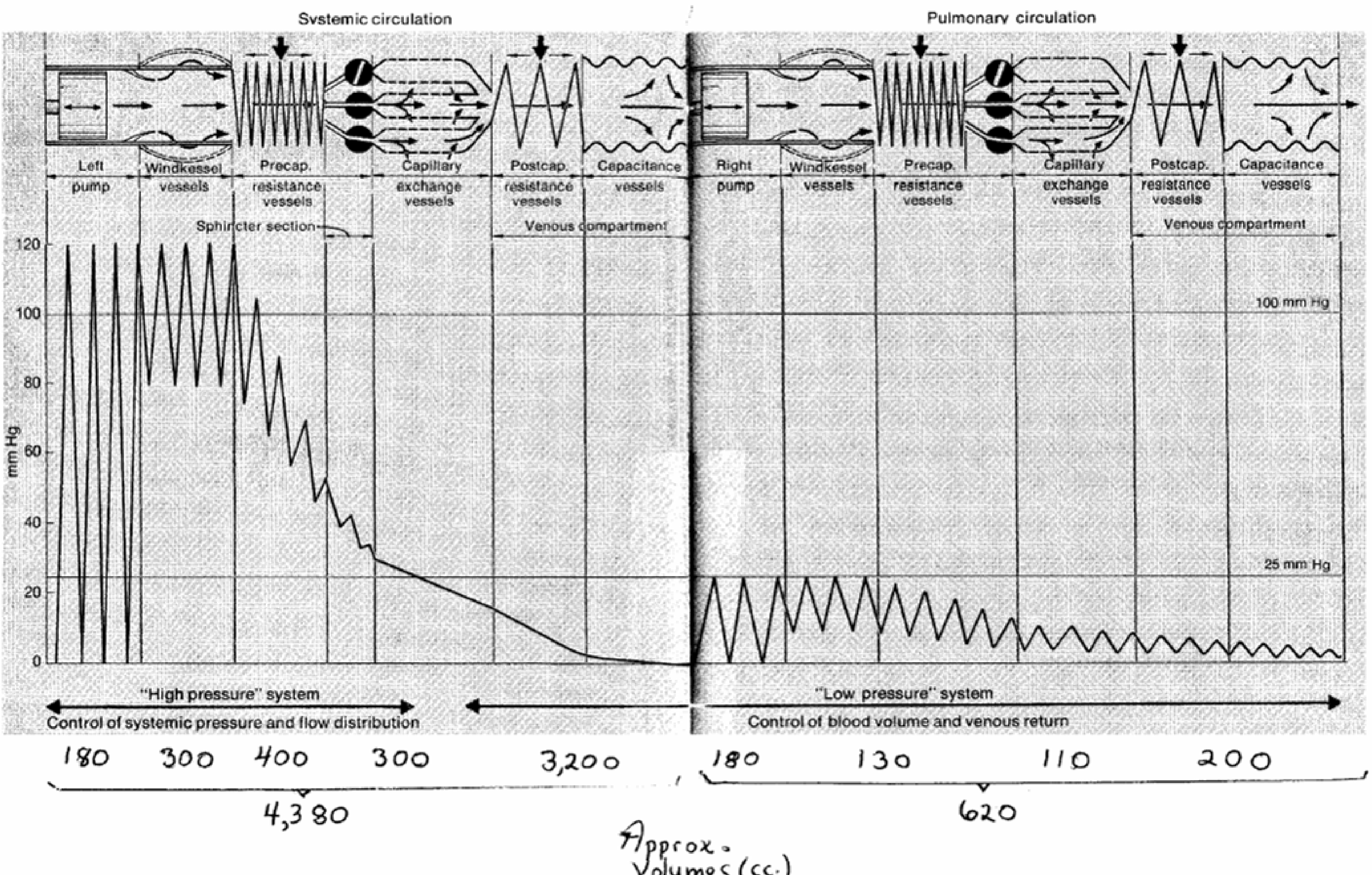
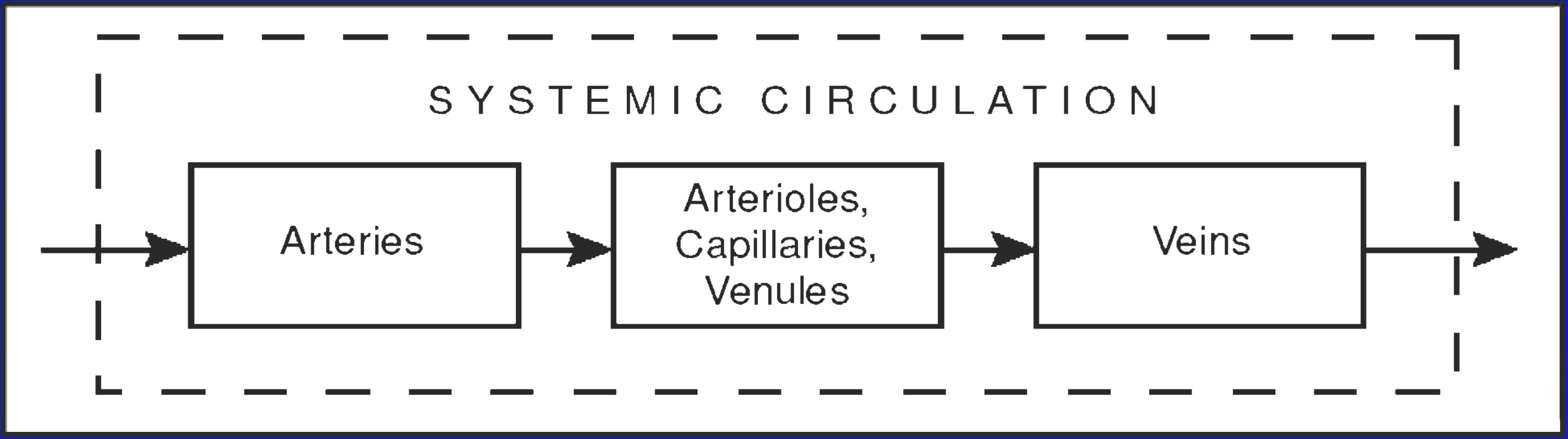
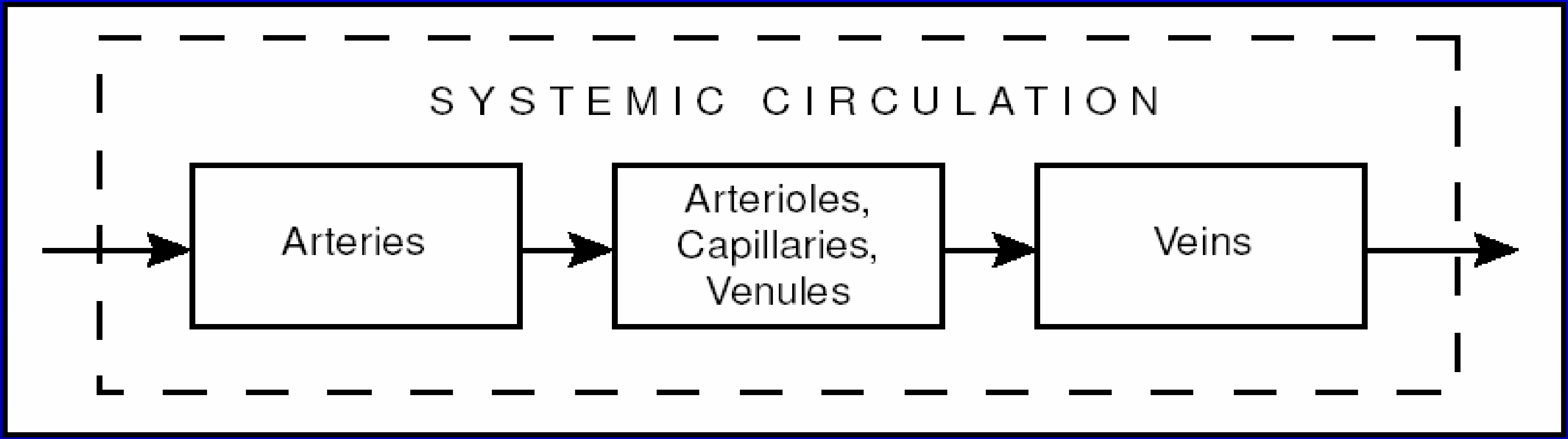
The Peripheral Circulation

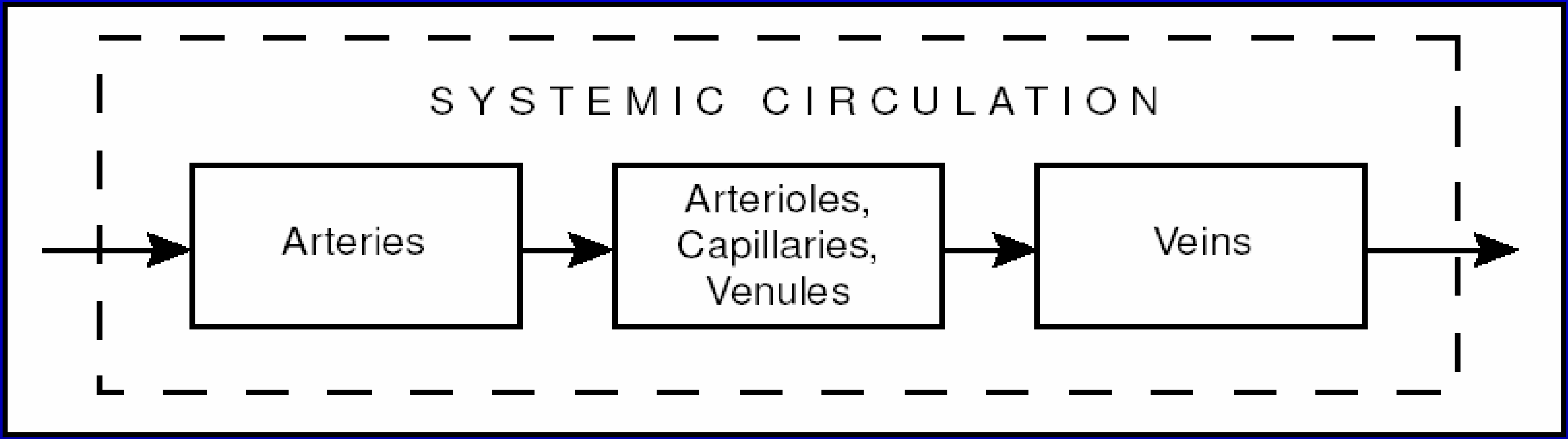
CV System: Series Connection




SYSTEMIC CIRCULATION
Arteries
Arterioles,
Capillaries,
Venules
Veins



Storage-elastic walls
Bolus flow
Pulse propagation
Oscillating Flow
Momentum high



