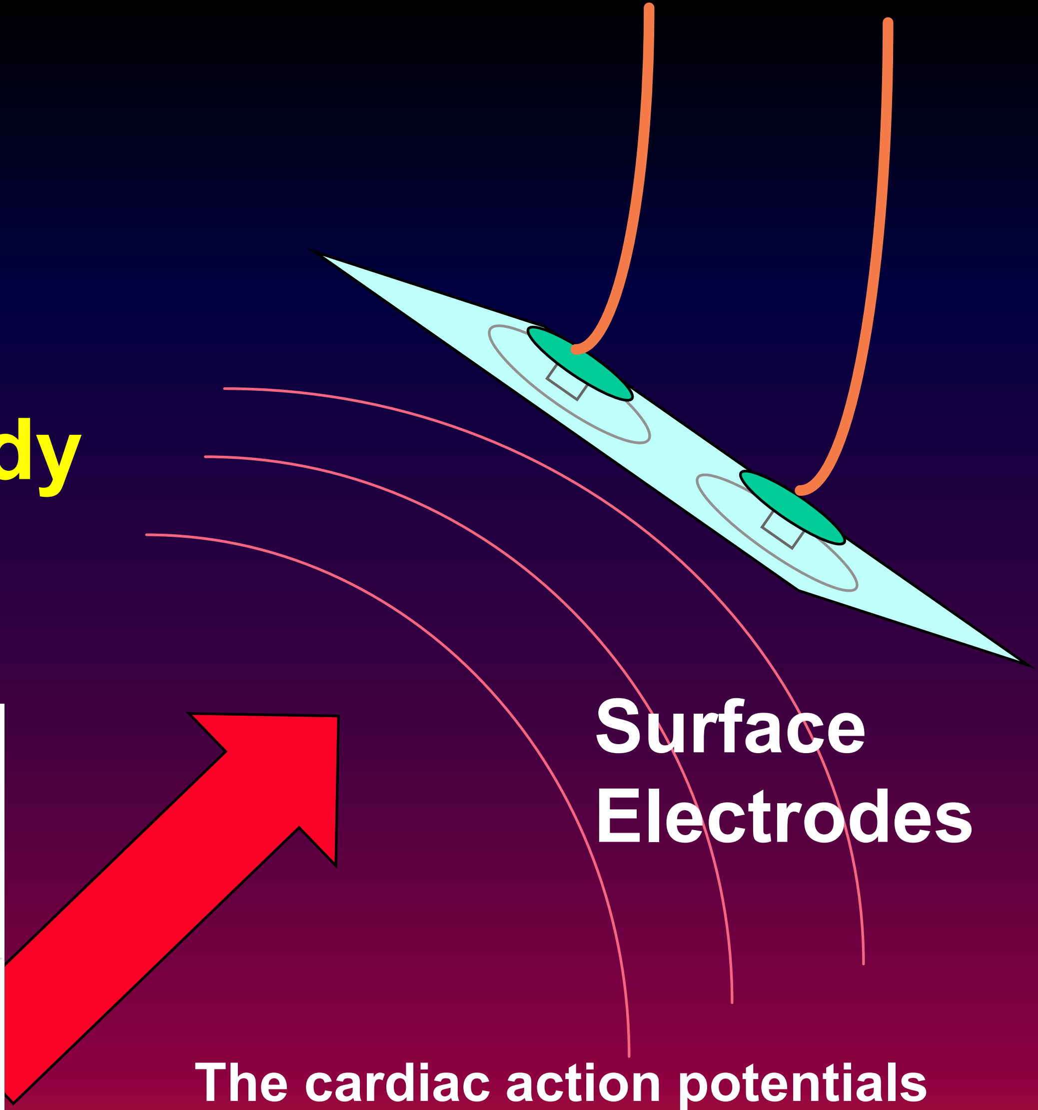
Origin of the Electrocardiogram



A single cardiac action potential as it moves in both time and space through the heart becomes the characteristic ECG recorded at the surface of the body.

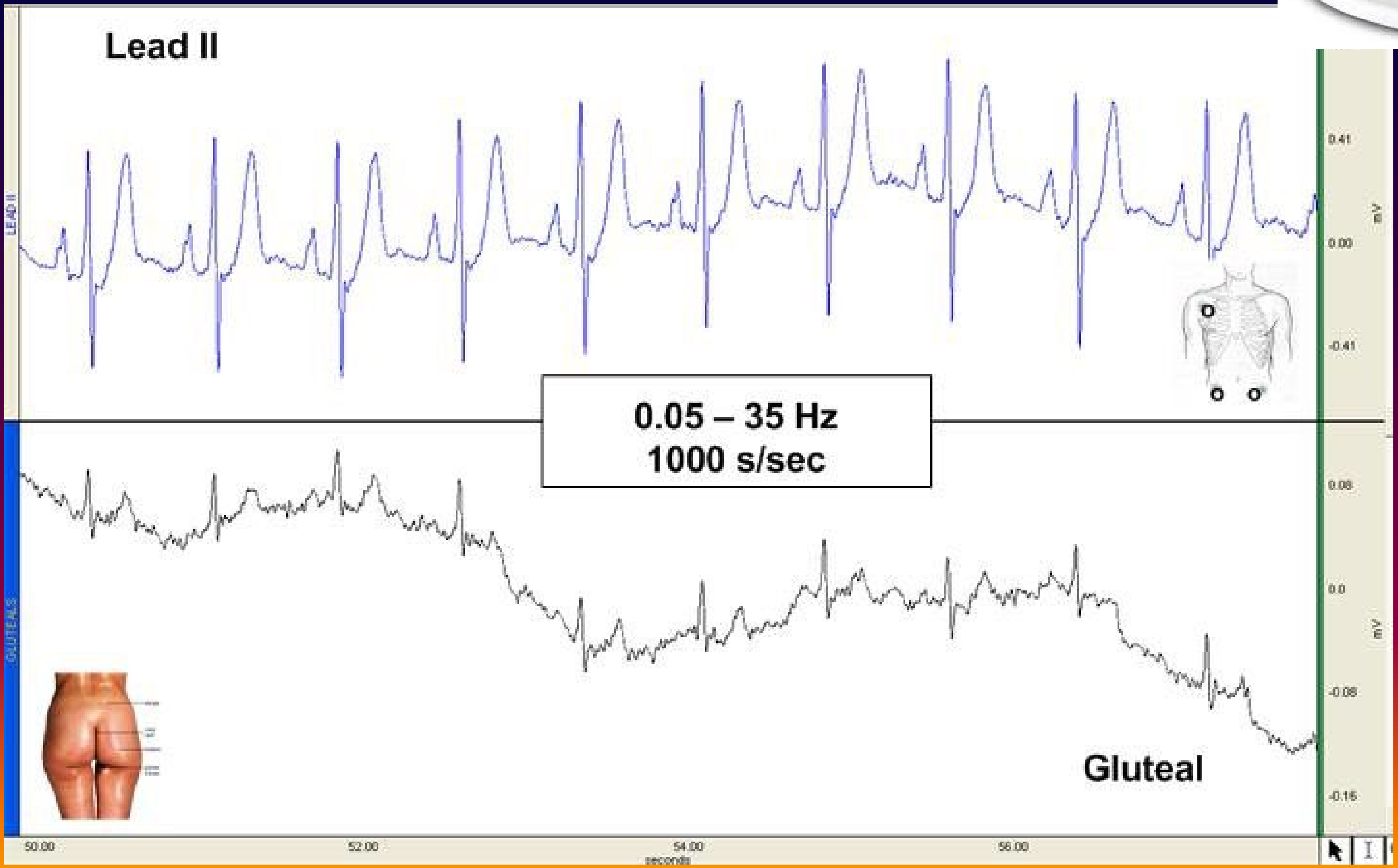
Cardiac action potentials and the ECG travel throughout the body





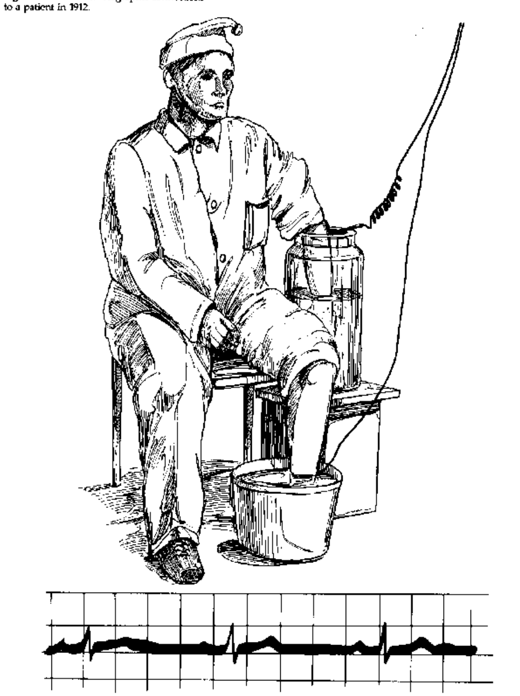
The cardiac action potentials continues to travel through the heart and surrounding tissues until they arrive at the surface of the skin.

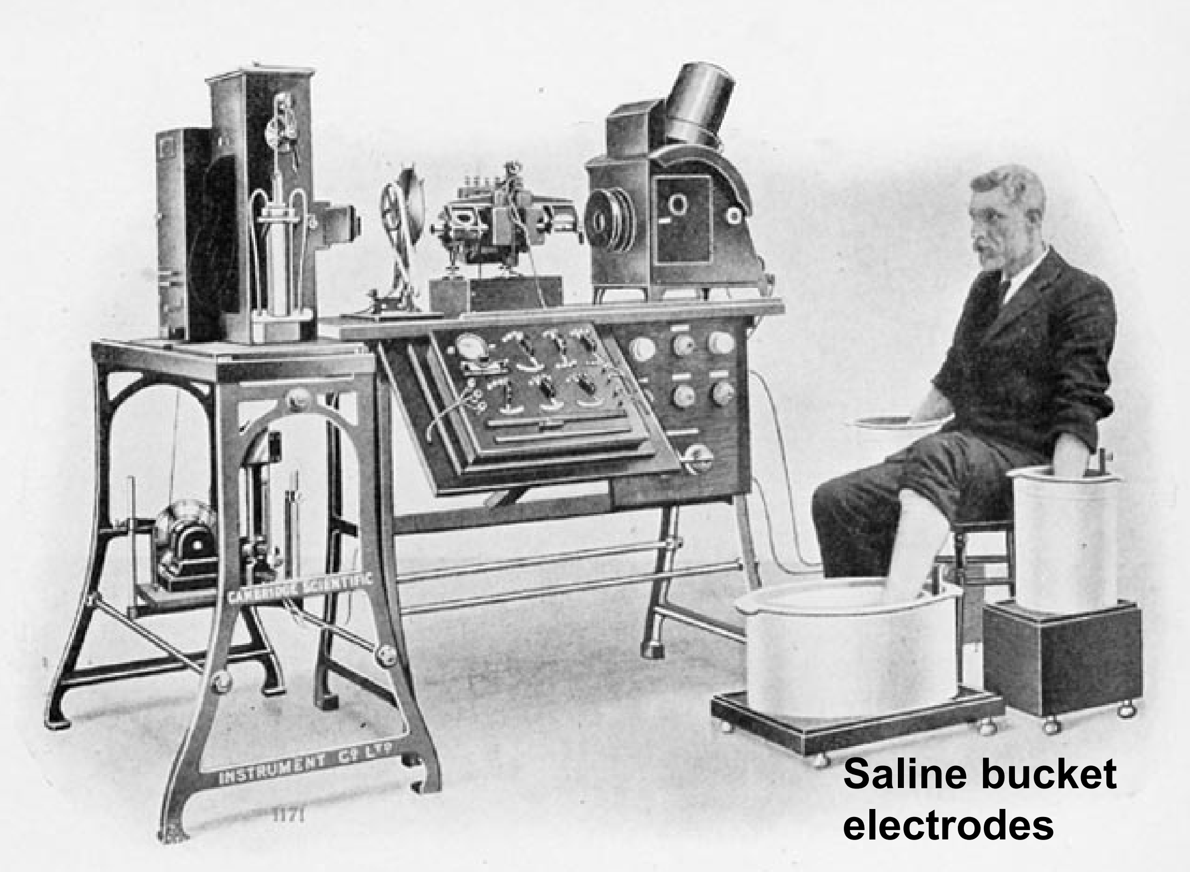
ECG's can be recorded from a variety of places on the body . . .



Early electrocardiograph

Figure 4.1— Electrocardiographic connections to a patient in 1912.





PHOTOGRAPH OF A COMPLETE ELECTROCARDIOGRAPH, SHOWING THE MANNER IN WHICH THE ELECTRODES ARE ATTACHED TO THE PATIENT, IN THIS CASE THE HANDS AND ONE FOOT BEING IMMERSED IN JARS OF SALT SOLUTION

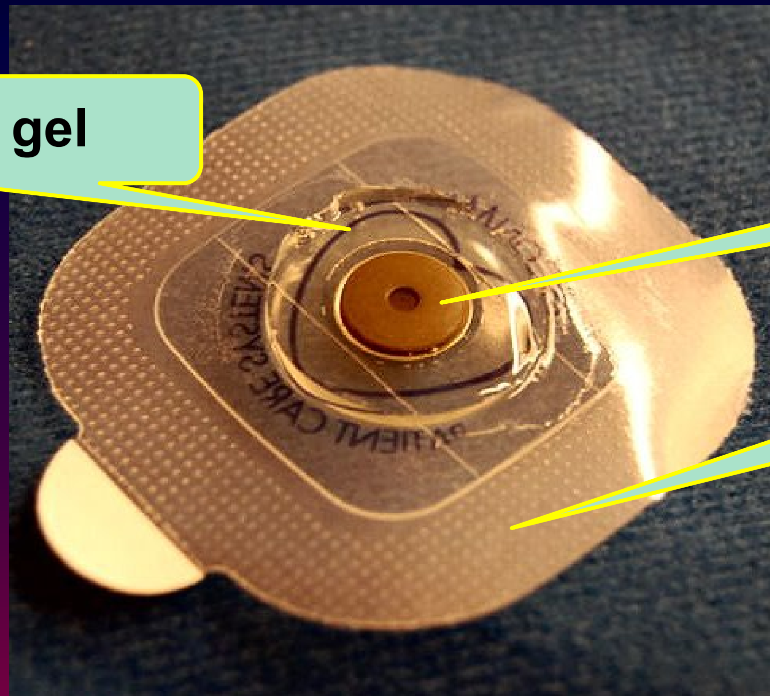
Our current electrode designations, e.g., LA, RA, RL, etc., come from these early studies.

What we use today - Silver- Silver Chloride Electrode:

Conductive gel

Ag-AgCl coating

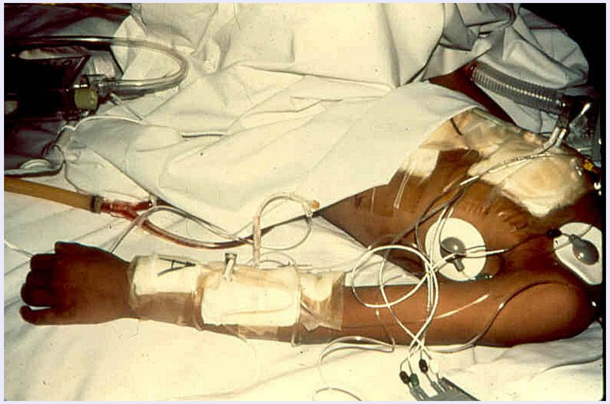
Hypoallergenic tape



Lead wire connection

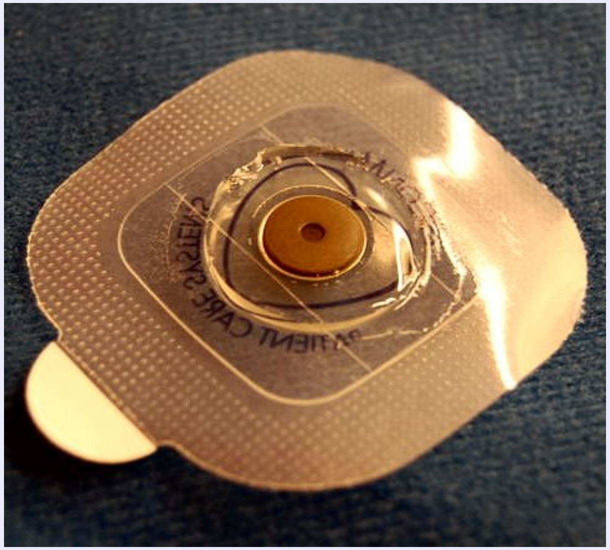
Biopotential Electrodes:

- Provide the interface between the body and measurement instrumentation.

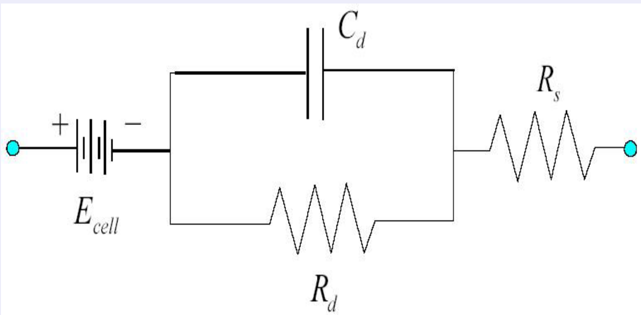


- Transduce, or convert ionic current from the body into electric current detectable by bioinstrumentation.

- Behavior is dictated by electrochemical reactions that occur anytime a metal electrode is placed in an electrolyte.



Electrode Equivalent Circuit



C_d : capacitance of electrode-electrolyte interface

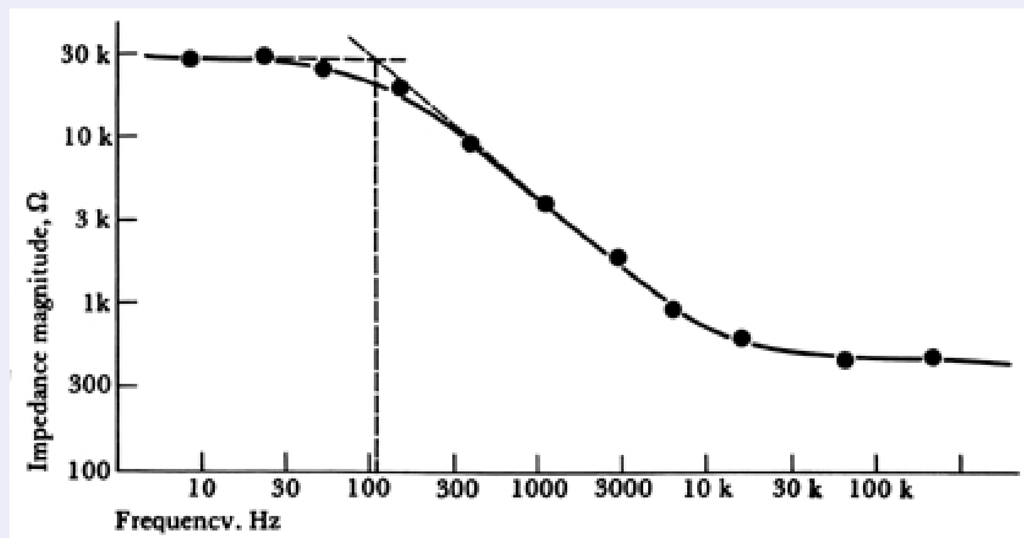
R_d : resistance of electrode-electrolyte interface

R_s : resistance of electrode lead wire

E_{cel} : electrode half-cell potential

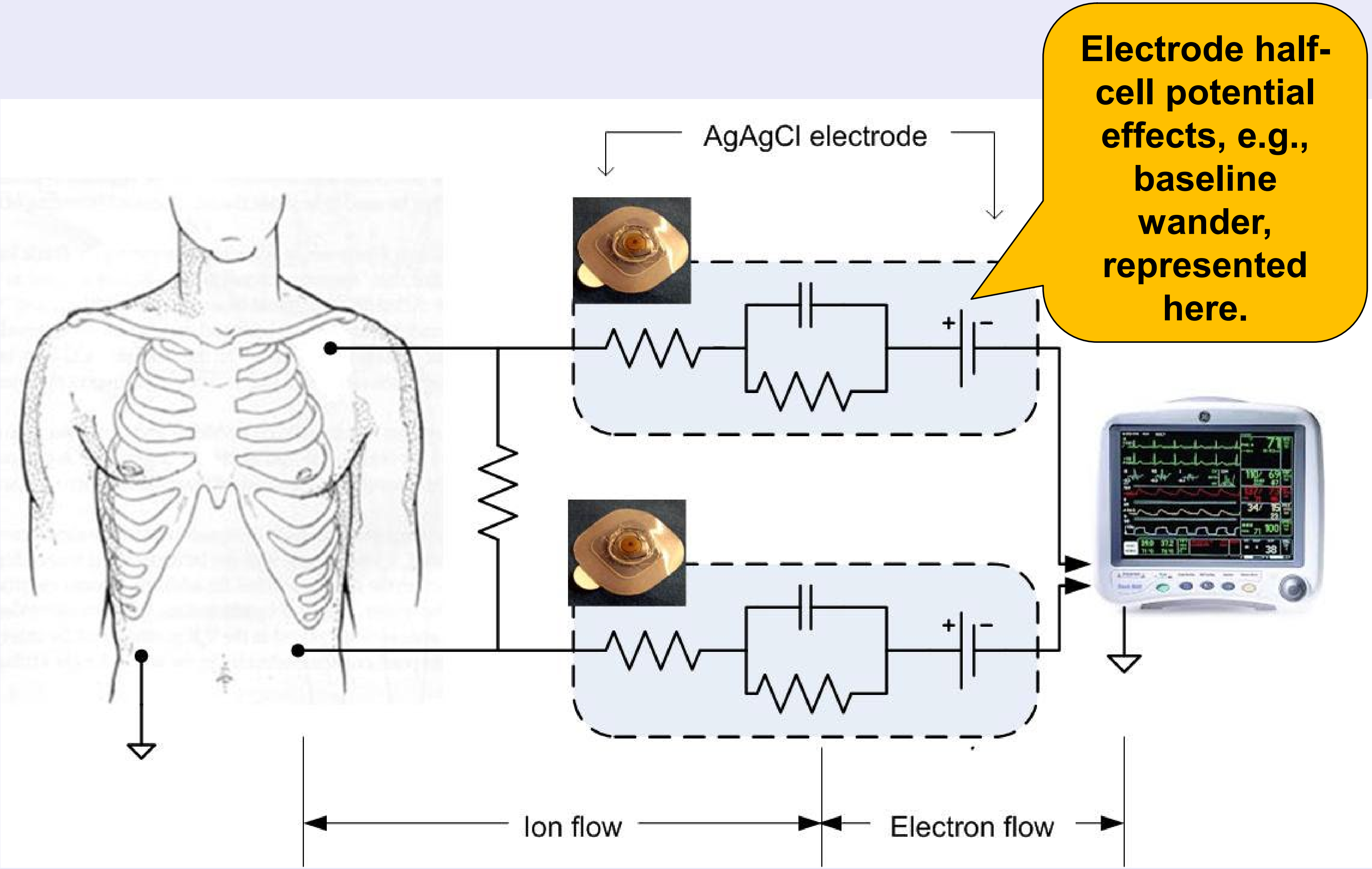
Some half cell potentials

reduction reaction	E^o (V)
$Al^{3+} + 3e^- \rightarrow Al$	-1.662
$Zn^{2+} + 2e^- \rightarrow Zn$	-0.762
$Cr^{3+} + 3e^- \rightarrow Cr$	-0.744
$Fe^{2+} + 2e^- \rightarrow Fe$	-0.447
$Cd^{2+} + 2e^- \rightarrow Cd$	-0.403
$Ni^{2+} + 2e^- \rightarrow Ni$	-0.257
$Pb^{2+} + 2e^- \rightarrow Pb$	-0.126
$2H^+ + 2e^- \rightarrow H_2$	0.000
$AgCl + e^- \rightarrow Ag + Cl^-$	$+0.222$
$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	$+0.268$
$Cu^{2+} + 2e^- \rightarrow Cu$	$+0.342$
$Cu^+ + e^- \rightarrow Cu$	$+0.521$
$Ag^+ + e^- \rightarrow Ag$	$+0.780$
$Au^{3+} + 3e^- \rightarrow Au$	$+1.498$
$Au^+ + e^- \rightarrow Au$	$+1.692$



Frequency Response

Complexity of 'simple' ECG electrodes . . .



