Cardiovascular Physiology

Cardiac Control

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Capillary Exchange

- Cardiovascular process involving
  - all three functional systems
    - heart, blood & blood vessels
  - and physics
    - velocity of blood flow
    - cross-sectional area of capillaries
    - Exchange processes
      - diffusion & transcytosis
    - Pressures
      - Filtration
        - Influenced by capillary hydrostatic pressure
      - colloid osmotic pressures (oncotic pressure)
        - Influence bulk flow

Capillary Exchange

- The physics involved: Exchange Processes
  - Diffusion factors
    - Surface area for diffusion
      - 6300 m^2 (two football field surfaces)
      - Direct result of the large cross-sectional area and length of capillaries (~50,000 miles)
    - membrane permeability
      - Differing capillaries have differing permeability's
        - Continuous vs. Fenestrated vs. Sinusoid
      - Also influenced by surrounding cells
        - Pericytes are weakly contractile cells that form a network around capillaries…
        - The more pericytes the less permeable the capillaries are
        - Can be associated with other cells to form barriers

Capillary Exchange

- The physics involved:
  - Exchange processes
    - Diffusion of smaller molecules between the cells
      - paracellular pathway
    - Diffusion of larger molecules through the cells via
      - endothelial transport (transcytosis)

Capillary Exchange

- The physics involved: Pressures
  - Capillary hydrostatic pressure (P_{out})
    - The filtration force in the capillaries
    - Created by the fluid pressure of blood entering the capillaries
    - Variable throughout the length of the capillary
      - highest on arteriole end (**32 mm Hg**)
      - lowest on venule end (**15 mm Hg**)
    - Direct relationship between capillary hydrostatic pressure (CHP) and movement of fluids across the capillary membrane
    - There should be no filtration pressure moving fluid back into the capillary (interstitial fluid hydrostatic pressure)

      $P_{IF} = 0$ mm Hg

      …So the outward filtration pressure (P_{out}) is attributable to the capillary hydrostatic pressure (P_{cap})

Capillary Exchange

- The physics involved:
  - colloidal osmotic pressures **[<u>Oncotic</u>** (π)]
    - Created by the "solids" in the blood that are not capable of crossing through the capillary.
    - Inverse relationship between fluid movement and <u>colloid osmotic pressure</u> or <u>*oncotic pressure*</u>
      - π_{cap} remains constant
        - However the effect of this is variable again from ateriolar end to venule end as the filtration pressure is reduced due to the length of the capillary and the loss of fluid
      - π_{IF}
        - The interstitial colloid osmotic pressure should be 0 mm Hg
        - This is what makes colloidal osmotic pressure in the capillary a reabsorption pressure

