Cardiac output and Venous Return

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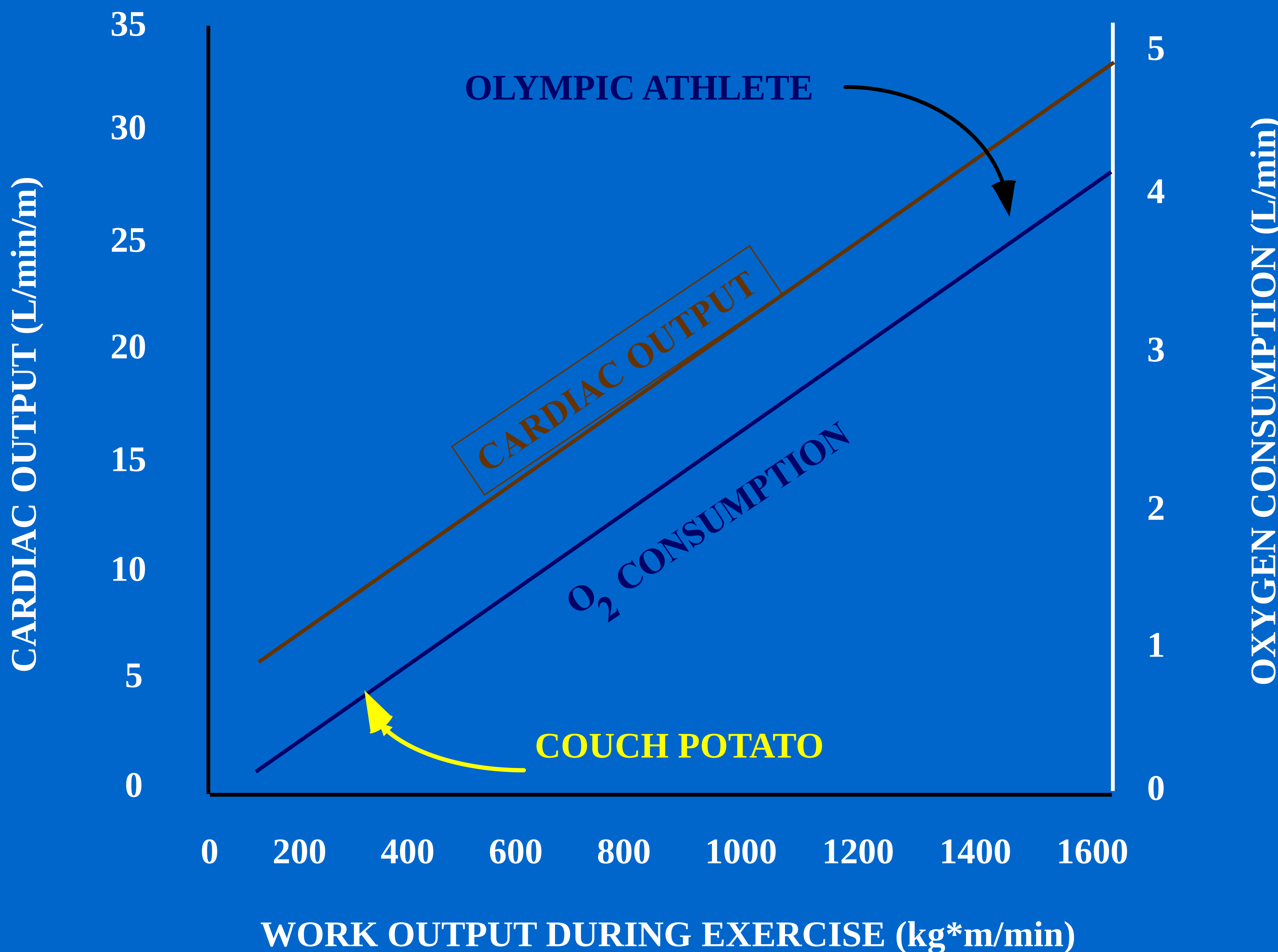
Objectives

- 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

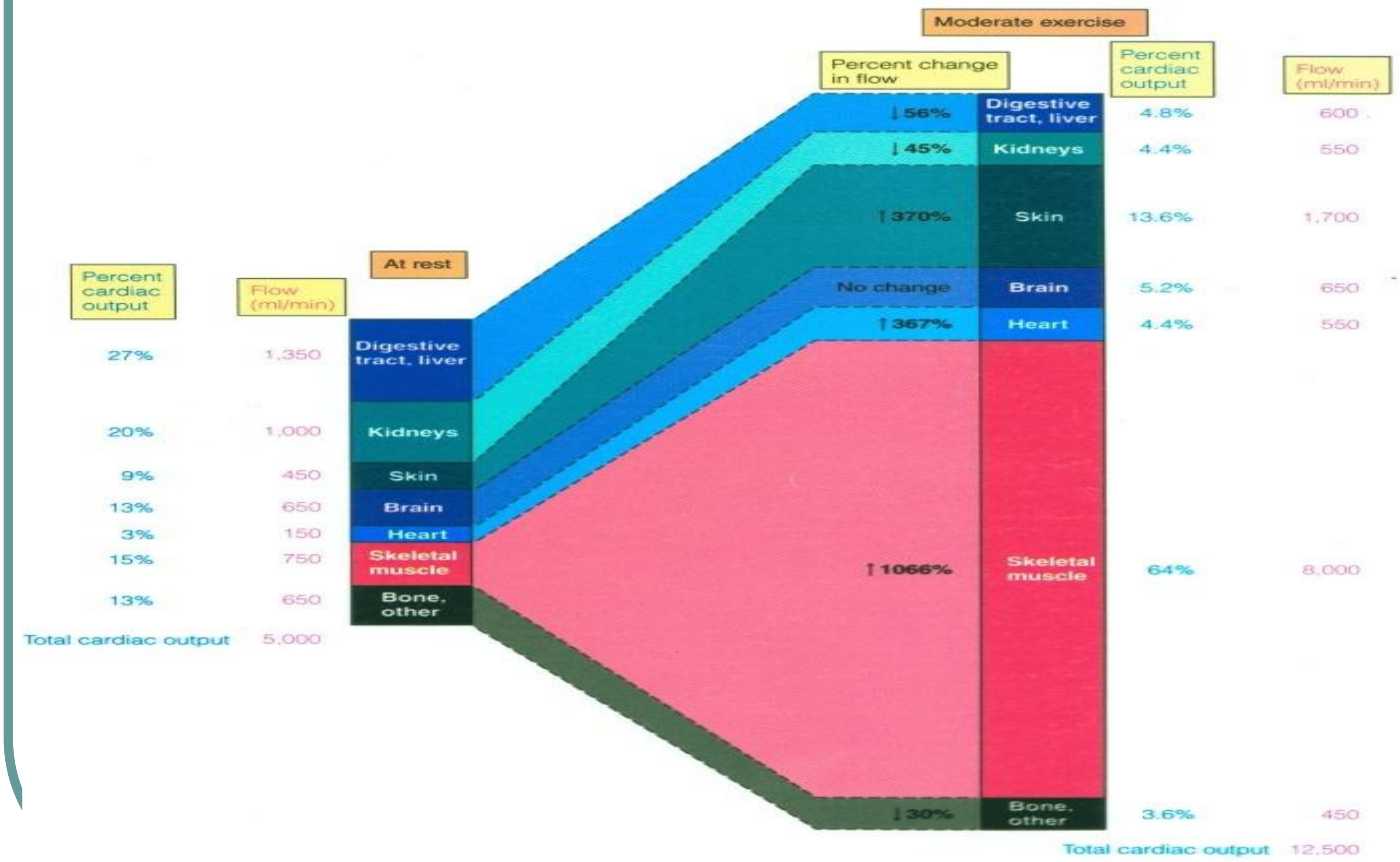
Important Concepts About Cardiac Output (CO) Control

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



CARDIAC OUTPUT (L/min/m)
35
30
25
20
15
10
5
0
OLYMPIC ATHLETE
CARDIAC OUTPUT
O2 CONSUMPTION
COUCH POTATO
OXYGEN CONSUMPTION (L/min)
5
4
3
2
1
0
0
200
400
600
800
1000
1200
1400
1600
WORK OUTPUT DURING EXERCISE (kg*m/min)

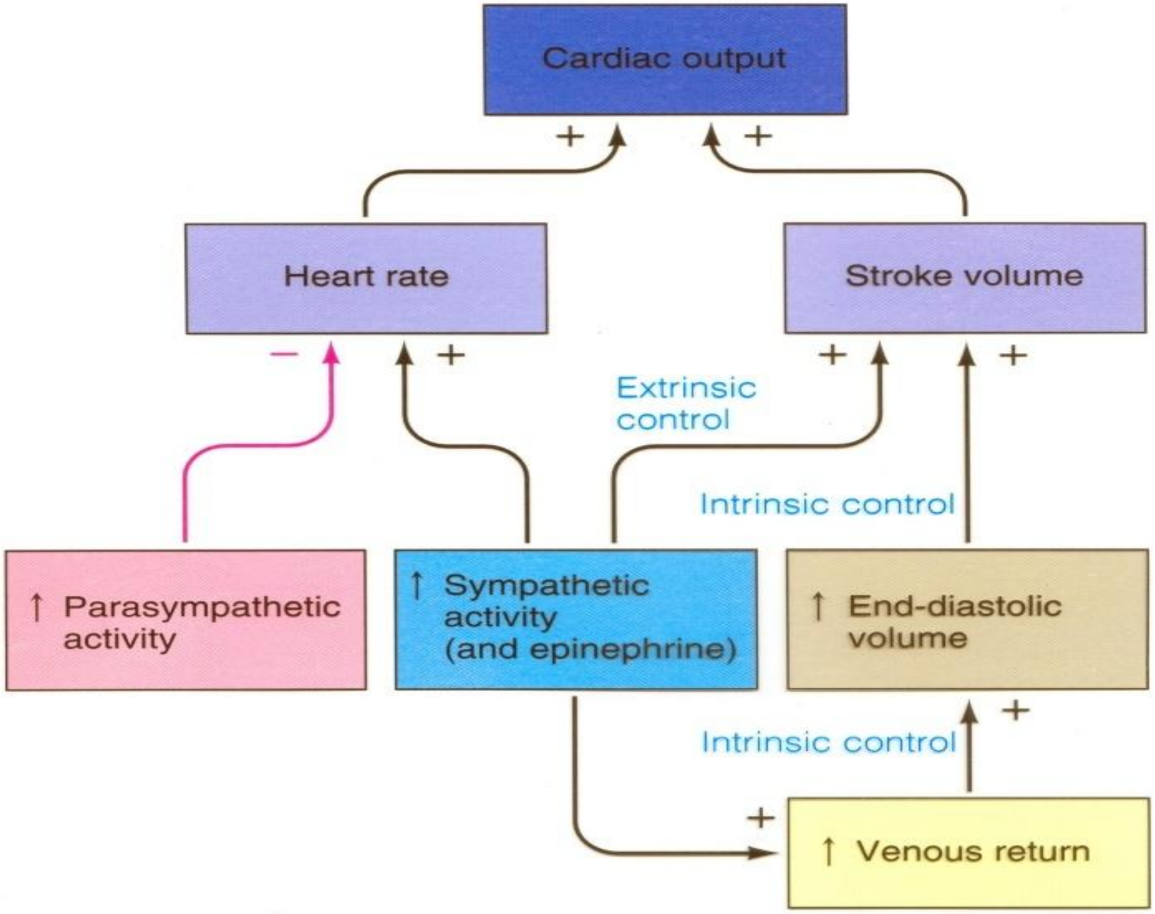
Magnitude & Distribution of CO at Rest & During Moderate Exercise



