Western

UNIVERSITY · CANADA

Tutorial 12
Sections 009/010

TA: Greydon Gilmore
Physiology 2130
Dec 3rd, 2019

Western

Your TA reminding you…

- 2nd Quiz (1%)
  - Opens: Dec 2nd @ 4pm
  - Closes: Dec 4th @ 4pm
- 2nd Midterm (15%)
  - When: Dec 19th @ 9am-10am
  - **Room Assignments:**
    - ABBA-GANE: Alumni Hall 15
    - GHAB-POSA: Alumni Hall 201
    - PRIM-WOOD: Alumni Hall Stage
    - WU-ZIA: Somerville House 2316
- 2nd Midterm review session
  - When: Monday Dec 16th from 6-8pm
  - Where: Auditorium B University Hospital, 3rd floor

Today

- Group work activity
- Learning Catalytics Question
- Almost finish cardiovascular anatomy

Group Work

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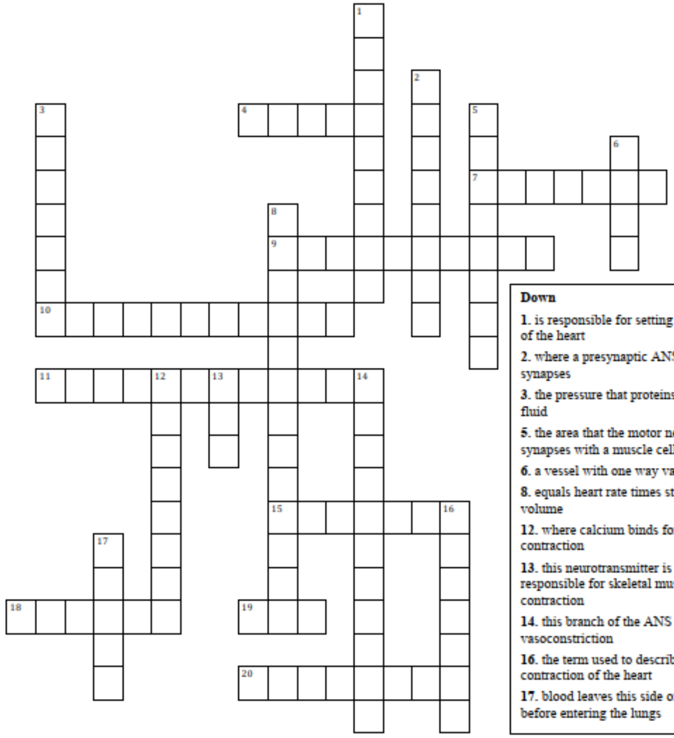
Crossword Puzzle!

Midterm 2 review



Down

1. is responsible for setting the pace of the heart
2. where a presynaptic ANS neuron synapses
3. the pressure that proteins exert in a fluid
5. the area that the motor neuron synapses with a muscle cell
6. a vessel with one way valves
8. equals heart rate times stroke volume
12. where calcium binds for a muscle contraction
13. this neurotransmitter is responsible for skeletal muscle contraction
14. this branch of the ANS causes vasoconstriction
16. the term used to describe the contraction of the heart
17. blood leaves this side of the heart before entering the lungs

Across

4. the electrical event seen when the ventricle repolarizes
7. the pupil does this when stimulated by norepinephrine
9. the blood vessels with the greatest resistance
10. forms when myosin binds actin
11. master controller of the ANS
15. a sustained muscle contraction
18. a gas exchanged at the capillaries
19. required to pump calcium back into the SR
20. is released from the zona fasciculata

Learning Catalytic Question

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The Cardiovascular System:
Mechanical Performance of the Heart

Chapter 7: Professor Stavraky

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Heart Rate (HR)

- Average: 70 bpm
- Lower HR = “healthier” (i.e. athletes: 45 bpm)
- Max HR = 220 – age
- Controlled by autonomic nervous system
  - PS-NS: decreases HR
  - S-NS: increases HR

Stroke Volume = EDV -ESV

- End-Diastolic Volume (EDV): volume of blood in ventricles at end of ventricular diastole (just before they contract; end of Phase 1)
- End-Systolic Volume (ESV): volume of blood in ventricles at end of ventricular systole (just after contraction; end of Phase 3)
- Stroke volume = EDV –ESV

  = 160 ml –90 ml

  = 70 ml
- Altering either EDV or ESV will change stroke volume

Cardiac output can be determined by which of the following formulas?

A. HR – SV
B. HR divided by SV
C. HR + SV
D. HR x SV

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Cardiac Output (CO)

- Volume of blood pumped by each ventricle per minute
- CO = Heart Rate x Stroke Volume
  - Heart Rate = Beats per minute
  - Stroke Volume = Amount of blood pumped by each ventricle per beat
- At rest:
  - CO = 5 L/min
  - HR = 70 beat/min
  - SV = 70-80 mL/beat
  - CO = (70 beat/min)(0.07 L/beat) = 4.9 L/min
- During exercise:
  - CO can increase to 20-40 L/min
  - How? By changing HR and/or SV!

Which of the following is INCORRECT regarding diastole (filling of the heart)?

a. Atrioventricular valves are open.
b. Semilunar valves are closed.
c. Blood is flowing from the atria into the ventricles.
d. Pressure in the ventricles is greater than in the atria.

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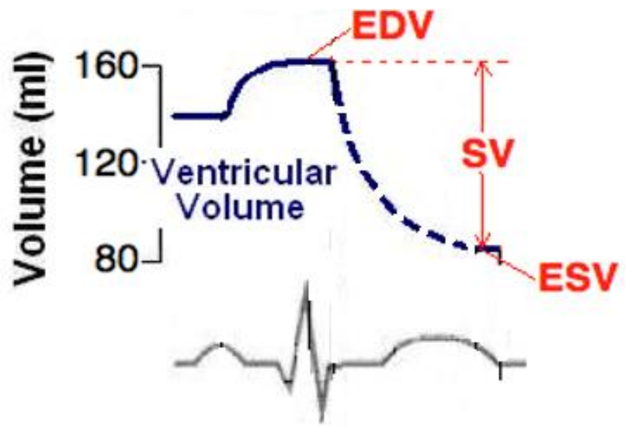
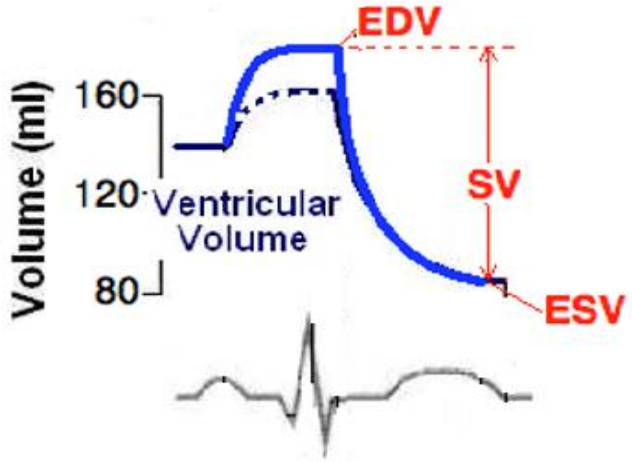
Overall Control of SV by ANS

- Stroke volume is amount of blood pumped by each ventricle per beat
- Two factors that affect stroke volume:
  - ANS
  - Preload (End diastolic volume)
- PS-NS decreases SV
  - ↓Ca^{2+} flow into cardiac cells
  - ↓force of contraction
- S-NS increases SV
  - ↑Ca^{2+} flow into cardiac cells
  - ↑force of contraction