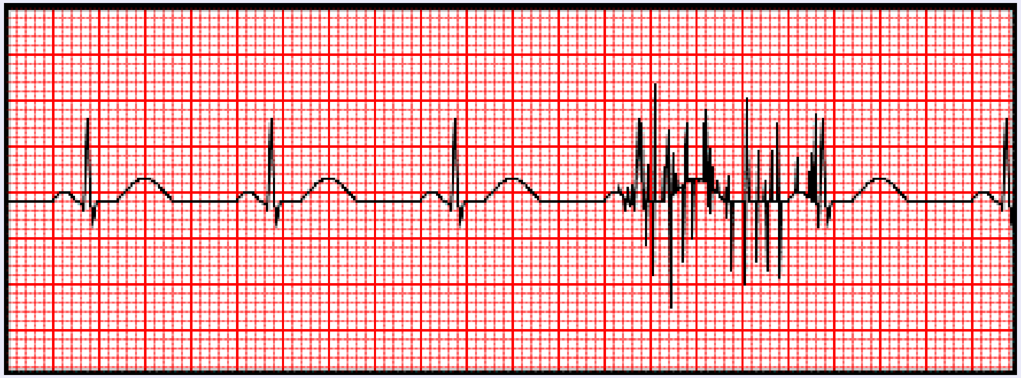
Adapted from: J. Carr, J. Brown. Introduction to Biomedical Equipment Technology, Prentice-Hall, 4th ed., 2001, p. 98.

Motion Artifact

When the electrode moves with respect to the electrolyte, the distribution of the double layer of charge on polarizable electrode interface changes. This changes the half-cell potential temporarily.

If a pair of electrodes is in an electrolyte and one moves with respect to the other, a potential difference appears across the electrodes known as *motion artifact.* This is one source of noise and interference in biopotential measurements.

(motion artifact may also result from the skeletal muscle EMG)



Electrode offset voltage recovery after defibrillation

Voltage transients are introduced during defibrillation – temporarily disrupting the balance of charge at the electrode-electrolyte interface.

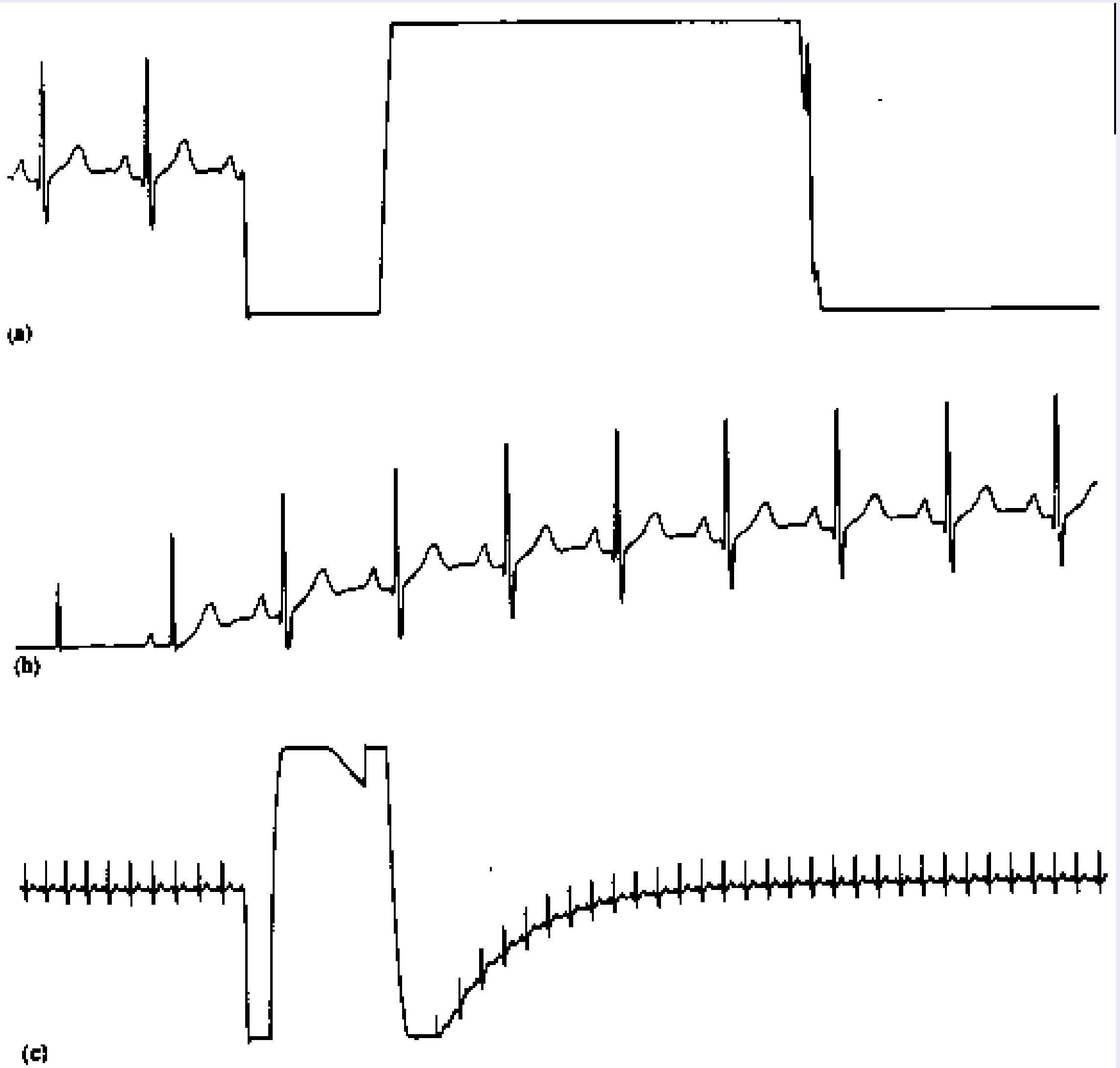


Figure 6.11 Effect of a voltage transient on an ECG recorded on an electrocardiograph in which the transient causes the amplifier to saturate, and a finite period of time is required for the charge to bleed off enough to bring the ECG back into the amplifier's active region of operation. (a) Initiation of the transient. (b) Continuation of (a), showing recovery. (c) Similar transient at reduced gain to illustrate first-order recovery of the system.

60 Hz and EMG interference with an ECG

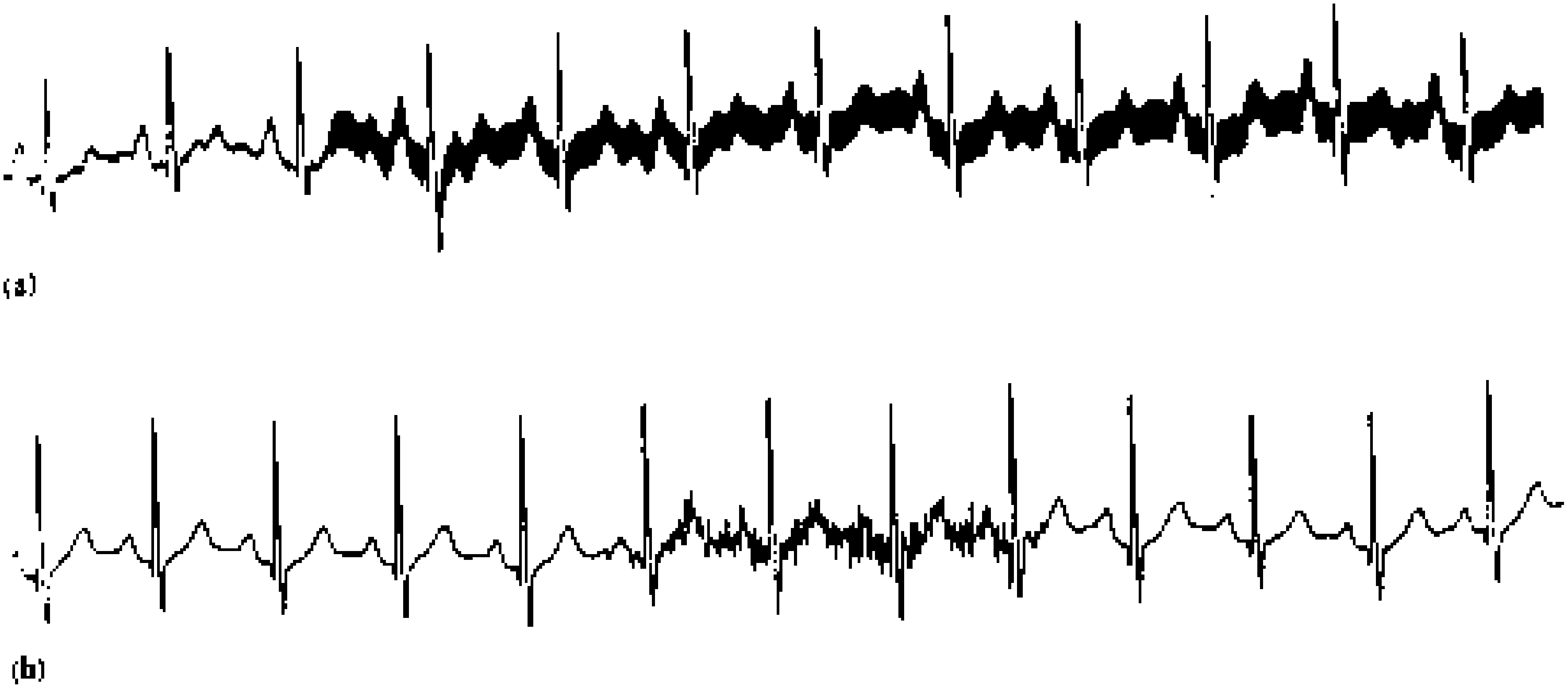
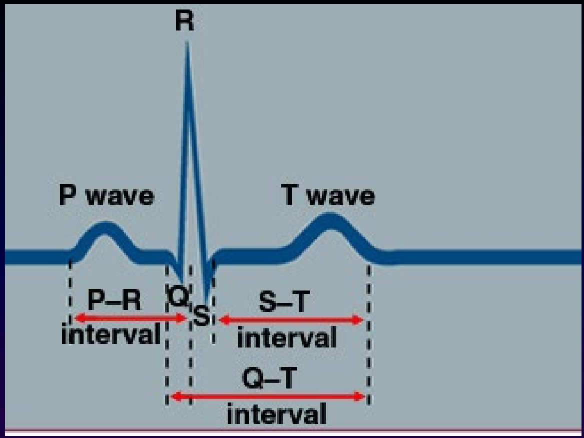
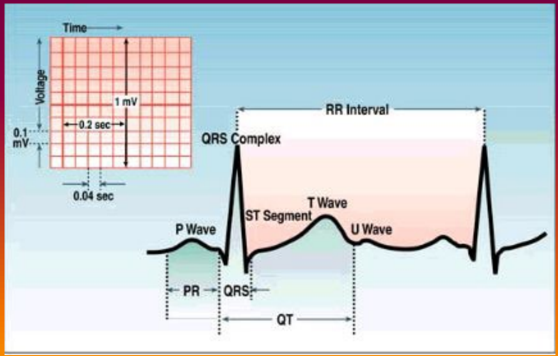


Figure 6.12 (a) 60-Hz power-line interference. (b) Electromyographic interference on the ECG. Severe 60-Hz interference is also shown on the bottom tracing in Figure 4.14.

ECG

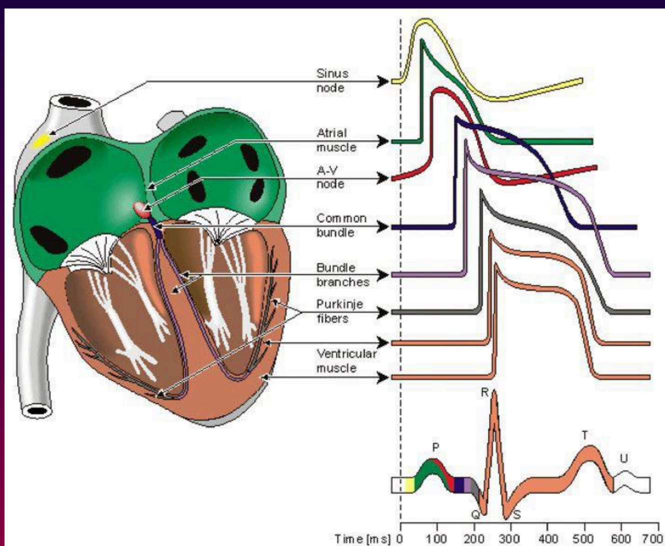


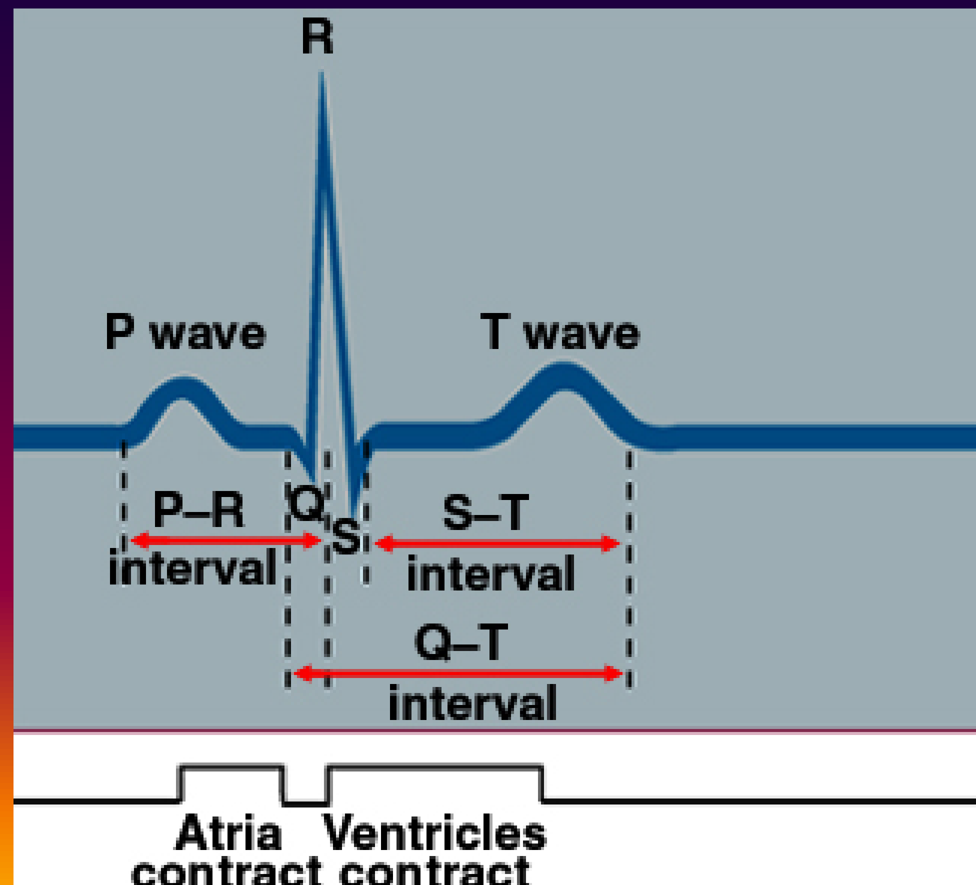
- P wave
  - SA node fires, atrial depolarization
  - atrial systole
- QRS complex
  - atrial repolarization and diastole (signal obscured)
  - AV node fires, ventricular depolarization
  - ventricular systole
- T wave
  - ventricular repolarization
- U wave
  - Not always seen

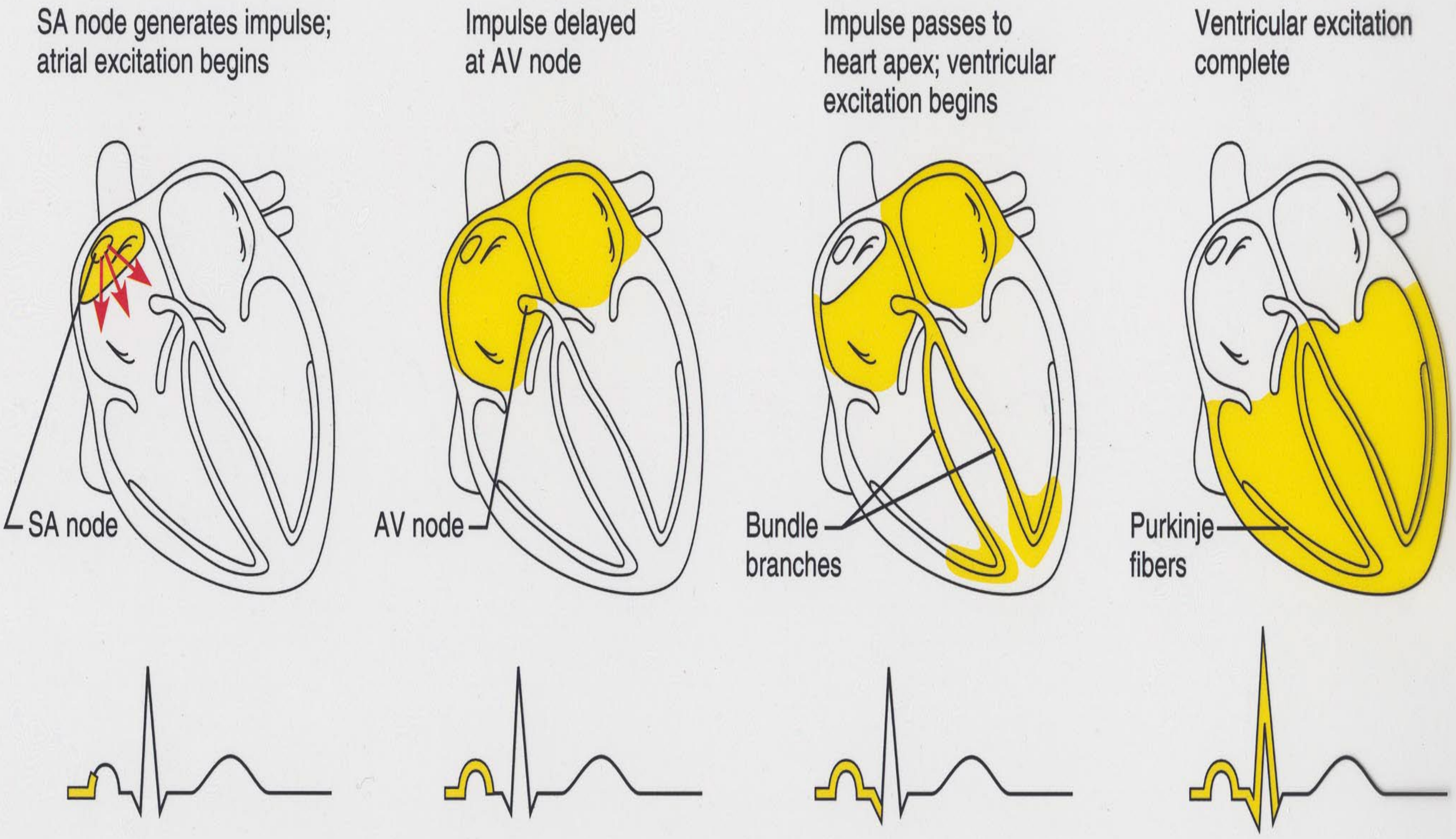


Electrocardiogram (ECG)

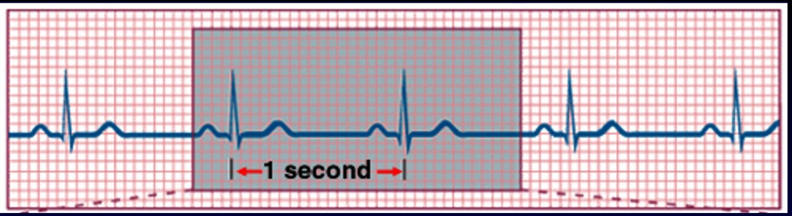
- Composite of all action potentials of nodal and myocardial cells detected, amplified and recorded by electrodes on arms, legs and chest

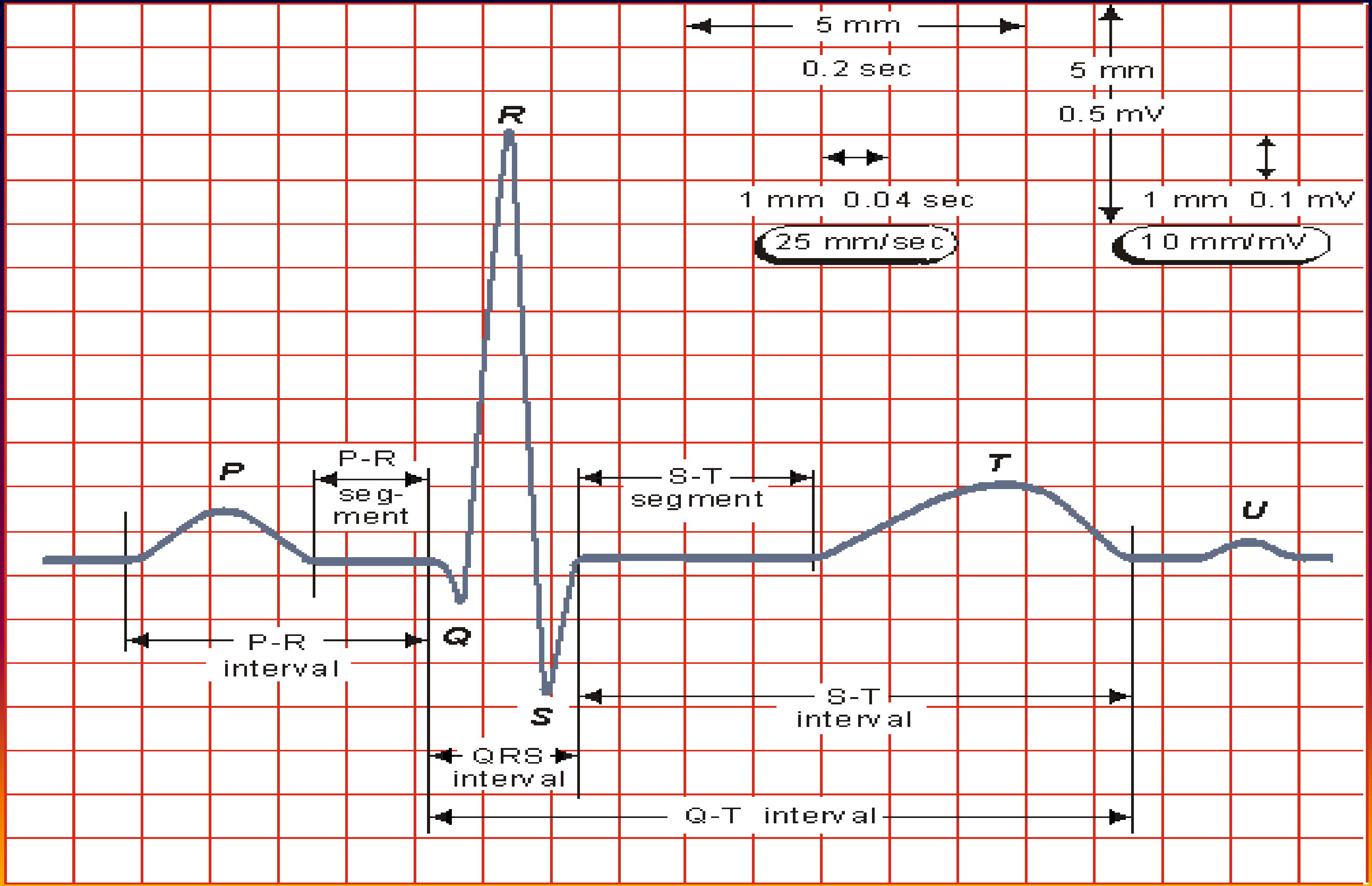





SA node generates impulse; atrial excitation begins
Impulse delayed at AV node
Impulse passes to heart apex; ventricular excitation begins
Ventricular excitation complete
SA node
AV node
Bundle branches
Purkinje fibers

