The Cardio-VASCULAR System

○ Anatomy
○ Histology
○ Pathology
○ Pharmacology
● Physiology
○ Microbiology

Lec #: Cardiac Output and Venous Return

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Done By:

○ Handout
○ Sheet
● Slide

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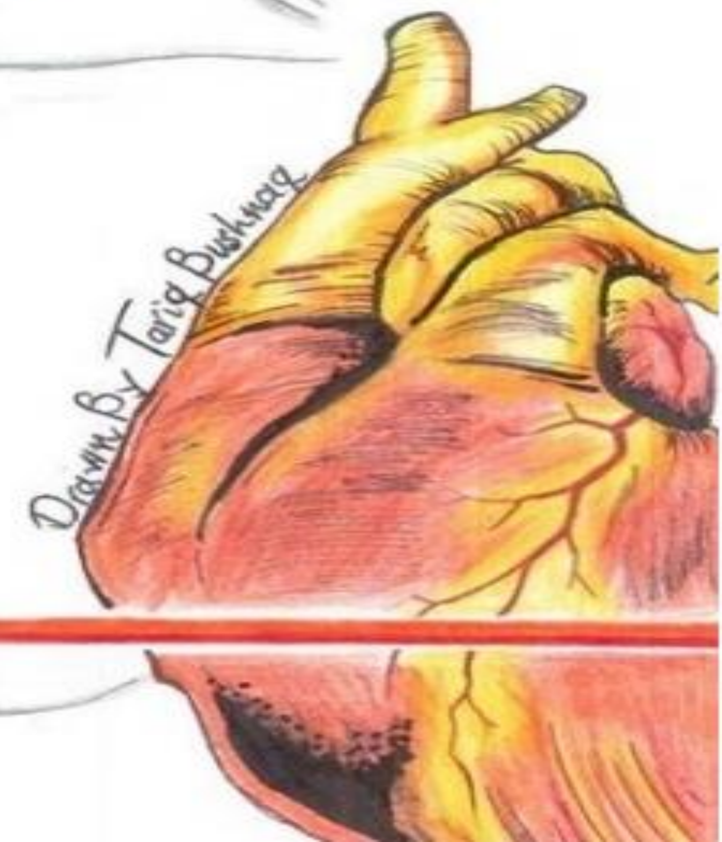


Cardiac output and Venous Return

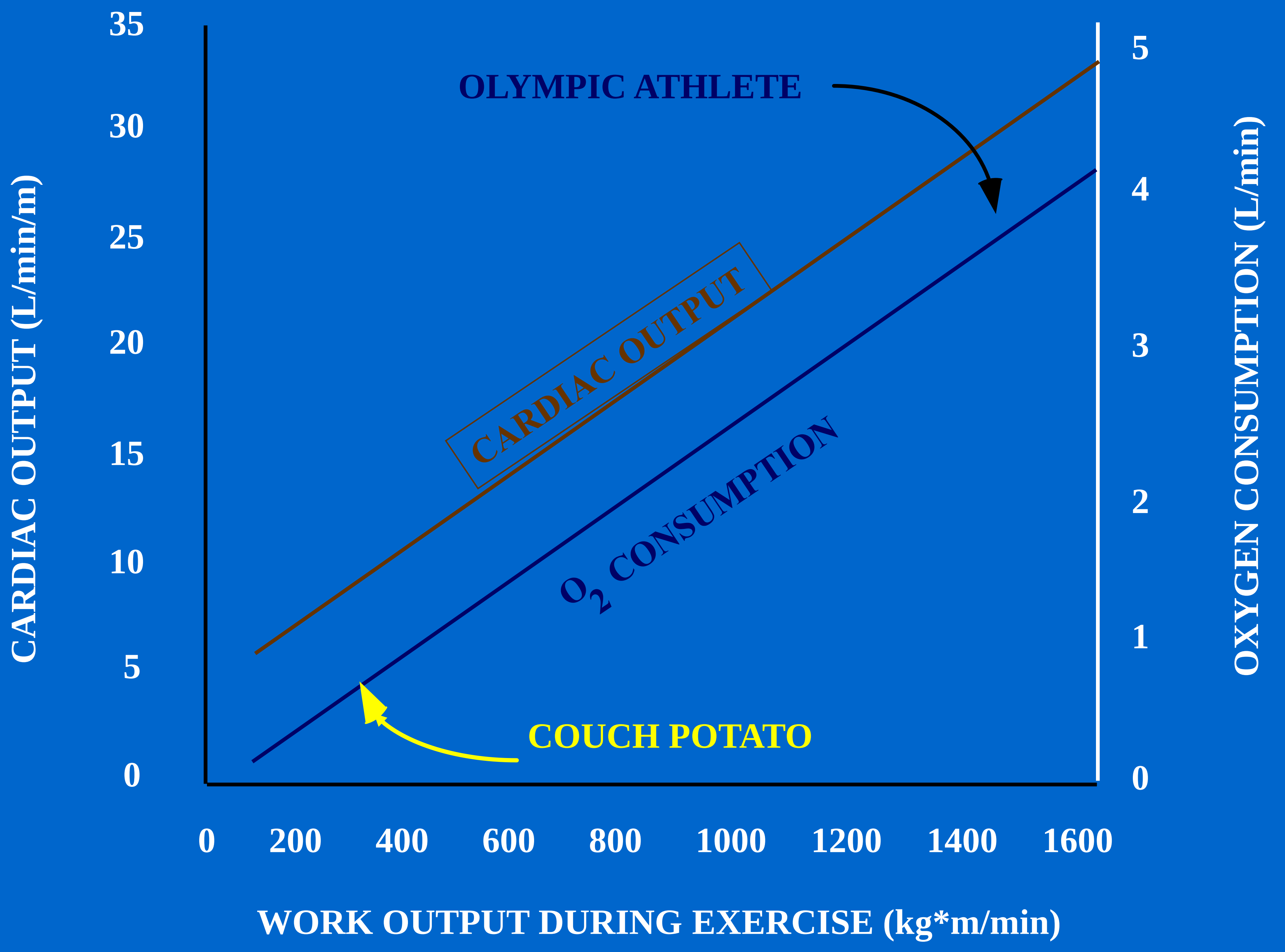
Faisal I. Mohammed, MD, PhD

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

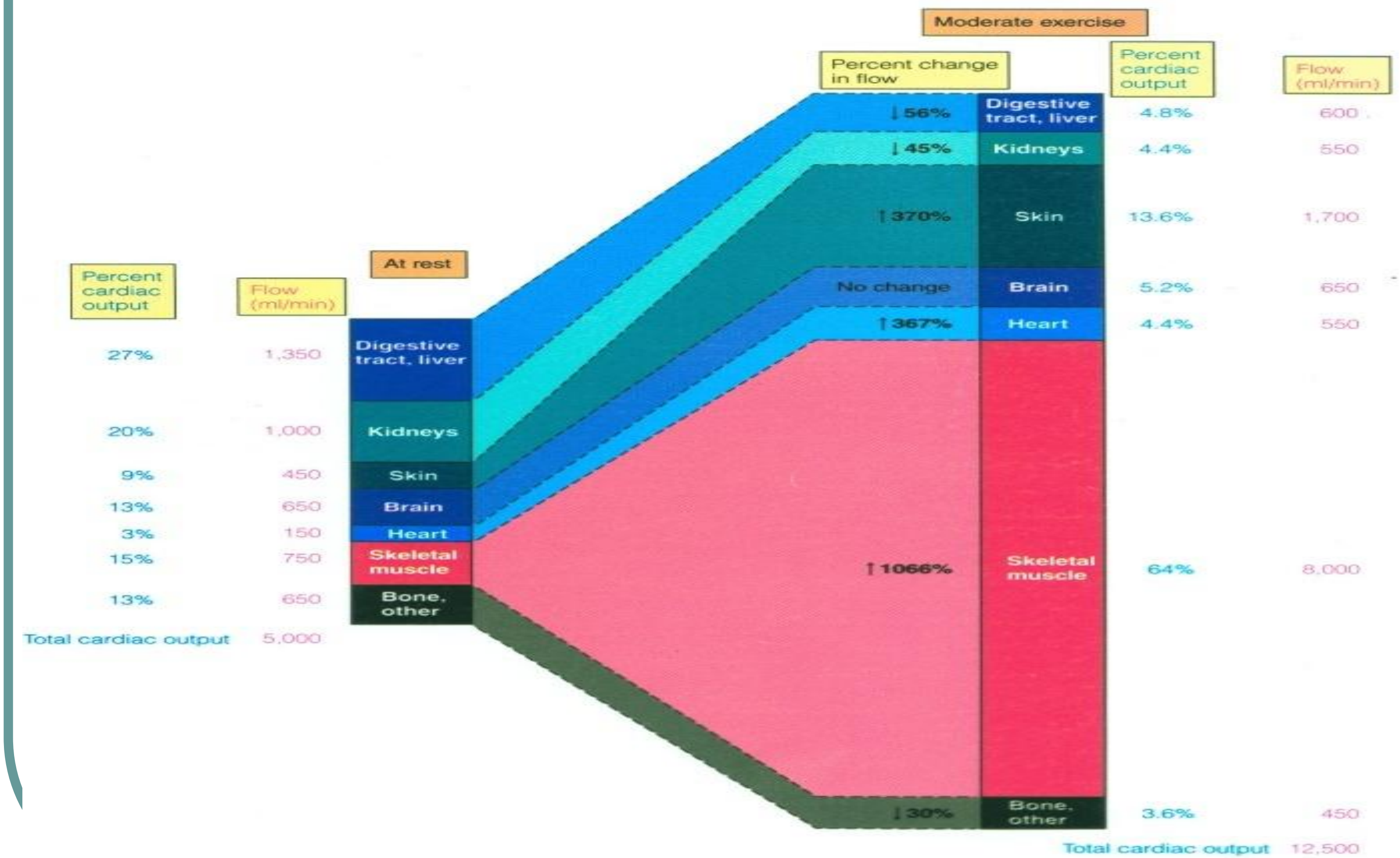
Important Concepts About Cardiac Output (CO) Control

- 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***



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

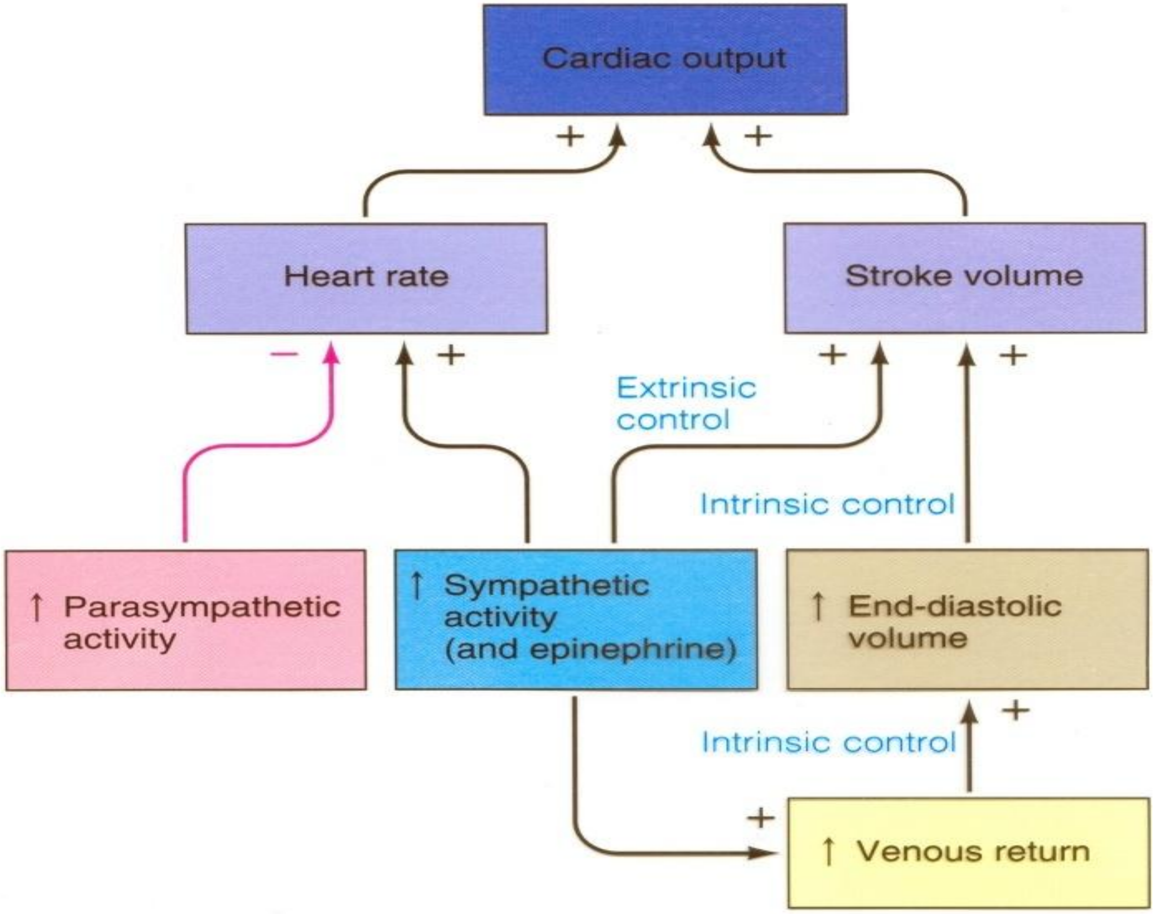
Magnitude & Distribution of CO at Rest & During Moderate Exercise



