

# Cardiac output and Venous Return

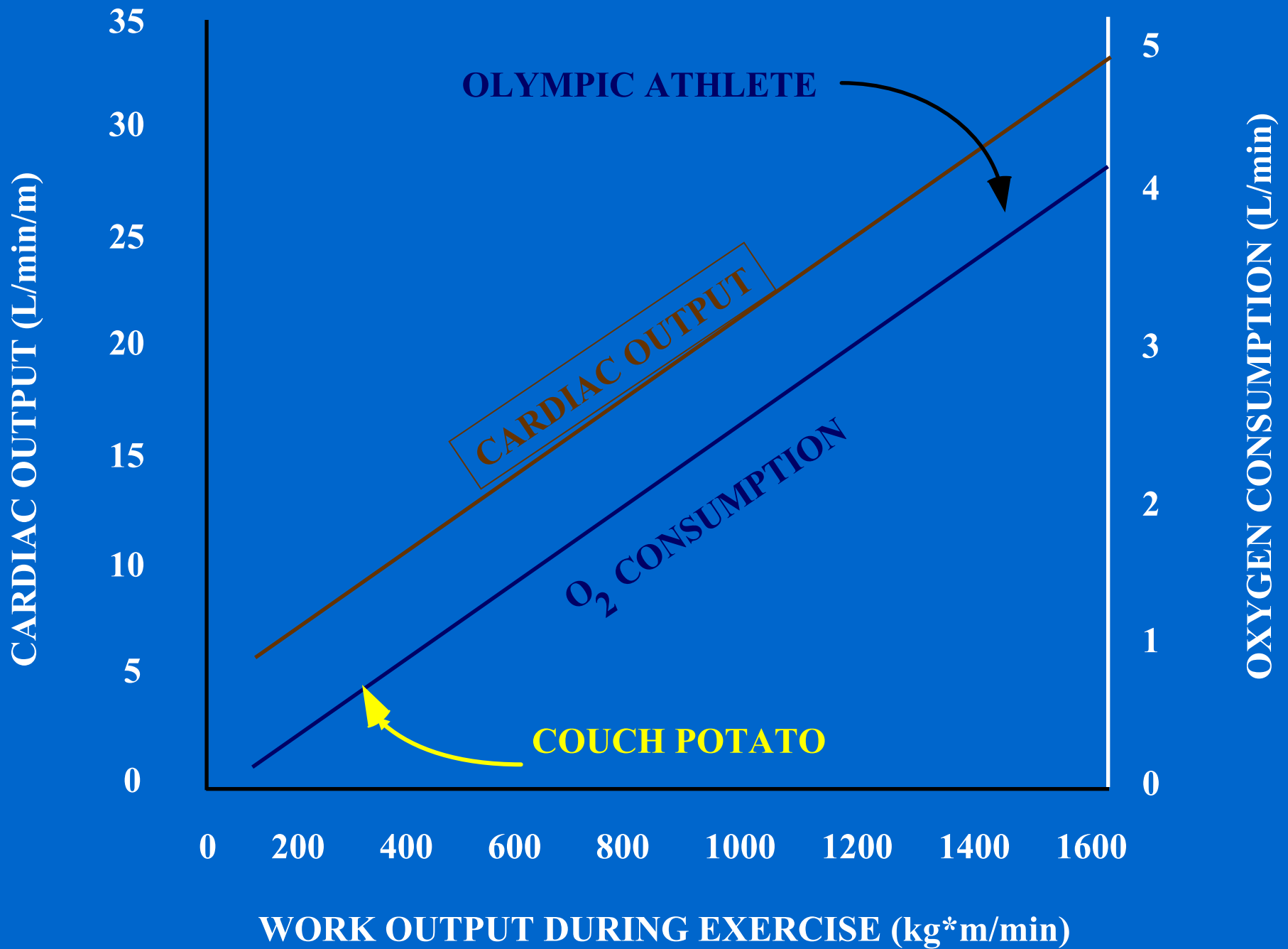
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# Objectives

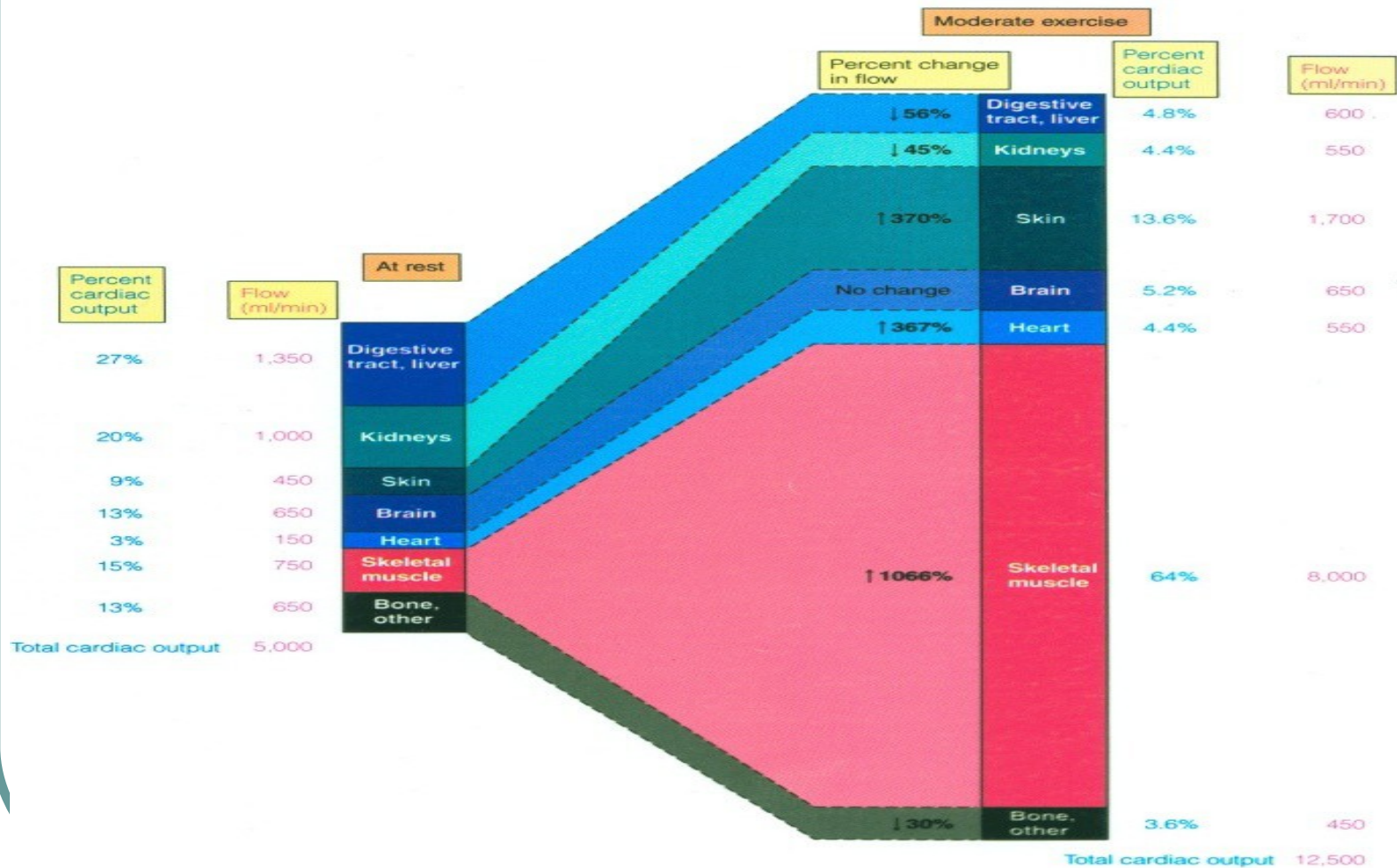
- Define cardiac output and venous return
- Describe the methods of measurement of CO
- Outline the factors that regulate cardiac output
- Follow up the cardiac output curves at different physiological states
- Define venous return and describe venous return curve
- Outline the factors that regulate venous return curve at different physiological states
- Inter-relate Cardiac output and venous return curves

# Important Concepts About Cardiac Output (CO) Control

- Cardiac Output is the sum of all tissue flows and is affected by their regulation ( $CO = 5\text{L/min}$ , cardiac index  $= 3\text{L/min/m}^2$ ).
- CO is proportional to tissue  $O_2$  use.
- CO is proportional to  $1/TPR$  when AP is constant.
- $F = \Delta P / R$  (Ohm's law)
- $CO = (MAP - RAP) / TPR$ , ( $RAP=0$ ) then
- $CO = MAP / TPR$  ;  $MAP = CO * TPR$



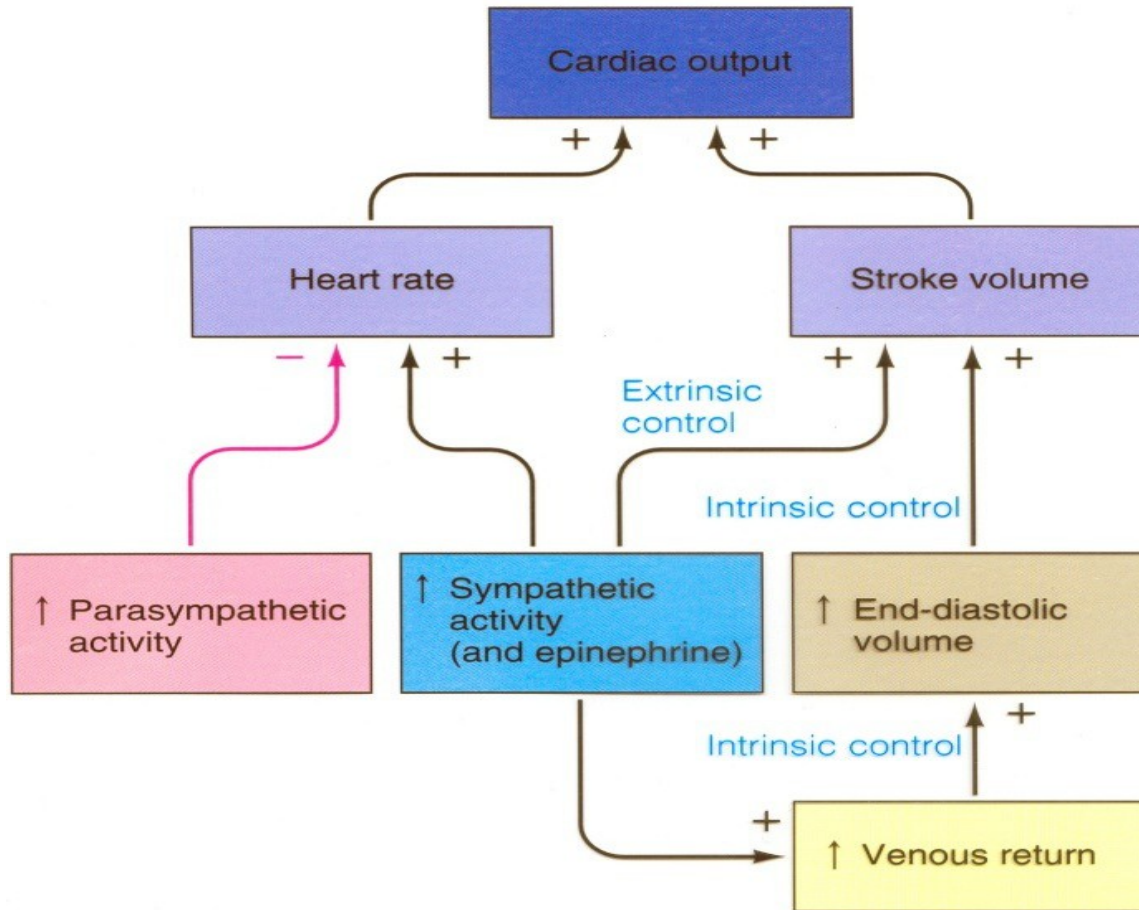
# Magnitude & Distribution of CO at Rest & During Moderate Exercise