$\pi_{in} = (\pi_{IF} - \pi_{cap})$ = (0 mm Hg – 25 mm Hg) = **–25 mm Hg**

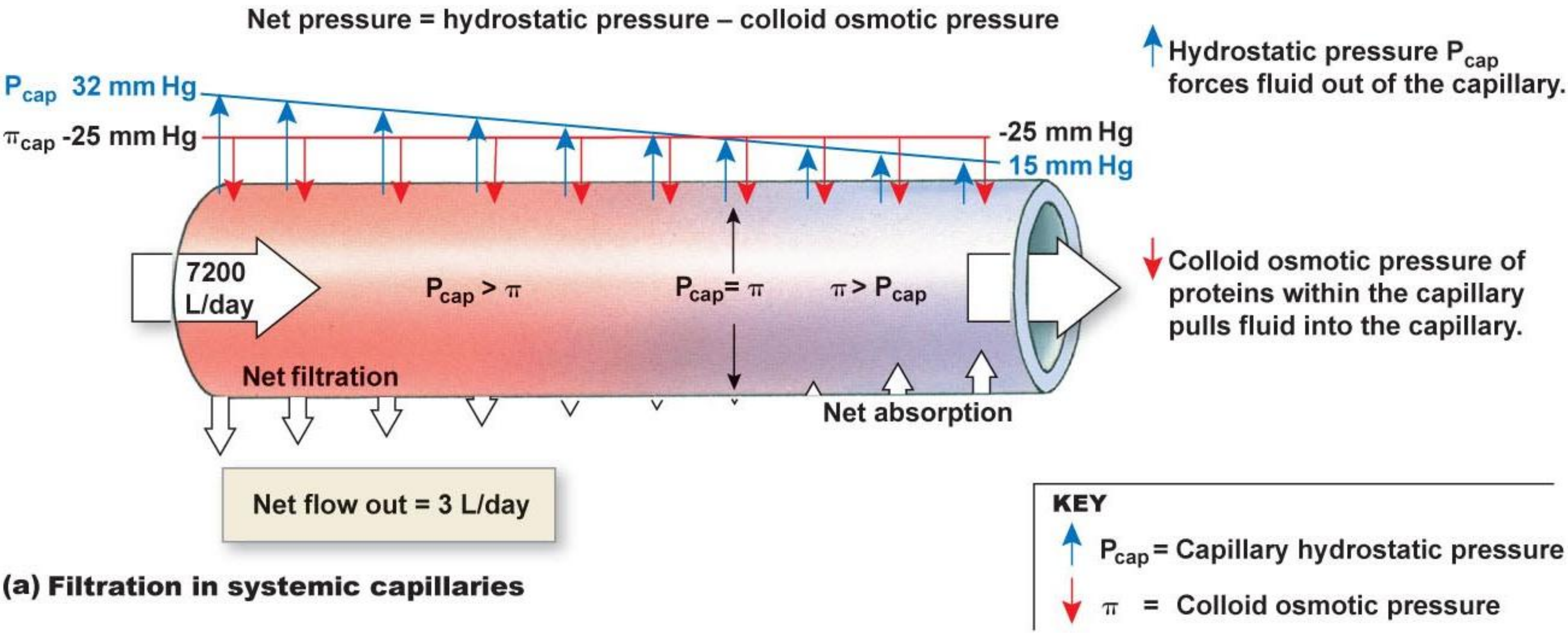
Capillary Exchange

- All the major factors
  - Filtration Pressure (P_{out}) is equal to the change in capillary hydrostatic pressure ΔP_{CHP} (P_{cap} – P_{IF})
  - Absorption Pressure (π_{in}) is equal to the change in colloid osmotic pressure $\Delta P_{\pi} = (\pi_{IF} - \pi_{cap})$
- Coming together to create
  - Net Pressure = $P_{out} - \pi_{in}$

Capillary Exchange

- The Net Pressure will change in a gradient along the length of the capillary.
  - Net Pressure $_{arterial\ end} = (P_{cap} - P_{IF}) + (\pi_{cap} - \pi_{IF})$
    $(32\ mm\ Hg - 0\ mm\ Hg) + (0\ mm\ Hg - 25\ mm\ Hg) =$
    $(32\ mm\ Hg + -25\ mm\ Hg) =$ **7 mm Hg**
    - **This is a filtration pressure**
  - Net Pressure $_{venous\ end} = (P_{cap} - P_{IF}) + (\pi_{cap} - \pi_{IF})$
    $(15\ mm\ Hg - 0\ mm\ Hg) + (0\ mm\ Hg - 25\ mm\ Hg) =$
    $(15\ mm\ Hg + -25\ mm\ Hg) =$ **–10 mm Hg**
    - **This is a reabsorption pressure**
- filtration pressure is greater than the reabsorption pressure ($P_{out} > \pi_{in}$)
- This means there is a net loss of capillary fluid to the interstitial fluid on a constant basis

