The peripheral vascular system delivers continuous blood flow to supply nutrients to and remove waste products from the cells of the local interstitial environment

The heart is the pump, and pressure at the inlet (aorta) is greater than at the outlet (vena cava). Blood flows downhill seeking the path of least resistance. The peripheral vascular system alters resistance of its pathways to direct blood flow where it is needed.

The Fick principle governs how substances are transported between capillary beds in one organ to another. The Fick principle offers a method to deduce a tissues steady state rate of consumption (or production) of any substance.

$X_{tc} = Q \times ([X]_a - [X]_v)$

X_{tc} = transcapillary efflux rate of X

TRANSCAPILLARY SOLUTE DIFFUSION

passive diffusion from high to low concentration
diffusion rate is determined by 4 factors:
1. **concentration difference**
2. **SA for exchange**
3. **diffusion distance**
4. **permeability of capillary wall to the diffusing substance**

capillaries maximize SA and minimize distance over which substances must travel.

capillary permeability : ease with which a solute can cross the capillary wall.

2 pathways for transcapillary exchange:
1. **lipid soluble substances (O_2, CO_2) cross/diffuse across the capillary wall**
2. **Na, K use water filled channels or pores (maximum 40 A such that plasma proteins do not cross)**

TRANSCAPILLARY FLUID MOVEMENT

these water filled channels also allow movement of fluid through capillary wall
1. filtration: net fluid movement out of capillaries
2. reabsorption: net fluid movement into capillaries

the basic flow equation ($Q = \triangle P/R$) dictates how fluid moves through these transcapillary channels in response to pressure difference between the interstitial and intracapillary fluids

- **hydrostaic**
    - Pc = 25 mmHg drives blood to return to right side heart, also causes fluid to flow through pores into interstitium where Pi = 0 mmHg. **So normally a large drive for filtration.**
- **osmotic**: plasma has a higher protein concentration than interstitial fluid. osmotic pressure is equal to hydrostatic pressure necessary to prevent water movement into test soliton when exposed to pure water across a membrane permeable only to water, and is proportional to the total concentration of solute particles in solution. Plasma oncotic pressure is about 5000 mmHg (almost all NaCl and KCl)
- **oncotic pressure** (colloid osmotic pressure): portion of total osmotic pressure that is due to particles that do not mov freely across capillaries. Plasma oncotic pressure = 25 mmHg while that of interstitial fluid is near 0 mmHg. **So there is large osmotic force for fluid reabsorption into capillaries.**

The starling hypothesis expresses the relationship among the factors that influence transcapillary fluid movement:

Net Filtration Rate = $K([P_c-P_i] - [\pi_c-\pi_i])$

In most tissues, rapid net filtration of fluid is abnormal and leads to edema.

THE LYMPHATIC SYSTEM

prevents edema by accumulation of large particles in interstitial space

1. returns excess interstitial fluid to plasma space

2. removes colloid particles from interstitium (decreasing interstitial colloid osmotic pressure)

very porous blind end lymphatic capillaries in the tissues collect large particles and interstitial fluid (lymph) which is moved through lymphatic vessels and is eventually filtered through LN (remove bacteria and particulate matter) and reenters circulatory system near to where blood enters right heart

flow of lymph is promoted by

1. increases in tissue interstitial pressure (fluid accumulation , movement of surrounding tissue)

2. contraction of the lymphatic vessels

valves in lymphatic vessels prevent backward flow

RESISTANCE AND FLOW IN NETWORKS OF VESSELS

basic flow equation $Q = \triangle P/R$

*** any network of resistances can be reduced to a single equivalent resistor that relates total flow through the network to the pressure difference across the network.**

overall vascular system has 2 patterns

1. **arterial, arteriolar, capillary and venous segments are connected in series (one after the other)**
   a. **overall resistance of the network is the sum of the individual resistances**
   b. flow through the network is equal to flow through each element in the series
   c. a portion of the total pressure drop across the network occurs with each element of the series *** the largest portion of the overall pressure drop will occur across the element in the series with the largest resitance to flow. *** **elements with the highest resistance to flow contribute more to the networks overall resistance than do elements with relatively low resistance.**
2. **within each segment there are many vessels arranges in parallel (beside on another)**
   a. **$1/R_p = 1/R_1 + 1/R_2 + 1/R_3$.....**
   b. overall effective resistance will always be less than that of any element in the network ***** the more parallel elements in the network the lower the overall resistance*****

NORMAL CONDITIONS IN THE PERIPHERAL VASCULATURE

PERIPHERAL BLOOD FLOW VELOCITIES

Flow (volume/time) through all segments of PVS must be equal. But, the total cross sectional area through which CO is flowing varies greatly between different segments of the peripheral vasculature, so **blood must travel with greater velocity through regions with smaller cross sectional area.**

laminar flow: efficient because little energy wasted on anything other than forward fluid motion.

