2003b(13)/1999b(3)/1998b(8): Describe the factors that affect airways resistance

**Airways Resistance** = resistance caused by air moving through the airways.
- \[ R = \frac{\Delta P}{Q} \] where \( \Delta P = \) ‘driving pressure’, pressure gradient b/n mouth and alveoli, \( Q = \) air flow
- Normally quite low (2cmH\(_2\)O/L/s)
- Movement is **laminar, transitional, and turbulent**

**Laminar Flow**
- Occurs in straight smooth-walled tubes
- Air tends to move in concentric tubes parallel to the walls
  - Forms a ‘velocity profile’ where velocity of air at the centre is twice the velocity at the walls
- Resistance in laminar flow is calculated in accordance with the Hagen-Poiseuille equation:
  - \[ R = \frac{8\eta l}{\pi r^4} \] Where \( R = \) resistance (cmH\(_2\)O/l/s)
  - \( \eta = \) viscosity, \( l = \) length of tube, \( r = \) radius
  - From this it can be seen that resistance is proportional to the viscosity of the gas and length of the tube and inversely proportional to the fourth power of the radius, i.e. small changes in airways diameter has large effects on resistance
- It is also proportional to the velocity of air moving such that
  - \[ P = k.v \] where \( P = \) pressure, \( k = \) constant, \( v = \) velocity (flow rate)
  - In the airways, laminar flow tends to occur in the small airways (terminal bronchioles), as length and viscosity remain constant through airways, only variable factor is radius, which is affected by:
    - ↓intramural radius: oedema, ↑mucous, wall hypertrophy
    - smooth mm tone: bronchospasm (↓r), connective tissue loss, \( \beta_2 \)-agonists (↑r), adrenaline neb (↑r)
    - External compression: tumour, haemorrhage, PTX, dynamic airways compression with forced expiration

**Lung Volume**
- Indirectly, lung vol becomes a determinant in airways resistance.
  - As ↑lung vol → ↓airways resistance 2° radial traction on airways by the expanding chest
    - Airways resistance is minimal at TLC
- Factors include:
  - Radial traction on intra-thoracic bronchi
  - Negative transpleural pressure → maintains patency of small airways

**Transitional flow**
- This occurs through most of the airways
- Air flow is a mixture of laminar flow and turbulent flow
  - This is because of the multiple bifurcations present as well as the ↓smoothness of the tubes 2° to cilia, mucous, debris

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- Here, pressure is determined by both the flow rate and the square of the flow rate
  \[ P = kv + kv^2 \]

**Turbulent flow**
- Occurs mainly in the larger airways (nose, pharynx, larynx, trachea)
- Occurs when air movement is not longer occurring in a straight line as with laminar flow, but instead gas movement is disorganized and causes the formation of small eddies, which increase the resistance.
- Resistance in turbulent flow is also dependent on flow rate as seen above, however it now has the relationship such that
  \[ P = k.v^2 \]
  where it is proportionate to the square of the flow rate

**Reynold's number**
- Used to predict the likelihood of laminar or turbulent flow
  \[ Re = \frac{2rvd}{\eta} \]
  where \( Re = \) Reynold's number, \( r = \) radius, \( v = \) velocity, \( \eta = \) density of gas, \( \eta = \) viscosity
- \( Re > 2000 \): inertial forces dominate viscous forces and flow is turbulent
- \( Re < 2000 \): viscous forces dominate and the flow is laminar
- Density rather than viscosity becomes the 1° determinant of turbulent flow.
  - Heliox will have ↓turbulent flow due to addition of low density He
- It can be seen from this that only in the smaller airways will \( Re \) be small enough (~1) to allow for laminar flow.