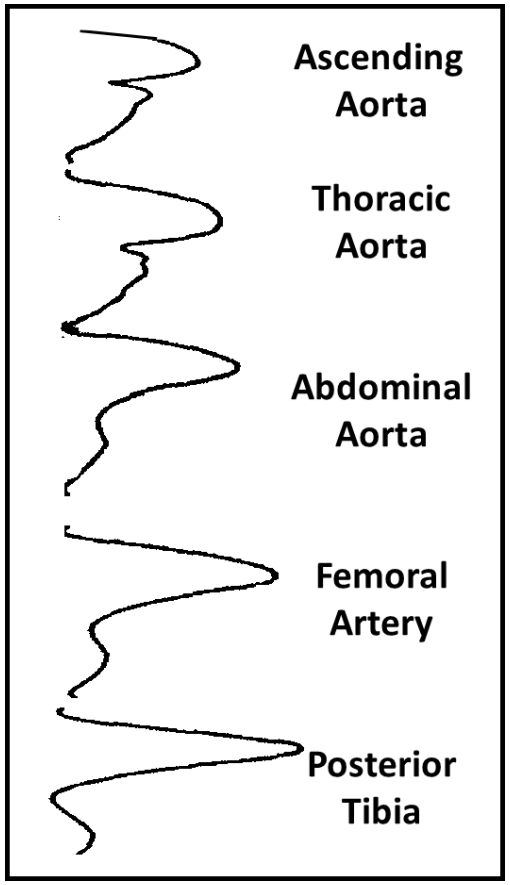
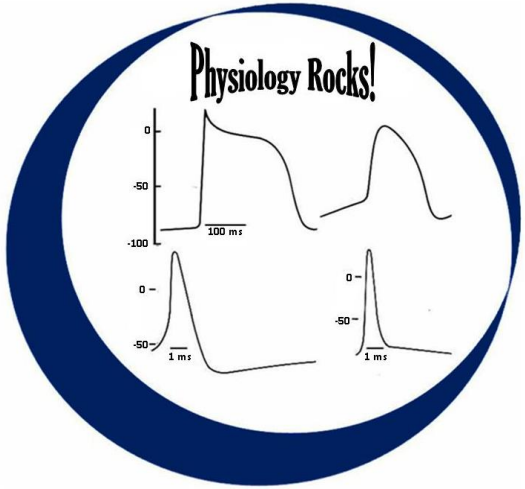
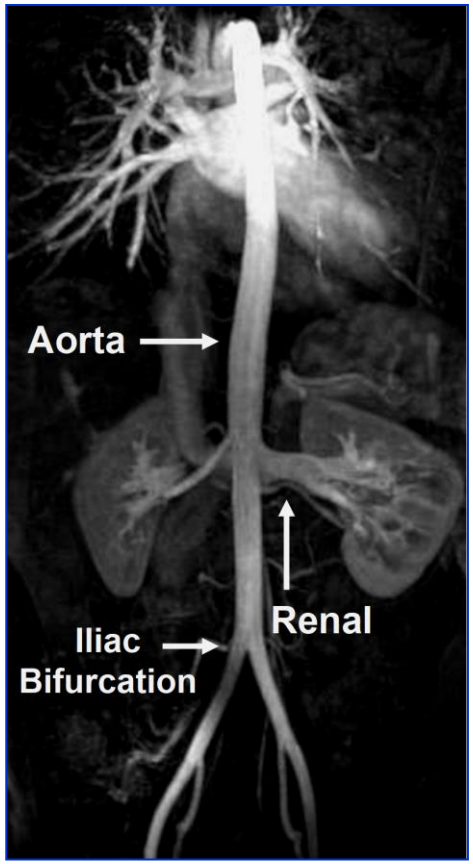
Lecture 30

Arterial Pressures-Pulses-Propagation







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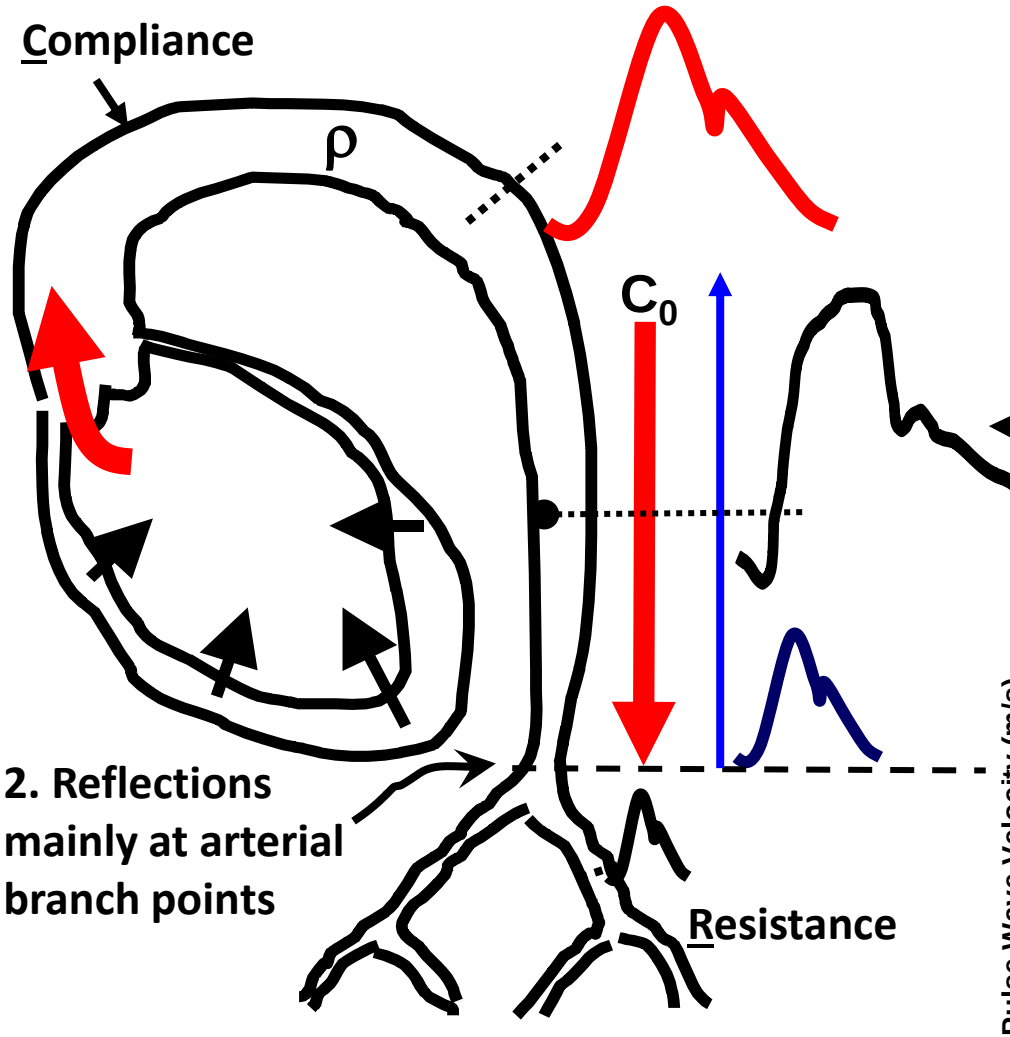
Transmission and Reflection of Pulses