Storage-elastic walls
Bolus flow
Pulse propagation
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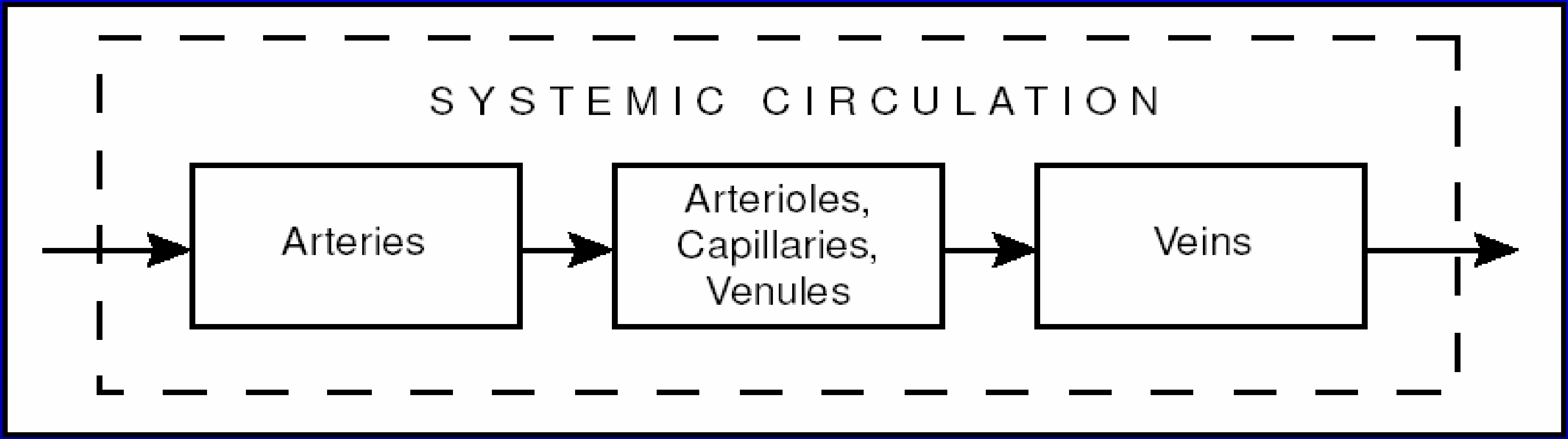
Momentum high

Resistance
Exchange
Laminar flow
Viscosity high
(Low Reynold's #)

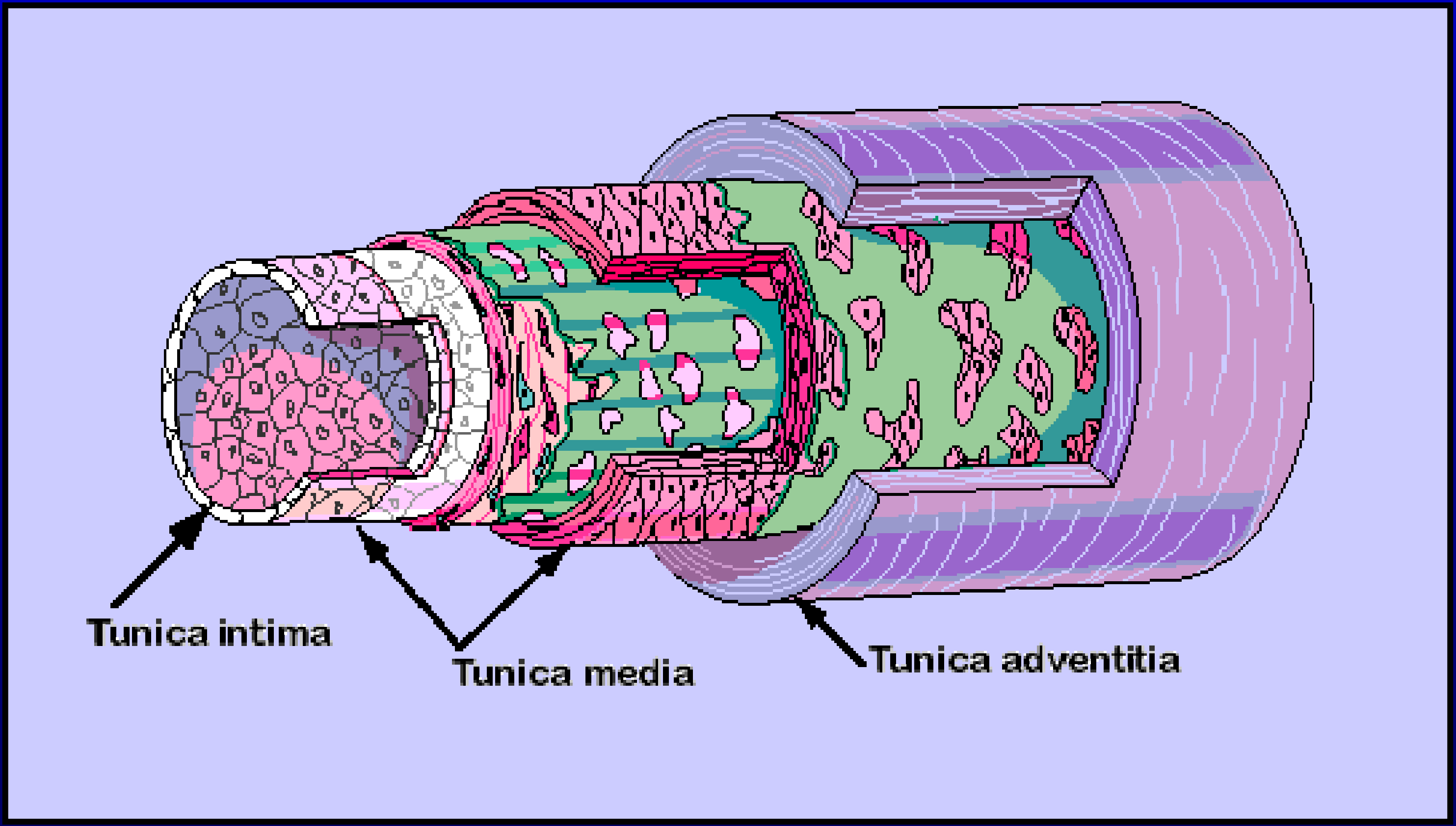


Storage-elastic walls
Bolus flow
Pulse propagation
Oscillating Flow
Momentum high

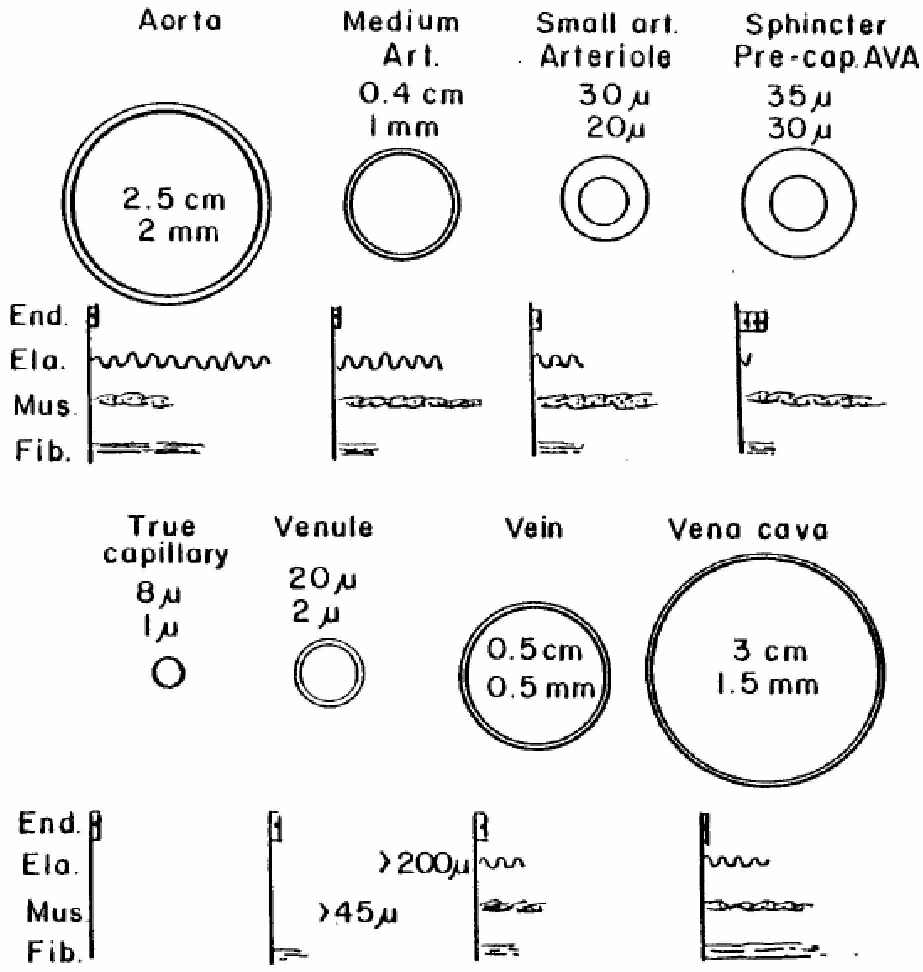
Resistance
Exchange
Laminar flow
Viscosity high
(Low Reynold's #)