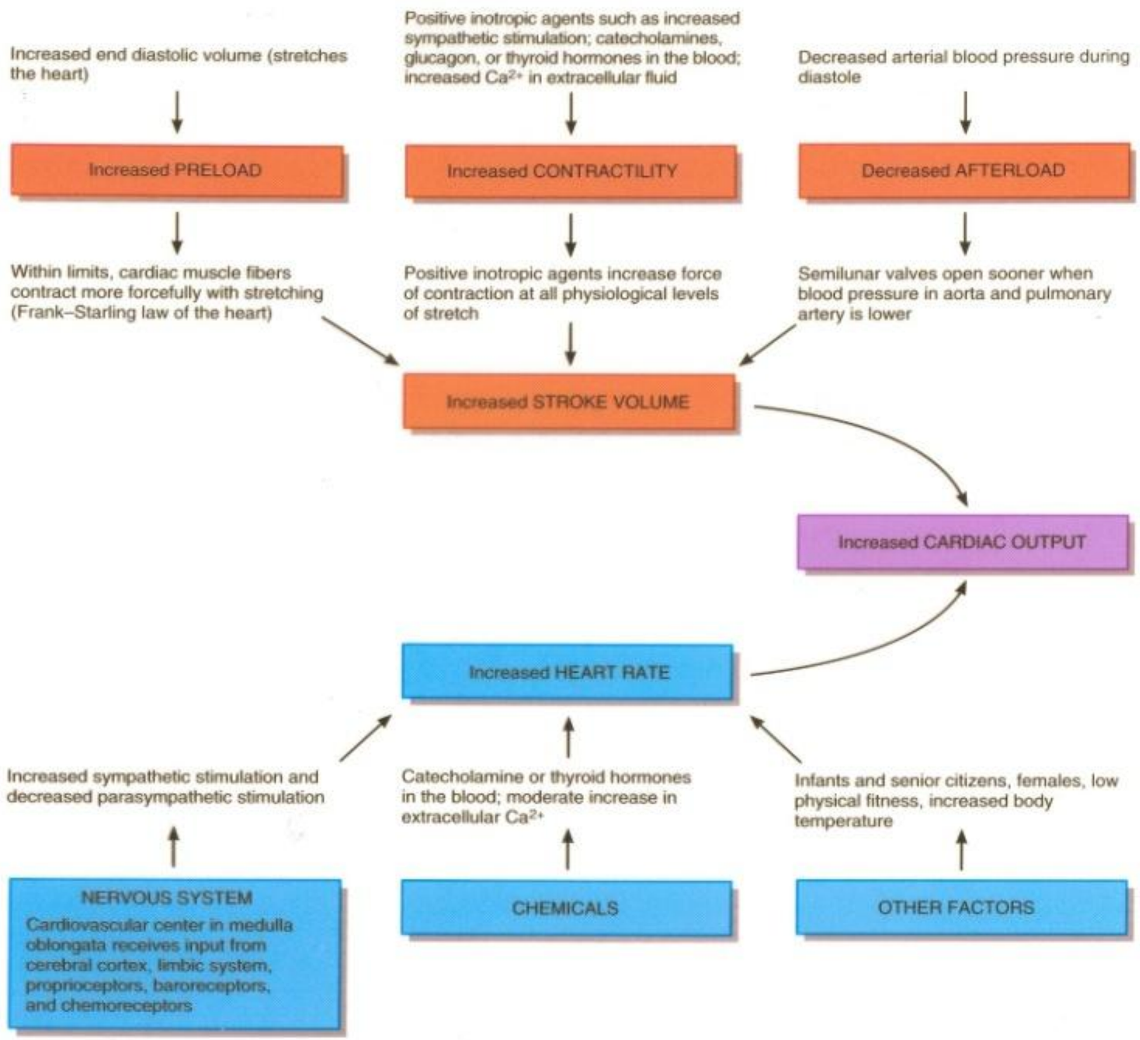
Variations in Tissue Blood Flow

	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	---

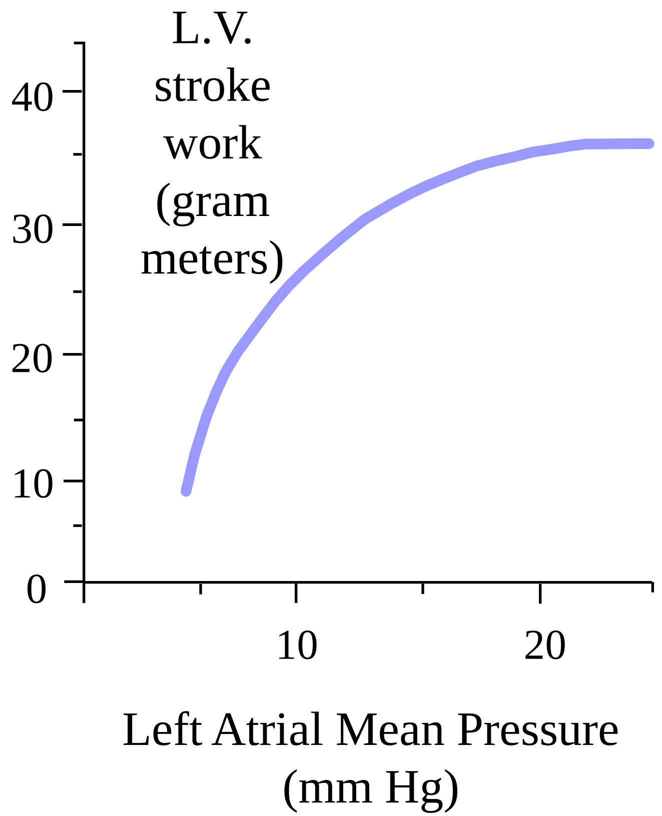
Control of Cardiac Output

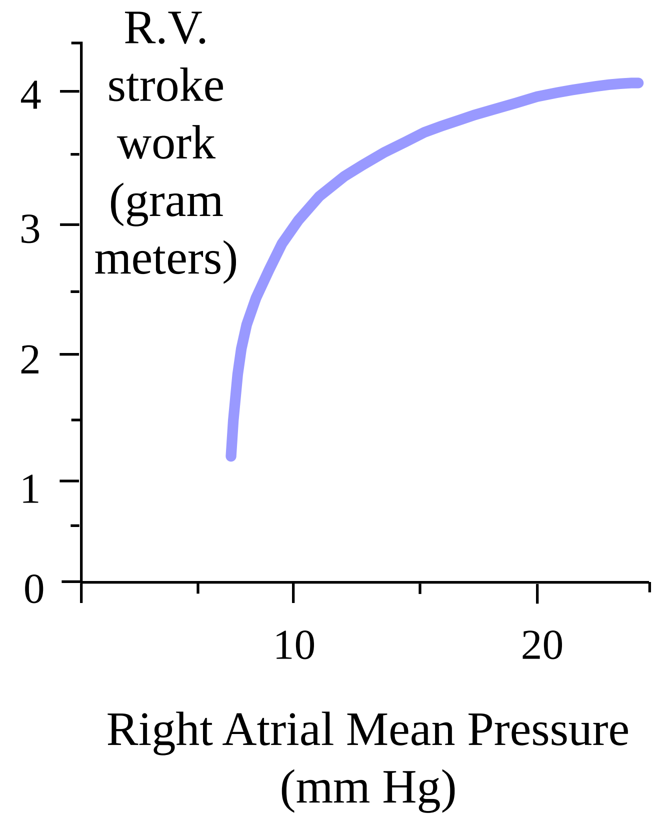


Factors that affect the Cardiac Output

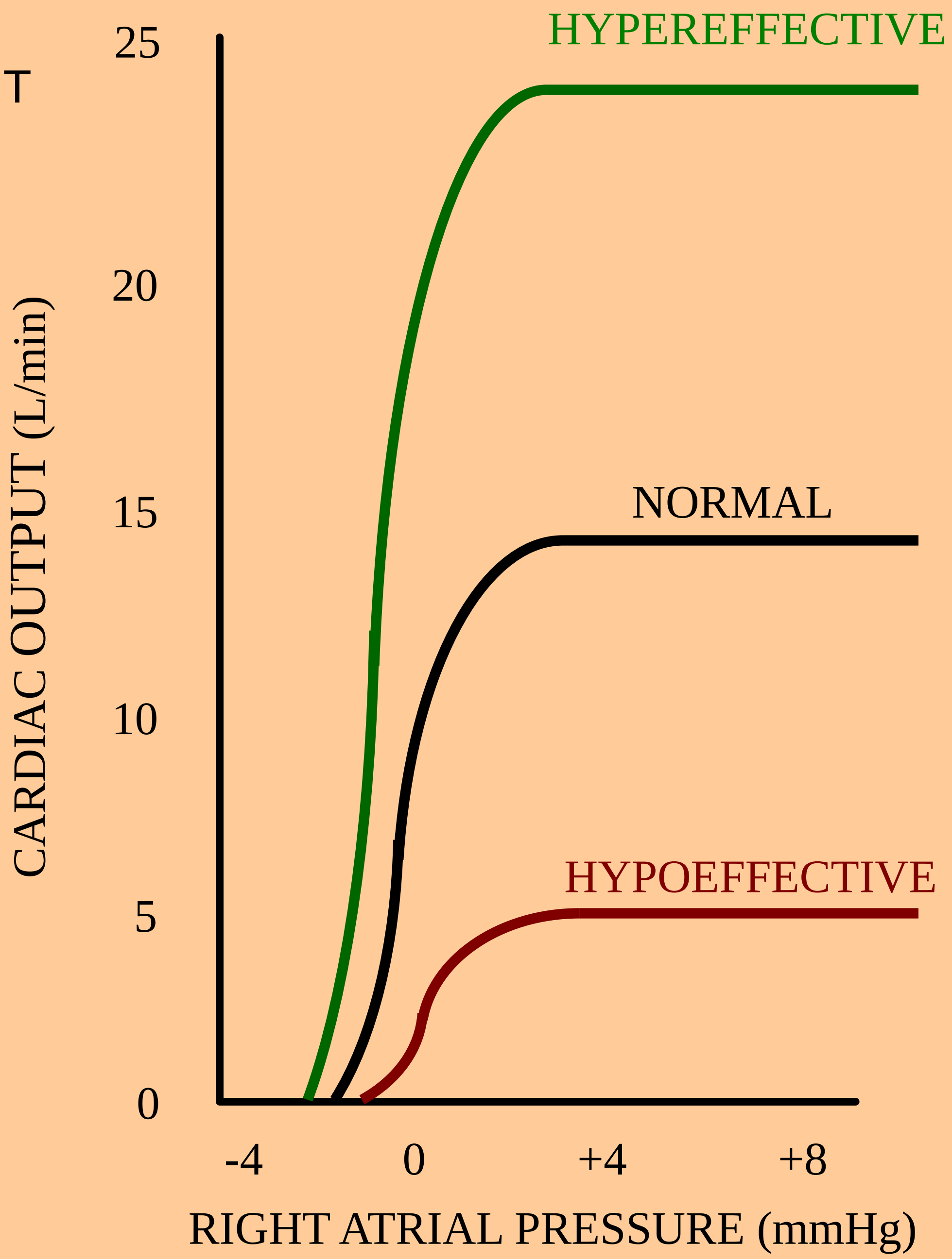


Ventricular Stroke Work Output

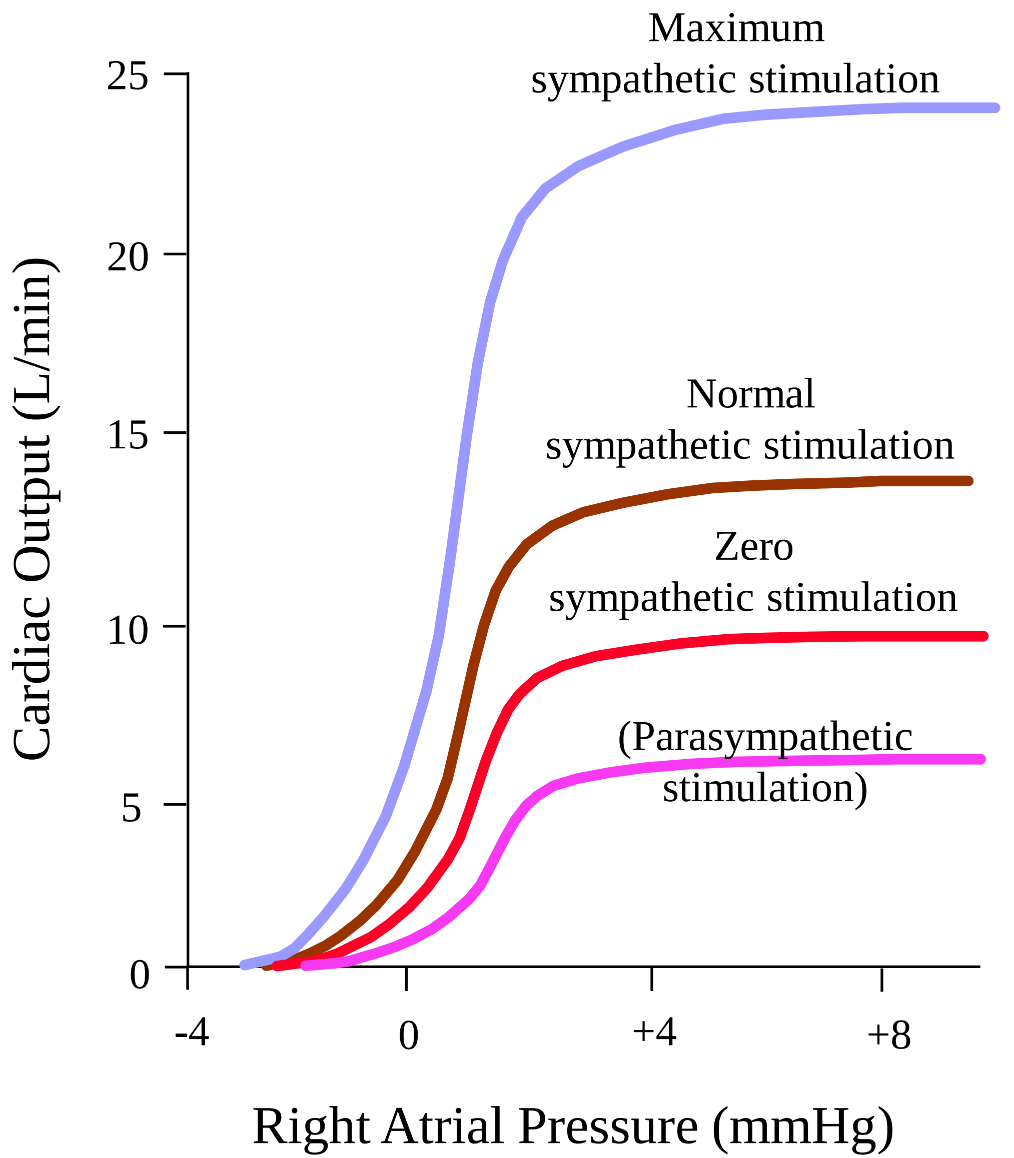