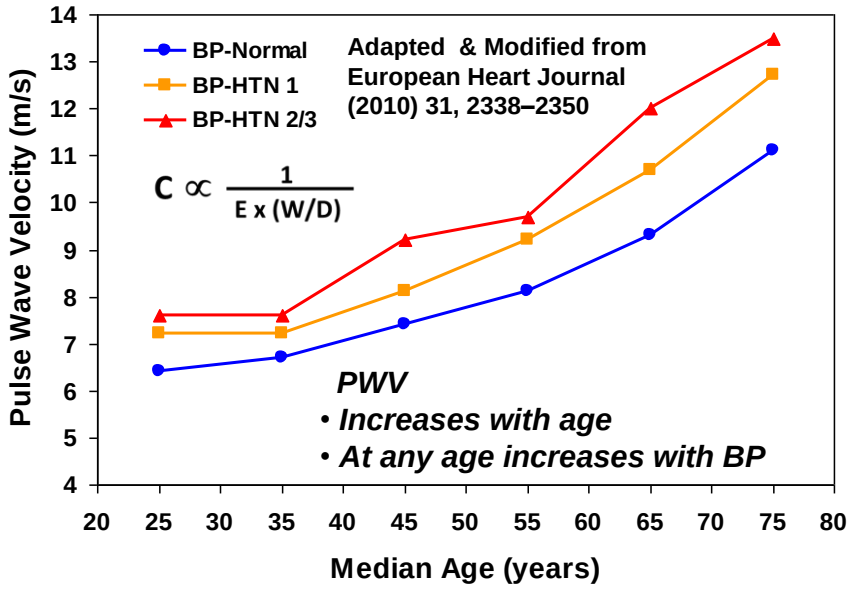


1. Pulse "wave-speed" (C_0) is inverse to Compliance (C)
Stiffer arteries ~ higher speed

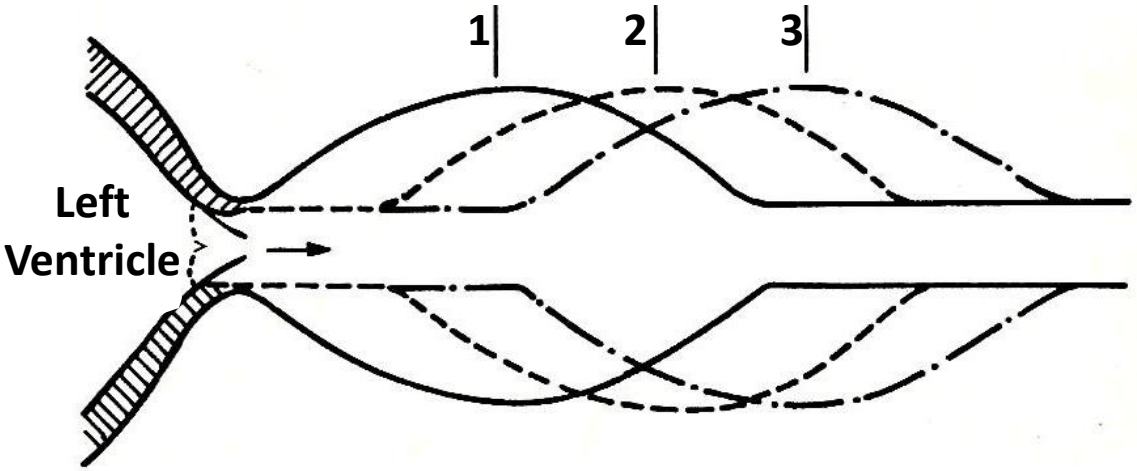
$$c_0 \sim \sqrt{\frac{1}{\rho C}}$$

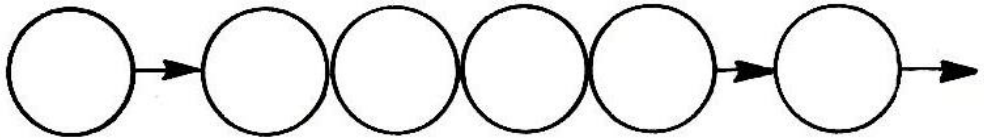
3. Pulse is algebraic sum of forward & backward pulses

2. Reflections mainly at arterial branch points



Arterial Pulse Wave Transmission Process

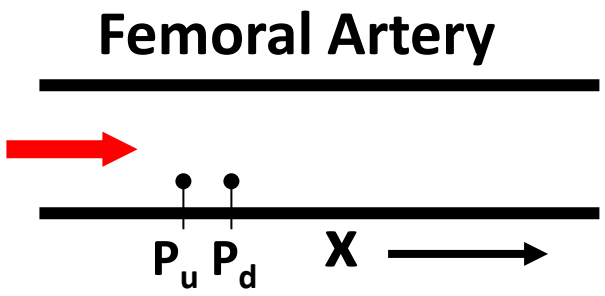




Billiard Balls with Impact Transmission

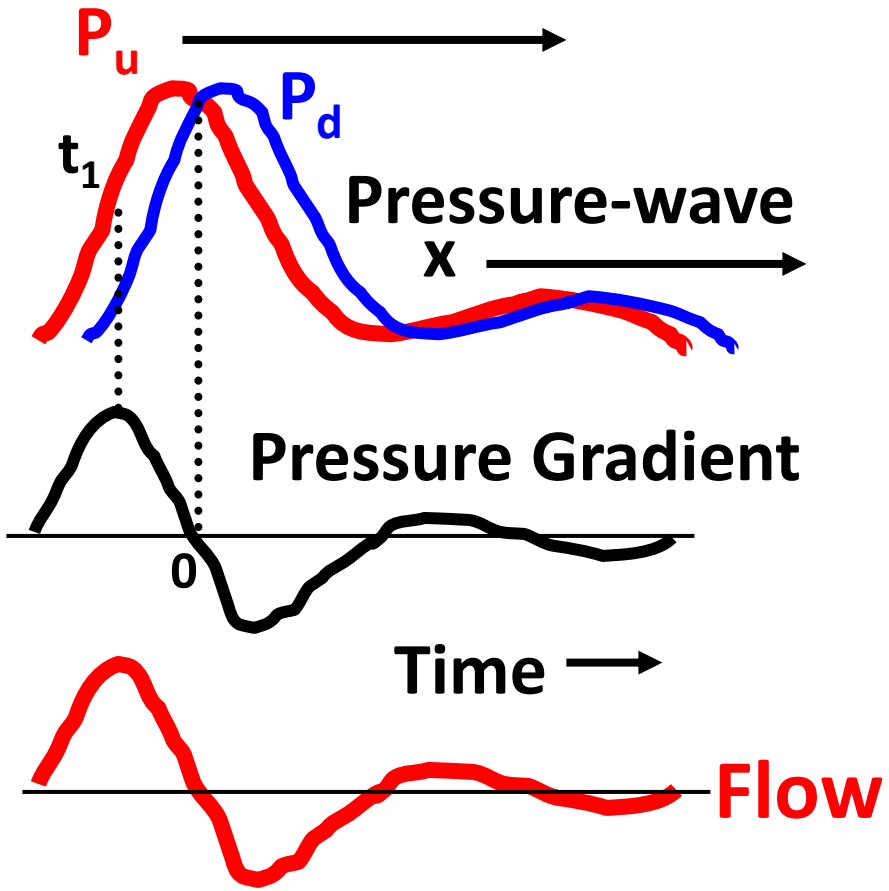
- Volume ejected initially distends aortic wall at 1 and progresses to site 2 and then to site 3 as a pulse wave
- Wave speed much greater than speed that blood cells themselves move
- Pulse wave speed vs blood velocity concept can be compared to the impact on a billiard ball combination
- The end ball moves off quickly (high speed transmission) but the group hardly moves
- Pulse wave speed is inverse to the square root of the vessel compliance wall in which the wave is travelling