Large storage capacity
Variable size
Collapse
Valves

Blood Vessel Structure

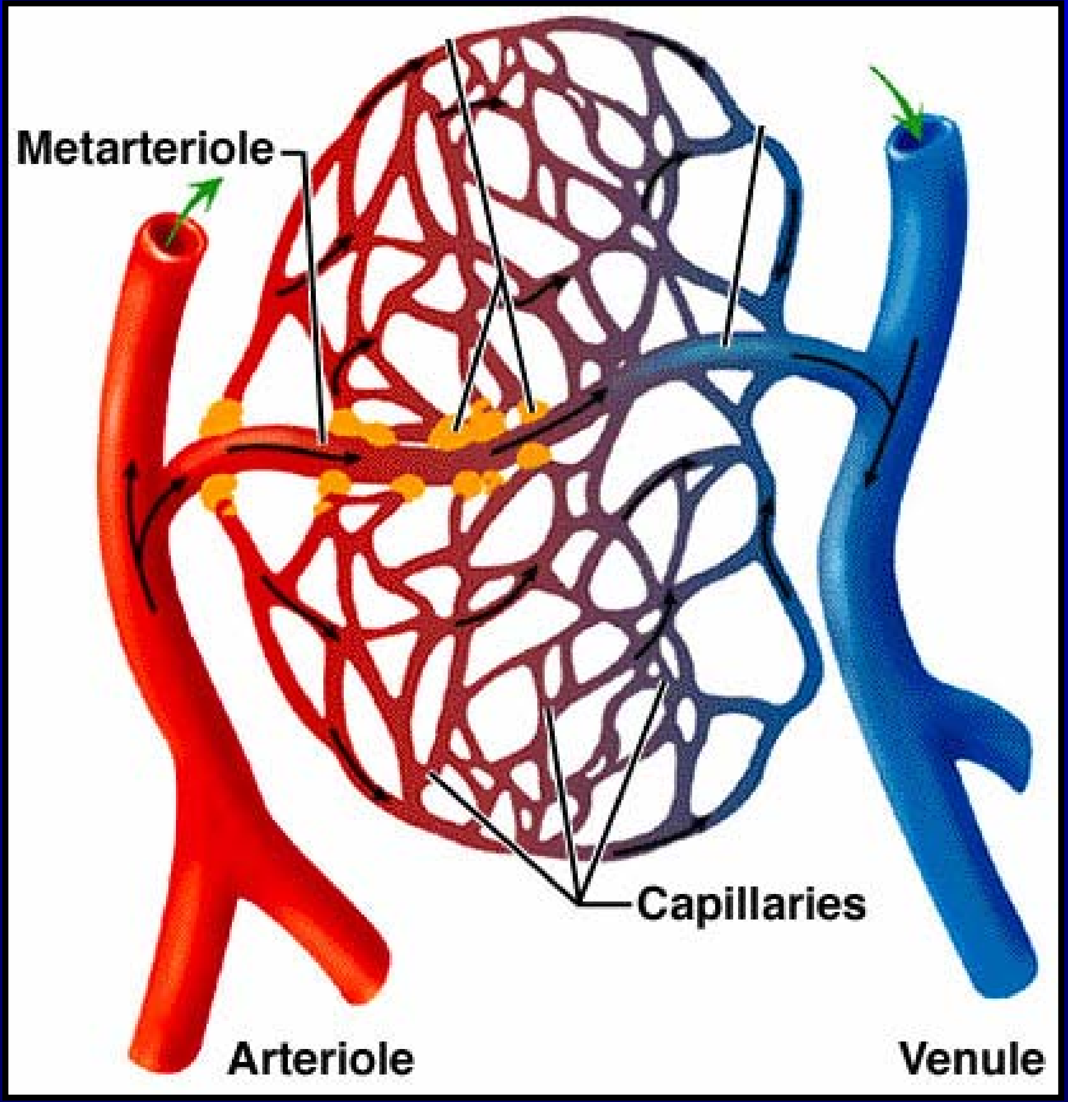


Blood Vessel Wall Composition

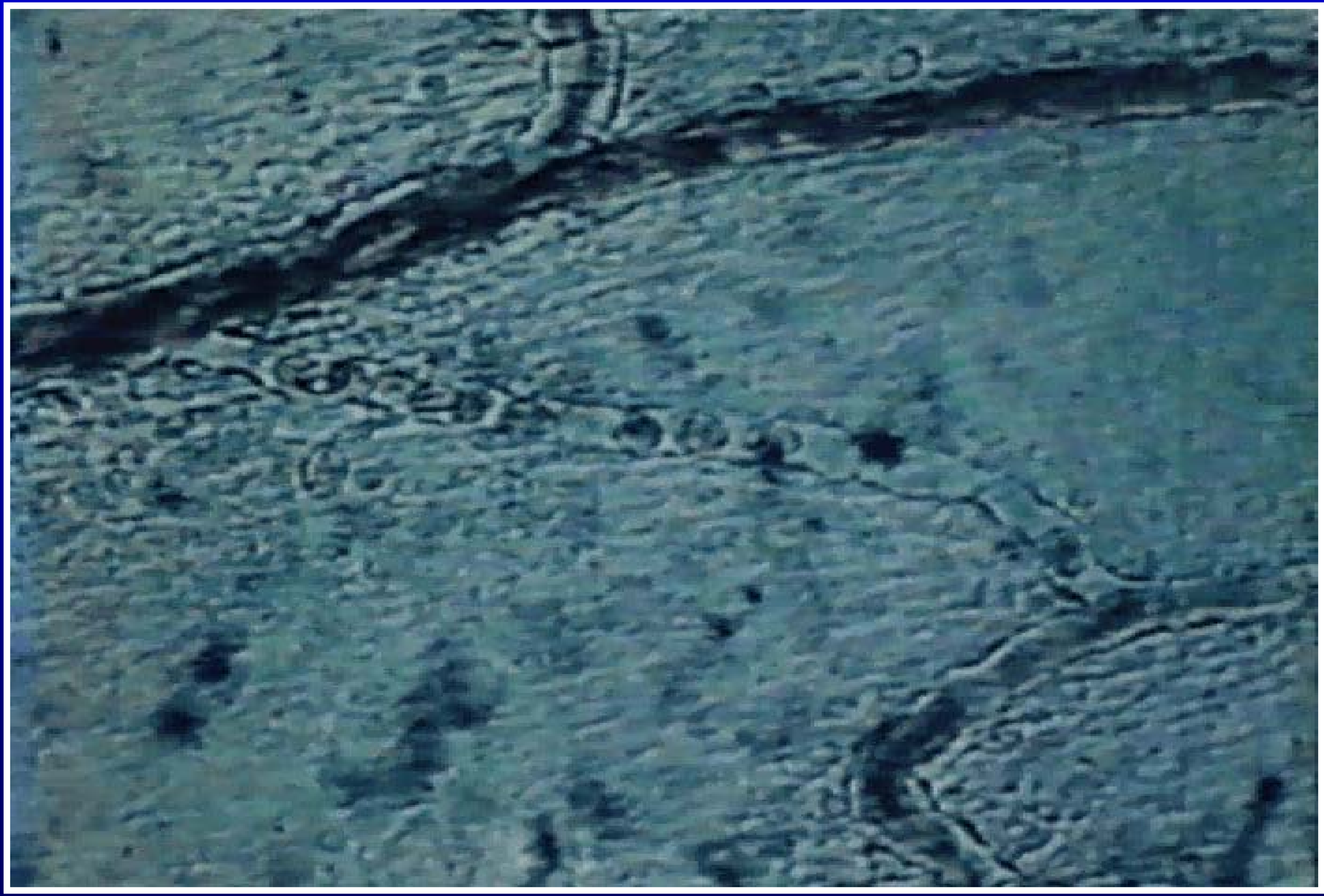


Variety of size, thickness of wall and admixture of the four basic tissues in the wall of different blood vessels. The figures directly under the name of the vessel represent the diameter of the lumen; below this, the thickness of the wall. *End.*, endothelial lining cells. *Ela.*, elastin fibers. *Mus.*, smooth muscle. *Fib.*, collagen fibers. (From Burton 1972, p. 64.)

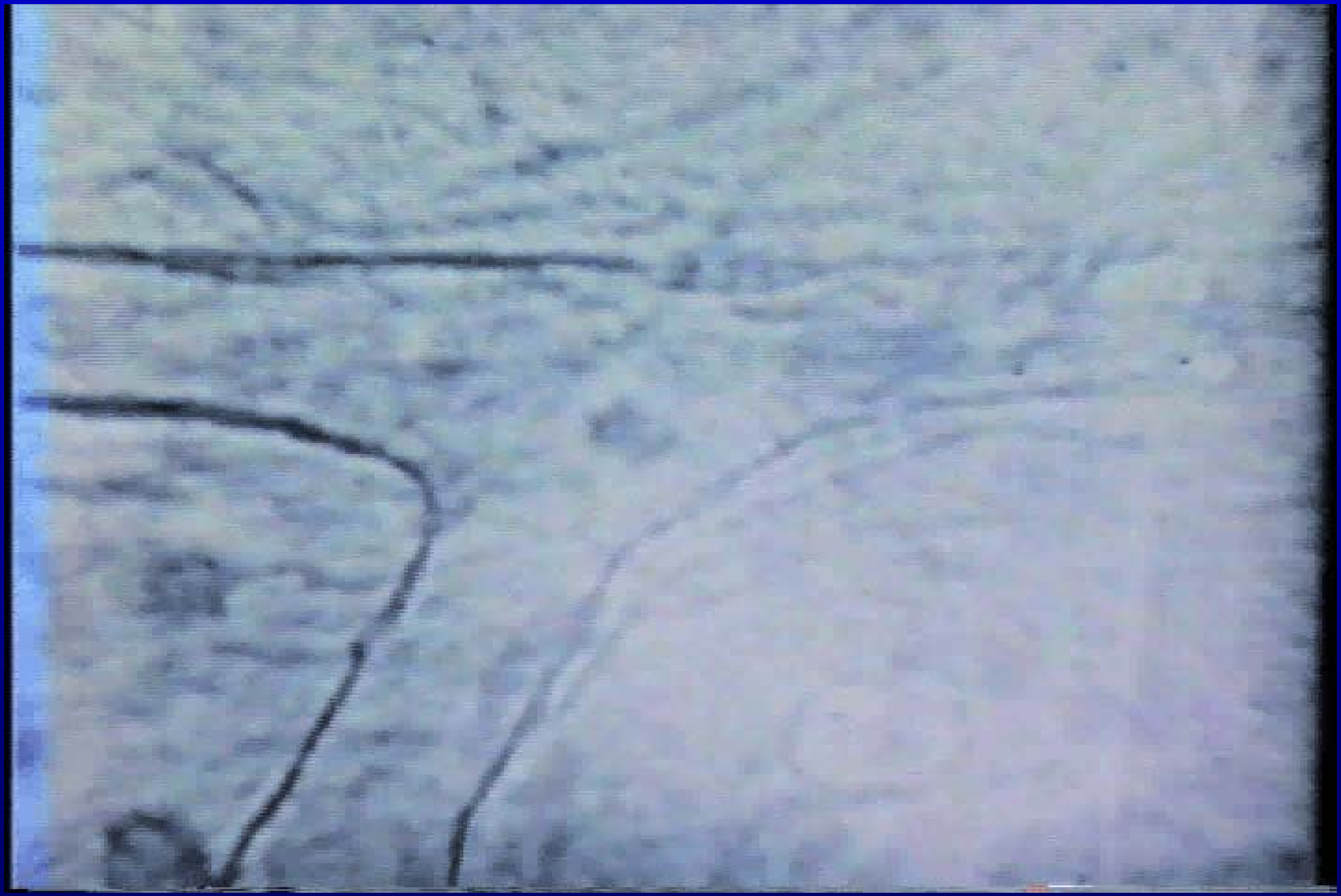
Microcirculation



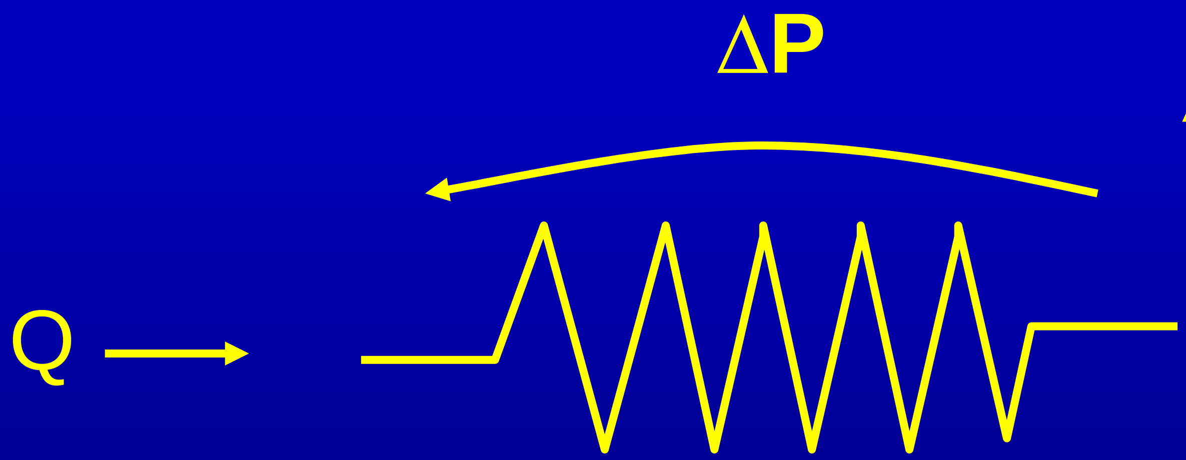
Capillary Function



Sphincters in the Microcirculation



Microcirculation Model



$\Delta P = RQ$

For laminar viscous flow in a tube of length, l, and radius, r, resistance is given by:

$$R = \frac{8}{\pi}\mu\frac{l}{r^4}$$

Estimating Peripheral Resistance

$$\Delta \boldsymbol{P} \approx 90 - 5 = 85\,\boldsymbol{mmHg}$$

$$\boldsymbol{Q} = 5\,\boldsymbol{liters}/\min = 83\,\boldsymbol{cc}/\sec$$

$$\boldsymbol{R} = 85/83 \approx 1\frac{\boldsymbol{mmHg}}{\boldsymbol{cc}/\sec} \equiv 1\,\boldsymbol{PRU}$$

$$\boldsymbol{Note}: 1\,\boldsymbol{mmHg} = 1330\,\boldsymbol{dynes}/\boldsymbol{cm}^2$$