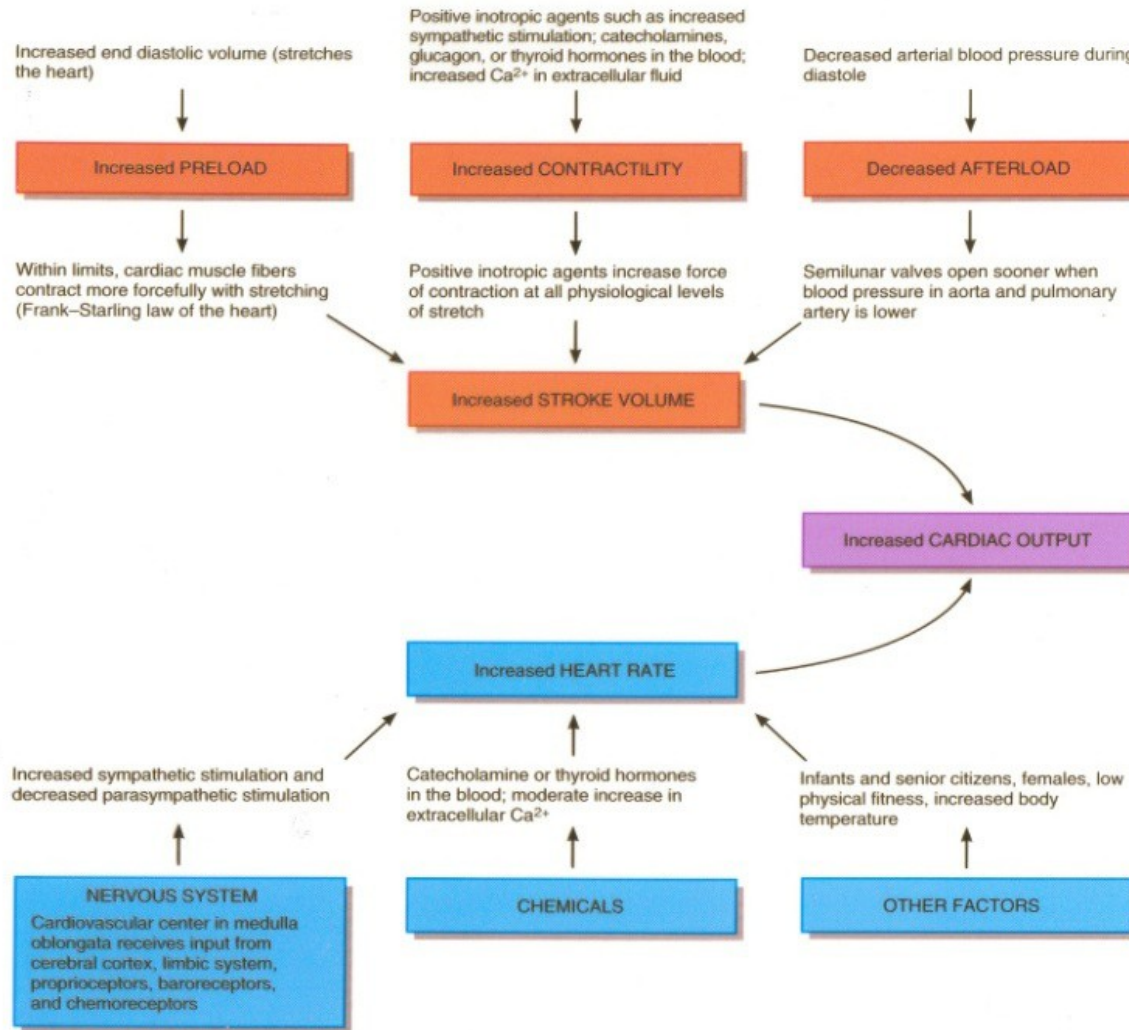
# Variations in Tissue Blood Flow

	Per cent	ml/min	ml/min/ 100 gm
<b>Brain</b>	<b>14</b>	<b>700</b>	<b>50</b>
<b>Heart</b>	<b>4</b>	<b>200</b>	<b>70</b>
<b>Bronchi</b>	<b>2</b>	<b>100</b>	<b>25</b>
<b>Kidneys</b>	<b>22</b>	<b>1100</b>	<b>360</b>
<b>Liver</b>	<b>27</b>	<b>1350</b>	<b>95</b>
<b>Portal</b>	<b>(21)</b>	<b>(1050)</b>	
<b>Arterial</b>	<b>(6)</b>	<b>(300)</b>	
<b>Muscle (inactive state)</b>	<b>15</b>	<b>750</b>	<b>4</b>
<b>Bone</b>	<b>5</b>	<b>250</b>	<b>3</b>
<b>Skin (cool weather)</b>	<b>6</b>	<b>300</b>	<b>3</b>
<b>Thyroid gland</b>	<b>1</b>	<b>50</b>	<b>160</b>
<b>Adrenal glands</b>	<b>0.5</b>	<b>25</b>	<b>300</b>
<b>Other tissues</b>	<b>3.5</b>	<b>175</b>	<b>1.3</b>
<b>Total</b>	<b>100.0</b>	<b>5000</b>	<b>---</b>

# Control of Cardiac Output

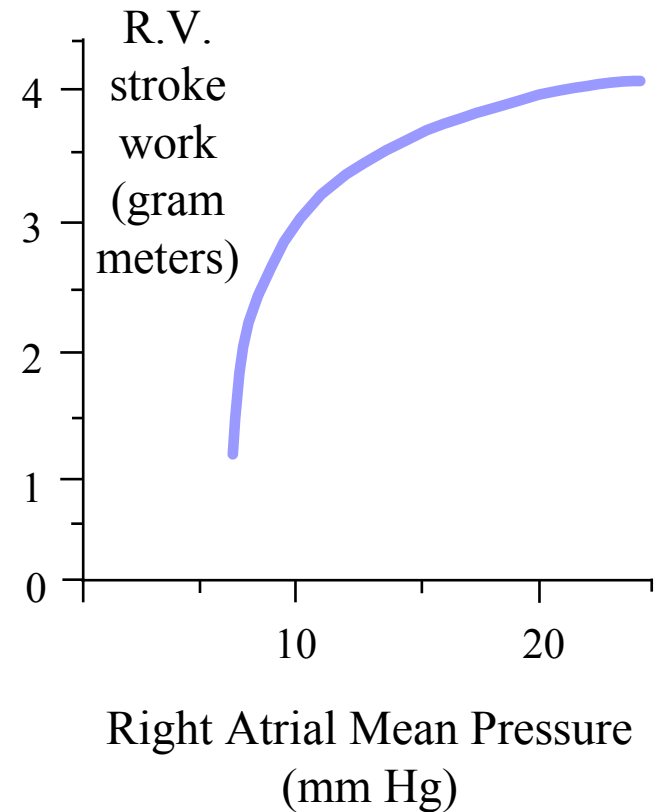
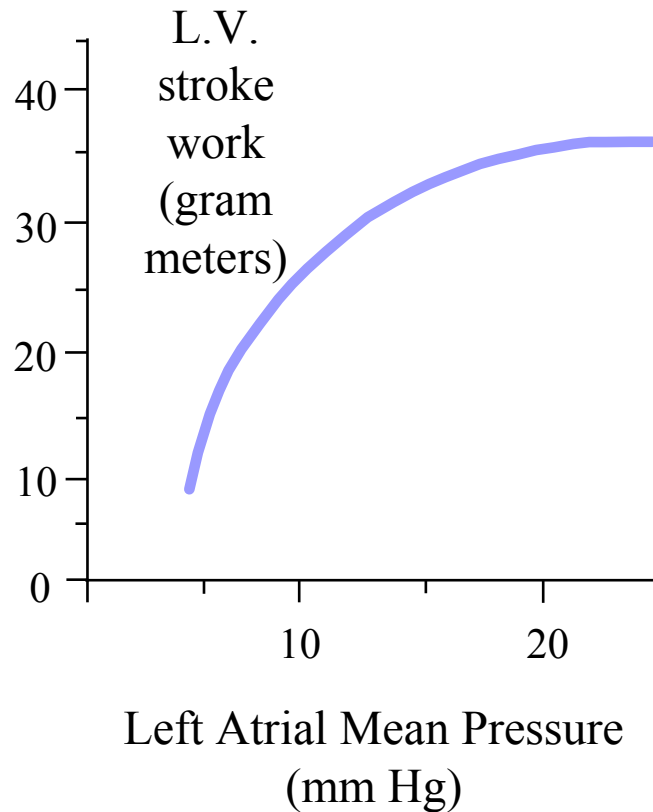