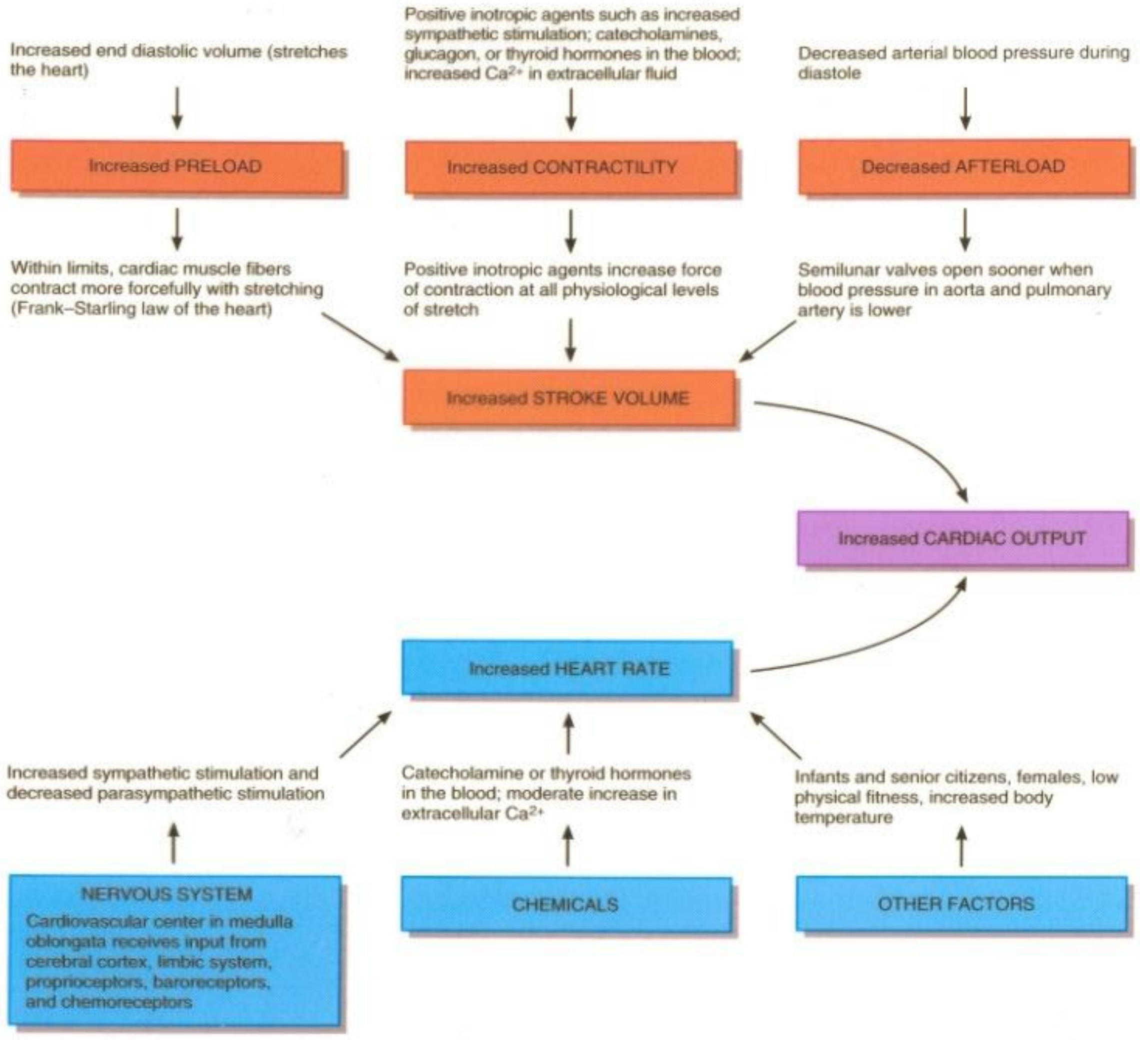
Variations in Tissue Blood Flow

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

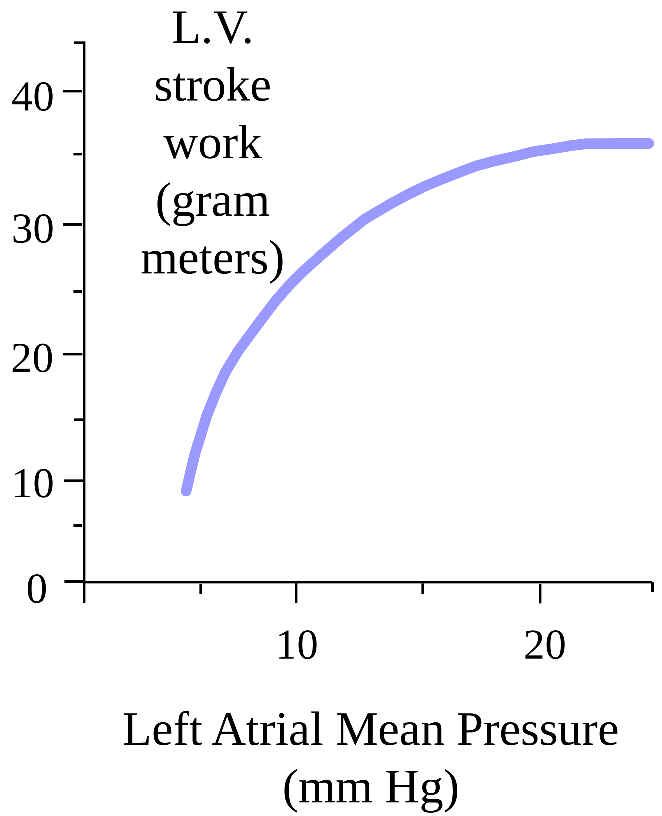
Control of Cardiac Output

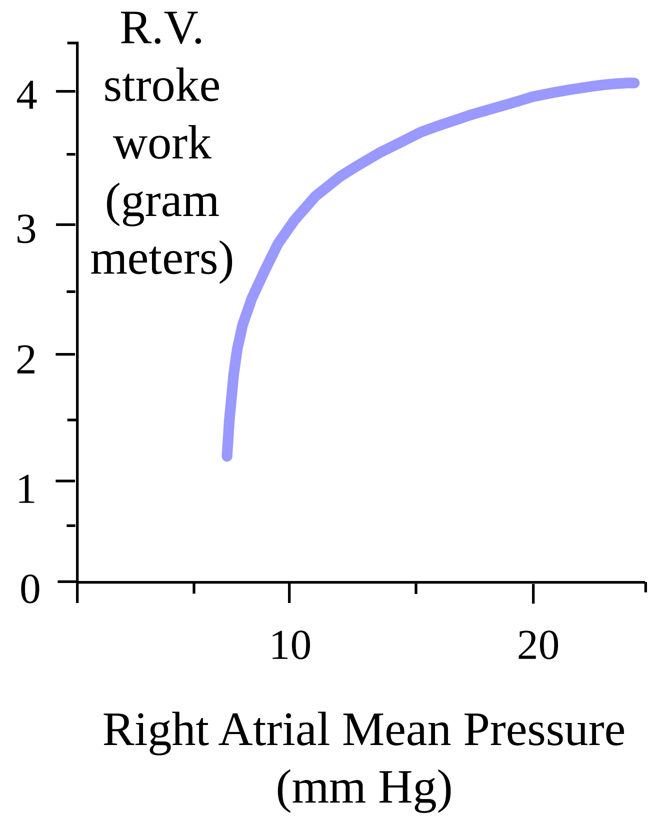


Factors that affect the Cardiac Output

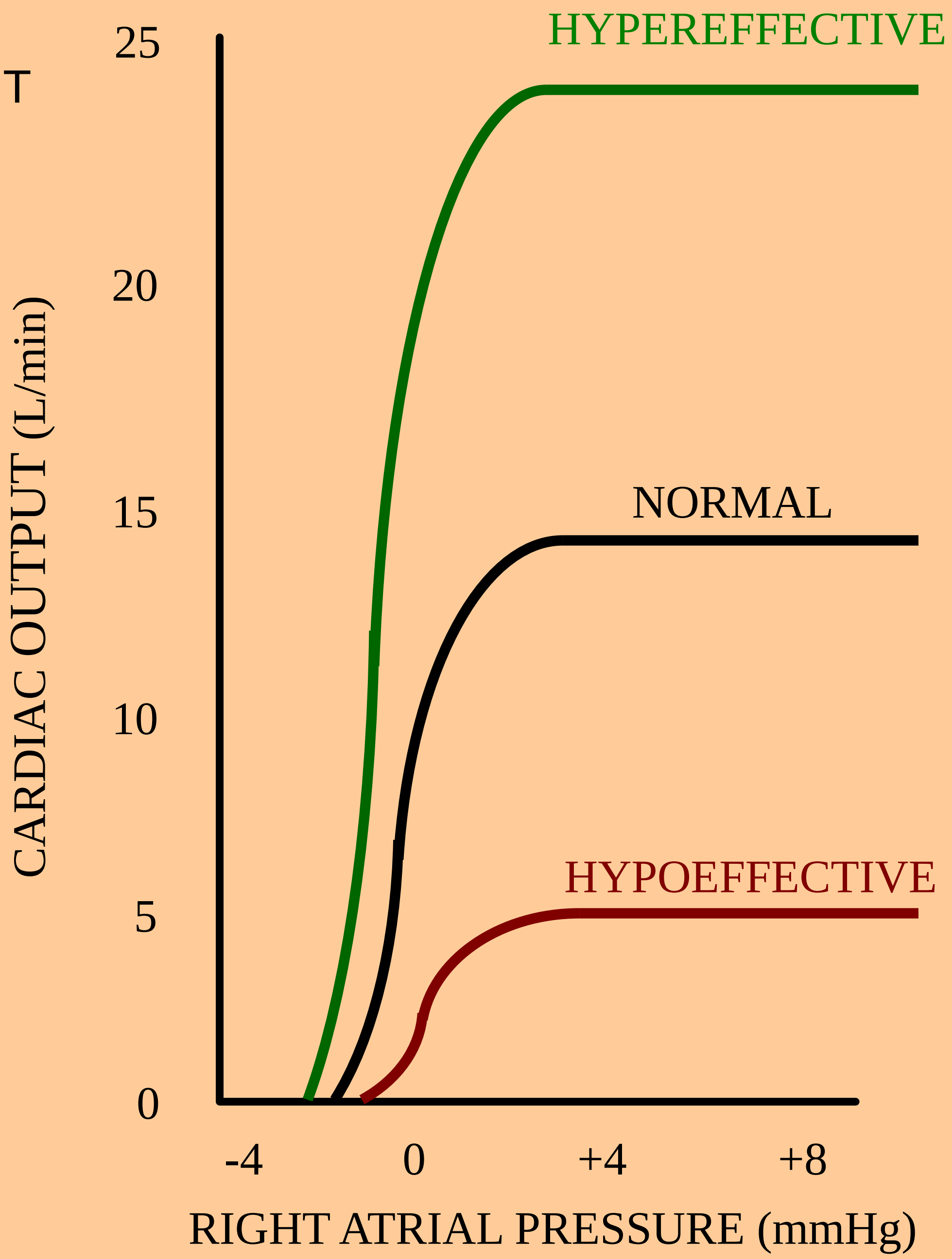


Ventricular Stroke Work Output

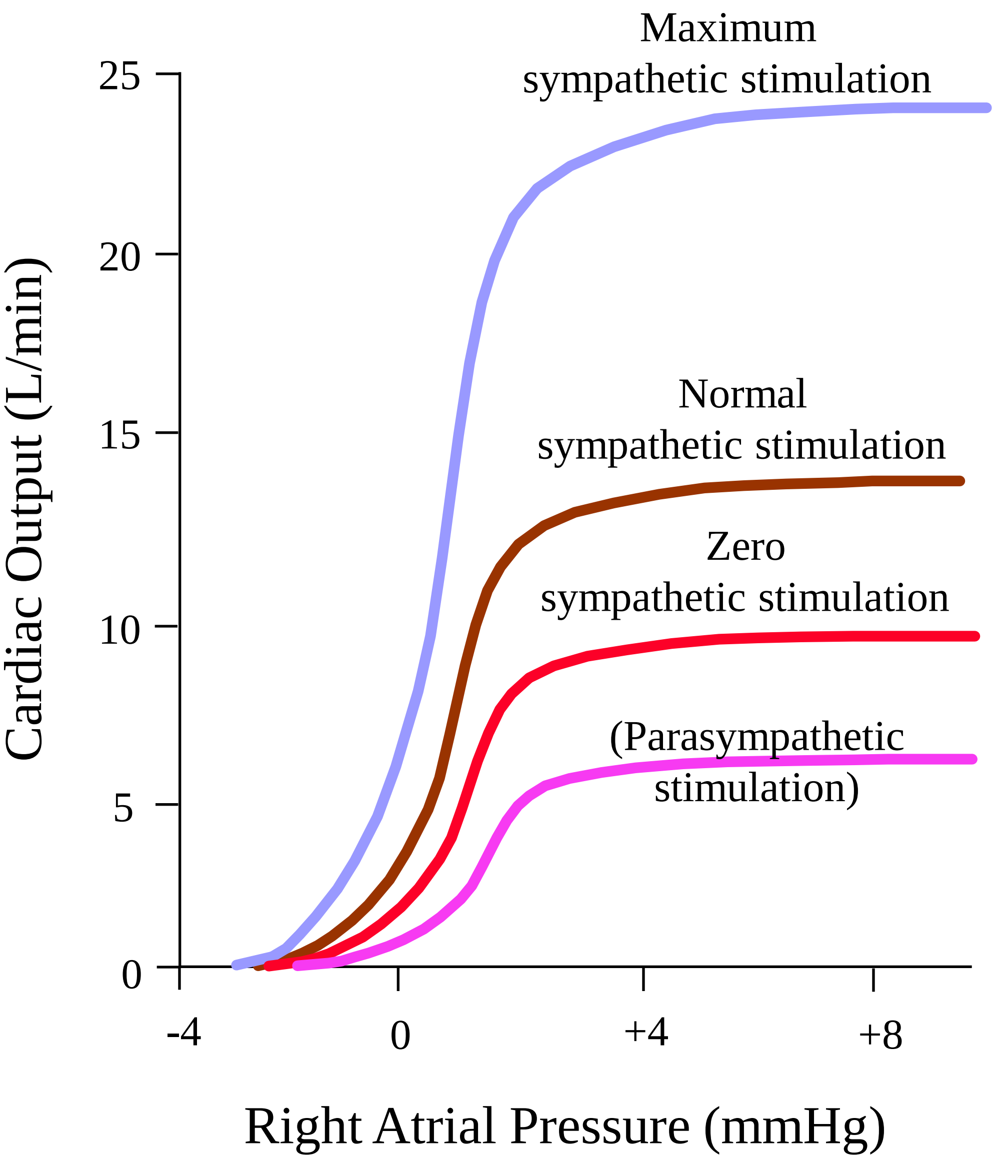


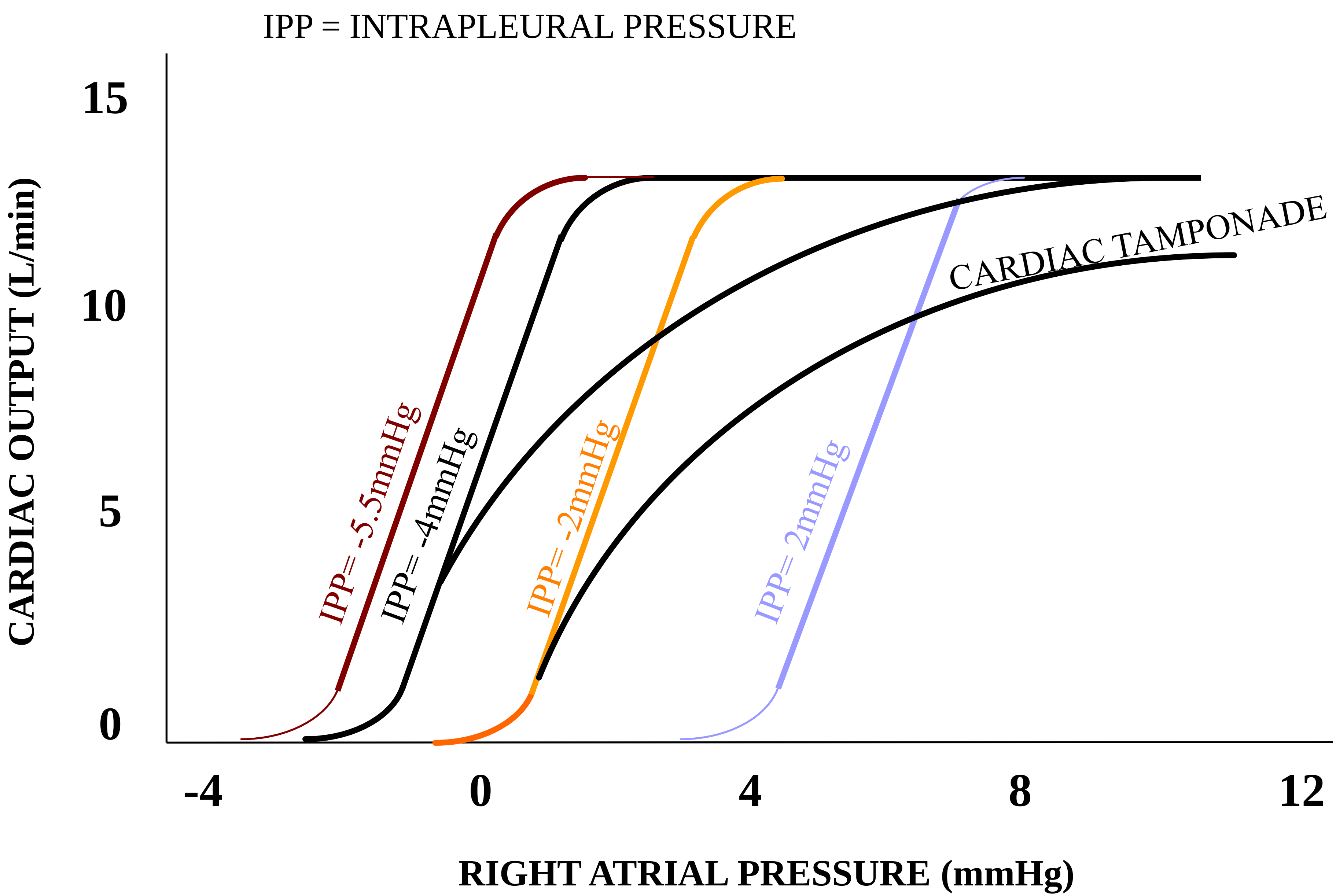


CARDIAC OUTPUT CURVES



Effect of Sympathetic and Parasympathetic Stimulation on Cardiac Output





IPP = INTRAPLEURAL PRESSURE
CARDIAC OUTPUT (L/min)
15
10
5
0
-4
0
4
8
12