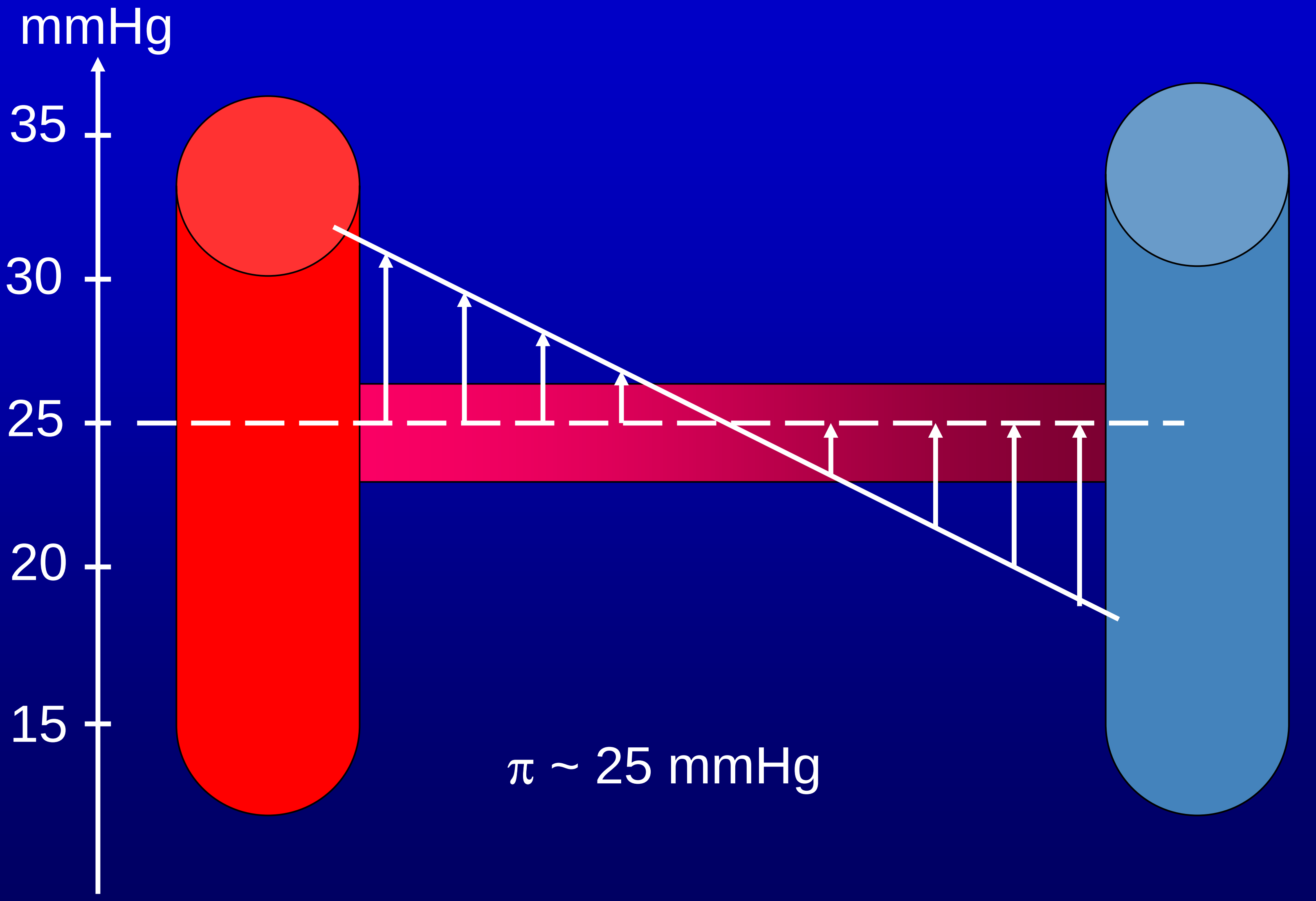
$$\boldsymbol{Thus}, 1\,\boldsymbol{PRU} = \frac{1330\,\boldsymbol{dynes}/\boldsymbol{cm}^2}{\boldsymbol{cc}/\sec} = \frac{1330\,\boldsymbol{dynes} - \sec}{\boldsymbol{cm}^5}$$

Relative Resistance to Flow in the Vascular Bed

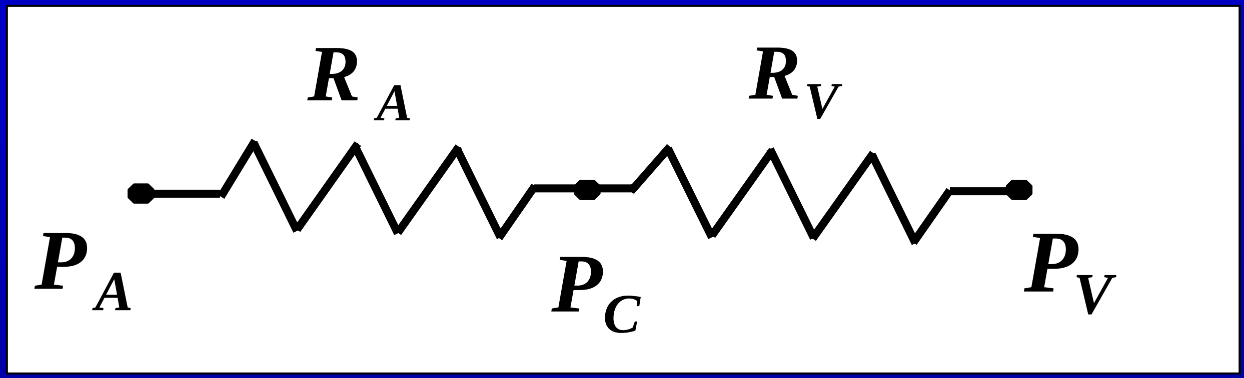
Aorta	4%	Venules	4%
Large arteries	5%	Terminal Veins	0.3%
Mean arterial branches	10%	Main venous branches	0.7%
Terminal branches	6%	Large veins	0.5%
Arterioles	41%	Vena cava	1.3%
Capillaries	27%		
Total: arterial + capillary = 93%		Total venous = 7%	

(From Burton 1972, p. 91)

Starling's Law of Capillary Filtration



Capillary Pressure



$$P_C = P_V + \frac{R_V}{R_A + R_V} \bullet (P_A - P_V)$$

$$P_C = \frac{P_A\left(\frac{R_V}{R_A}\right) + P_V}{1 + \frac{R_V}{R_A}} = \frac{0.25P_A + P_V}{1.25}$$

What Can Cause Edema?

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- **Increased Hydrostatic Pressure**
  - Venous valve failure and gravity
  - High central venous pressure
  - Blockage to venous flow

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    - Starvation
    - Liver disease
  - Excess loss of protein
    - Renal disease: nephrotic syndrome

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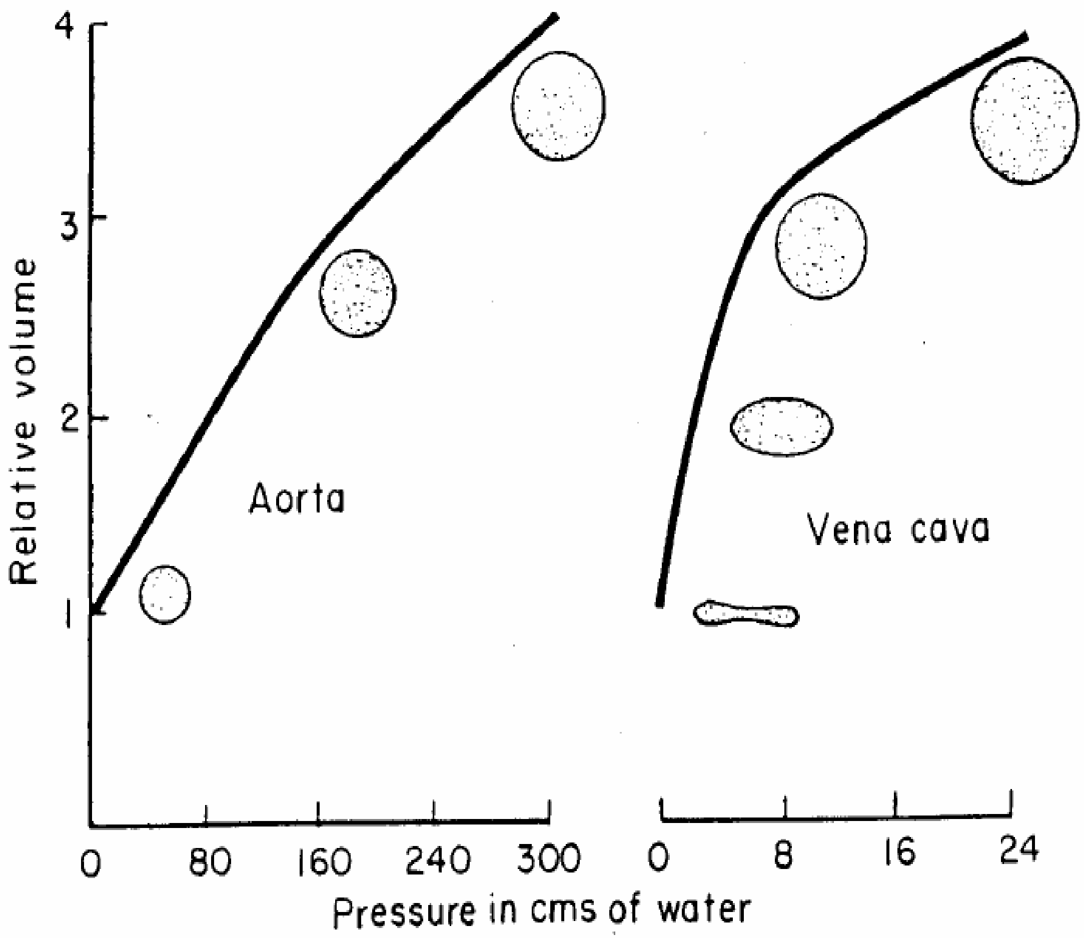
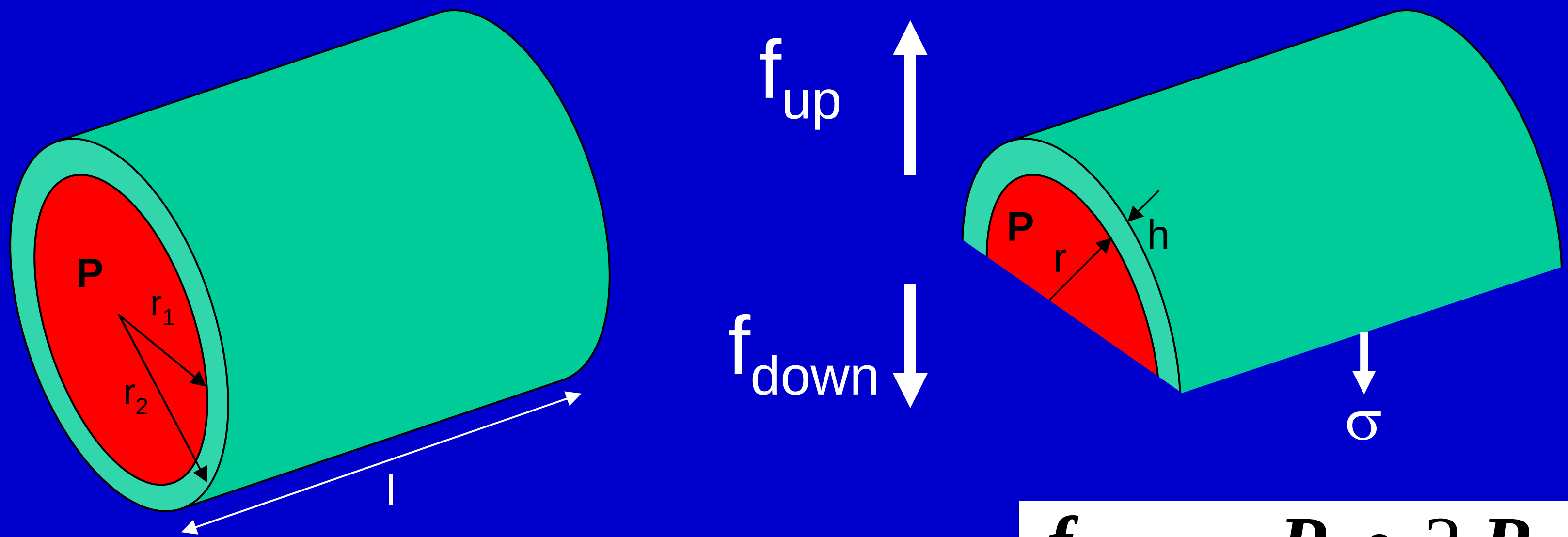
- **Capillary wall damage**
  - Inflammation
  - Trauma

Vascular Distensibility



Comparison of the distensibility of the aorta and of the vena cava. The way in which the cross-section of the vessels changes in the two cases is also indicated. (From Burton 1972, p. 55.)