# Factors that affect the Cardiac Output

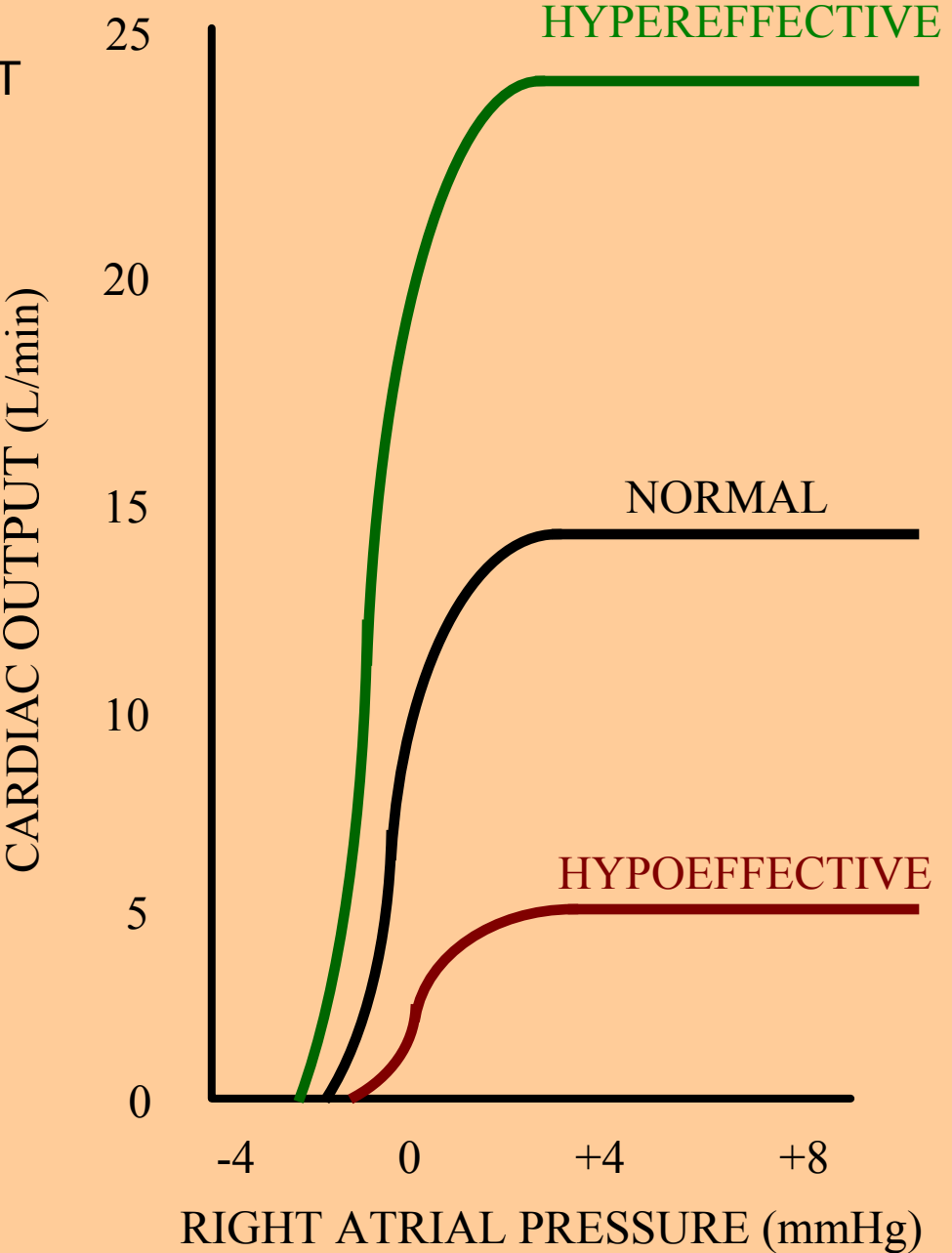




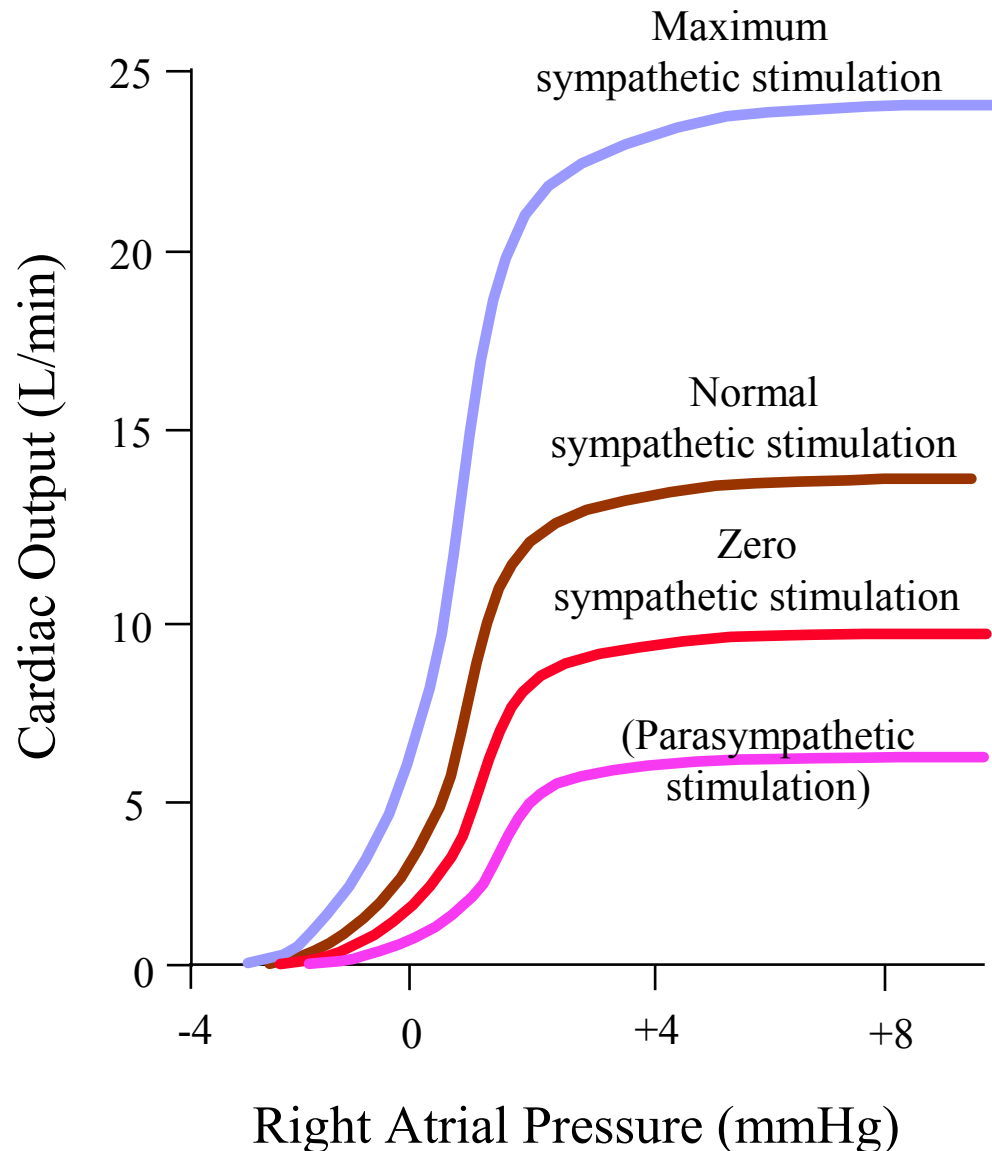
# Ventricular Stroke Work Output



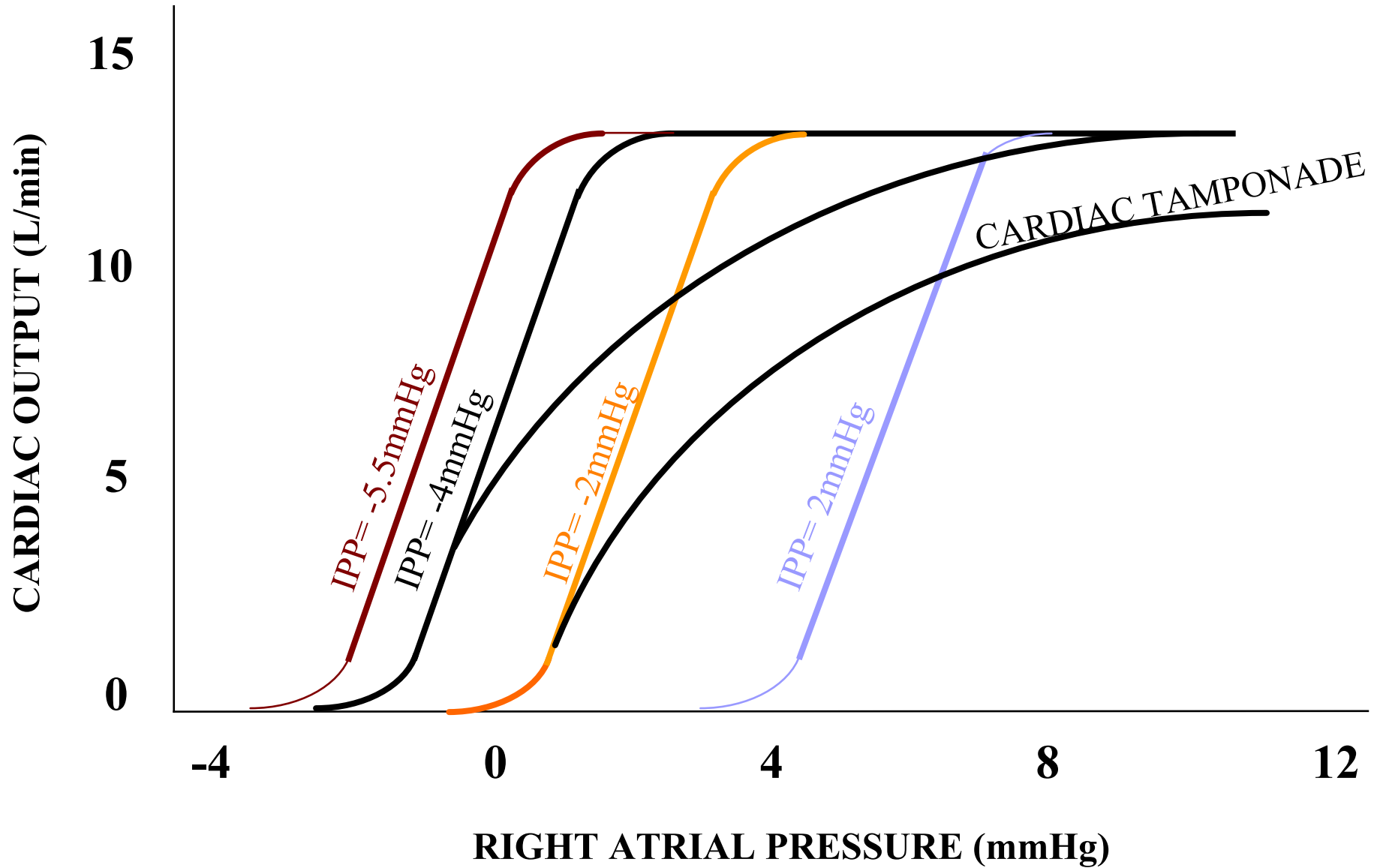
CARDIAC OUTPUT  
CURVES



# Effect of Sympathetic and Parasympathetic Stimulation on Cardiac Output



IPP = INTRAPLEURAL PRESSURE



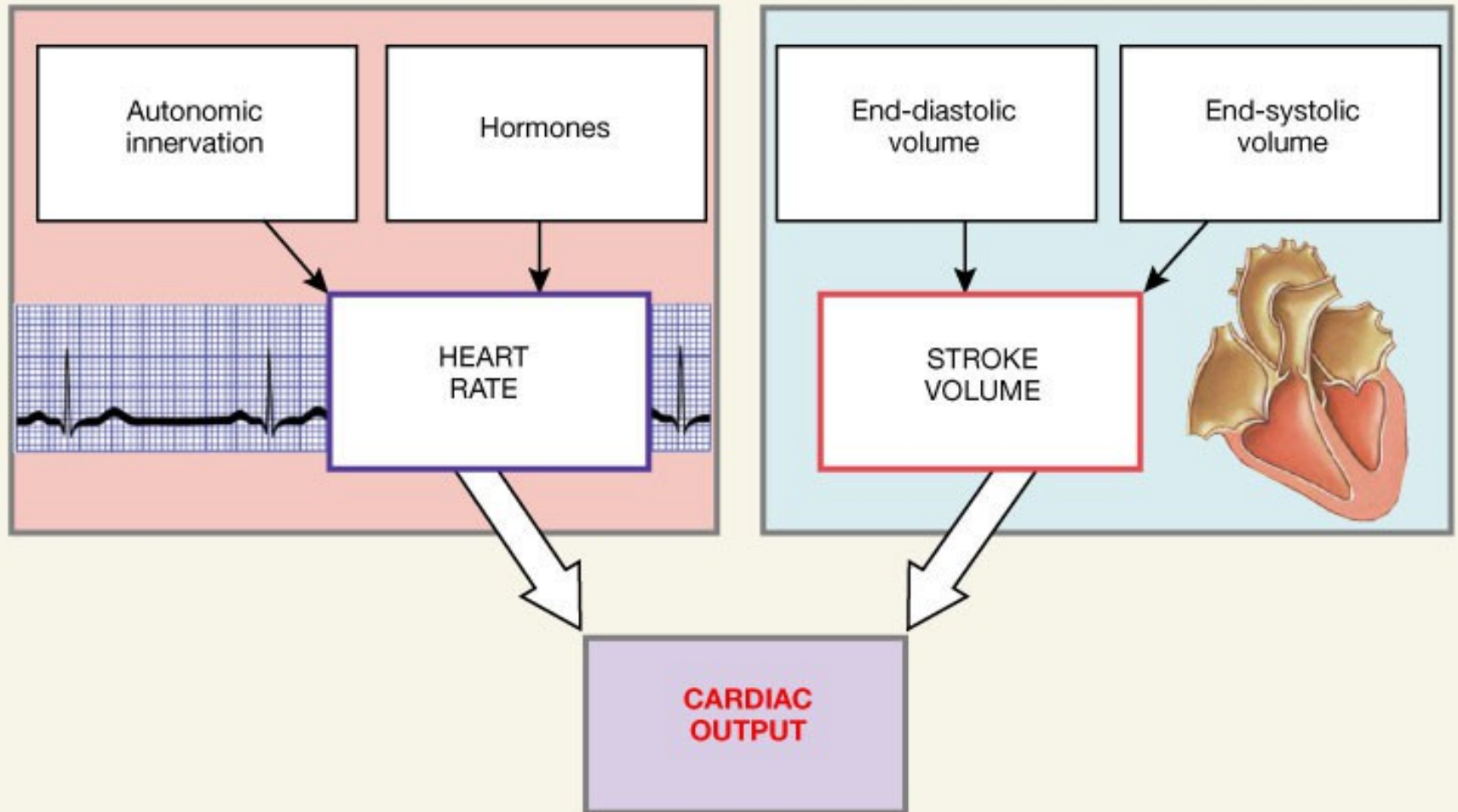
# The Cardiac Output Curve

- Plateau of CO curve determined by heart strength (contractility +  $\uparrow$ HR)
- $\uparrow$  Sympathetics  $\Rightarrow \uparrow$  plateau
- $\downarrow$  Parasympathetics (HR $\uparrow$ )  $\Rightarrow$  (? plateau)
- $\uparrow$  Plateau
- Heart hypertrophy  $\Rightarrow \uparrow$ 's plateau
- Myocardial infarction  $\Rightarrow$  (? plateau)
- $\downarrow$  Plateau

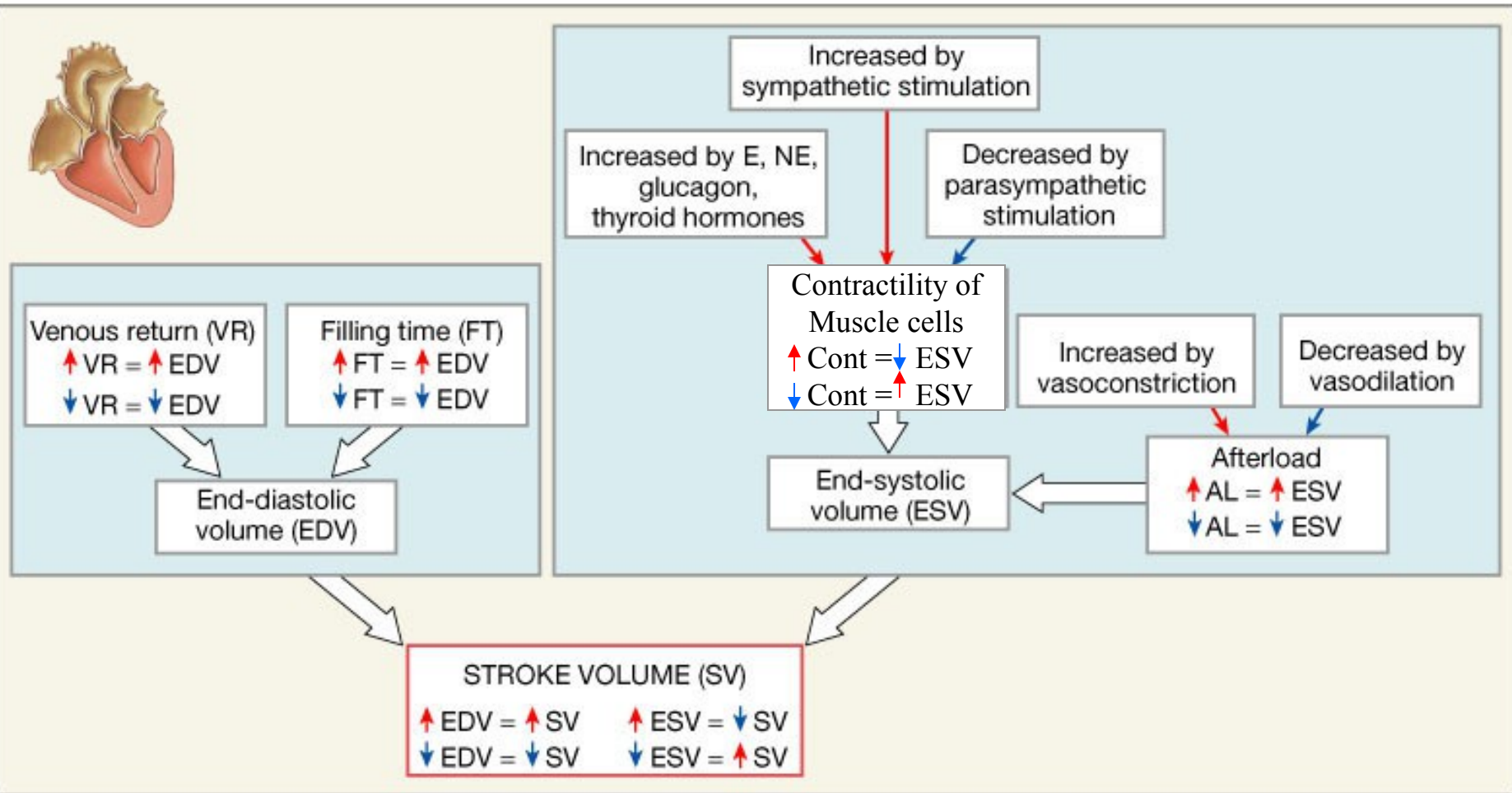
# The Cardiac Output Curve (cont'd)

- Valvular disease  $\Rightarrow$   $\downarrow$  plateau  
(stenosis or regurgitation)
- Myocarditis  $\Rightarrow$   $\downarrow$  plateau
- Cardiac tamponade  $\Rightarrow$  (? plateau)
- $\downarrow$  Plateau
- Metabolic damage  $\Rightarrow$   $\downarrow$  plateau