RIGHT ATRIAL PRESSURE (mmHg)
IPP= -5.5mmHg
IPP= -4mmHg
IPP= -2mmHg
IPP= 2mmHg
CARDIAC TAMPONADE

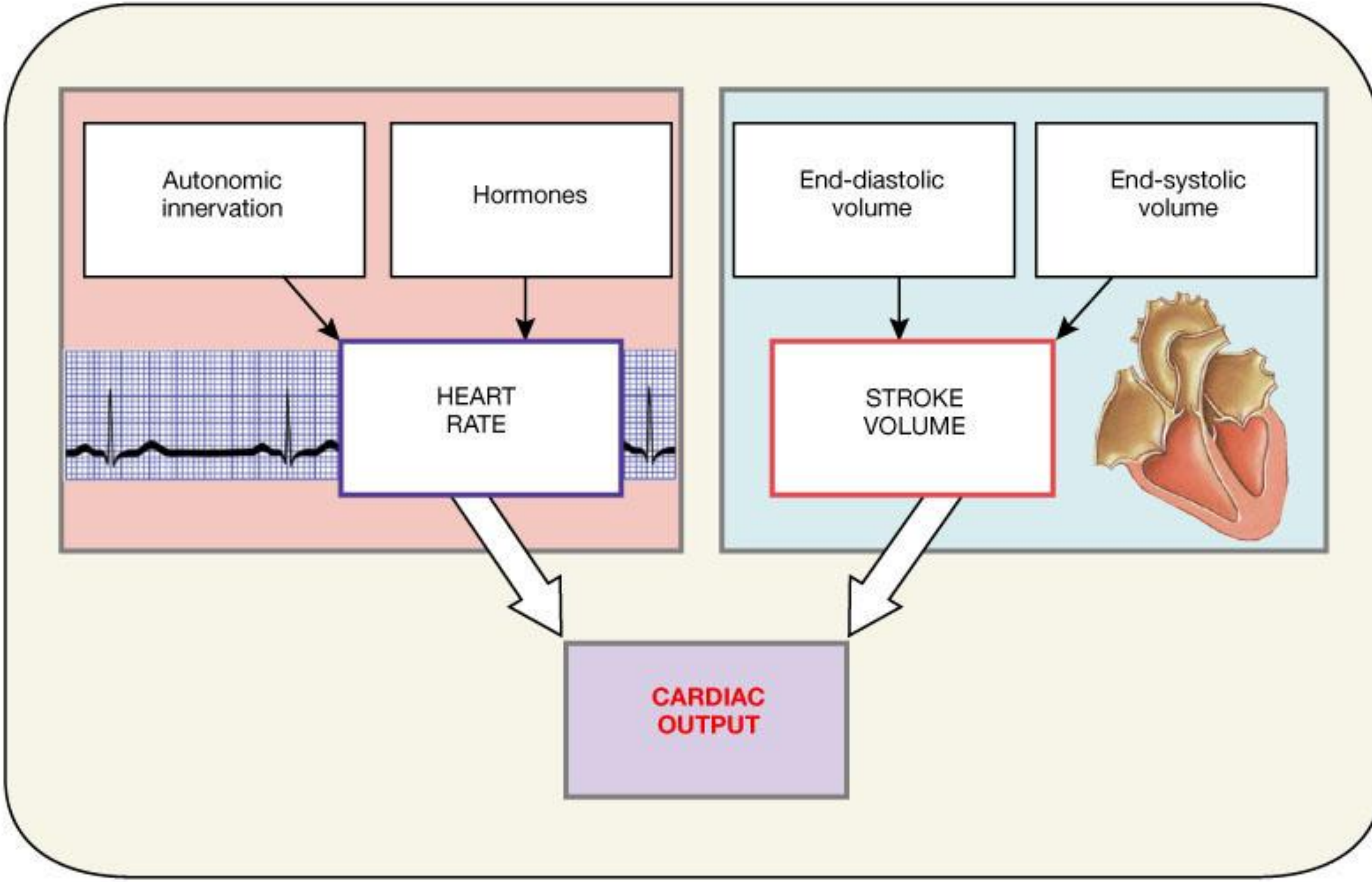
The Cardiac Output Curve

- Plateau of CO curve determined by
  heart strength (contractility + ↑HR)
- ↑ Sympathetics ⇒ ↑ plateau
- ↓ Parasympathetics (HR↑) ⇒ (? plateau)
- ↑ Plateau
- Heart hypertrophy's ⇒↑ plateau
- Myocardial infarction ⇒ (? plateau)
- ↓ Plateau

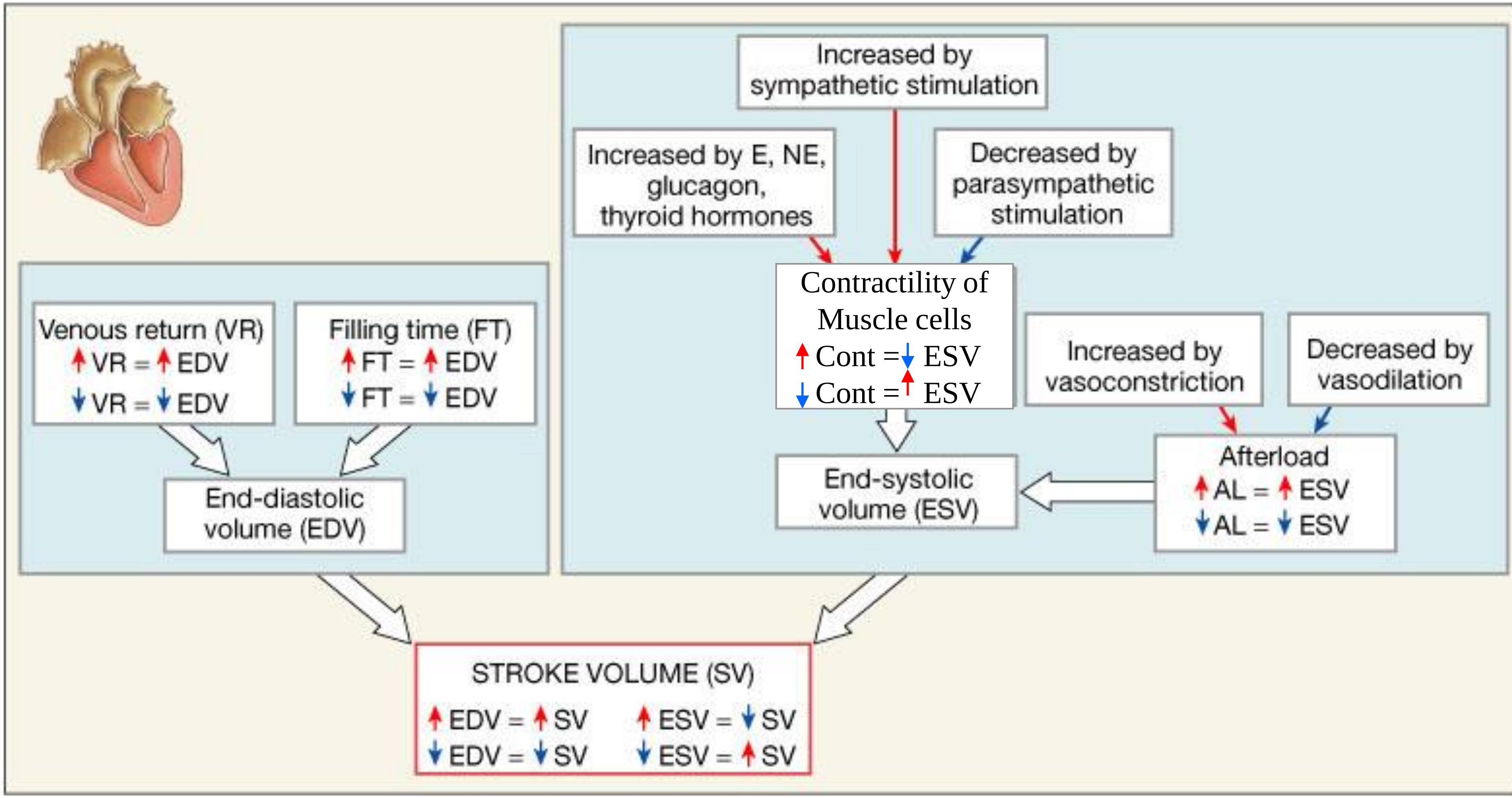
The Cardiac Output Curve (cont'd)

- Valvular disease ⇒ ↓ plateau (stenosis or regurgitation)
- Myocarditis ⇒ ↓ plateau
- Cardiac tamponade ⇒ (? plateau)
- ↓ Plateau
- Metabolic damage ⇒ ↓ plateau

