

# CRFS – Tackling the Difficult Exam Questions

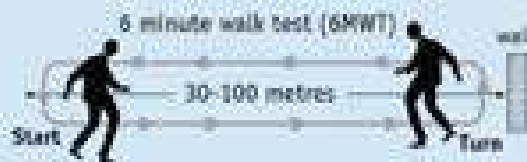
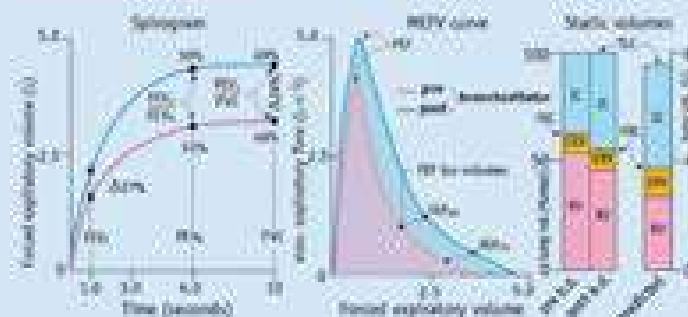
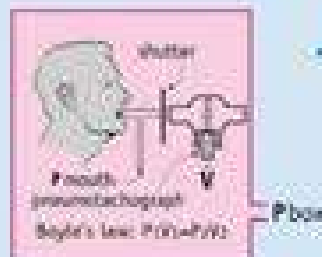
Jarrold Warner CRFS  
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a new book

J M B HUGHES

## Physiology and Practice of

# Pulmonary Function



Foreword: Neil Pride  
Illustrator: Daig Simmonds

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Respiratory Technology & Physiology



## Q 1

- A Valsalva's manoeuvre results in
  - A - Decreased alveolar pressure
  - B - Decreased intrathoracic pressure
  - C - No change in transpulmonary pressure
  - D - Increased venous return to the heart