# Factors Affecting Cardiac Output

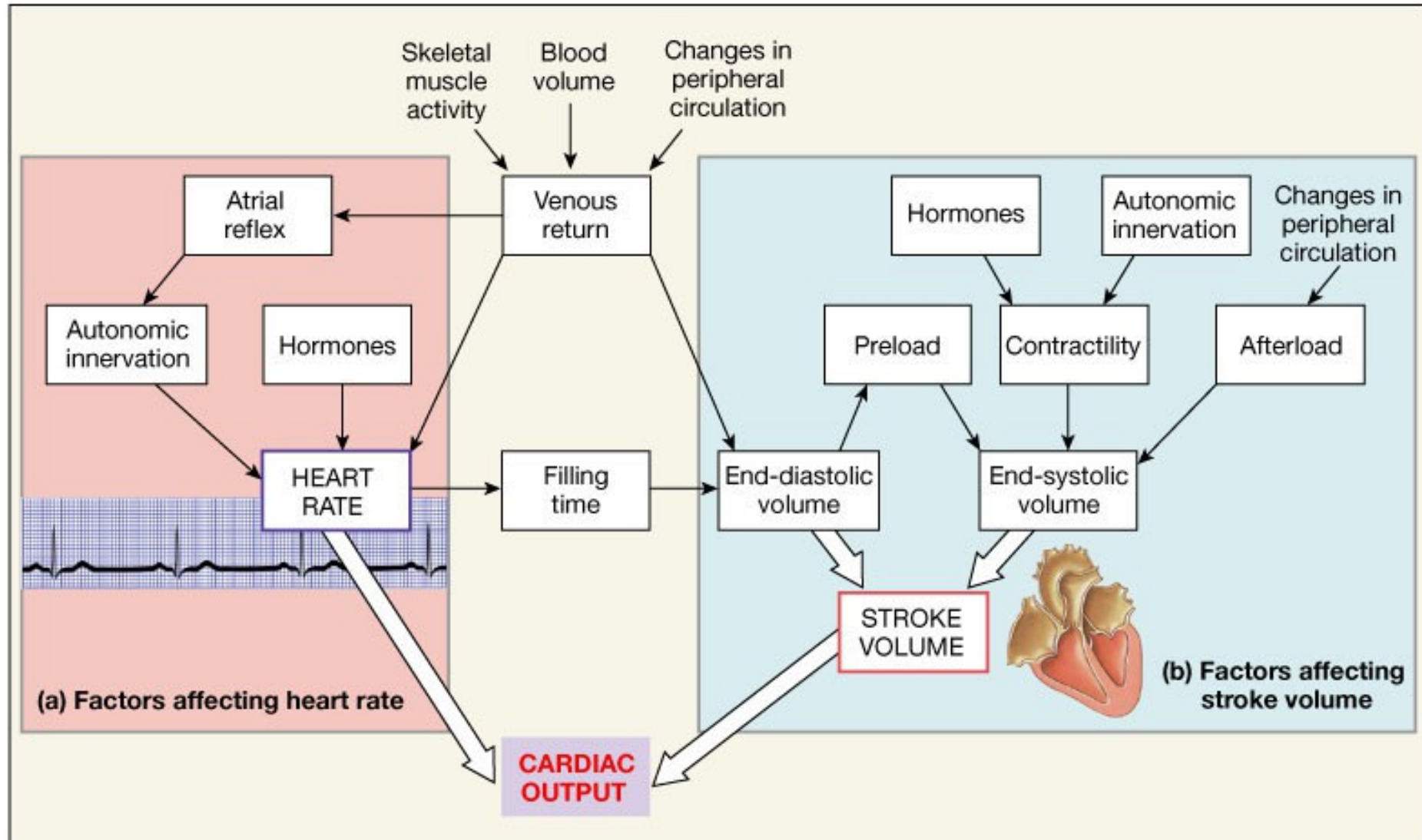


# Factors Affecting Stroke Volume

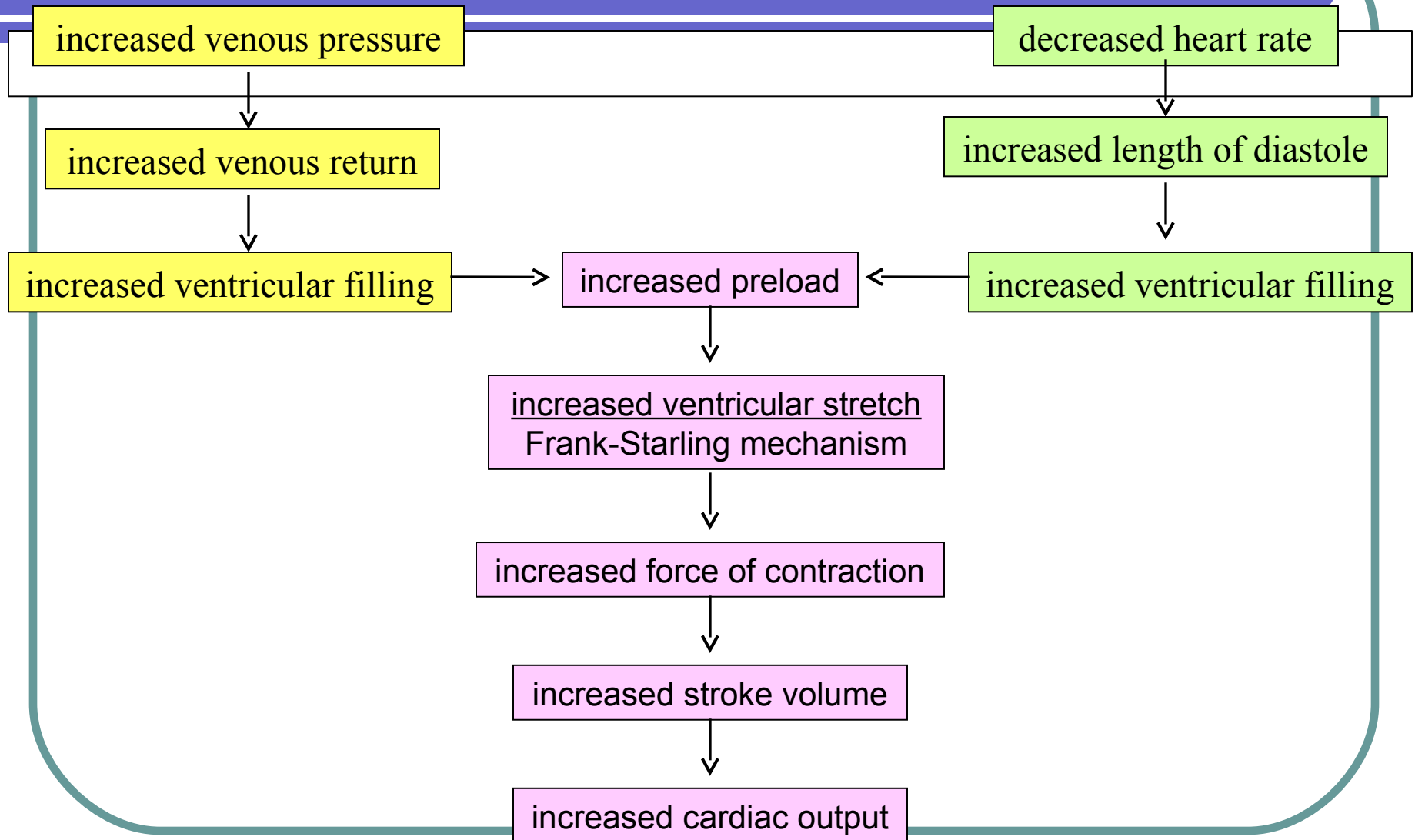




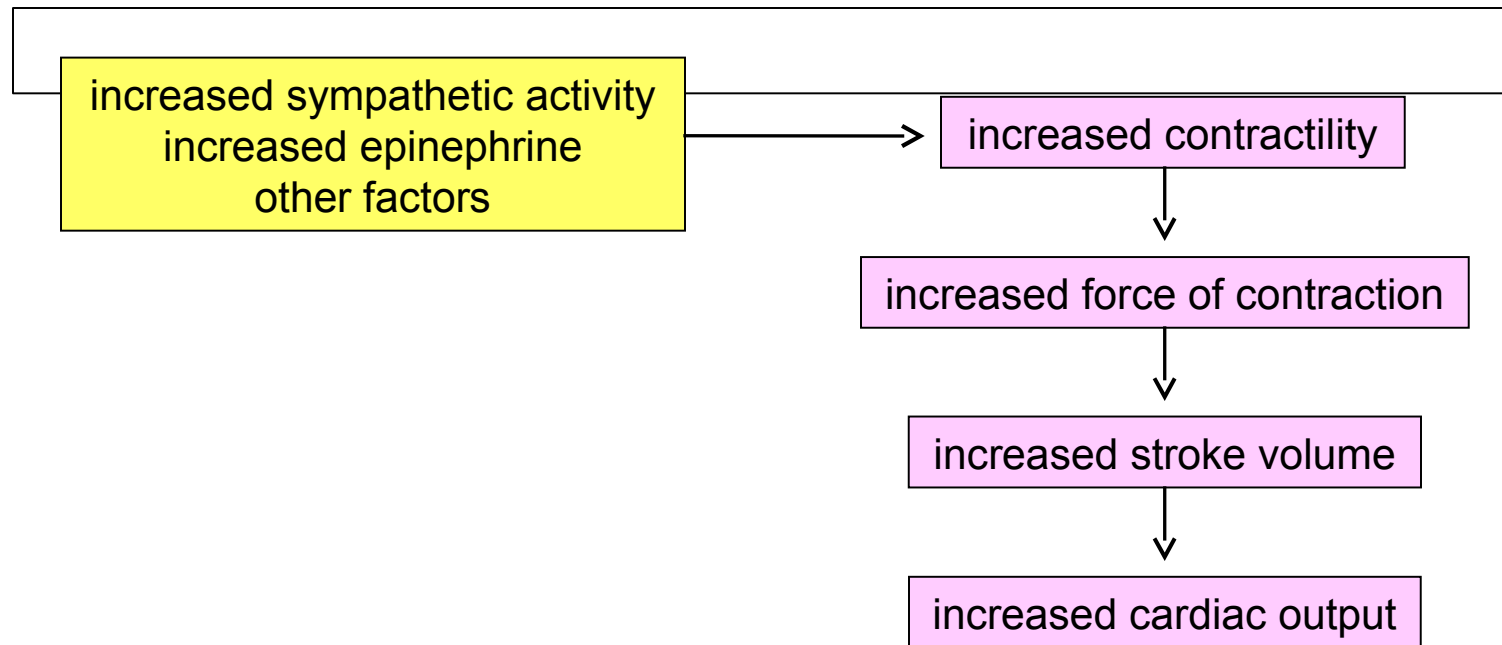
# A Summary of the Factors Affecting Cardiac Output



# REGULATION OF STROKE VOLUME: PRELOAD



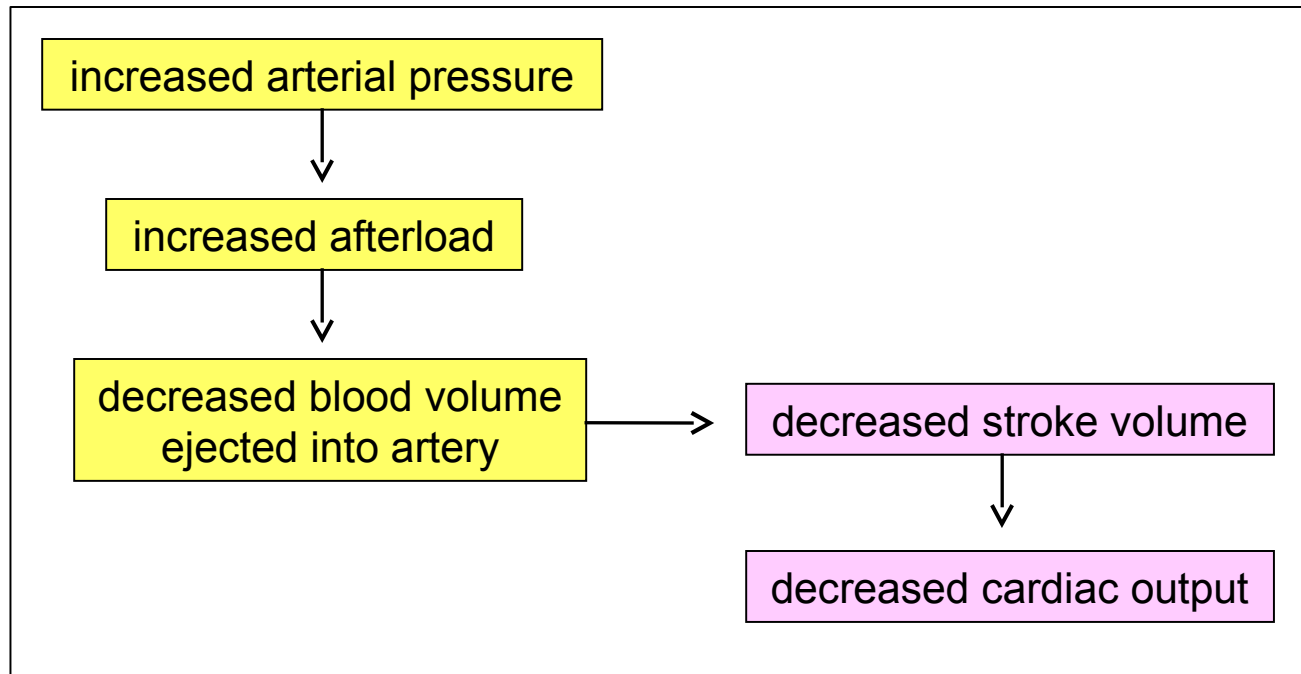
# REGULATION OF STROKE VOLUME: CONTRACTILITY



# Cardiac Contractility

- Best is to measure the C.O. curve, but this is nearly impossible in humans.
- $dP/dt$  is not an accurate measure because this increases with increasing preload and afterload.
- $(dP/dt)/P_{\text{ventricle}}$  is better.  $P_{\text{ventricle}}$  is instantaneous ventricular pressure.
- Excess  $K^+$  decreases contractility.
- Excess  $Ca^{++}$  causes spastic contraction, and low  $Ca^{++}$  causes cardiac dilation.