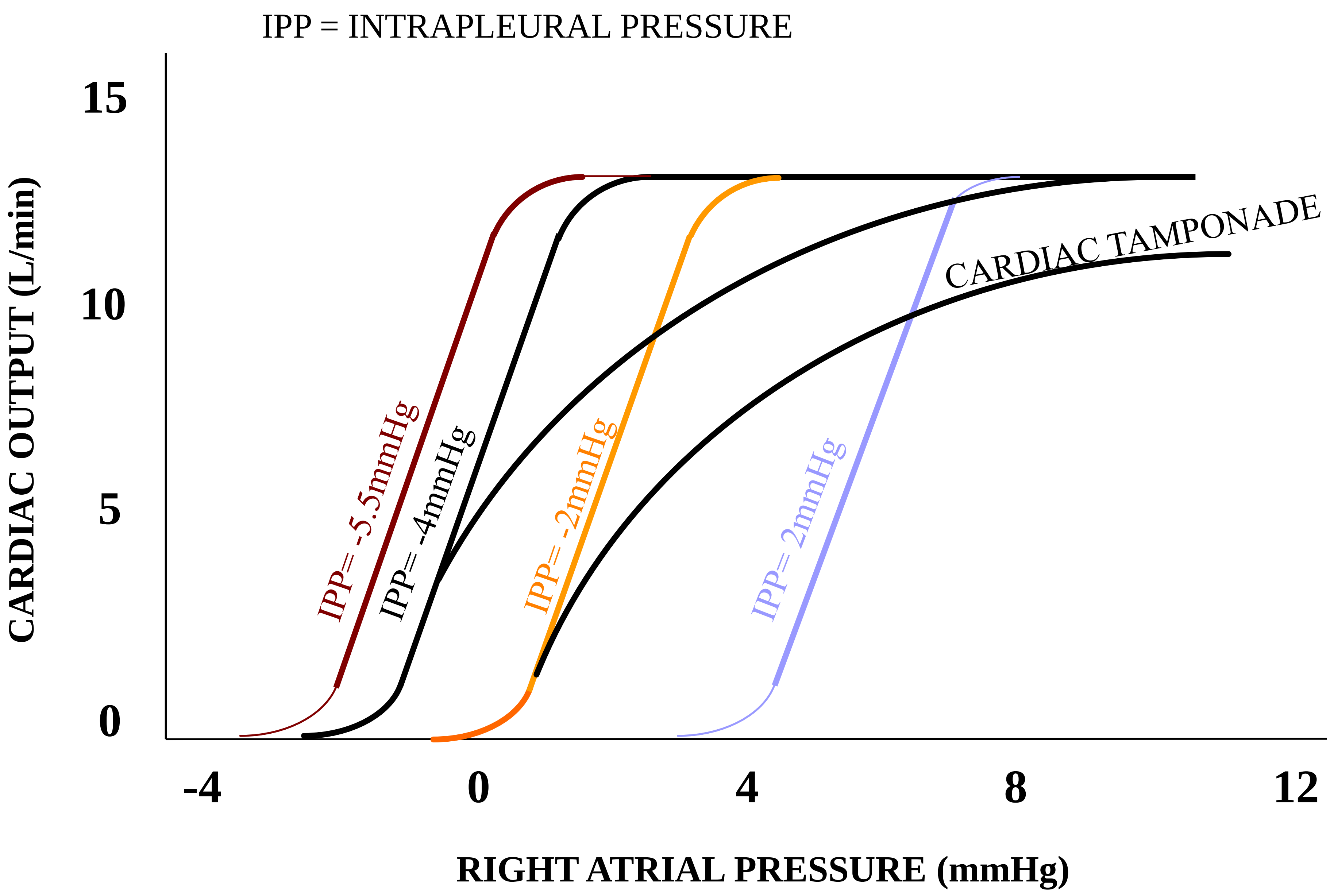


CARDIAC OUTPUT
CURVES



Effect of Sympathetic and Parasympathetic Stimulation on Cardiac Output





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

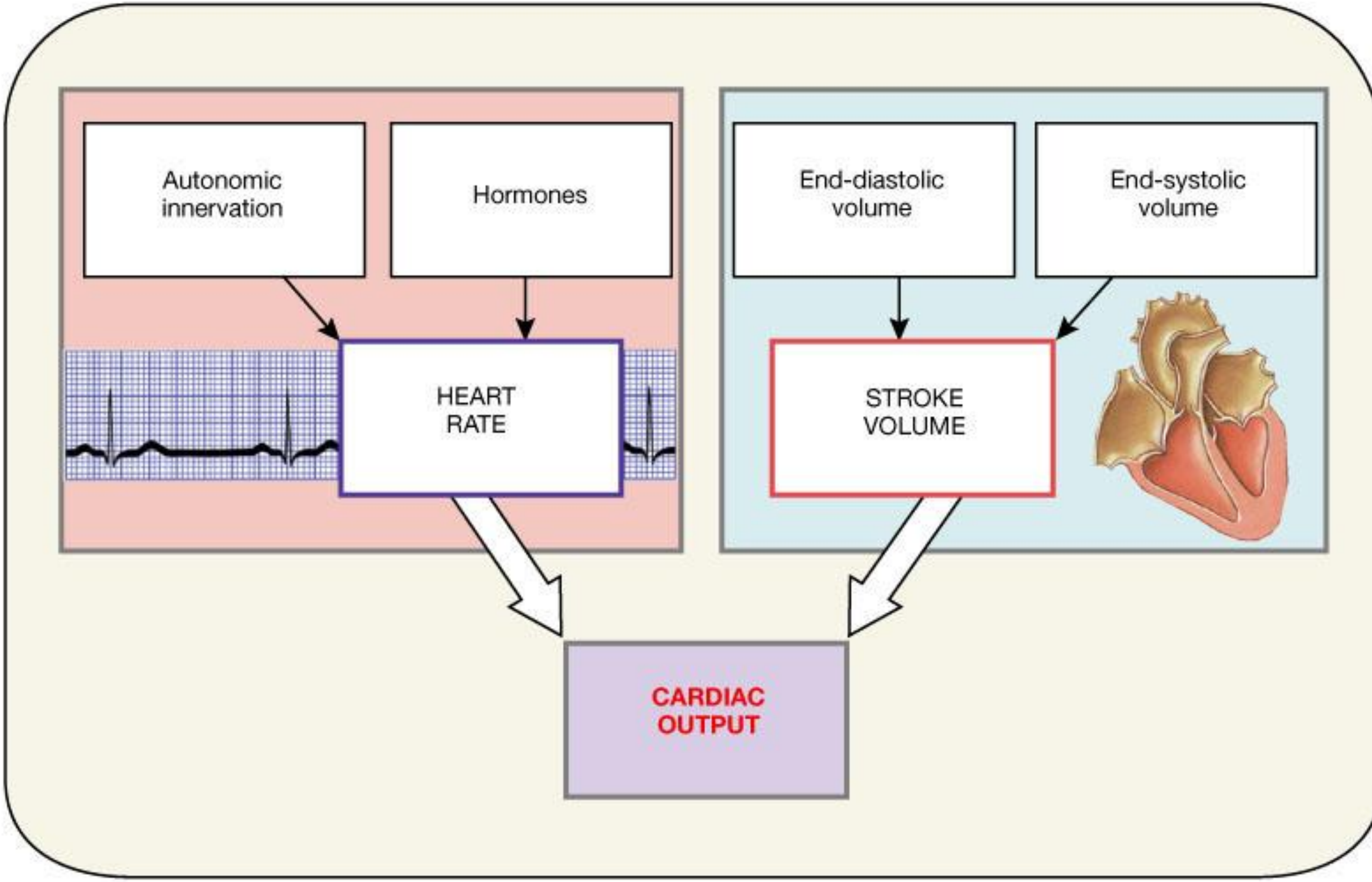
The Cardiac Output Curve

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

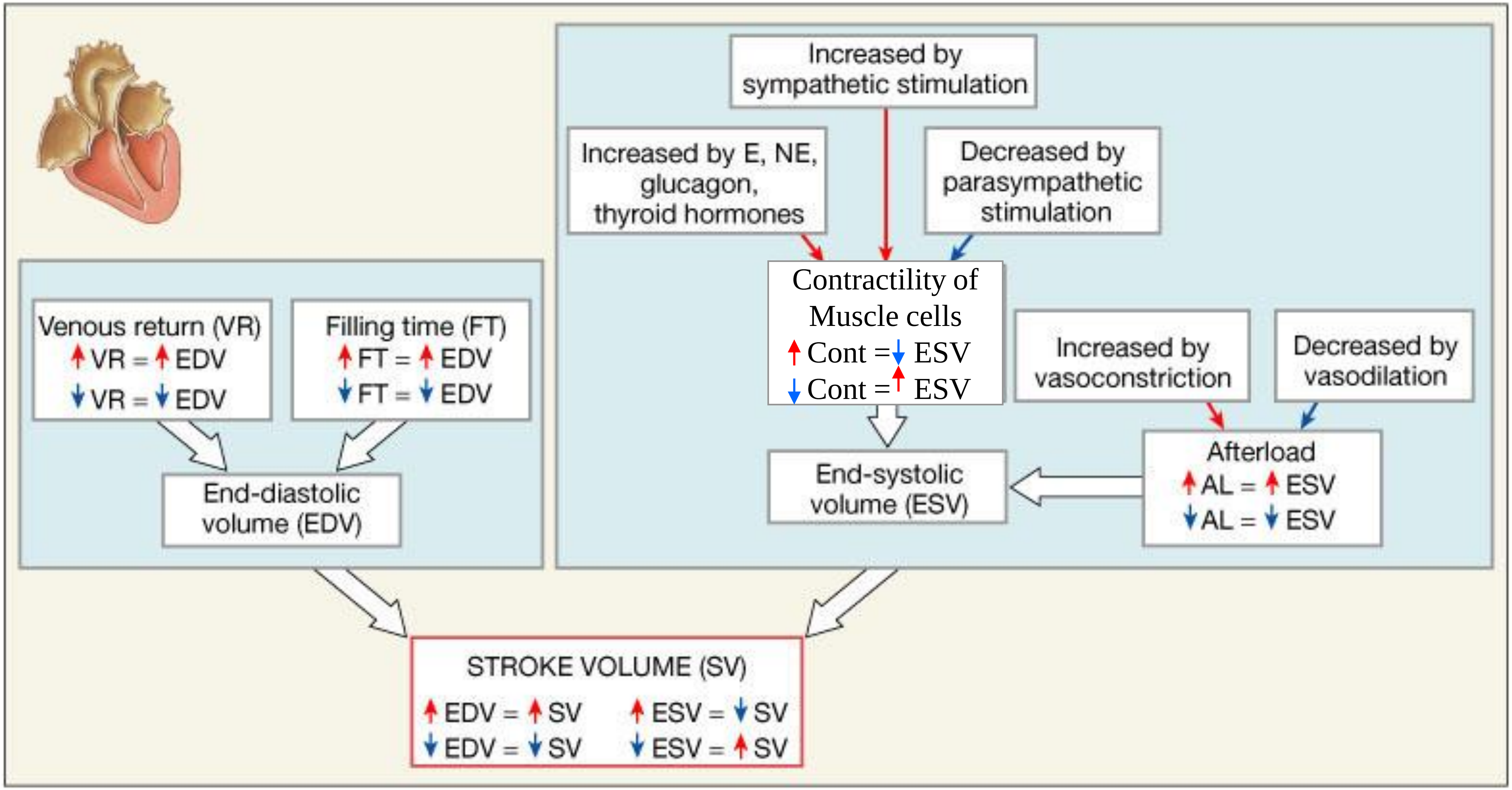
The Cardiac Output Curve (cont'd)