Stroke Volume

- During exercise, the S-NS is activated:
  - ➢ Heart contracts more forcefully and ejects more blood
  - ➢ Thus, ESV decreases
- Meanwhile, the heart is filling with more blood
  - ➢ Thus, EDV increases



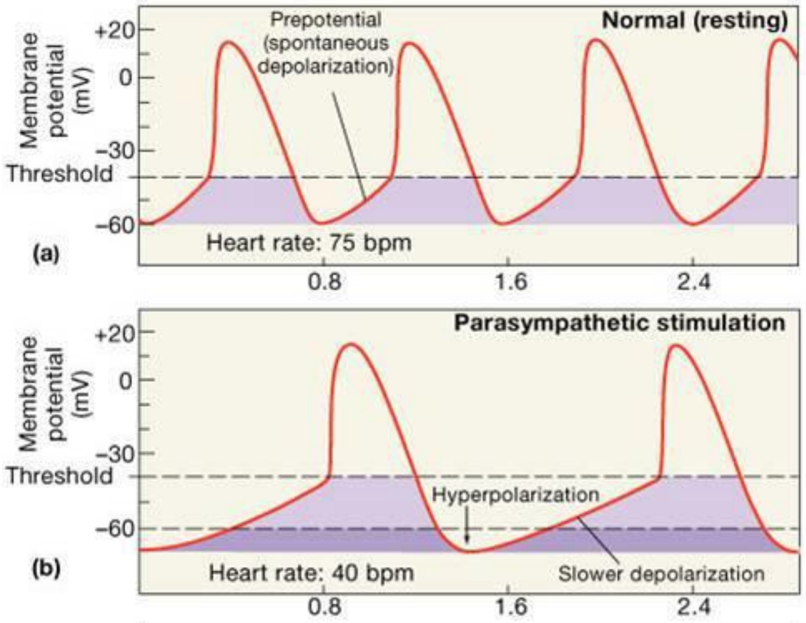


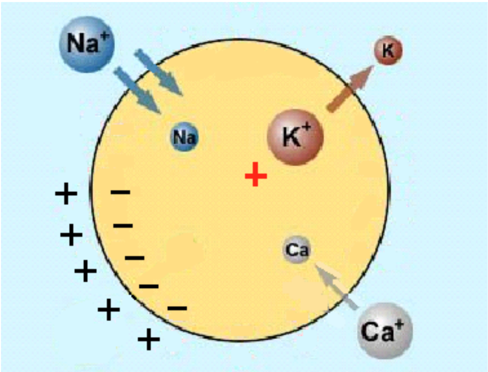
Stroke Volume and Preload

- Preload: The "load" on the cardiac muscle before contraction
- This "load" comes from the blood in the ventricles that stretches the ventricular muscle
  - Thus, higher EDV = greater preload

PNS Effect on HR

- PNS innervates SA and AV nodes through vagus nerve
    - ➢ PNS releases Ach, which binds to receptors on cells of SA and AV nodes
- ↑ K^+ permeability (i.e. more exits cell) and ↓ Ca^{2+} permeability (i.e. less enters cell)
- Net effect:
    - ➢ K^+ = HYPERPOLARIZATION
    - ➢ Ca^{2+} = Decreases slope of pacemaker potential





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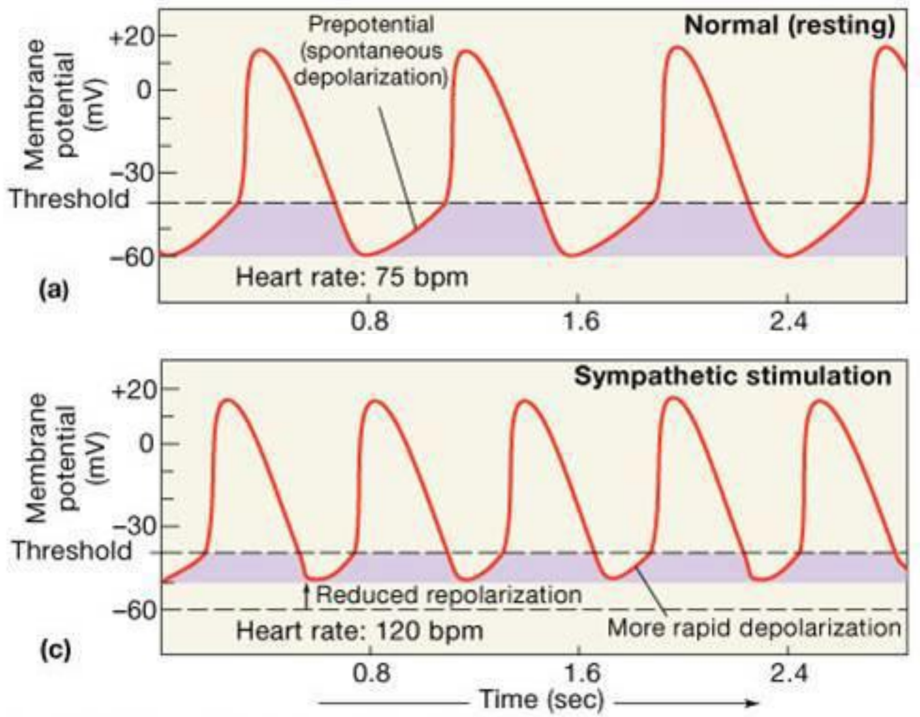
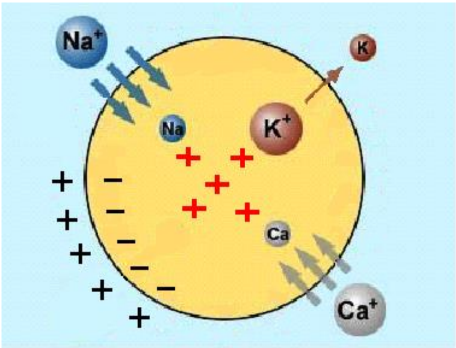
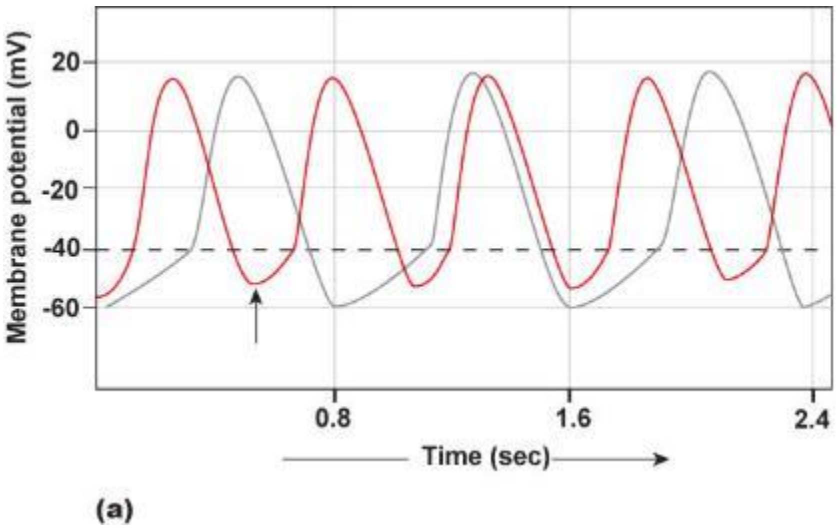
SNS Effect on HR