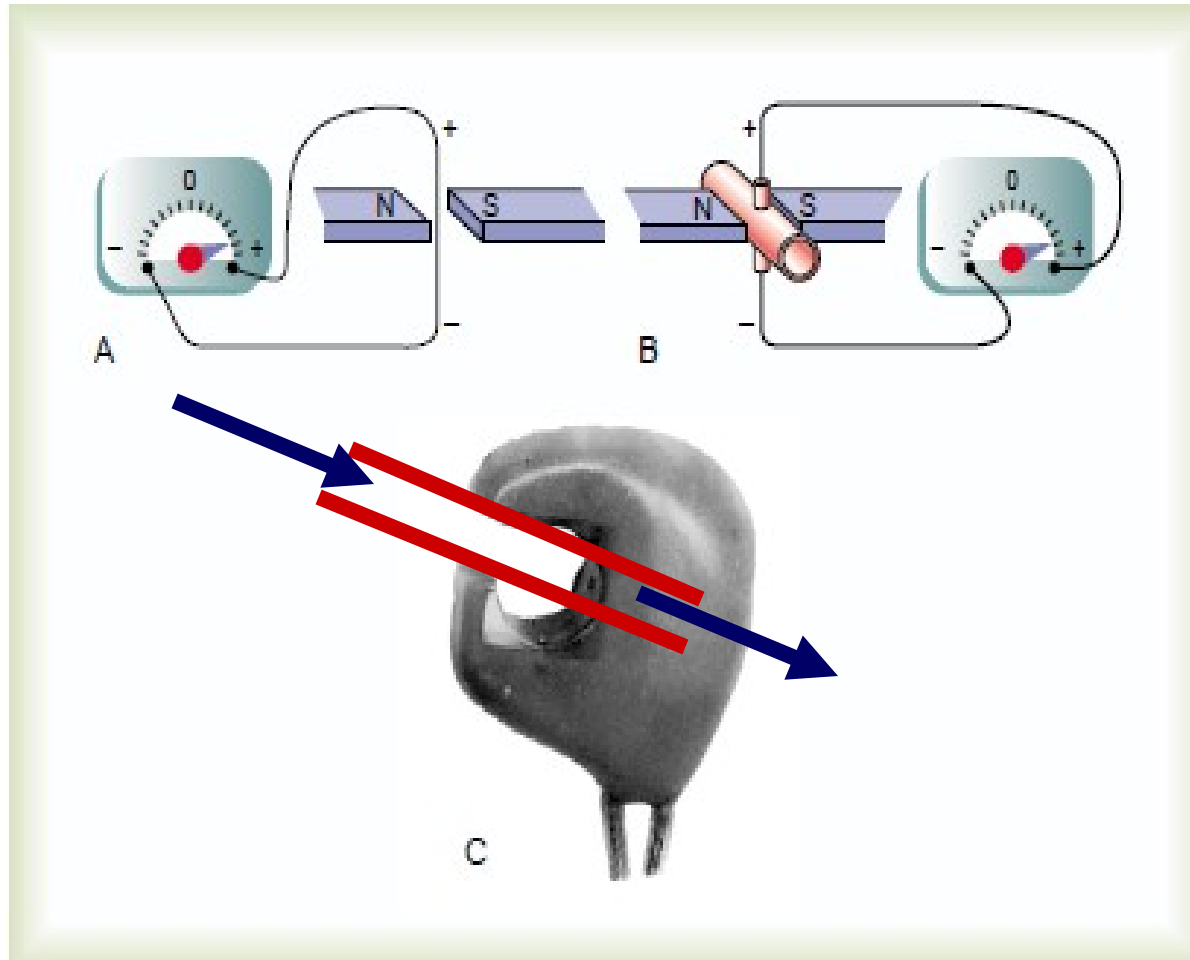
# REGULATION OF STROKE VOLUME: AFTERLOAD

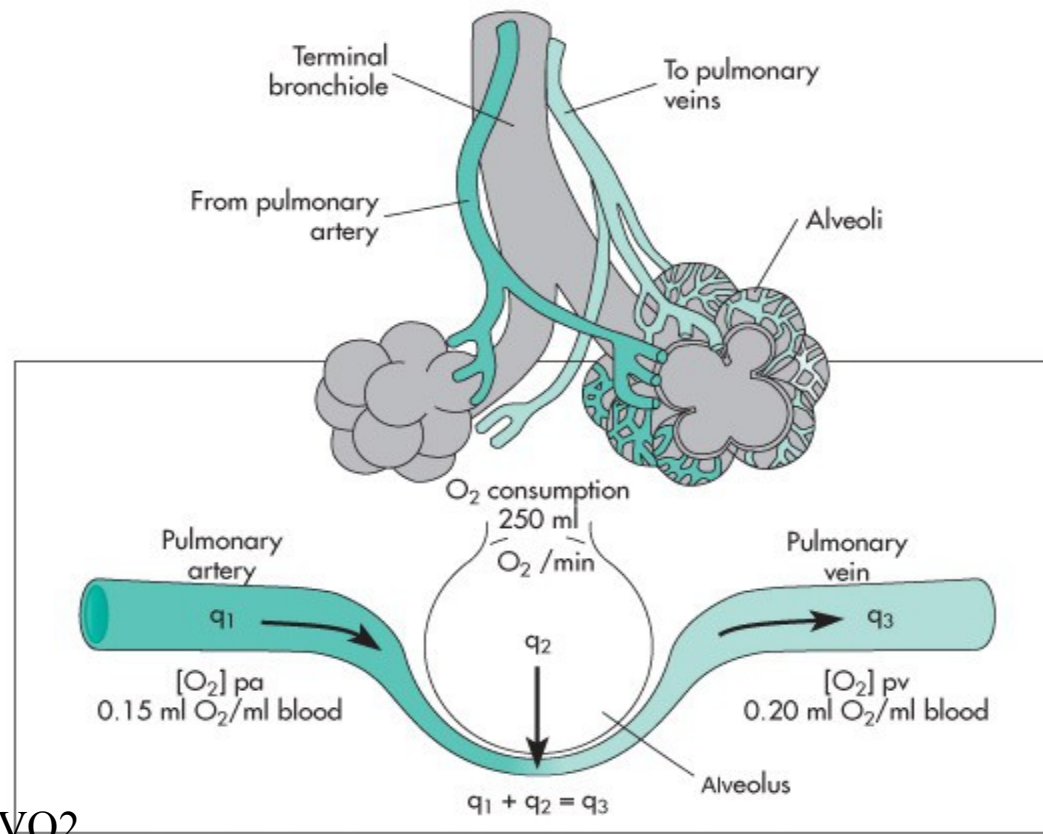


# Measurement of Cardiac Output

- Electromagnetic flowmeter
- Indicator dilution (dye such as cardiogreen)
- Thermal dilution
- *Oxygen Fick Method*
- *$CO = (O_2 \text{ consumption} / (A-V O_2 \text{ difference}))$*

# Electromagnetic flowmeter





$$q_1 = CO * C_{VO_2}$$

$q_2$  = amount of Oxygen uptake by the lungs

$q_3 = CO * C_{AO_2}$  and equals  $= CO * C_{VO_2} + O_2$  uptake

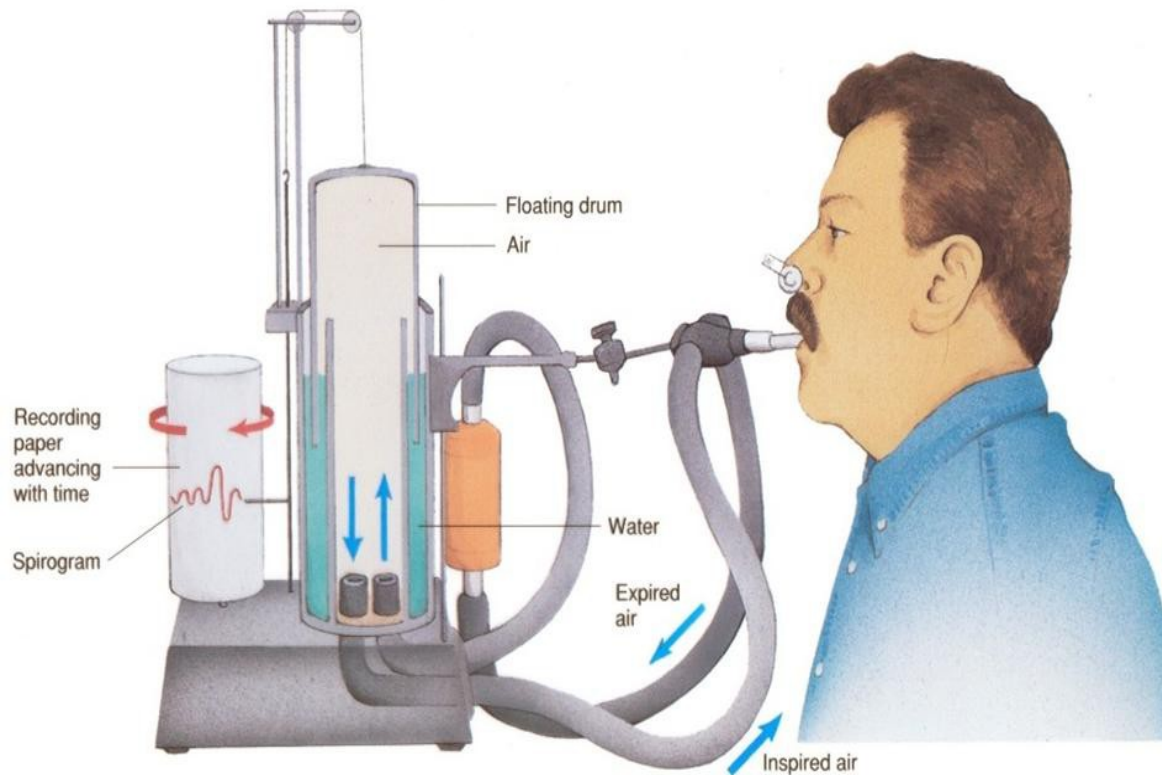
Oxygen uptake =  $CO \{ C_{AO_2} - C_{VO_2} \}$

