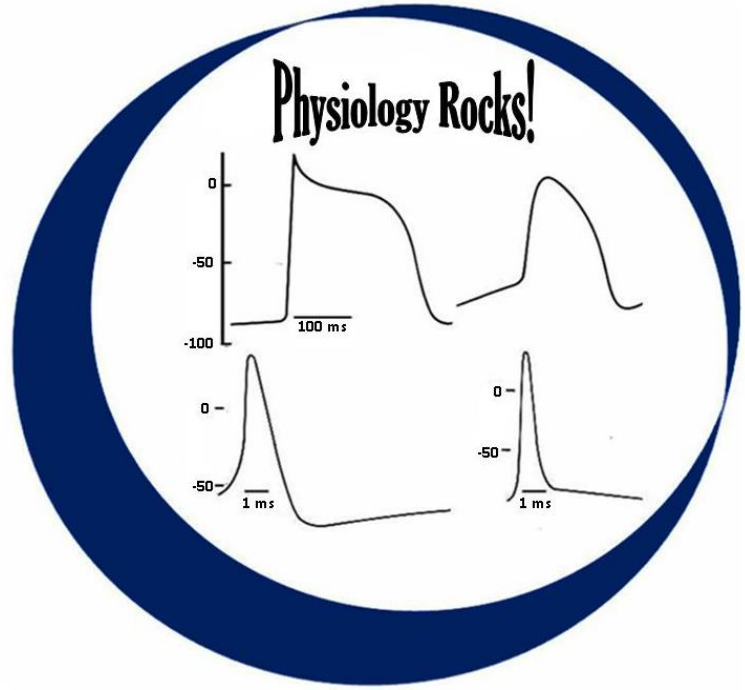
Lecture 5
Blood Flow, Pressure & Resistance - 2



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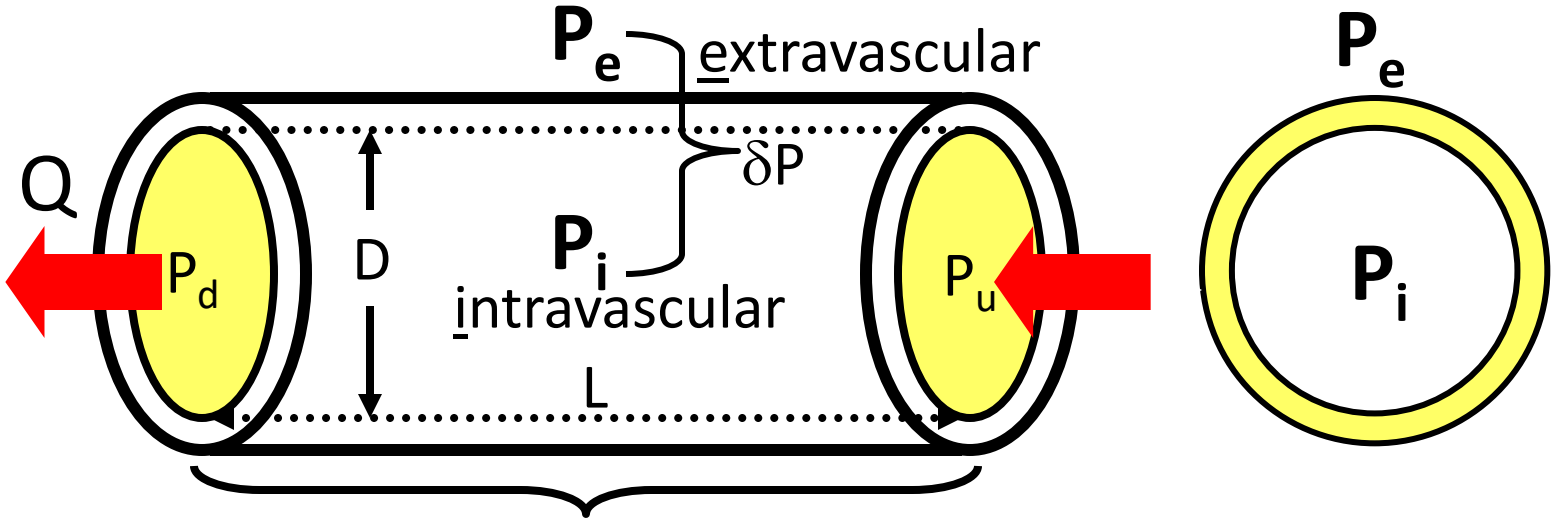
Topics

- Pressures and resistance of individual blood vessels
- Blood flow, velocity, and shear in individual blood vessels
- Blood's viscosity and its effects
- Laminar and turbulent blood flow considerations
- Hemodynamics of cardiac valve and vascular stenosis
- Vascular partitioning for blood flow and pressure calculations
- Blood flow in collapsible vessels
- Interactive questions
- What's your diagnosis

Pressures and resistance in individual vessels



ΔP = Perfusion Pressure

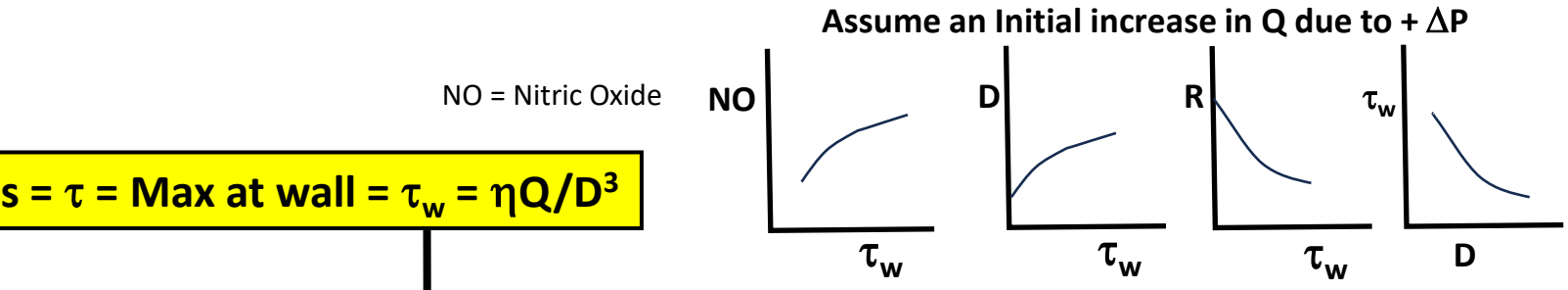
Pressure = Force/Area = Energy/Volume
[dynes/cm^2 or mmHg]

- **Perfusion Pressure = $P_u - P_d = \Delta P$**
- **Transmural Pressure = $P_i - P_e = \delta P$**

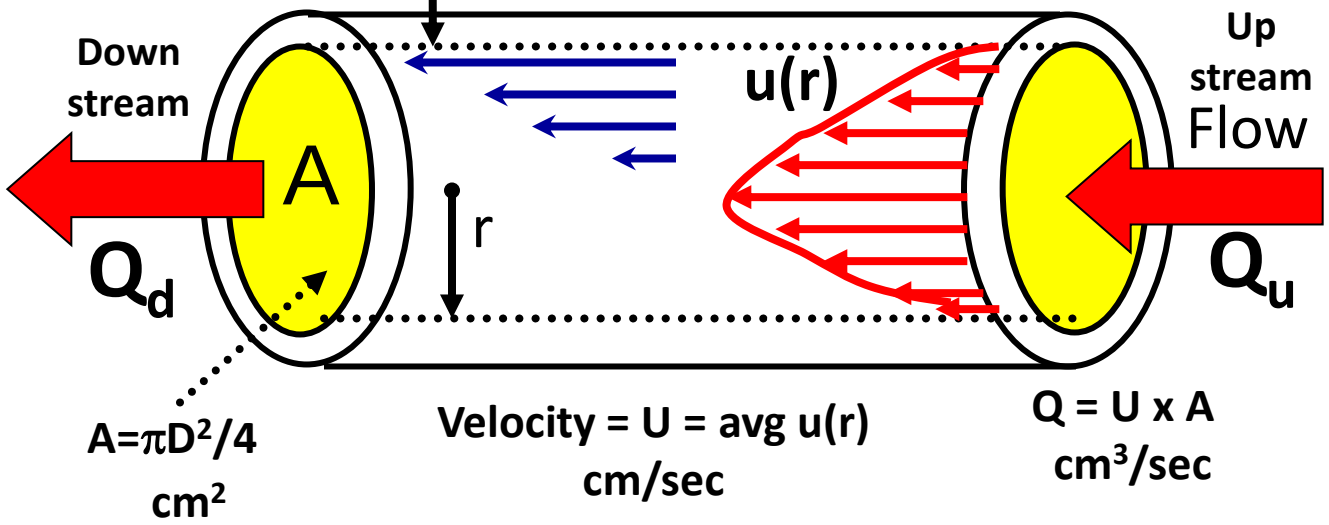
- **Resistance $R = (128/\pi) \times \eta \times (L/D^4)$**