The Normal ECG

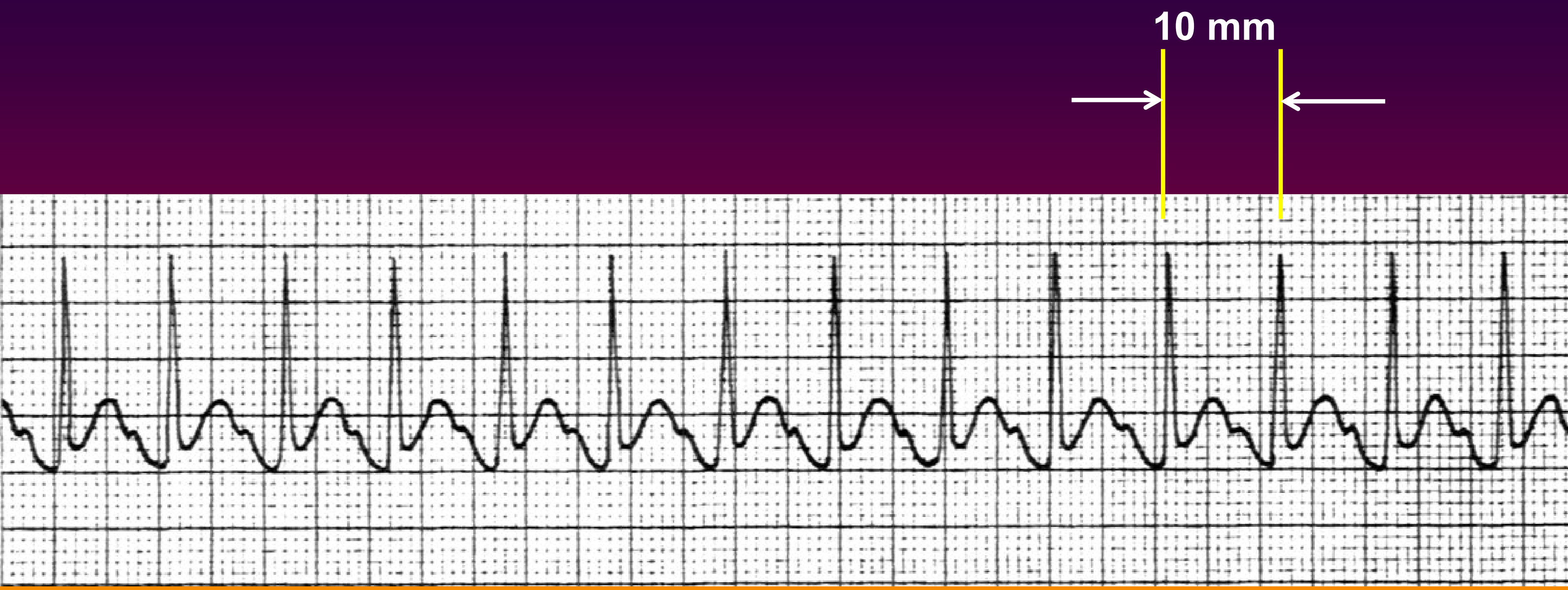




Determining heart rate from a strip . . .

Heart rate, in bpm = (25 mm/sec)(60 sec/min) / (mm/beat), or and for example:

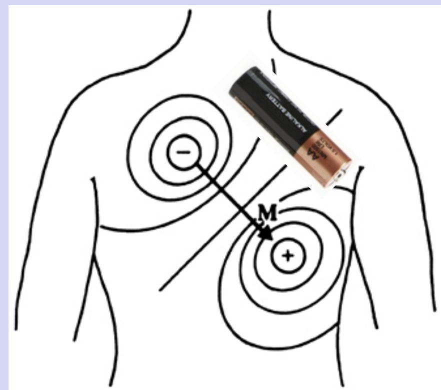
1500 / R-R interval in mm = 1500/10 =150 bpm

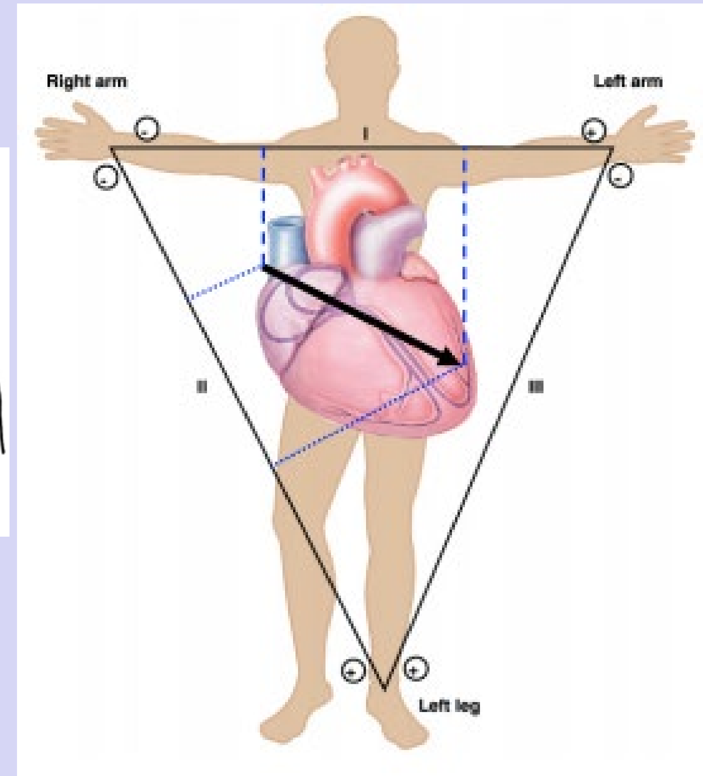


(when recorded at 25 mm/sec)

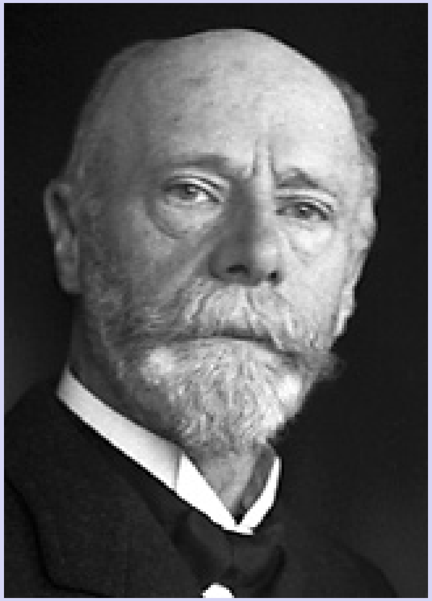
Cardiac Axis

- **The electrical activity of the heart can be modeled as a vector quantity: an electric dipole, M, whose magnitude and direction changes in time. Also called the cardiac vector or cardiac axis.**

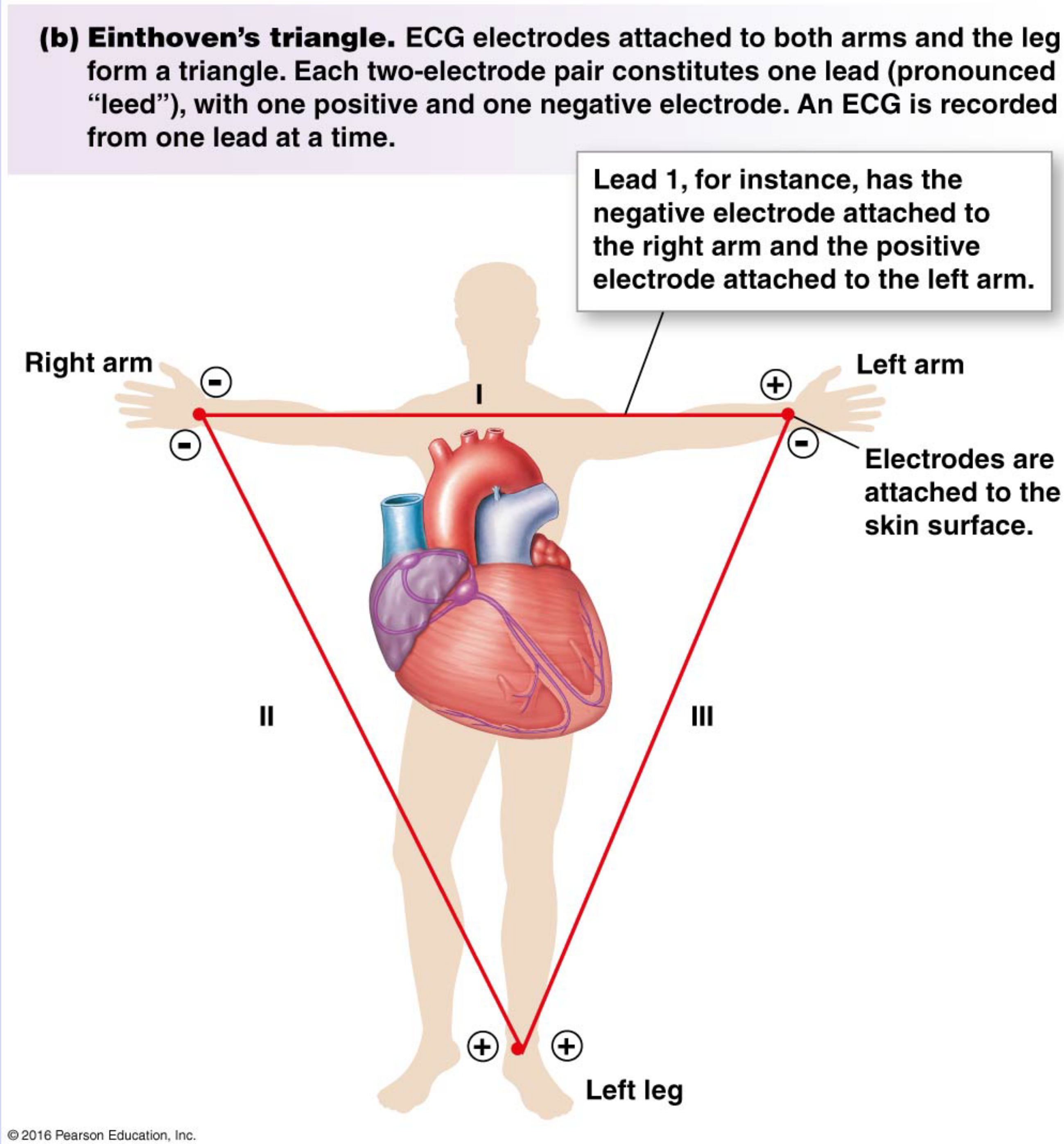




For a 'normally' positioned heart, the angle associated with this axis is approximately 60º.

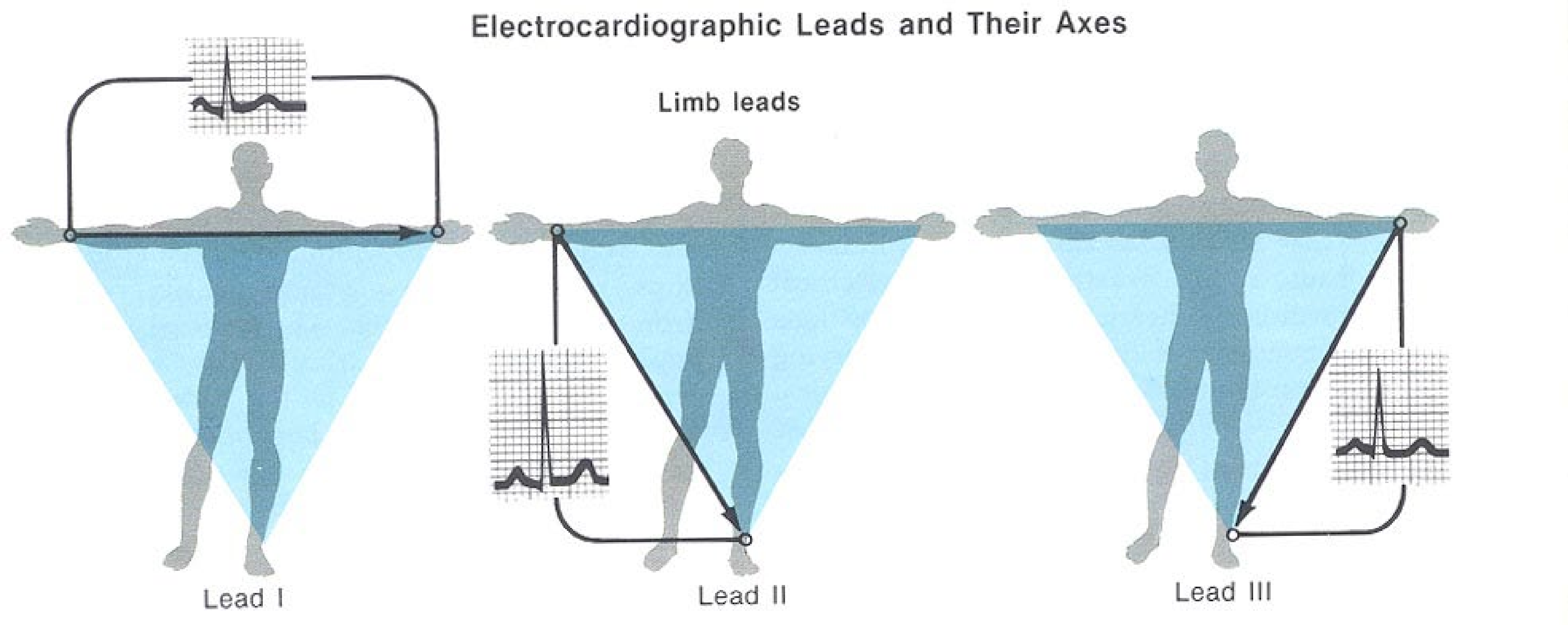


Willem Einthoven
(1860 – 1927)



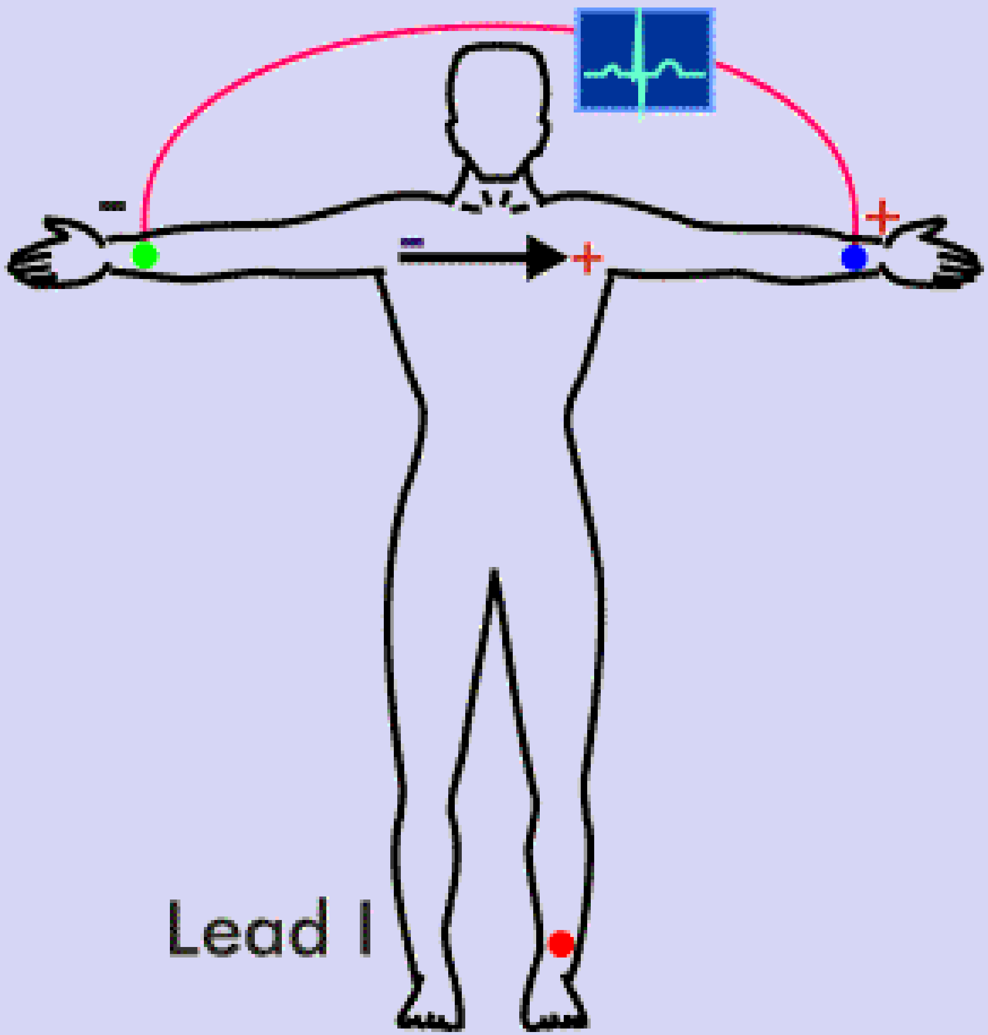
ECG Limb Leads

(bipolar limb leads)



Forms Einthoven's Triangle

Lead I



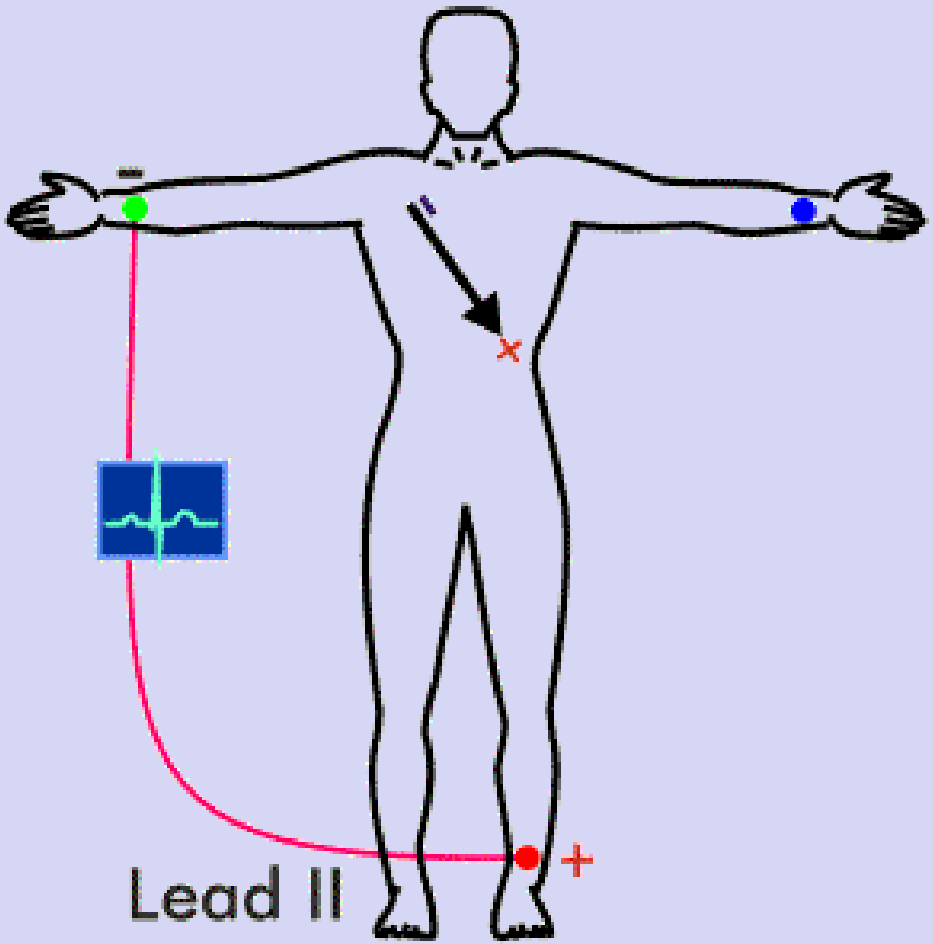
Lead I is the first of three standard limb leads (I, II, III).
Limb leads measure cardiac depolarization in the frontal (coronal) plane.

The negative electrode is connected to the RIGHT ARM.
The positive electrode is connected to the LEFT ARM.

The axis is 0 degrees.

When an action potential starts on the right and proceeds toward the left side of the heart, a positive inflection will be seen in lead one. This holds true for all leads. Whenever a current proceeds toward a positive electrode, an upright inflection is seen on the ECG tracing.

Lead II



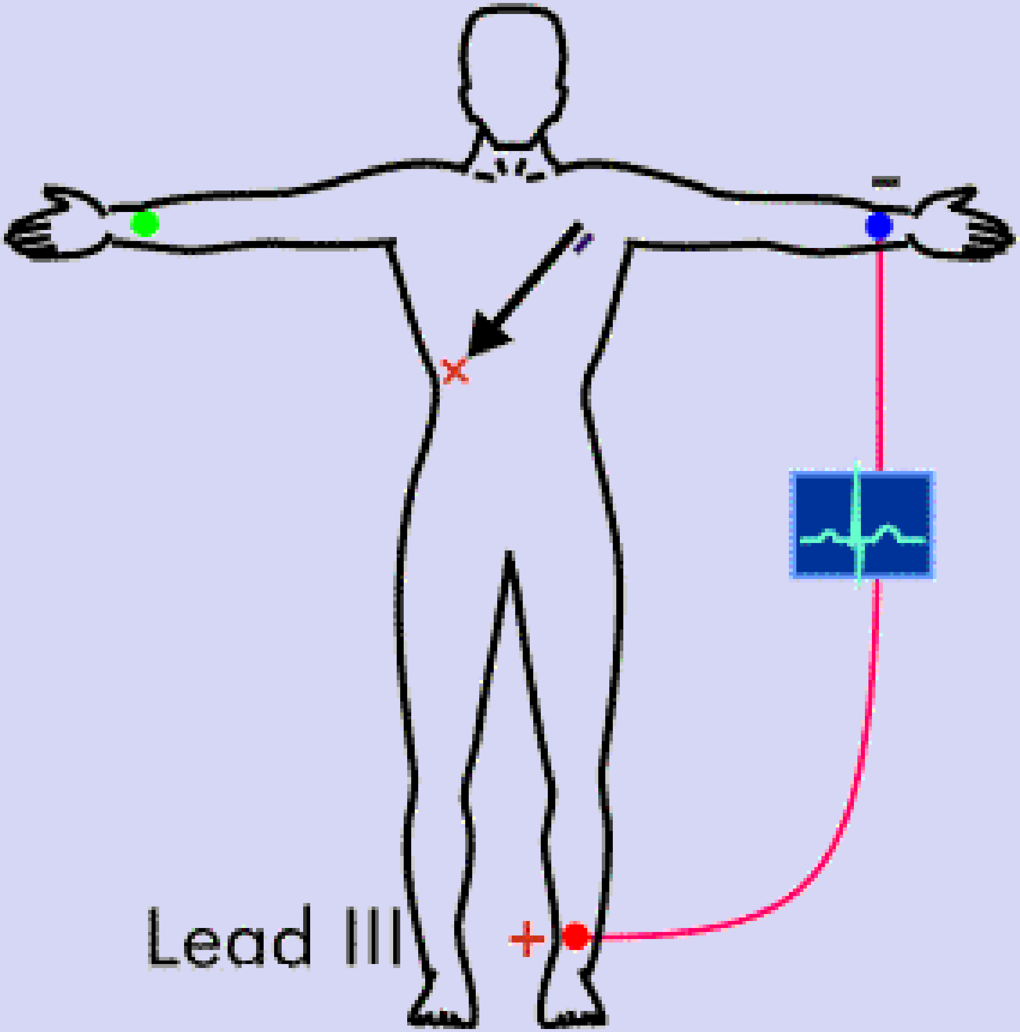
Lead II is used alone quite frequently. Normal rhythms present with a prominent P wave and a tall QRS.