$CO = \text{Oxygen uptake} / \{ C_{AO_2} - C_{VO_2} \}$

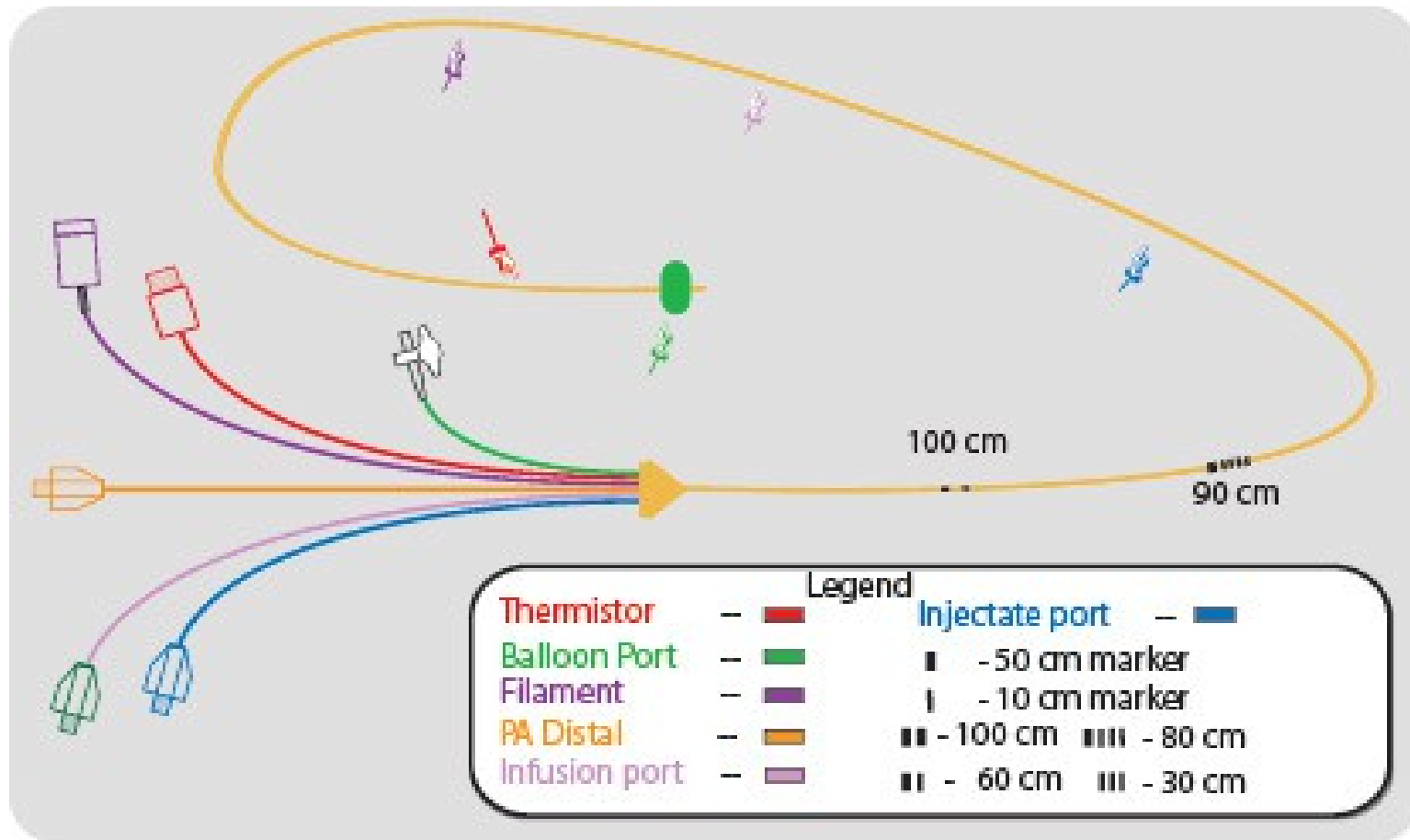


# Spirometer

A spirometer



# Swan-Ganz catheter

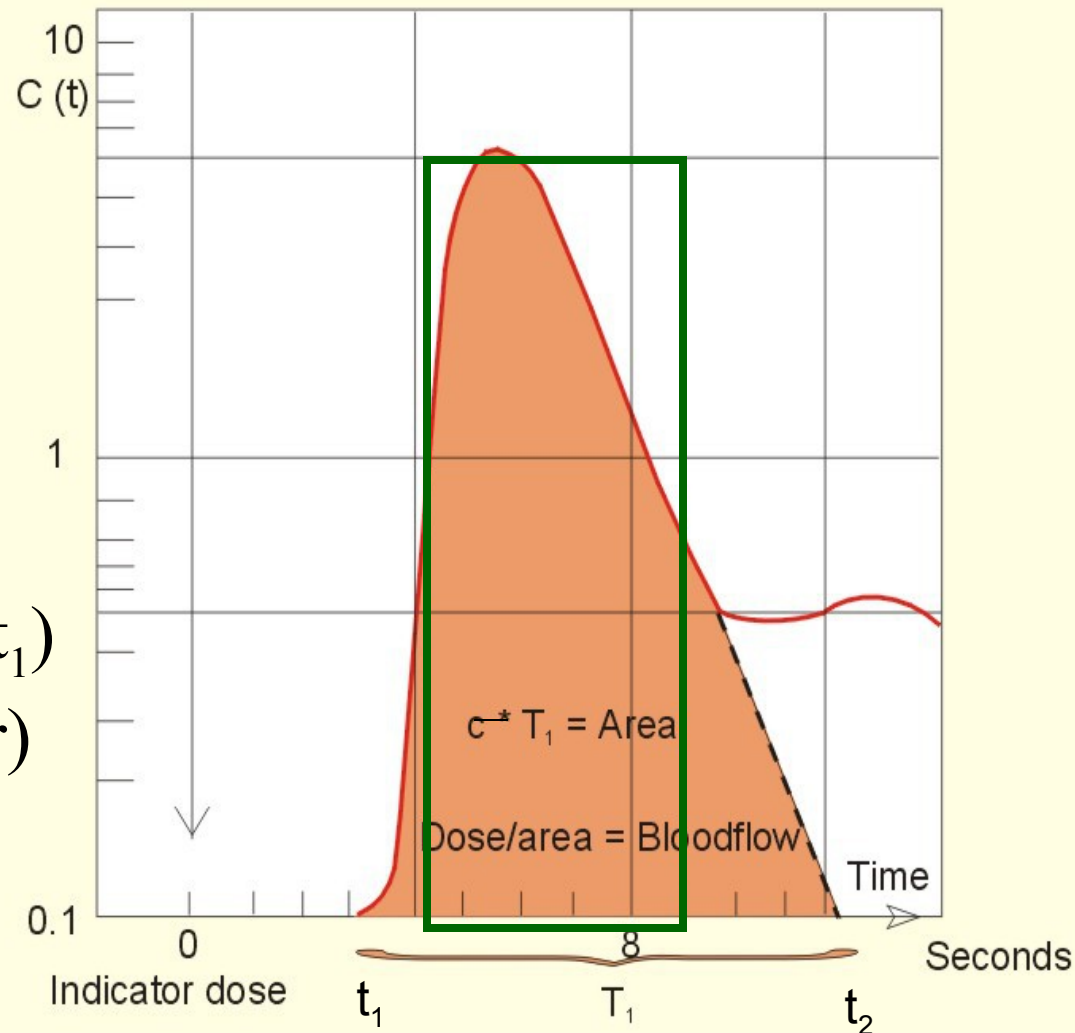


# O<sub>2</sub> Fick Problem

- If pulmonary vein O<sub>2</sub> content = 200 ml O<sub>2</sub>/L blood
- Pulmonary artery O<sub>2</sub> content = 160 ml O<sub>2</sub> /L blood
- Lungs add 400 ml O<sub>2</sub> /min
- What is cardiac output?
- Answer:  $400/(200-160) = 10$  L/min

# THE INDICATOR DILUTION PRINCIPLE

Indicator concentration



KMc

$$\text{Area} = \int_{t_2}^{t_1} dc \cdot dt$$

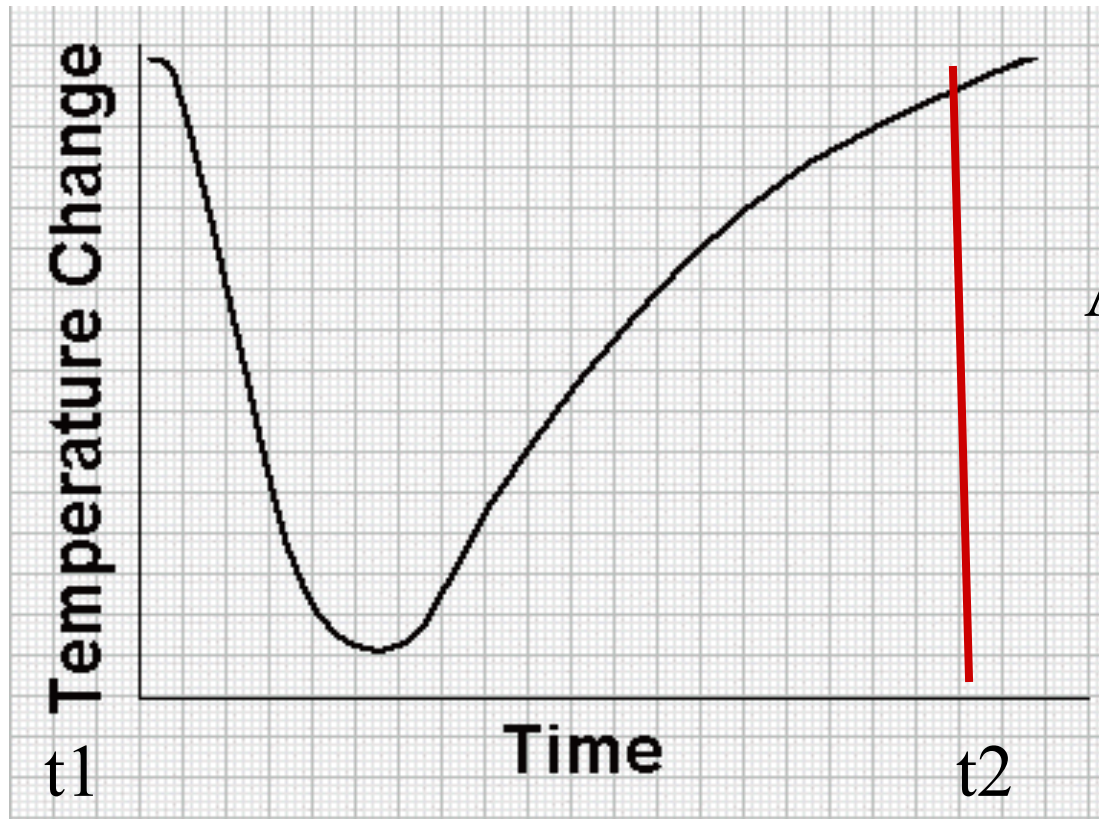
$$\text{Area} = \bar{C}^* (t_2 - t_1)$$

(Rectangular)

$$\bar{C} = \text{Area} / (t_2 - t_1)$$

$$\text{Cardiac output} = \frac{q}{C} X \frac{60}{\text{duration in seconds}}$$

# Thermodilution Method Curve

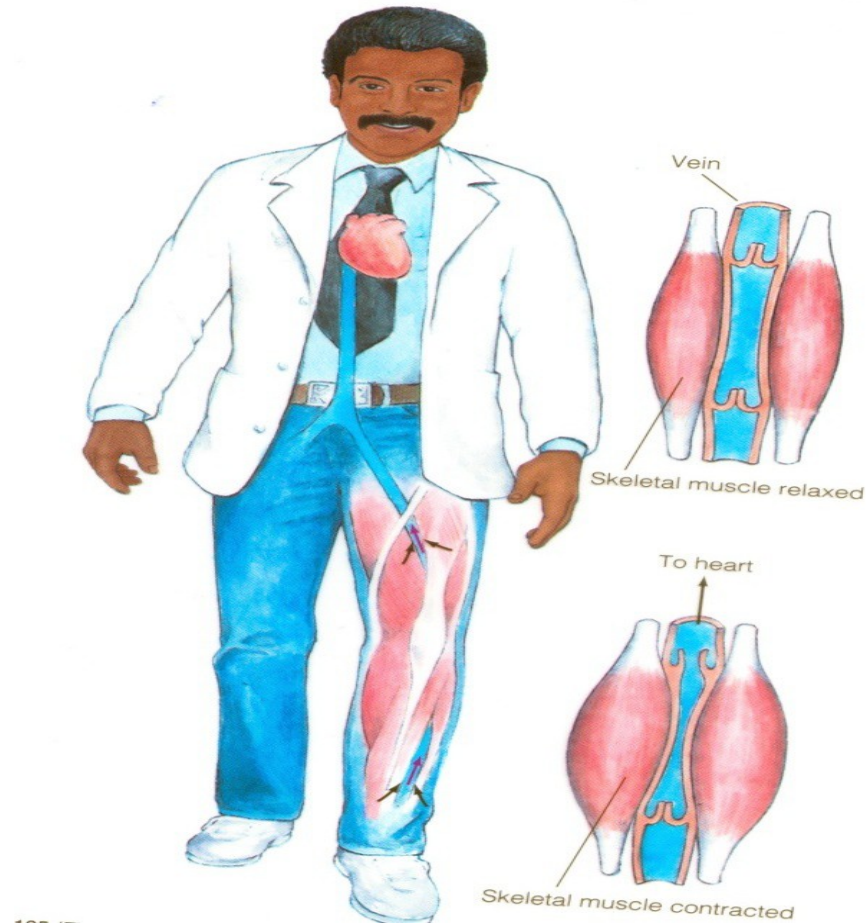


$$\text{AREA} = \int_{t1}^{t2} dT . dt$$

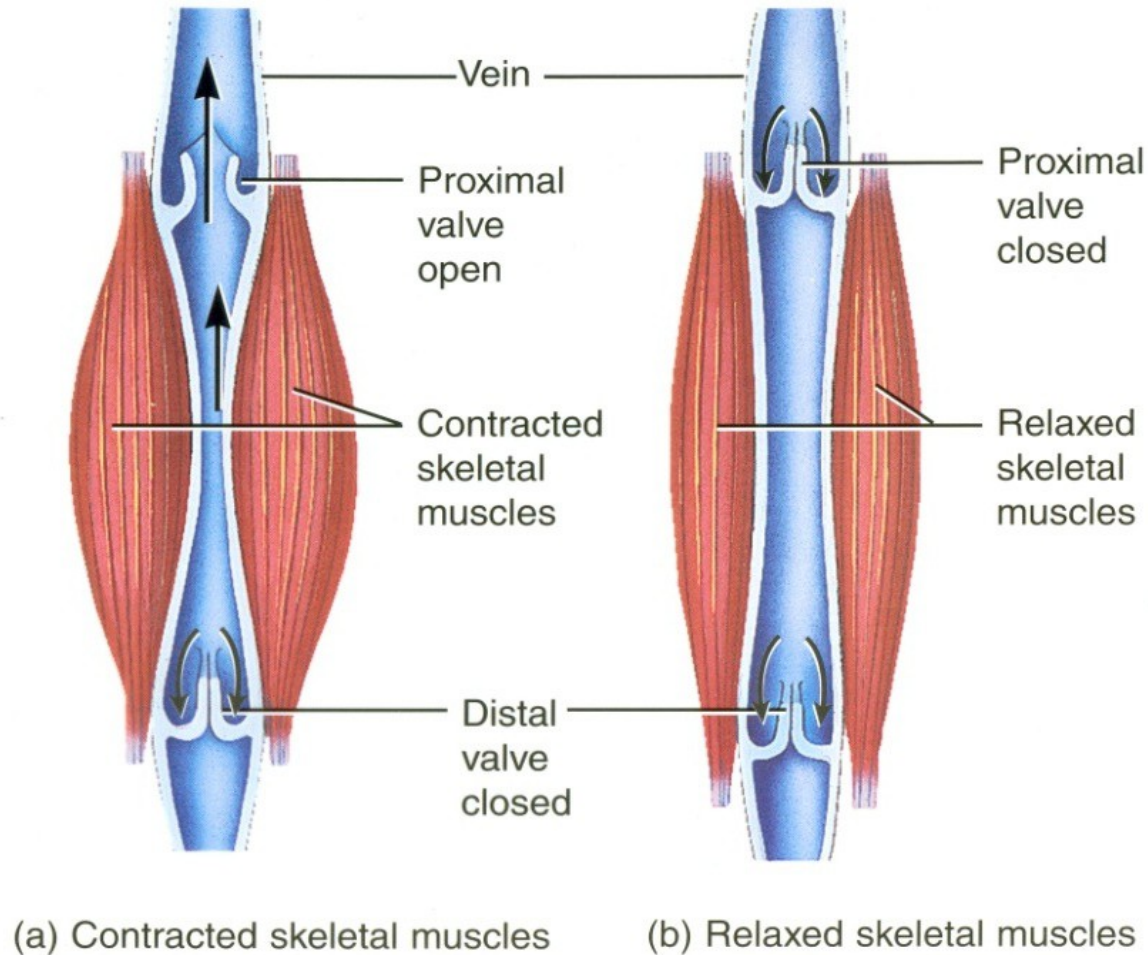
# VENOUS RETURN

- Definition: Volume of blood returns to either the left side or right side of the heart per minute
- $VR = CO = \Delta P/R$
- $VR = (\text{Venous pressure} - \text{Rt. Atrial pressure}) / \text{resistance to venous return}$