η = Blood Viscosity

Blood Flow vs. Blood Velocity vs Shear



Shear Stress = τ = Max at wall = $\tau_w = \eta Q/D^3$



$A=\pi D^2/4$ cm^2

Velocity = U = avg u(r) cm/sec

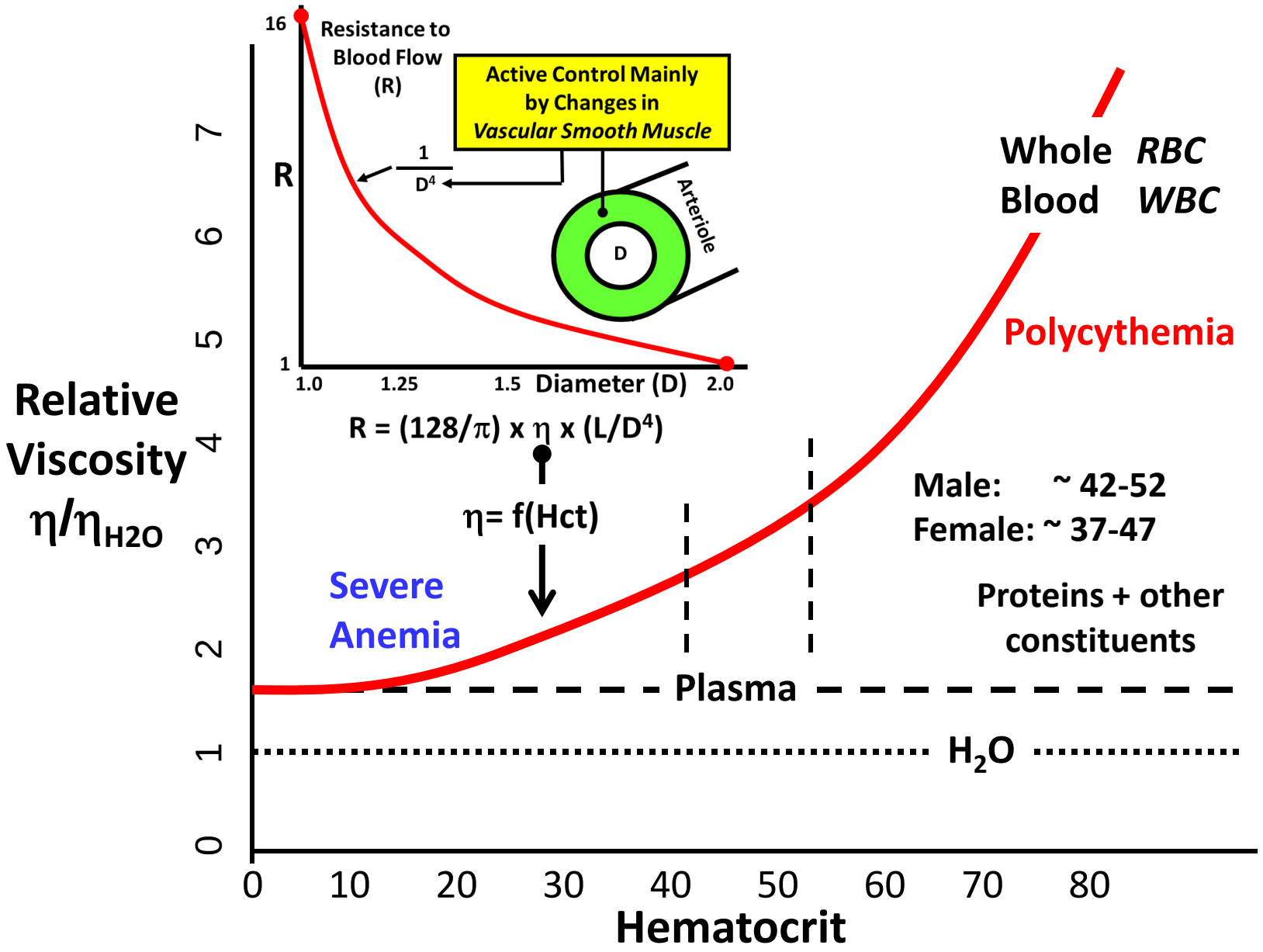
Q = U x A cm^3/sec

For a given Flow, Velocity is *inverse* to Area $U = \frac{Q}{A}$

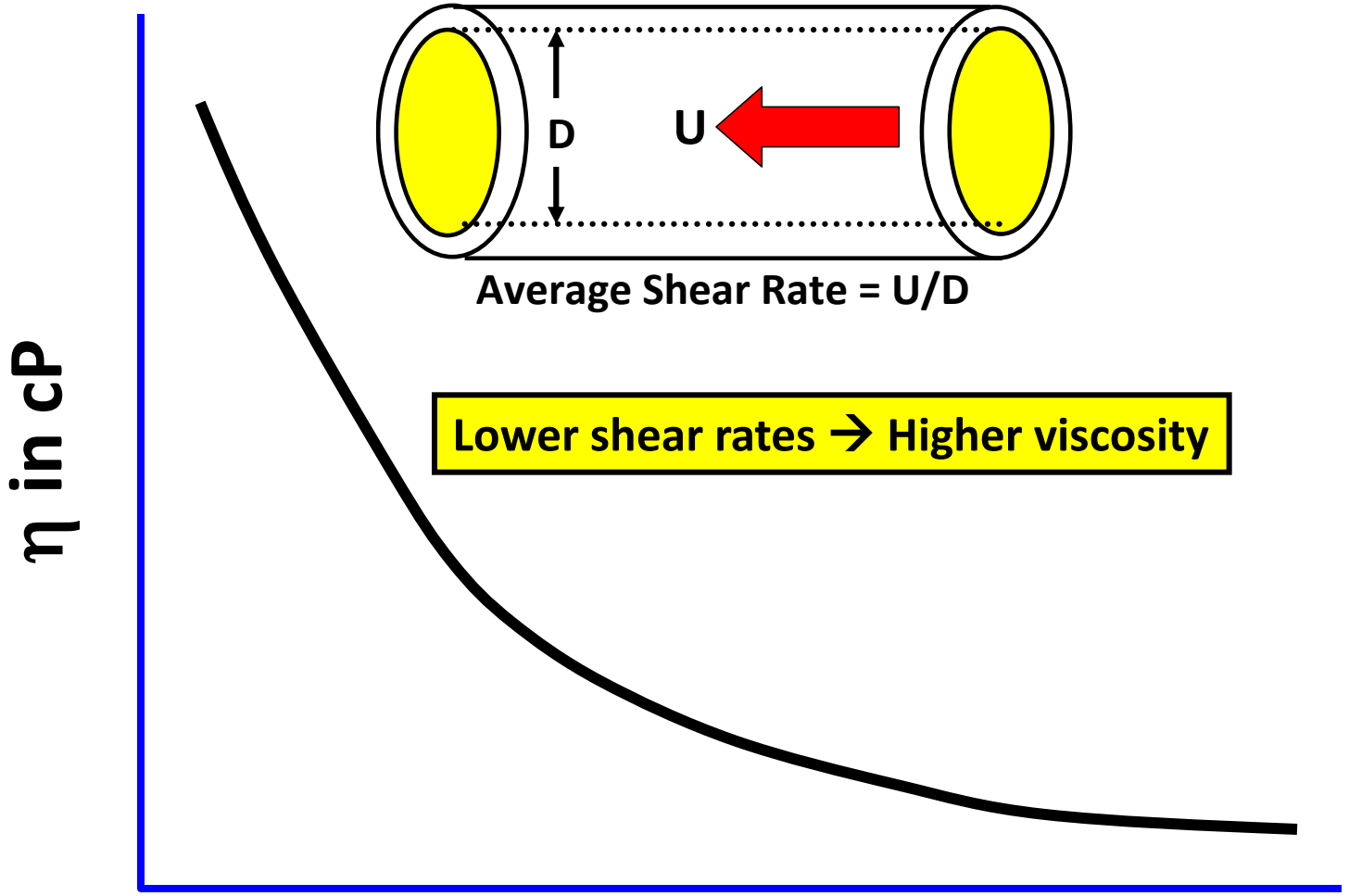
Velocity gradient = du/dr = Shear Rate; $\tau = \eta$ x du/dr