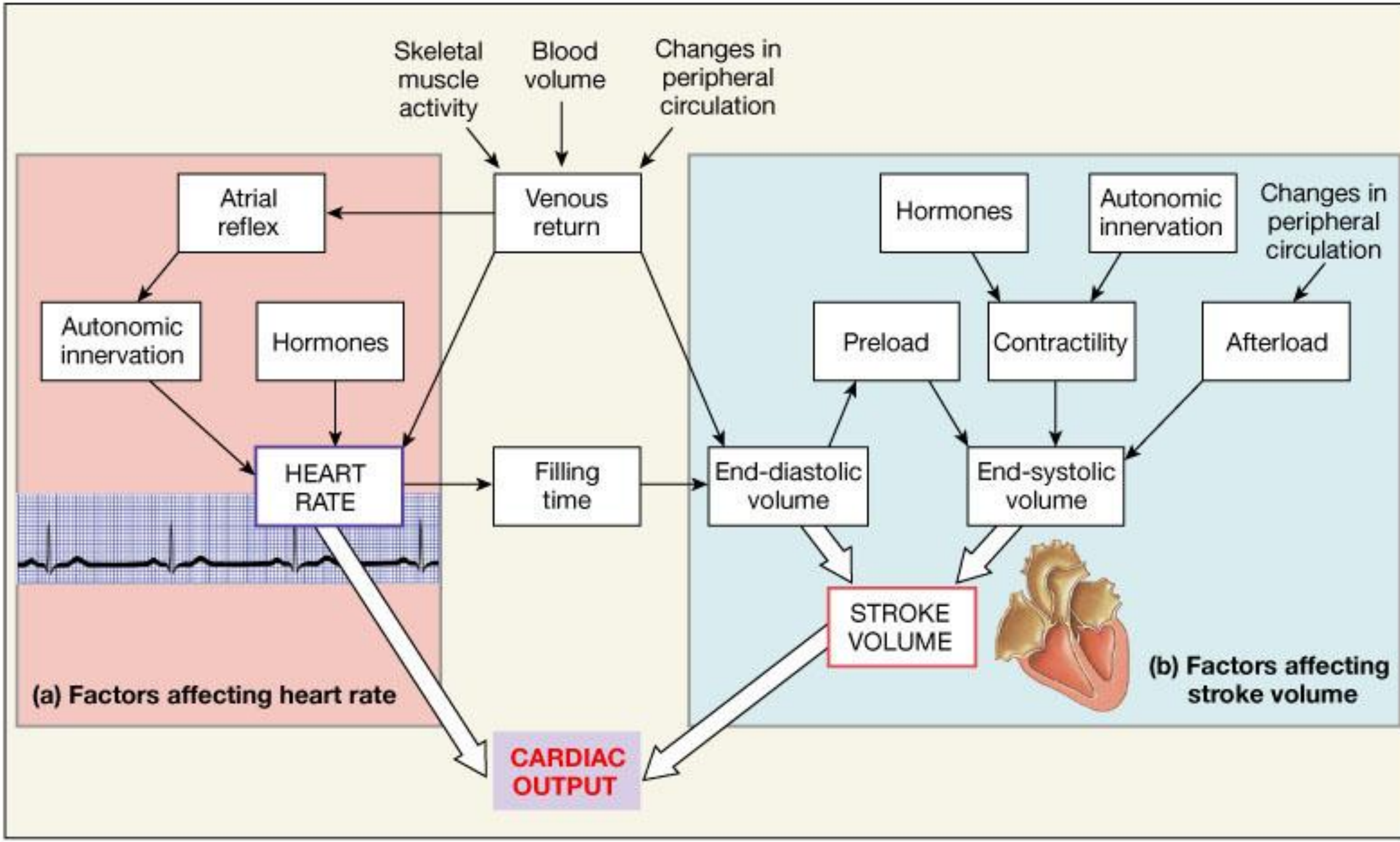
Factors Affecting Cardiac Output



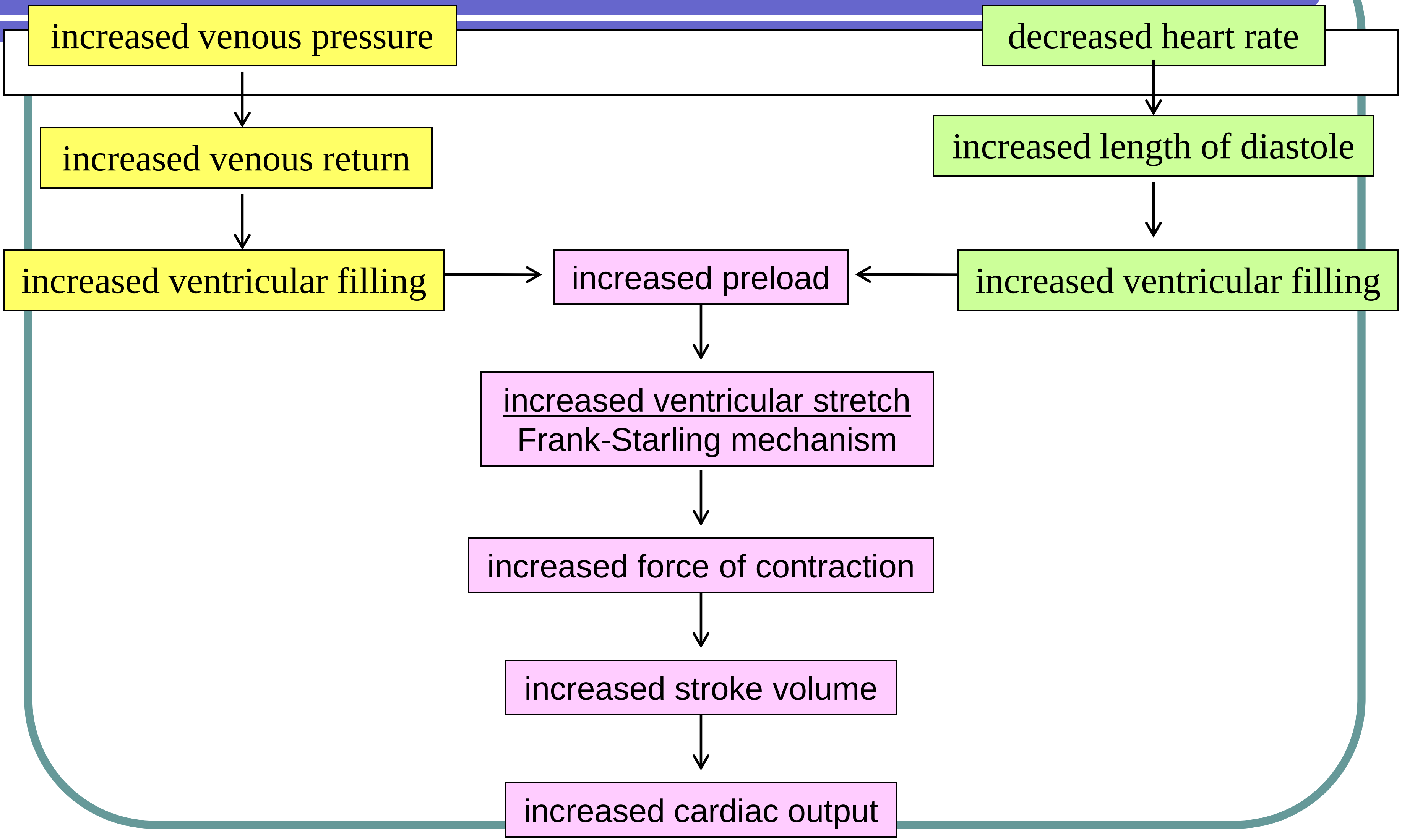
Factors Affecting Stroke Volume



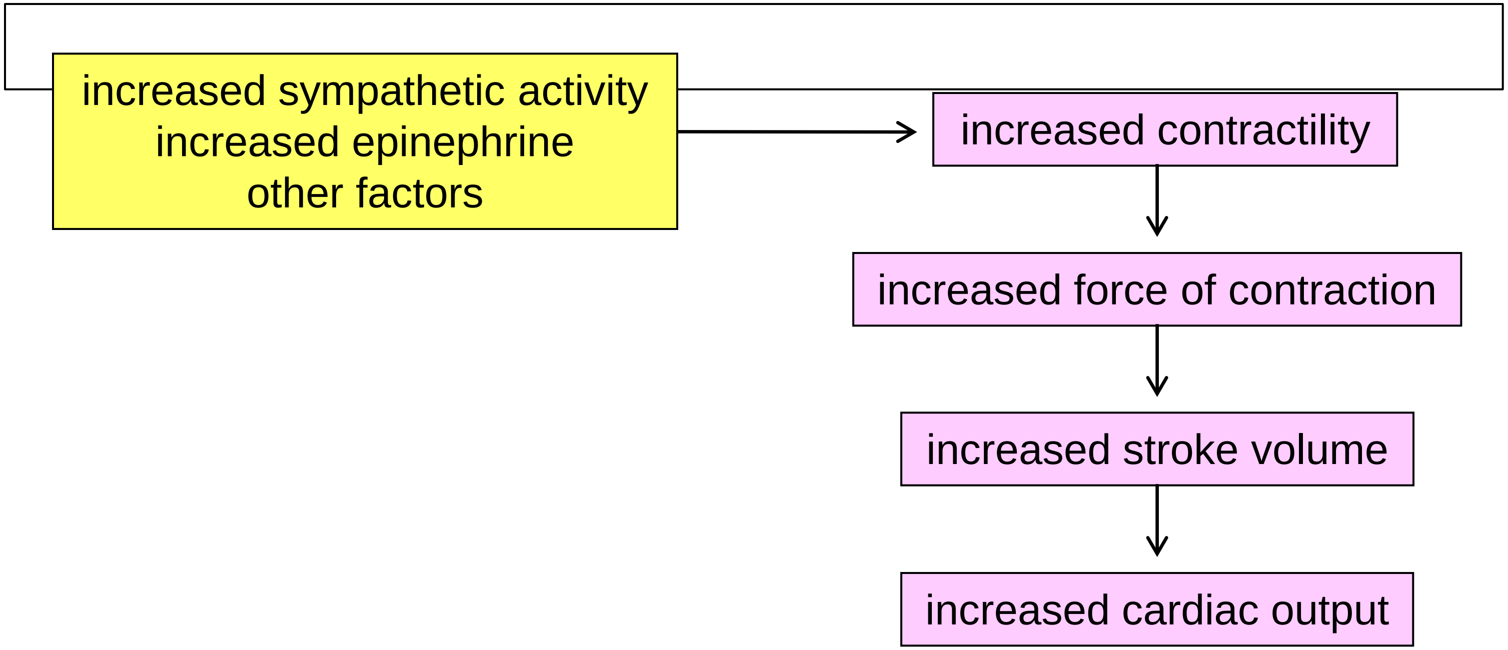
A Summary of the Factors Affecting Cardiac Output



REGULATION OF STROKE VOLUME: PRELOAD



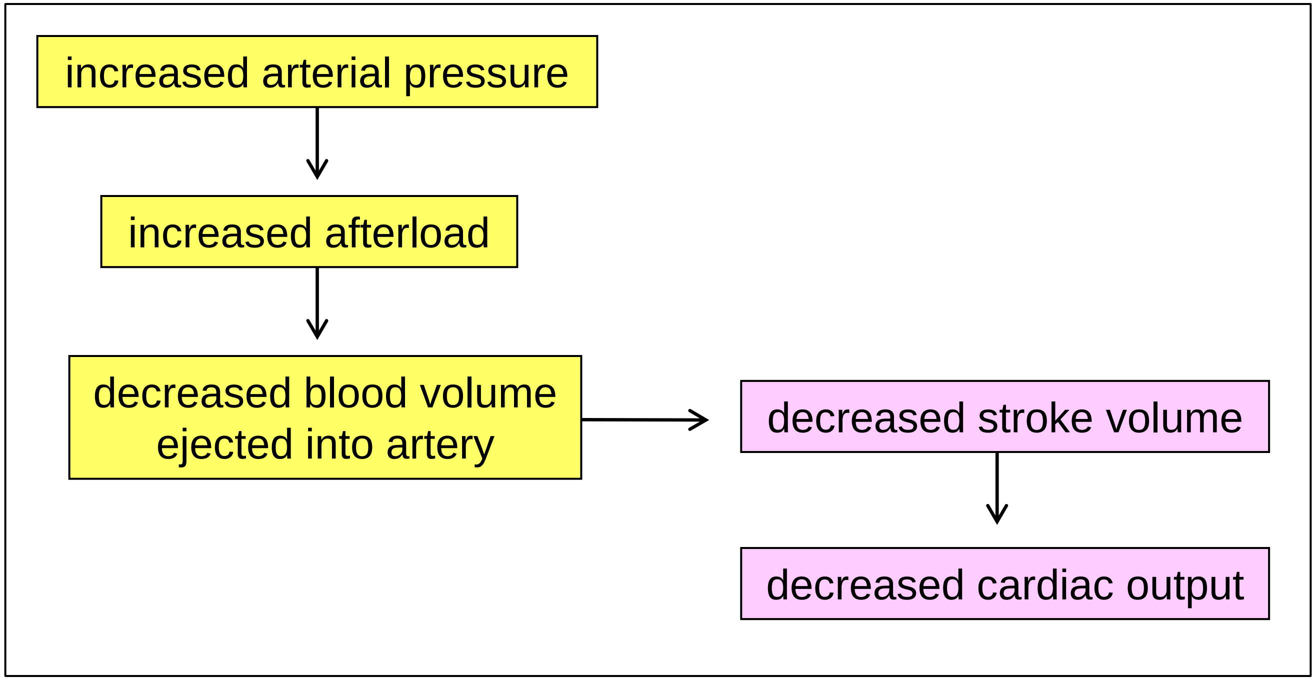
REGULATION OF STROKE VOLUME: CONTRACTILITY



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.
- $(dP/dt)/P_{ventricle}$ is better. $P_{ventricle}$ is instantaneous ventricular pressure.
- Excess K^+ decreases contractility.
- Excess Ca^{++} causes spastic contraction, and low Ca^{++} causes cardiac dilation.