LaPlace's Law for Cylinders



$$\sigma \equiv tensile\ stress \equiv \frac{force}{area}$$

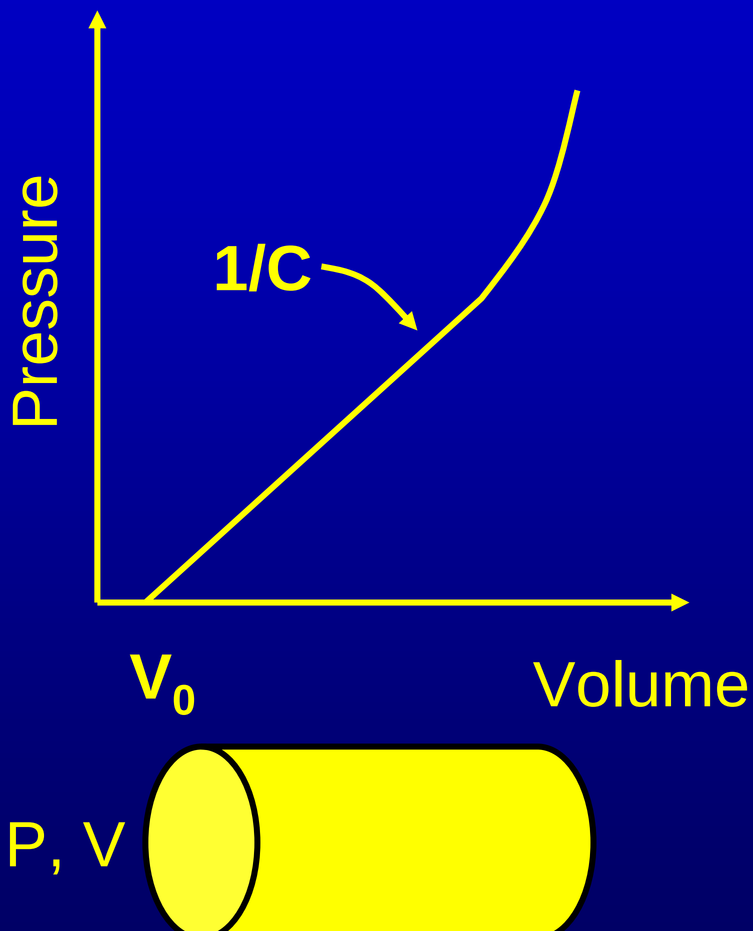
$$f_{up} = P \bullet 2R \bullet l$$

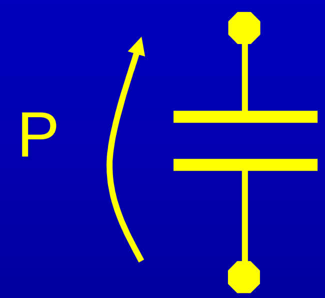
$$f_{down} = 2\sigma hl$$

$$f_{up} = f_{down}$$

$$\sigma = \frac{PR}{h}$$

Vascular Capacitance

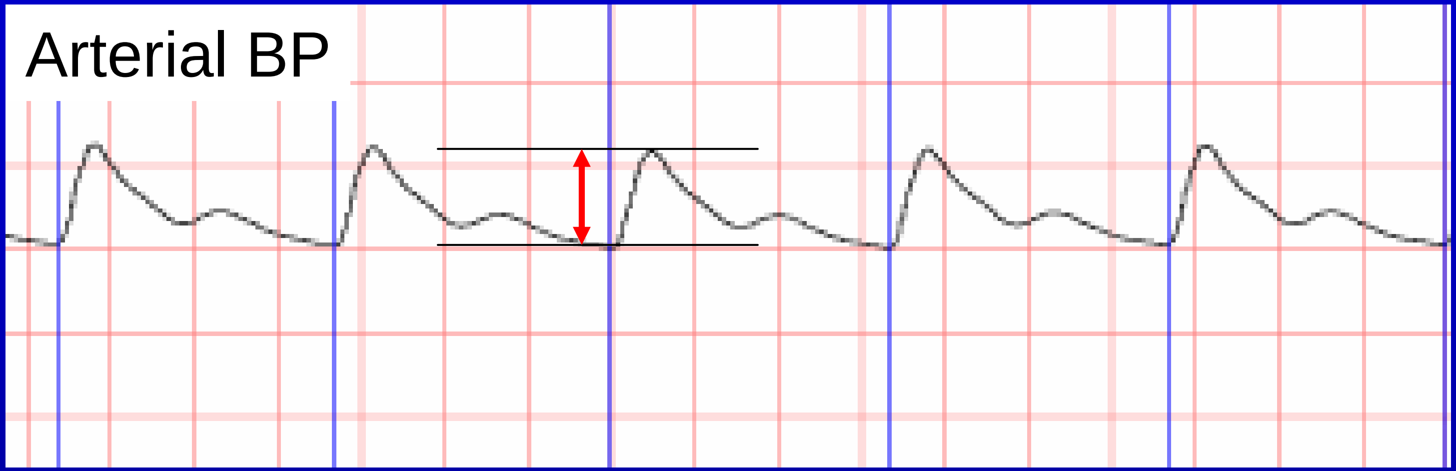




$C_a = \Delta V / \Delta P$

Estimating arterial Capacitance

C_a= SV / pulse press
= 80cc / 40 mmHg
= 2 cc / mmHg



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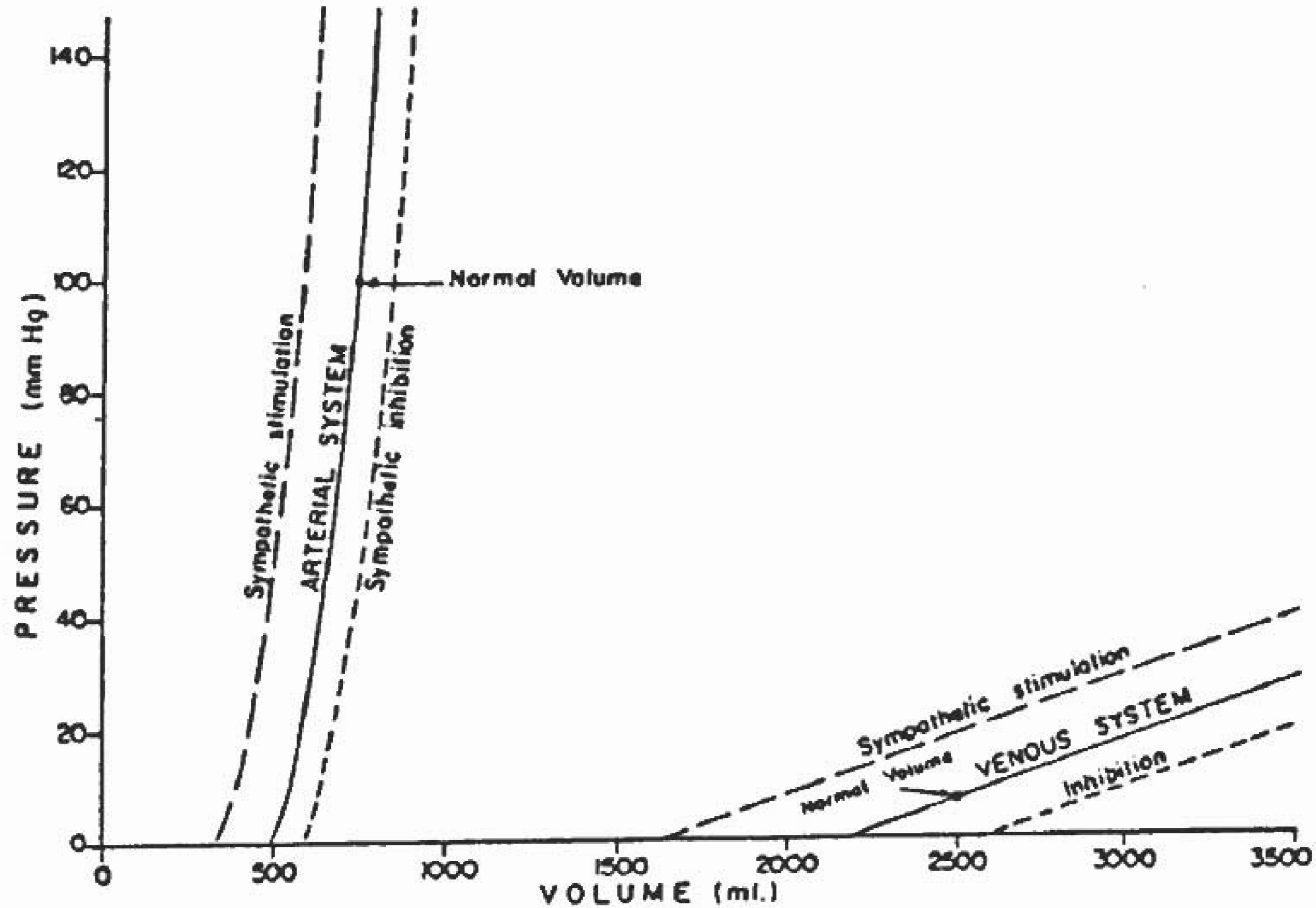
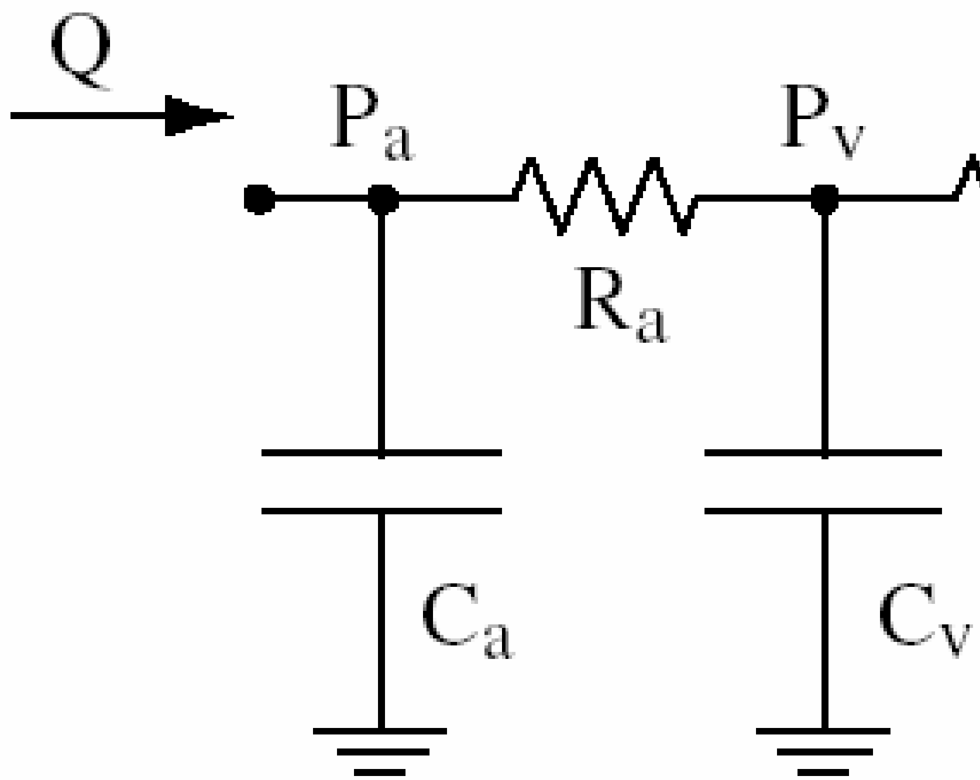


Volume-pressure curves of the systemic arterial and venous systems, showing also the effects of sympathetic stimulation and sympathetic inhibition. (From Guyton, A. C.: Human Physiology and Mechanisms of Disease, 3rd ed. Philadelphia, W. B. Saunders Co., 1982.)