The more rapidly velocity changes in radial direction, the greater is the local shear stress
This will act to reduce the tendency for cell interactions and thrombus formation
Conversely, low τ caused by either low Q or larger D tend to cause the opposite

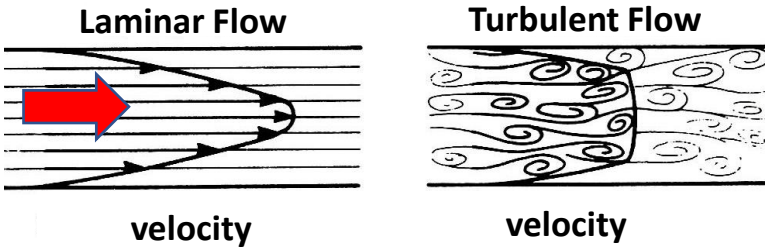
Resistance depends on Diameter (D) & Viscosity (η)

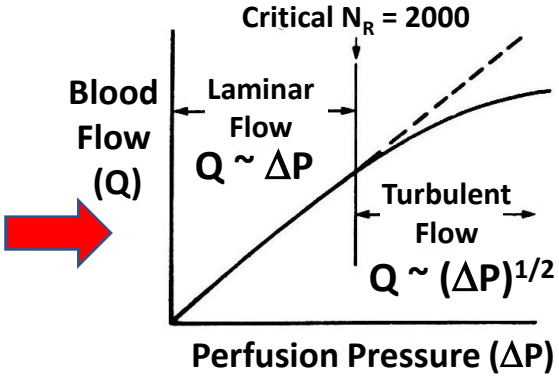


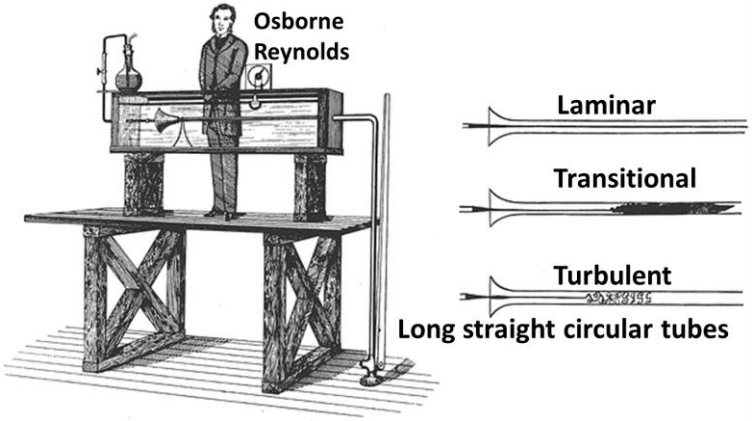
Blood Viscosity Depends on Shear Rate



Laminar vs. Turbulent Blood Flow



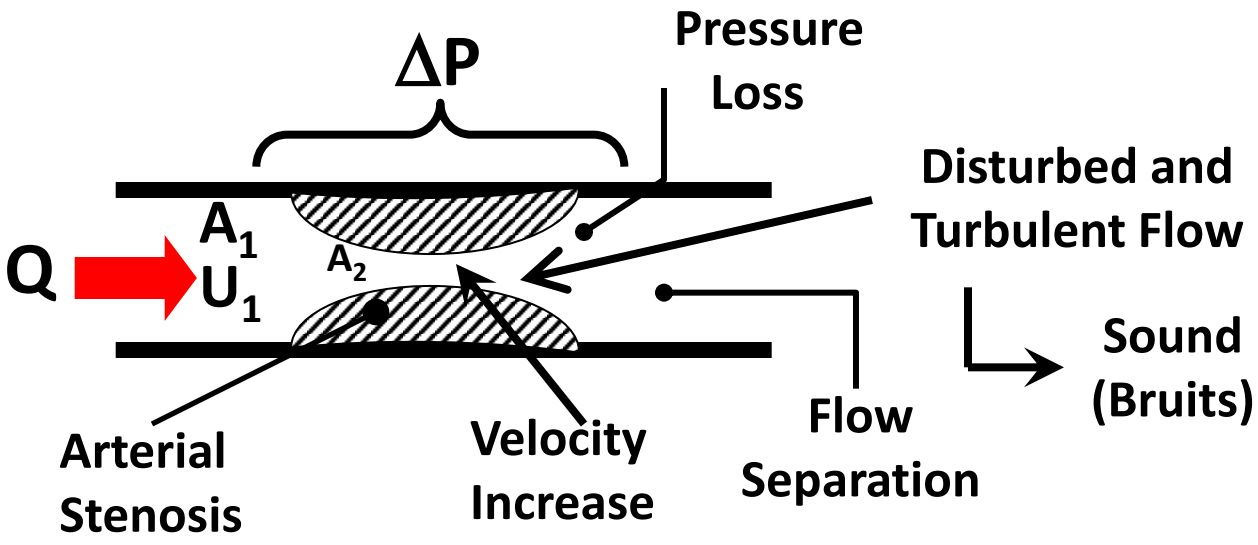




- **Laminar** flow has **steady streamlines** with no crossover and flow (Q) vs. perfusion pressure (ΔP) is linear
- **Turbulent** flow has **chaotic stream lines** that cross each other causing additional energy loss
- Added energy loss increases resistance to flow requiring more perfusion pressure so **Q not ~ ΔP** as in laminar flow but is **$Q \sim (\Delta P)^{1/2}$** for turbulent flow
- Transition from laminar to turbulent occurs at a critical value of **Reynolds number** (N_R) that depends on blood's density (ρ) , viscosity (η) and velocity (U) and vessel diameter (D) as: **$N_R = U \times D \times (\rho/\eta)$**
- The **critical Reynolds number** (**N_{RC}**) has a value of **2000**
- An alternate form, useful when Q is known is

  $N_R = (4/\pi) \times Q/D^2 \times (\rho/\eta)$
- Turbulence: more likely at **high blood flow** or velocity and **reduced blood viscosity**
- For fixed blood flow, turbulence is more likely at areas of diameter reduction (vascular or valvular **stenoses**).
- If turbulence occurs sounds it generates are **murmurs**