# Effect of Venous Valves

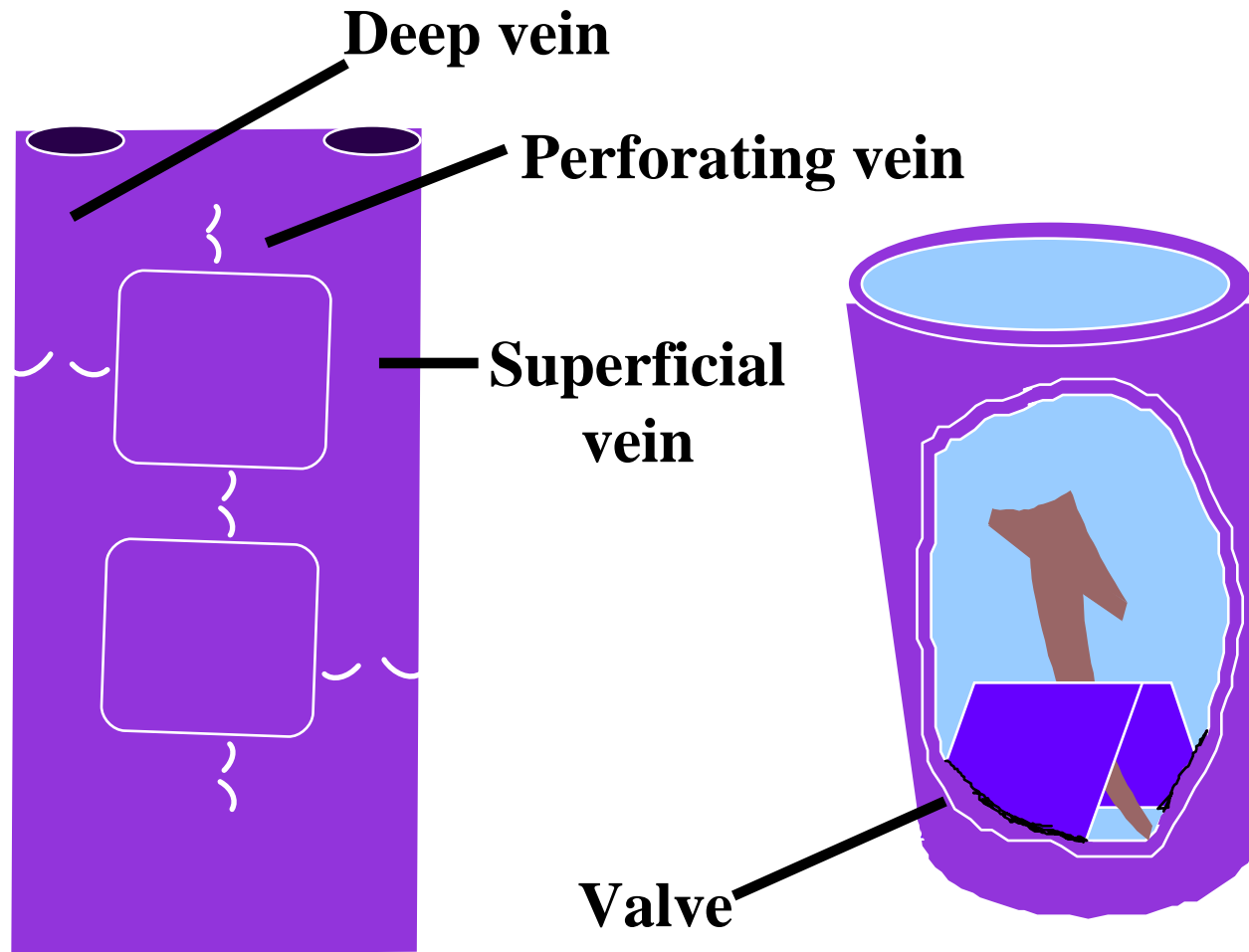


# Effect of Venous Valves

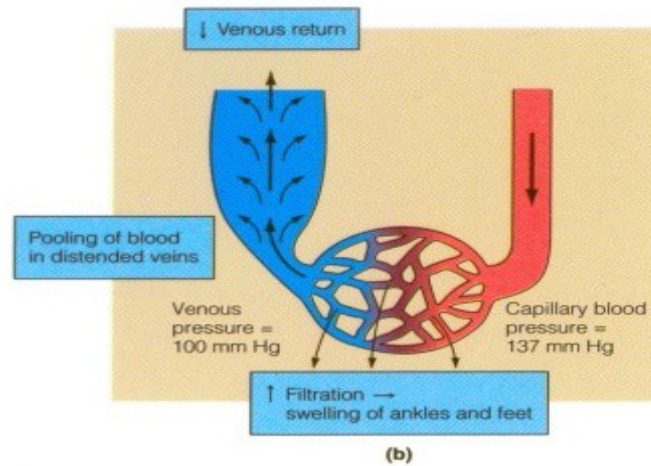
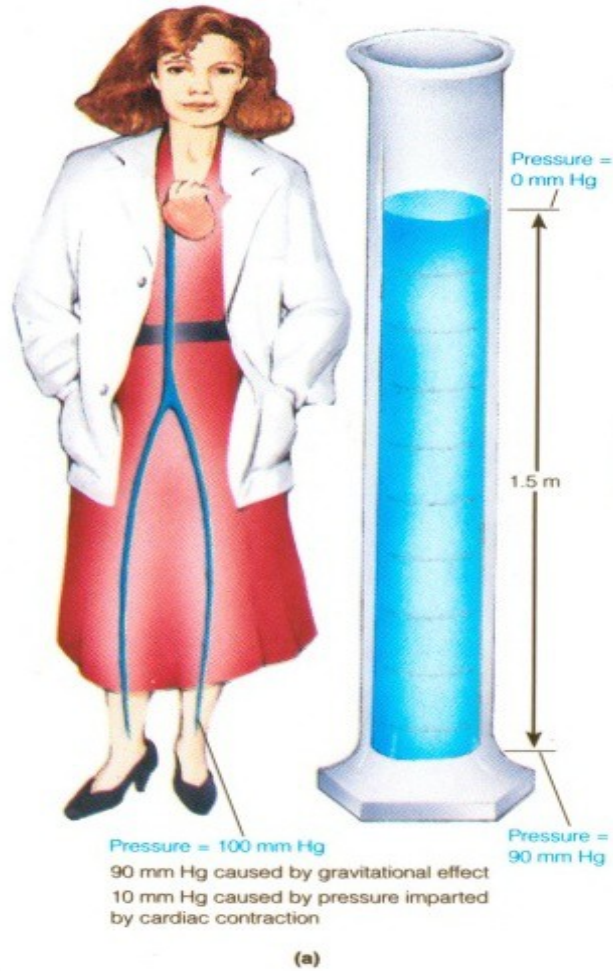




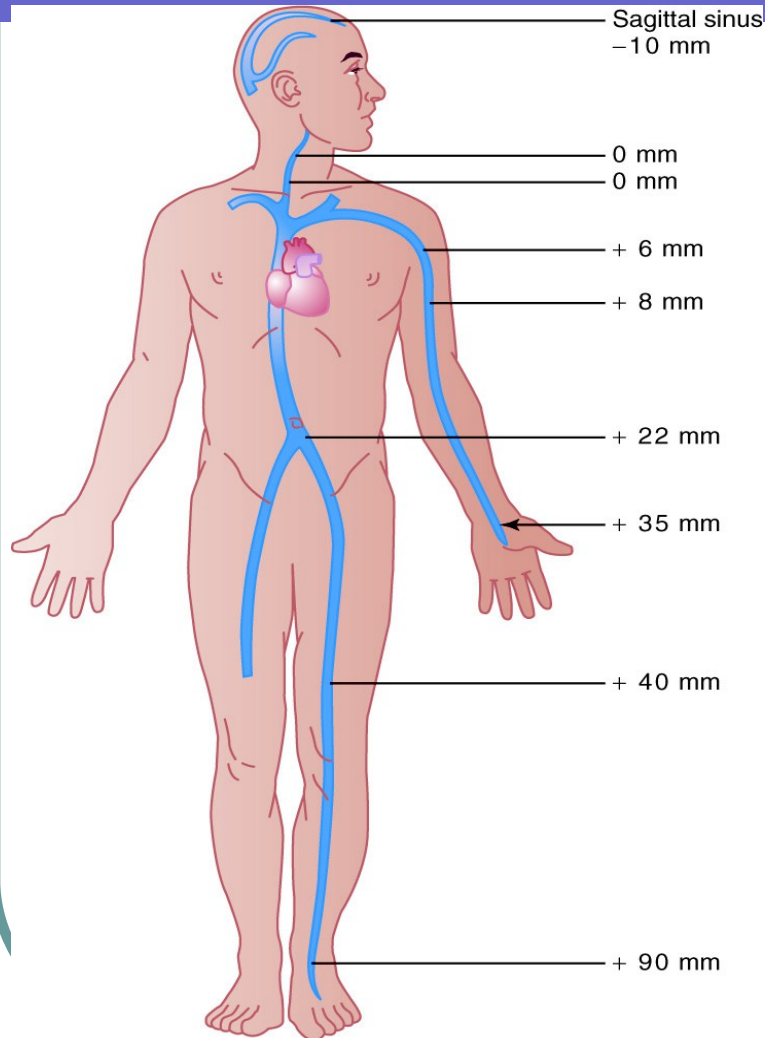
# Venous Valves



# Effect Of Gravity on Venous Pressure



# Venous Pressure in the Body



- Compressional factors tend to cause resistance to flow in large peripheral veins.
- Increases in right atrial pressure causes blood to back up into the venous system thereby increasing venous pressures.
- Abdominal pressures tend to increase venous pressures in the legs.

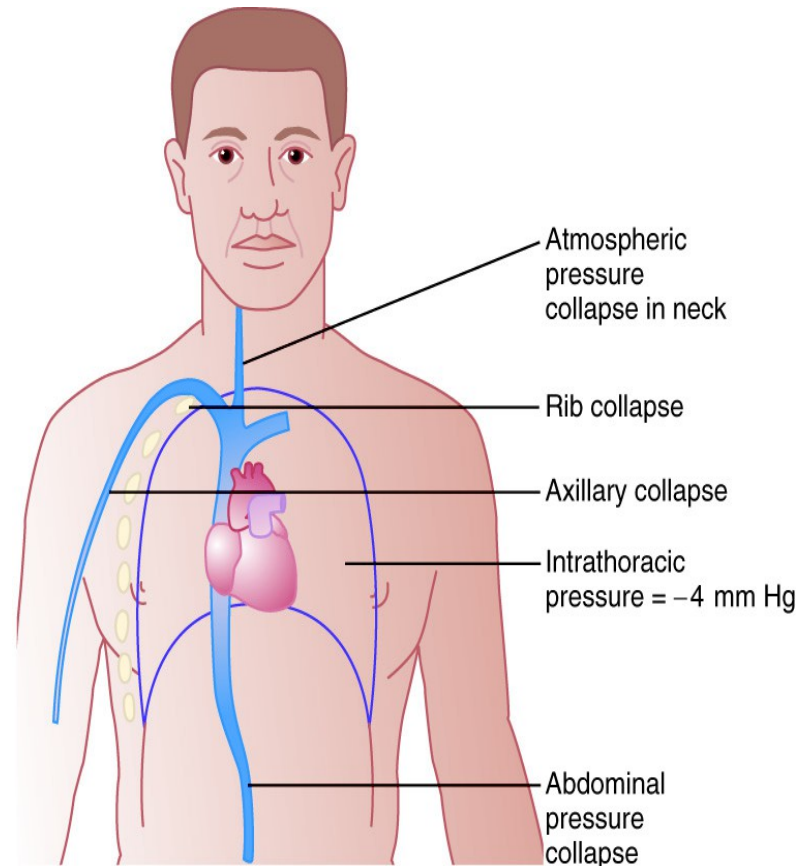
# Central Venous Pressure

- ❖ Pressure in the right atrium is called *central venous pressure*.
- ❖ *Right atrial pressure* is determined by the balance of the heart pumping blood out of the right atrium and flow of blood from the large veins into the right atrium.
- ❖ Central venous pressure is normally 0 mmHg, but can be as high as 20-30 mmHg.

# Factors affecting Central Venous Pressure

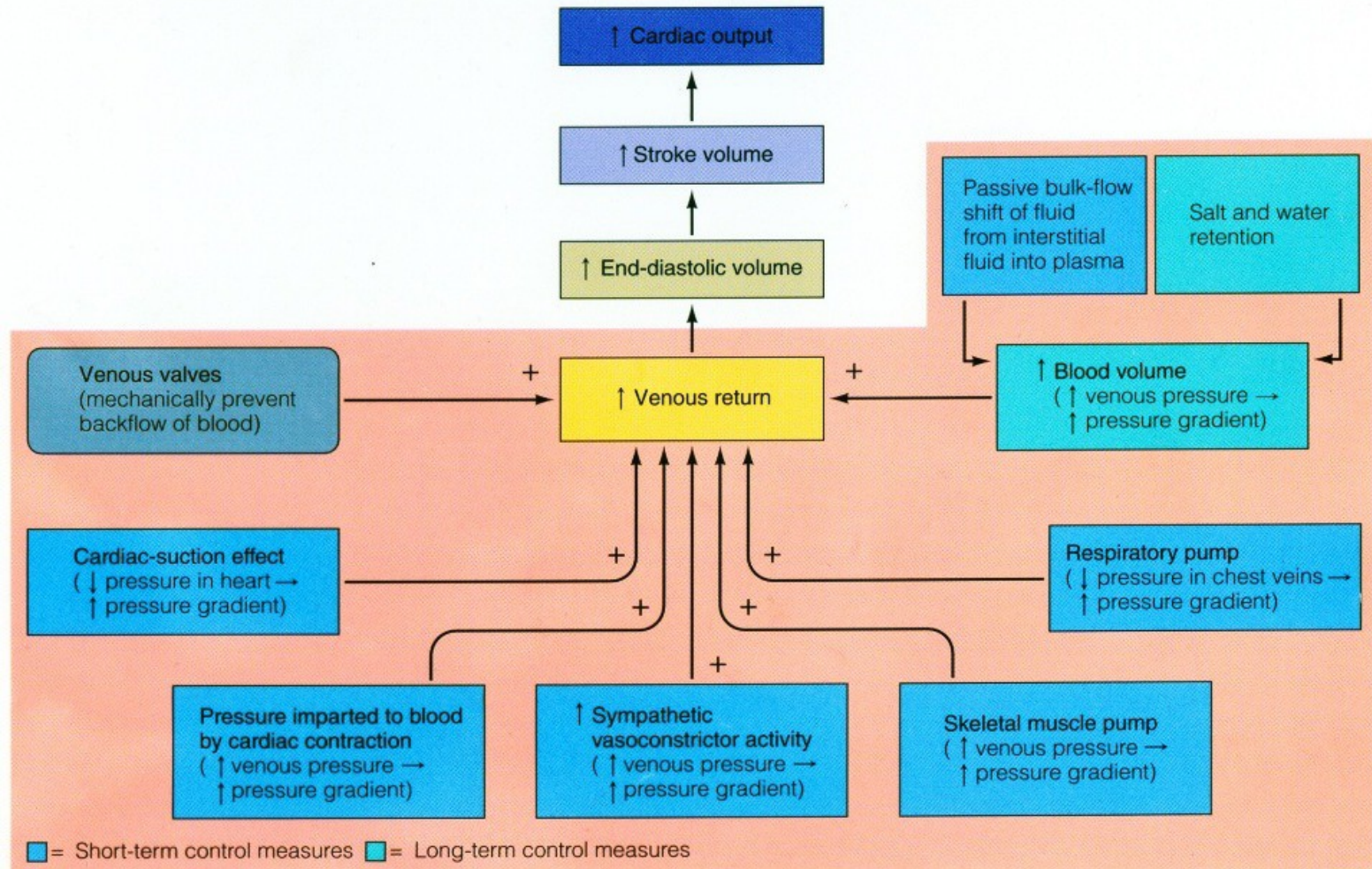
⚙️ Right atrial pressure (RAP) is regulated by a balance between the ability of the heart to pump blood out of the atrium and the rate of blood flowing into the atrium from peripheral veins.