Pressure Gradient Produces Pulsatile Blood Flow

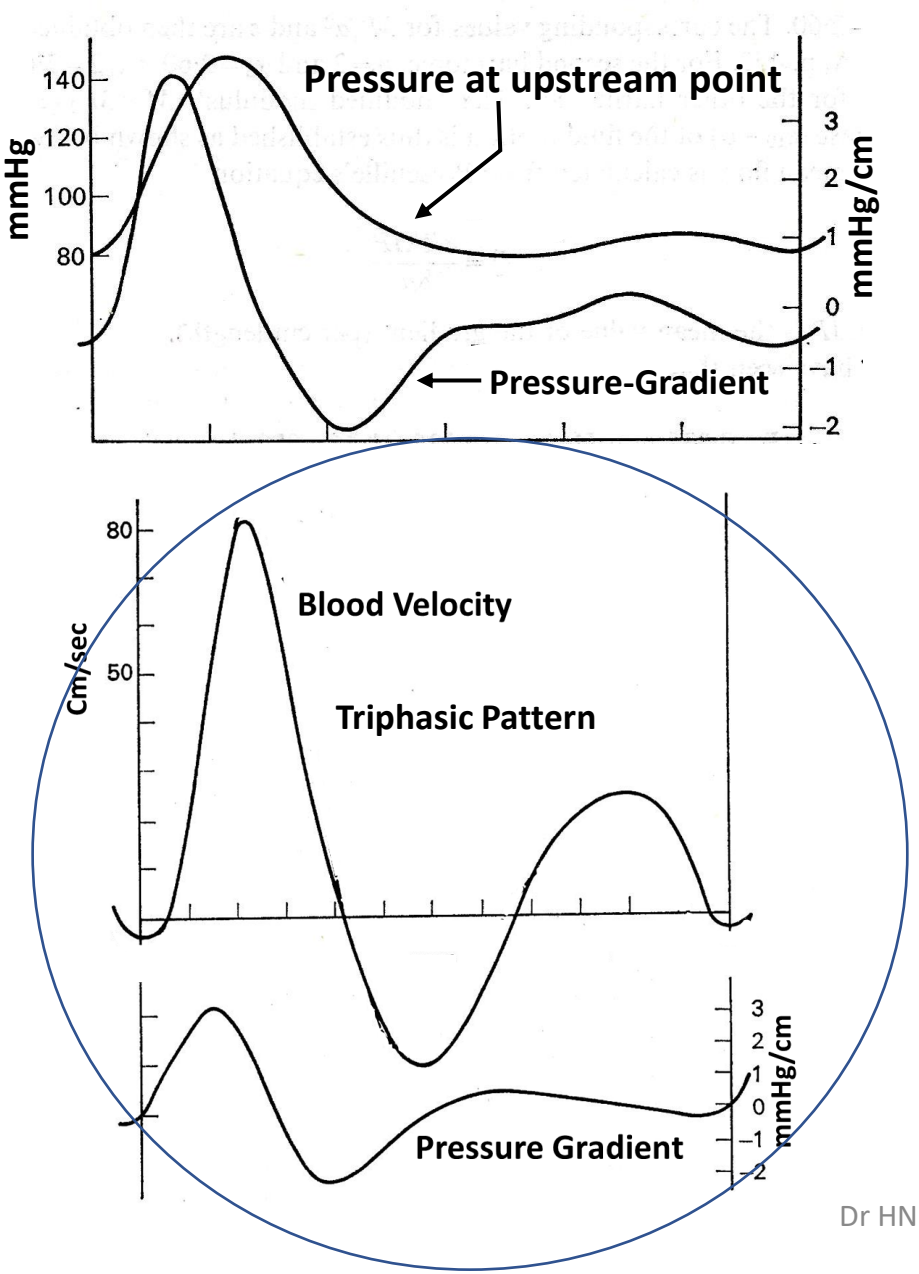


$$\frac{P_u - P_d}{dx}$$ Pressure gradient (space derivative)