The negative electrode is connected to the RIGHT ARM. The positive electrode is connected to the LEFT LEG.

The axis is +60 degrees.

In all the limb leads, the electrodes may be positioned close to the torso. For convenience, they are often placed at the shoulders and hips.

Lead III



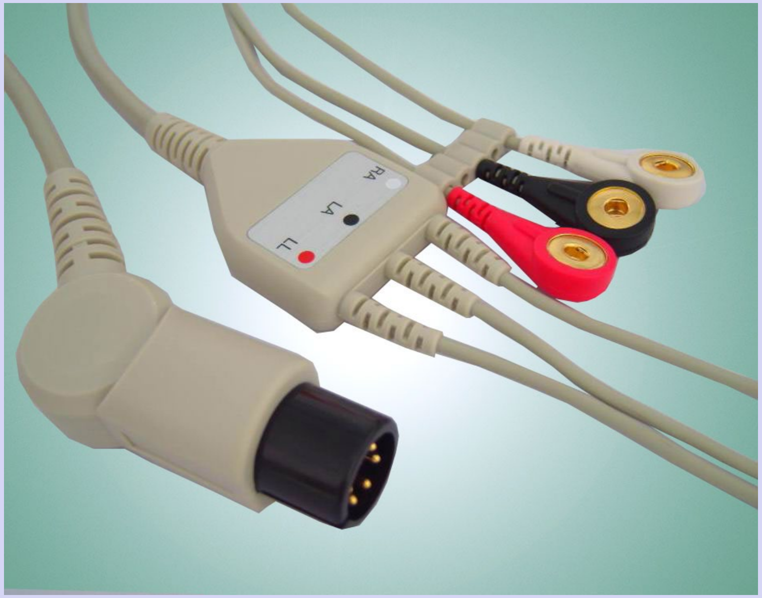
Lead III is the last of the three standard limb leads.

The negative electrode is connected to the LEFT ARM.
The positive electrode is connected to the LEFT LEG.

The axis is 120 degrees.

The ECG Lead Color Code

- **The standard American Heart Association (AHA) color code associated with each of the bipolar limb leads is:**
  - **RA = white**
  - **LA = black**
  - **RL = green**
  - **LL = red**
  - **Chest, or V lead, = brown**

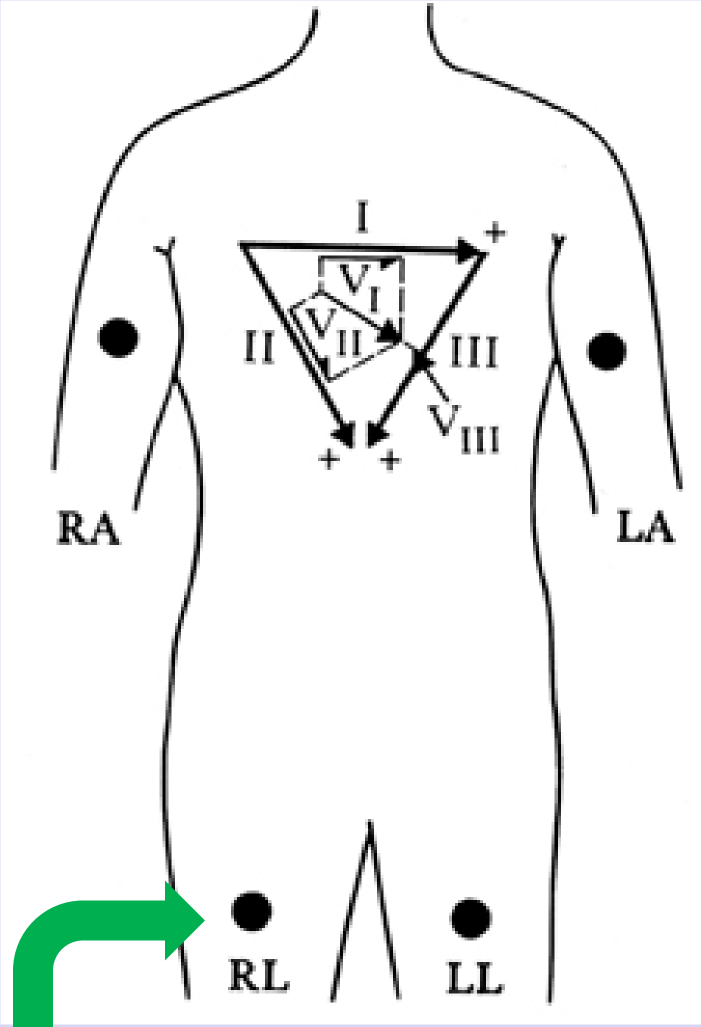


Electrode position defines ECG Leads

- 3 standard limb leads (bipolar)
  - Einthoven's Triangle
    - Lead I: RA (-) and LA (+)
    - Lead II: RA (-) and LL (+)
    - Lead III: LA (-) and LL (+)

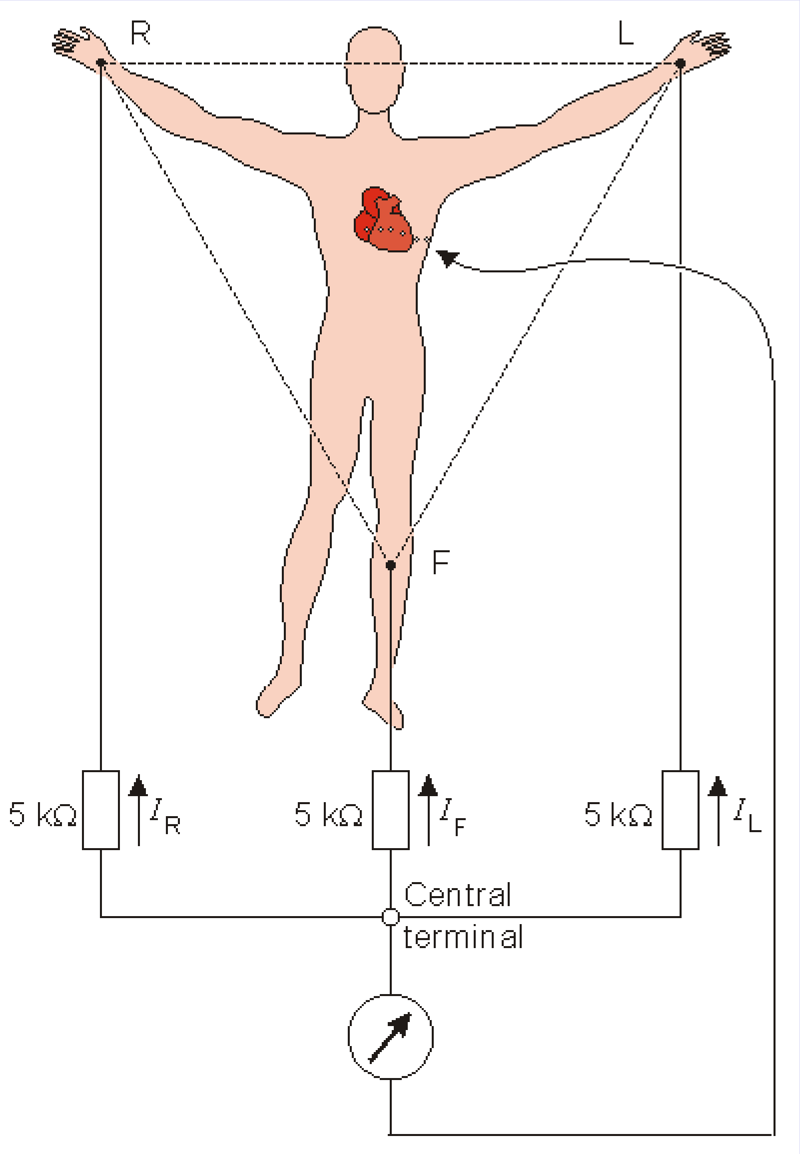
- 3 augmented limb leads (unipolar)
  - left arm (aV_L)
  - right arm (aV_R)
  - left leg (aV_F)

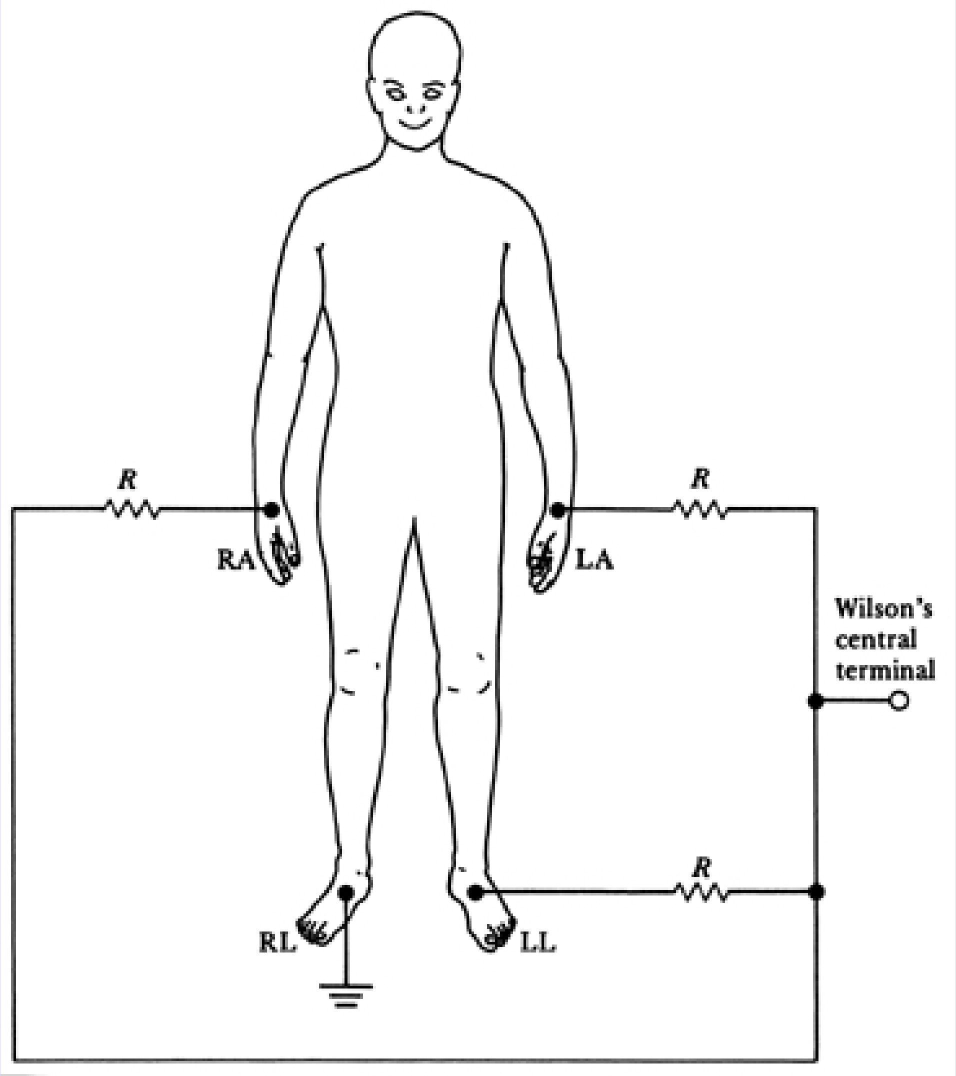
- 6 chest leads (unipolar)
  - V_1 - V_6



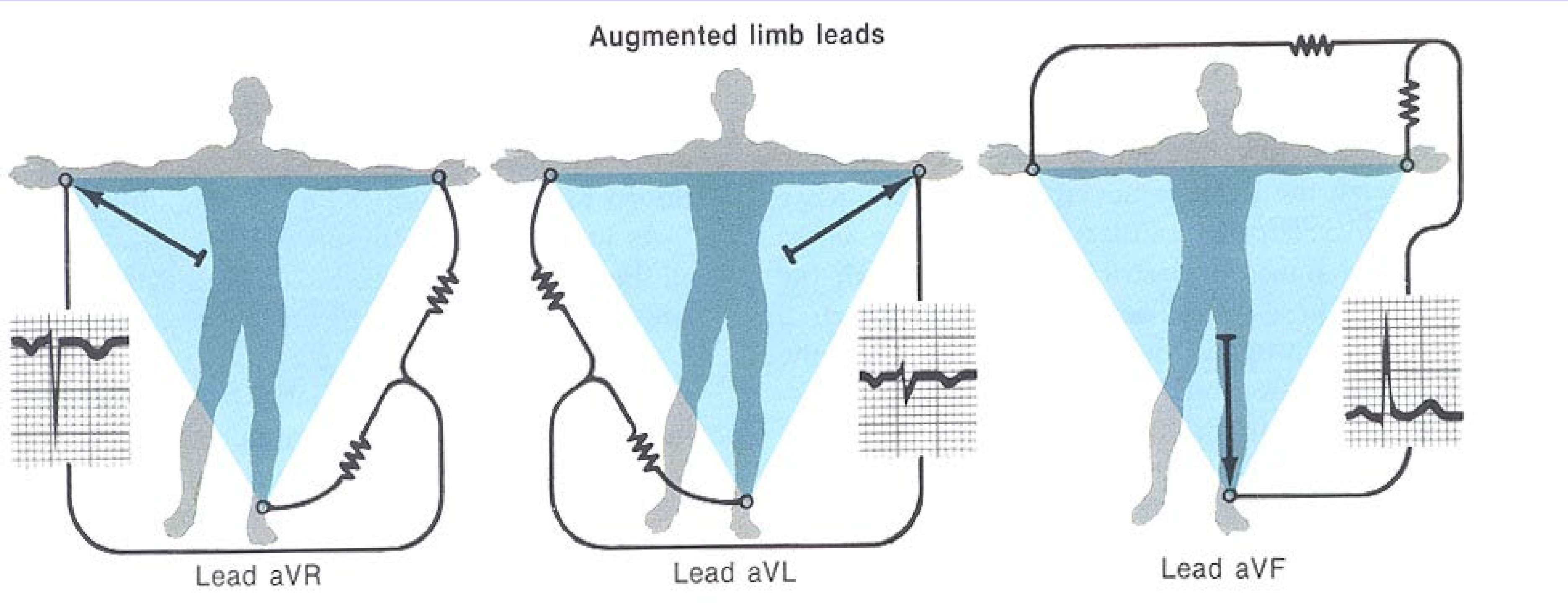
Right Leg electrode is common to all leads

Wilson's Central Terminal





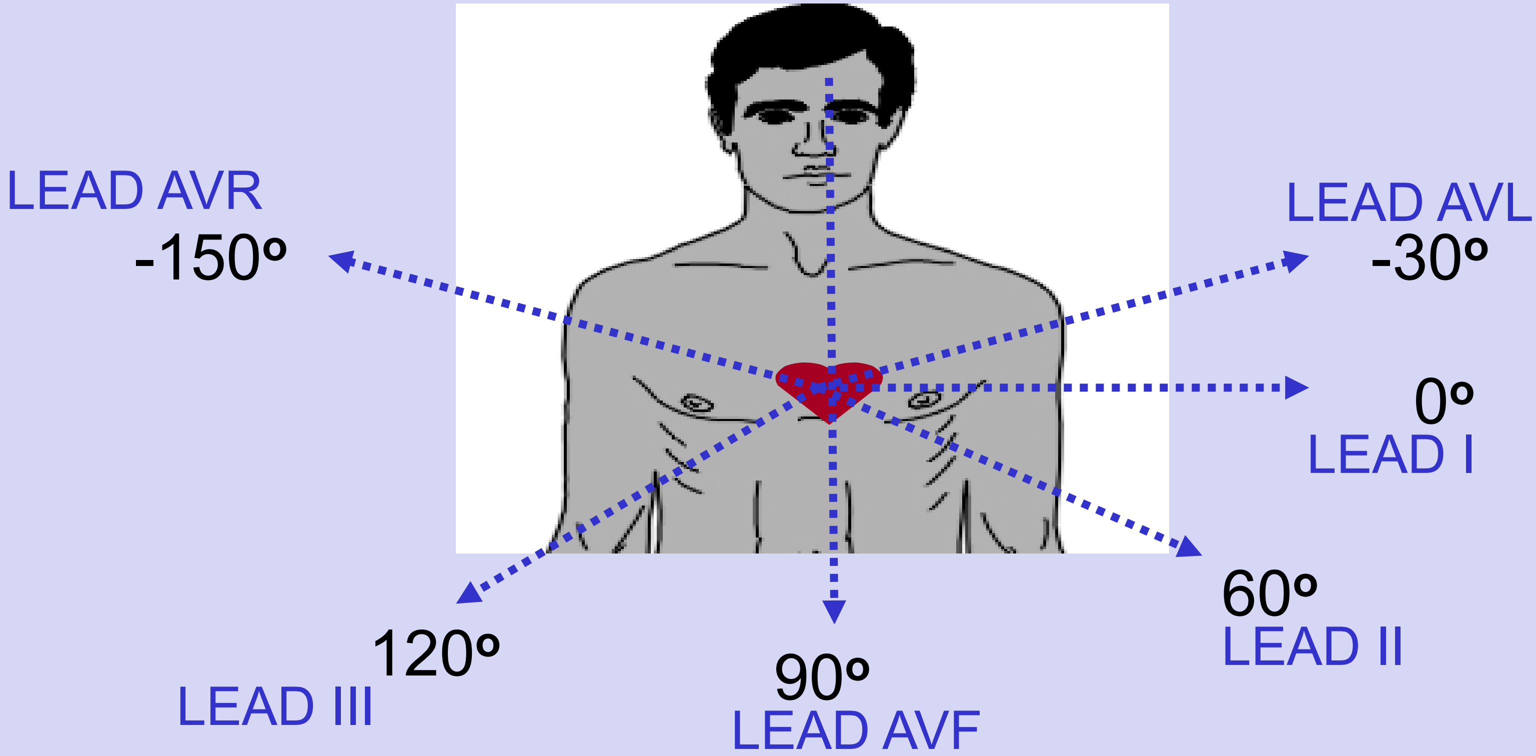
ECG Augmented Limb Leads



aVR = RA - 1/2(LA + LL)	aVL = LA – ½(RA + LL)	aVF = ½(RA + LA)

The average of these leads are used to create Wilson's (or Goldberger's) central terminal – essentially a new reference connection.

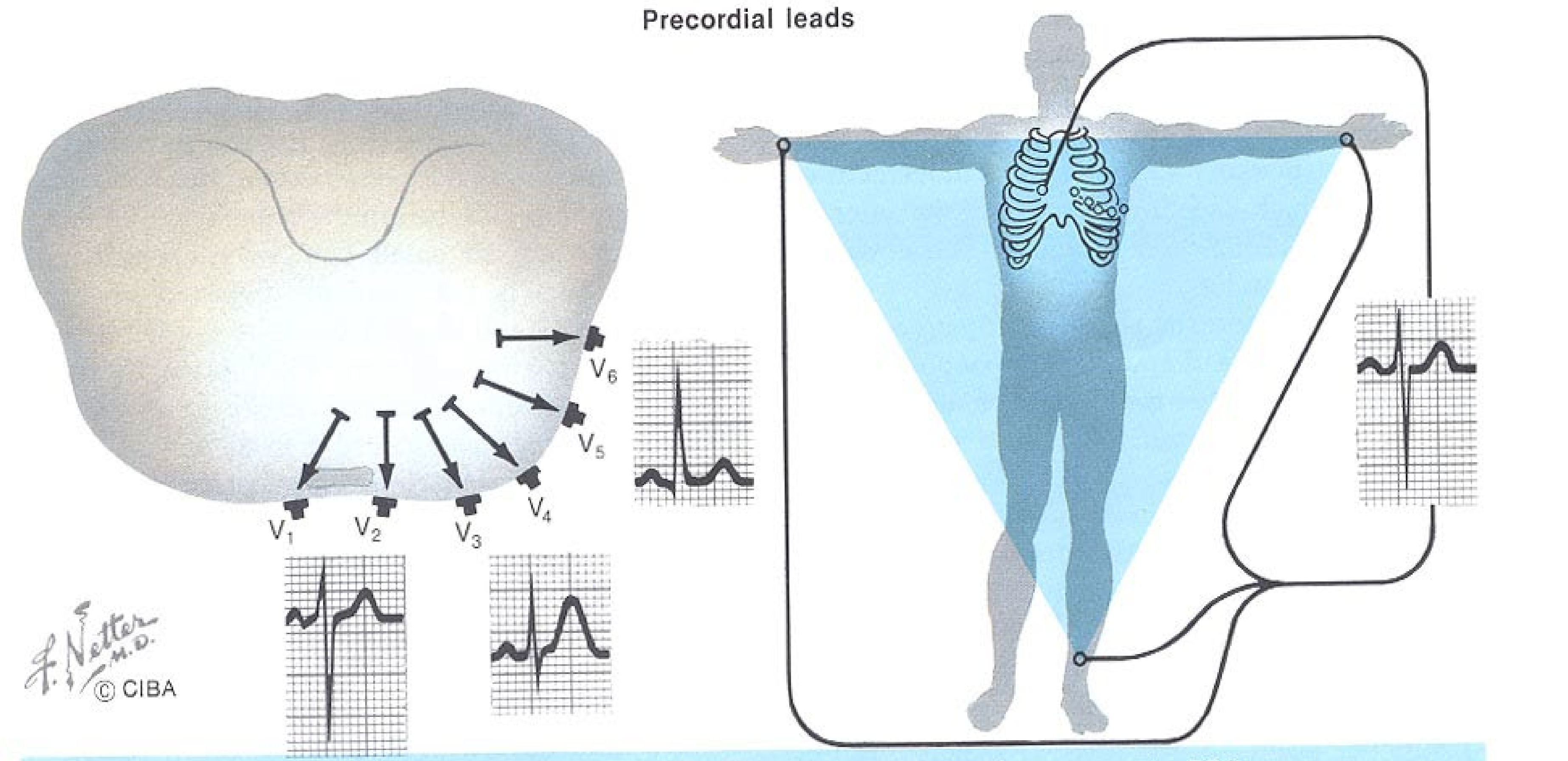
The Limb Leads . . .



Each of the limb leads (I, II, III, AVR, AVL, AVF) can be assigned an angle of clockwise or counterclockwise rotation to describe its position in the frontal plane.

