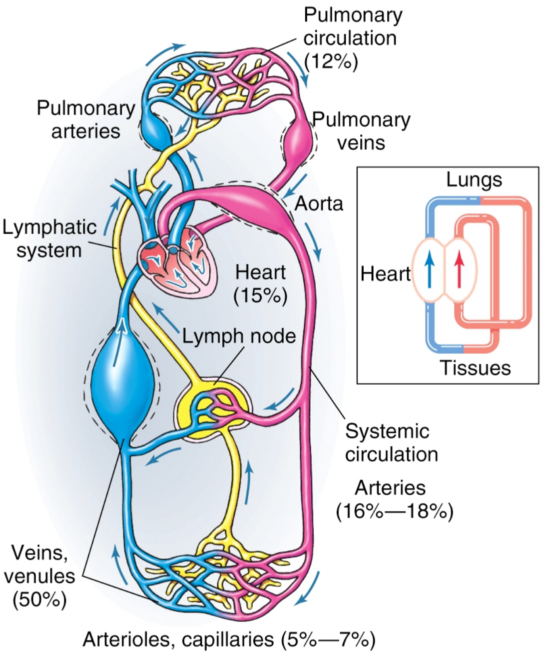
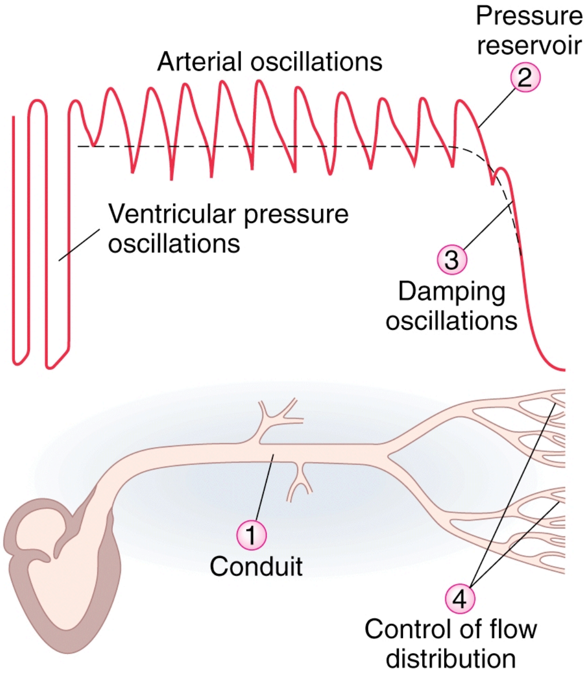
Arterial System
Lecture Block 10

