2016-2-19  Describe how Starling forces determine fluid flux within the pulmonary capillary bed.

**General:**
Capillaries contain semipermeable membranes to allow the movement of fluid and solutes.
- it is normally impermeable to large protein
- Plasma ultrafiltrate is filtered by bulk flow through the capillary wall by the action of opposing hydrostatic and oncotic pressures
- **Starling Equation:** Forces are kept in balance such that
  \[
  \text{Net fluid flux} = k_f[(P_c - P_i) - \sigma(\pi_i - \pi_c)],
  \]
  where \( k_f \) is capillary filtration constant (SA x hydraulic permeability);
  - \( \sigma \) is reflection coefficient (leakiness of membrane to protein 0-1)

**The key features of the pulmonary microcirculation are:**
- The pulmonary capillaries (and the alveoli) have very thin walls which minimises the barrier to diffusion.
- In the alveolar walls, the capillaries form a dense network which has been considered to be almost a continuous thin film of blood. This provides a large capillary surface area.
- The pressures in the pulmonary circuit are much lower than in the systemic circulation and the pulmonary vascular resistance is very low. The pressure is just sufficient to perfuse the apical areas of the lungs in the erect healthy adult.

**4 Starling forces exist between capillary and interstitium:**

<table>
<thead>
<tr>
<th></th>
<th>Pulmonary</th>
<th>Systemic</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_c ) Capillary hydrostatic pressure</td>
<td>( 13 \rightarrow 6 ) Art\rightarrow ven Variable due to hydrostatic effects of gravity in different parts of lung</td>
<td>( \sim 35 \rightarrow 15 \text{mmHg} ) (Arterial ( \rightarrow ) venous)</td>
</tr>
<tr>
<td>( P_i ) Interstitial hydrostatic pressure</td>
<td>Variable, but 0 to slightly negative</td>
<td>5mmHg</td>
</tr>
<tr>
<td>( \pi_c ) Plasma oncotic pressure</td>
<td>25 mmHg</td>
<td>( \sim 20 \text{mmHg} )</td>
</tr>
<tr>
<td>( \pi_i ) Interstitial fluid oncotic pressure</td>
<td>17 mmHg</td>
<td>( \sim 0 \text{mmHg} )</td>
</tr>
</tbody>
</table>

- where \( k_f \) is capillary filtration constant (SA x hydraulic permeability);
- \( \sigma \) is reflection coefficient (leakiness of membrane to protein 0-1) = 0.5 for lung
Oncotic pressure gradient
• The interstitial oncotic pressure is high indicating significant leak of protein (mostly albumin) across the thin capillary walls under normal circumstances. The reflection coefficient has been estimated at about 0.5
• Considering the typical values and allowing for the reflection coefficient, it can be estimated that the net oncotic gradient is small but favours reabsorption.

Hydrostatic pressure gradient
• The capillaries are called intra-alveolar vessels and the pressure they are exposed to is close to alveolar pressure (zero to slightly negative, due to surfactant) and become more negative closer to the hilum
• This favours flow of fluid from the alveolar interstitium into the pulmonary lymphatics.
• The capillary hydrostatic pressure is variable because of the effects of gravity.
• The pulmonary circuit has a low resistance and about half of this resistance is due to the pulmonary capillaries which have no muscle in their walls. The capillary hydrostatic pressure is quickly affected by changes in pulmonary artery pressure and left atrial pressure without much protective buffering.

Overall Effect
The balance of Starling forces in the lung is generally stated as favouring reabsorption because of the clinical fact that the lungs are generally dry and clearly need to be to facilitate gas exchange

Safety Factors Preventing Pulmonary Oedema
• Increased lymph flow
• Decrease in interstitial oncotic pressure (oncotic buffering mechanism)
• High interstitial compliance

Examiner Comments:
25% of candidates passed this question. The equations for nett fluid flux and for nett filtration pressure were incorrect in many answers. Better answers presented the equations and discussed each of the elements as relevant to the pulmonary capillary bed, including difference from systemic capillary beds. Mention of the role of lymphatics and of the effect of surfactant, left atrial pressure, gravity and posture gained marks, also