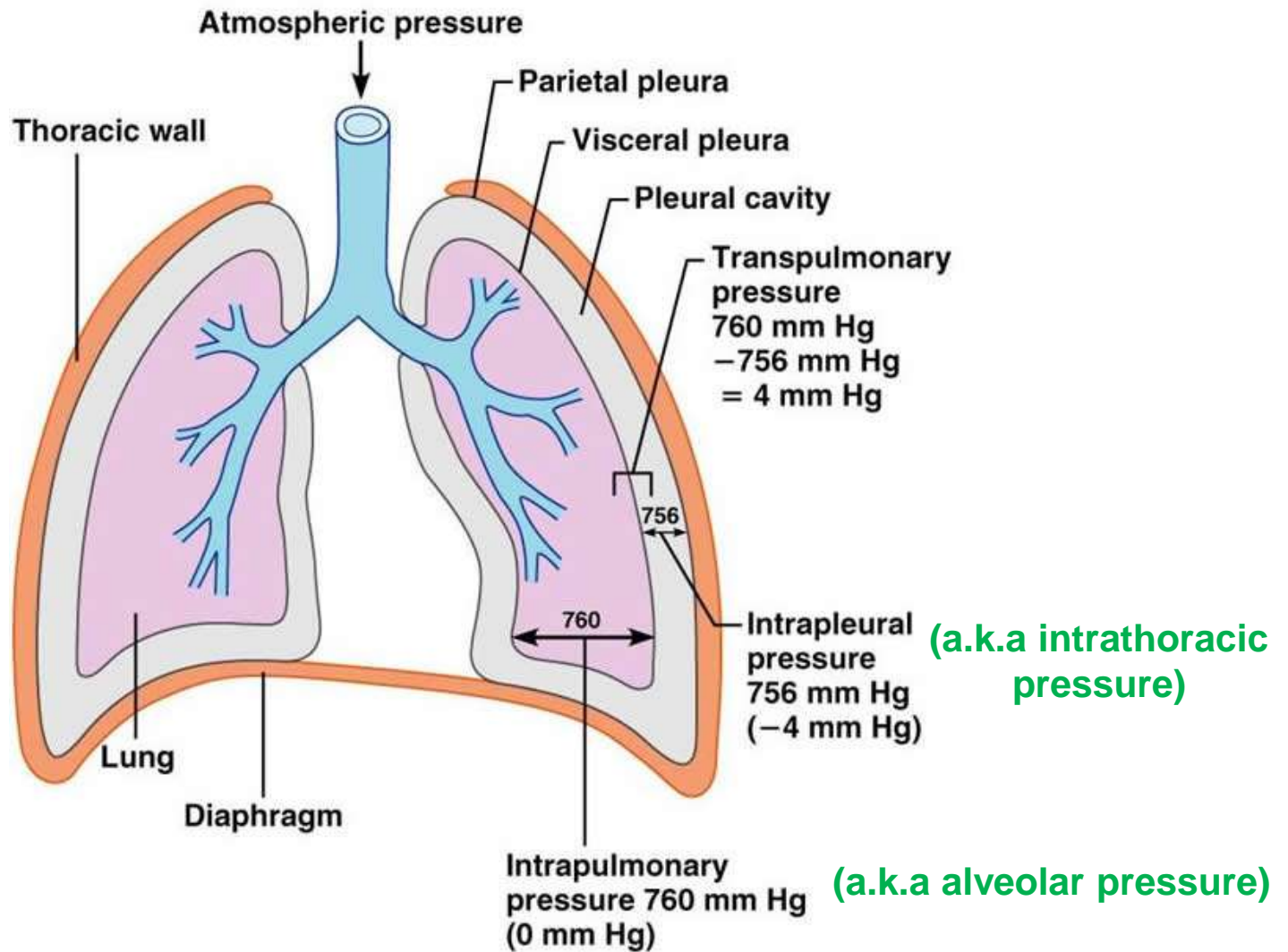
# Q 1



# Q 1

	<b>Physiology</b>
<b>Phase I</b> Onset of strain	<ul style="list-style-type: none"><li>• Increased intrathoracic pressure compresses vessels within thorax</li><li>• Increase arterial pressure</li></ul>
<b>Phase II</b> Maintenance of strain	<ul style="list-style-type: none"><li>• Reduced venous return to right atrium</li><li>• Decreased Q and systolic BP</li><li>• Peripheral vasoconstriction</li></ul>
<b>Phase III</b> Release of strain	<ul style="list-style-type: none"><li>• Venous return of pulmonary bed increase abruptly</li></ul>
<b>Phase IV</b> Relaxation	<ul style="list-style-type: none"><li>• Accumulated venous return reaches LV, increased SV is pumped into constricted systemic vascular bed causing overshoot of arterial pressure</li></ul>

# Q 1



# Q 1

- Transpulmonary Pressure = Alveolar Pressure – Intrathoracic Pressure

**OR**

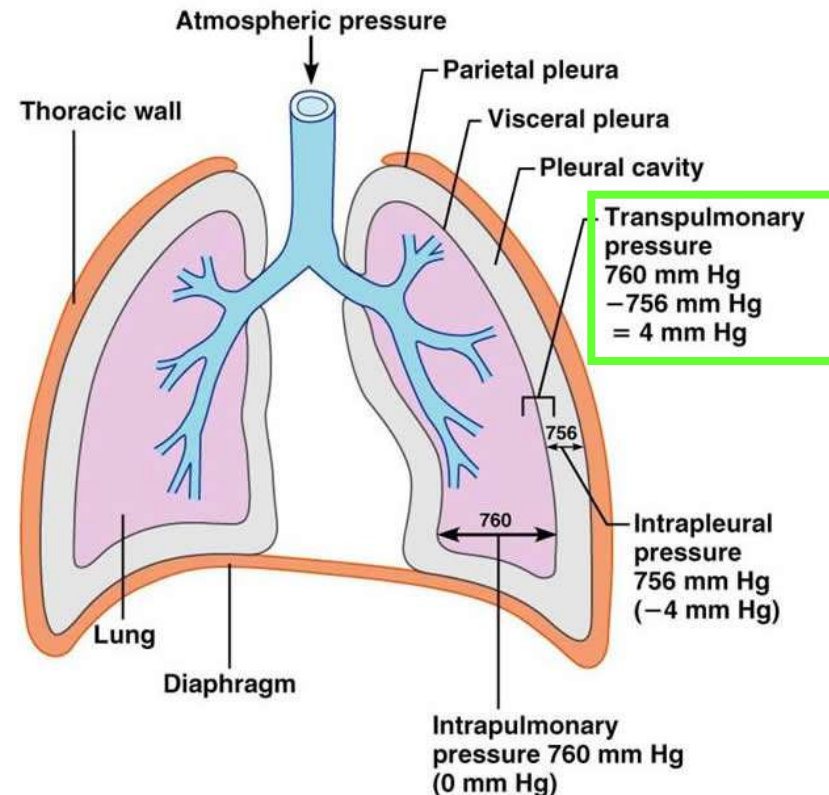
- Transpulmonary Pressure = Intrapulmonary Pressure - Intrapleural Pressure
- Transpulmonary Pressure = 760 mmHg – 756 mmHg = +4 mmHg
- Transpulmonary pressure, under normal physiological conditions, is always positive
- Pneumothorax (not normal physiological conditions)
  - Intrapleural space punctured
  - Alveolar Pressure = Intrapleural Pressure
  - Lung collapses