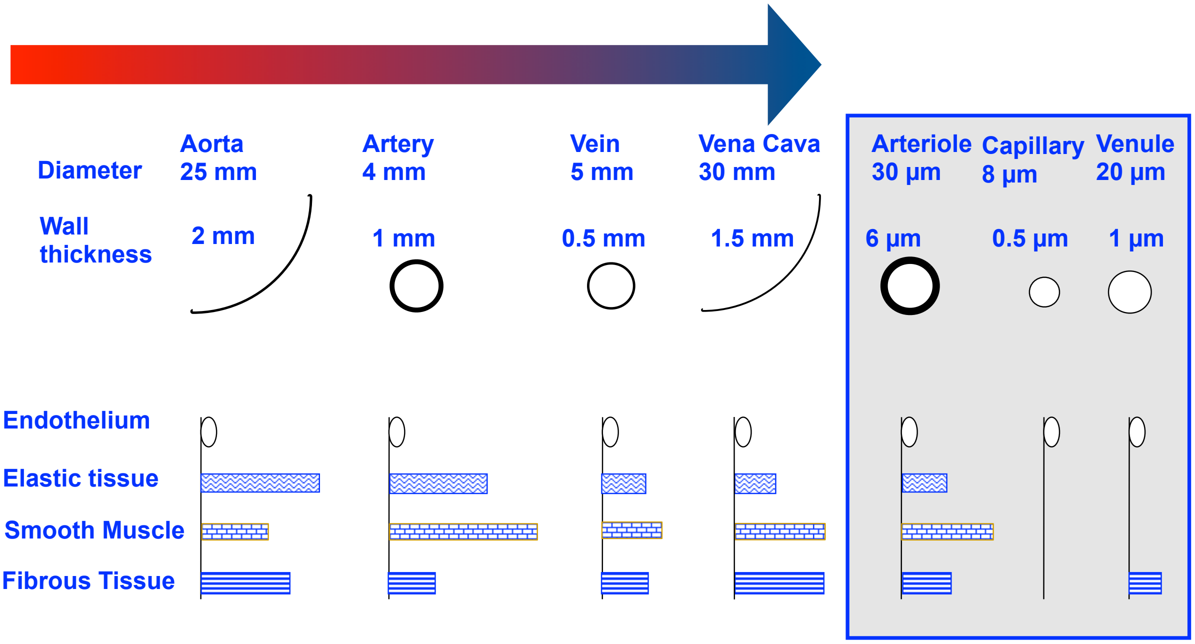
Vascular Structure/Function

Functional Overview





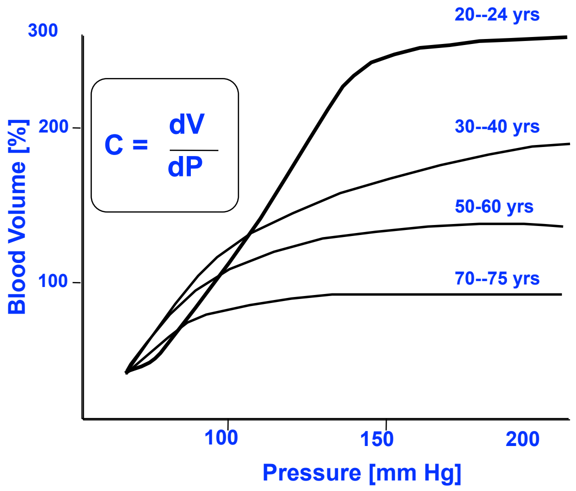
Vessel Structure



	Aorta	**Artery**	**Vein**	**Vena Cava**	**Arteriole**	**Capillary**	**Venule**
Diameter	**25 mm**	**4 mm**	**5 mm**	**30 mm**	**30 µm**	**8 µm**	**20 µm**
Wall thickness	**2 mm**	**1 mm**	**0.5 mm**	**1.5 mm**	**6 µm**	**0.5 µm**	**1 µm**

Aortic Compliance

- Factors:
  - age
  - athersclerosis
- Effects
  - more pulsatile flow
  - more cardiac work
  - not hypertension



Laplace's Law
(thin-walled cylinder):
T = wall tension
P = pressure
r = radius

$$T = Pr$$

For thick wall cylinder
P = pressure
σ = wall stress
r = radius
w = wall thickness

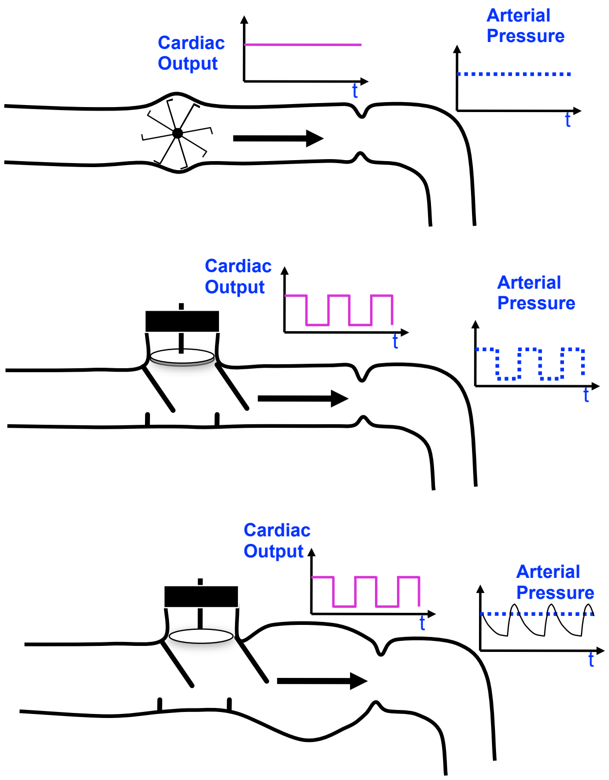
$$\sigma = \frac{Pr}{w}$$

	Tension [dyne/cm]	Wall Stress [dyne/cm^2]
Aorta	2 x 10^5	10 x 10^5
Capillary	15-70	1.5 x 10^5