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

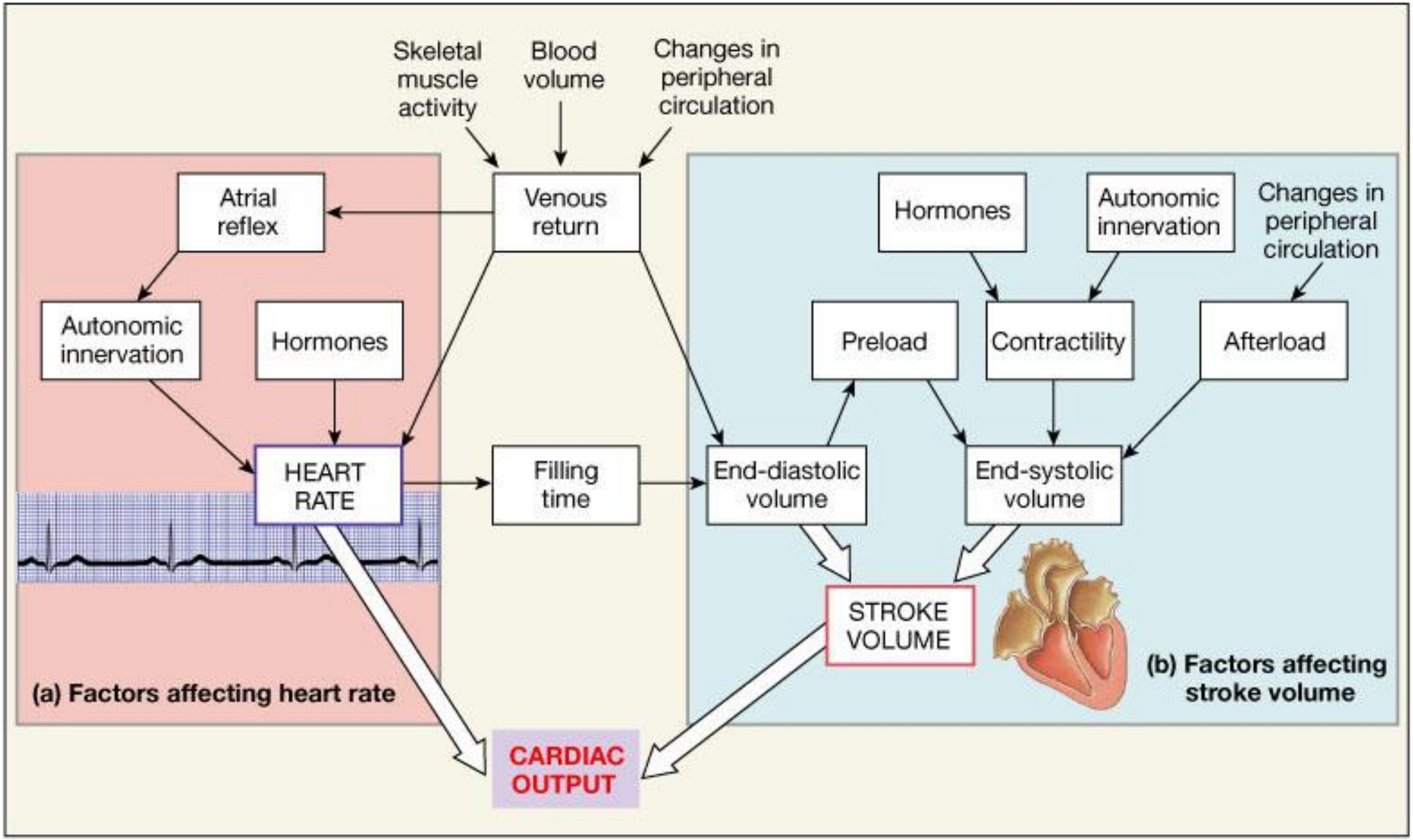
Factors Affecting Cardiac Output



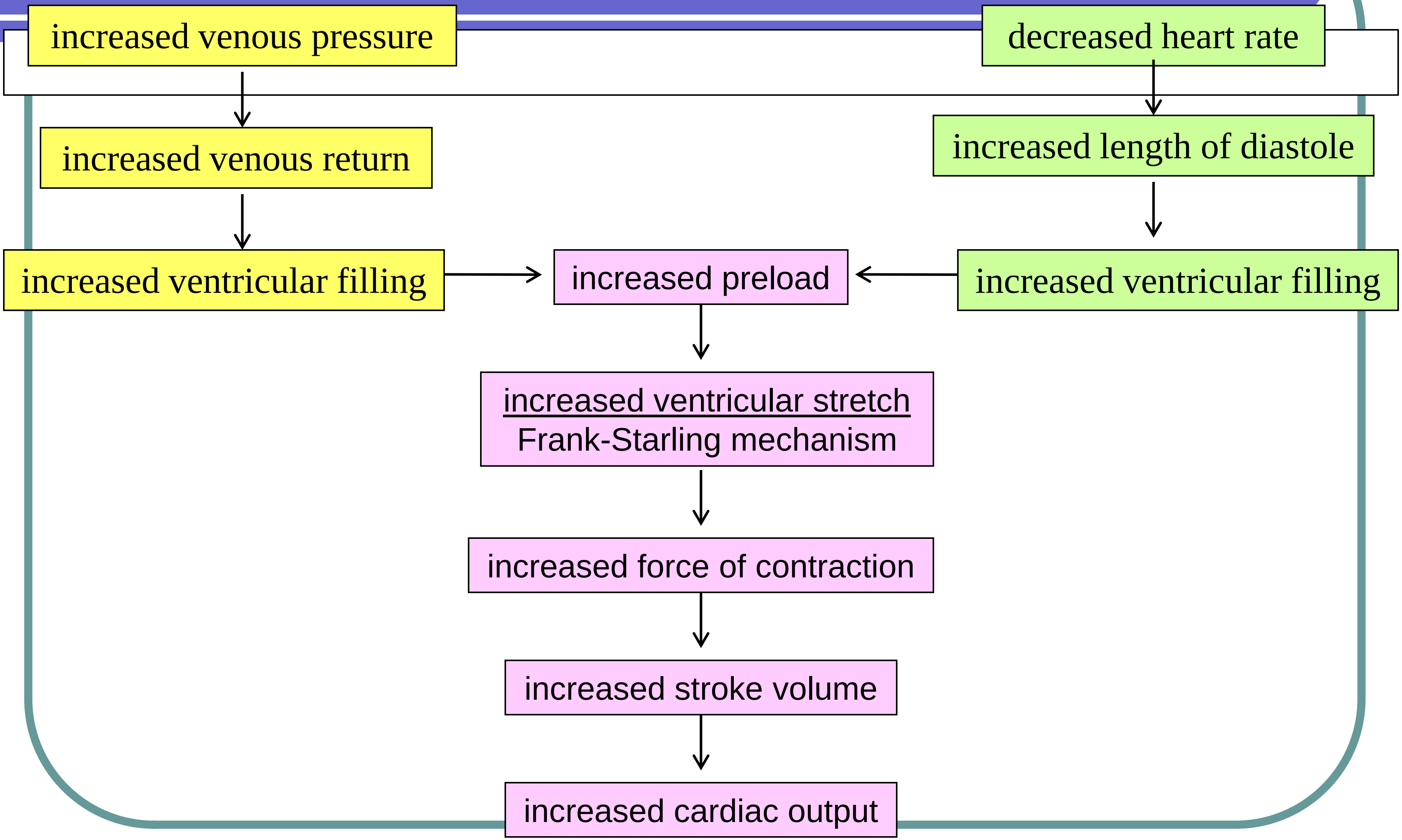
Factors Affecting Stroke Volume



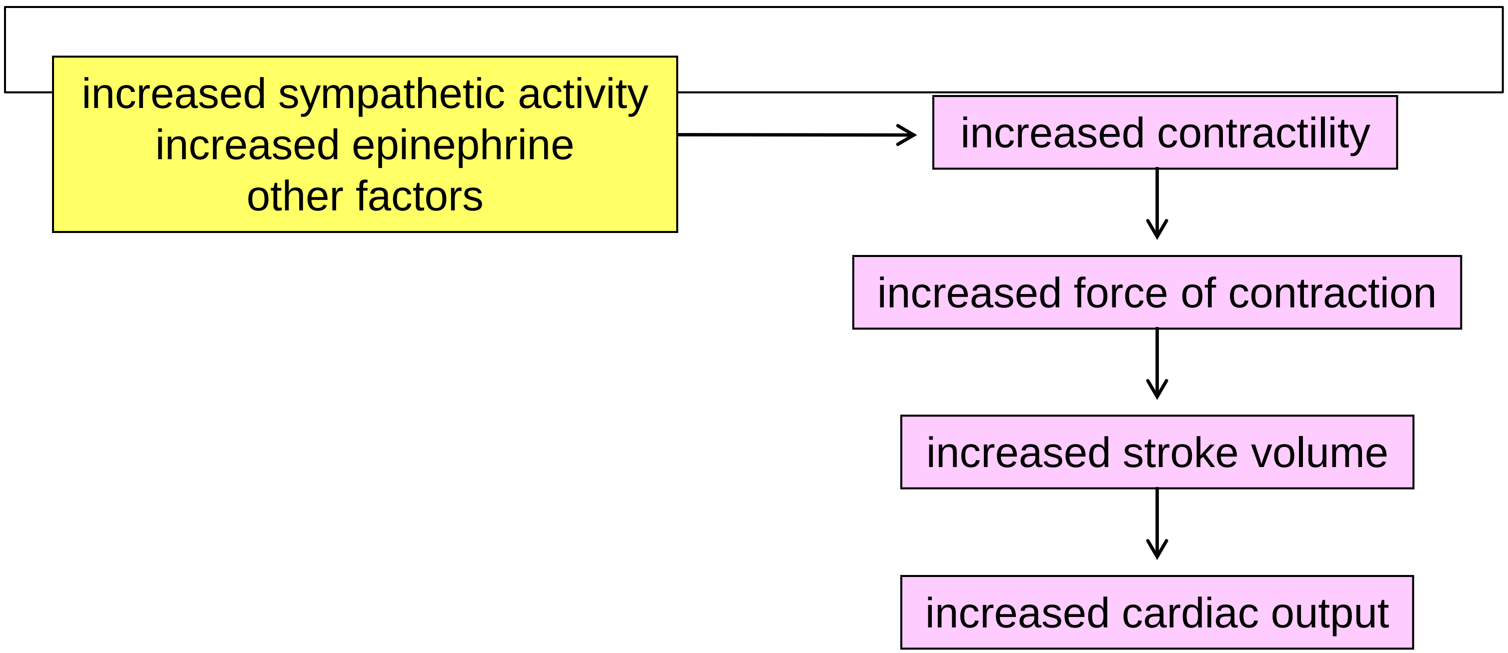
A Summary of the Factors Affecting Cardiac Output



REGULATION OF STROKE VOLUME: PRELOAD



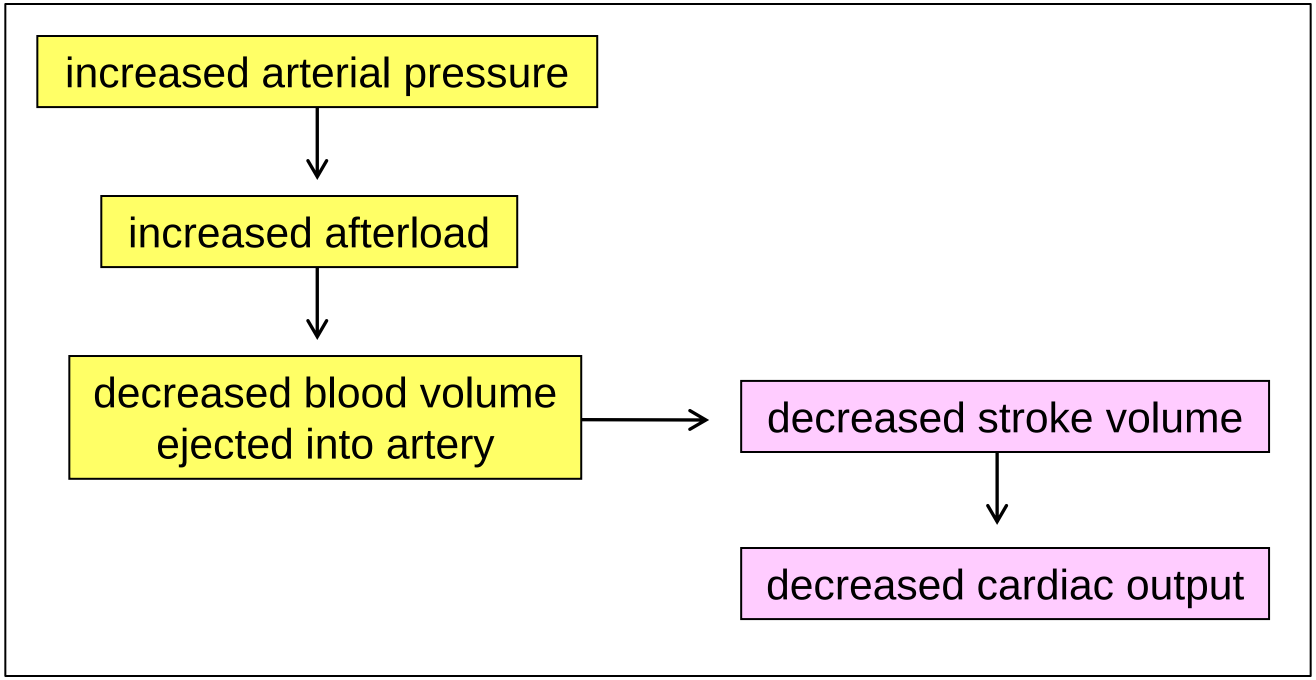
REGULATION OF STROKE VOLUME: CONTRACTILITY



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.

