Fluid Movements:

1. **End Diastolic Volume** (EDV)
   - Total amount of blood :

   ✴

2. **Stroke Volume** (SV):
   - Total amount of blood :
   - Contraction ejects
   - ✴ ~70 mls / beat (per ventricle)

3. **End Systolic Volume** (ESV)
   - Total amount of blood remaining in ventricles
   - Remaining:
   - ✠ ~45 mls / beat (per ventricle)

Cardiac Function:

- Quantified as:
  - Volume of blood pumped :

- Dependent upon:
  a. **Cardiac Rate**:
  b. **Stroke Volume**:

  ✠ Amount of blood ejected per Ventricle

\[
CO \text{ (mls/min)} = CR \text{ (beats/min)} \times SV \text{ (mls/beat)}
\]

<table>
<thead>
<tr>
<th></th>
<th>CR (beats/min)</th>
<th>SV (mls/beat)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rest</td>
<td>75</td>
<td>70</td>
</tr>
<tr>
<td>Exercise</td>
<td>104</td>
<td>150</td>
</tr>
</tbody>
</table>

- Affected by:
  1. Autonomic Nervous System:
     a. Sympathetic NS:
        ✠
        ✠
b. Parasympathetic NS:

2. Cardiac Stretch (Frank-Starling Effect)
   a. Greater ventricle filling: EDV
      - Increased EDV =
      - Increased
      - Increases

3. Peripheral Resistance: Vascular Resistance
   a. Mean Arterial Pressure
      - Increased Arterial pressure =
      - Increased resistance =
      - Decreases

Body Fluids: “Water Compartments”
- 60% of:

1. Intracellular Fluid:
   -
2. Extra-cellular Fluid:
   -
   a. Interstitial Fluid:
      - Fluid surrounding cells in:
      -
   b. Plasma & Lymph: Fluid contained w/in:
      -
Capillaries: “Exchange Vessels”:
- Branched network of vessels connecting:
  - W/in:
  - Site of fluid exchange between:
- Fluid exchange determined by balance between:
a. **Filtration**: Movement of water:

b. **Absorption**: Movement of fluid:

- Fluid movement determined by: **2 Forces**
  - Starling Forces
    - 1. **Hydrostatic (blood) Pressure**
      - Pressure fluid exerts w/in:
        - "Fluid PUSH"
    - 2. **Oncotic Pressure**: "Protein Concentration Pressure"
      - Fluid compartment’s:
        - "Fluid PULL"
      - Directly related to:
        - Water is PULLED into compartment of:
        - Degree of PULL =

  ✓ **NET Fluid movements** determined by **BOTH forces**:

**Hydrostatic Pressure**

- Produced by:
  - Arterial end:
  - Venule End:

  ✗ **Pressure decreases due to loss of**:
  - Pushed into:

**Oncotic Pressure**

- Osmotic Pressure produced by:
Filtration pushes fluid:

a. Small solutes distribute:

b. Plasma proteins Cannot filter across the capillary epithelium:

Therefore: Protein concentration is:

- Protein concentration gradient results in fluid:
  - Capillary Oncotic Pressure:
    - Plasma Proteins:
    - Produced by:

Oncotic pressure PULLS:

- Capillary Oncotic Pressure:
  - SAME on arteriole & venule sides of capillary:

NET Fluid Movement:

- Balance between 2 Forces:
  - Collectively called:

\[
\text{Fluid OUT} - \text{Fluid IN} = \text{Net Movement}
\]

Arterial Side:

Hydrostatic pressure (OUT) – Oncotic Pressure (IN)

\[
32\text{mmHg} - 22\text{mmHg}
\]

Push OUT greater Pull IN

- Net FORCE OUT = \(~10\text{mmHg}\)

Venule Side:

Hydrostatic pressure (OUT) – Osmotic Pressure (IN)
15mmHg - 22 mmHg
Push OUT lower Pull IN

✓ Net FORCE IN = ~ 7 mmHg
✓ Absorption Force =

• Starling Forces do NOT balance:

✓ Filtration forces greater than re-absorption force

~ More fluid pushed out than:

☆ ONLY 85% filtered fluid is:

☆ 15% filtered remains as:

Interstitial Fluid Circulation:

• 85% reabsorbed DIRECTLY into:

• 15% returned:

يتها Use alternate circulation:

• Lymphatic Vessels:

✓ Function: Return Interstitial fluid to:

✓ Characteristics:

a. VERY LOW:
b. POROUS: Openings between:
c. PERVASIVE: Present

⇒

⇒ Absorbed fluid called:

✓ Lymph returned to Systemic circulation:

a.
b.
Clinical Significance:

- **Edema**: “Tissue swelling”
  - Accumulation of:

Causes:

1. **High Blood Pressure**:
   - Increased:
     - Favors:
     - Increases:

2. **High Tissue Protein Pressure**:
   - Increased:
     - Favors:
     - Increases:
     - Increased vascular permeability:
       - **Histamine**: Increases “escape” of blood:

3. **Decreased Plasma Protein Pressure**
   - Decreased:
     - Decreased capillary:
Decreased:

- **Liver Damage**
  - Decreased:

- **Starvation**:
  - Decreased:

4. **Lymphatic Obstruction**:
  - Decrease *Lymphatic fluid return*
    - Inhibits removal of:
      - Filaria worms block:

5. **Plastic Surgery, cancer and cancer treatment**:
  - Decreased:
    - Nodes and or lymph structures:

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**Study Questions**:

1. What is the cardiac output, stroke volume and end diastolic volume? What is the equation for cardiac output? Approximately how much blood is ejected in a resting stroke volume? What percent of the EDV is the stroke volume?
2. How does the autonomic nervous system affect the cardiac output? How does cardiac stretch (by EDV) cause changes in cardiac output? What effect does the mean arterial resistance have on cardiac output?
3. An individual with chronic hypertension (long lasting high peripheral blood pressure) is a high risk candidate of cardiac failure. Explain how hypertension can put an undue physical stress on the heart.
4. Describe the difference between plasma, interstitial fluid and lymph. What is the approximate distribution of each intracellular and extracellular fluid in the body? What percentage of the extracellular fluid is plasma and what percentage is extracellular fluid?
5. What two forces are involved in moving fluid across the capillary? Which force results in a net filtration from the capillary? Which force result in a net absorption into the capillary?
6. Explain the process of filtration across the capillary wall. (include approximate pressures).
7. Explain the process of absorption across the capillary wall (include approximate pressures). What is osmotic pressure? What creates the vascular osmotic pressure? What organ produces the plasma proteins?
8. What are the Starling Forces? Why is there a need for additional fluid re-absorption (ie Why is there a need for the Lymph system)?
10. If the blood pressure was increased (hypertension), what is the affect on tissue fluid and edema? Describe why hypertension is often associated with peripheral tissue swelling. What is pitting edema?
11. Associated with a site of infection, tissue redness and swelling are commonly related symptoms. Describe why an infection would result in edema.
12. Why might liver damage result in peripheral edema and ascites? (hint what does the Liver produce and release into the blood which will assist in fluid re-absorption into the capillaries?)
13. Why would starvation result in kwashiorkor (the characteristic distended belly)?
13. Often times in experimental animals, if an experimenter wants to increase the animal’s blood volume they can introduce a large insoluble molecule into the blood. Explain why this would tend to increase blood volume.

14. One of the most dramatic examples of tissue edema is in anaphylactic shock. In response to an allergen, the immune system can become hyper-sensitized and respond with an overcompensated immune response. Why do you think that the tissue fluid is accumulating? (Hint think about what the immune cells – specifically basophils might be doing to contribute to this reaction.

15. Elephantiasis is an extreme case of inhibited lymphatic return. Explain why you would see these dramatic symptoms?

16. In the US the most common cause of lymph edema is plastic surgery and cancer treatment. Explain why these would result in edema.