Fluid Variable	**Electrical Variable**
Pressure, P	Voltage, e
Flow, Q	Current, i
Volume, V	Charge, q
Resistance, $R = \Delta P/Q$	Resistance, $R = \Delta e/i$
Capacitance, $C = \Delta V/\Delta P$	Capacitance, $C = \Delta q/\Delta e$

Model of Peripheral Circulation



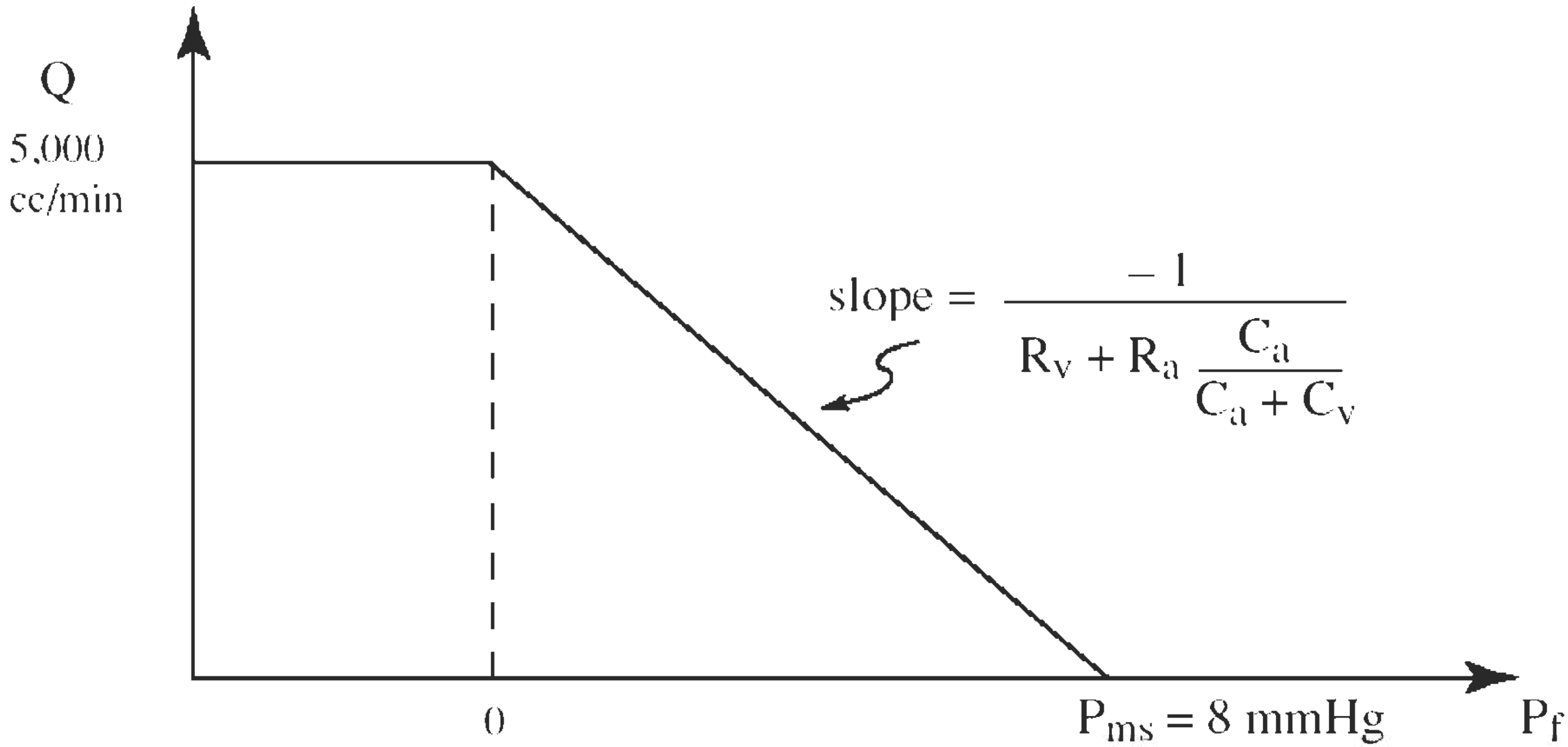
C_a = 2 ml/mmHg

C_v = 100 ml/mmHg

R_a = 1 mmHg/ml/sec.

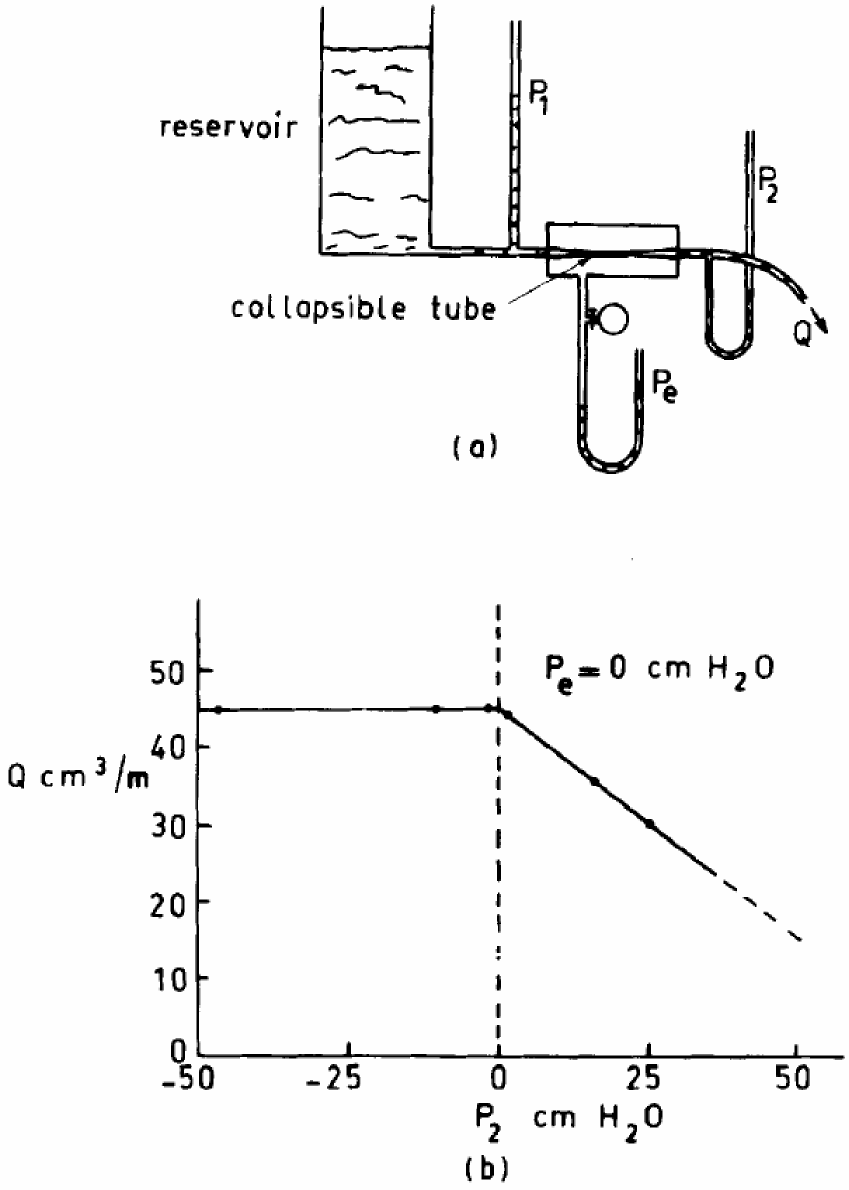
R_v = .06 mmHg/ml/sec.

