2011a(13)/2006b(10)/2000a(5): Describe the determinants of work of breathing in an adult human at rest.

(2006b(10)/2000a(5): Explain how to minimize work)
In the adult human at rest, breathing involves inspiration and expiration
Work = pressure x volume (Joules)

**Inspiration**
Inspiration is an active process
- **Inspiratory mm: Diaphragm, external intercostals**
  - O₂ requirement 3ml/min
  - Contraction of diaphragm → vertical downward movement → ↑vertical volume of thorax
  - Contraction of external intercostals → bucket handle movement of ribs → ↑AP and lat vol of thorax
- ↑ in all dimensions of thorax ↓intra-pleural pressure, ↓alveolar pressure of mouth → movement of air into lungs
Air movement requires the overcoming of forces of friction, airways resistance and elastic forces of the lung
- **Friction / Airways Resistance**: 50% of inspiratory work (blue area)
- **Elastic Forces of Lung**: 50% of work
  - Inspiration: stretching of elastic fibres / overcoming surface tension (minimised with surfactant)
    - Energy stored as potential energy (green area)
  - Minimal energy required to overcome elastic force as resting lung (at FRC) sits on steep part of compliance curve

**Expiration**
In an adult at rest → passive process
- Needs to overcome friction / airways resistance
- Potential energy (green area) stored in stretched elastic tissue is released when fibres return to resting length
- Energy released to overcome friction (red area) covered by potential energy → rest dissipated as heat

**Minimise work of breathing**
- Breathing from FRC
  - Keeps lung on steep part of compliance curve
- RR controlled
  - ↑RR → ↑flow → ↑friction
  - ↓RR Advantageous in obstructive lung disease → large slow breaths minimize friction work
  - ↑RR If ↓compliance of lung (restrictive lung disease) → small, rapid breaths advantageous (minimize elastic work)
- Minimise resistance
  - Poiseuille-Hagan equation
  - \[ R = \frac{8 \eta l}{\pi r^4} \]
    - \( R \) = resistance, \( \eta \) = viscosity of gas, \( l \) = length of tube, \( r \) = radius

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- Small ↑ airway radius → large ↓ resistance
  - Reynolds Number
    - \( \frac{\rho D v}{\eta} \)  \( \rho = \) density of gas, \( D = \) diameter of tube, \( v = \) velocity, \( \eta = \) viscosity of gas
    - Flow rate controlled (\( v \))
  - Reynolds Number > 2000 ↑ turbulent flow → ↑ work of breathing

Total WOB → to move lung and chest
- Difficulty to measure
- Estimates previously obtained by ventilating paralysed Pts in an ‘iron lung’
- Can be calculated as **O\(_2\) cost of breathing**
  
  Efficiency % = \( \frac{\text{useful work}}{\text{O}_2 \text{ cost (total energy expended)}} \) x 100
  
  = 5 – 10%

- ↑ with ↑ RR (30%)
- COAD → \( \text{O}_2 \) cost may limit exercise ability