1. Pressure gradient (not pressure) determines pulsatile blood flow
2. Pressure gradient depends on wave speed

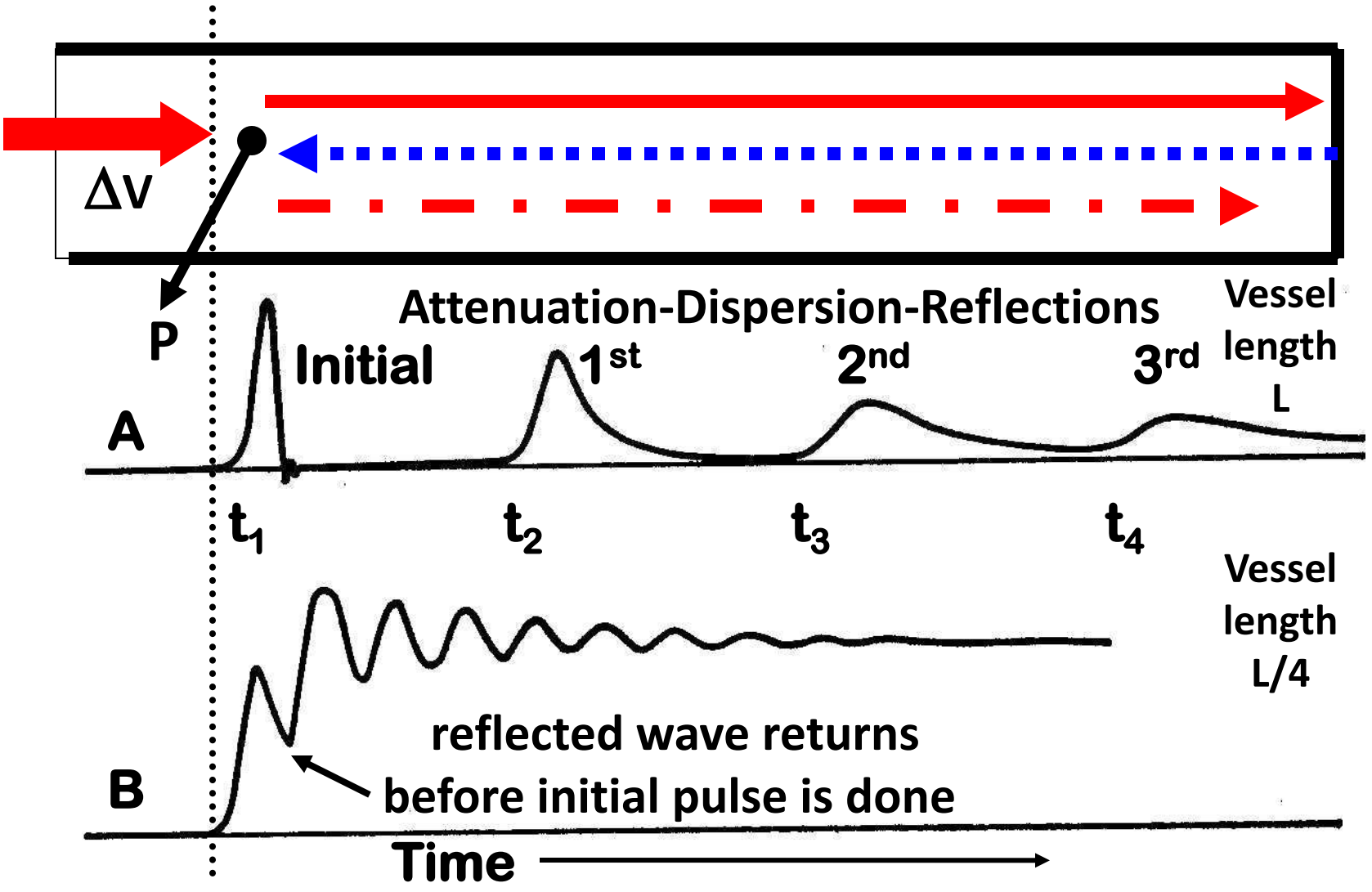


Arterial Pressure vs. Pressure Gradient: Summary



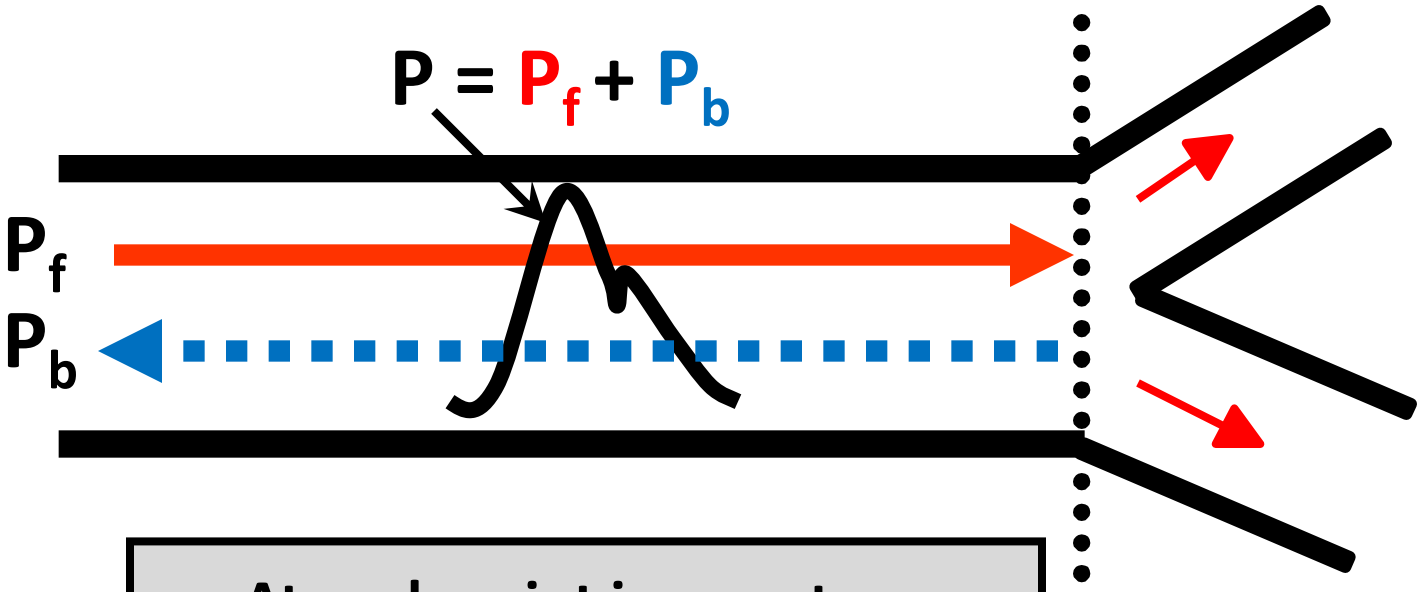
- Pressure is measured in a femoral artery at two sites separated by 5 cm
- Pressure difference (upstream – downstream) is calculated and the difference divided by the separation → this is the pressure-gradient
- It is pressure-gradient that is the driving force to cause pulsatile blood flow NOT the pressure!
- The intensity and pattern of the pulsatile flow depends on the intensity and pattern of the pressure gradient
- Note the similarity of the patterns of blood velocity and pressure gradient

Multiple Pulse Wave Interactions



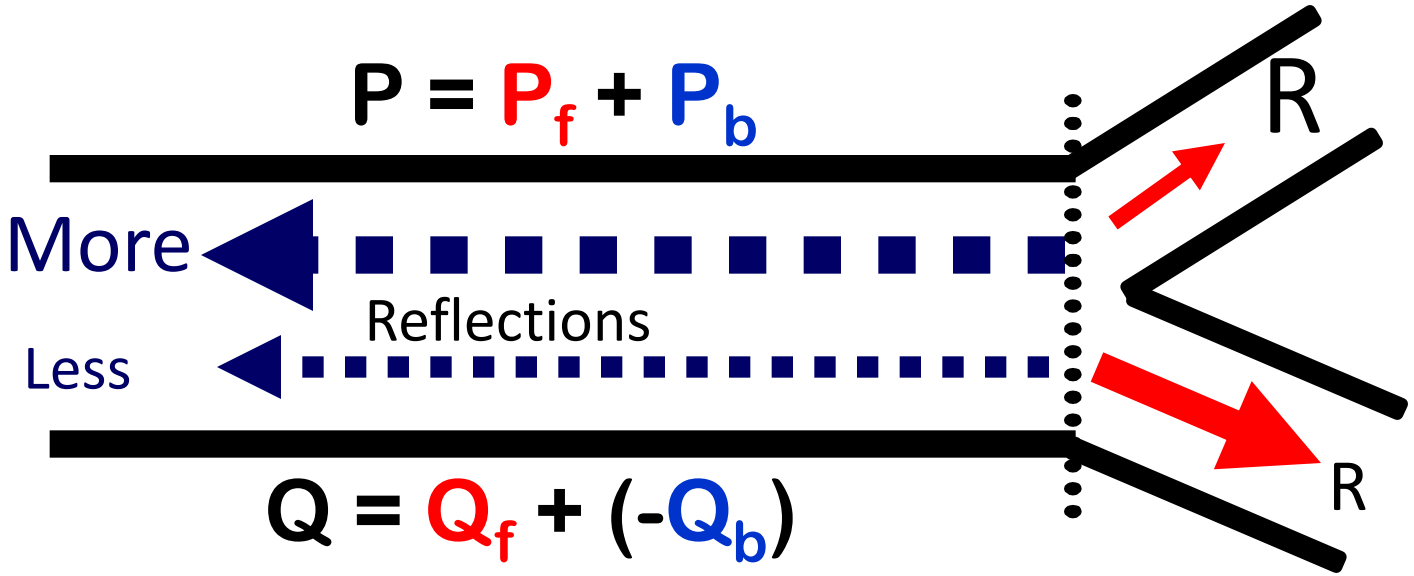
Pulse Reflections and Related Issues

Forward and Backward Waves



At each point in an artery,
COMPOSITE P & Q pulses
are composed of the sum of
forward & reflected pulses
Reflected P-waves ADD
Reflected Q-waves SUBTRACT