Arterial Hydraulic Filter

Arterial System as Hydraulic Filter

- Pulsatile --> smooth flow
- Cardiac energy conversion
- Reduces total cardiac work

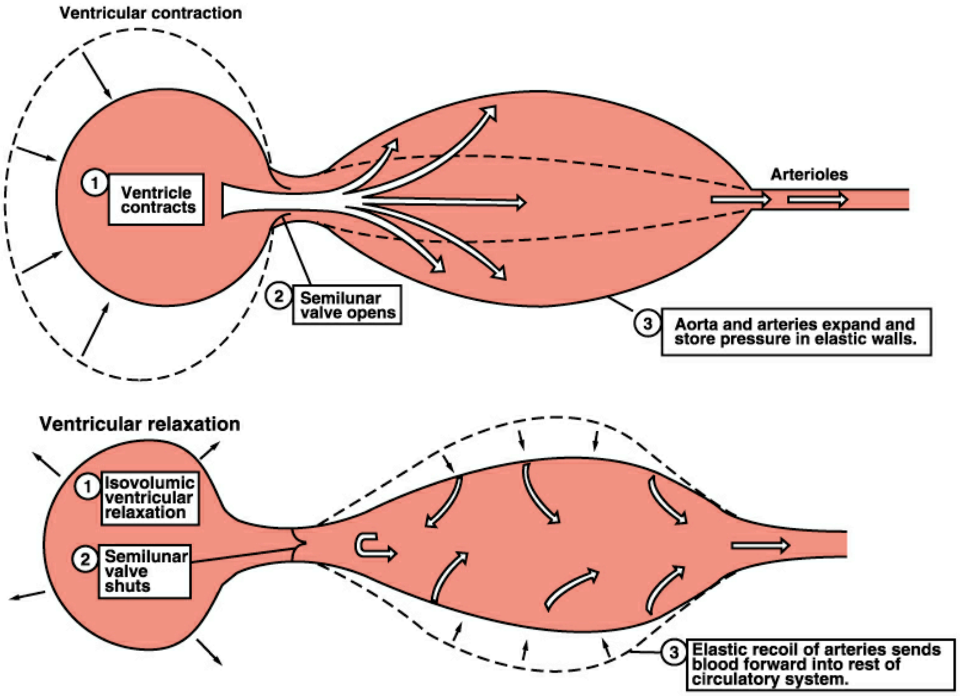


Physiological Ideal

Pulsatile Challenge

Filtered Reality

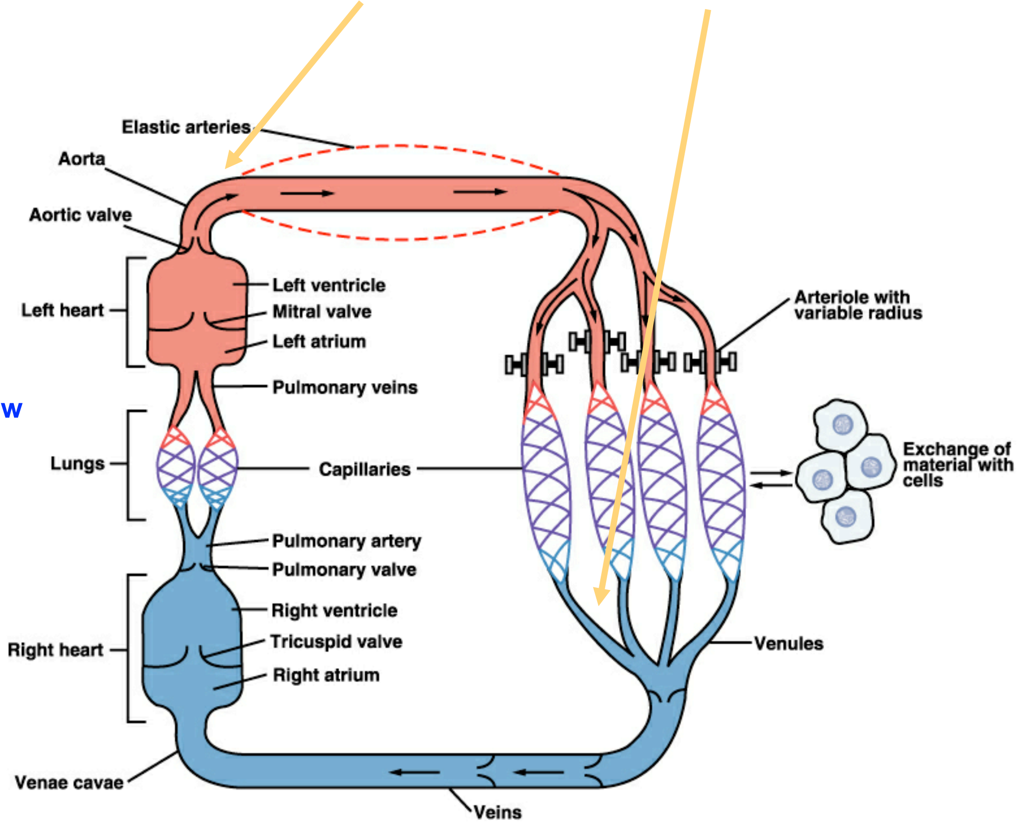
Elastic Recoil in Arteries



Effects of Vascular Resistance and Compliance

Cardiac Output vs. Runoff

Arterial Pressure/Flow



Basic Pressure Equations

Mean arterial pressure:

$$\bar{P}_a = \frac{\int_{t_1}^{t_2} P_a \, dt}{t_2 - t_1}$$

which we can ***approximate*** as

$$\bar{P}_a = P_d + 1/3(P_s - P_d)$$

with P_s = systolic pressure
P_d = diastolic pressure

Total peripheral resistance is

$$R_p = (\bar{P}_a - \bar{P}_{ra})/\bar{Q}_r$$