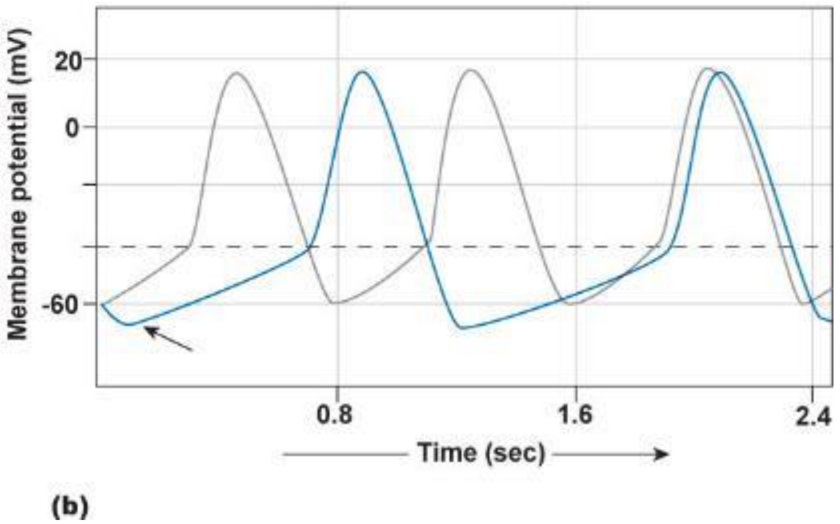
- SNS innervates SA, AV nodes and ventricular muscles
  - ➢ SNS releases NE, which binds to receptors on cells of nodes and muscle
- ↑ Na^+ and Ca^{2+} permeability (i.e. more enters cell)
- Net effect: DEPOLARIZATION and increased slope of pacemaker potential





Which graph represents sympathetic influence on heart rate (in both cases the light grey line is under resting conditions)?





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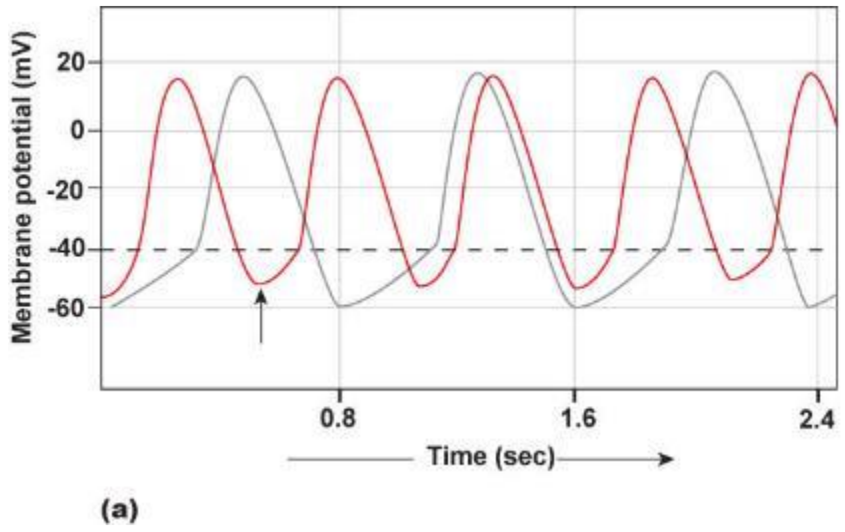
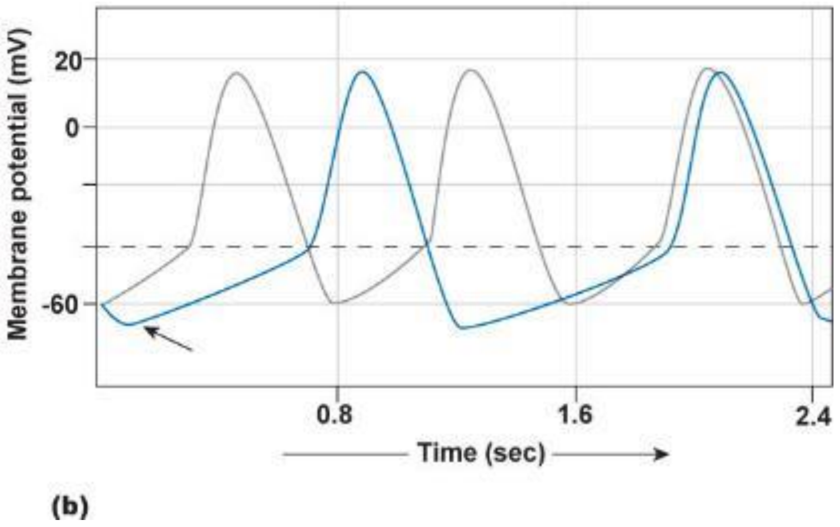




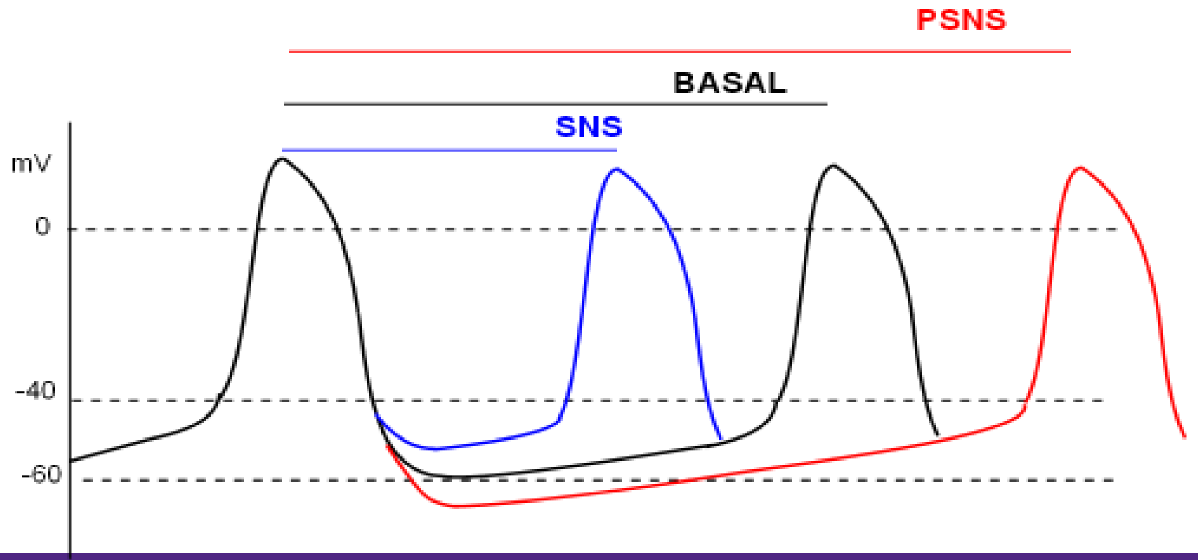
Summary of ANS Control of Heart Rate

PSNS

- Acetylcholine released onto these areas
  - ➢ Increase K+, decrease Ca2+ permeabilities
  - ➢ Decreases slope of pacemaker potential

SNS

- Release norepinephrine onto these areas (indirect: epinephrine)
- Increases heart rate and force of contraction
  - ➢ Increase Na and Ca permeability
  - ➢ Increase slope of pacemaker potential



Frank-Starling Law

- Frank-Starling Law states that "an increase in EDV will increase stroke volume"