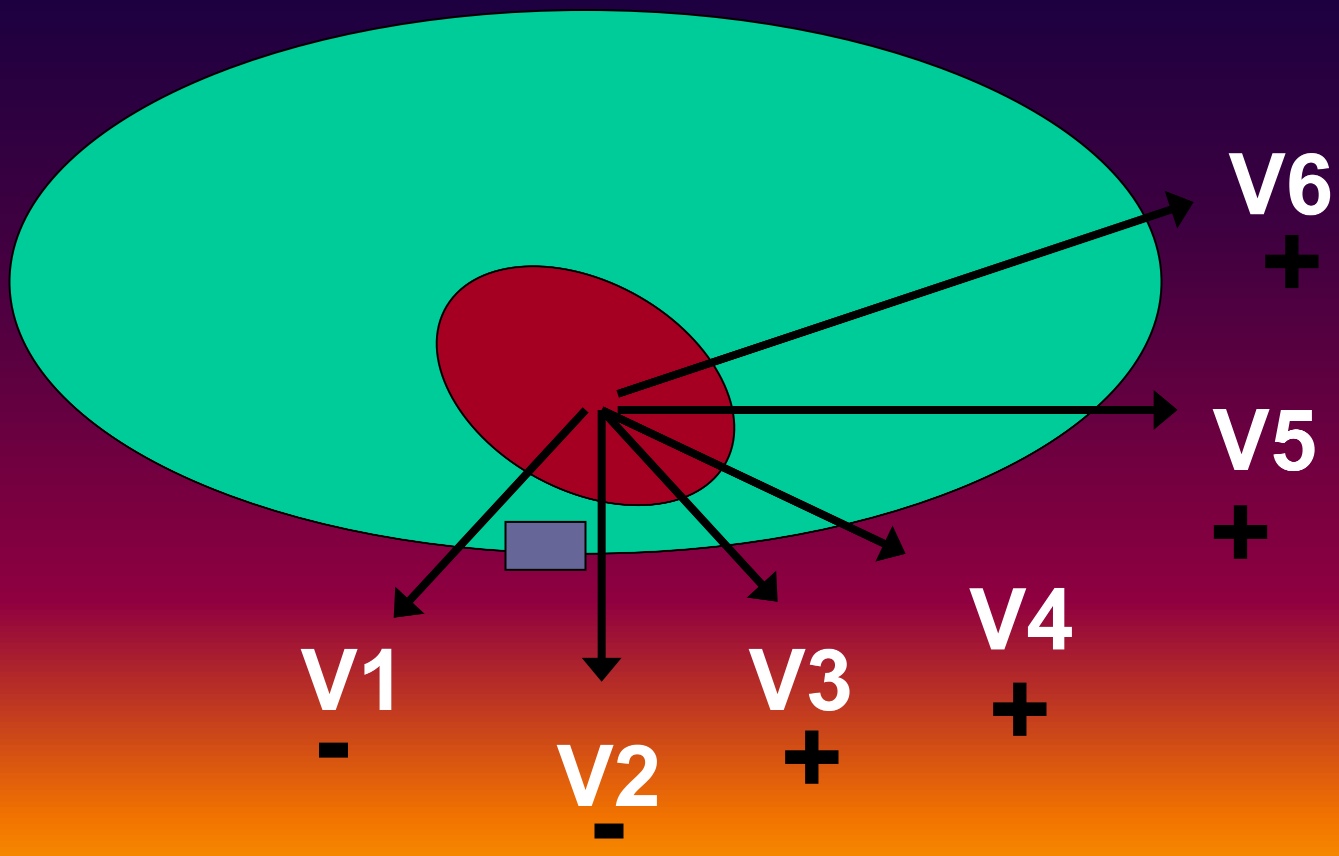
ECG Precordial Leads

(V, chest, or transverse plane leads)



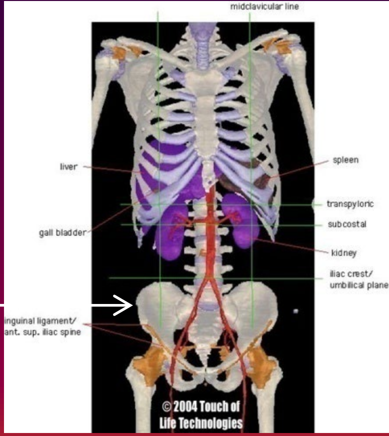
When current flows toward arrowheads (axes), upward deflection occurs in ECG
When current flows away from arrowheads (axes), downward deflection occurs in ECG
When current flows perpendicular to arrows (axes), no deflection occurs

"Seeing" the heart in the Transverse plane: The Chest Leads



12-Lead ECG: Electrode Placement

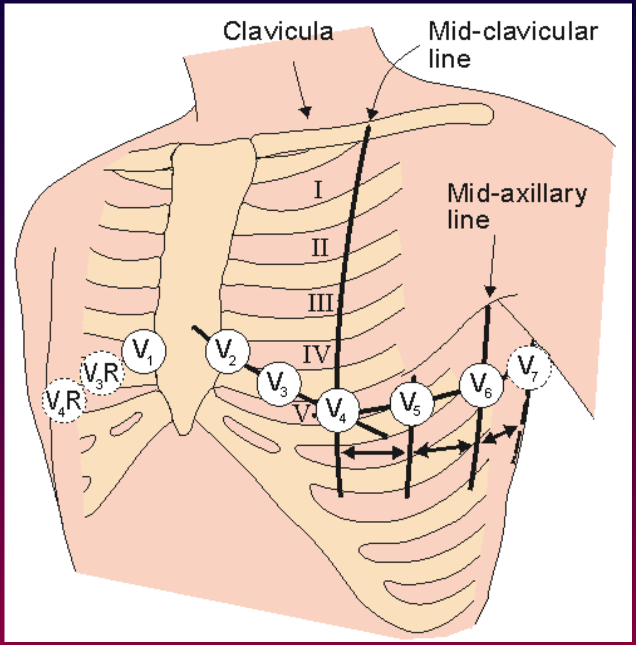
- RA / LA:
  - On Shoulders at distal ends of clavicles: (Not over large muscle masses or directly over bone)
- RL / LL:
  - Base of Torso: Just medial to the iliac crests

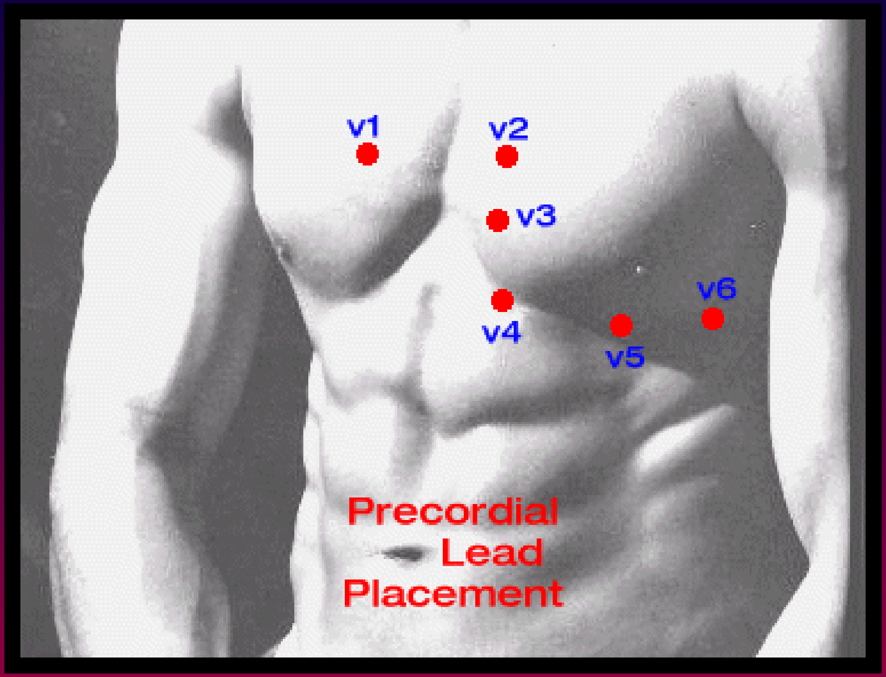


- Chest Leads: V1-V6
  - Traditional pre-cordial positioning

Chest Leads

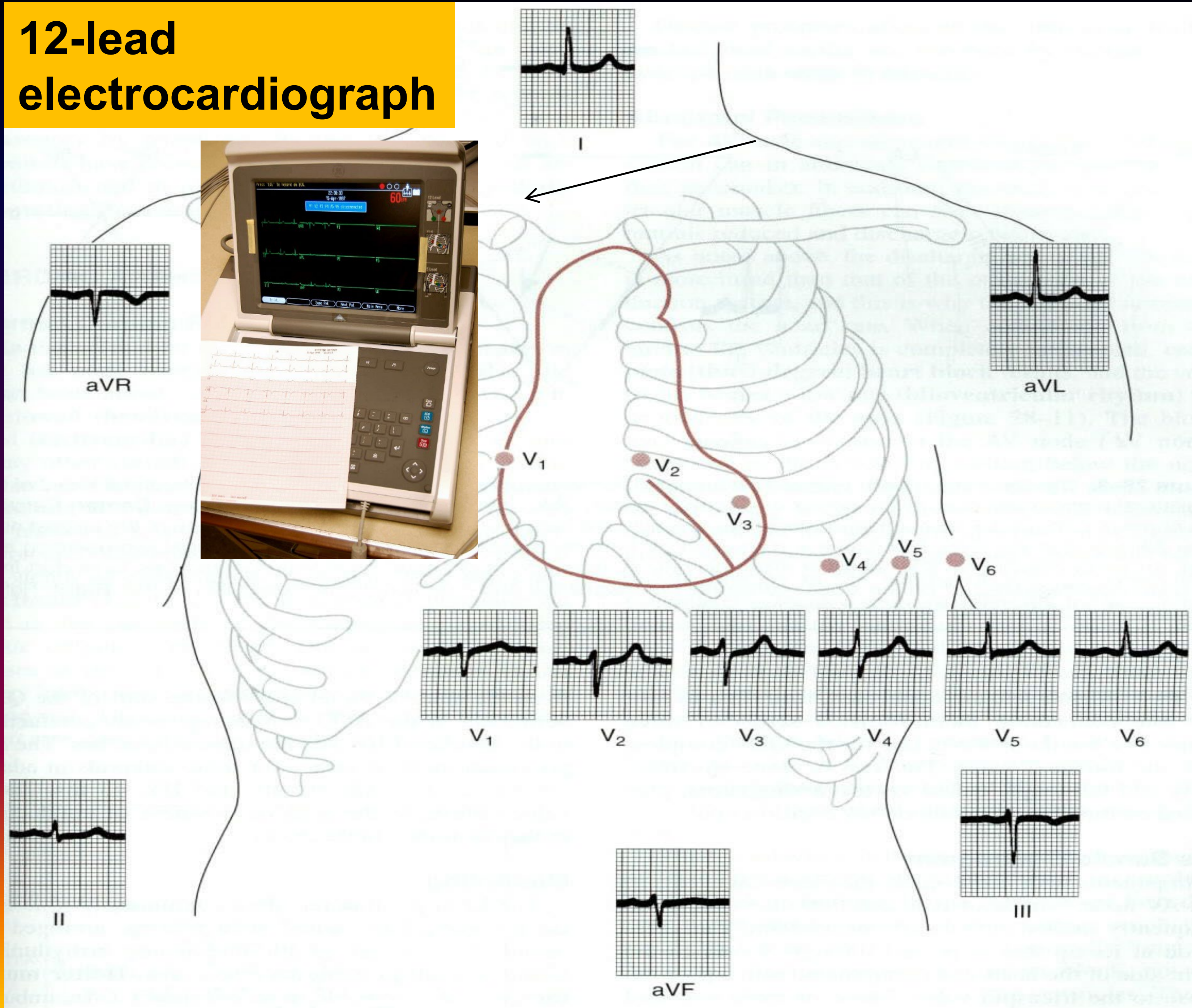
- Additional set of six leads, placed on the chest, also known as the precordial leads. These too are unipolar, that is they measure the potential with respect to WCT.





V1-V2: 4th intercostal space –R/L of sternum
V4: 5th intercostal space – midclavicular line
V3: Between V2 and V4
V5: At horizontal level of V4, anterior to axilla
V6: Midaxillary at horizontal level of V4

12-lead electrocardiograph



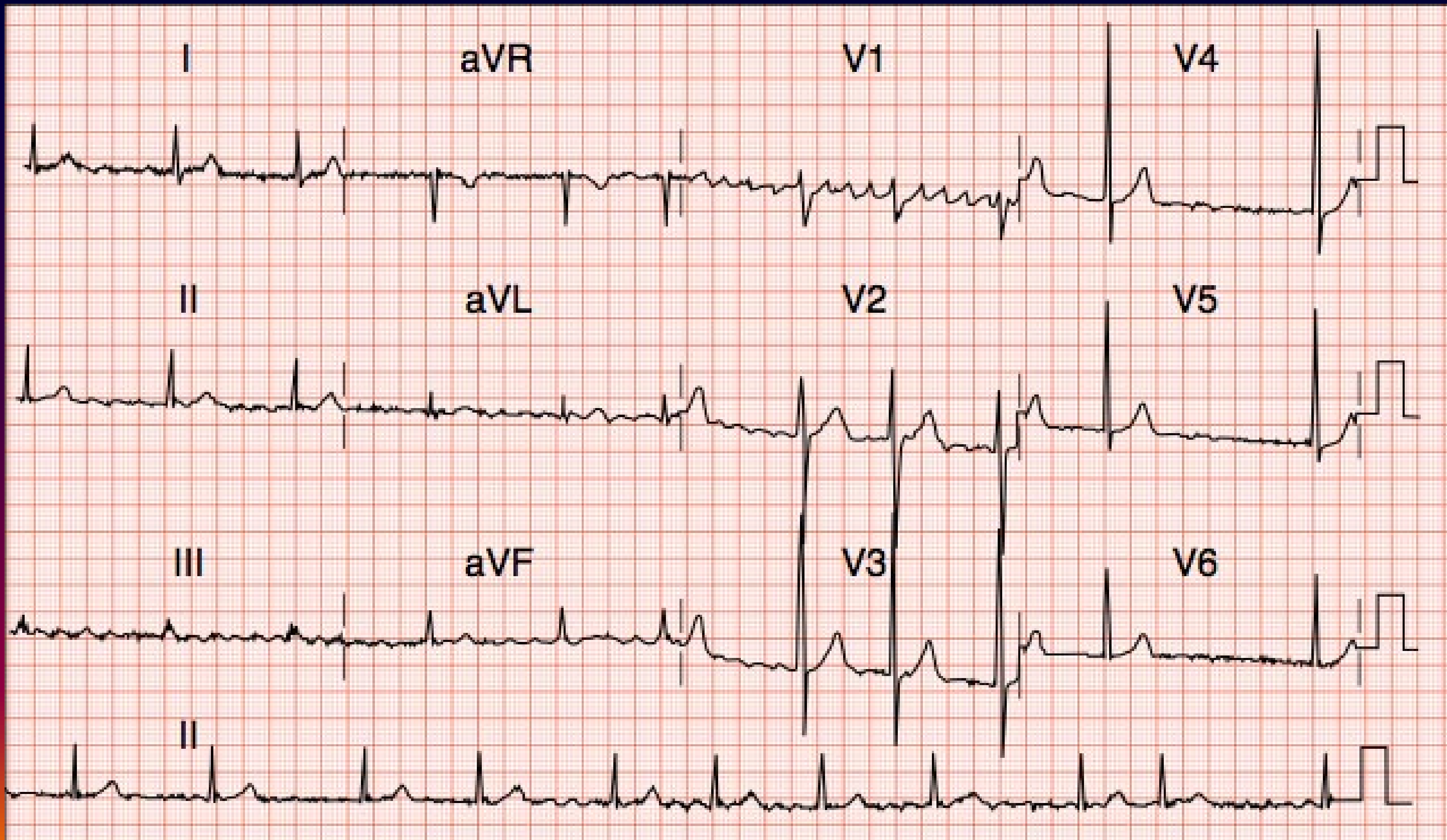
Cardiac Arrhythmias

- Abnormal heart rhythm where the heart may beat too quickly = tachycardia; too slowly = bradycardia; or with irregular patterns.
- Common arrhythmias include:
  - Atrial fibrillation
  - Atrial flutter
  - Ventricular tachycardia
  - Ventricular fibrillation

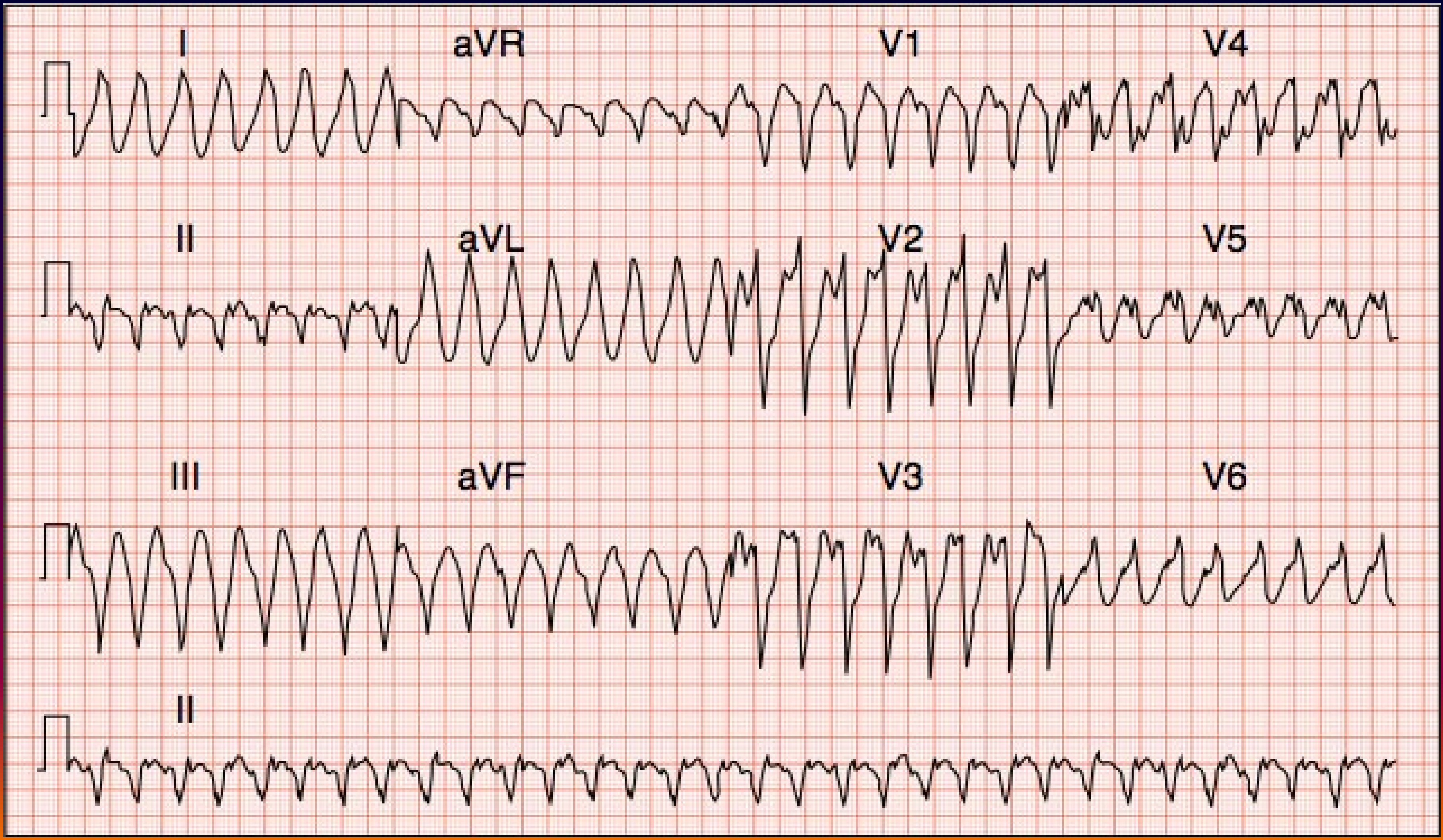
Symptoms:

- Shortness of breath
- Chest pain
- Decreased level of consciousness
- Low blood pressure
- Slow or fast heart rate varying greatly from baseline
- Pulmonary edema
- Congestive heart failure
- Acute MI, or shock