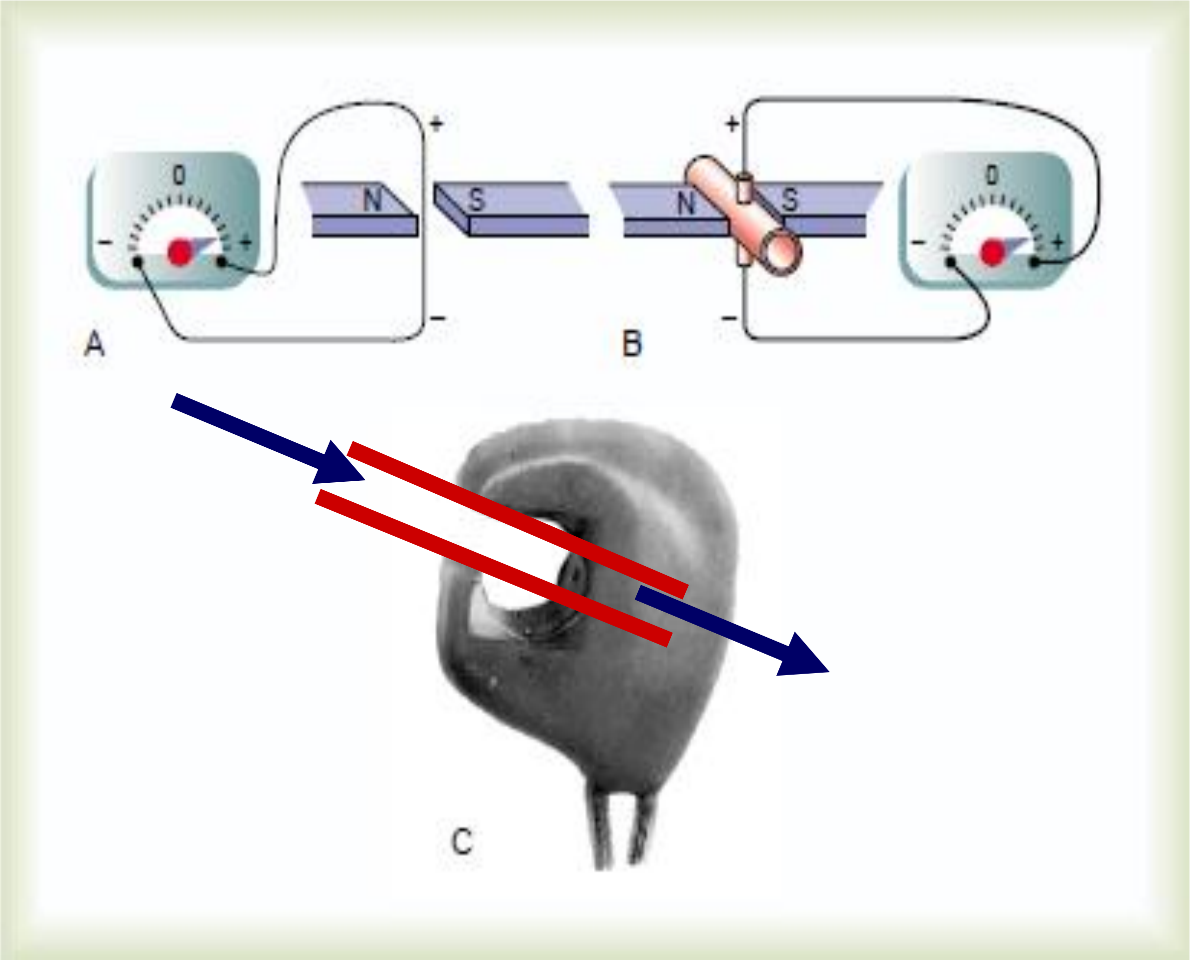
REGULATION OF STROKE VOLUME: AFTERLOAD

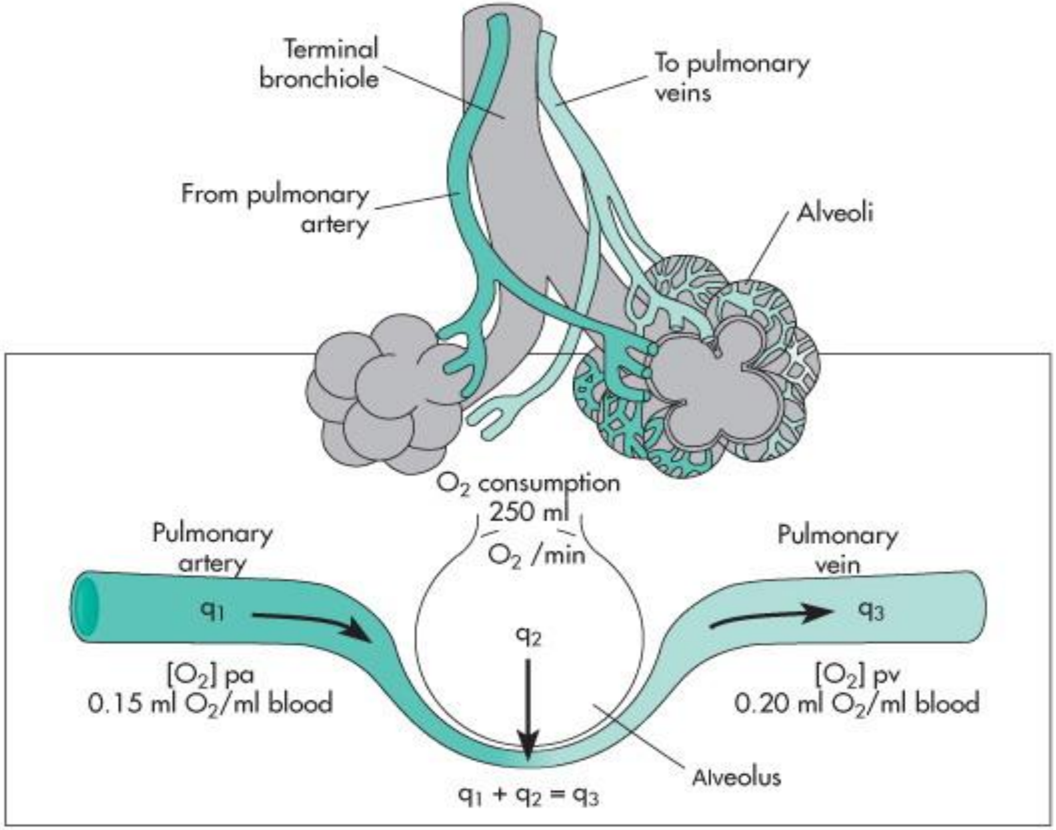


Measurement of Cardiac Output

- Electromagnetic flowmeter
- Indicator dilution (dye such as cardiogreen)
- Thermal dilution
- ***<u>Oxygen Fick Method</u>***
- ***<u>CO = (O_2 consumption / (A-V O_2 difference)</u>***

Electromagnetic flowmeter





q_1=CO*C_{VO2}

q_2=amount of Oxygen uptake by the lungs

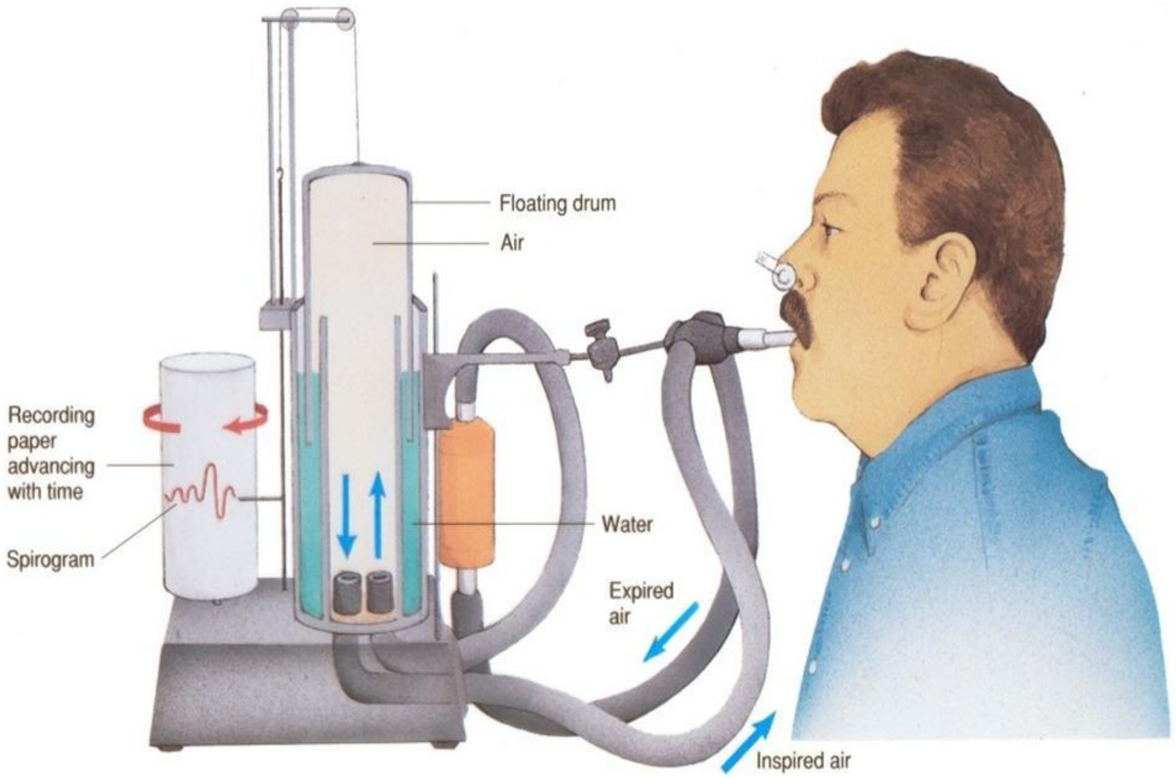
q_3= CO* C_{AO2} and equals = CO*C $_{VO2}$+ O_2 uptake

Oxygen uptake = CO{C_{AO2}-C $_{VO2}$}

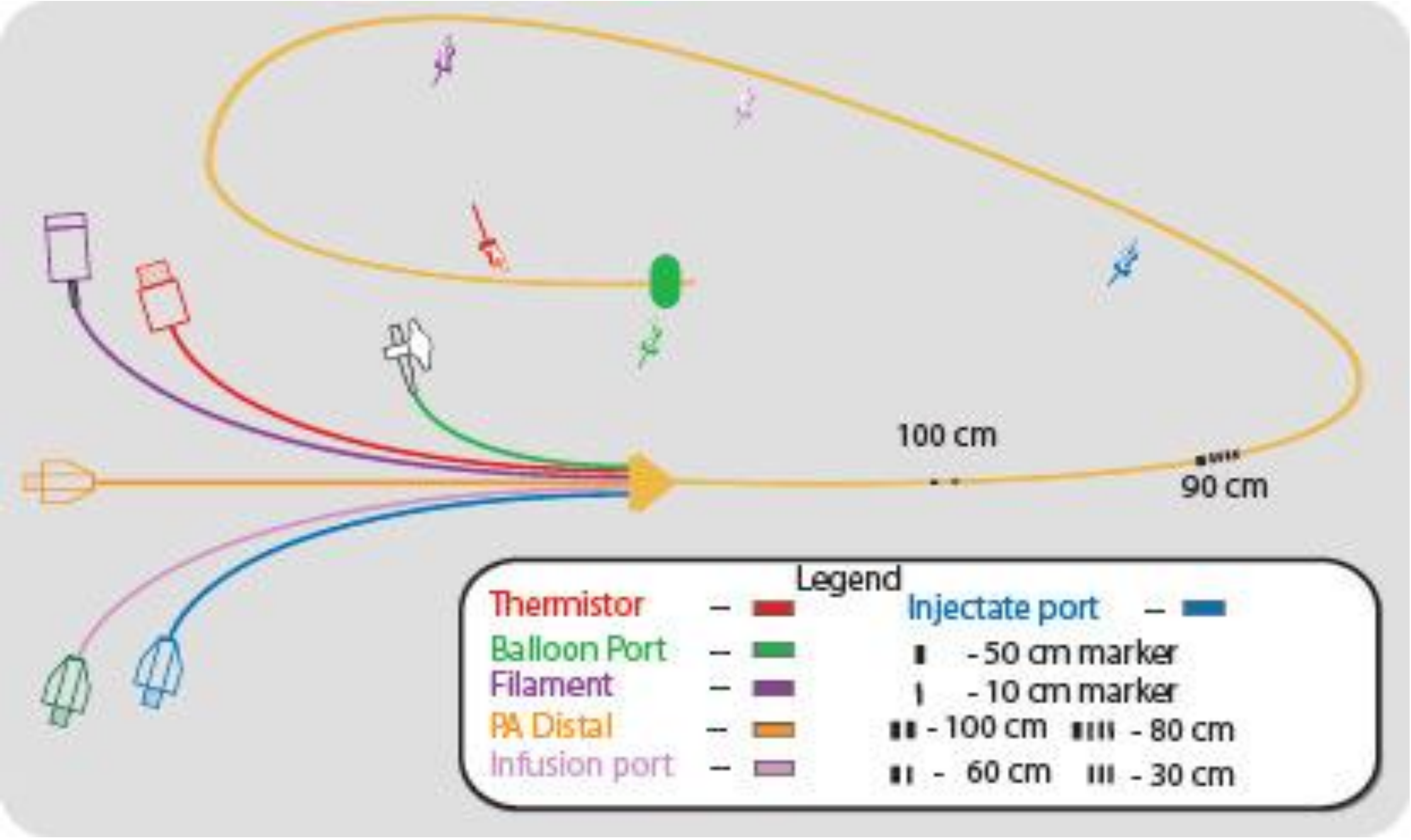
CO=Oxygen uptake/{C_{AO2}-C V_{O2}}

Spirometer

A spirometer



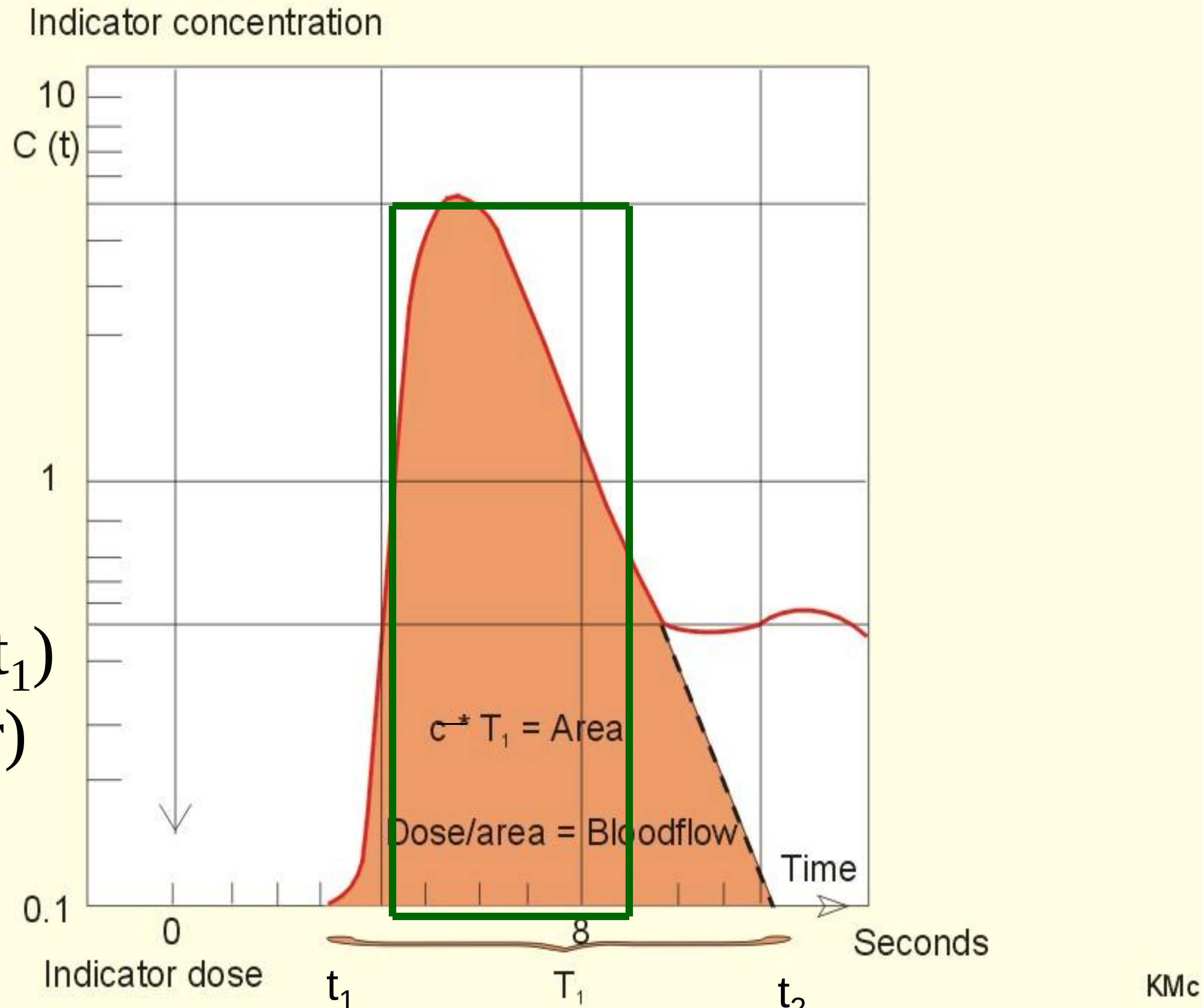
Swan-Ganz catheter



O_2 Fick Problem

- If pulmonary vein O_2 content = 200 ml $O_{2/}$L blood
- Pulmonary artery O_2 content = 160 ml O_2 /L blood
- Lungs add 400 ml O_2 /min
- What is cardiac output?
- Answer: 400/(200-160) =10 L/min