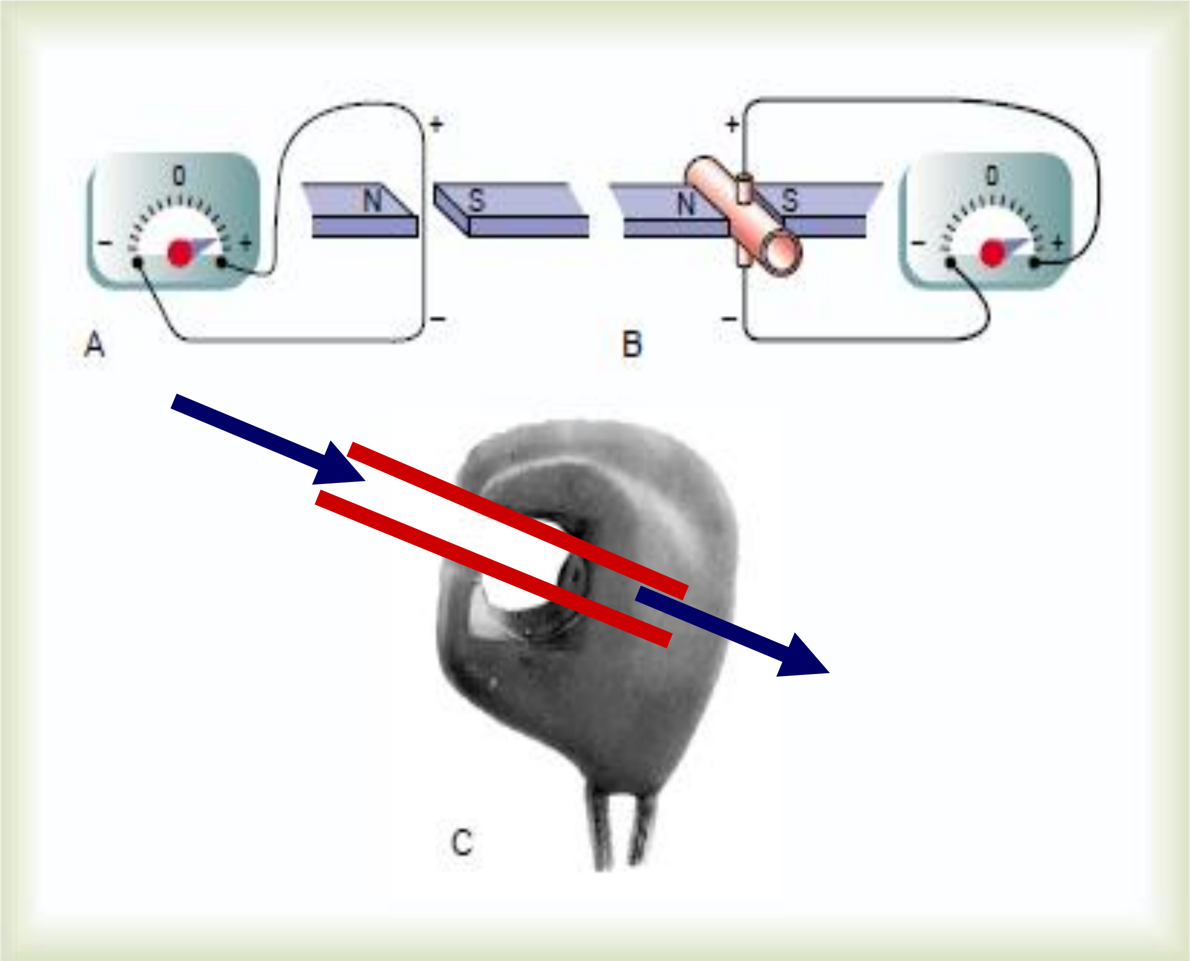
REGULATION OF STROKE VOLUME: AFTERLOAD

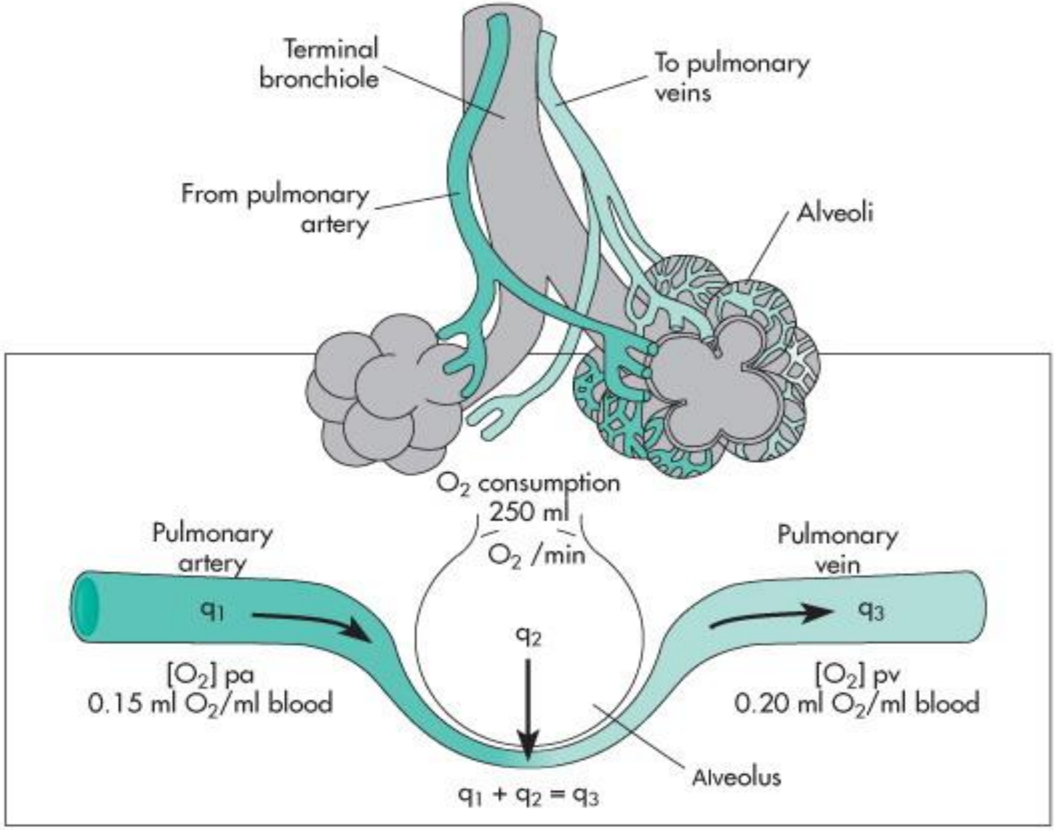


Measurement of Cardiac Output

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

Electromagnetic flowmeter





q_1=CO*C_{VO2}

q_2=amount of Oxygen uptake by the lungs

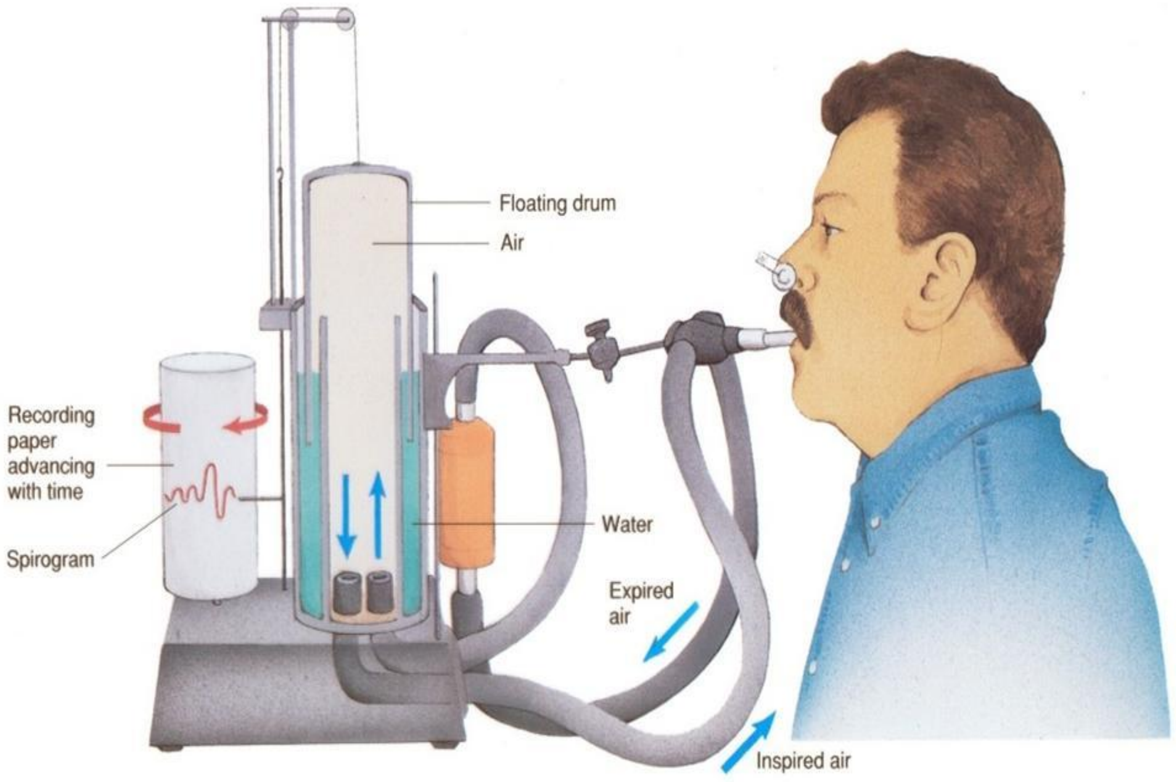
q_3= CO* C_{AO2} and equals = CO*C $_{VO2}$+ O_2 uptake