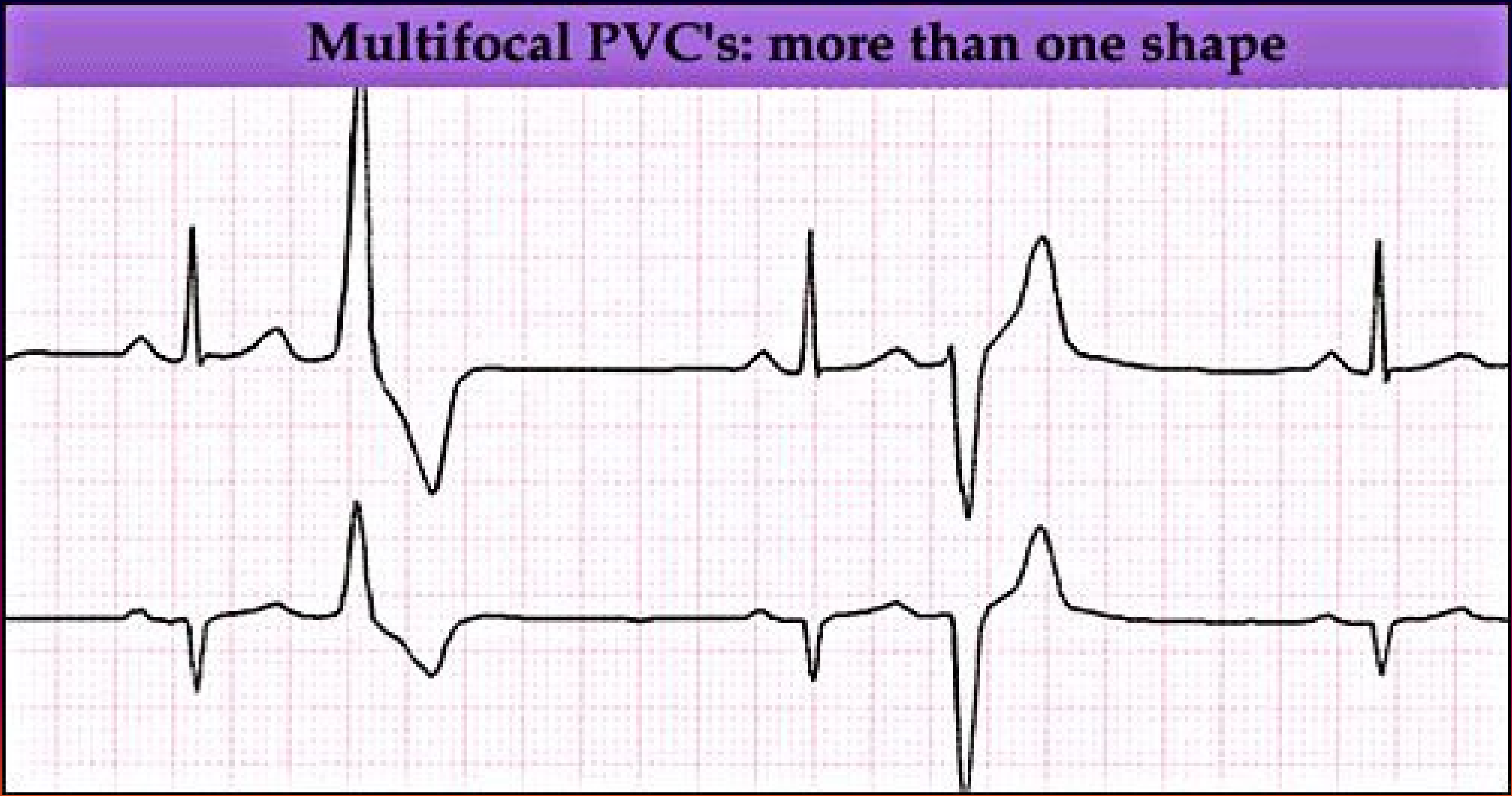
Atrial Fibrillation



Ventricular Tachycardia



ECTOPIC BEATS



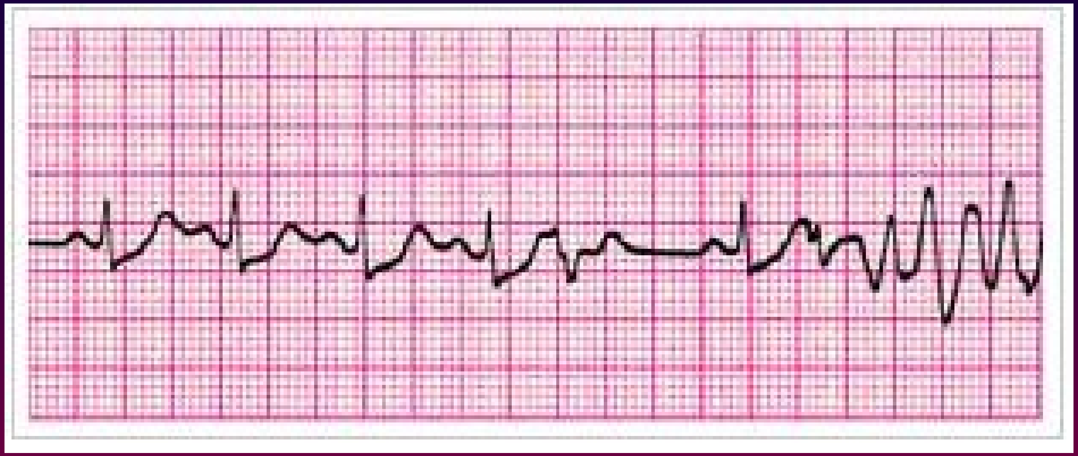
PVC = Premature Ventricular Contraction

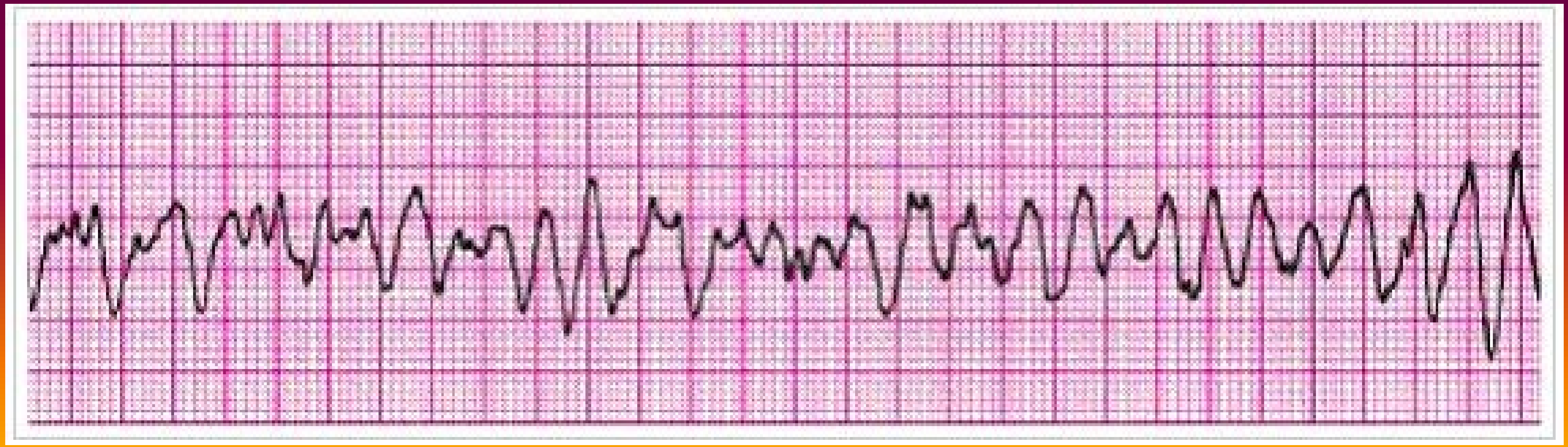
ECTOPIC BEATS

Triplet PVC's: occur in groups of three

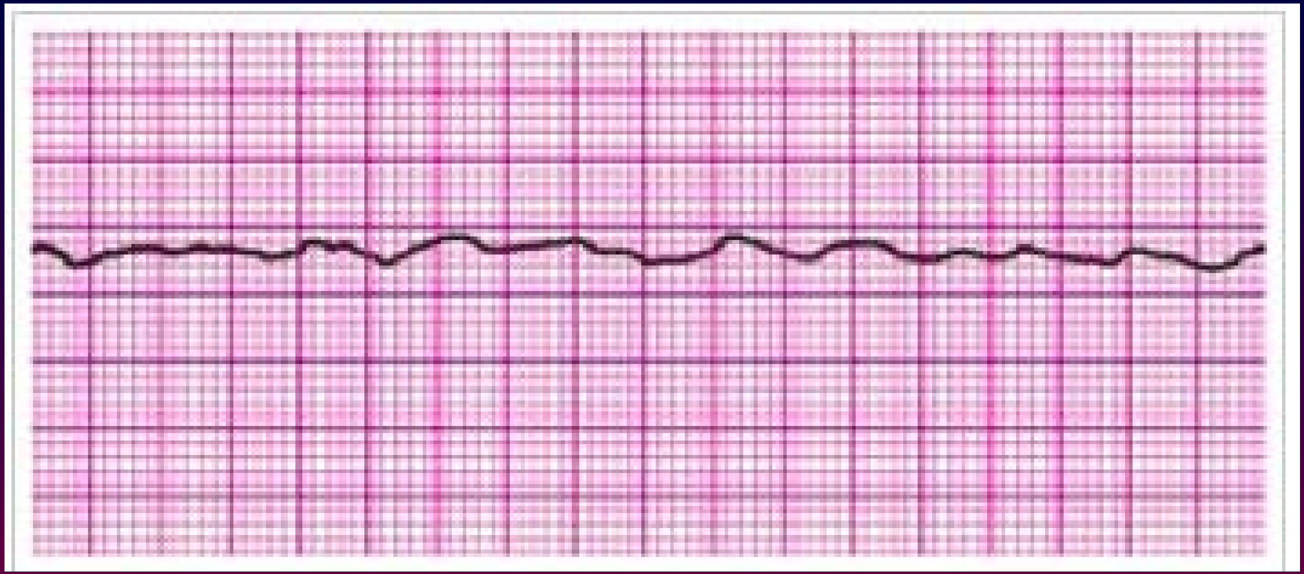
Course Ventricular Fibrillation

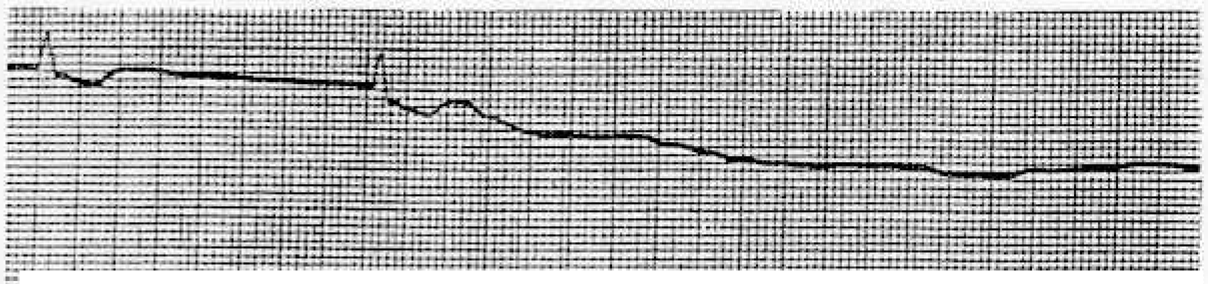
Uncoordinated beating of heart cells, resulting in no blood pressure or cardiac output. Needs an electrical shock urgently… brain damage in ~ 4+ minutes.





Fine ventricular fibrillation

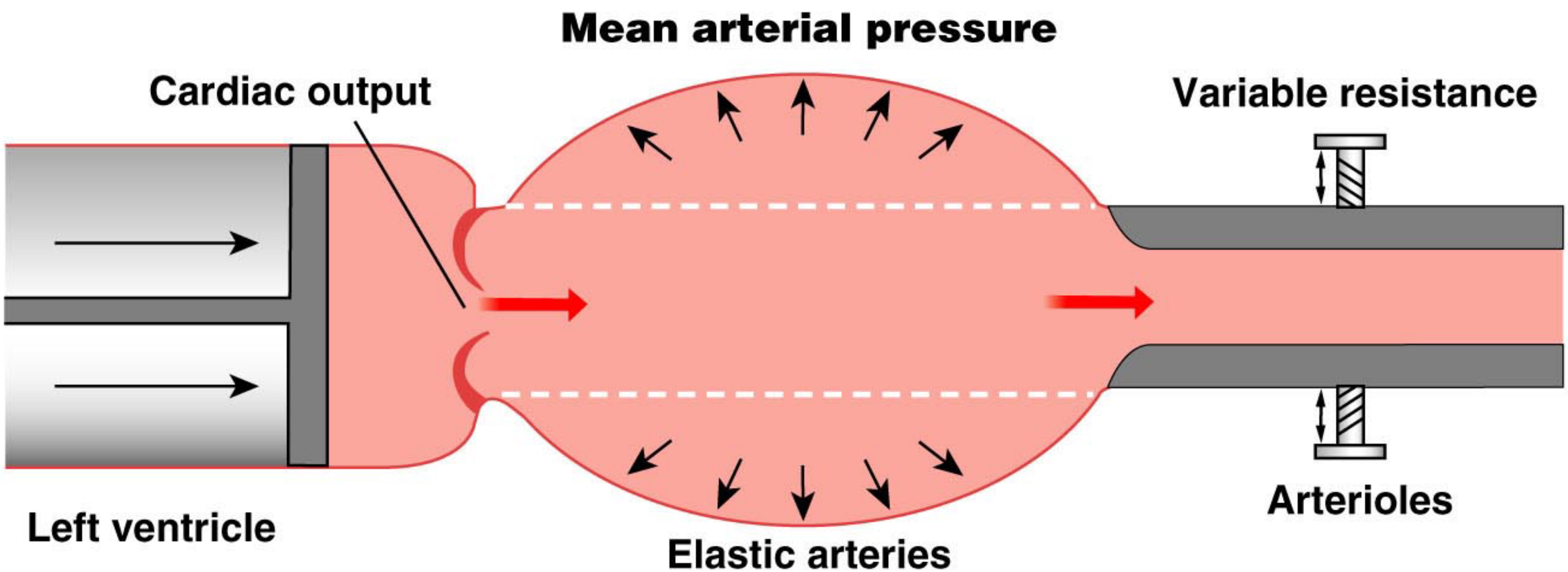




Ventricular asystole

Blood Pressure

Blood pressure creates blood flow or cardiac output



Mean arterial pressure ∝ cardiac output × resistance

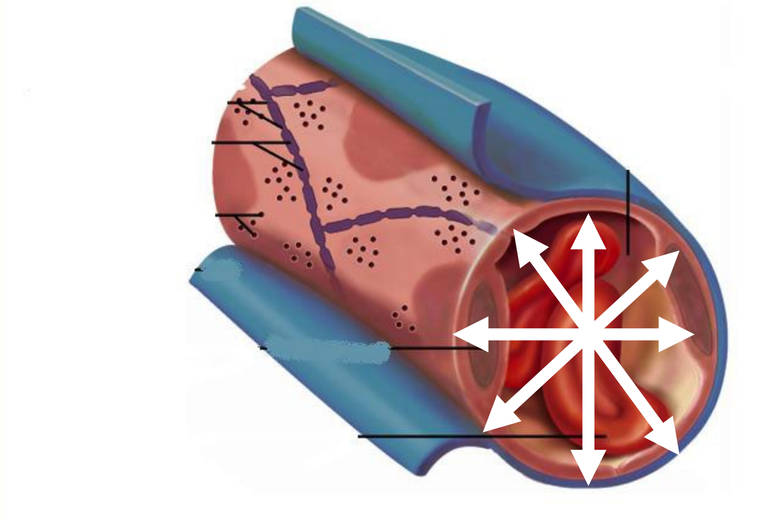
Think: Ohm's Law: V = I x R

Blood pressure:

- **The pressure that blood exerts across the blood vessel wall**

Pressure, P, is defined as force, F, per unit area, A:

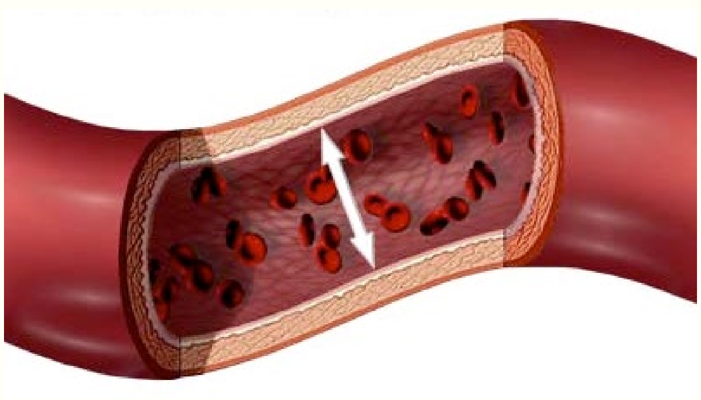
$$P = F / A$$



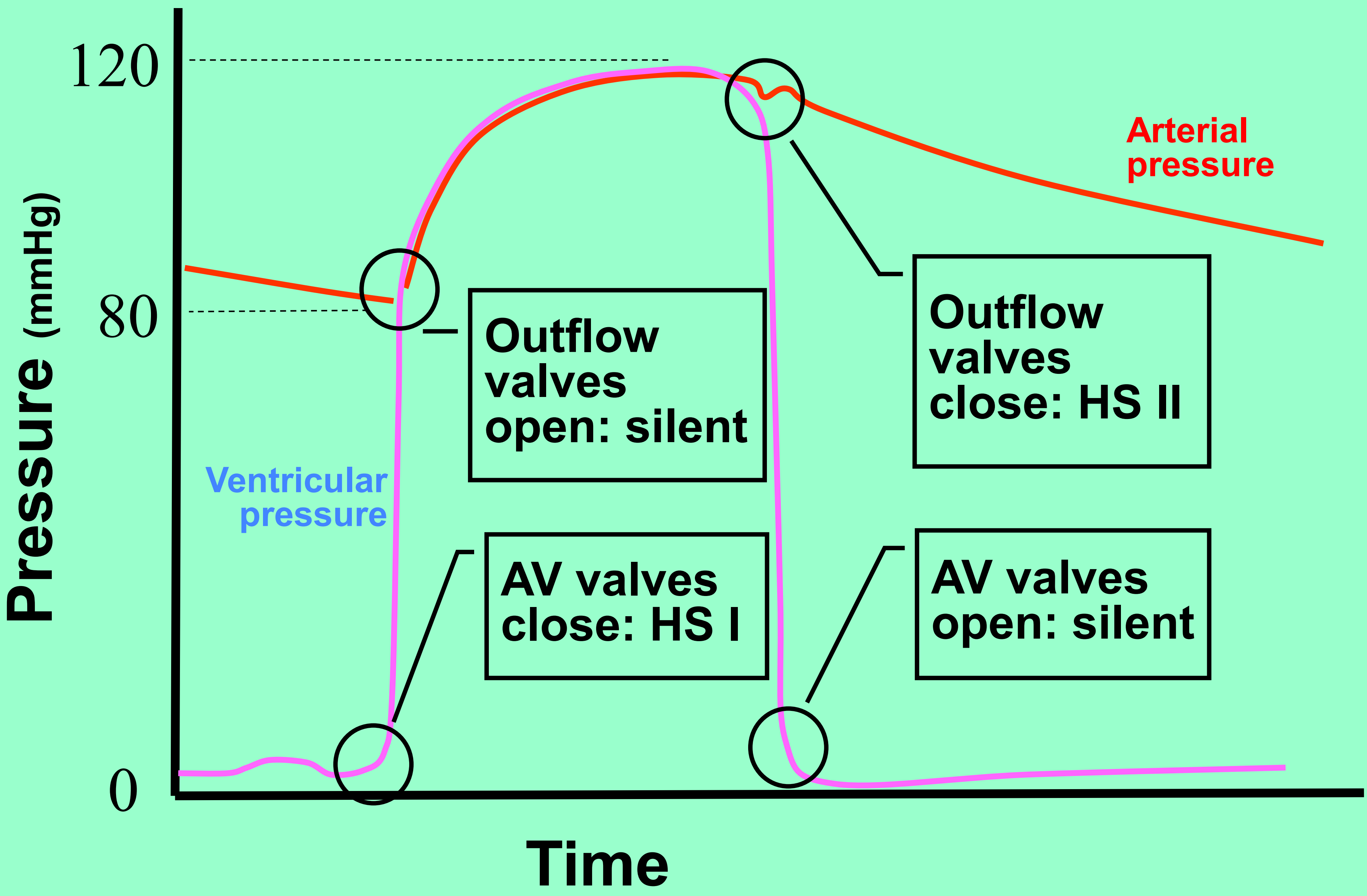
Pressure can also be stated in terms of the force exerted by a column of fluid.

Example:

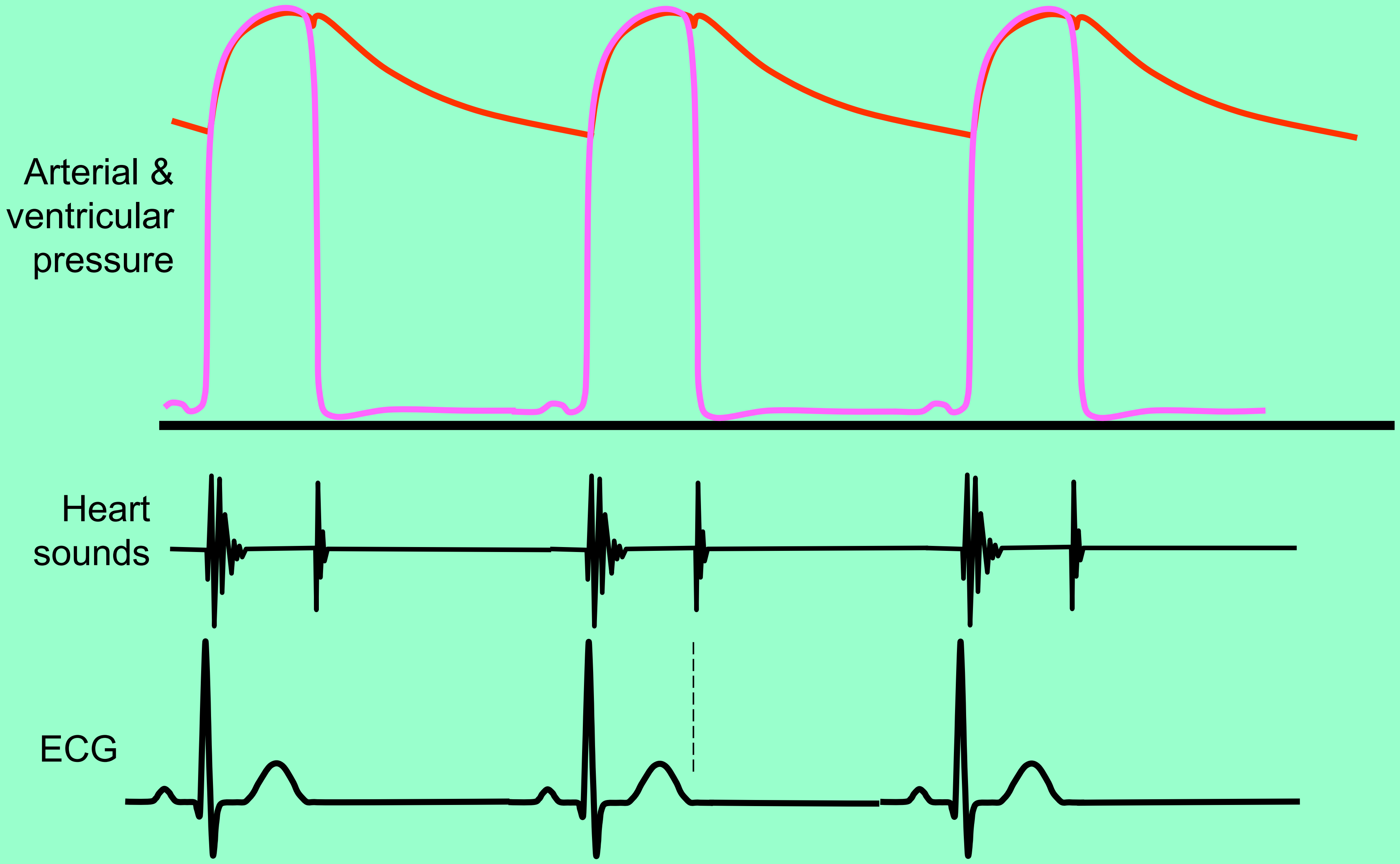
100 mmHg = 53.53 in $H_2 0$
= 1.934 psi = 13.33 kPa