Capillary Exchange

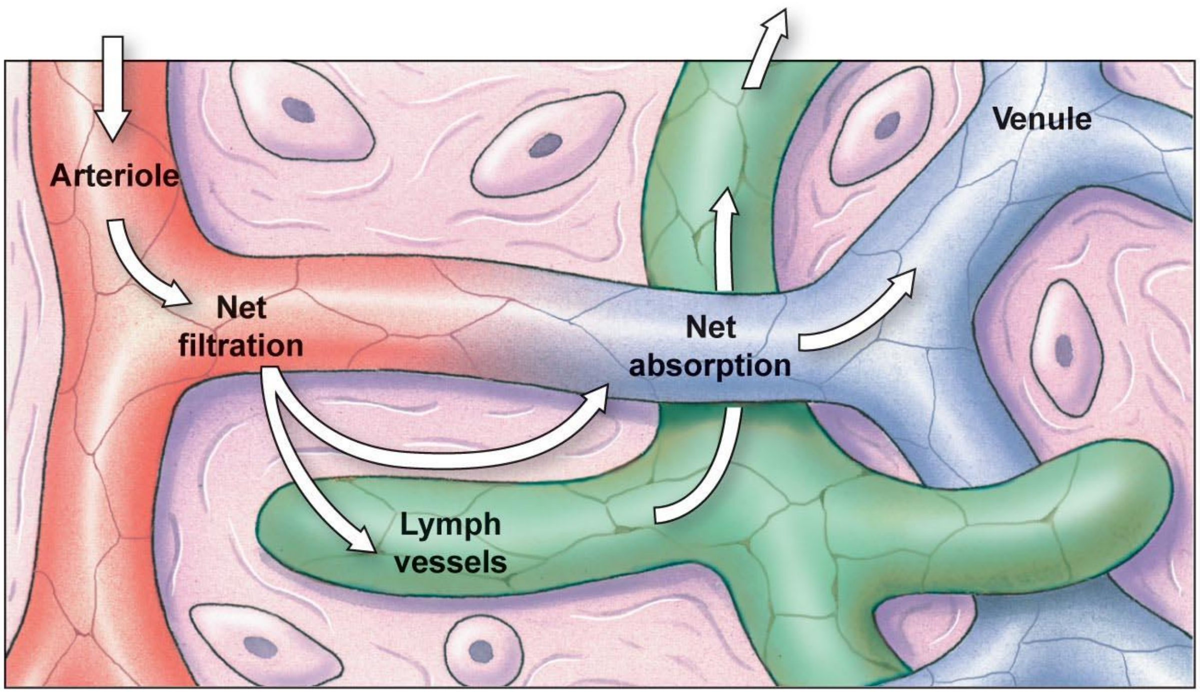


(a) Filtration in systemic capillaries

Where does the excess fluid of 3 L/day go?

Capillary Exchange

- The return of the fluid gained in the interstitial space due to a greater filtration force than reabsorption force is done by
- the lymphatic system