An increase in EDV = An increase in preload

↓

Increases the stretch of myocardial cells

↓

Increases the force of contraction of these cells when the heart contracts

↓

Increases the amount of blood ejected

↓

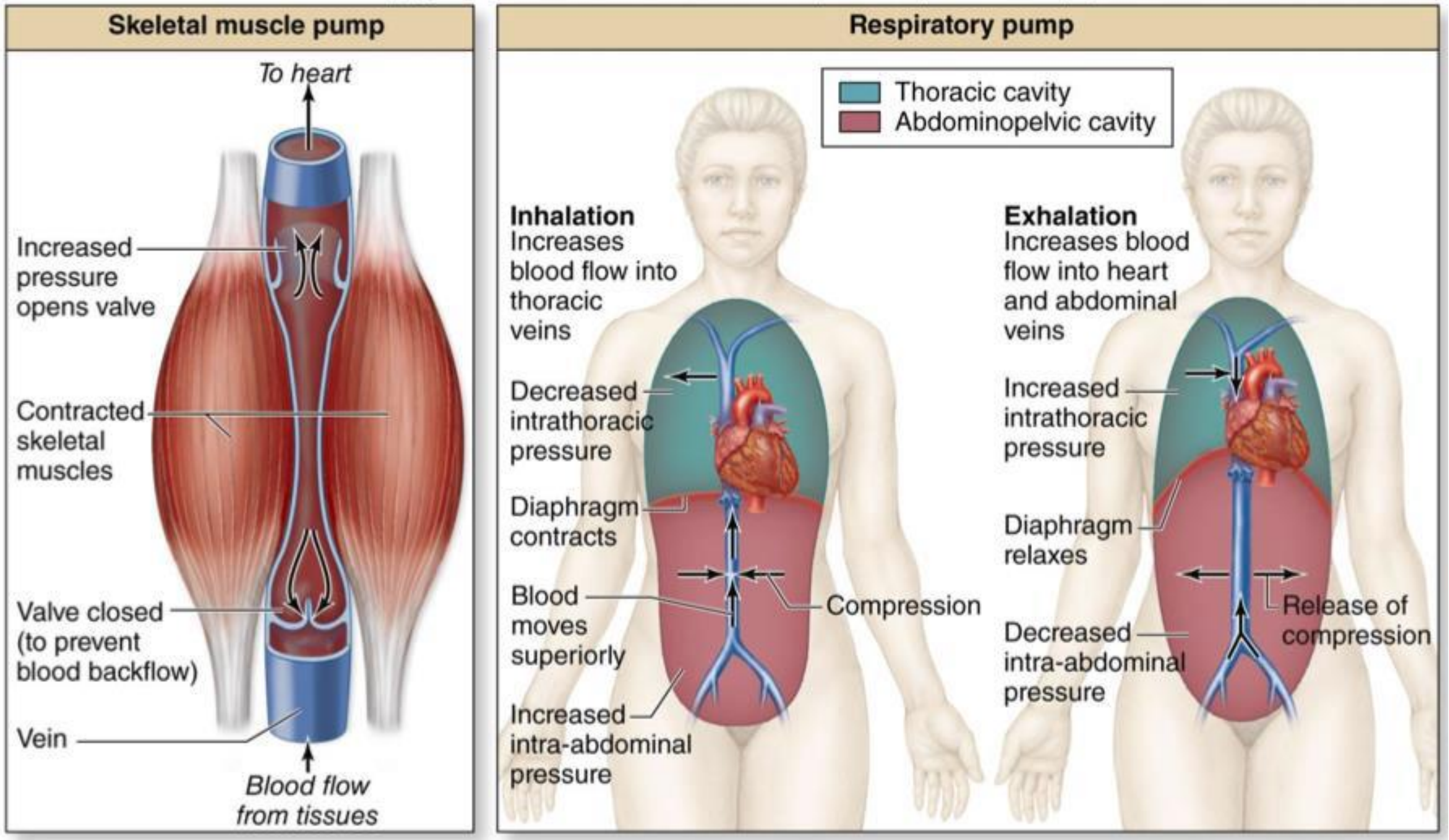
Increases Stroke Volume (Increases Cardiac Output)

Frank-Starling Law and Venous Return

- How to increase EDV? Increase venous return to the heart!
- During dynamic exercise:

1. Muscle Pump: Contracted skeletal muscle around veins pushes blood to heart
2. Respiratory Pump: Changes in pressure during breathing pushes blood towards the heart
3. S-NS: Constriction of veins squeezes blood to heart

Frank-Starling Law and Venous Return



The aortic semilunar valve prevents blood from returning to the ______.

A. left ventricle
B. Aorta
C. Right ventricle
D. Left atrium

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The Cardiovascular System: Vascular Function

Chapter 7: Dr. Stavraky

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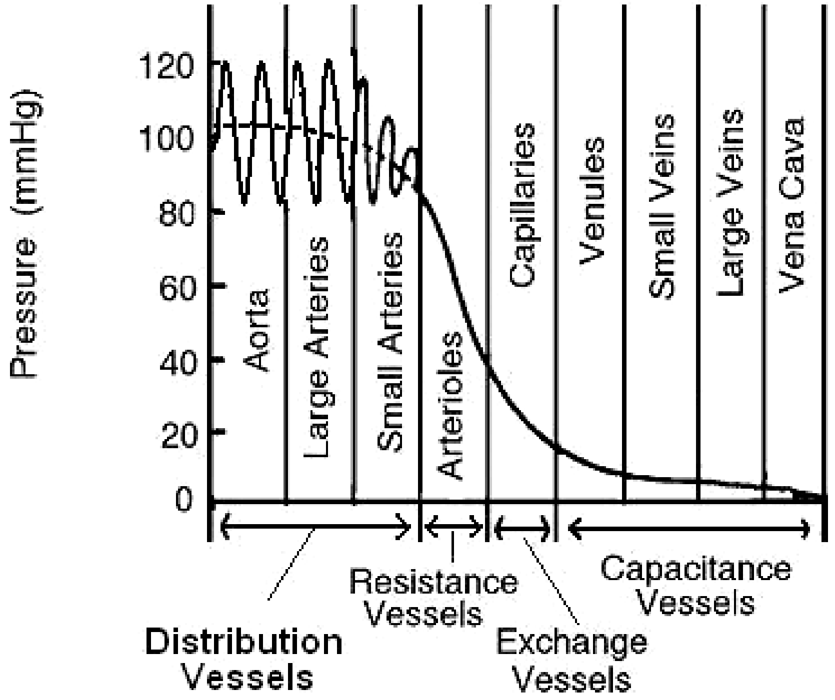
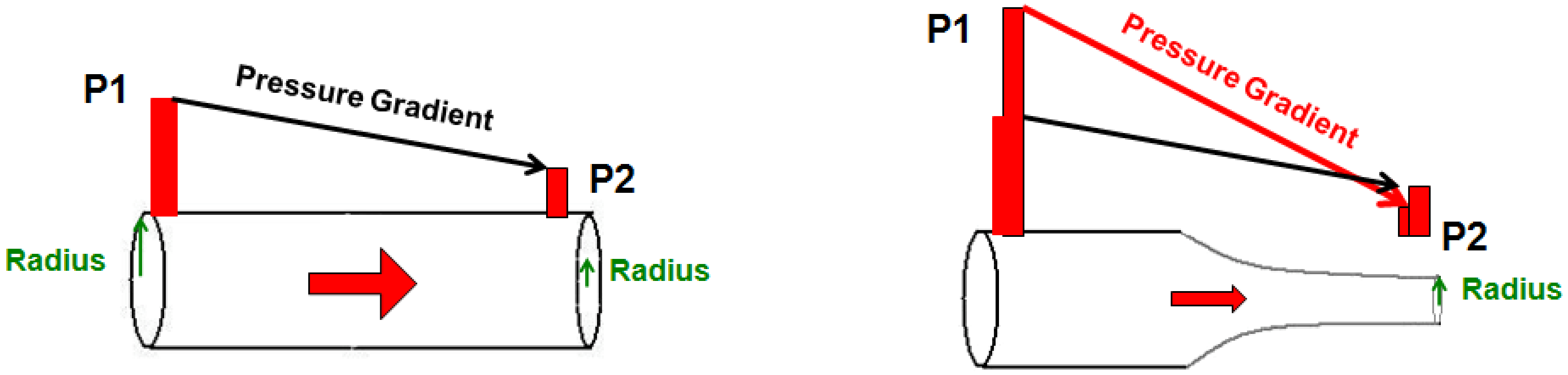
Blood Vessels

- Structural properties of vessels are what contribute to the blood pressure characteristics seen in circulation



Vessel Constriction and Blood Flow

- As the radius decreases the pressure gradient increases.