with P_a = mean arterial pressure
P_{ra} = right atrial pressure
Q_r = runoff flow into veins (=Q_h at equilibrium)

If we assume P_{ra}=0

$$\bar{P}_a = R_p\bar{Q}_r$$

Time Course of Arterial Flow

We can estimate change in arterial volume as:

Cardiac output

Runoff flow

Arterial volume change

$$\frac{d\bar{V}_a}{dt} = Q_h - Q_r \qquad (1)$$

Arterial compliance we define as

$$C_a = d\bar{V}_a/d\bar{P}_a \qquad (2)$$

Which we differentiate w.r.t time to get

$$\frac{d\bar{V}_a}{dt} = \bar{Q}_a = C_a\frac{d\bar{P}_a}{dt} \qquad (3)$$

Substituting (1) into (3), we get

$$Q_h - Q_r = C_a\frac{d\bar{P}_a}{dt} \qquad (4)$$

or

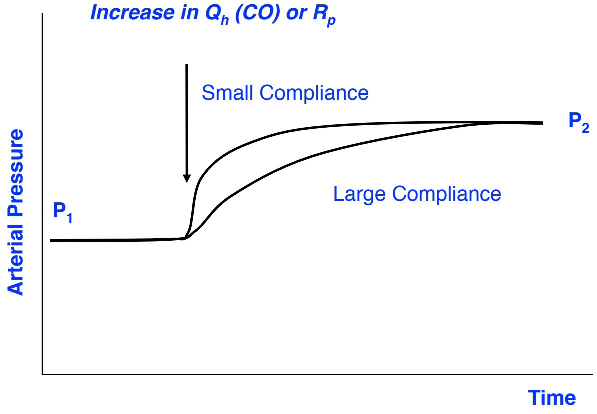
$$\frac{d\bar{P}_a}{dt} = \frac{Q_h - Q_r}{C_a} \qquad (5)$$