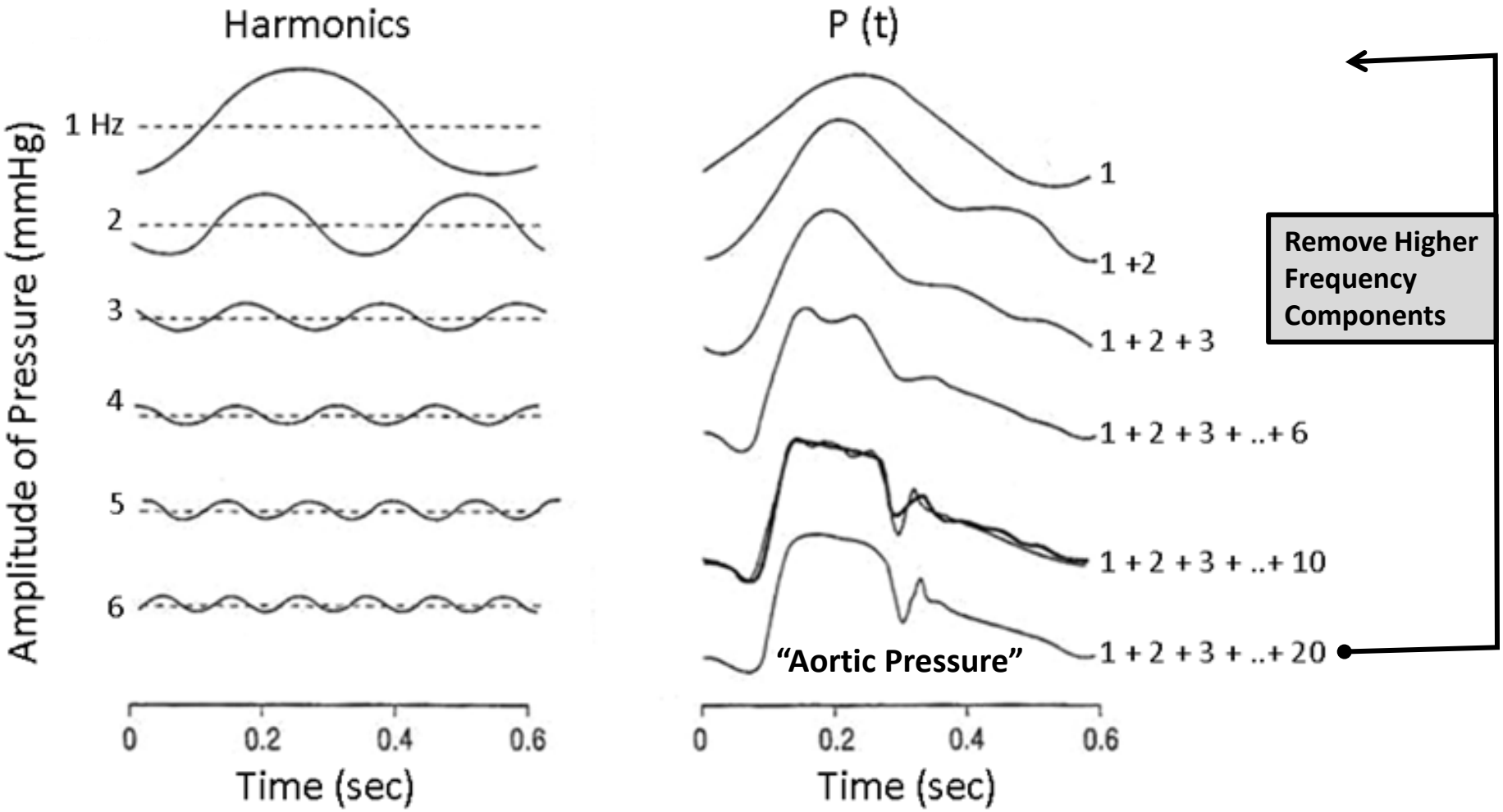
Reflection and Resistance



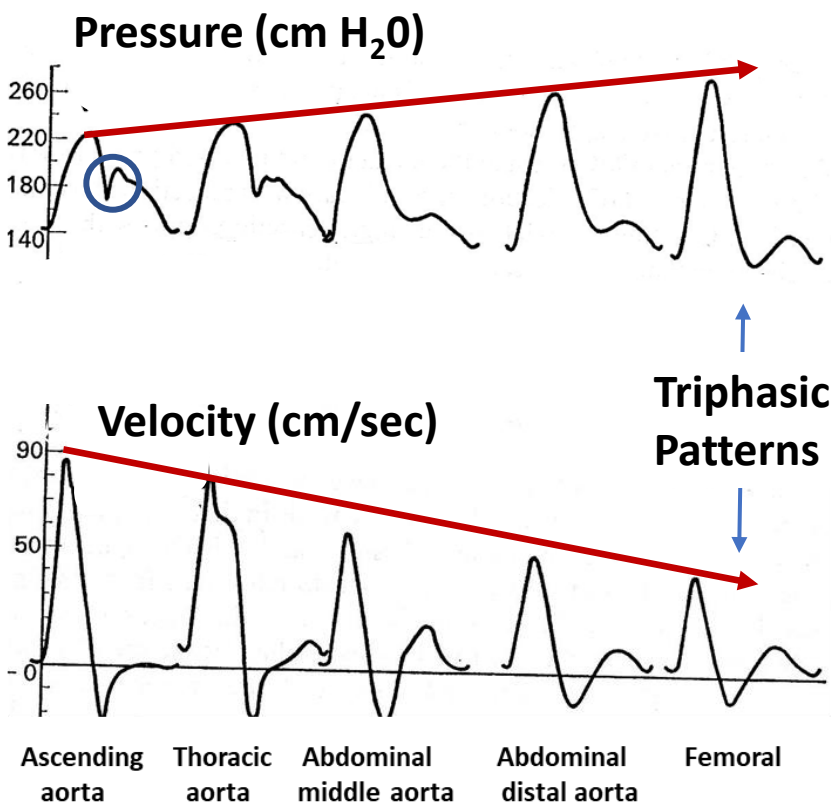
Reflected energy (P & Q) is less if branch pathways lead to vascular beds that have less Resistance. Reflection is greater if these have greater R.

Spectral Content of Pressure and Flow Pulses

Heart Rate = 60 beats/min = 1 beat/sec = 1 Hz = 1st Harmonic

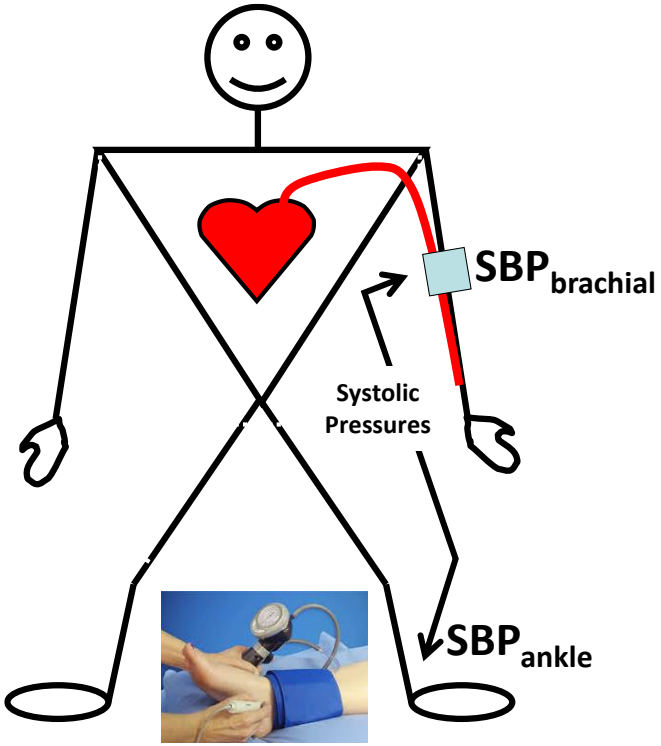


Pulse Pressure Variations with Arterial Position



- Pressure pulses increase and smooths from aorta toward periphery
- Factors involved are due to combined effects of
  (1) high frequency filtering because arterial system acts a low frequency filter
  (2) greater transmission speed of higher frequency components (fast upstroke part) because wall does not expand rapidly enough
  (3) wave reflections due to interactions
- Peak blood velocity decreases with distance but the smoothing of the waveforms occurs for the same reasons as the pressure effects
- Pulse wave velocity increases in more peripheral arteries due to compliance decrease

Ankle Brachial Systolic BP Index (ABI)