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

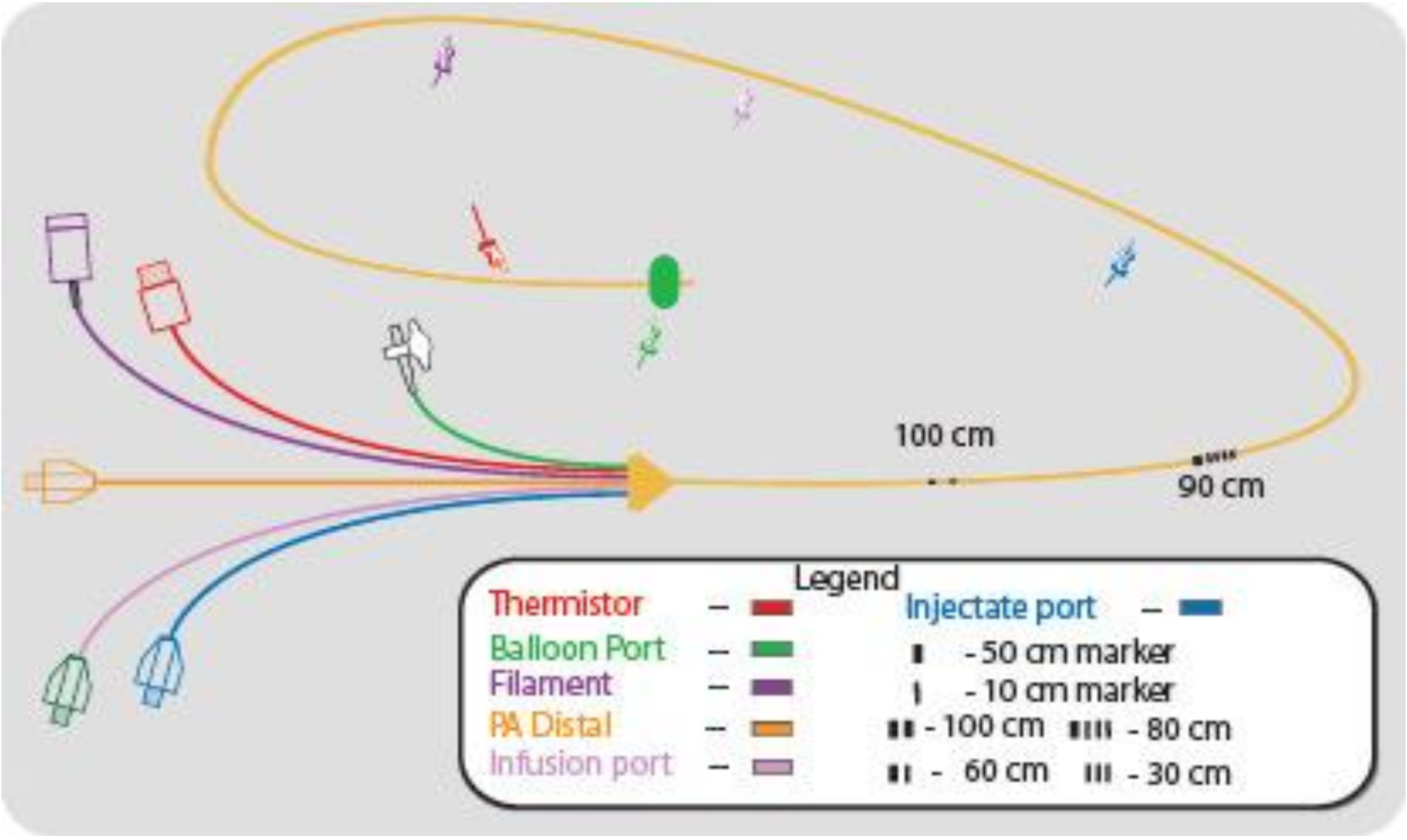
CO=Oxygen uptake/{C_{AO2}-C V_{O2}}

Spirometer

A spirometer



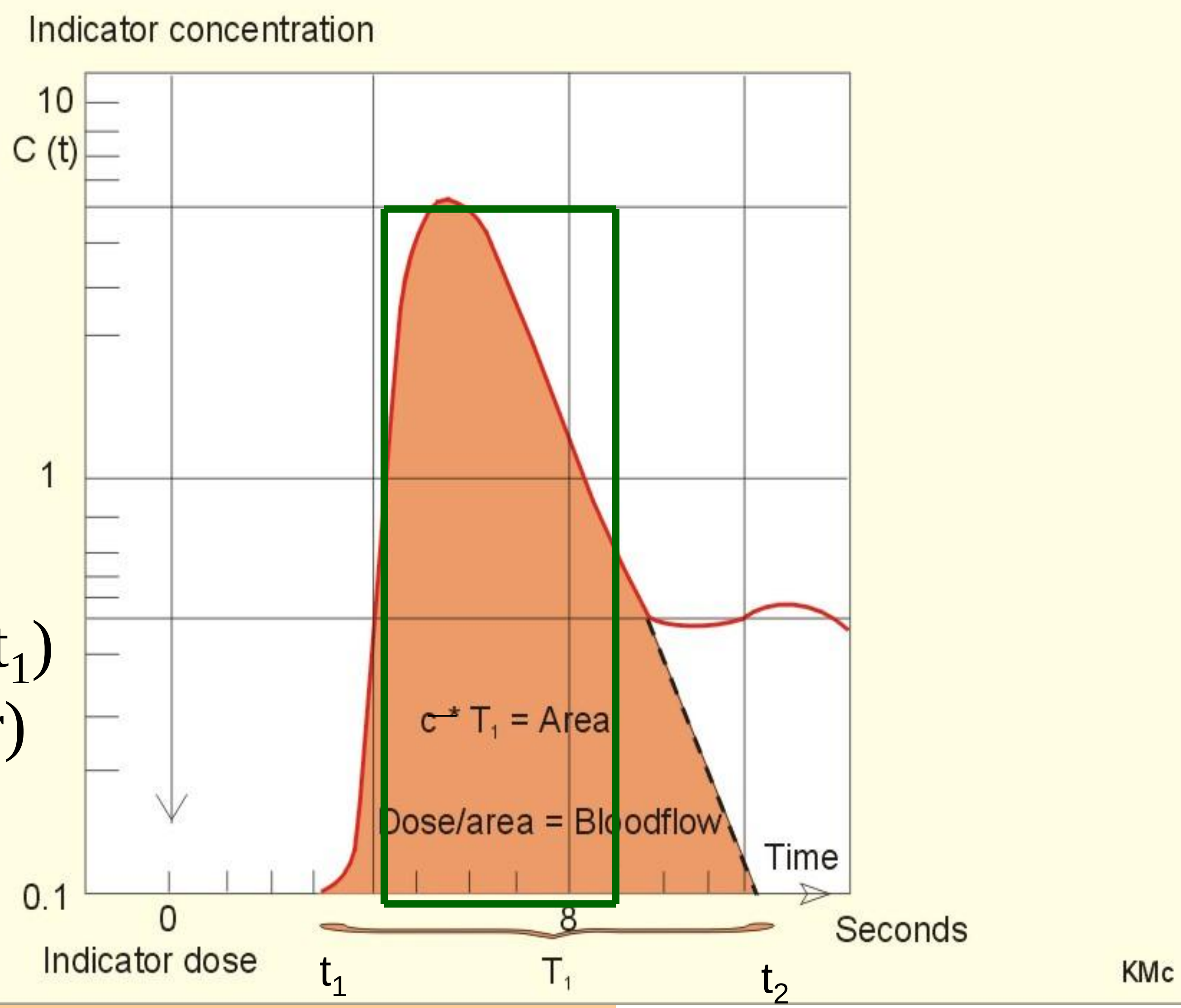
Swan-Ganz catheter



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



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

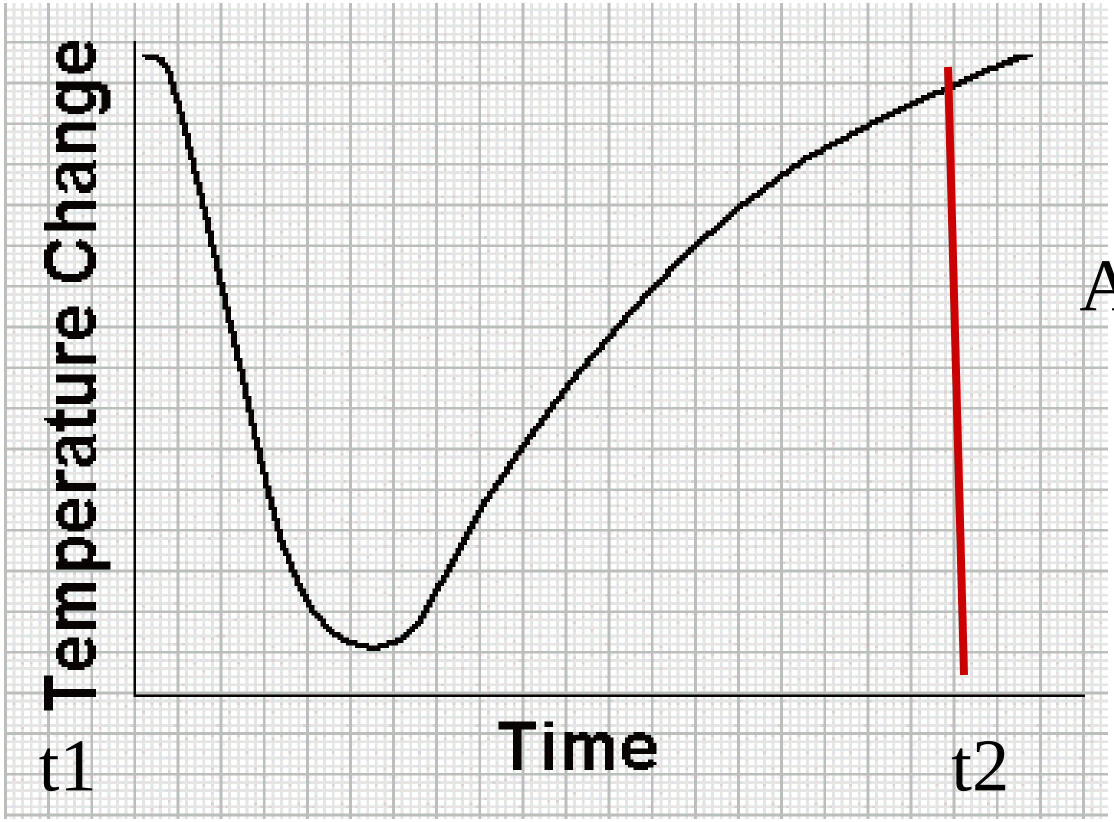
$$\text{Area} = \bar{C} * (t_2 - t_1)$$

(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

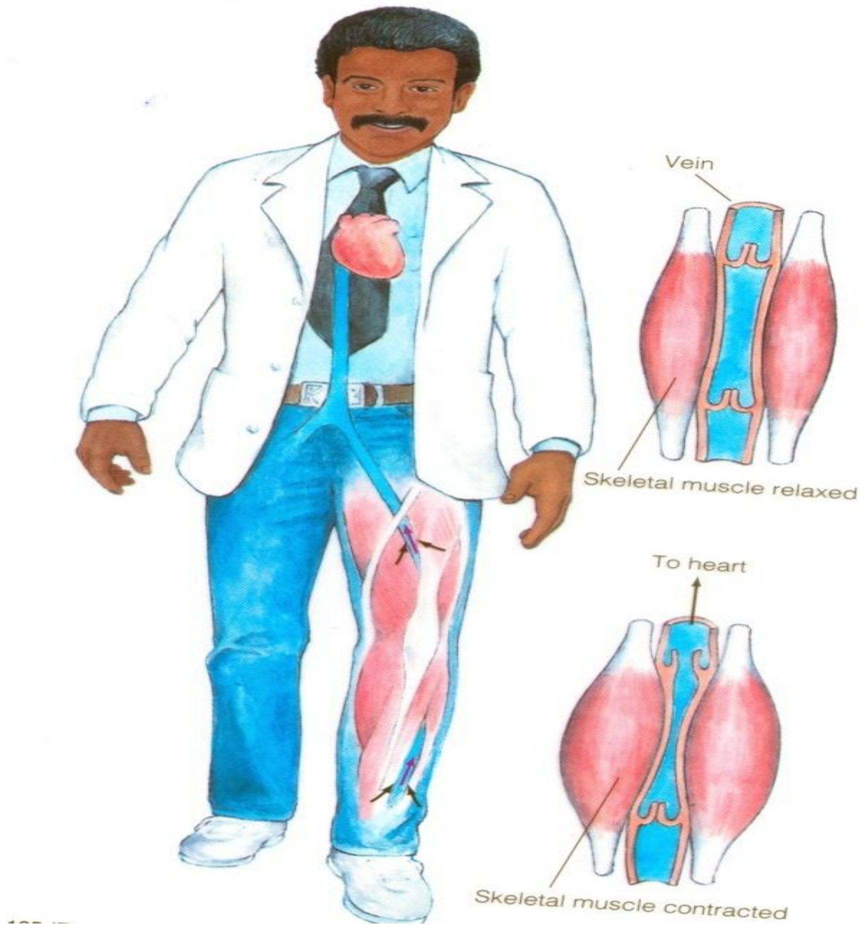


$$AREA = \int_{t1}^{t2} dT.dt$$

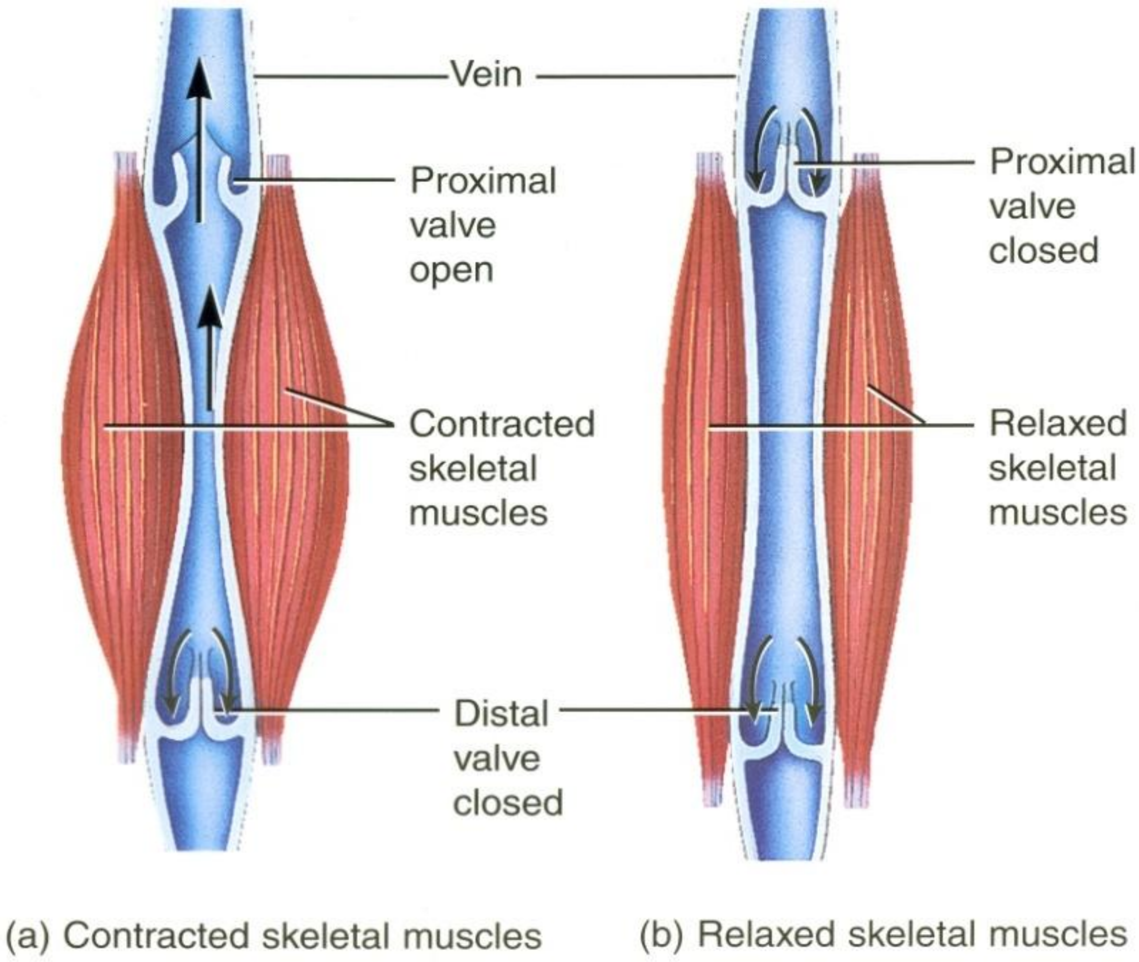
VENOUS RETURN