Relationship Between Pressure, Flow and Resistance (Page 232)

$$\boldsymbol{Resistance = \frac{L\,\eta}{r^4}}$$

L = length of vessel
η = viscosity of the fluid
r = radius of the vessel

$$\boldsymbol{Resistance = \frac{1}{r^4}}$$

$$\boldsymbol{Blood\ Flow = \frac{P_1 - P_2}{\frac{1}{r^4}} = \boxed{(P_1 - P_2)\ *\ r^4}}$$

Just know this part of the equation

A small change in radius will have a LARGE effect on blood flow

Relationship Between Pressure, Flow and Resistance

$$\boldsymbol{Blood\ Flow = (P_1 - P_2) * r^4}$$

$$\boldsymbol{Blood\ Flow = (4 - 2) * 1^4}$$

$$\boldsymbol{Blood\ Flow = 2}\ \textbf{L/min}$$

$$\boldsymbol{Blood\ Flow = (P_1 - P_2) * r^4}$$

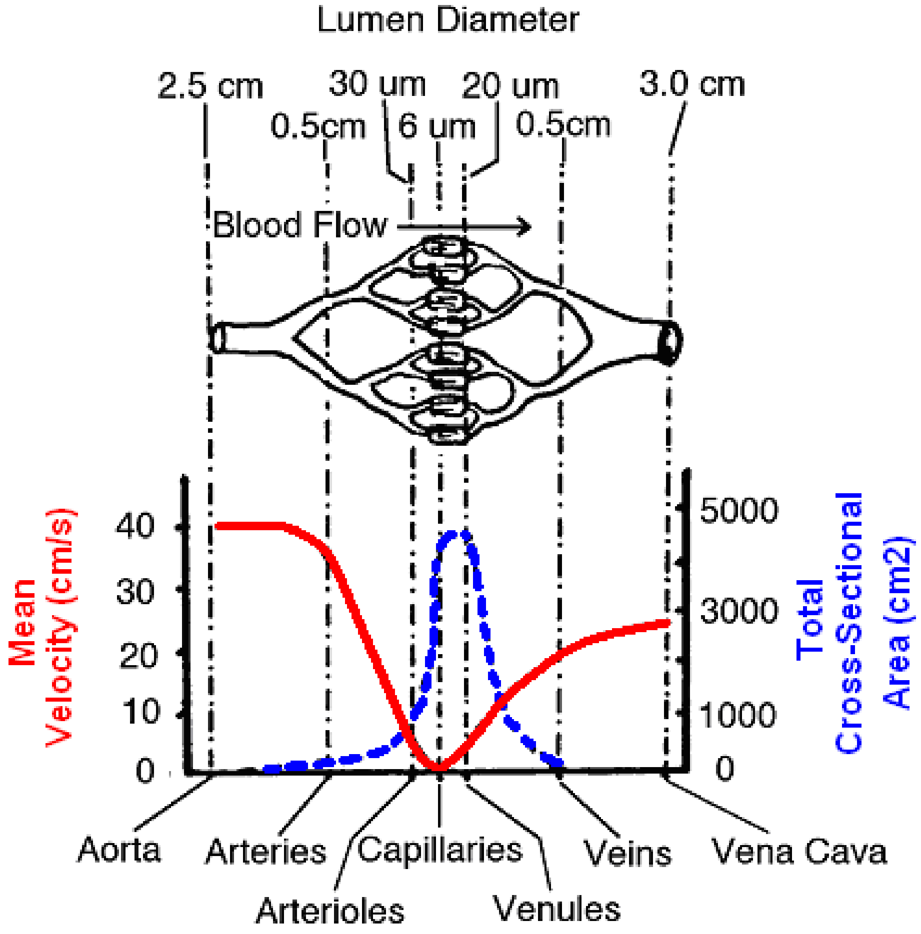
$$\boldsymbol{Blood\ Flow = (10 - 2) * 0.5^4}$$

$$\boldsymbol{Blood\ Flow = 0.5}\ \textbf{L/min}$$

A small change in radius will have a LARGE effect on blood flow

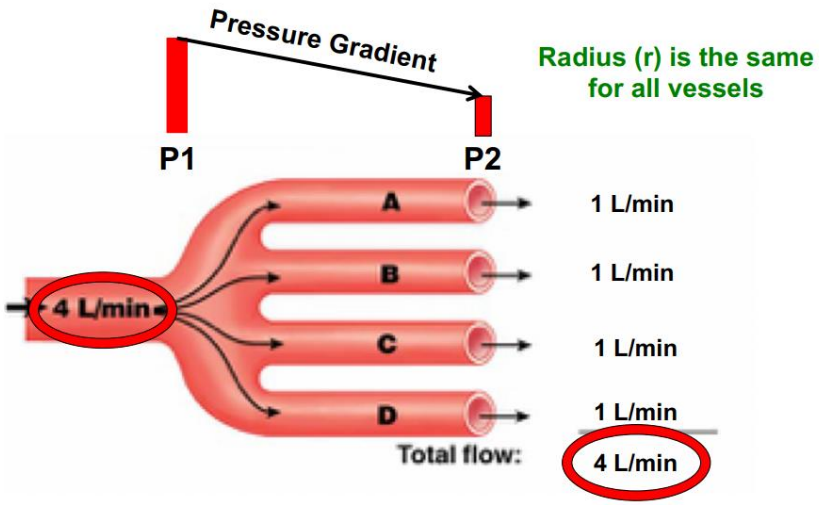
Defining terms

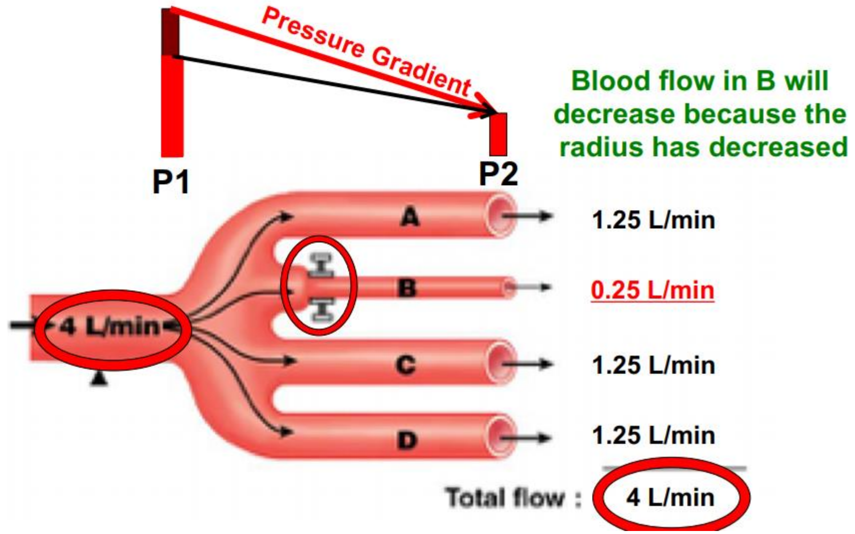
- Blood velocity (cm/sec): speed at which blood is moving through particular blood vessel
  - Fluid flows faster through a narrow tube than a larger tube
  - As cross sectional area increases mean velocity decreases
- Blood flow (L/min): volume of blood moving through set of vessels.