ABI = (Ankle/Brachial) Systolic Pressure

Normal → 1.00 – 1.40

Borderline → 0.90 – 0.99

< 0.90 → Abnormal

Claudication →

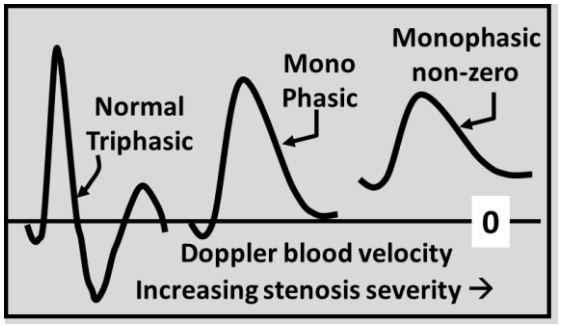
Rest Pain →

0.80 – 0.89 Mild Blockage

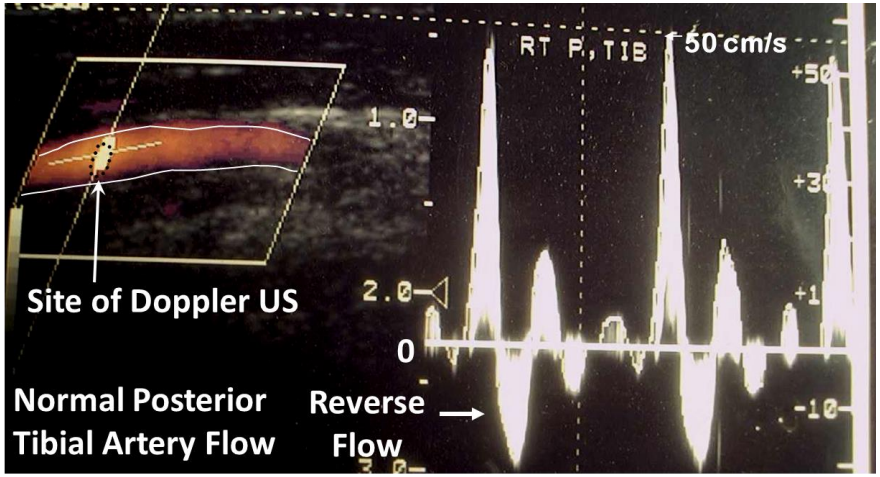
0.50 – 0.79 Moderate Block

< 0.50 Severe Block

Triphasic pattern lost due to upstream stenosis

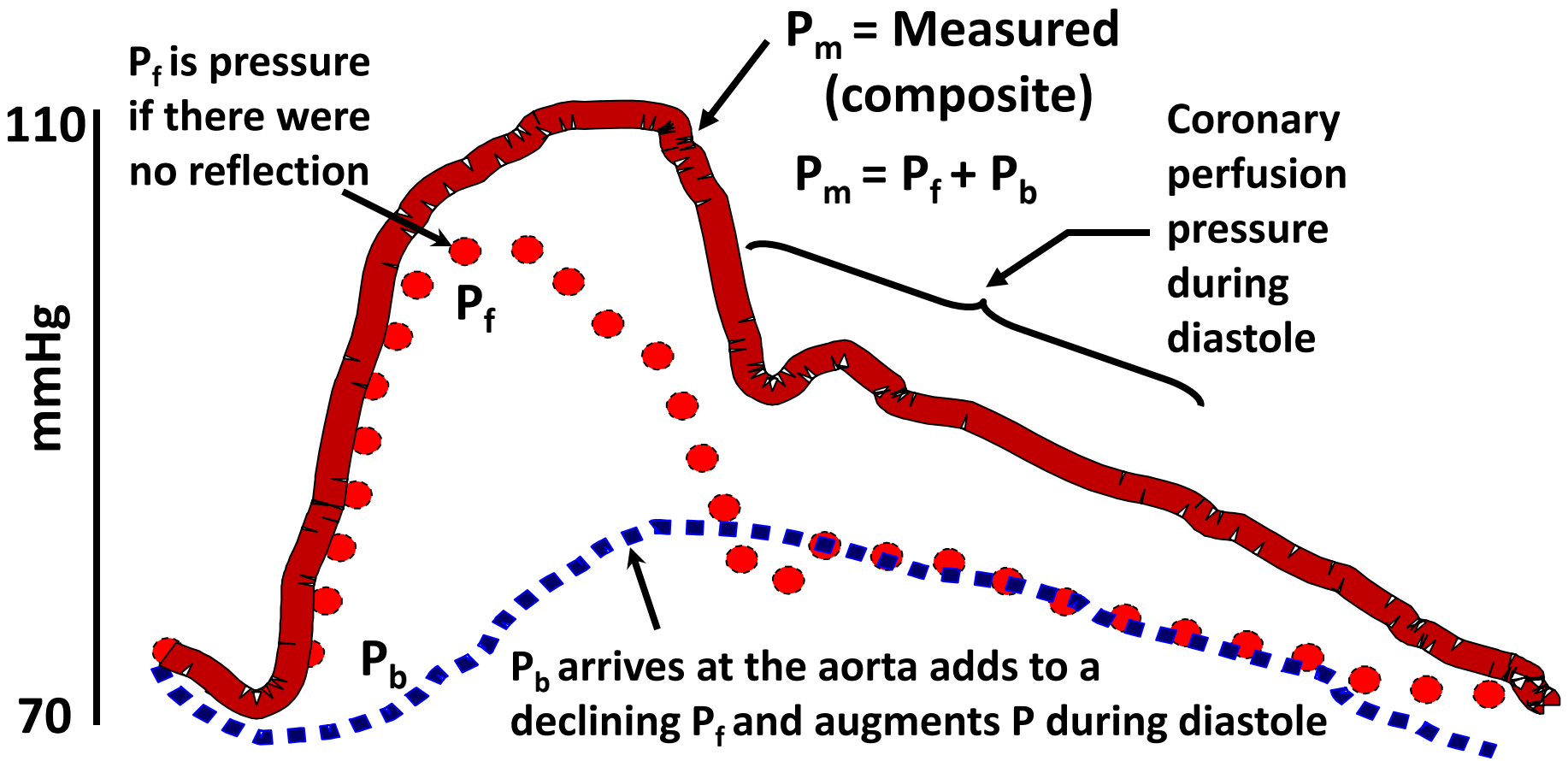


Normal Velocity Pulse Pattern is Triphasic

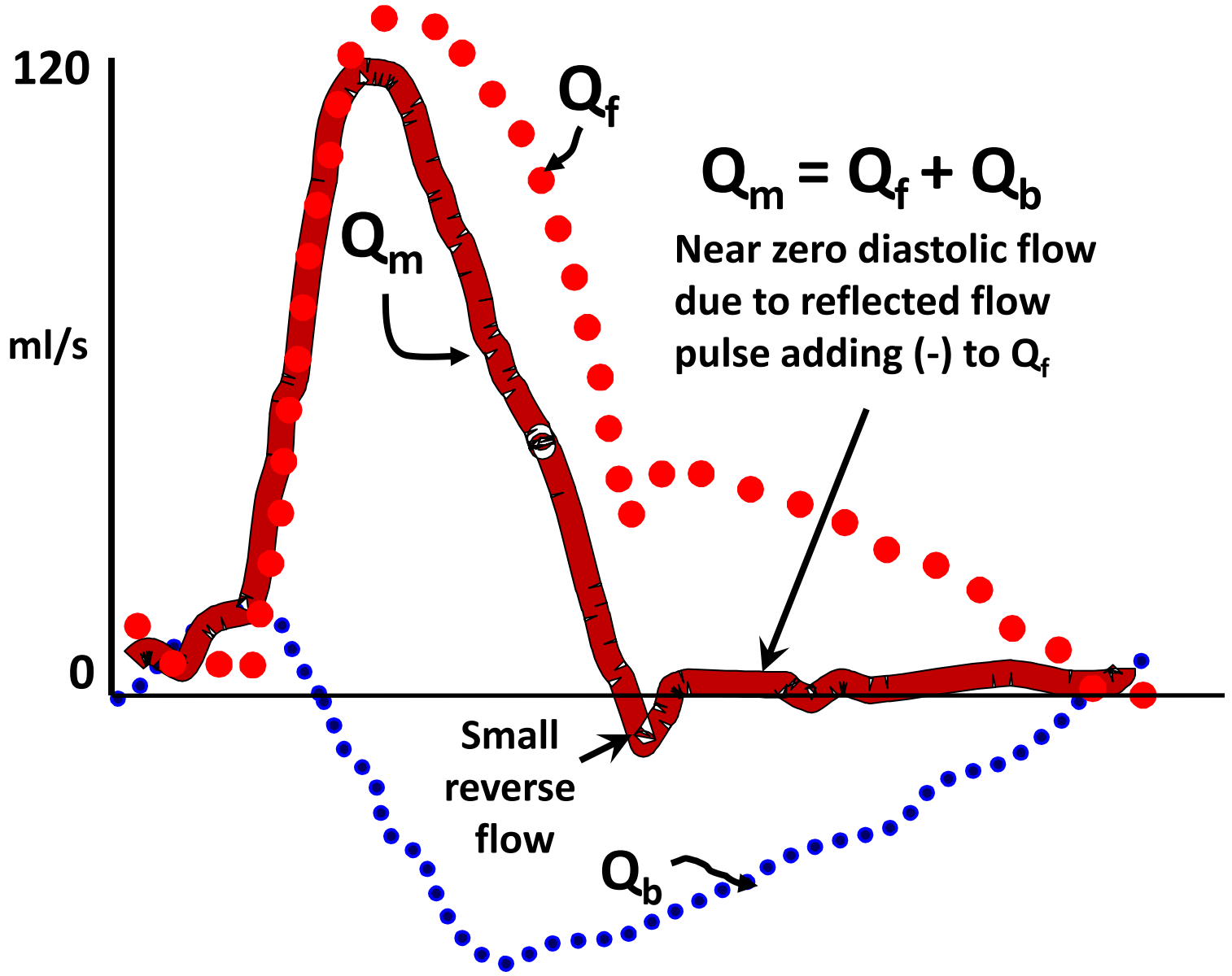


Manifestations of Pulses

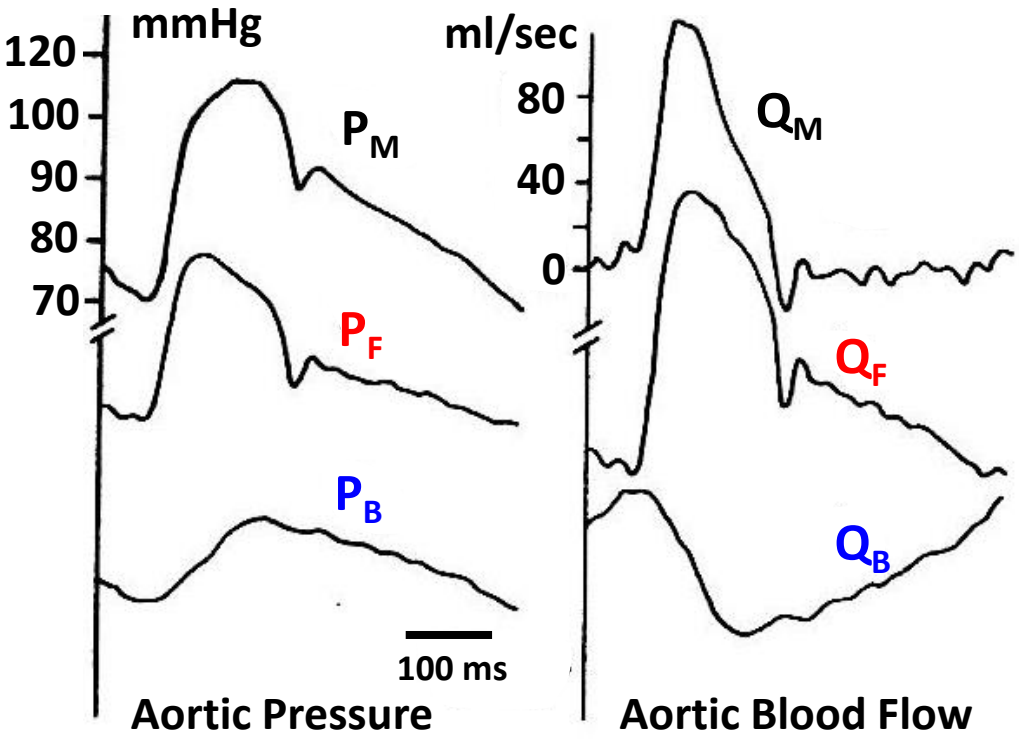
Forming Normal Ascending Aortic Pressure



Forming Normal Ascending Aortic Blood Flow



Aortic Pressure and Flow Reflections: Summary



Subscripts F and B denote forward and backward wave components. Subscript M denotes measured value that depends on both forward and backward waves

Take Hope Points