- 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

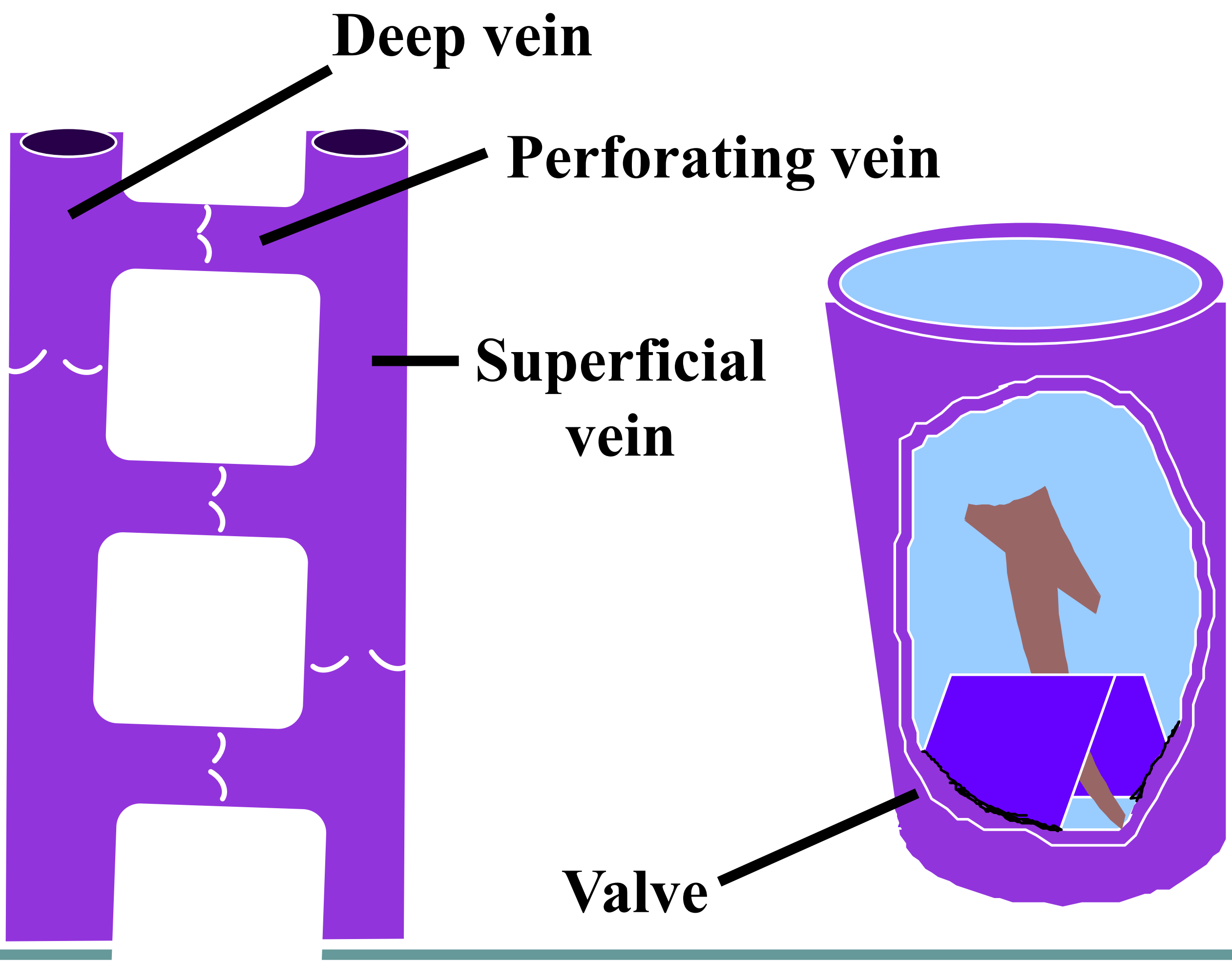
Effect of Venous Valves



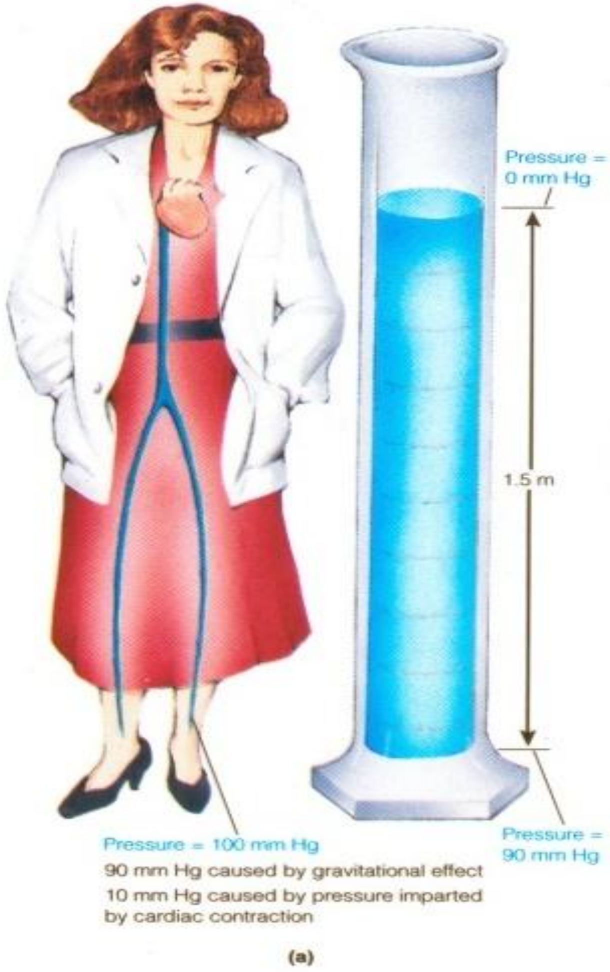
Effect of Venous Valves

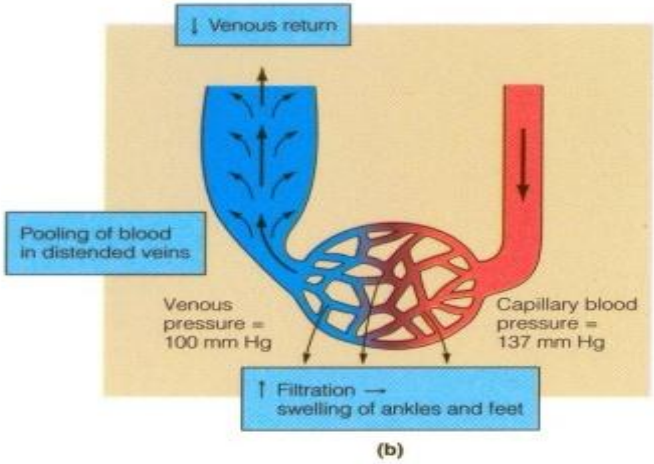


Venous Valves

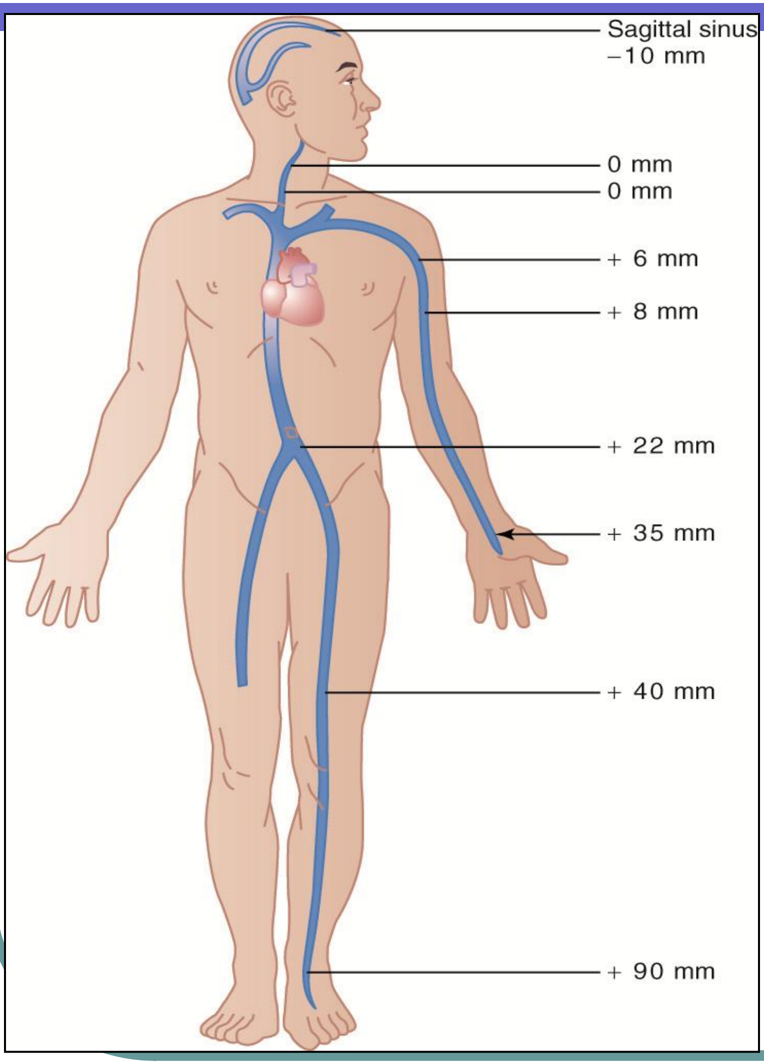


Effect Of Gravity on Venous Pressure





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.

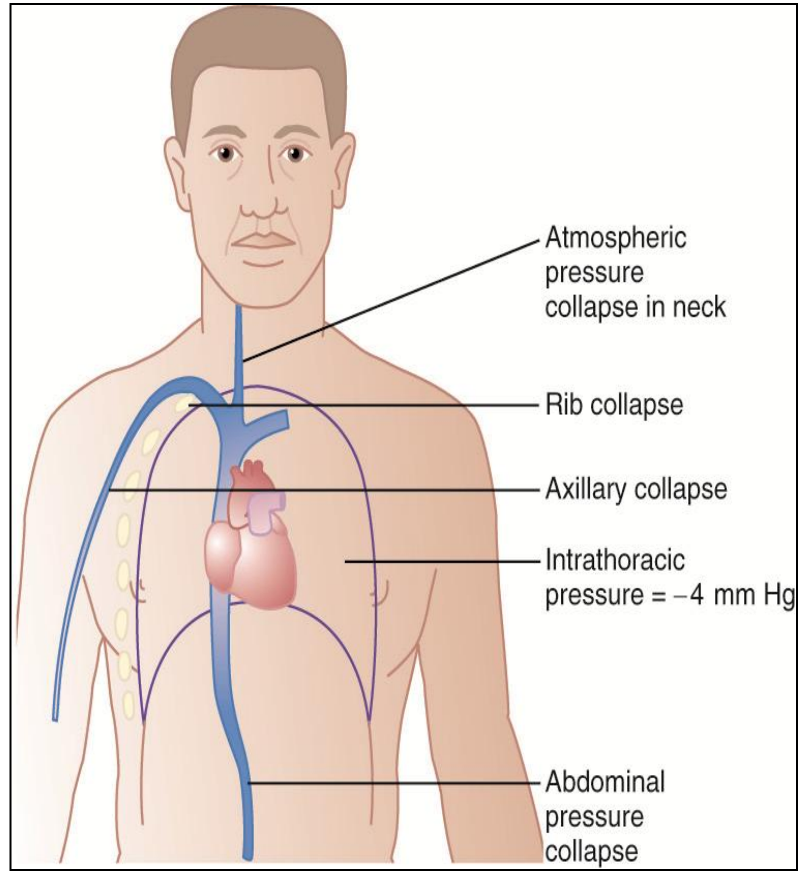
Central Venous Pressure

- 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.

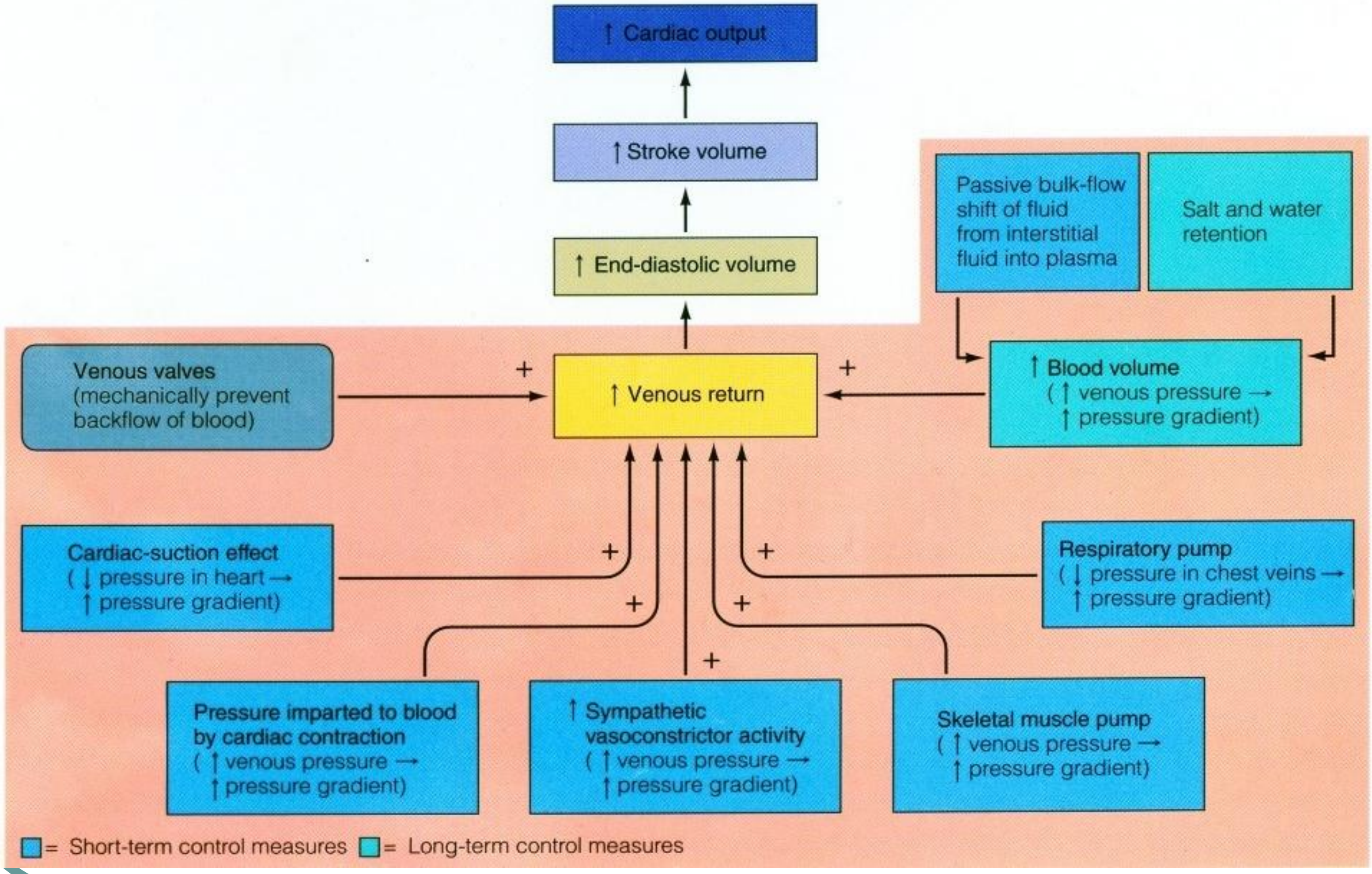
Factors affecting Central Venous Pressure

- 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.