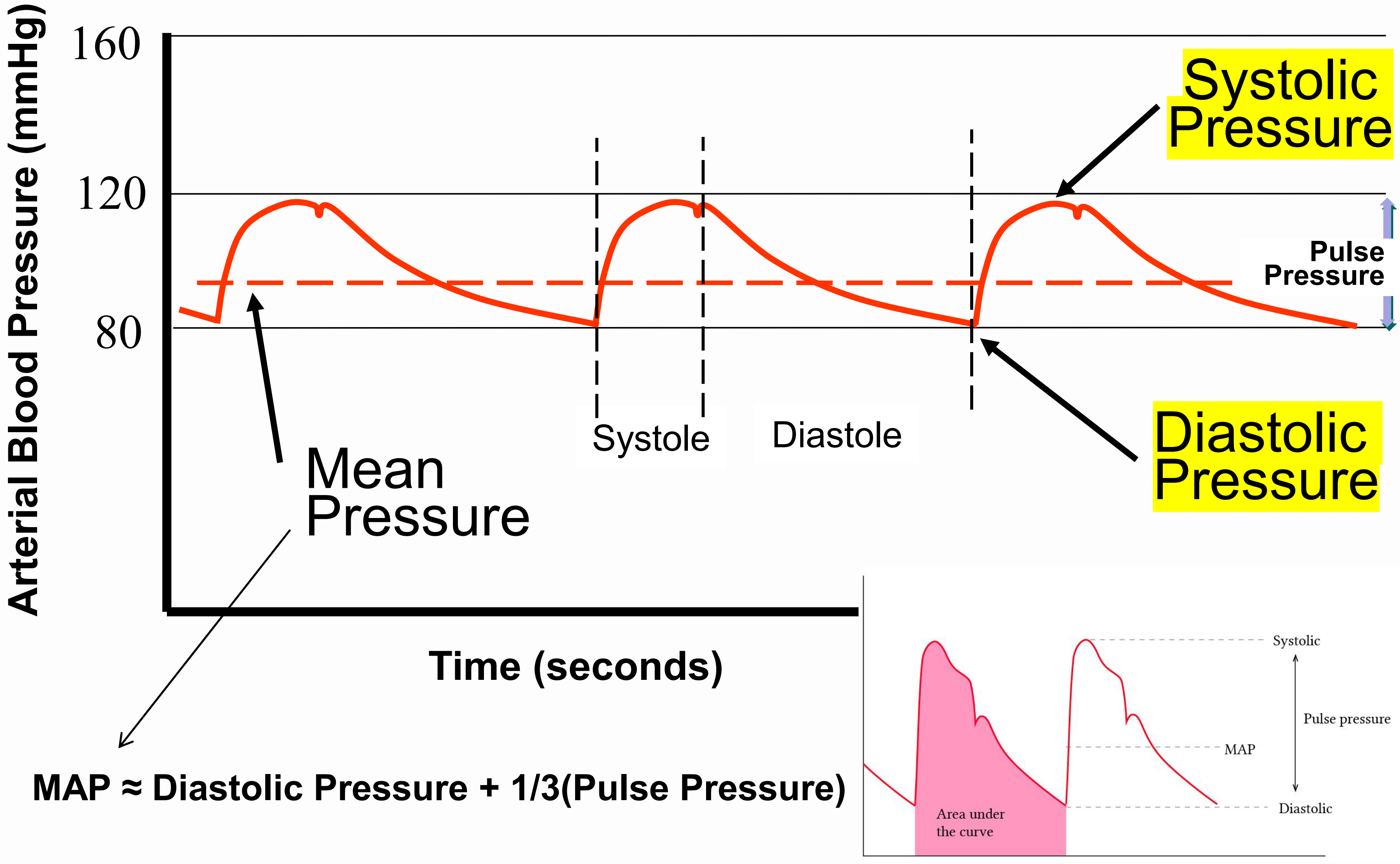
Valve Events



ECG, Heart Sounds, and Pressures



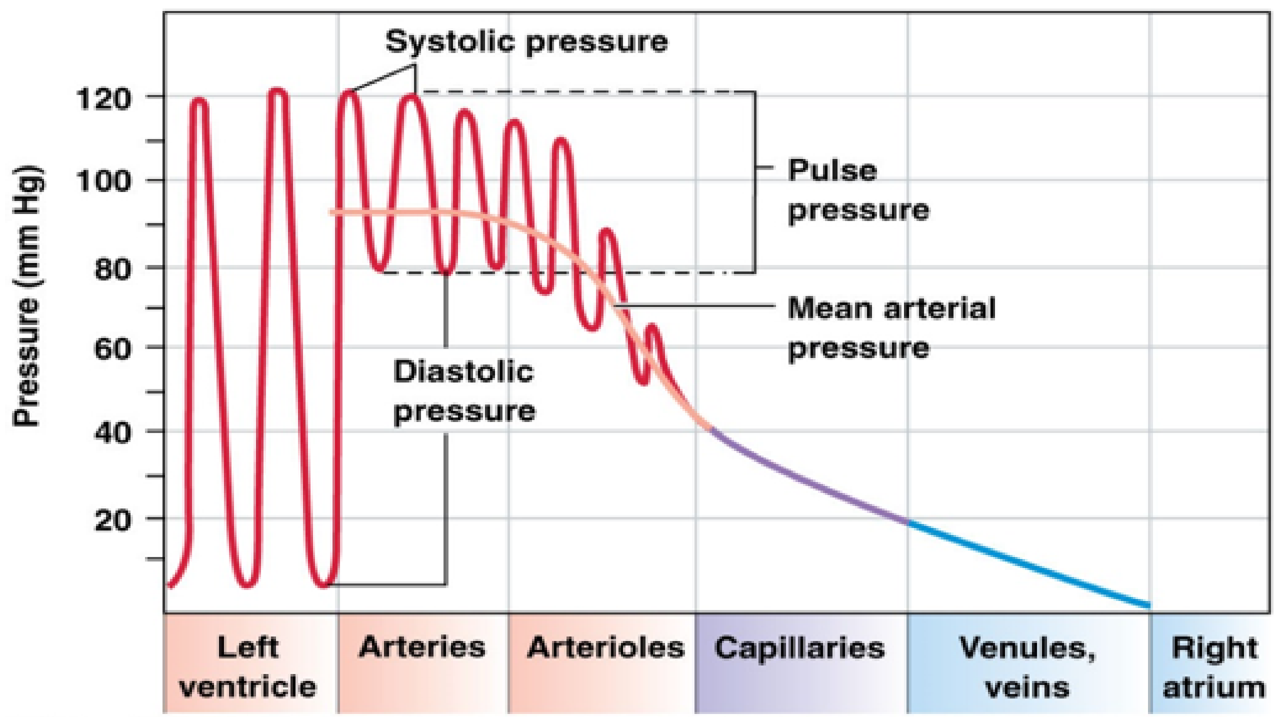
The Arterial Pressure Wave



MAP ≈ Diastolic Pressure + 1/3(Pulse Pressure)

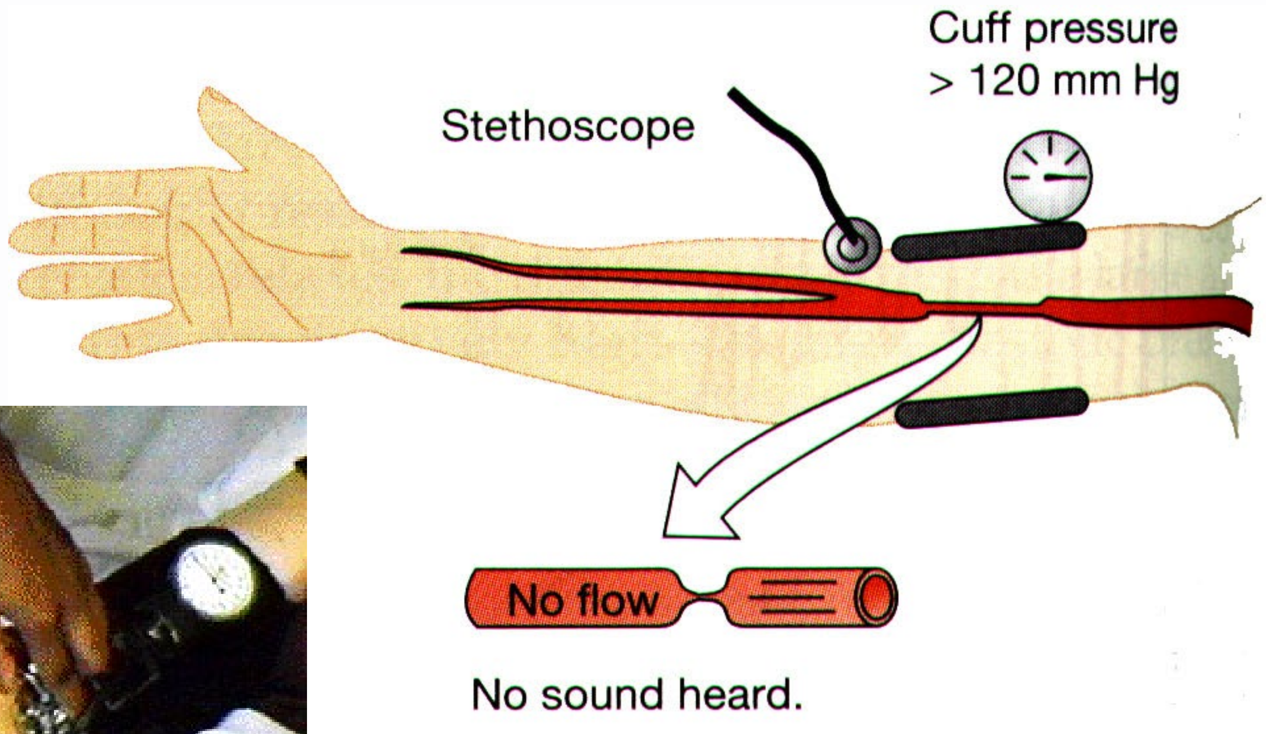
Systemic Circulation Pressures

- Pressure waves created by ventricular contraction travel into the blood vessels
- Pulsatile pressures in the arterial tree
- Pressure pulsations diminish and disappear altogether by the capillaries (due to elasticity of the vessels)



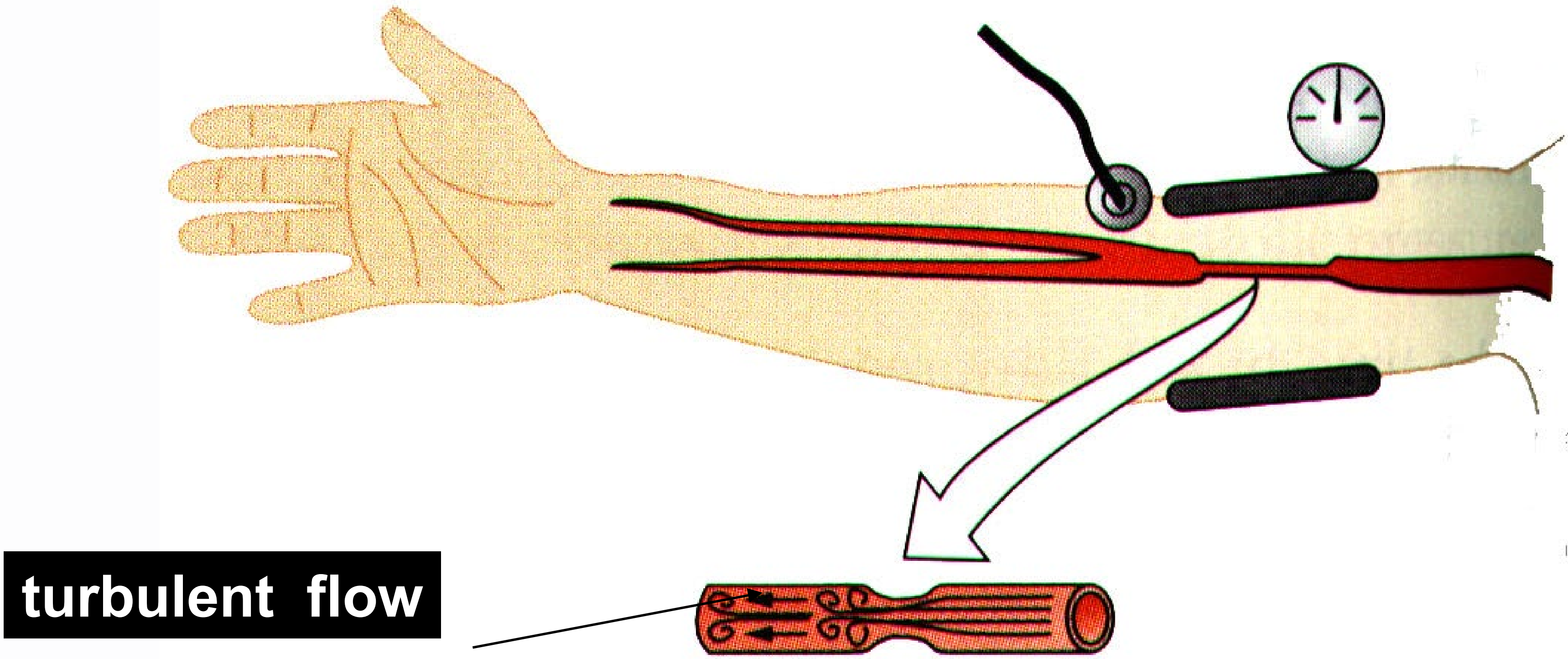
Principles of Sphygmomanometry

1. **Cuff inflated until brachial artery compressed and blood flow stopped**



Principles of Sphygmomanometry

2. Cuff pressure is slowly released



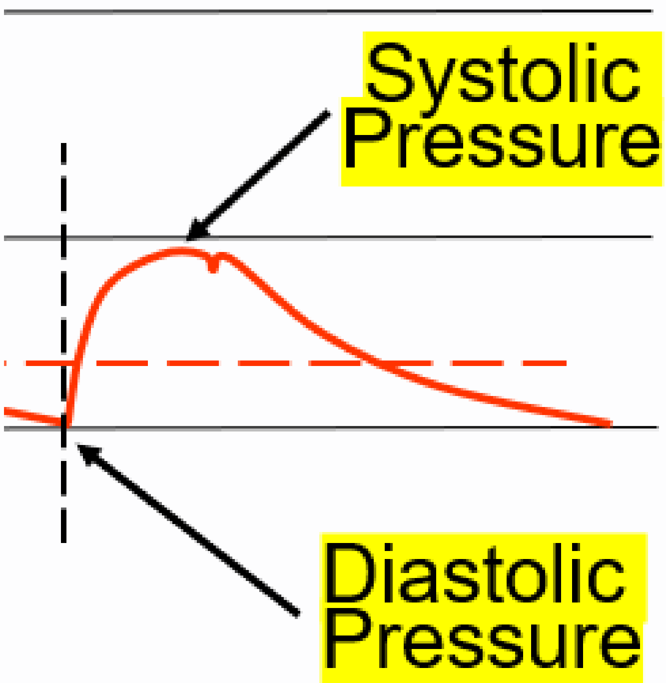
Flow through partially constricted artery creates turbulence; which creates vibrations that are heard as <u>Korotkoff</u> sounds.

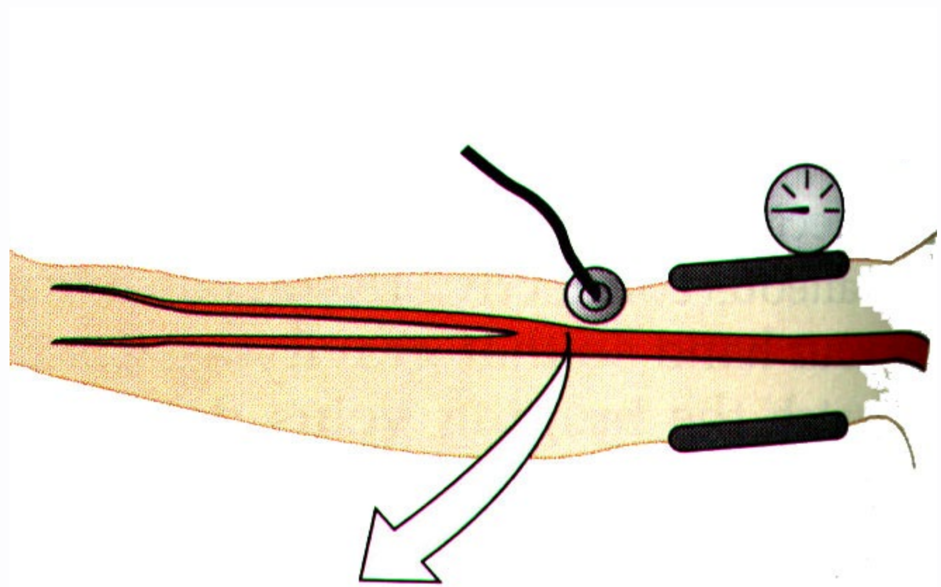
Principles of Sphygmomanometry

3. Pressure at which . . .

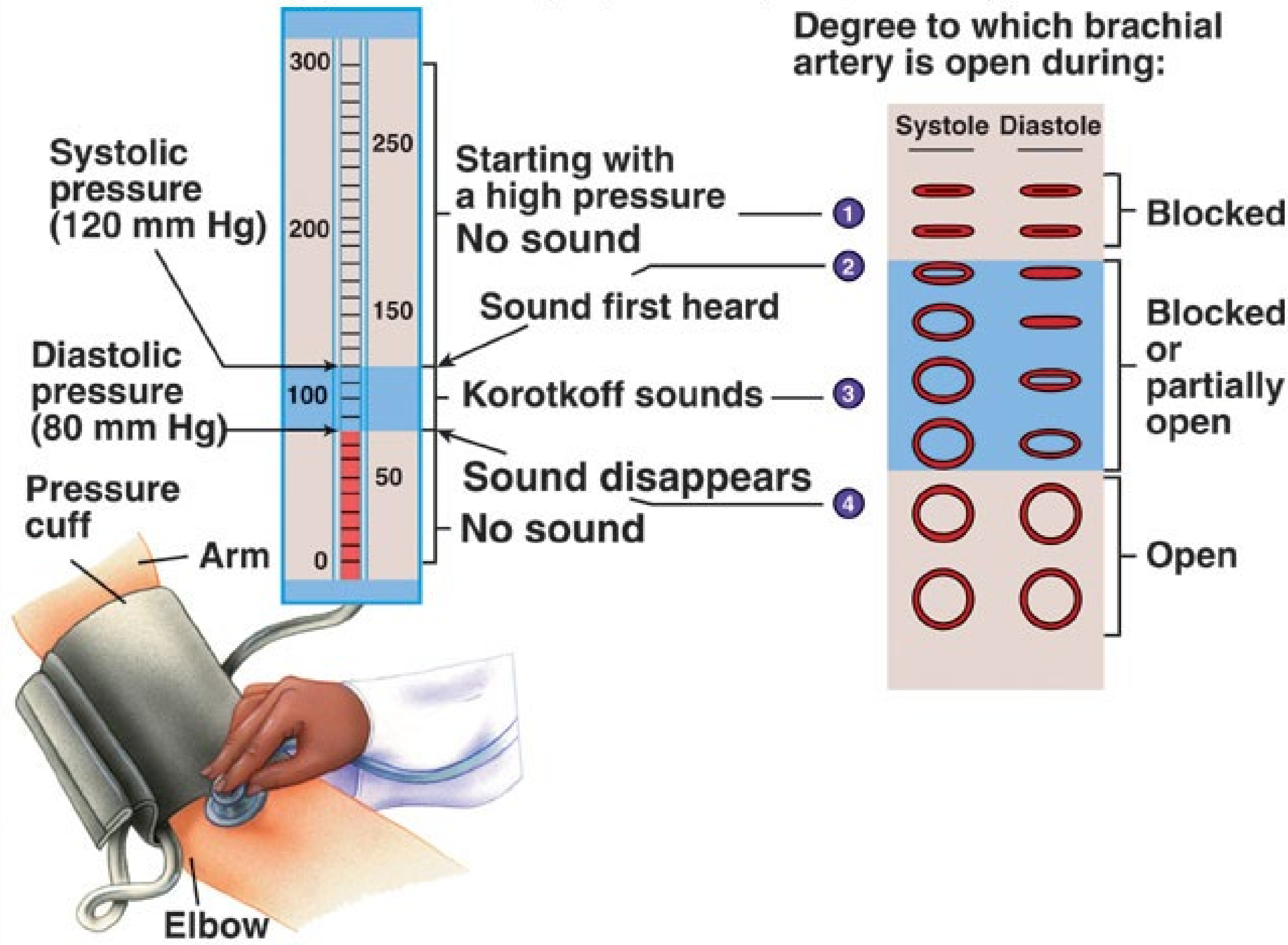
first sound heard = systolic pressure

sound disappears = diastolic pressure





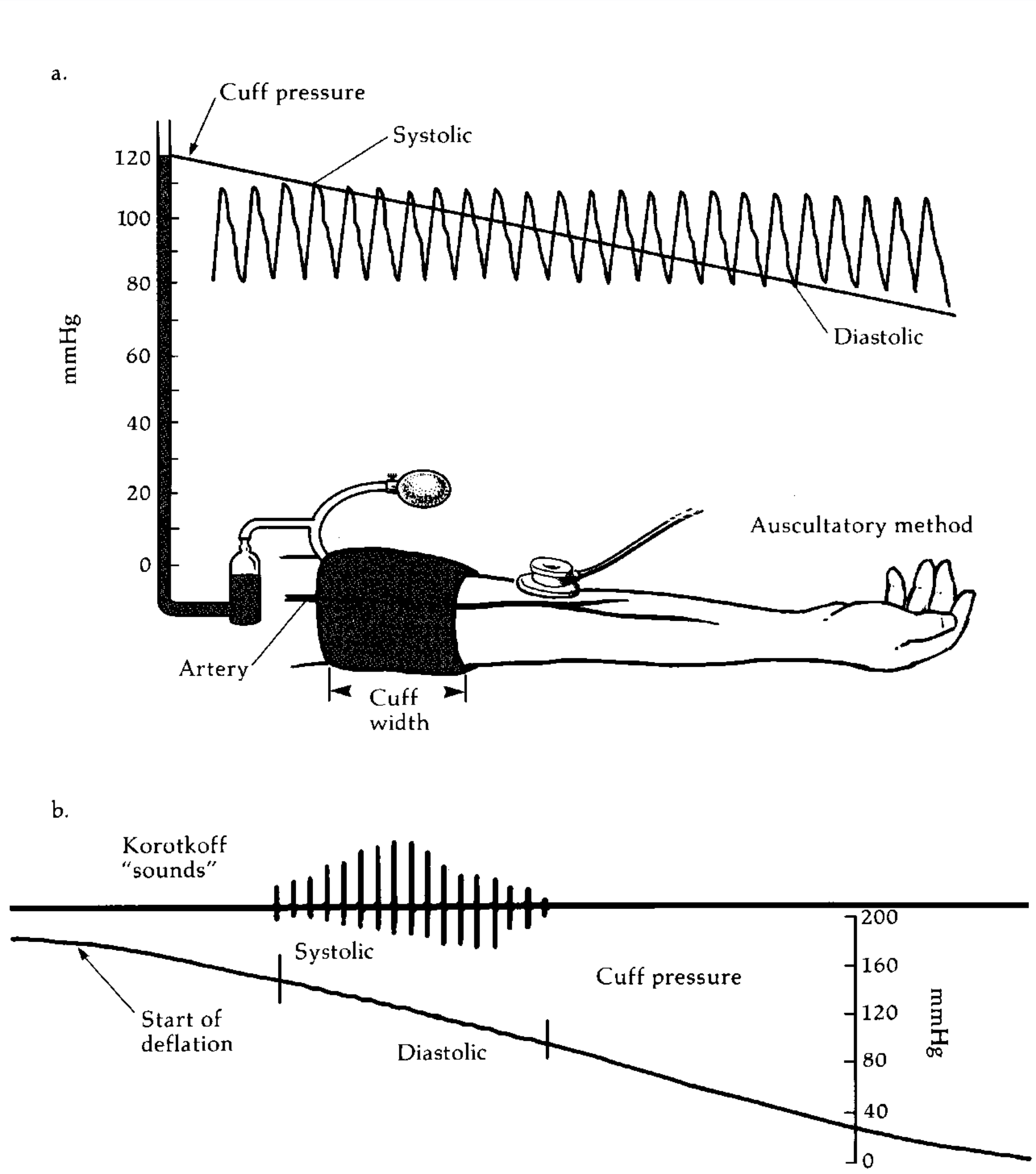
Blood Pressure Measurement



Blood Pressure Measurement

Blood pressure as obtained through auscultation is *an <u>indirect</u> measure (or* estimate*)* of the actual arterial pressure. *<u>And, is why it may not agree with that obtained invasively.</u>*

sphygmomanometer



Sources of Error in BP Measurement

Equipment Factors

- Aged mercury devices
- Non-calibrated aneroid devices
- Non-validated automated devices
- Improper cuff size

Observer Factors

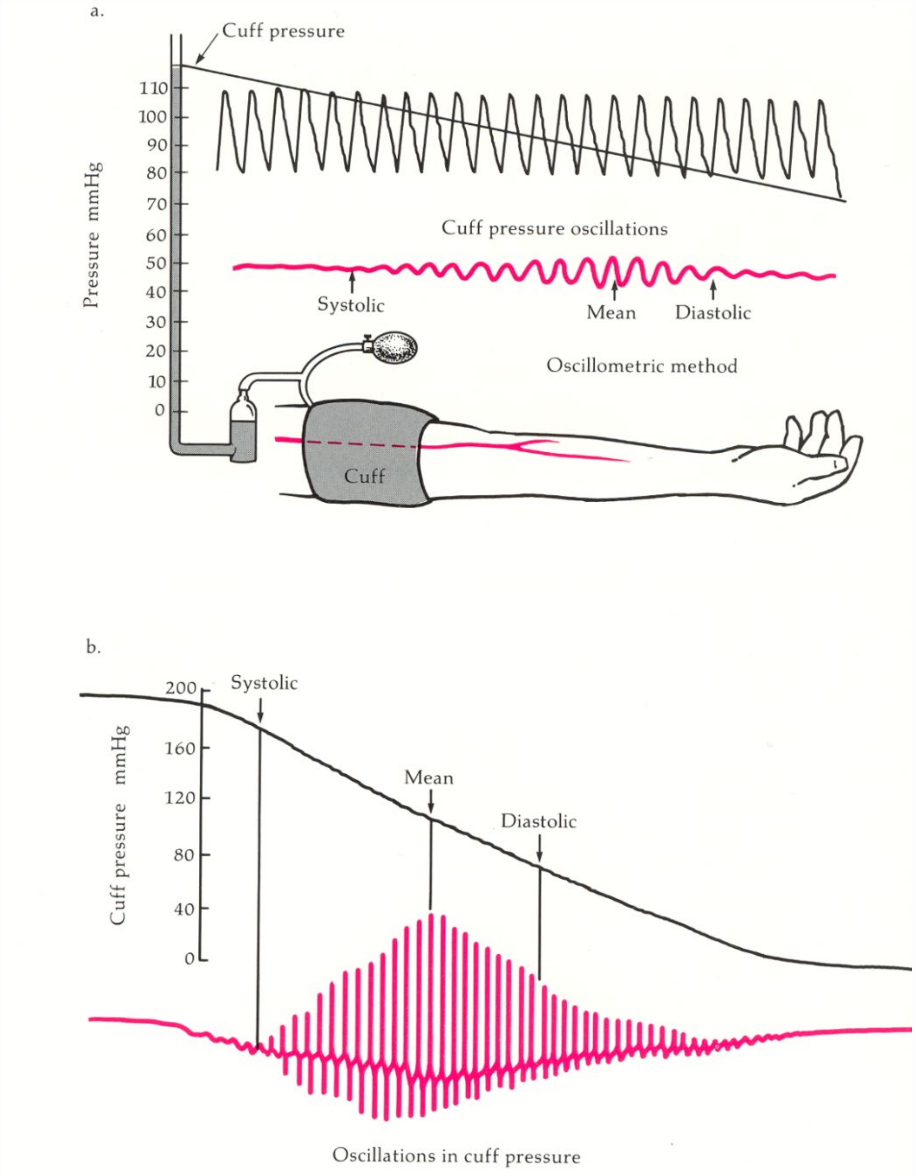
- Poor measurement technique
- Digit preference
- Expectation bias
- Background noise
- Distractions
- Hearing acuity

Patient Factors

- Conversation with observers
- No rest period before measurement
- White coat effect
- Alcohol
- Caffeine
- Smoking
- Full bowel/bladder

Blood Pressure Measurement

The oscillometric method of blood pressure measurement (estimation) is also an indirect measure that does not require use of a stethoscope. Systolic, diastolic, and mean pressures are derived from cuff pressure oscillations transmitted from the artery during cuff deflation.