Arterial Pressure Response to Cardiac Output

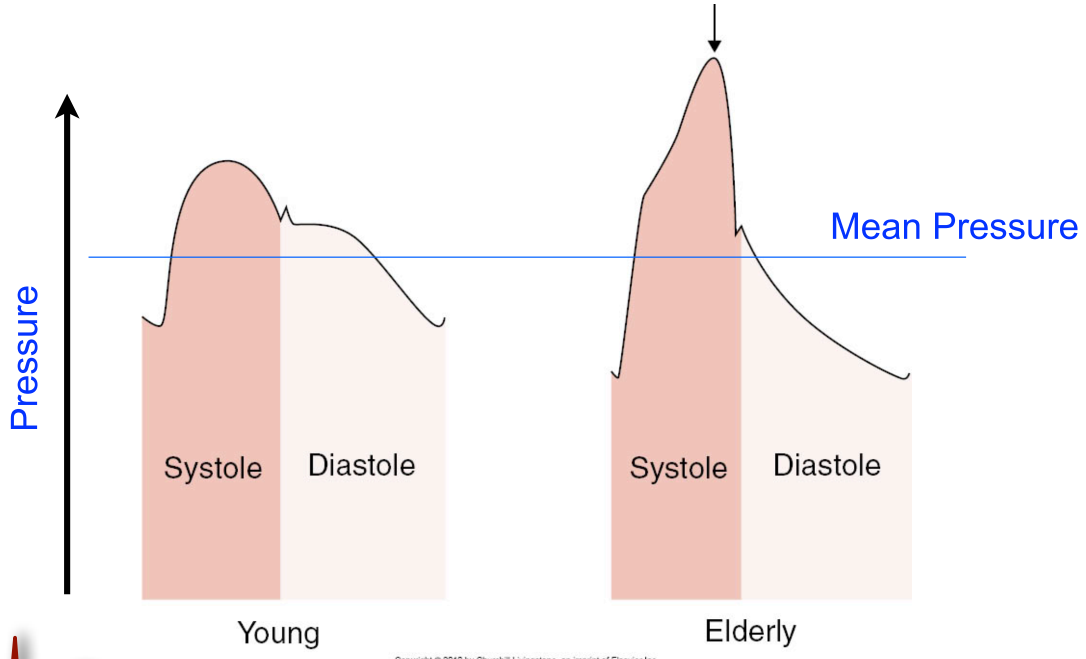
- Stable pressure determined by flow and peripheral resistance
- Increase in CO or R_p both increase pressure
- Pressure always changes to force CO to equal runoff flow
- Compliance affects rate but not final values

$$\bar{P}_a = R_p \bar{Q}_r$$

$$\frac{d\bar{P}_a}{dt} = \frac{Q_h - Q_r}{C_a}$$

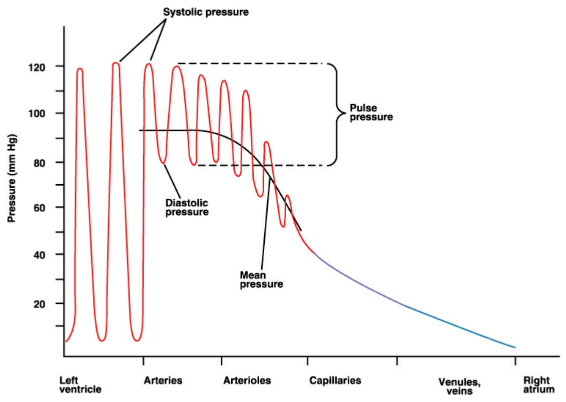


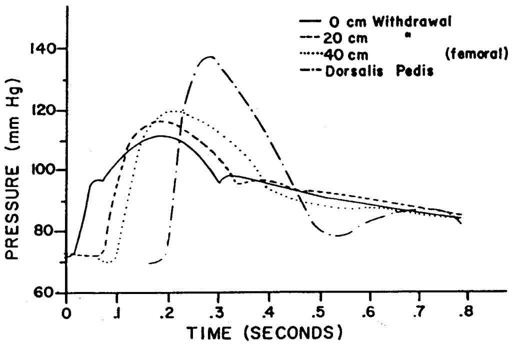
Pressure and Age (Compliance)



Peripheral Pulse Pressure

- Pressure wave velocity
  - $v_p = k/C$
  - v_p increases along the arteries and with age
- Pressure wave pulse amplitude grows with distance from heart
  - reflection/superposition
  - decrease in C
  - dispersion