THE INDICATOR DILUTION PRINCIPLE



$$\text{Area} = \int_{t2}^{t1} dc.dt$$

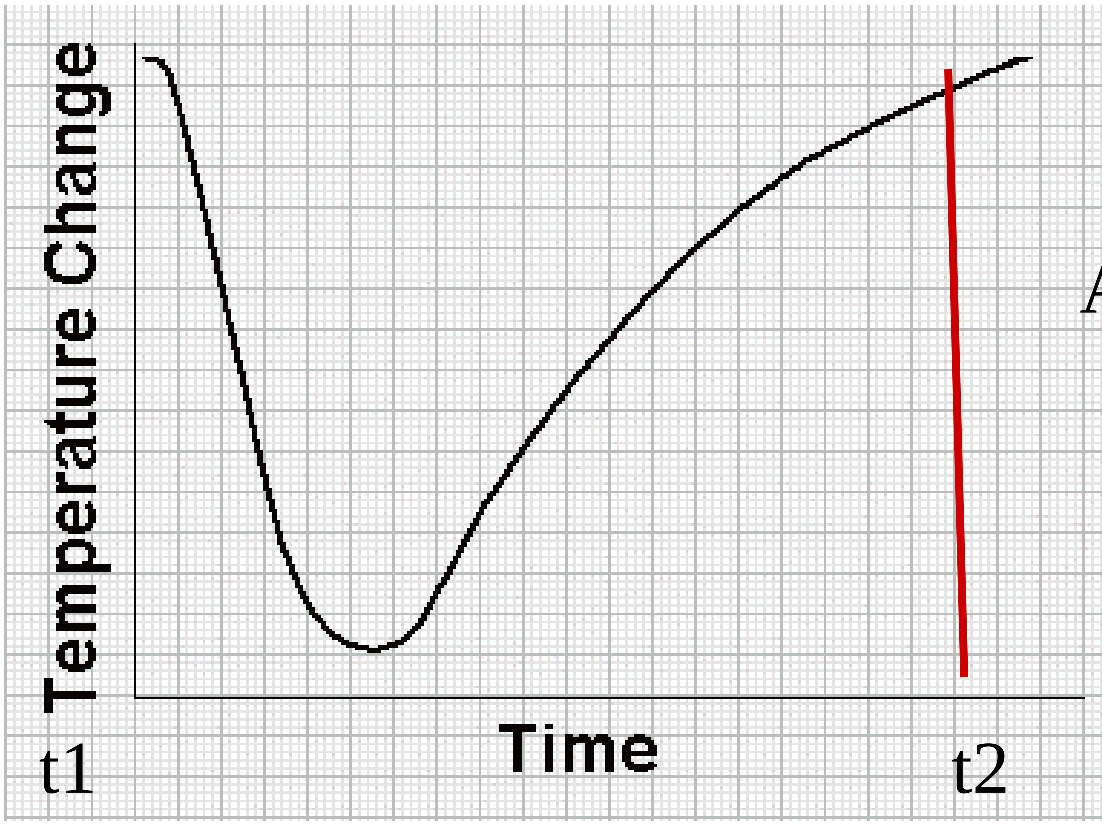
$$\text{Area} = \overline{C} * (t_2 - t_1)$$

(Rectangular)