Arterial pressure monitoring

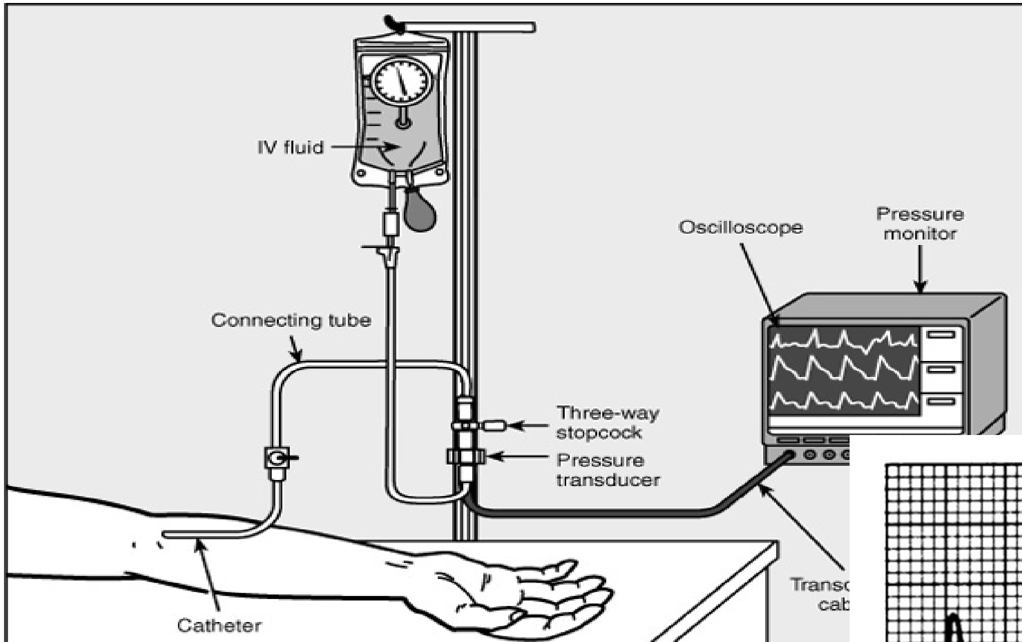


Figure 5-6 Essential components for invasive monitoring, using the brachial approach.
drawn to scale.) (From Jackle, M., & Halligan, M. [1980]. *Cardiovascular problems: A cri*
focus. Bowie, MD: Robert J. Brady.)

Disposable blood pressure transducer

Dicrotic notch. Due to abrupt closure of aortic valve.

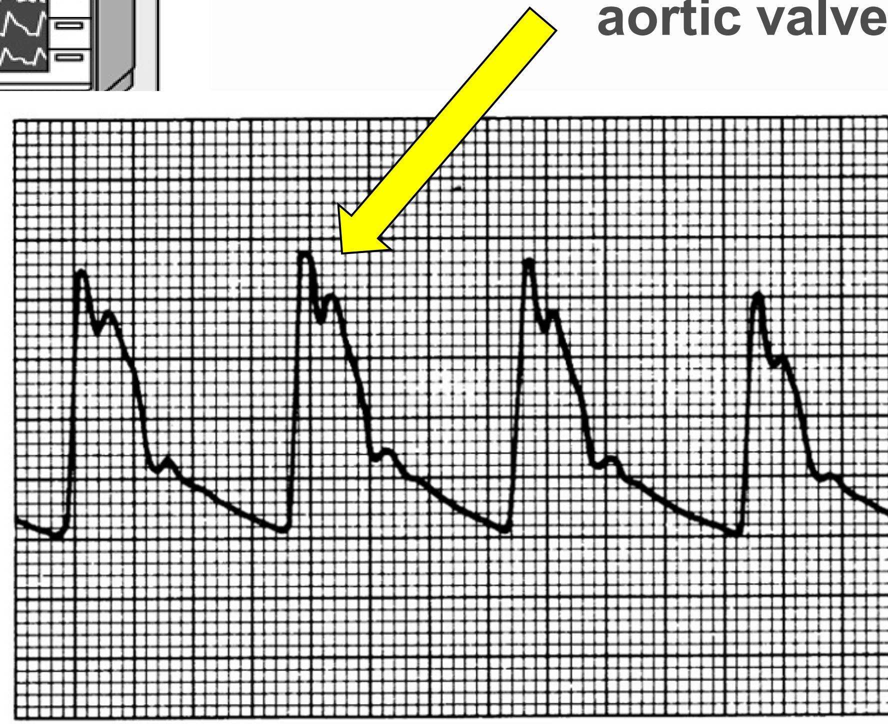
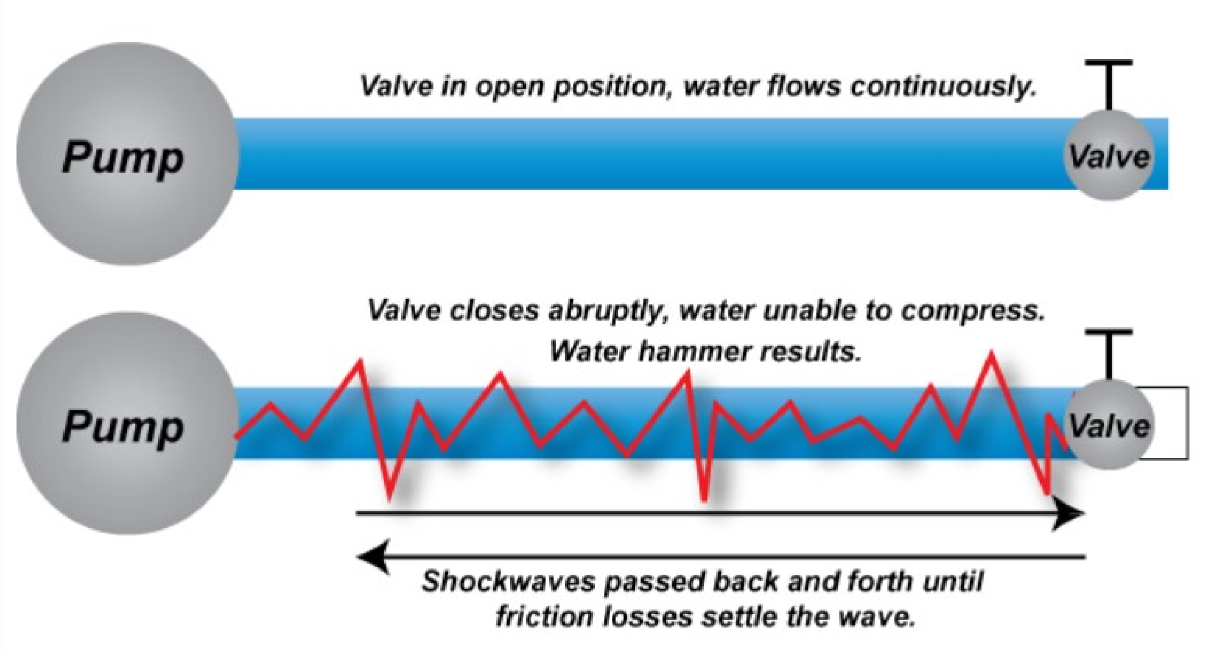


Figure 5-10 A, Normal arterial waveform depicting sharp upstroke and clear dicrotic notch. (From Jackle, M., & Halligan, M. [1980]. *Cardiovascular problems: A critical care nursing focus.* Bowie, MD: Robert J. Brady.)

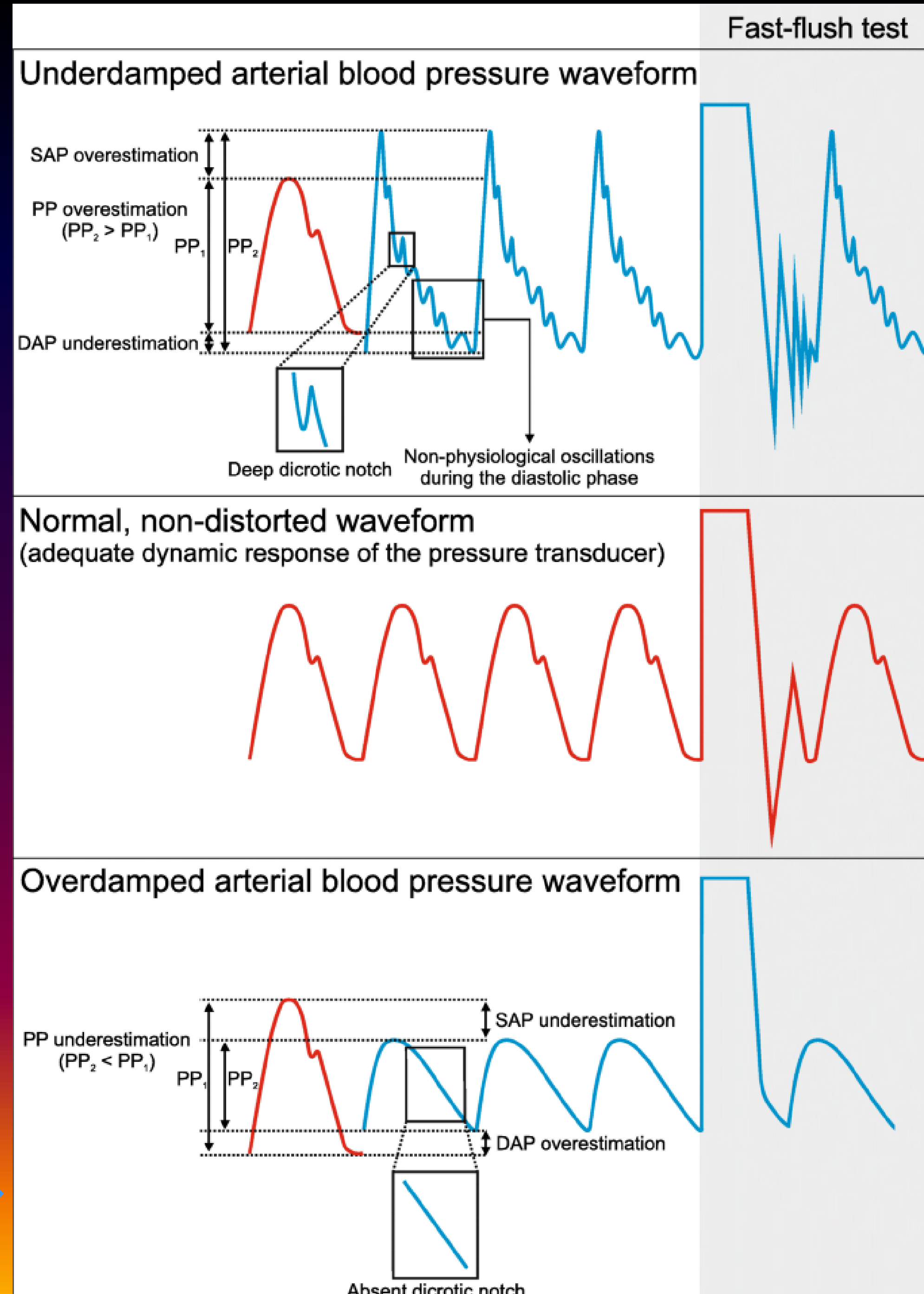
Normal Arterial Waveform



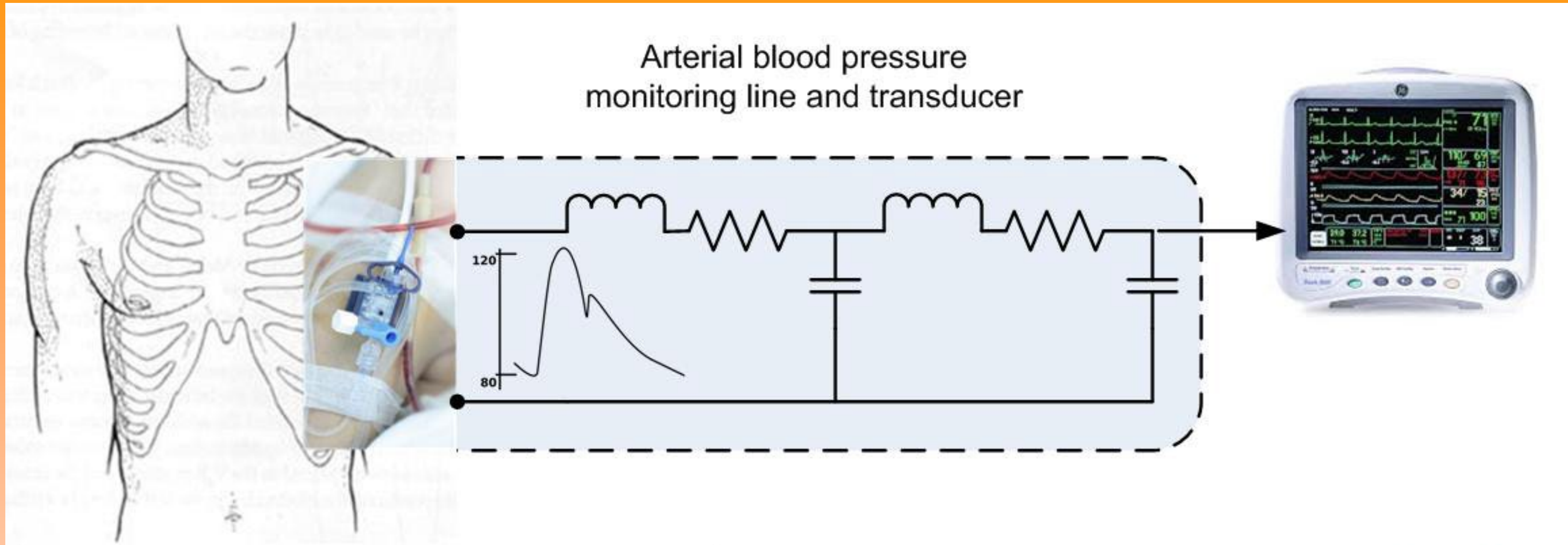
Dicrotic notch is a physiological form of water hammer effect caused by the abrupt closer of the aortic valve. A similar notch is also seen in the pulmonary artery pressure waveform produced by the right ventricle.

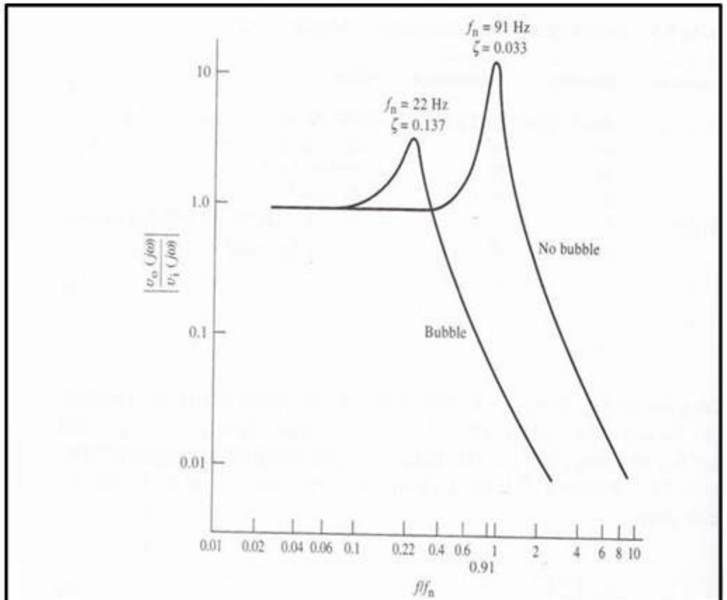
Errors in invasive BP measurements

BP monitor will display higher than actual systolic pressures and lower than actual diastolic pressures.



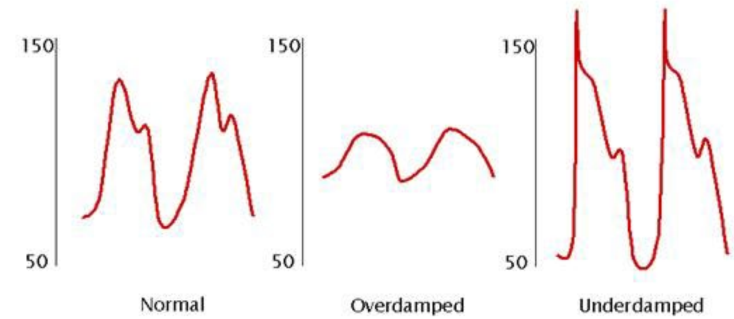
BP monitor will display lower than actual systolic pressures and higher than actual diastolic pressures.

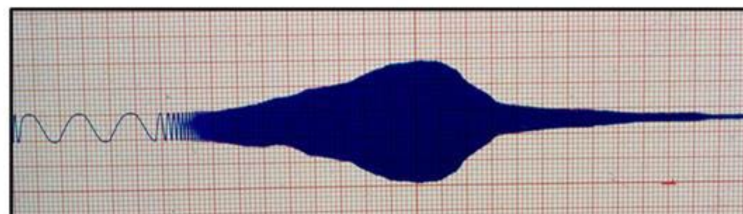




Air bubbles increase the compliance of the monitoring system which lowers its resonant frequency.

Adapted from: J. Webster. Medical Instrumentation: Application and Design. Wiley, 3rd ed., 1998, p. 300.

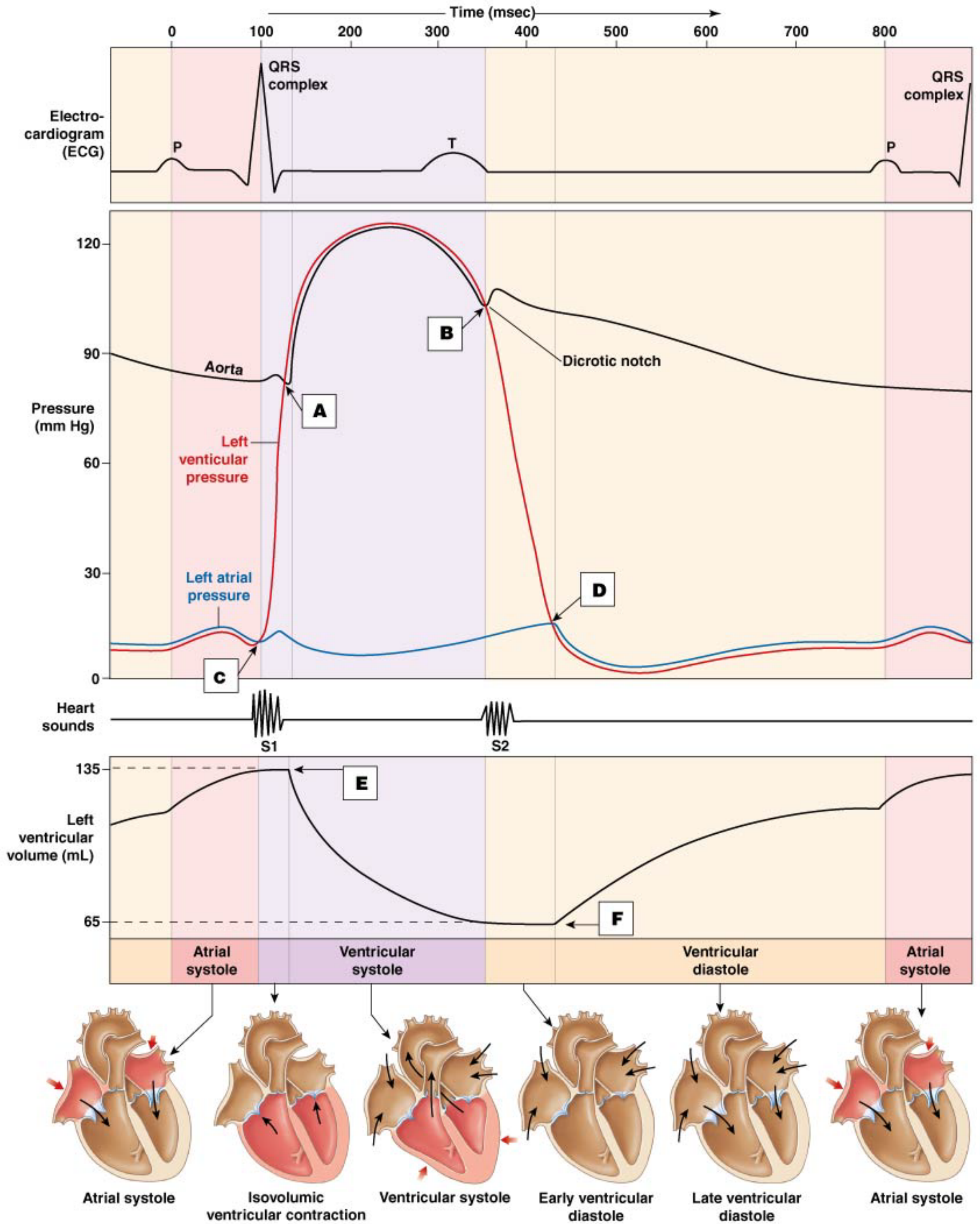




Arterial pressure waveform becomes increasingly distorted as measurement system approaches its resonant frequency.

Wigger's diagram summarizes the electrical and mechanical events during the cardiac cycle:

- Electrical events (ECG) causes cardiac muscle contraction, which
- Causes cardiac muscle contractions, which
- Creates pressure changes in the atria and ventricles, which
- Open and close heart valves, which
- Controls the filling and ejection of blood from the ventricles.



Questions ?

Feel free to contact me following this session or anytime in the future

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Thanks for attending!

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Thank You!