Arterial Stenosis: Increased Velocity - Turbulence

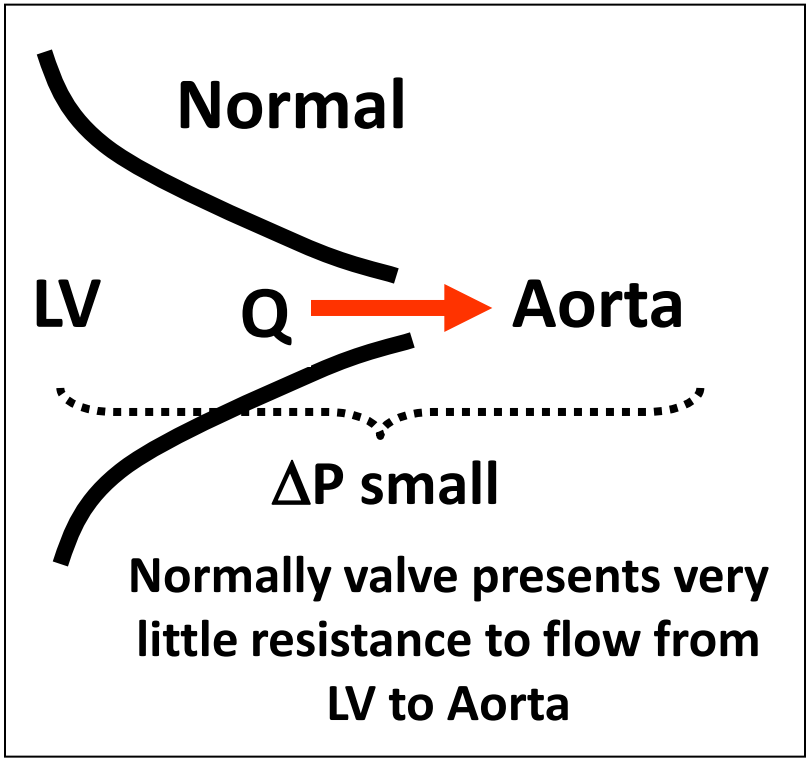


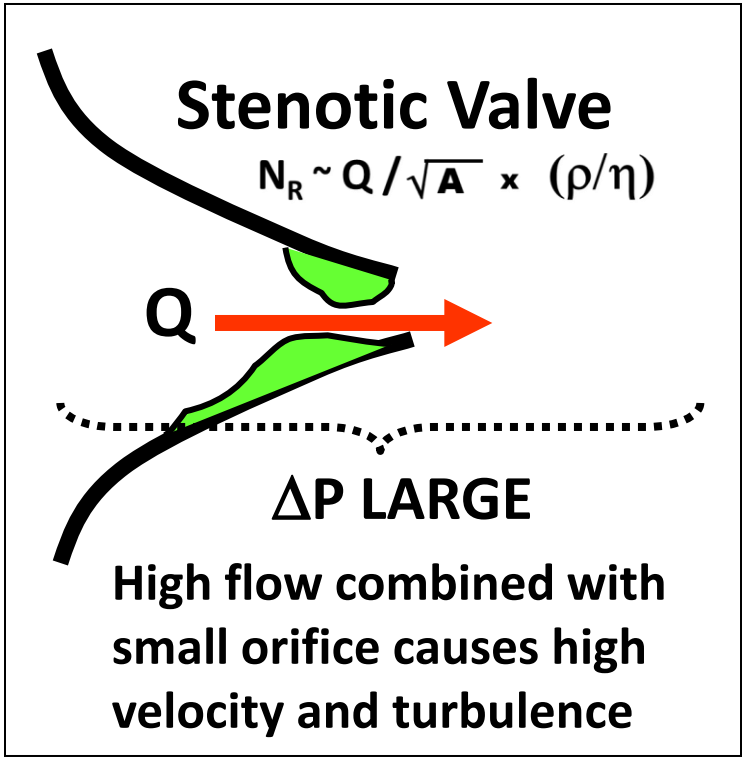
LARGER N_R ~ TURBULENT flow more likely

Critical threshold $N_{RC} = 2000$

$$N_R \sim Q / \sqrt{A} \times (\rho/\eta)$$

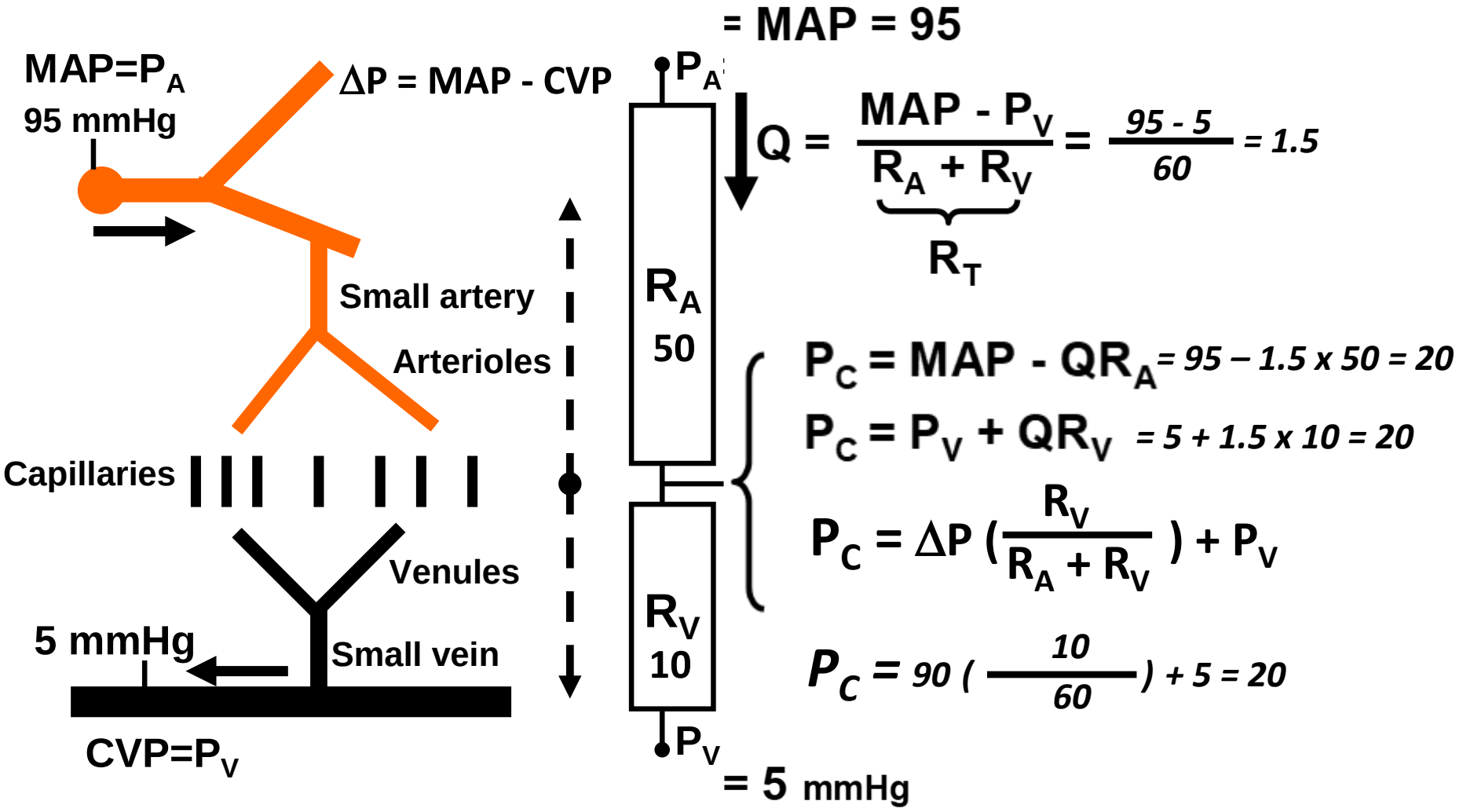
Valve Stenosis: Turbulence & Increased Resistance