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

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

Thermodilution Method Curve

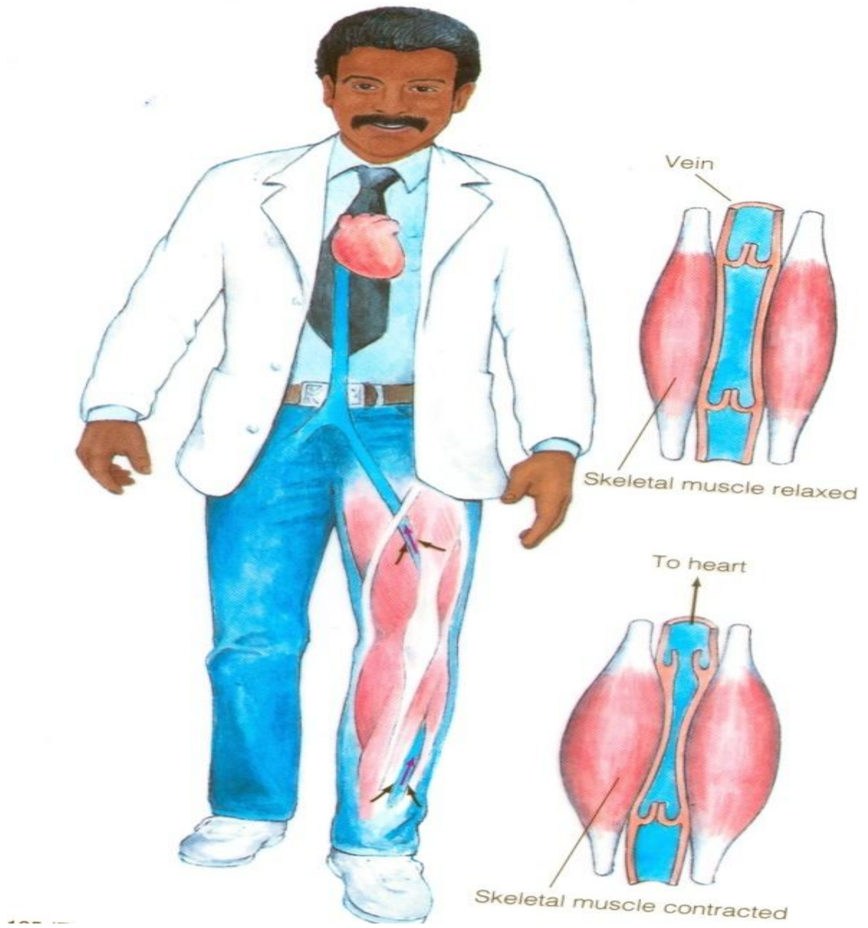


$$\text{AREA} = \int_{t1}^{t2} dT.dt$$

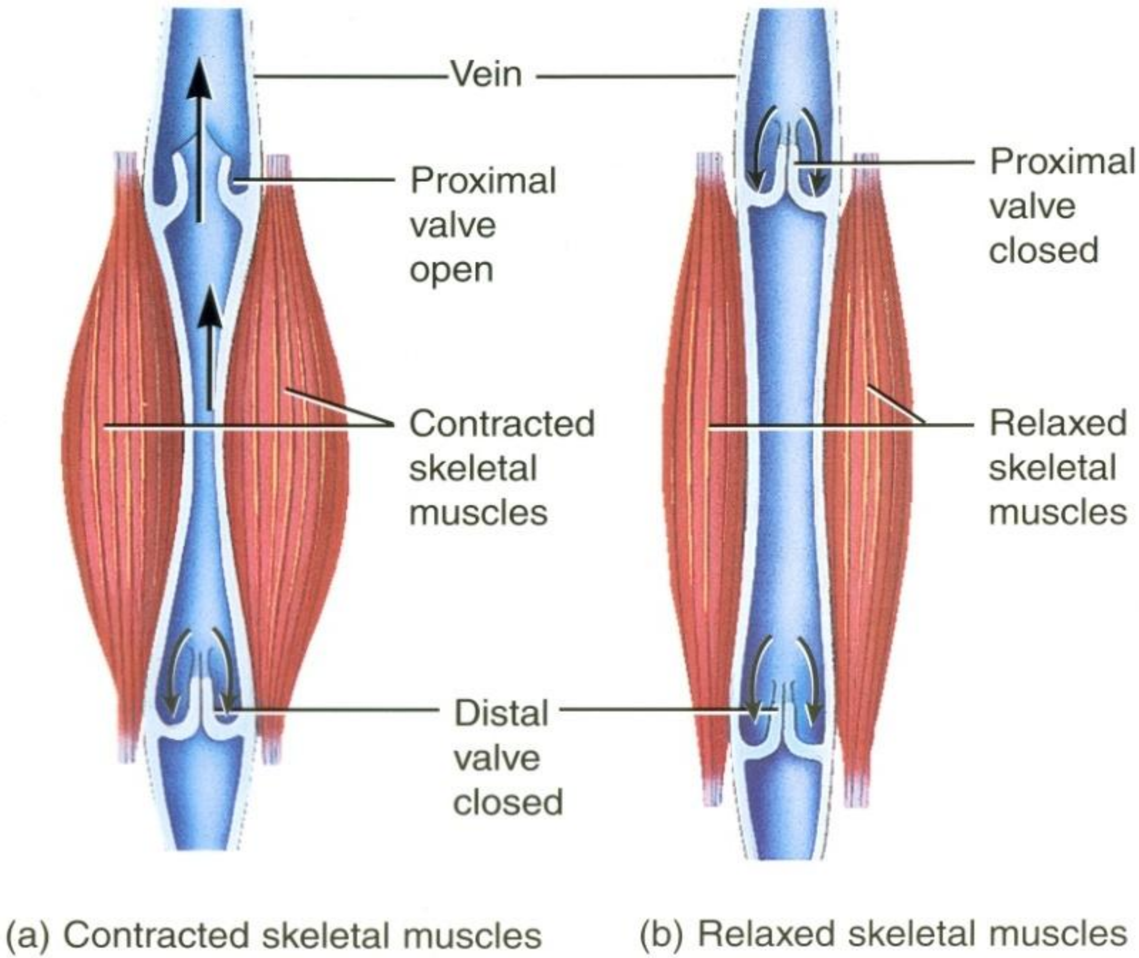
VENOUS RETURN

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

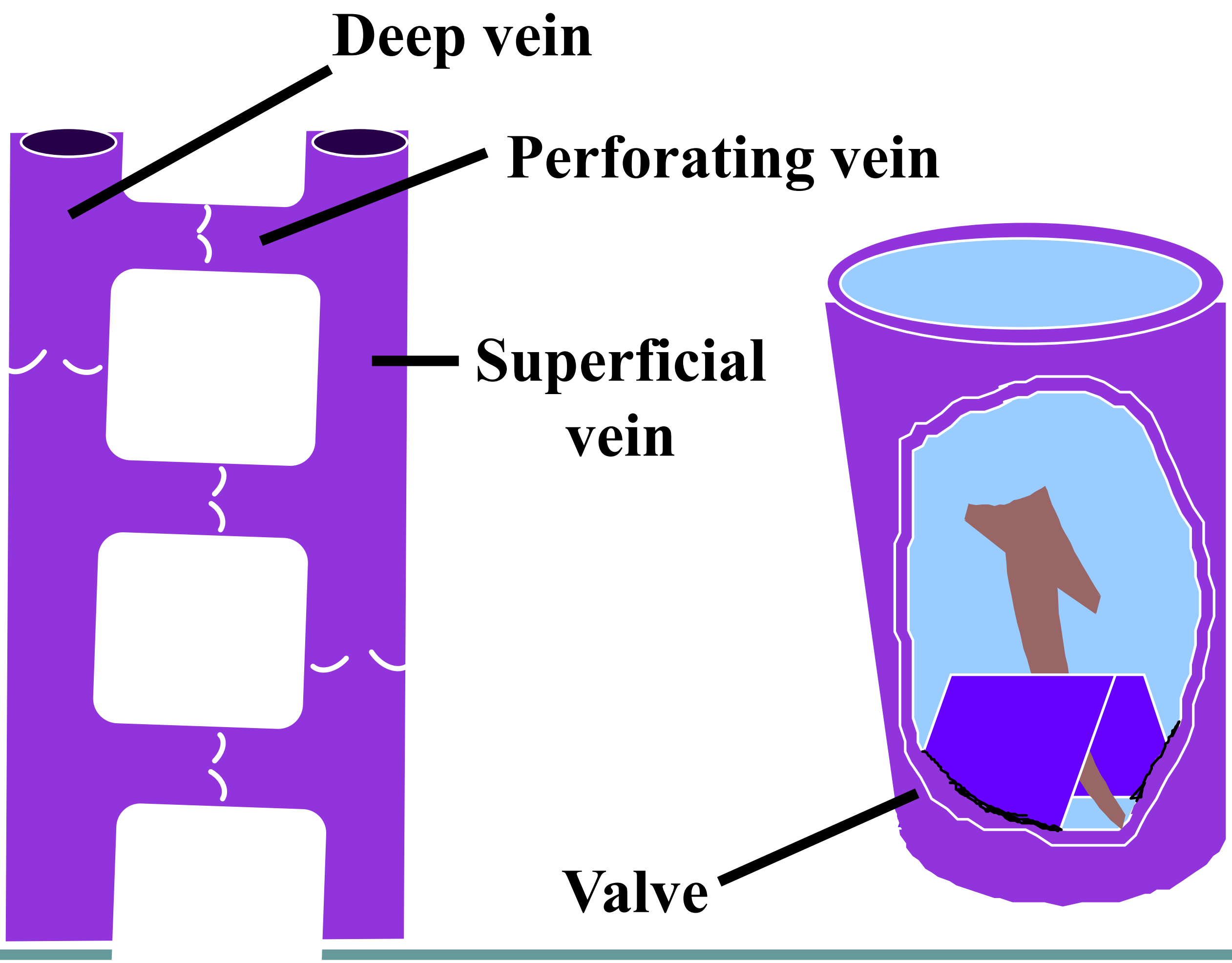
Effect of Venous Valves



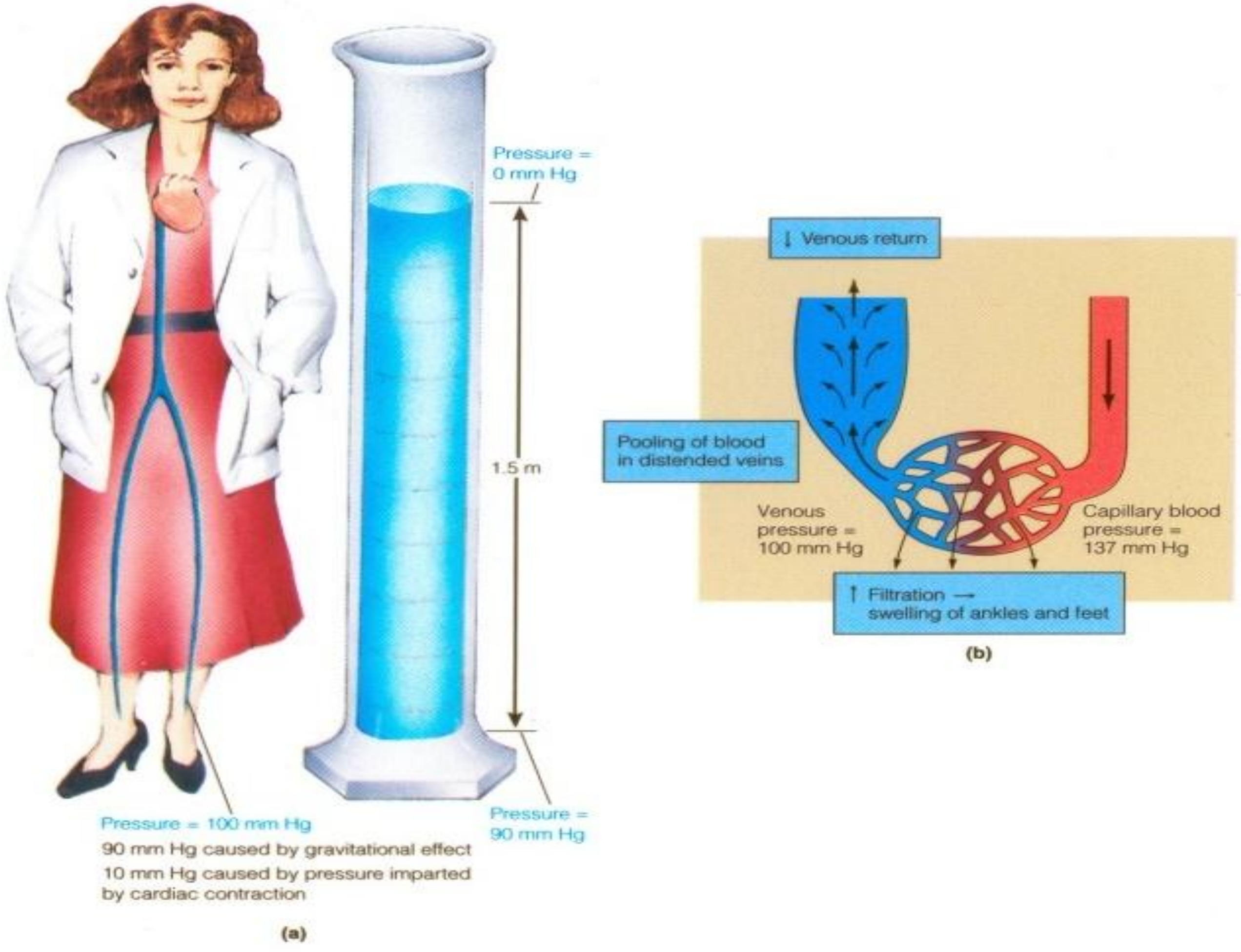
Effect of Venous Valves



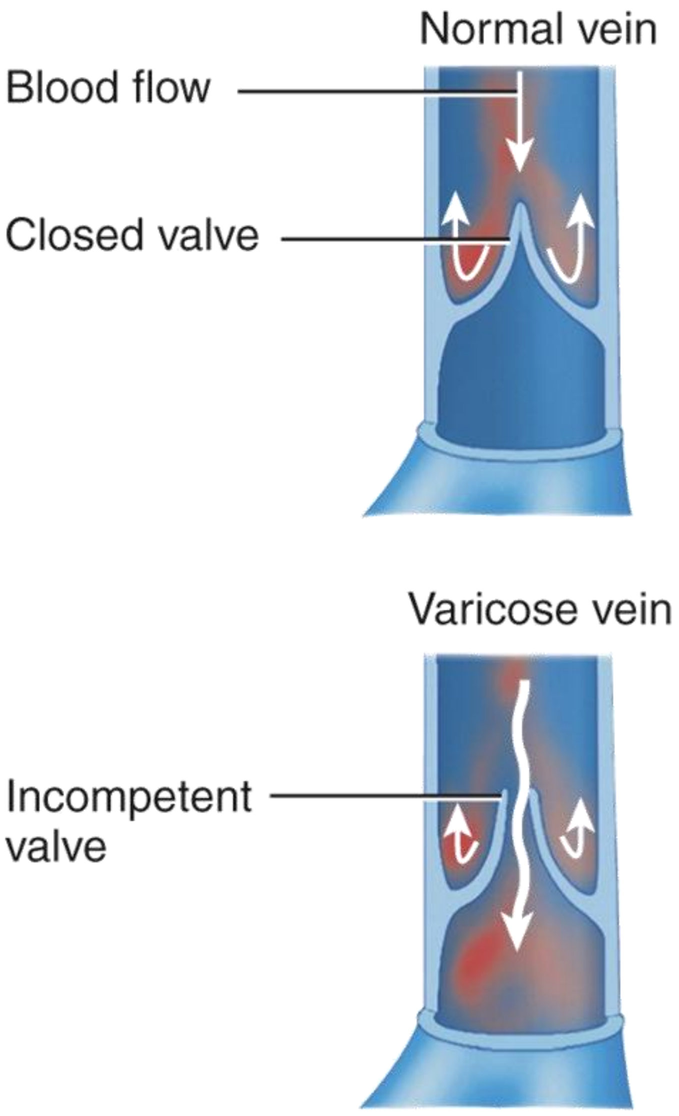
Venous Valves



Effect Of Gravity on Venous Pressure

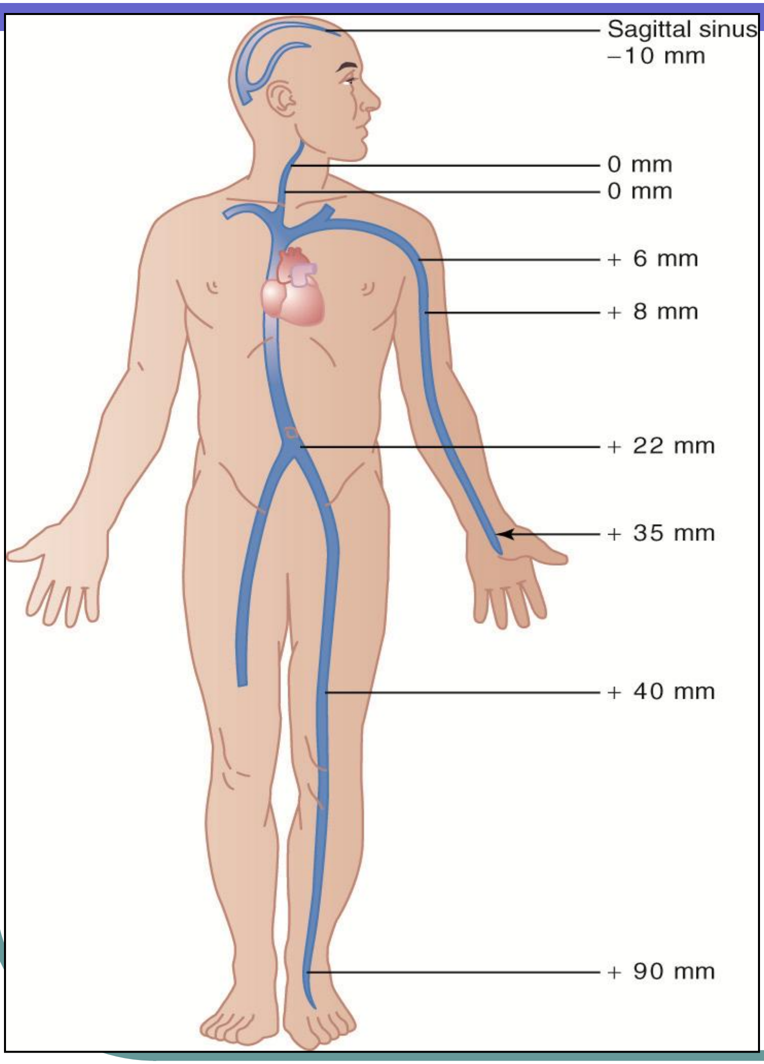


Vessel Structure and Function



Dilated and twisted appearance of varicose veins in the leg

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.

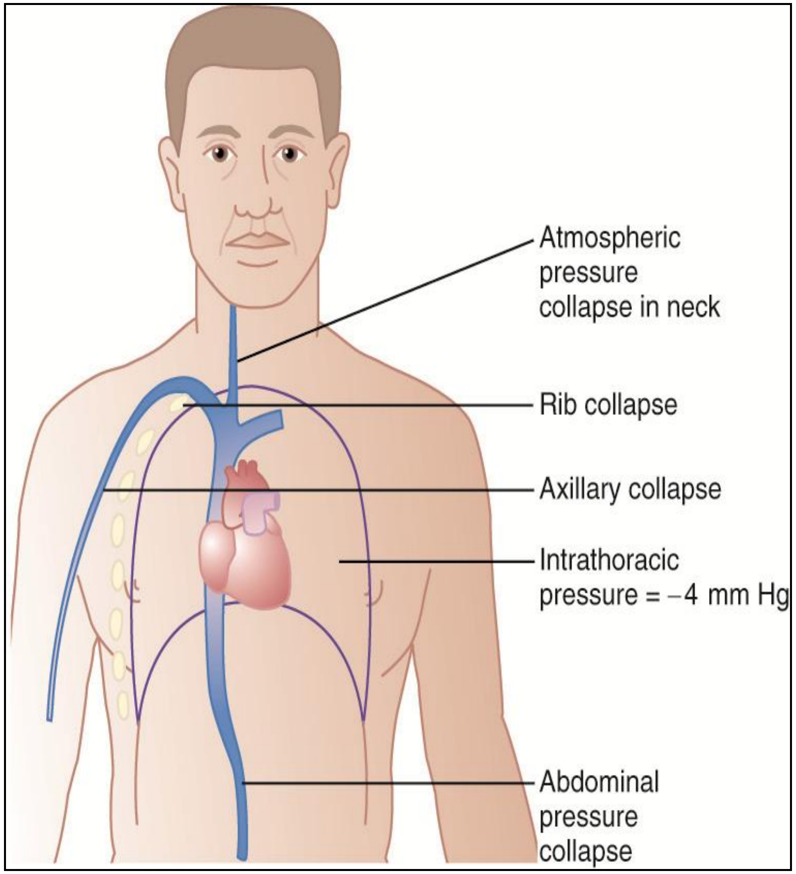
Central Venous Pressure

- 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.

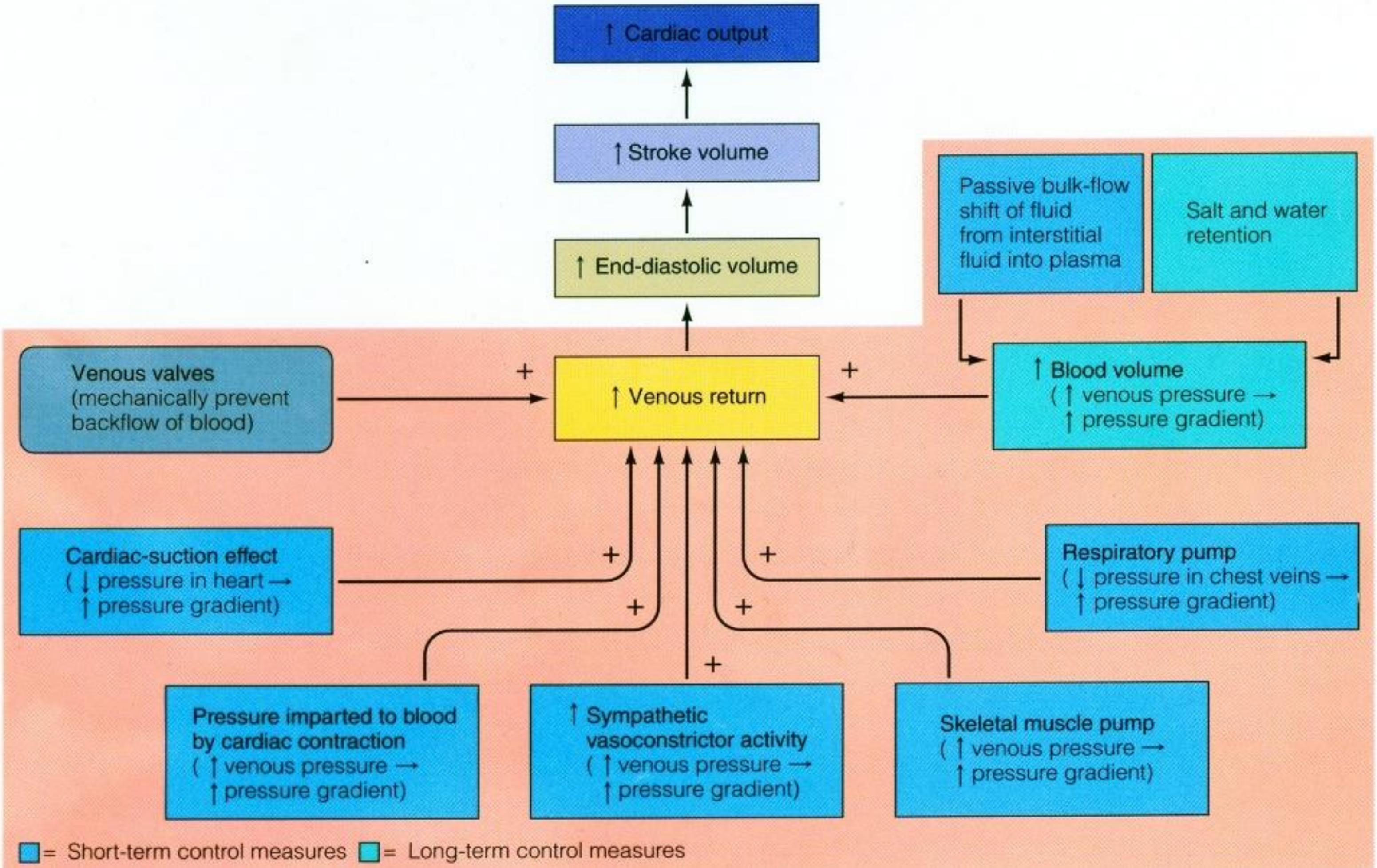
Factors affecting Central Venous Pressure

- 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.