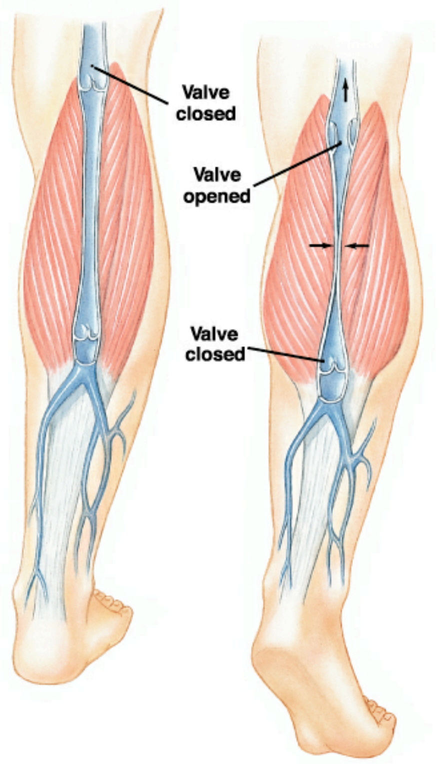
Venous System

Venous System

- Venous volume
  - Large volume, low pressure system
  - Reservoir of blood (50% of total volume)
  - Blood loss covered by venous system
    - Vasoconstriction, drinking (blood doning)
- Venous flow
  - Skeletal muscle activity
  - Valves
  - Breathing
  - Paristaltic contractions in venules

Venous Valves

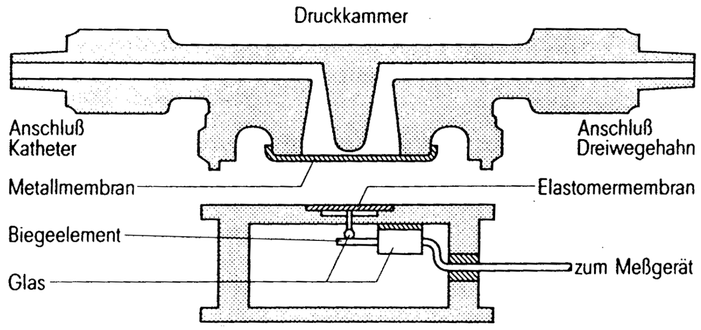
- Muscle pump
- Unidirectional flow
- Vericose veins

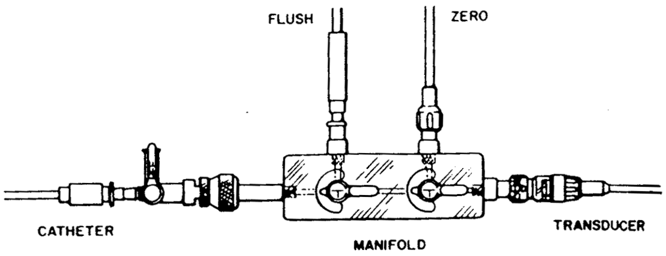


Measurement

Measuring Blood Pressure: Catheters

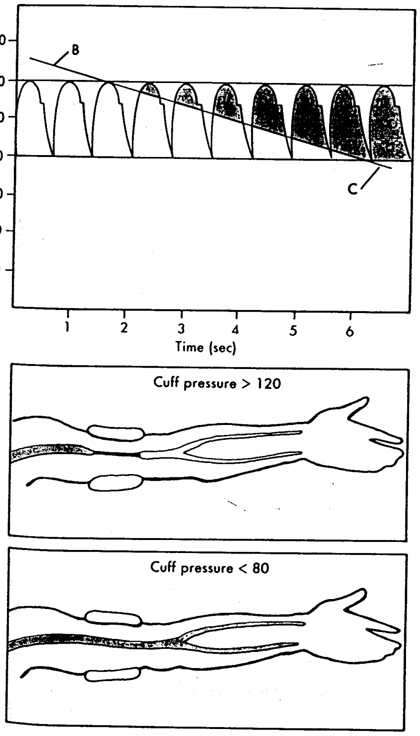
- Liquid column and external manometer
  - frequency response of transducer and fluid column
  - calibration and zeroing
  - motion artifacts
- Manometer-tipped catheters
  - higher frequency response
  - less motion artifact