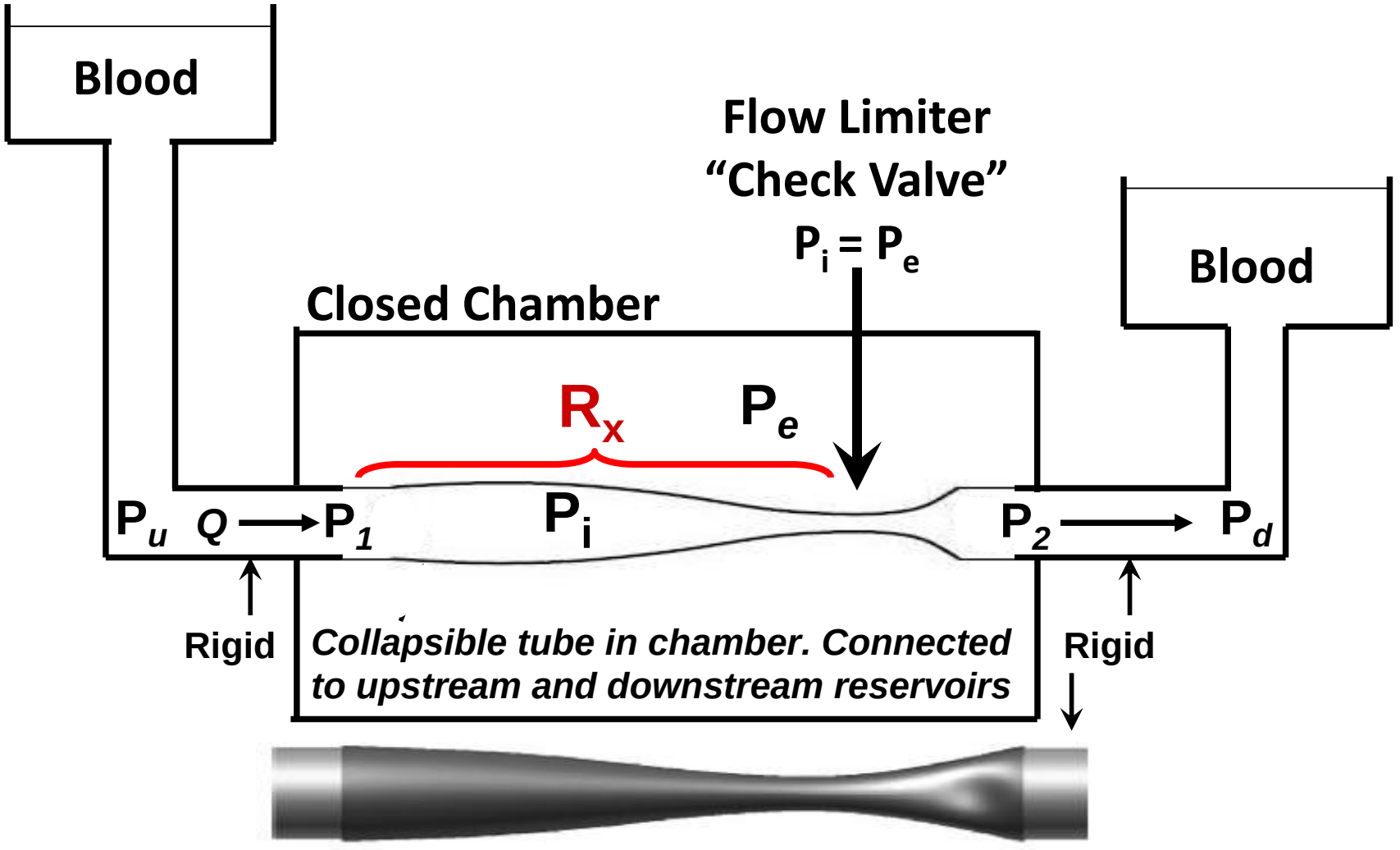


Flow through valve nearly same with or without stenosis until LV can no longer maintain CO

Vascular Partitioning: Blood Flow & Capillary Pressure



Blood Flow in Collapsible Vessels



If $P_i < P_e$ at any point, then $Q = (P_1 - P_e)/R_x$

Interactive Question

The figure shows a longitudinal section of a stenotic artery. 30s
At which site would you measure the greatest transmural pressure?

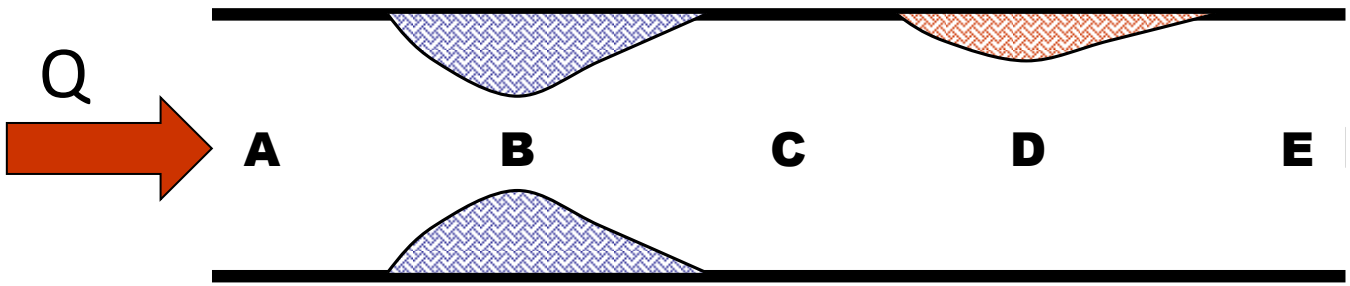
A. A

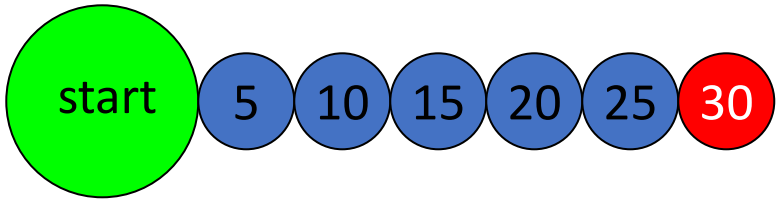
B. B

C. C

D. D

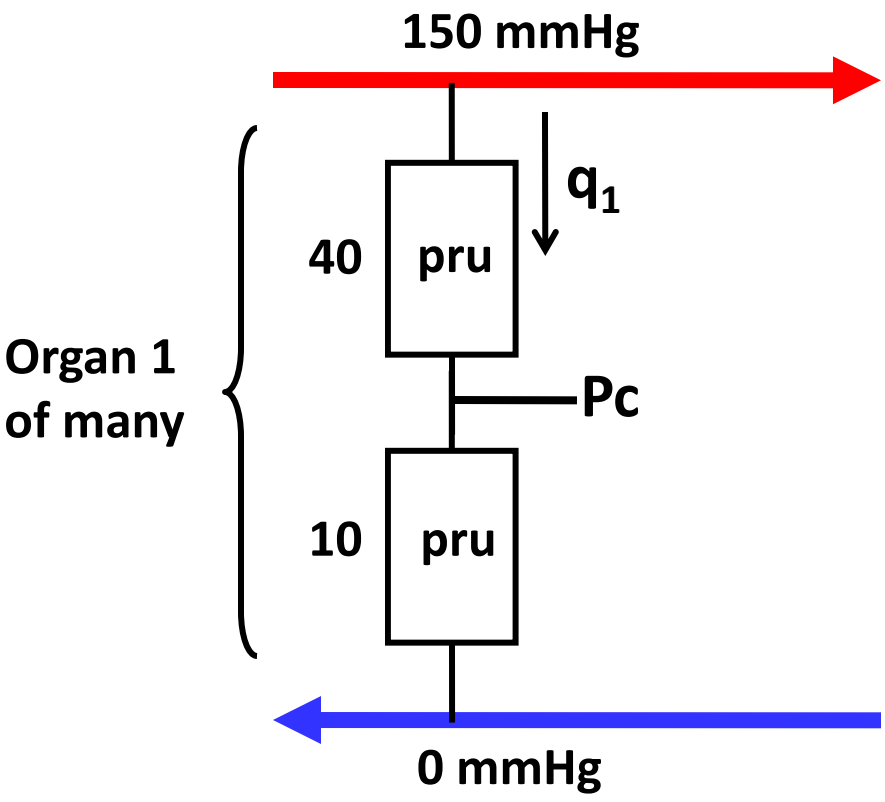
E. E





Solution?

Interactive Question



What is value of organ flow (q_1)?

$q_1 = (150 - 0) / 50 = 3$ ml/min

What is value of capillary pressure?