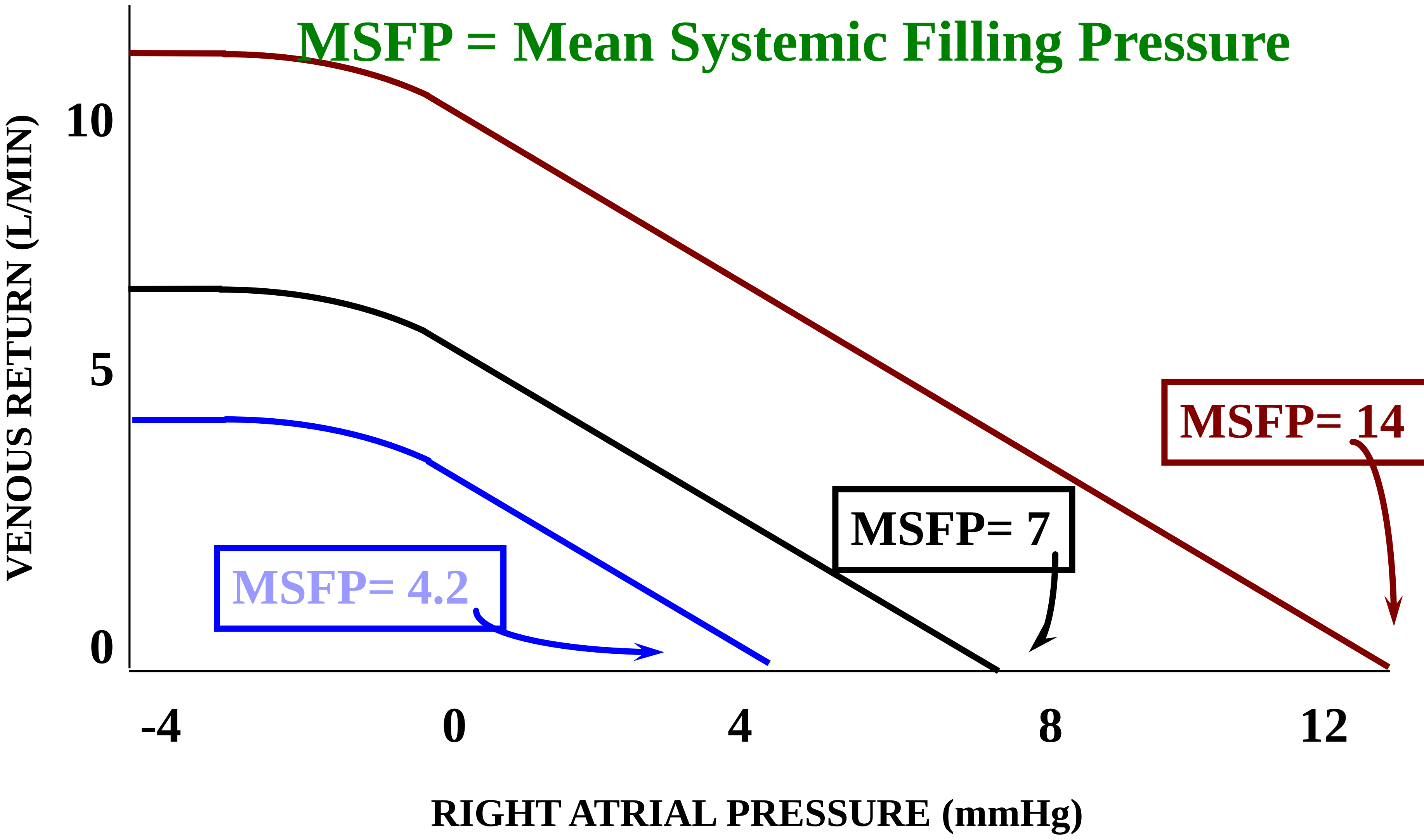
- Factors that increase RAP:
- -increased blood volume
- -increased venous tone
- - dilation of arterioles
- -decreased cardiac function

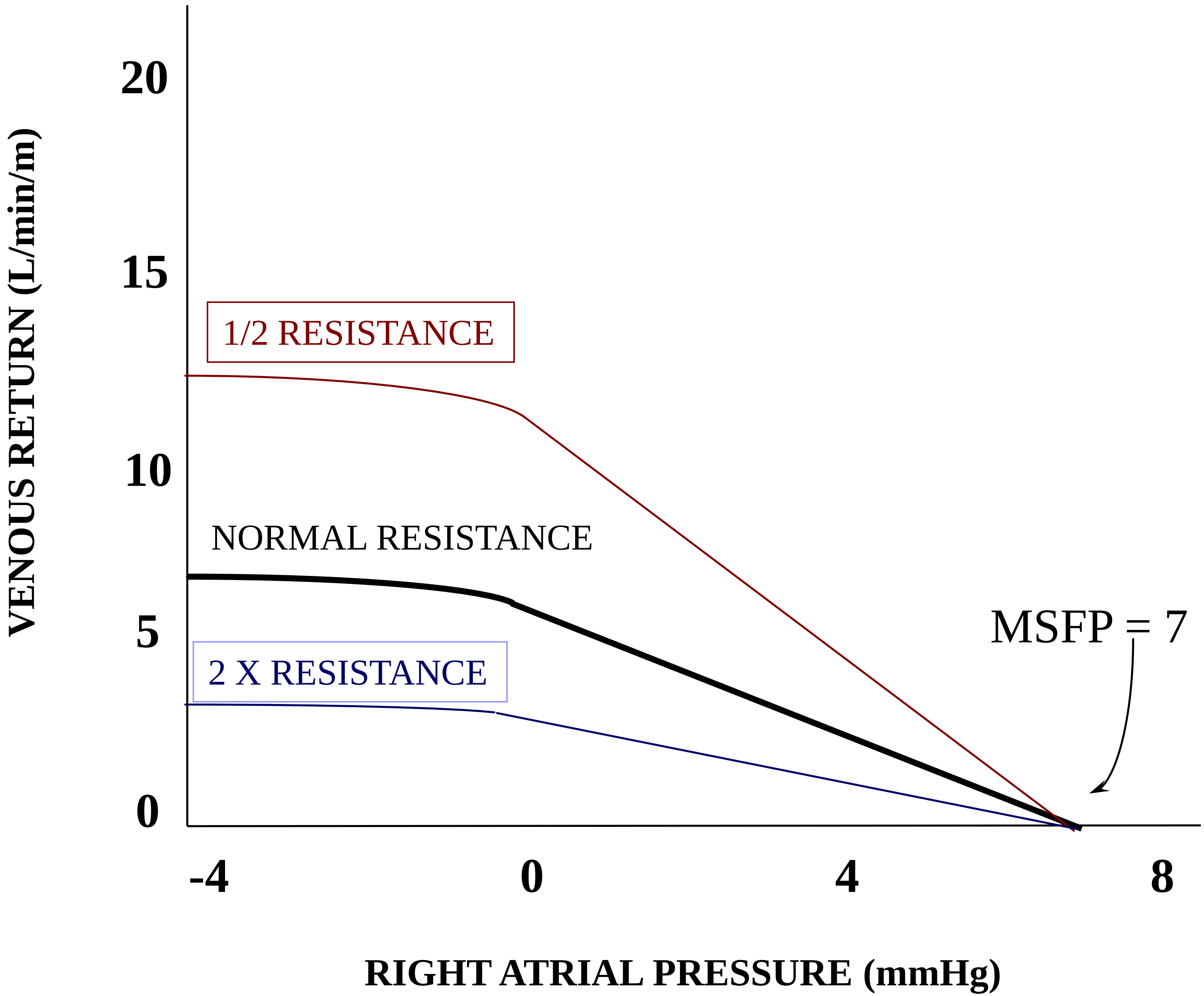


Factors that Facilitate Venous Return



The Venous Return Curve





VENOUS RETURN (L/min/m)
20
15
10
5
0
1/2 RESISTANCE
NORMAL RESISTANCE
2 X RESISTANCE
MSFP = 7
-4
0
4
8
RIGHT ATRIAL PRESSURE (mmHg)

Venous Return (VR)

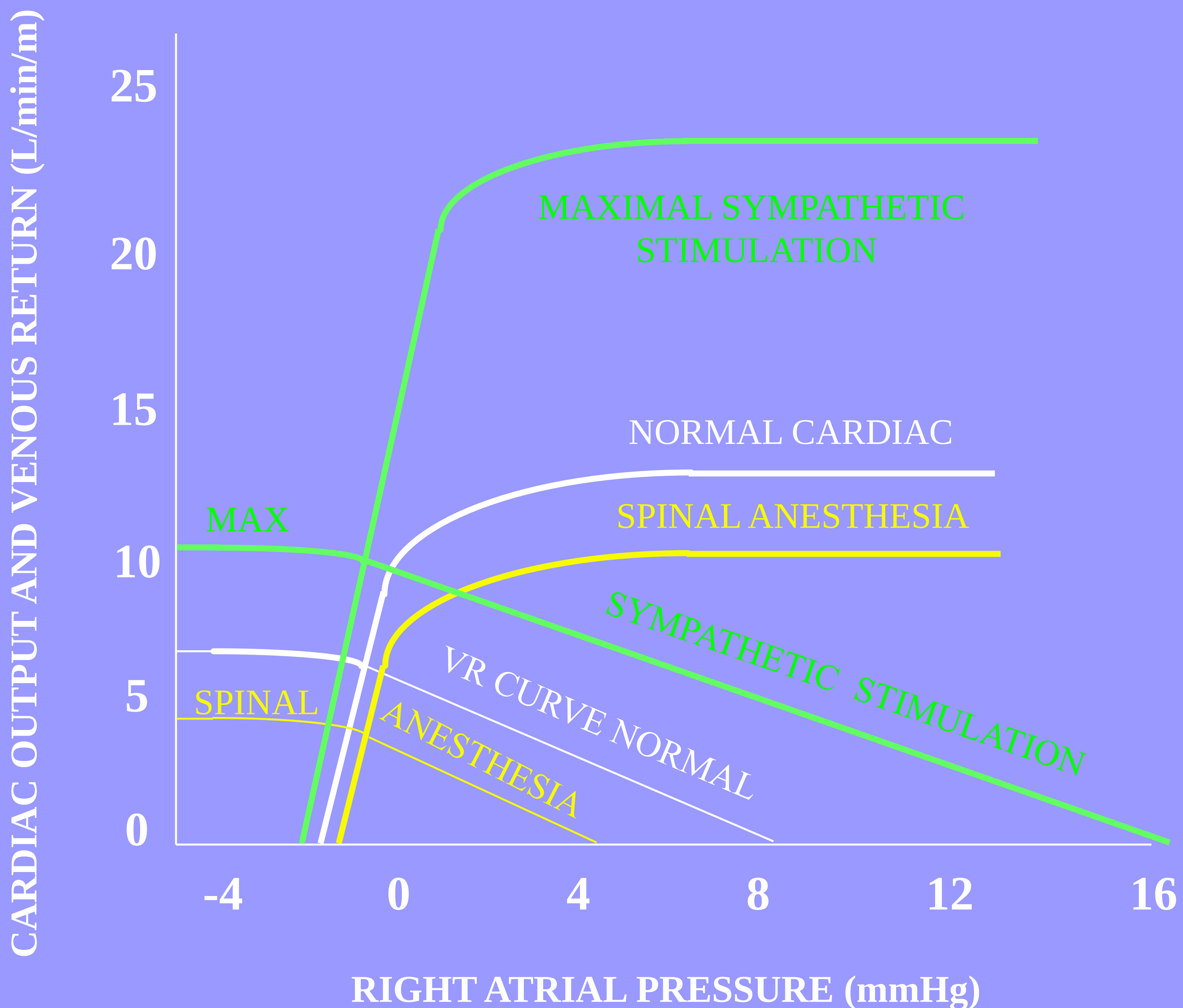
- Beriberi - thiamine deficiency $\Rightarrow$ arteriolar dilatation $\Rightarrow \downarrow$ RVR
- (RVR= resistance to venous return)
  because VR = (MSFP - RAP) /RVR
  (good for positive RAP's)
- A-V fistula $\Rightarrow$ (? RVR)
- $\downarrow$ RVR
- C. Hyperthyroidism $\Rightarrow$ (? RVR)
- $\downarrow$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

Venous Return (VR) (cont'd)

- Anemia ⇒ ↓ RVR (why?)
- ↑ Sympathetics ⇒ ↑ MSFP
- ↑ Blood volume ⇒ ↑ MSFP + small ↓ in RVR
- ↓ Venous compliance (muscle contraction or venous constriction) ⇒ (? MSFP)
- ↑ MSFP

Factors Causing ↓Venous Return

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



CARDIAC OUTPUT AND VENOUS RETURN (L/min/m)
25
20
15
10
5
0
-4
0
4
8
12
16
RIGHT ATRIAL PRESSURE (mmHg)
MAXIMAL SYMPATHETIC
STIMULATION
NORMAL CARDIAC
SPINAL ANESTHESIA
MAX
SYMPATHETIC STIMULATION
VR CURVE NORMAL
SPINAL
ANESTHESIA

Thank You