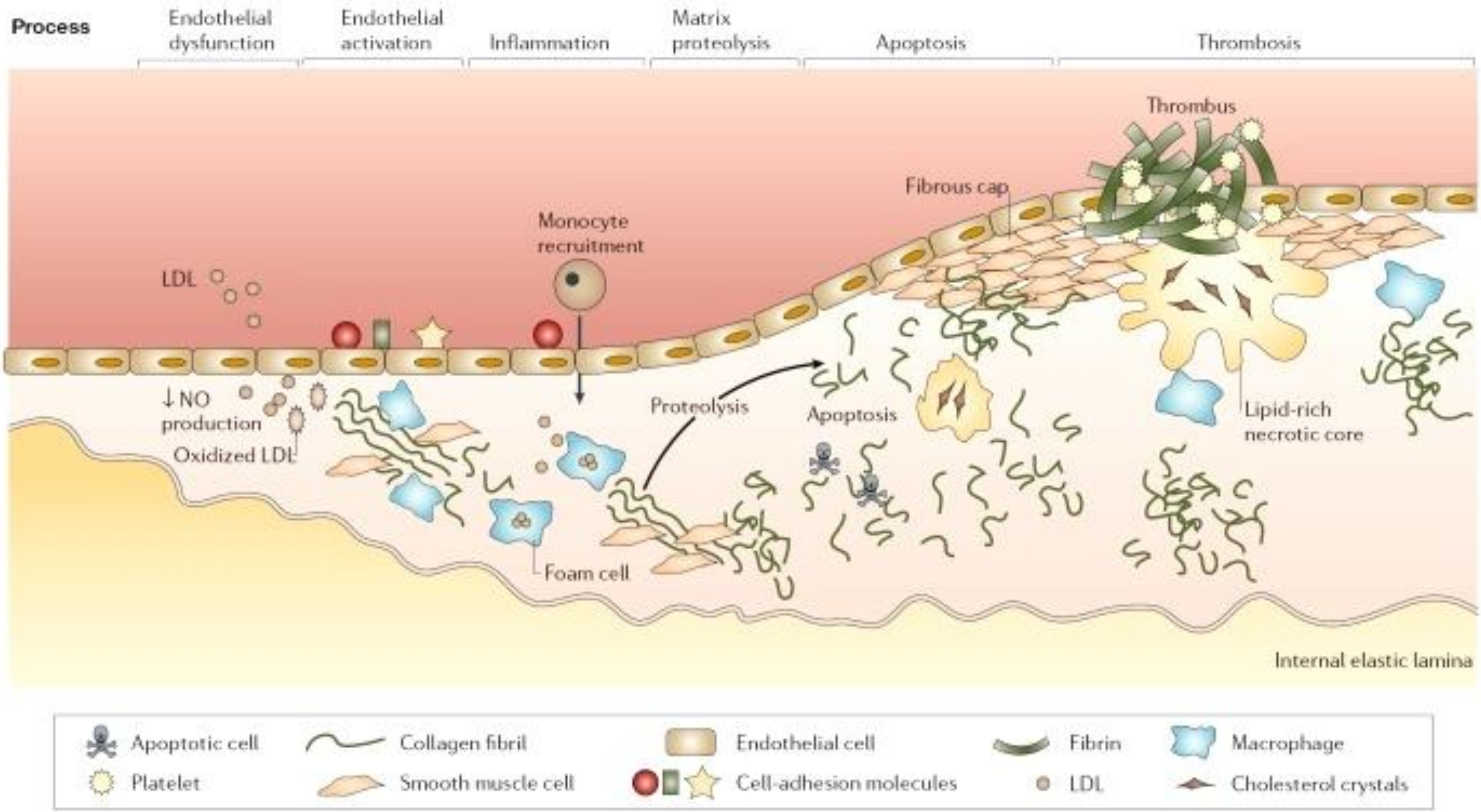
A Little Disease & Disorder
Diabetes

- What does diabetes have to do with CVD?
  - 2/3 of people with diabetes will die as a result of cardiovascular problems

    Why?
    - blood glucose that is normally available for cellular metabolism is not
    - fats and proteins are metabolized instead and fatty acids are released into the blood
    - LDL-cholesterol levels rise
    - leads to atherosclerosis and its progression

A little Disease & Disorder

Atherosclerosis Progression



A Little Disease & Disorder
Atherosclerosis

- So what is good cholesterol?
  - HDL-C (high density lipoprotein-cholesterol)
  - Should be carry about 30% of your total cholesterol
  - Why is it "healthy"?
    - It is associated with a lower risk of heart attack
      - Hypothesis is that it picks up cholesterol from plaques and transports it away = reverse cholesterol transport hypothesis
      - It also is involved with reducing inflammation and platelet activation/aggregation
- What are the recommended levels?

A Little Disorder & Disease

Hypertension and CVD

- Prolonged high pressure will cause the heart to fatigue leading to heart failure
  - Usually starts with the left side weakening leading to pulmonary edema and lack of O2
  - Further weakening occurs and congestive heart failure occurs