- ⚙️ Factors that increase RAP:
- ⚙️ -increased blood volume
  - ⚙️ -increased venous tone
  - ⚙️ - dilation of arterioles
  - ⚙️ -decreased cardiac function

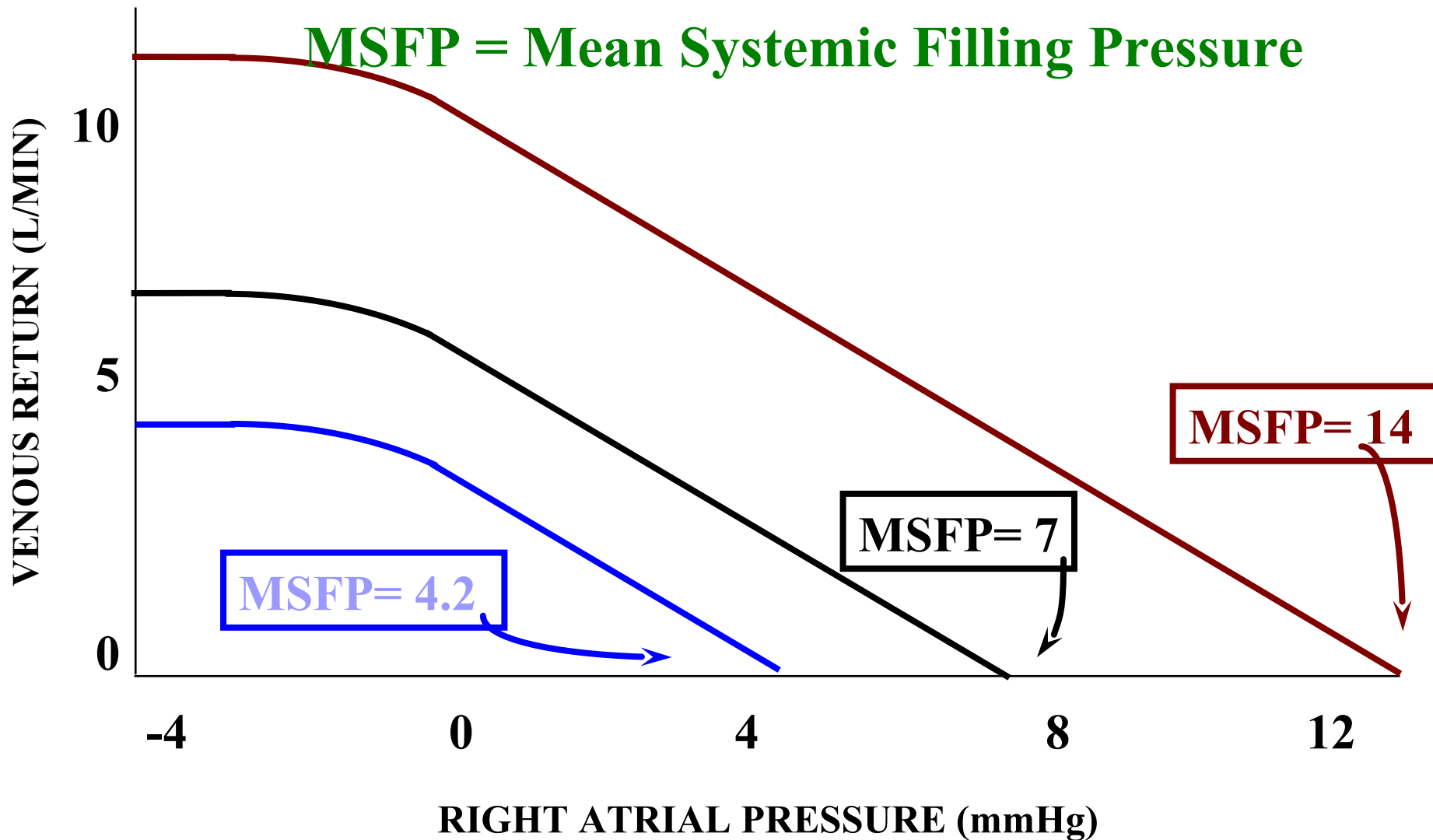


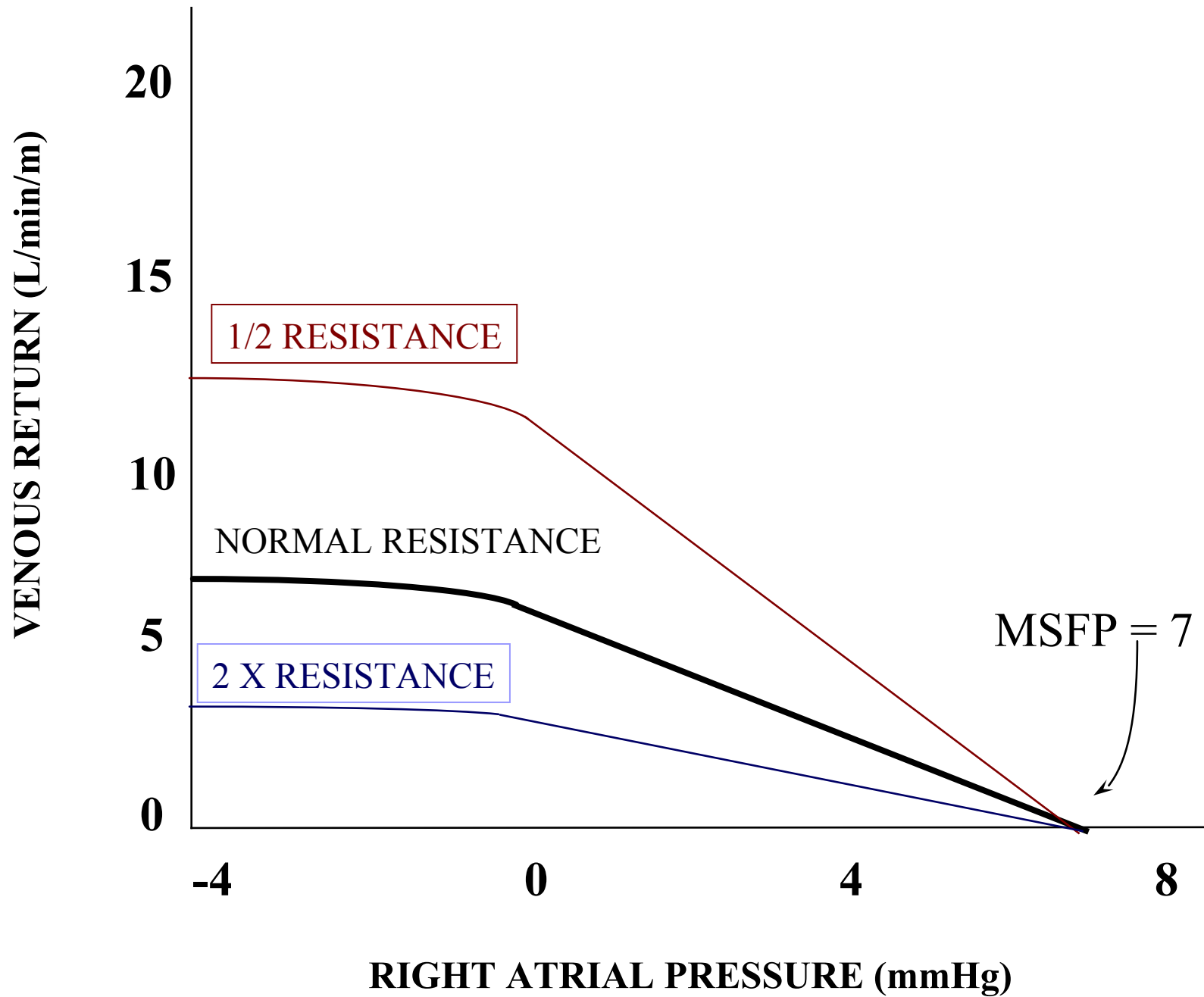


# Factors that Facilitate Venous Return



# The Venous Return Curve







# Venous Return (VR)

- Beriberi - thiamine deficiency  $\Rightarrow$  arteriolar dilatation  $\Rightarrow \downarrow$  RVR
- (RVR = resistance to venous return)  
because  $VR = (MSFP - RAP) / RVR$   
(good for positive RAP's)
- A-V fistula  $\Rightarrow$  (? RVR)
- $\downarrow$  RVR
- C. Hyperthyroidism  $\Rightarrow$  (? RVR)
- $\downarrow$  RVR

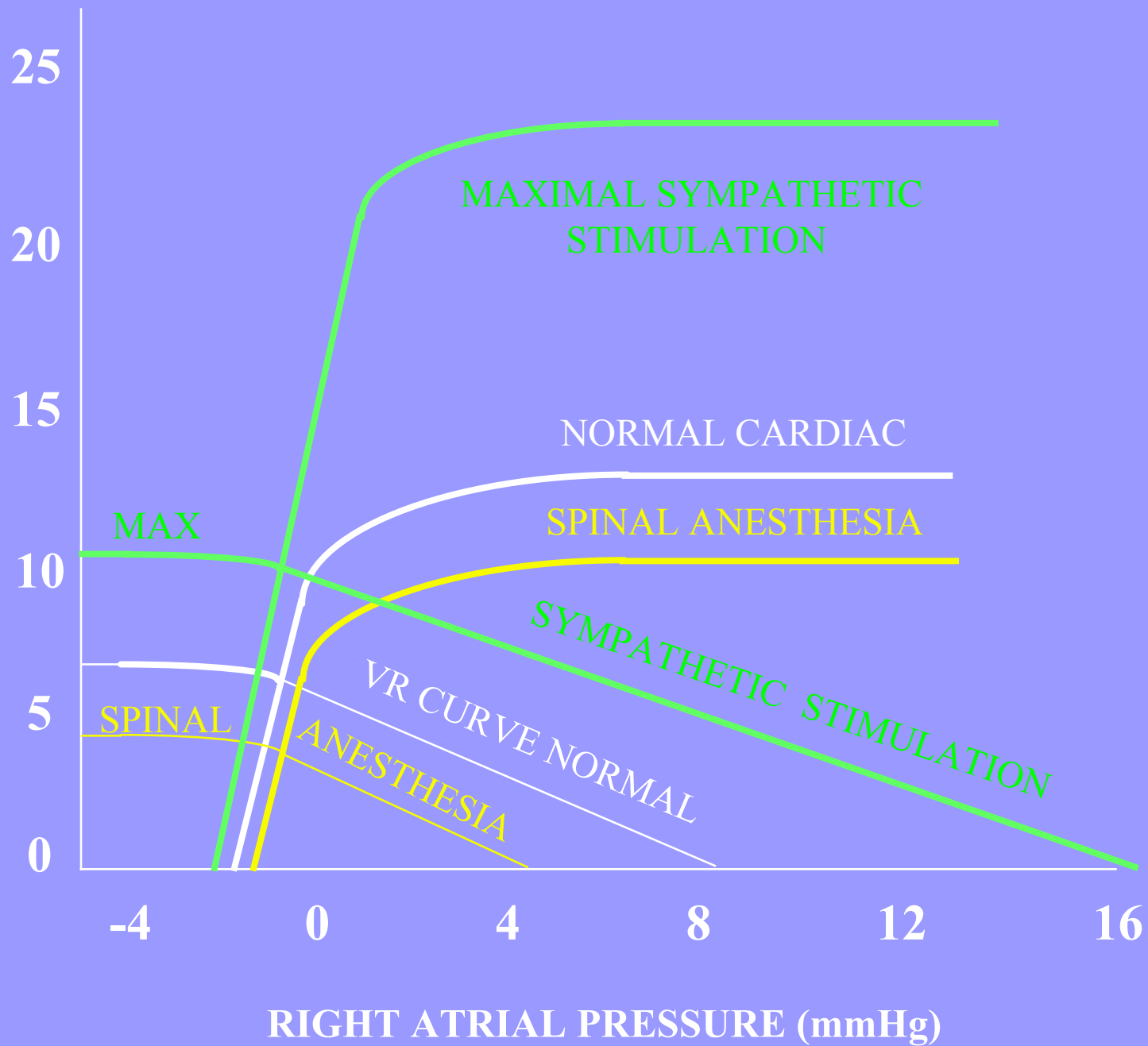
# Venous Return (VR) (cont'd)

- Anemia  $\Rightarrow$   $\downarrow$  RVR (why?)
- $\uparrow$  Sympathetics  $\Rightarrow$   $\uparrow$  MSFP
- $\uparrow$  Blood volume  $\Rightarrow$   $\uparrow$  MSFP + small  $\downarrow$  in RVR
- $\downarrow$  Venous compliance (muscle contraction or venous constriction)  
 $\Rightarrow$  (? MSFP)
- $\uparrow$  MSFP

# Factors Causing ↓ Venous Return

- ↓ Blood volume  $\Rightarrow$  ↓ MSFP
- ↓ Sympathetics  $\Rightarrow$  (? v. comp. and MSFP)
- ↑ Venous compliance and  
↓ MSFP
- Obstruction of veins  $\Rightarrow$  (? RVR)
- ↑ RVR

CARDIAC OUTPUT AND VENOUS RETURN (L/min/m)



# Thank You