- **Forward and backward *pressure* waves *add* to form measured (P_M) pressure.**
- **Backward *flow* wave *subtracts* from the forward wave to form the measured flow (Q_M)**
- **A greater pulse wave speed causes reflected waves to arrive back to the aortic site earlier causing an elevation in early systolic pressure and a reduction in diastolic pressure**
- **These effects cause an increase in cardiac afterload and decreased coronary perfusion respectively.**
- **The effect of earlier flow pulse return is to decrease net measured blood aortic pulse flow**

Central Pressure Augmentation via Pulse Reflection

Age related issues

↓

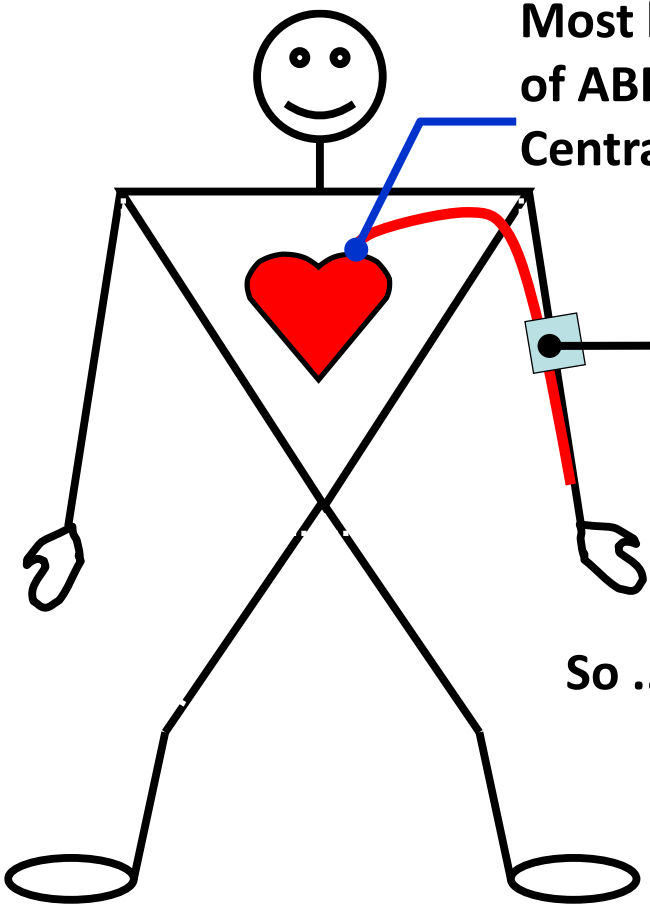
- compliance

↓

+ wave speed

↓

reflected wave earlier return



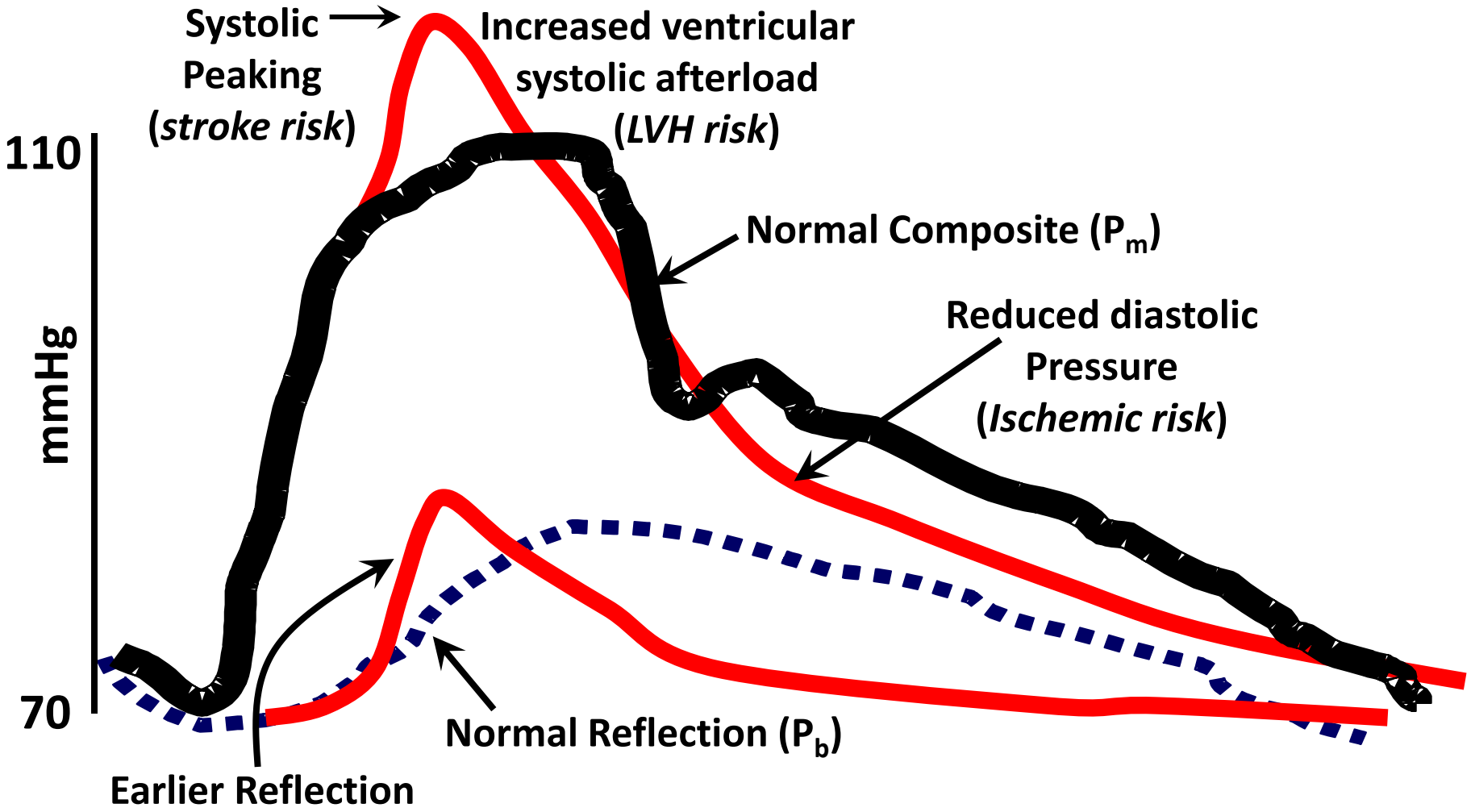
Most heart-related effects of ABP due to increased Central Artery Pressure