The Venous Return Curve

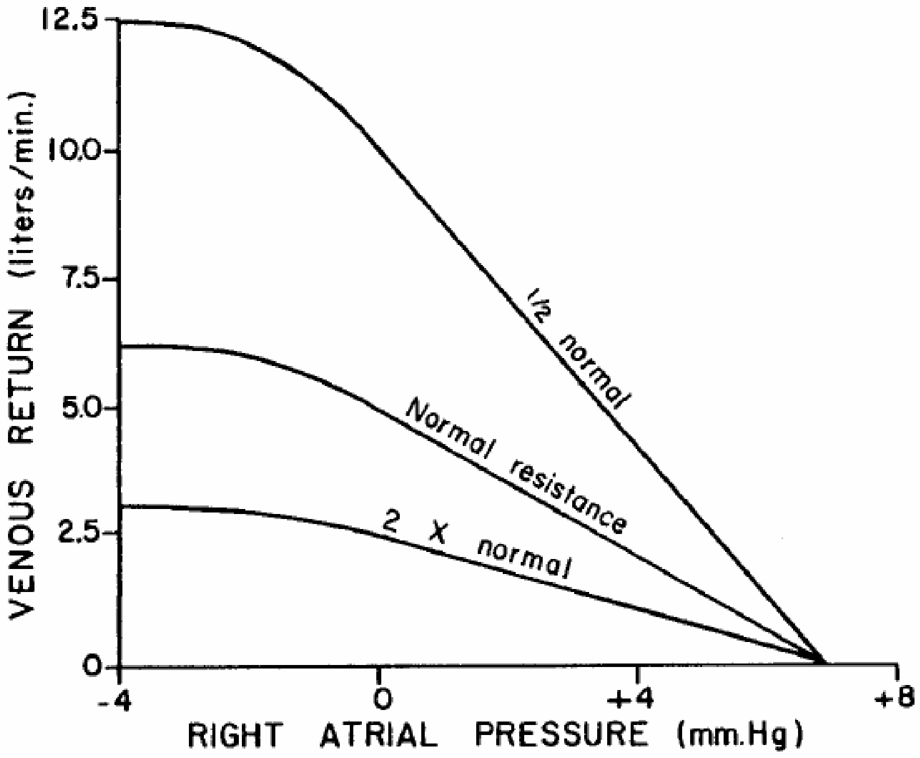


$$Q = \frac{P_{ms} - P_f}{R_v + R_a\left(\frac{C_a}{C_a + C_v}\right)}$$

Flow through Collapsible Tubes

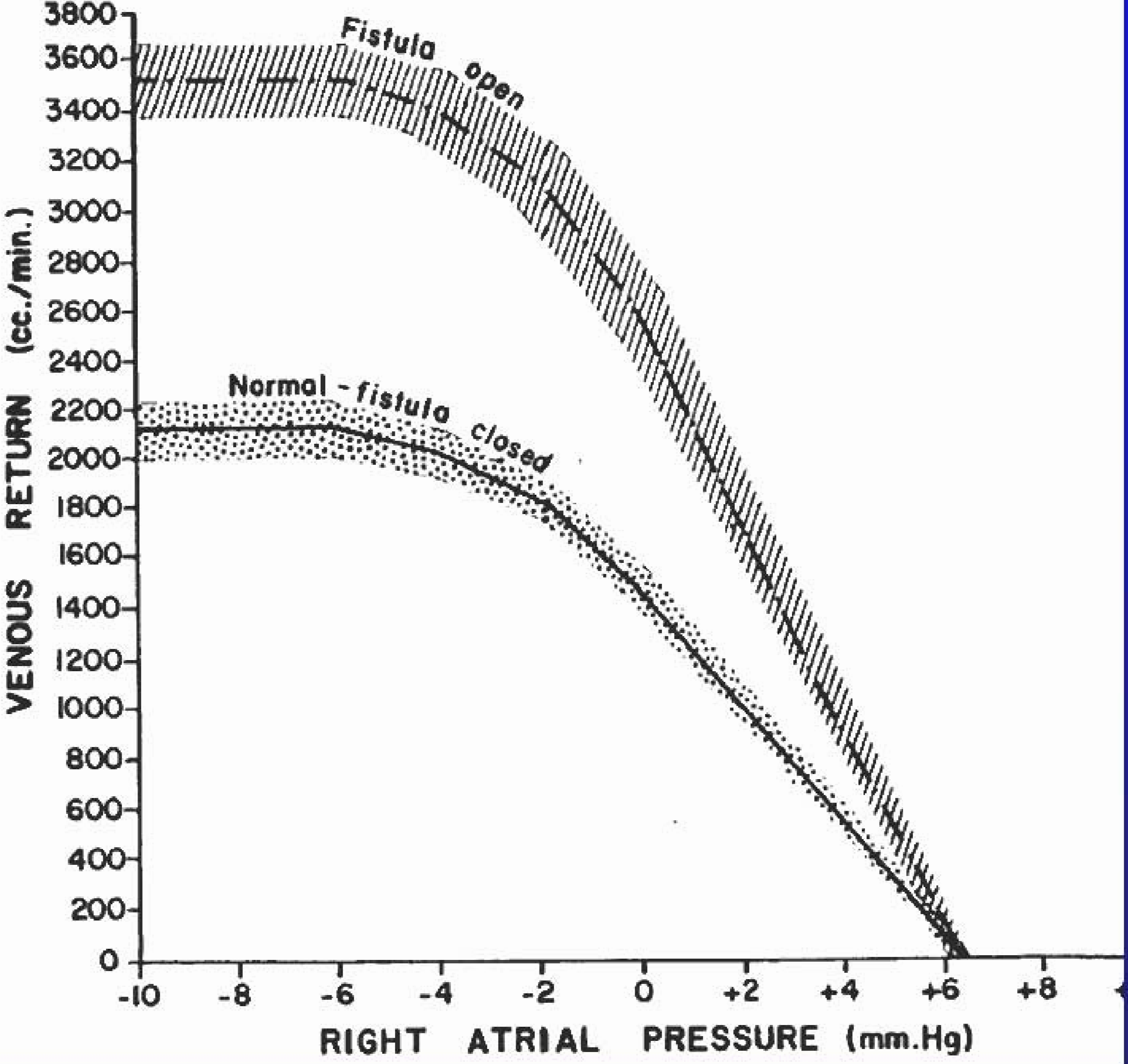


Changes in Resistance

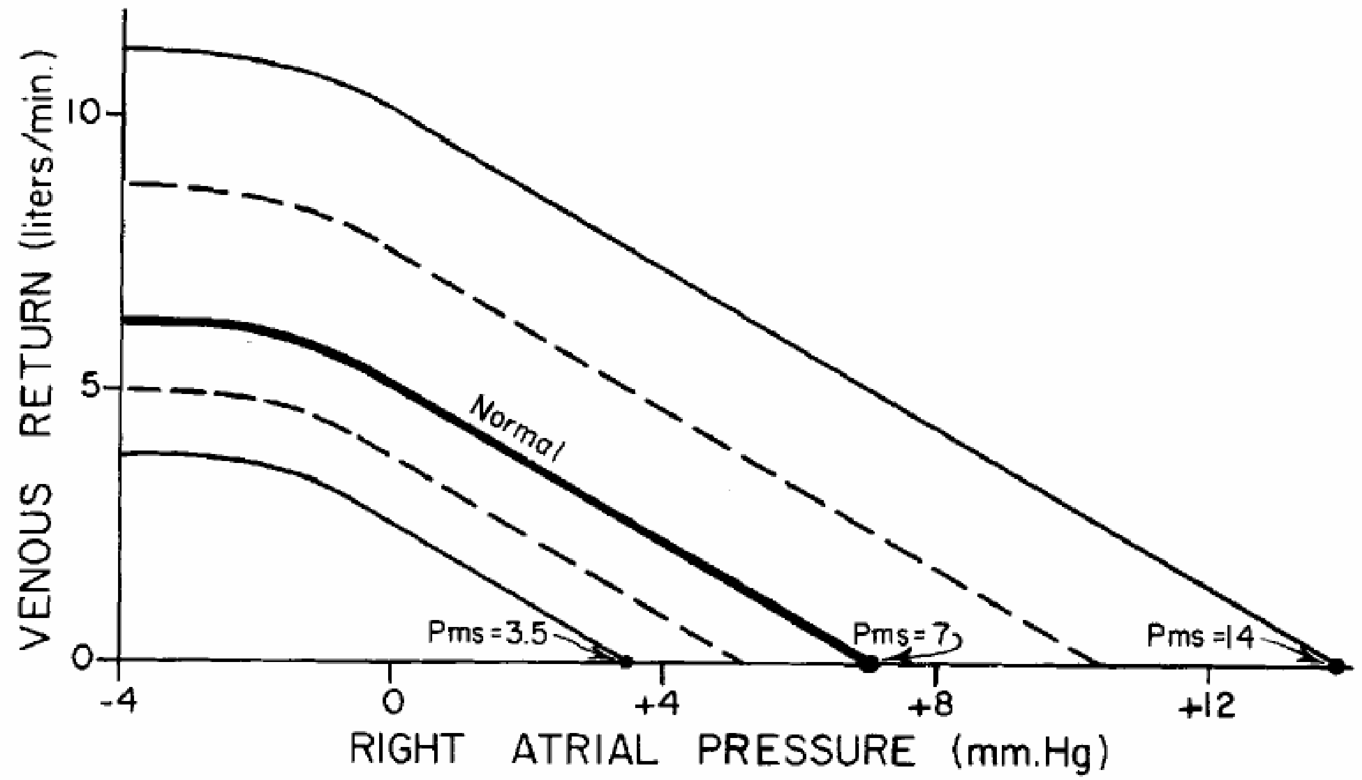


Calculated effects on the venous return curve caused by a two fold increase or a two fold decrease in total peripheral resistance when the resistances throughout the systemic circulation are all altered proportionately. (Guyton 1973, p. 223.)

(Experimental data from dogs)