Overall blood flow does not change

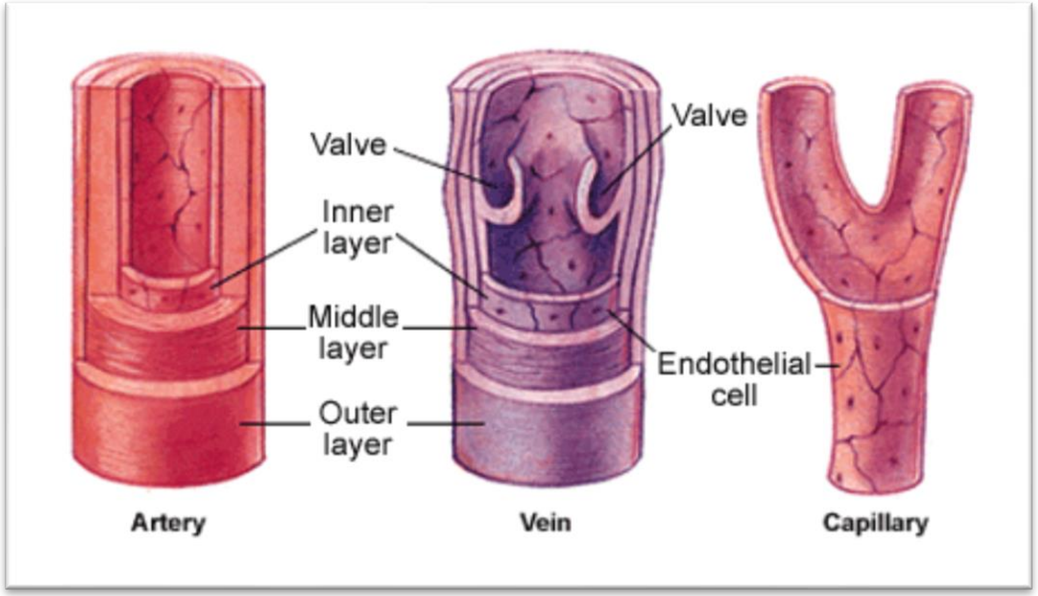
- Blood velocity can change but total blood flow needs to remain constant
  - If you have 5L of blood you can't add or subtract… unless you have a wound





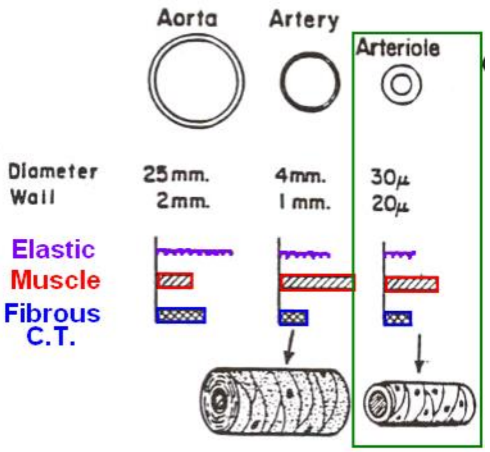
Arteries and Veins

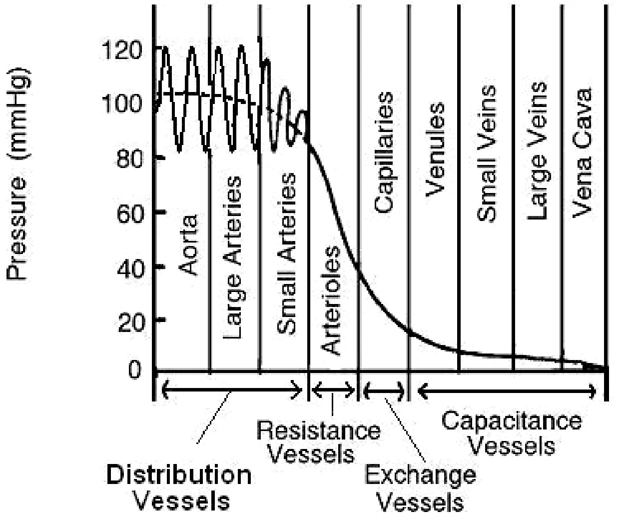
- Contain three layers:
  - ➢ Outer Layer – Tunica externa
    - Fibrous connective tissue
  - ➢ Middle Layer – Tunica media
    - Smooth muscle and elastic tissue
  - ➢ Inner Layer – Tunica interna
    - Endothelial cells
- Veins contain valves
- Capillaries have single layer of endothelial cells



Aorta and Large Arteries

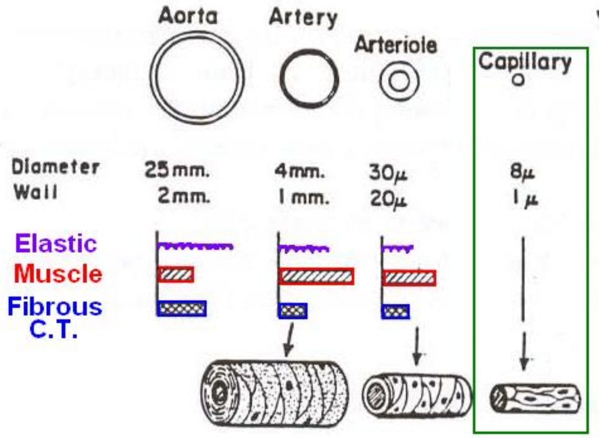
	Blood Characteristics	Structure	Purpose
Aorta/Large Arteries	- High blood pressure - 80-120 mmHg - High blood velocity	- Large diameter - Elastic tissue - Thin walls ▪ Easily distended ▪ Low resistance to blood flow ▪ Small drop in blood pressure	- 'Shock absorbers' - Distribute the blood

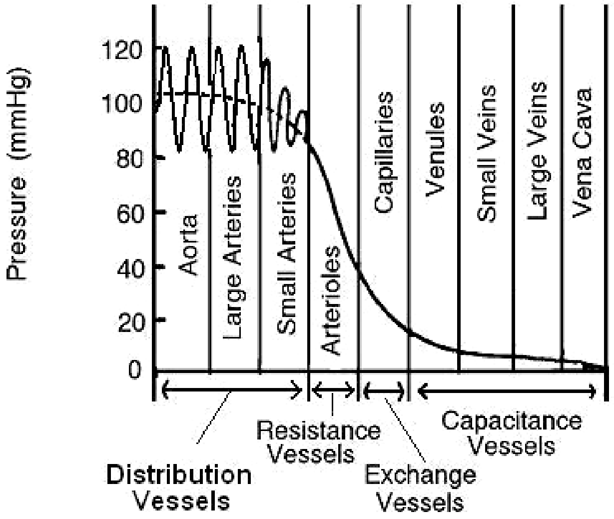




Capillaries

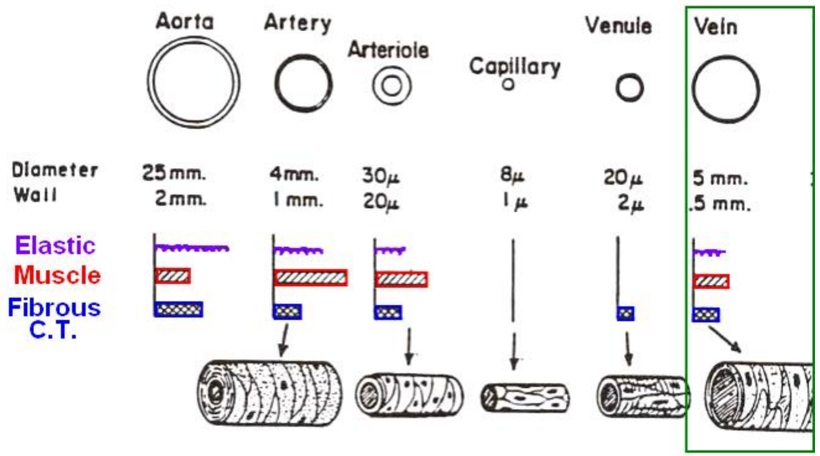
	Blood Characteristics	Structure	Purpose
Capillaries	- Low blood pressure - Small drop in blood pressure - Very low blood velocity (1-2 cm/sec)	- One endothelial cell thick - Large cross sectional area - Very large surface area ▪ Diffusion of gas, nutrients and waste	- Exchange vessels