(1) $Pc = 150 - 3 \times 40 = 30$ mmHg

(2) $Pc = 0 + 3 \times 10 = 30$ mmHg

(3) $\frac{10}{10 + 40} \times 150 = 30$ mmHg

1 pru = 1 mmHg/(ml/min)

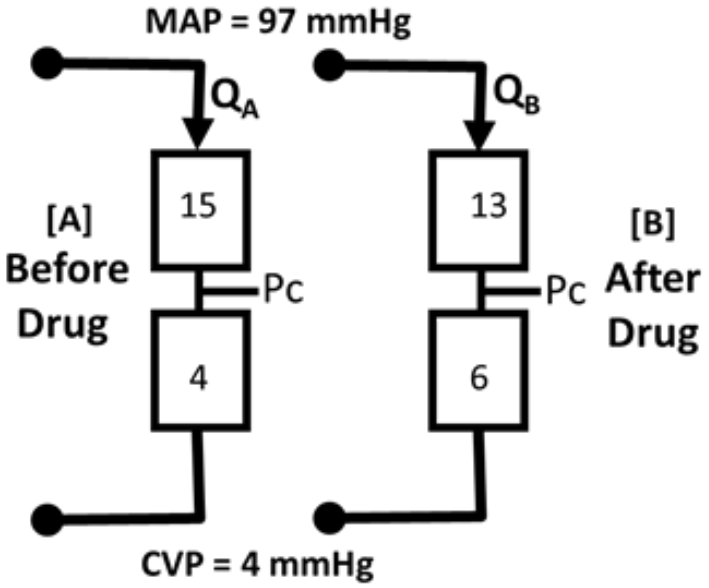
Interactive Question

A 59-year-old male has a MAP and CVP, as shown. His precapillary vascular resistance is 15 Wood units (WU), and his postcapillary vascular resistance is 4 Wood units.

He is given a vasoactive drug that causes the vascular resistance changes shown in part B of the figure. Average capillary pressure is denoted as Pc.

If his perfusion pressure does not change, which statement best describes the drug's action?

A. increases blood flow
B. Increases capillary pressure
C. causes venous smooth muscle to relax
D. causes arteriolar smooth muscle to contract
E. increases total vascular resistance

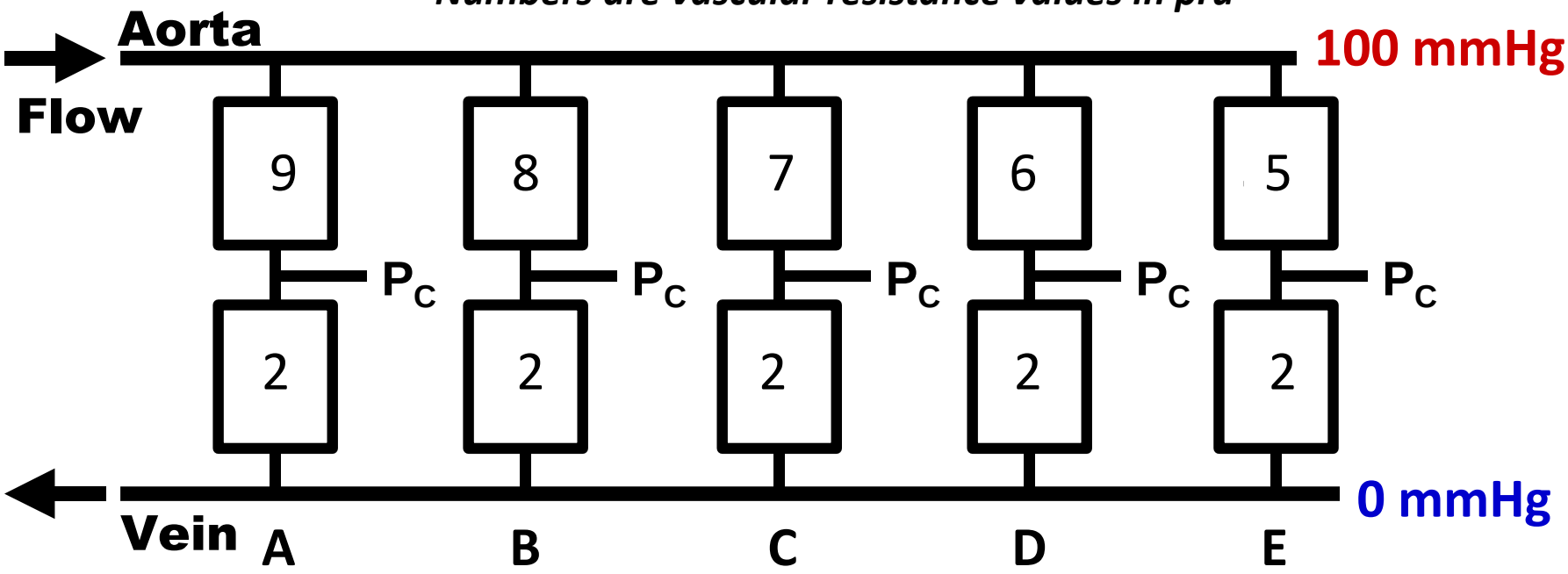


1 WU = 1 mmHg/(L/min)

Interactive Question

5 organs in parallel from artery to vein

Numbers are vascular resistance values in pru

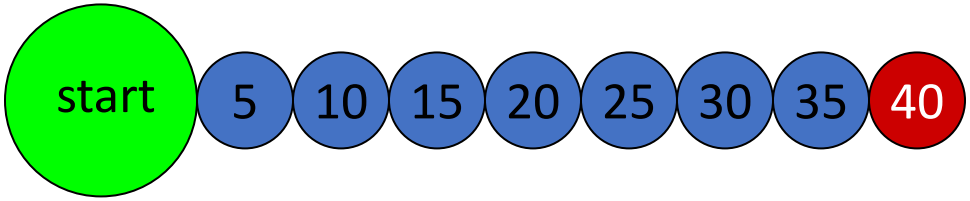


Which organ has the greatest blood flow? **E → 100/7**

Which organ has the least capillary pressure? **A→ 2/11 x 100**

What is the value of blood flow in organ B? **10 ml/min → 100/10**

Interactive Question



40 seconds

Reynolds Number:

A. Has its largest value in the large veins

B. Less than 2000 is usually associated with turbulence

C. Is directly proportional to the viscosity of flowing blood

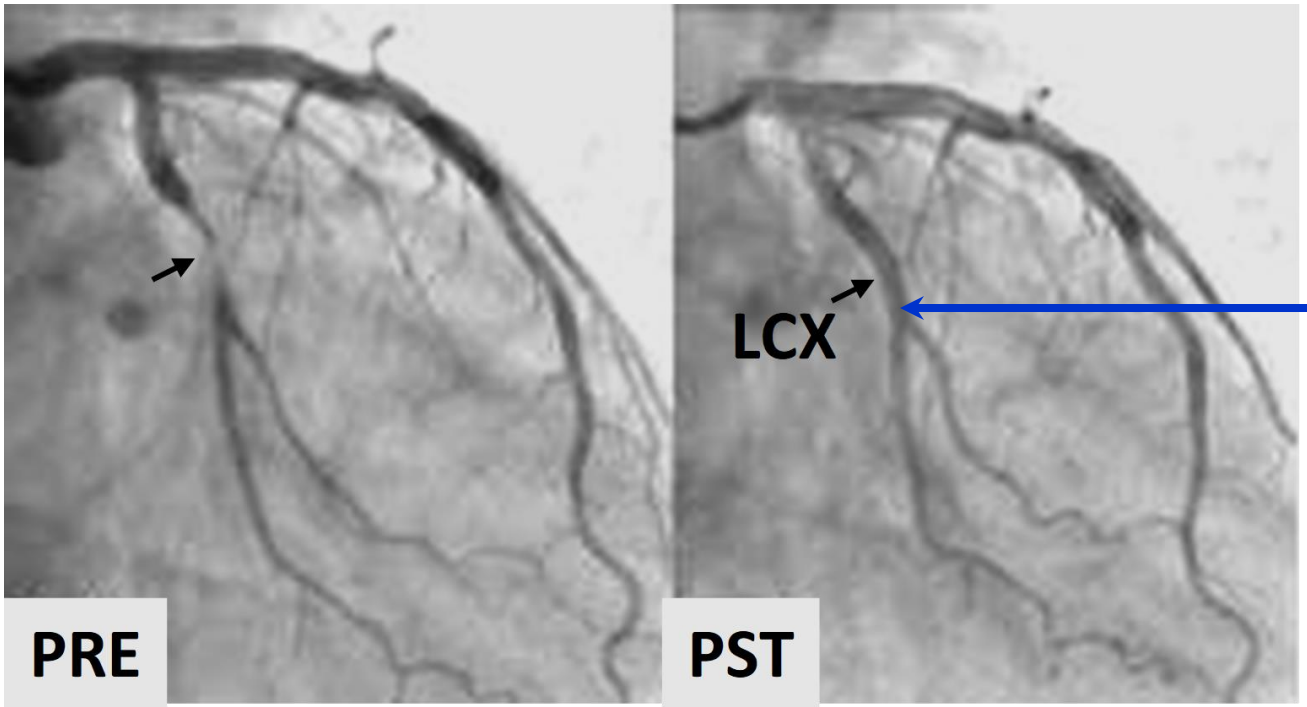
D. Increases with increasing blood flow

E. Assumes a high value in capillaries because of their small diameter

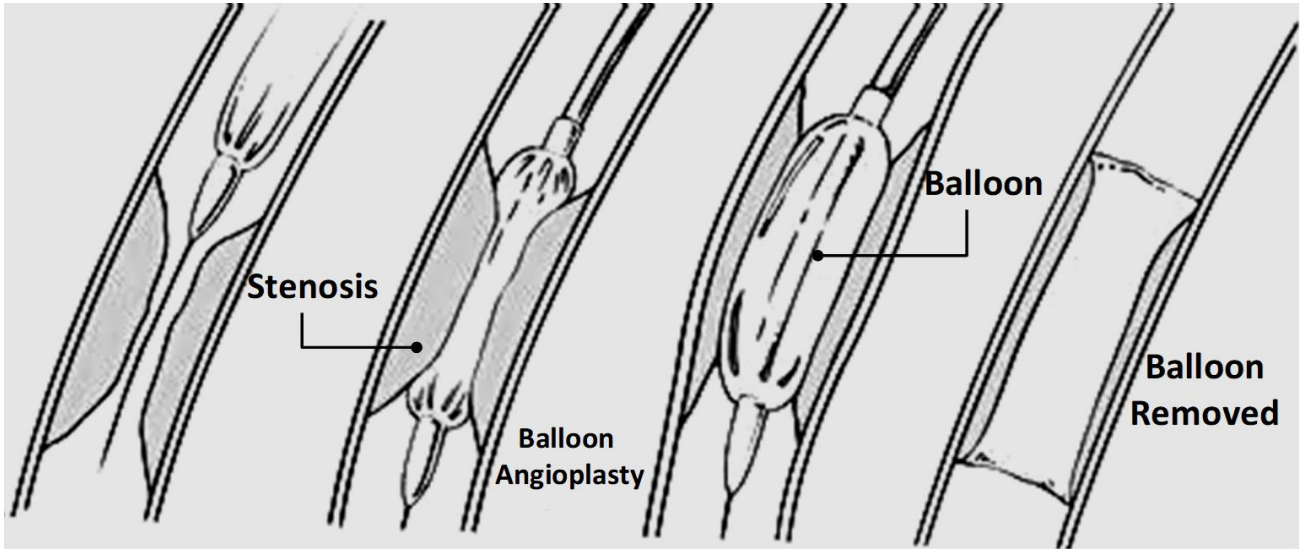
$$N_R = U \times D \times \left(\frac{\rho}{\eta}\right)$$

$$N_R = (4/\pi) \times (Q/D) \times (\rho/\eta)$$

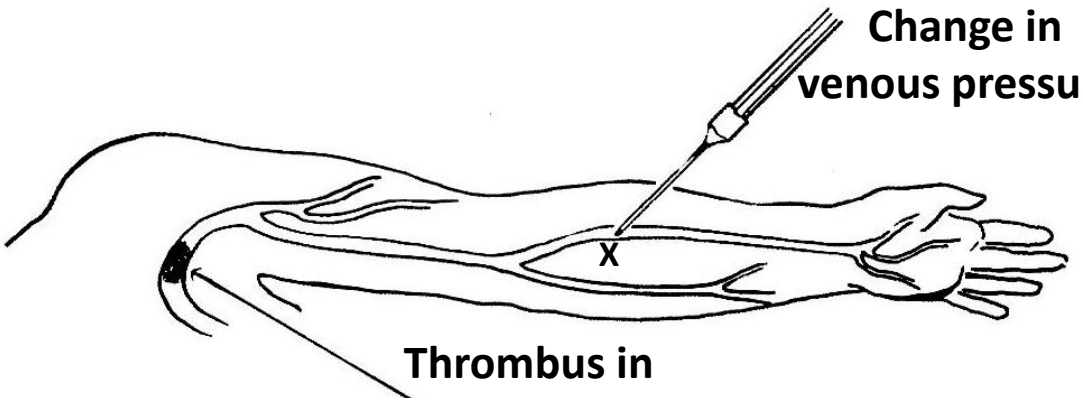
Interactive: LCX Stenosis: Pre & Post Angioplasty



What change in Distal Pressure? Increase or Decrease?



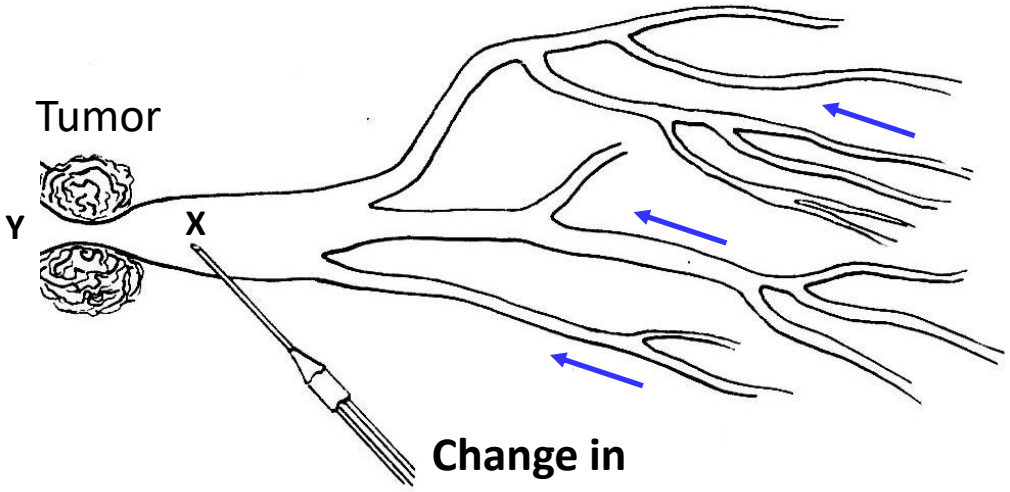
What is your diagnosis?



Bill is a 35-year-old postman who experiences a clot in his axillary vein. What happens to pressure at X?

A) Goes up
B) Goes down
C) Is little changed

What is your diagnosis?

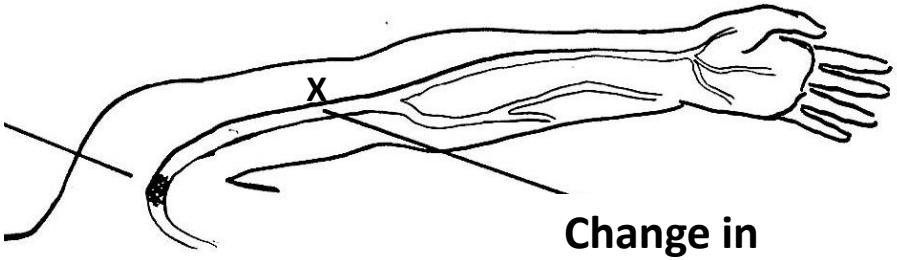


A growing tumor is compressing one of Mary's veins as shown.