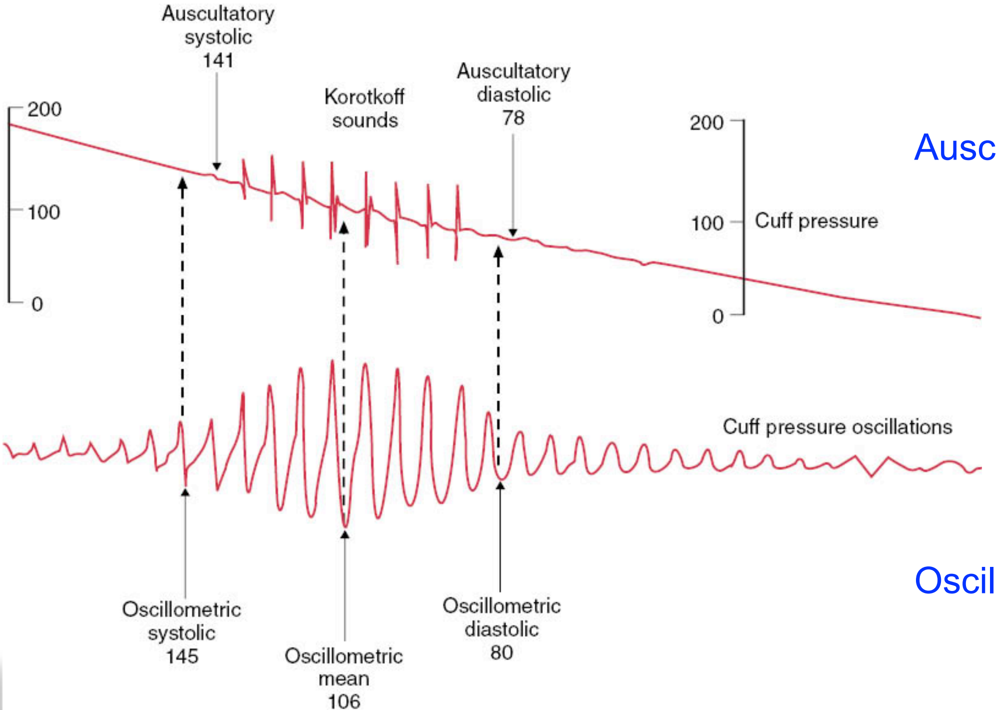


Auscultatory Blood Pressure Method

- Effect of arm position
- Alternate measurement locations (leg)
- Pressure varies during the day (lowest during sleep)
- Psychological bias in measurements (in subject and operator)



Automated Pressure Measurement



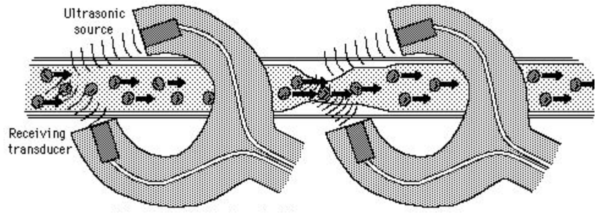
Ausculatory

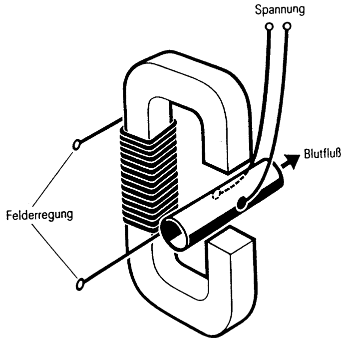
Oscillometric

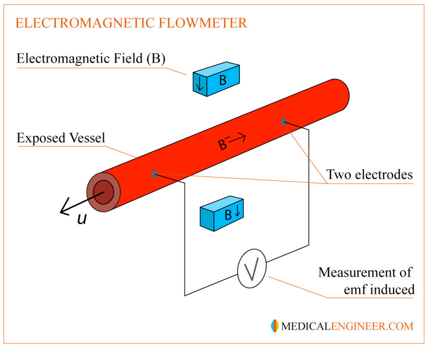
(From Geddes LA: Cardiovascular Devices and Their Applications. New York, John Wiley, 1984, Fig. 34-2. Reprinted by permission of John Wiley & Sons, Inc.)

Measuring Blood Flow

- Ultrasound flowmeter (velocity)
- Electromagnetic flowmeter (velocity)
- Thermal dilution
- Functional MRI (diffusion or oxygenation)







Measuring Blood Flow II

- Bioelectric impedance (plethysmography)
- Light (pulse oxymetry)