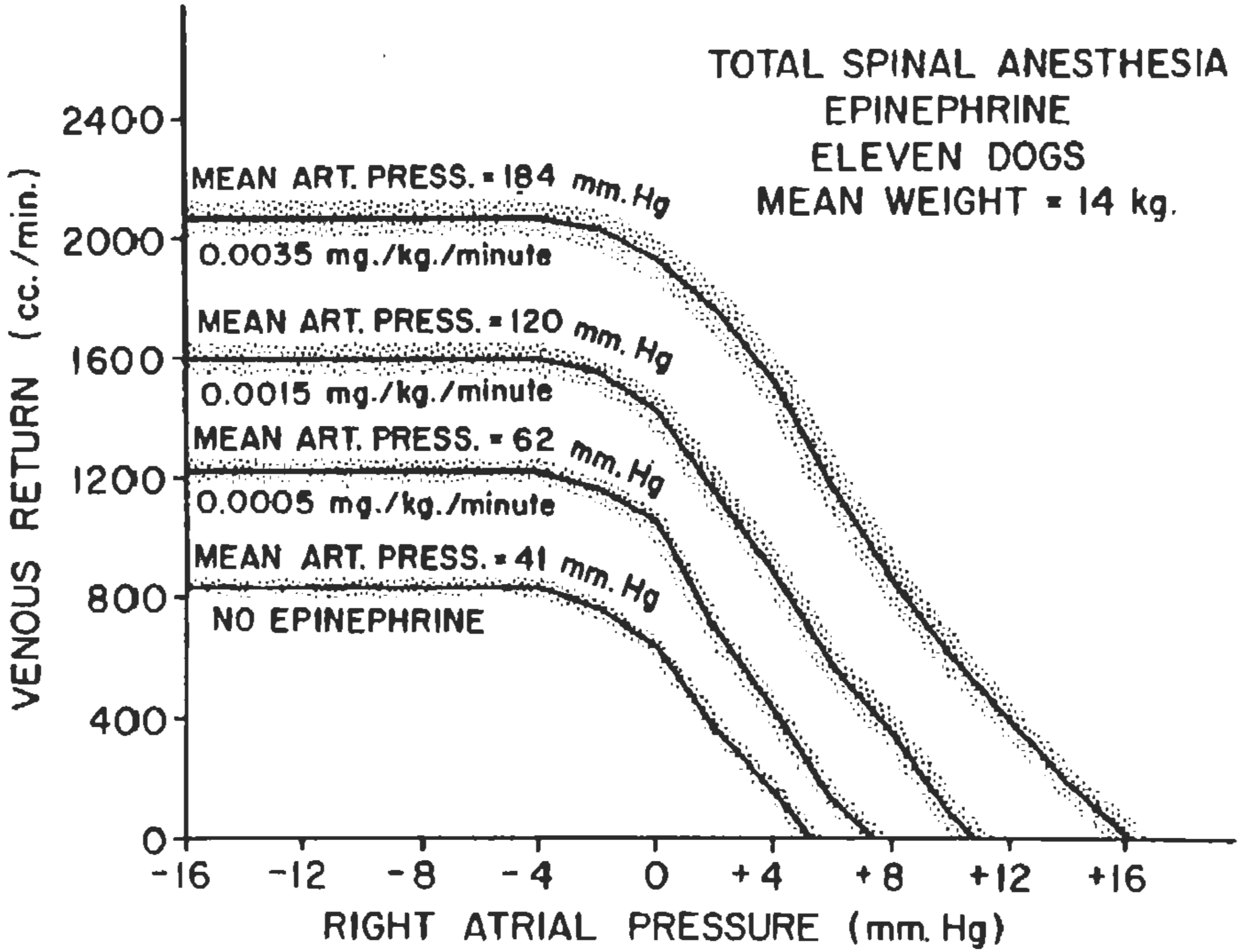


Changing P_{ms}

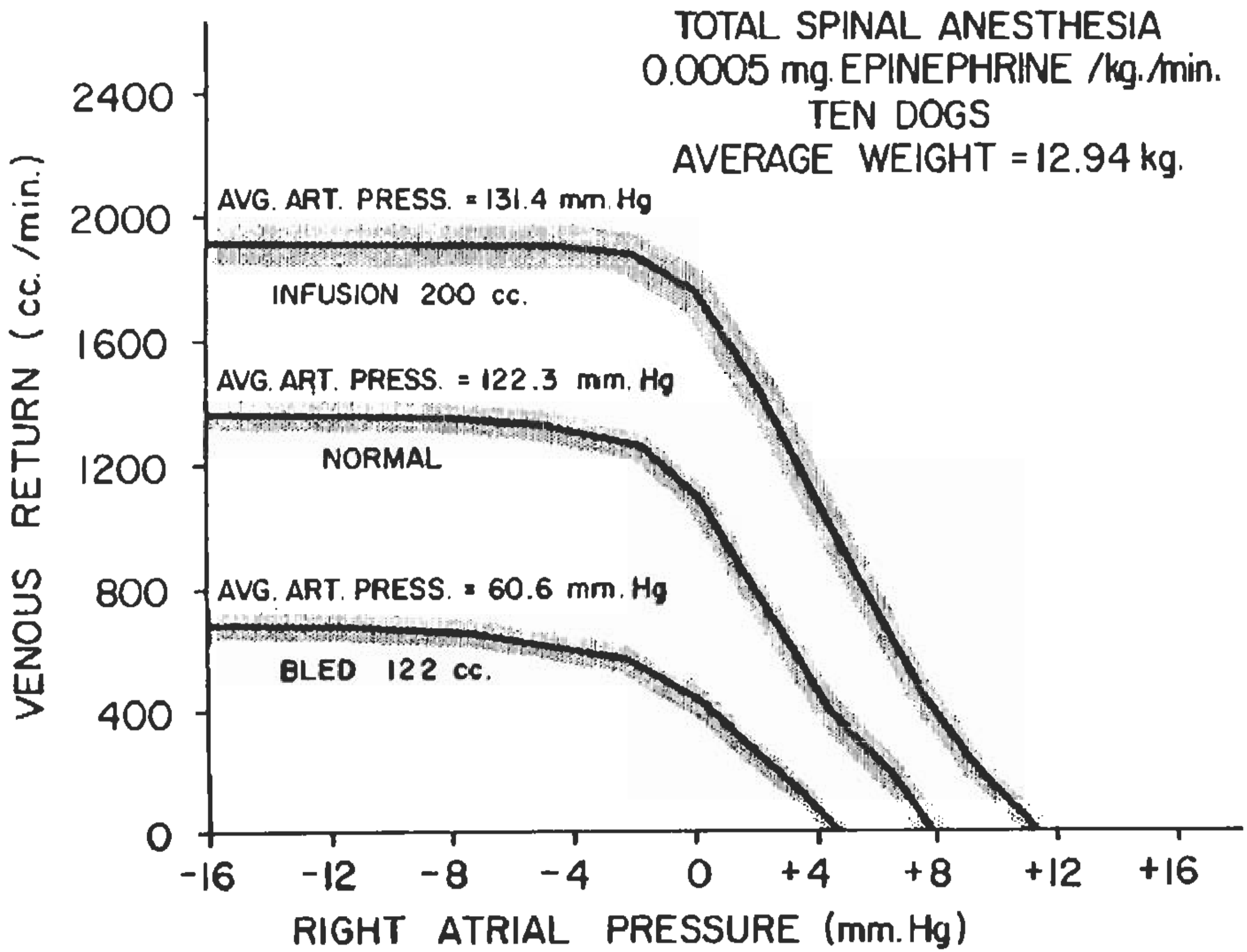


Idealized curves, showing the effect on the venous return curve caused by changes in mean systemic filling pressure. (Guyton 1973, p. 243.)

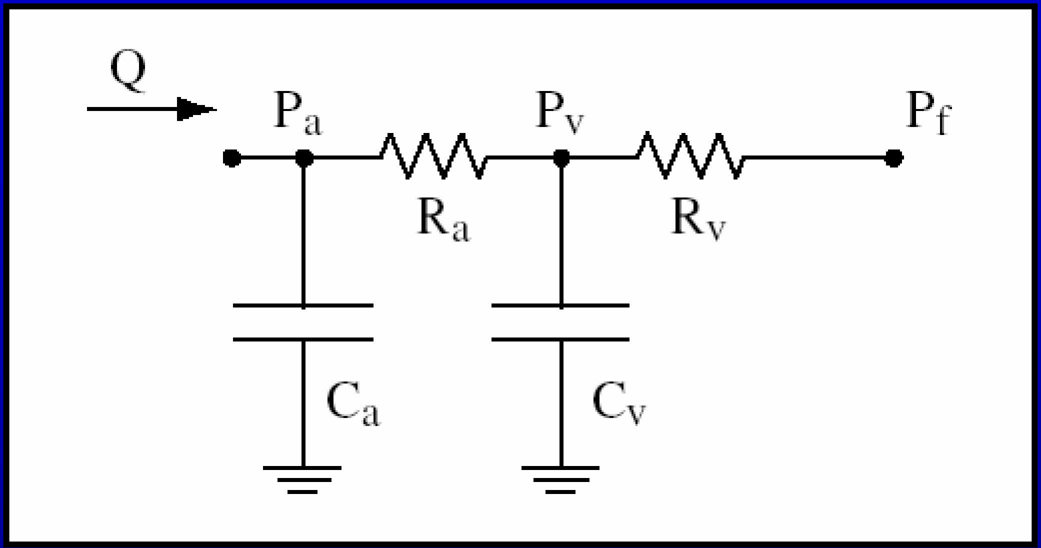
Changing P_{ms} by manipulating venous smooth muscle tone

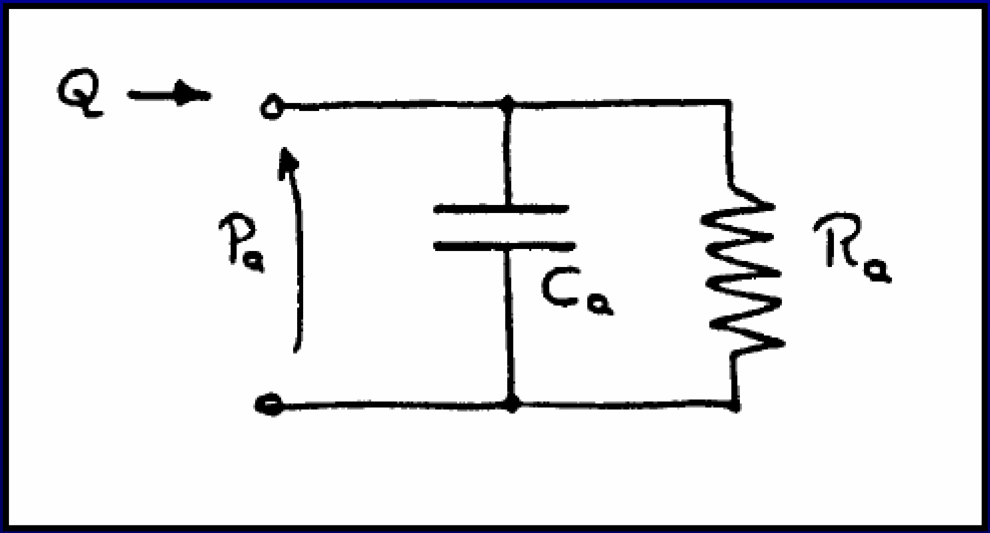


Changing mean systemic filling pressure by manipulation of blood volume



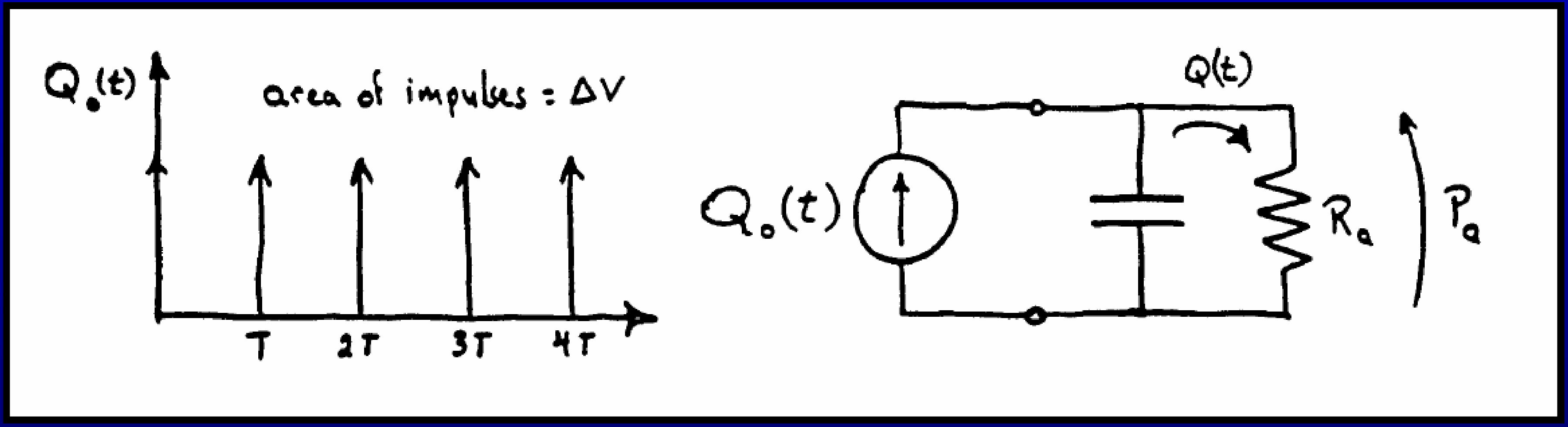
The Windkessel Approximation



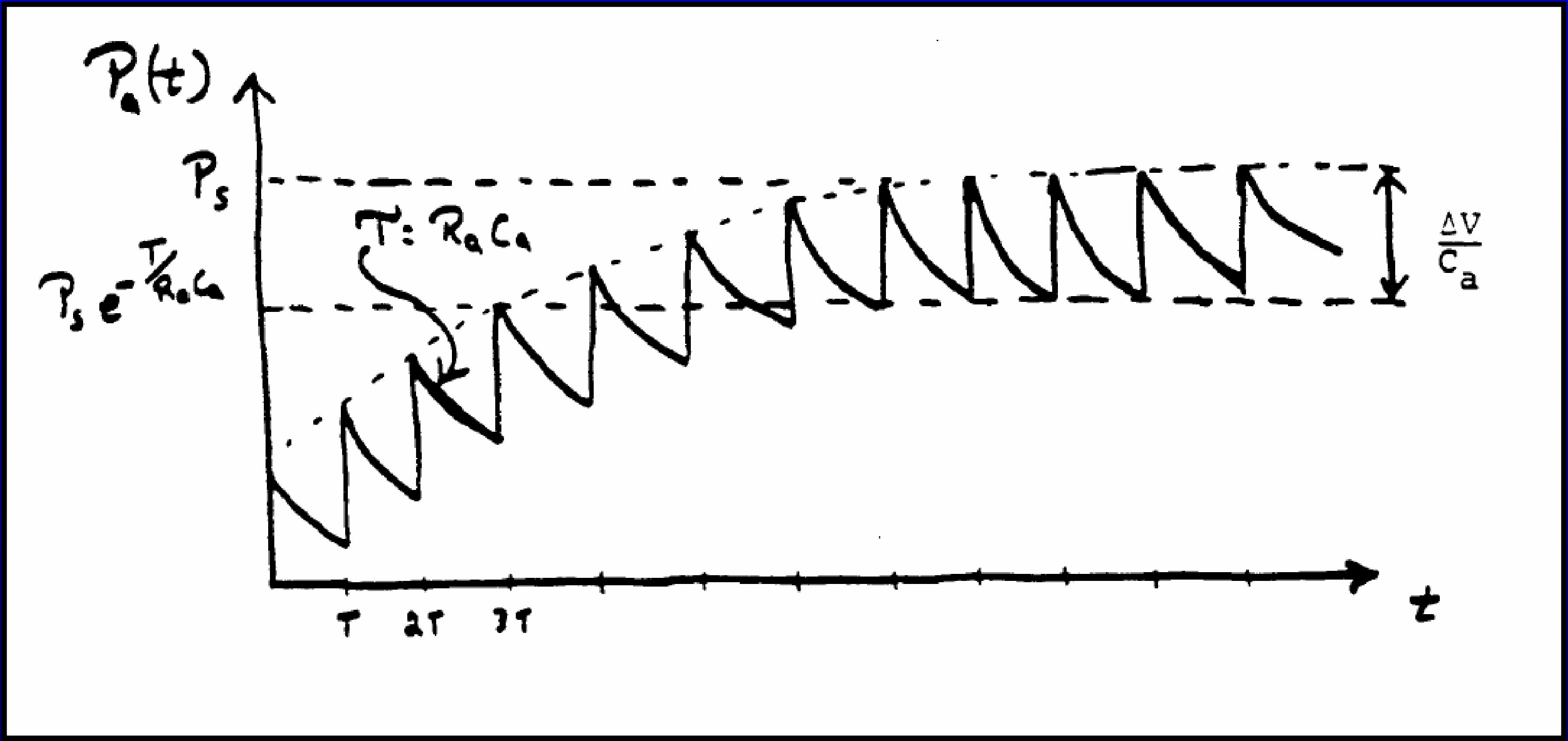


If venous pressure is approximately zero

Windkessel Driven by Current Impulses



Resultant "Arterial Blood Pressure"



Pressure and Flow in Rabbit Aorta