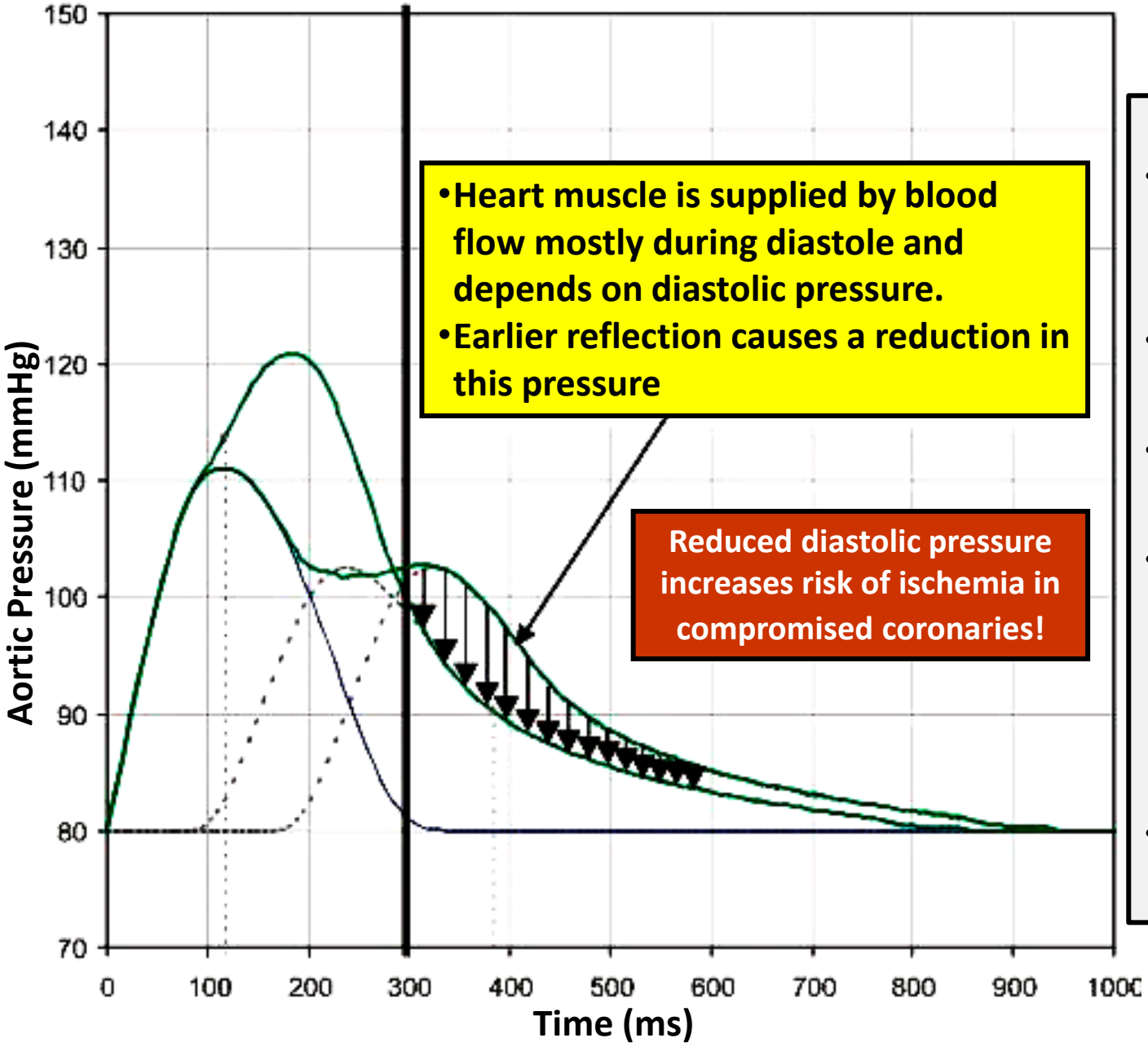
But ABP measured here

So .. What are we MISSING?

Central Pressure Augmentation →

Central Pressure Augmentation





SUMMARY

- Earlier return of reflected wave causes augmentation of aortic pressure
- This occurs if wave speed increases
- Low arterial compliance is a major factor
- Effect increases central BP that causes increased afterload and reduces aortic diastolic coronary perfusion pressure
- Complications include stroke risk and LVH

Interactive Question

The figure shows pressure pulses in Ana's brachial and posterior tibia arteries.

Which best describes Ana?

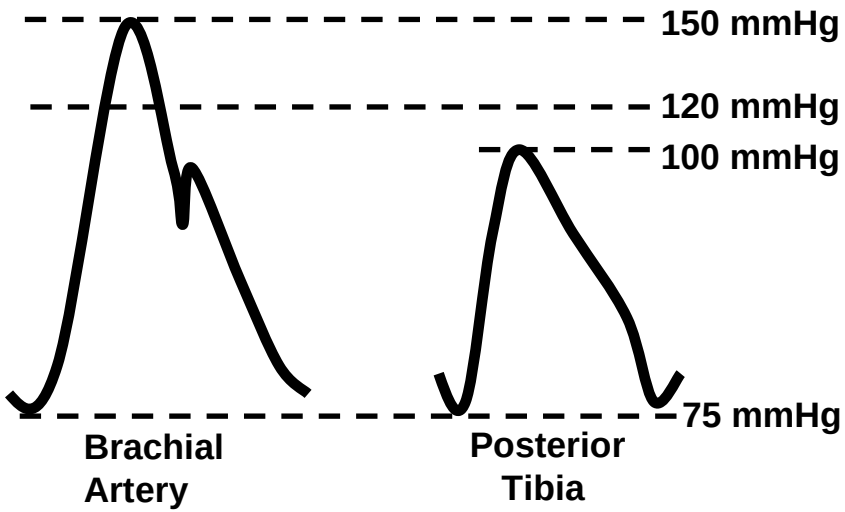
A. She is hypertensive with normal pulses in both arteries

B. Her ABI is less than 0.7 which is abnormal

C. She likely has rest pain due to her condition

D. Her ABI is less than 0.5 indicating a critical stenosis

E. She shows little evidence of significant arterial disease



End of Lecture 30
Your Questions if Time