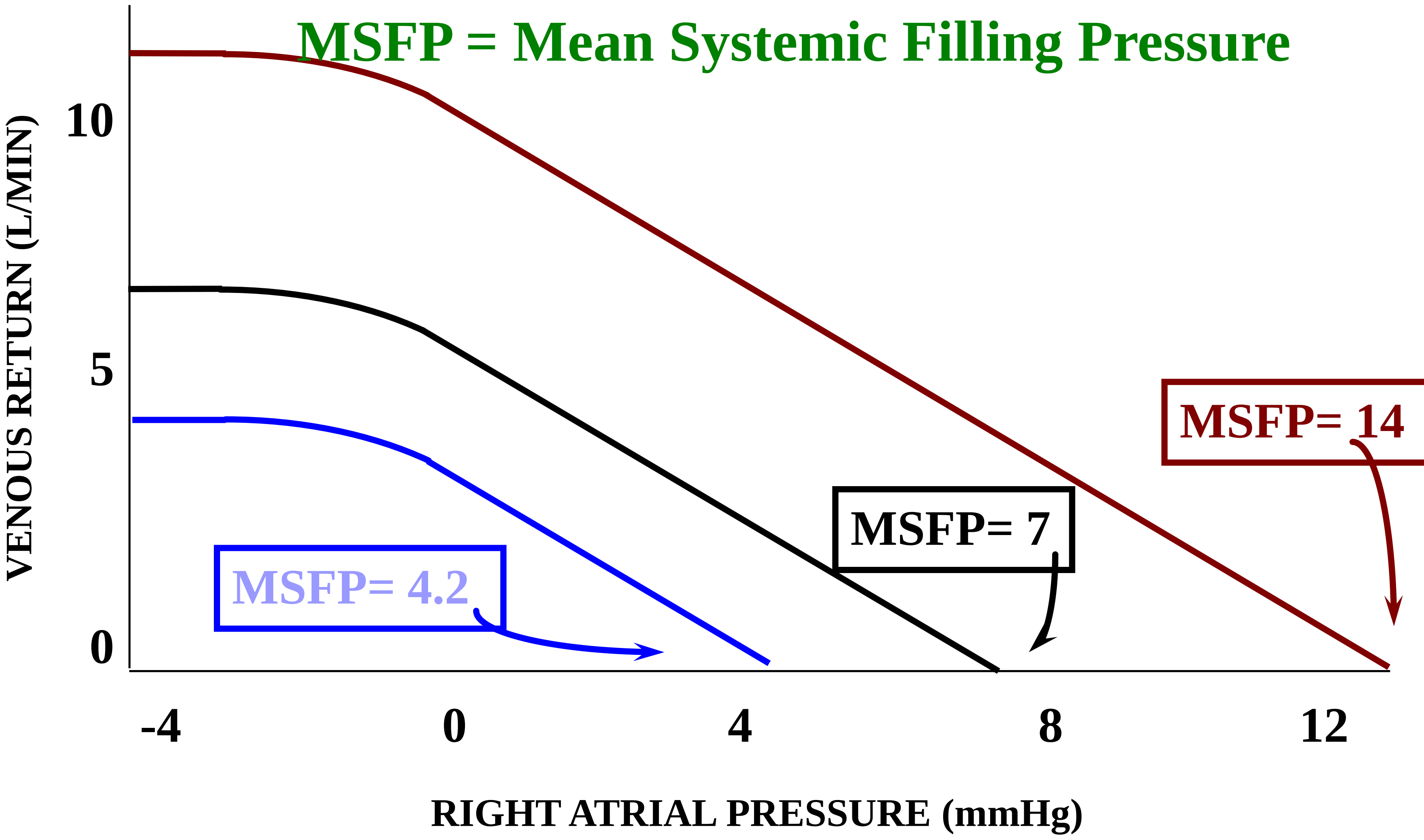
- Factors that increase RAP:
- -increased blood volume
- -increased venous tone
- - dilation of arterioles
- -decreased cardiac function

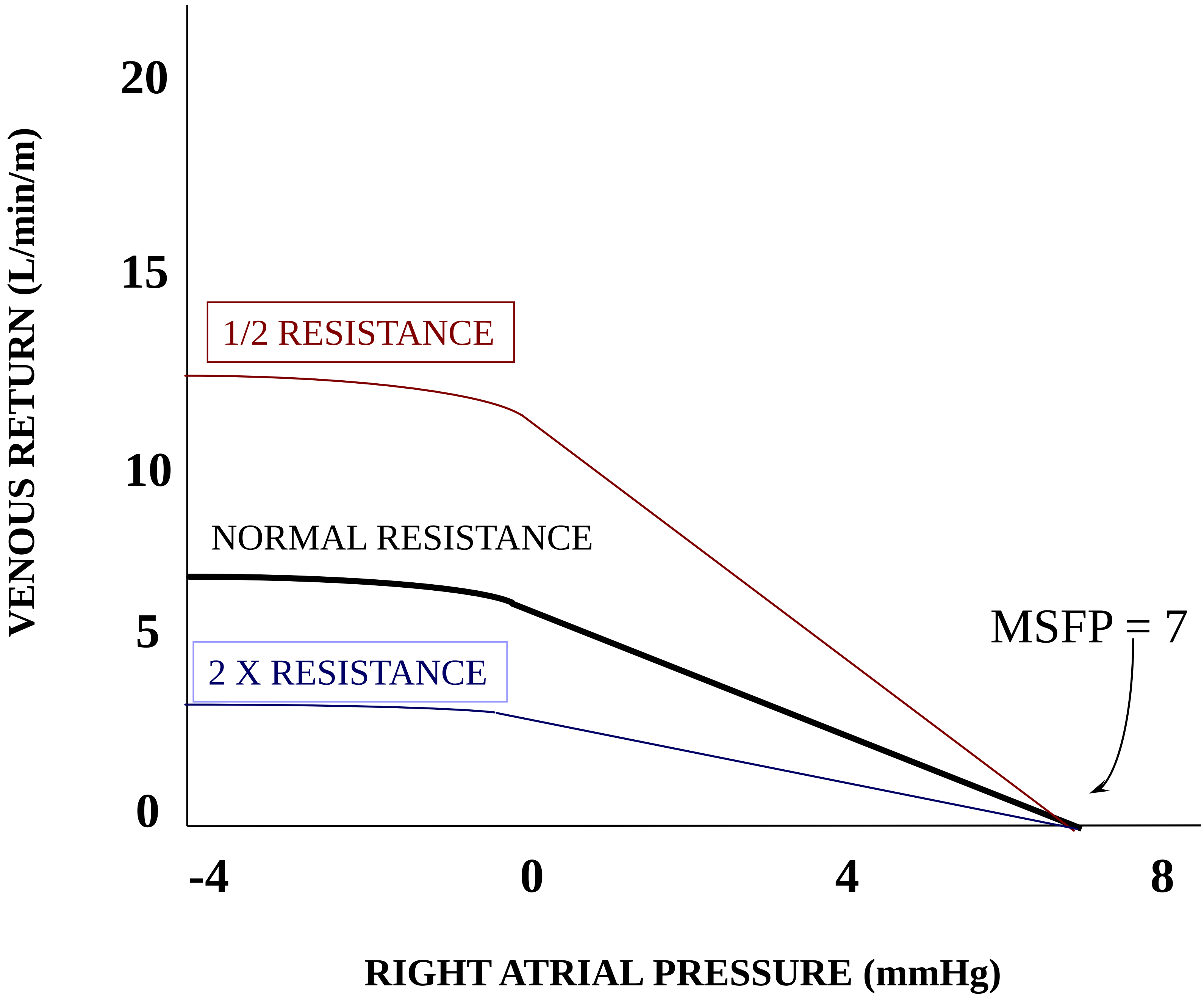


Factors that Facilitate Venous Return



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)

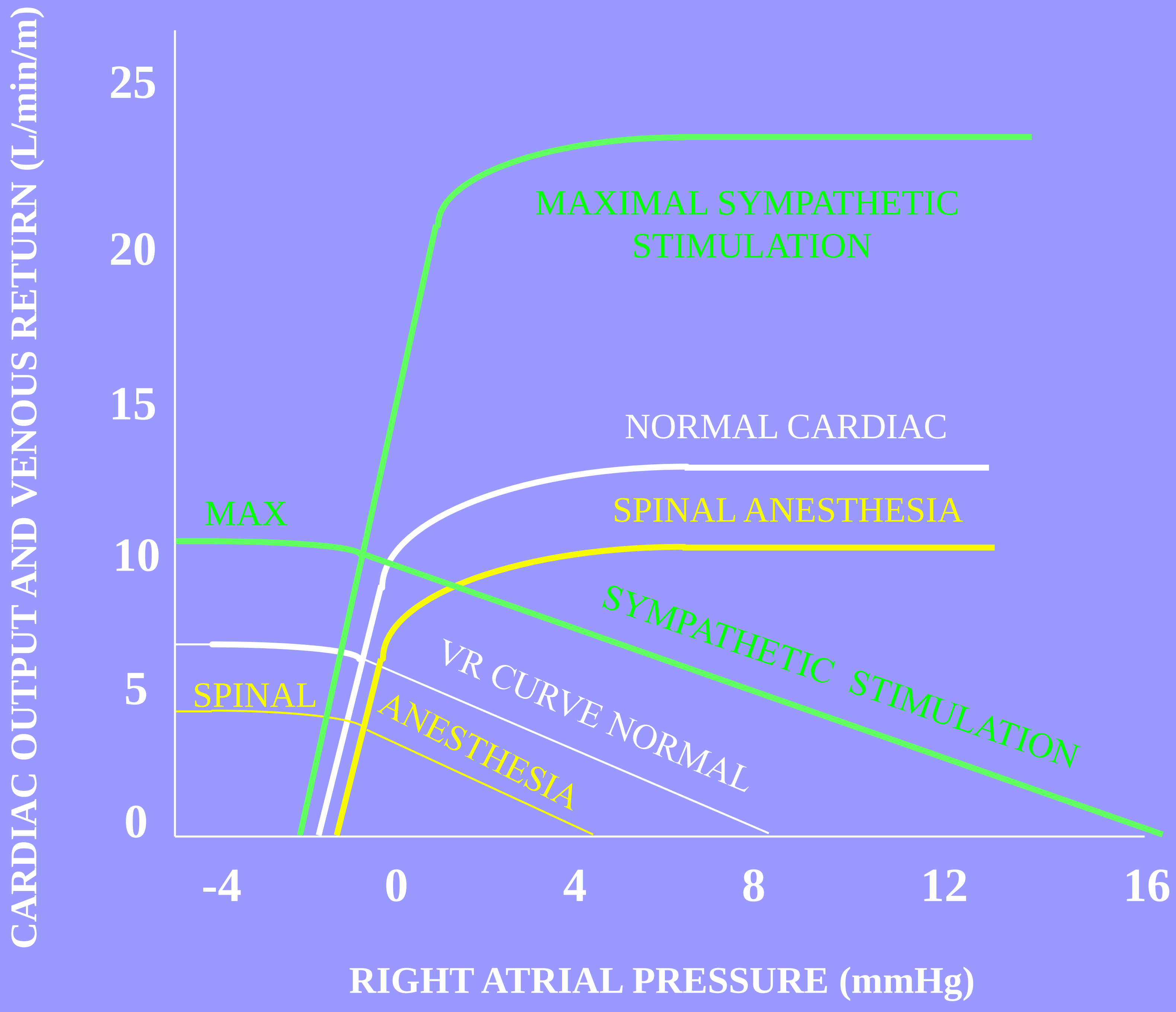
- Beriberi - thiamine deficiency ⇒ arteriolar dilatation ⇒ ↓ RVR
- (RVR= resistance to venous return)
  because VR = (MSFP - RAP) /RVR
  (good for positive RAP's)
- A-V fistula ⇒ (? RVR)
- ↓ RVR
- C. Hyperthyroidism ⇒ (? RVR)
- ↓ RVR

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
MAXIMAL SYMPATHETIC STIMULATION
NORMAL CARDIAC
SPINAL ANESTHESIA
MAX
SYMPATHETIC STIMULATION
VR CURVE NORMAL
SPINAL
ANESTHESIA
-4
0
4
8
12
16
RIGHT ATRIAL PRESSURE (mmHg)

Thank You