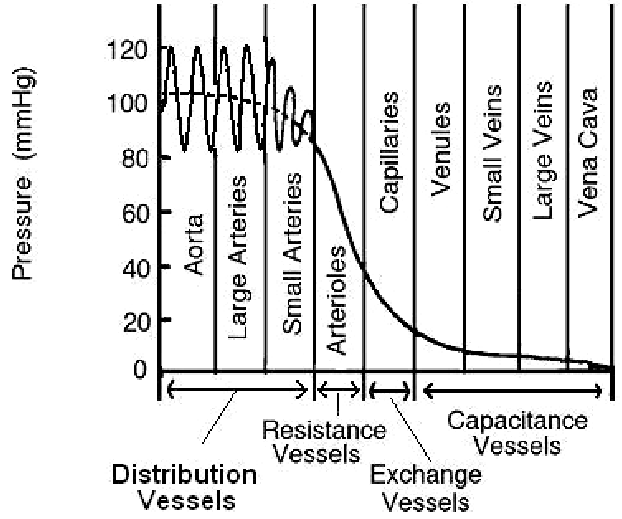




Veins

	Blood Characteristics	Structure	Purpose
Veins	- Low blood pressure - Low to medium blood velocity (5-10 cm/sec)	- Very thin walls with large diameter - Contain valves - Some elastic tissue - Smoth of smooth muscle innervated by ANS ▪ Vasoconstriction/dilation	- Capacitance vessels: 70% of TBV





Starling Forces

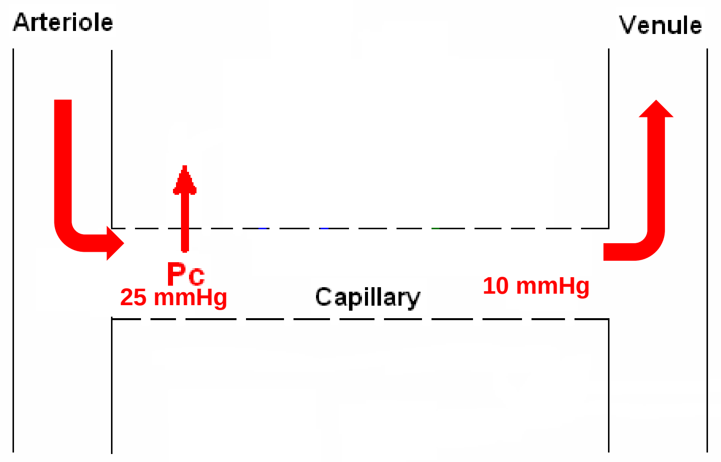
- Two hydrostatic pressures
  - Capillary hydrostatic pressure
  - Interstitial fluid hydrostatic pressure
- Two osmotic pressures
  - Plasma osmotic pressure
  - Interstitial osmotic pressure

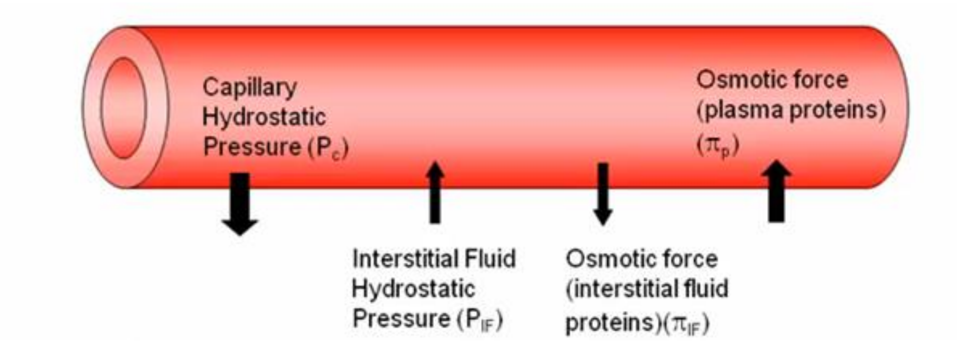
Exchange In Capillaries

- Diffusion
  - Down concentration gradients
  - Oxygen, CO^2, O^2, lipid soluble substances
- Filtration and reabsorption (Starling forces)
  - Filtration: movement of fluid out of capillary
  - Reabsorption: movement of fluid back into capillary

Capillary Hydrostatic Pressure (P_c)

- Pressure exerted by fluid in the capillary
- Pressure drives fluid OUT of capillary and is generated by ventricular systole (Filtration)

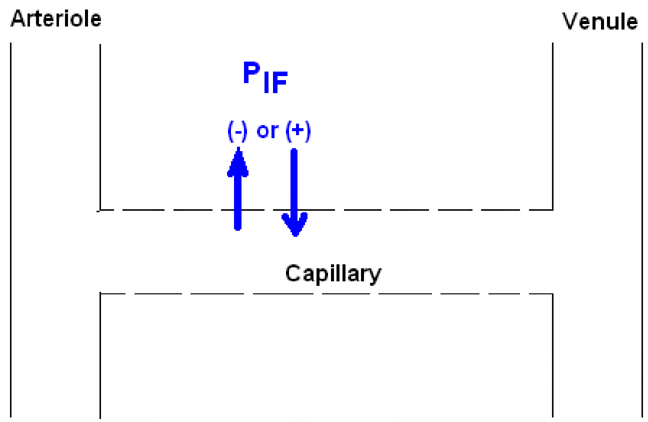


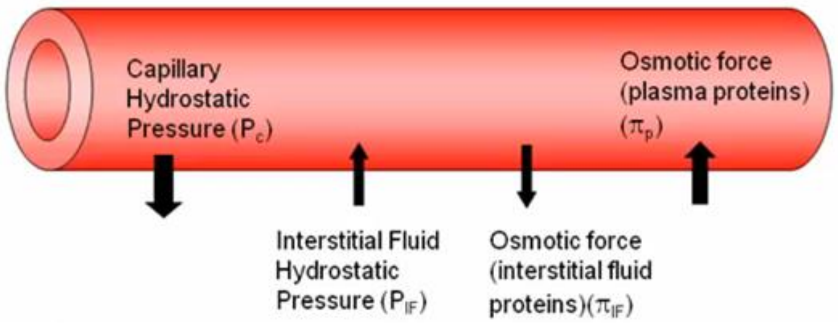


Interstitial Fluid Hydrostatic Pressure (P_{IF})

- Pressure exerted by fluid in the interstitial space between cells in the tissue
- Movement depends on pressure in the tissue
  - Can be negative → Filtration into tissue
  - Can be positive → Reabsorption into capillary