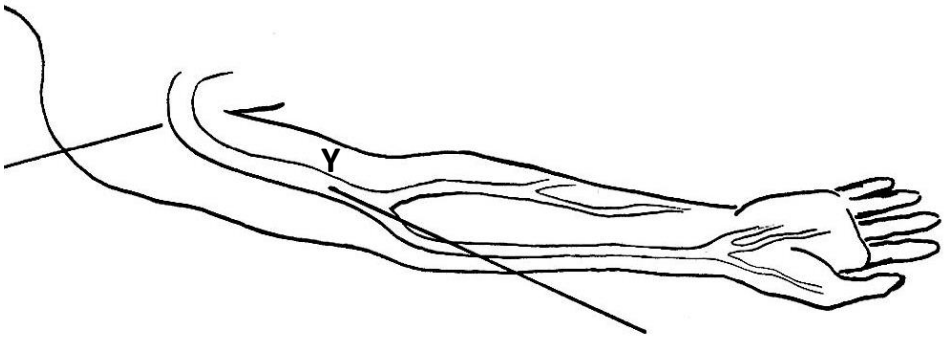
What happens to pressures at X?

A) Goes up
B) Goes down
C) Is little changed

What is your diagnosis?



Change in
venous pressure?



Change in
venous pressure?

Charles, a 23-year-old laborer, presents with swelling in his left forearm and hand. Ultrasound reveals a clot in his left axillary vein. What happens to pressures at X and Y?

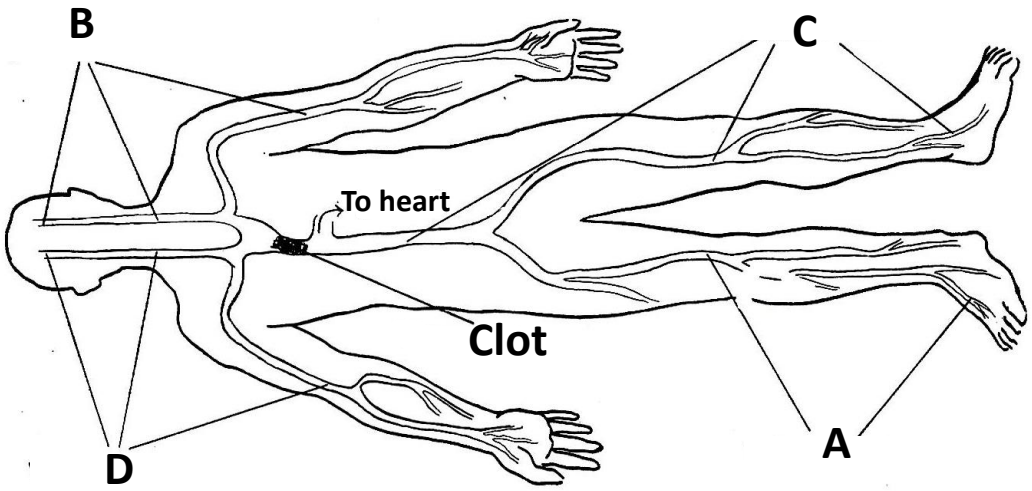
→ A) Goes up
B) Goes down
C) Is little changed

@X

A) Goes up
B) Goes down
→ C) Is little changed

@Y

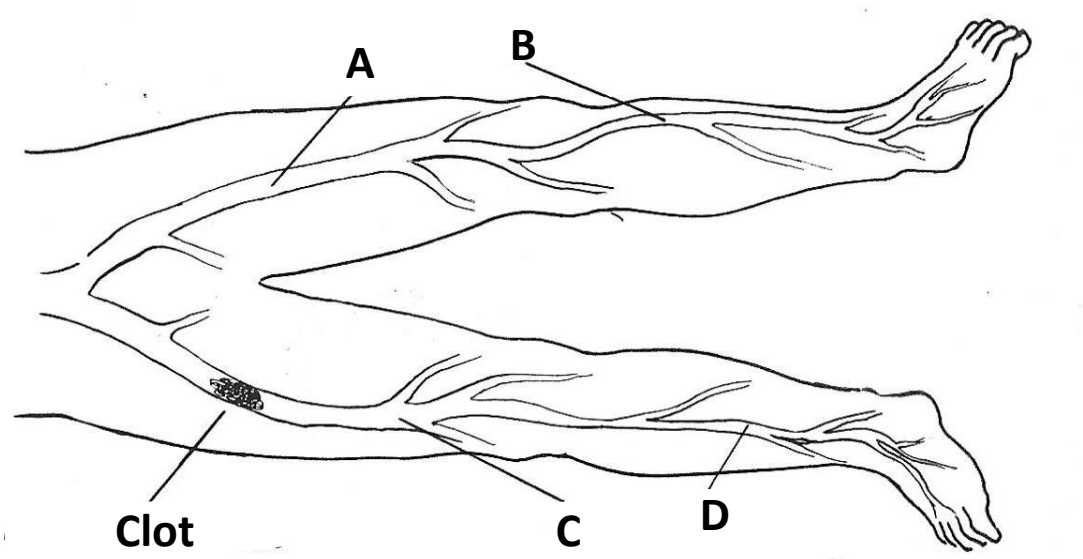
What is your diagnosis?



Brenda, is a 22-year-old student. Ultrasound reveals a clot in her superior vena cava. Because of this clot, which venous pressures are elevated?

A)
B)
C)
D)

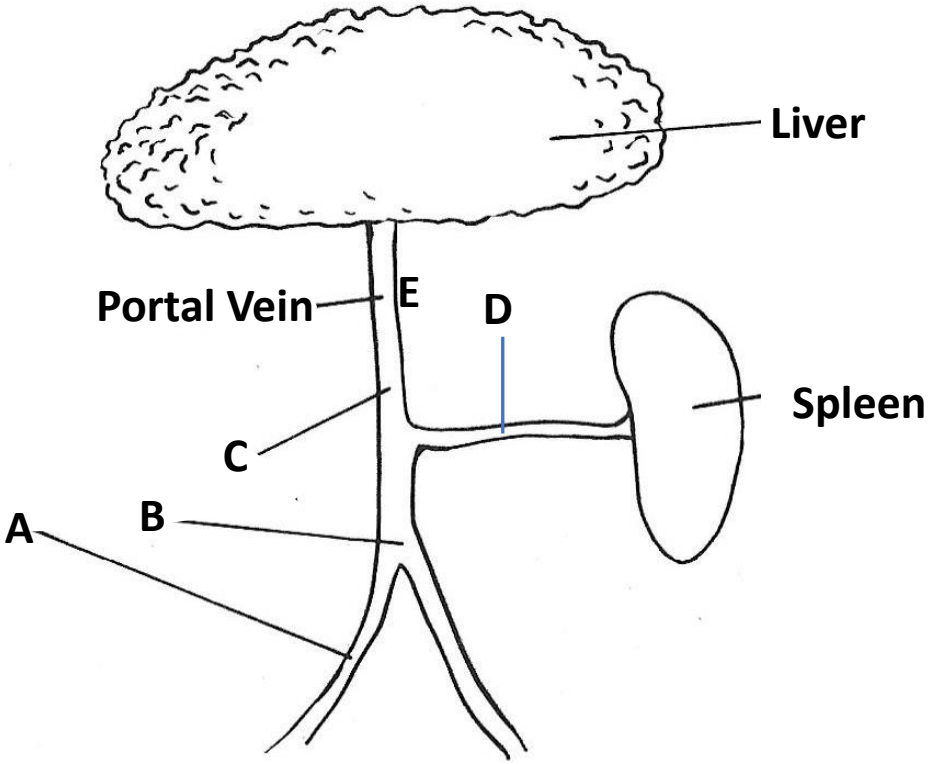
What is your diagnosis?



Barbara is a 42-year-old nurse who presents with a feeling of tightness of her right lower ankle. Ultrasound reveals a clot in her external iliac vein. Because of this clot, which venous pressures are elevated?

A)
B)
C)
D)

What is your diagnosis?



Andrew is a 66-year-old former heavy alcohol drinker who has been diagnosed with a cirrhotic liver. This condition is associated with an increase in liver vascular resistance among other things.

Which pressure is greatest?

A) A
B) B
C) C
D) D
E) E

End CV Physiology Lecture 5

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