shear stress on walls of vessel wants to drag endothelial layer long with flow. with laminar flow shear stress is proportional to rate of flow through the vessel. **when blood has to move with high velocity through narrow opening normal laminar flow may become turbulent, increasing resistance, and sound.** turbulence happen when reynolds number > 2000 where Re = (velocity x vessel diameter x blood density)/blood viscosity

flow velocities in arterioles, capillaries and veins are low. Turbulent flow never occurs normally in these vessels

PERIPHERAL BLOOD VOLUMES

20% of blood volume is in pulmonary system and heart chambers
****most of the circulating blood is contained in the veins of the systemic organs ("peripheral venous pool")****
a second pool ("central venous pool") in great veins of thorax and right atrium (when peripheral veins constrict blood enters the central venous pool, and increased CV volume leads to increase in CVP and enhanced cardiac filling, augmenting stroke volume. therefore ***peripheral veins act to influence cardiac output.)

PERIPHERAL BLOOD PRESSURES

the difference between systolic and diastolic pressures increases with distance from the heart in large arteries
- pressure in aortic arch (100 mmHg) close to that in arteries (MAP)
- large pressure drop in arterioles and continues to decrease in venules and veins
- CVP (filling pressure for right heart) normally close to 0 mmHg

PERIPHERAL VASCULAR RESISTANCES

because flow must be the same through each consecutive region, the pressure drop across the regions is a direct reflection of the resistance to flow within that region.

- **arterioles present a large resistance to flow**
    - **overall resistance of any organ is determined largely by arteriolar resistance** (which is strongly influence by diameter)
    - arteriolar dilation causes decreased arterial P and increased P on venous side --> transcapillary fluid filtration
    - arteriolar constriction causes greater pressure drop across arterioles increasing arterial pressure and decreases pressure on venous side -> trans capillary fluid reabsorption
- arteries and capillaries have low resistance to flow
- mean arterial pressure is relatively stable, so large changes in an organs blood flow are achieved by changes in overall vascular resistance to blood flow
- R organ = R arteries + R arterioles + R capillaries + R venules + R veins

TOTAL PERIPHERAL RESISTANCE

TPR = overall resistance to flow through-the entire systemic circulation
- systemic organs are in parallel
- important determinant of arterial blood pressure

ELASTIC PROPERTIES OF ARTERIES AND VEINS

arteries and veins contribute only a small portion of resistance to flow through vascular bed such that changes in diameter have no significant effect on blood flow through organs BUT elasticity is important as these vessels can act as reservoirs and large amounts of blood can be stored in them.

- arterial vs venous compartment, each with internal pressure related to volume of blood within it at any moment and how elastic its walls are
- compliance (C) describes how much a vessels volume changes in response to change in distending pressure (internal vs external pressure on vascular wall)
- veins are much more compliant than arteries at normal operating pressures (100 vs 2 mL/ mmHg)
    - because veins are so compliant even a small change in pressure can cause significant amount of circulating blood to shift into or out of venous pool
    - peripheral venous constriction --> inc peripheral venous pressure --> blood shifted out of venous compartment
    - arteries can act as a reservoir on a beat to beat basis. they convert the pulsatile outflow of the heart into a steady flow of blood through the vascular beds of systemic organs

DETERMINANTS OF ARTERIAL BP

MAP: average effective pressure that drives blood throughout the systemic organs
MAP = CO x TPR
MAP ~ Pd + 1/3 (Ps-Pd)

ARTERIAL PULSE PRESSURE

Pp = Ps-Pd

arterial pressure increases as arterial blood volume is expanded during cardiac ejection. the change in pressure depends on the volume and compliance of the arterial compartment

Pp ~ SV/C

Decreased arterial compliance as occurs with age leads to a larger pulse pressure for a given stroke volume. Stroke volume tends to decrease with age while arterial blood volume and mean arterial pressure tend (due to increase in TPR) to increase with age.

QUESTIONS

1. Which of the following conditions favor edema formation?
a. lymphatic blockage
b. thrombophlebitis (venous clot)
c. decreased plasma protein concentration
d. greatly increased capillary pore size
e. all of the above

2. Which of the following is consistent with a normal men arterial pressure but an abnormally high arterial pulse pressure?
a. low stroke volume
b. high heart rate
c. decreased TPR
d. increased arterial stiffness
e. aortic valve stenosis

3. True or False: Other factors being equal, a decrease in the renal vascular resistance increase TPR?

4. True or False: Acute increases in arterial pulse pressure usually result from increases in stroke volume.

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$Pp \sim SV/Ca$
$MAP = CO \times TPR$

3. True or False: Other factors being equal, a decrease in the renal vascular resistance increases TPR? FALSE

$1/TPR = 1/R(\text{kidneys}) + ...$
When the resitance of any single peripheral organ changes, TPR changes in the same direction.

4. True or False: Acute increases in arterial pulse pressure usually result from increases in stroke volume True or False? TRUE

Acute changes in arterial compliance do not usually occur and $Pp \sim SV/Ca$