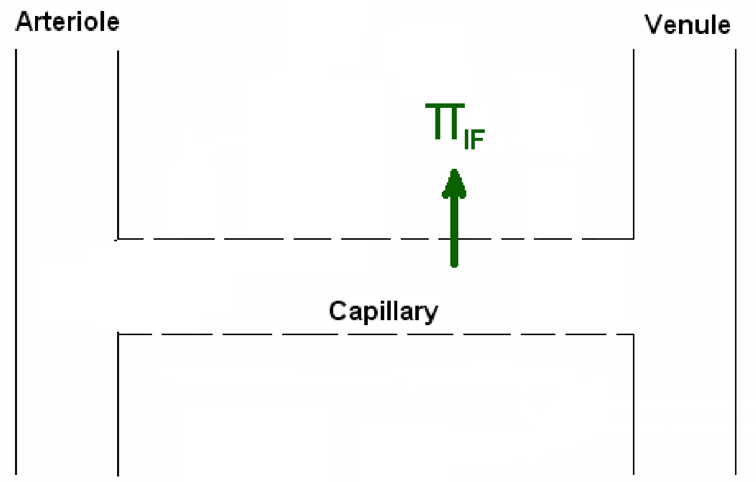
Subcutaneous tissues: -6mmHg
Interstitial fluid: +6mmHg

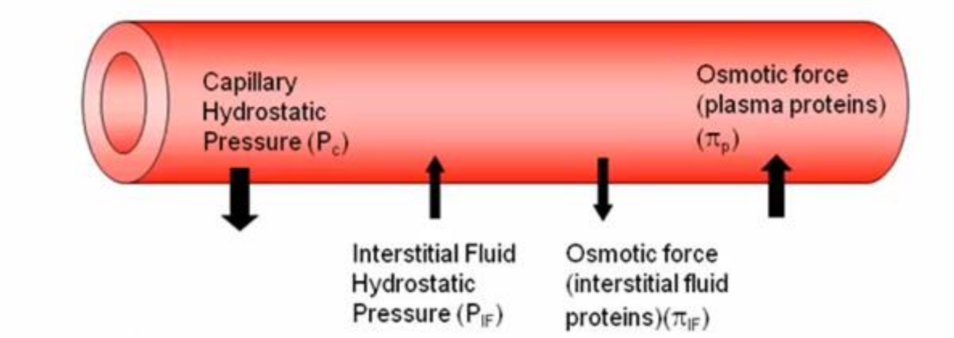




Interstitial Osmotic Pressure (π_{IF})

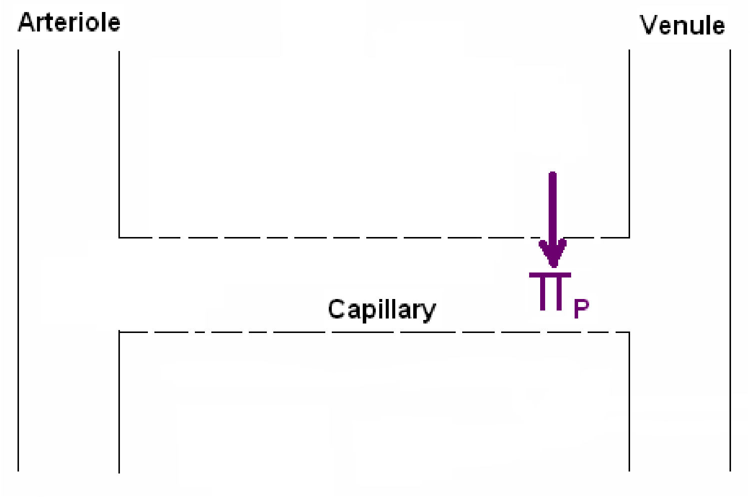
- Pressure caused by osmosis due to few proteins in interstitial fluid (5mmHg)
- Pressure drives fluid OUT of capillary and into tissue (Filtration)

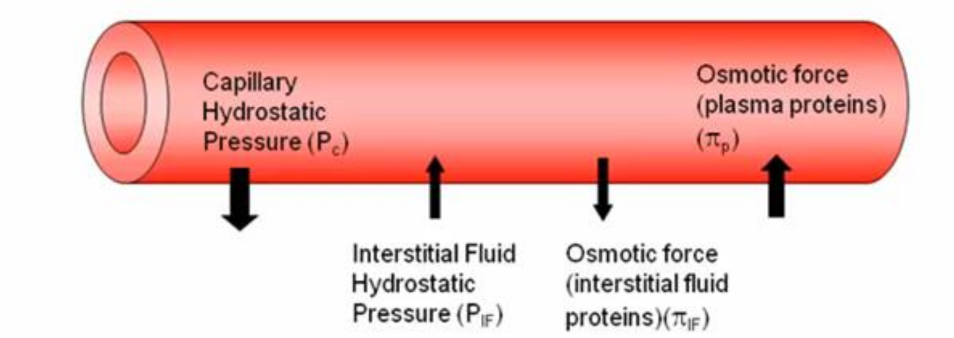




Plasma Osmotic Pressure (π_P)

- Pressure caused by osmosis due to proteins in plasma (28mmHg)
- Pressure drives fluid INTO capillary (Reabsorption)





Balance of Starling Forces

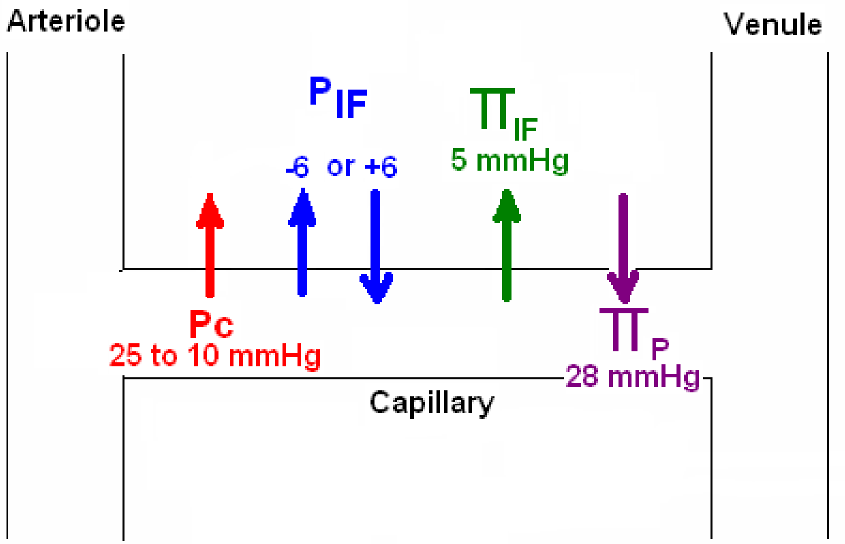
- Starling-Landis equation used to calculate net fluid movement (NFM) across capillary bed

$$NFM = K_f[(P_c - P_{IF}) - (\pi_P - \pi_{IF})]$$

- K_f is filtration coefficient, which represents permeability of capillary (assume 1)

$$NFM = 1[(25 - (-6)) - (28 - (+5))]$$
$$NFM = +8\,mmHg$$

- If positive filtration OUT of capillary, if negative reabsorption INTO capillary



$P_C = 10, P_{IF} = 1, \pi_{IF} = 5, \pi_C = 28$

- $NFM = K_f[(P_c - P_{IF}) - (\pi_P - \pi_{IF})]$
- $NFM = 1[(10 - (1)) - (28 - 5)]$
- $NFM = 1[9 - 23]$
- $NFM = -14$
- Thus, reabsorption into plasma from interstitial fluid

Next Tutorial (Jan 14th)

- Have a great New Year!

What Questions Do You Have?

You can ask in the **Owl forums** as well!

Also anonymously ask questions in the **online dropbox**!!

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