# Q 1

- Intrapleural pressure = pressure within pleural cavity
- Intrapleural pressure is always negative (-)
  - acts like a suction to keep lungs inflated
- Negative intrapleural pressure is due to three main factors:
  - Surface tension of alveolar fluid
    - alveolar fluid tends to pull each of the alveoli inward and pulls entire lung inward
    - surfactant reduces this force
  - Elasticity of lungs
    - elastic tissue in lungs tends to recoil and pull lung inward
    - as lung moves away from thoracic wall, the cavity becomes slightly larger
    - negative pressure created acts like a suction to keep lungs inflated
  - Elasticity of thoracic wall
    - elastic thoracic wall tends to pull away the lung, further enlarging pleural cavity and creating negative pressure
    - surface tension of pleural fluid resists actual separation of the lung and thoracic wall

# Q 1

- Transpulmonary pressure must remain positive (+)
  - Otherwise, lung will collapse
- During Valsalva
  - Intrathoracic pressure  $\uparrow$
  - Alveolar pressure  $\uparrow$



# Q 1

- A Valsalva's manoeuvre results in -
  - A - ~~Decreased alveolar pressure~~  
*alveolar pressure increases*
  - B - ~~Decreased intrathoracic pressure~~  
*intrathoracic pressure increases*
  - C - **No change in transpulmonary pressure**  
*otherwise lung would deflate*
  - D - ~~Increased venous return to the heart~~  
*reduced venous return*

## Q 2

- A patient performs 3 acceptable FVC efforts, with the following results from each effort:

	<b>1</b>	<b>2</b>	<b>3</b>
<b>FEV<sub>1</sub> (L)</b>	3.25	3.35	3.10
<b>FVC (L)</b>	4.15	4.00	4.20

According to ATS/ERS guidelines, which spirometric values should be reported from which efforts?

- A - FEV<sub>1</sub>, FVC and FEF<sub>25-75</sub> from effort 2
- B - FEV<sub>1</sub>, FVC and FEF<sub>25-75</sub> from effort 3
- C - FEV<sub>1</sub> from effort 2, FVC and FEF<sub>25-75</sub> from effort 3
- D - FEV<sub>1</sub> from effort 2, FVC from effort 3, FEF<sub>25-75</sub> from effort 1

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## **SERIES “ATS/ERS TASK FORCE: STANDARDISATION OF LUNG FUNCTION TESTING”**

**Edited by V. Brusasco, R. Crapo and G. Viegi**  
**Number 2 in this Series**

# Standardisation of spirometry

**M.R. Miller, J. Hankinson, V. Brusasco, F. Burgos, R. Casaburi, A. Coates,  
R. Crapo, P. Enright, C.P.M. van der Grinten, P. Gustafsson, R. Jensen,  
D.C. Johnson, N. MacIntyre, R. McKay, D. Navajas, O.F. Pedersen, R. Pellegrino,  
G. Viegi and J. Wanger**

**TABLE 5** Summary of within- and between-manoeuve acceptability criteria

**Within-manoeuve criteria**

Individual spiromgrams are “acceptable” if

They are free from artefacts [3]

Cough during the first second of exhalation

Glottis closure that influences the measurement

Early termination or cut-off

Effort that is not maximal throughout

Leak

Obstructed mouthpiece

They have good starts

Extrapolated volume <5% of FVC or 0.15 L, whichever is greater

They show satisfactory exhalation

Duration of  $\geq 6$  s (3 s for children) or a plateau in the volume–time curve or

If the subject cannot or should not continue to exhale

**Between-manoeuve criteria**

After three acceptable spiromgrams have been obtained, apply the following tests

The two largest values of FVC must be within 0.150 L of each other

The two largest values of FEV<sub>1</sub> must be within 0.150 L of each other

If both of these criteria are met, the test session may be concluded

If both of these criteria are not met, continue testing until

Both of the criteria are met with analysis of additional acceptable spiromgrams

or

A total of eight tests have been performed (optional) or

The patient/subject cannot or should not continue

Save, as a minimum, the three satisfactory manoeuvres

FVC: forced vital capacity; FEV<sub>1</sub>: forced expiratory volume in one second.

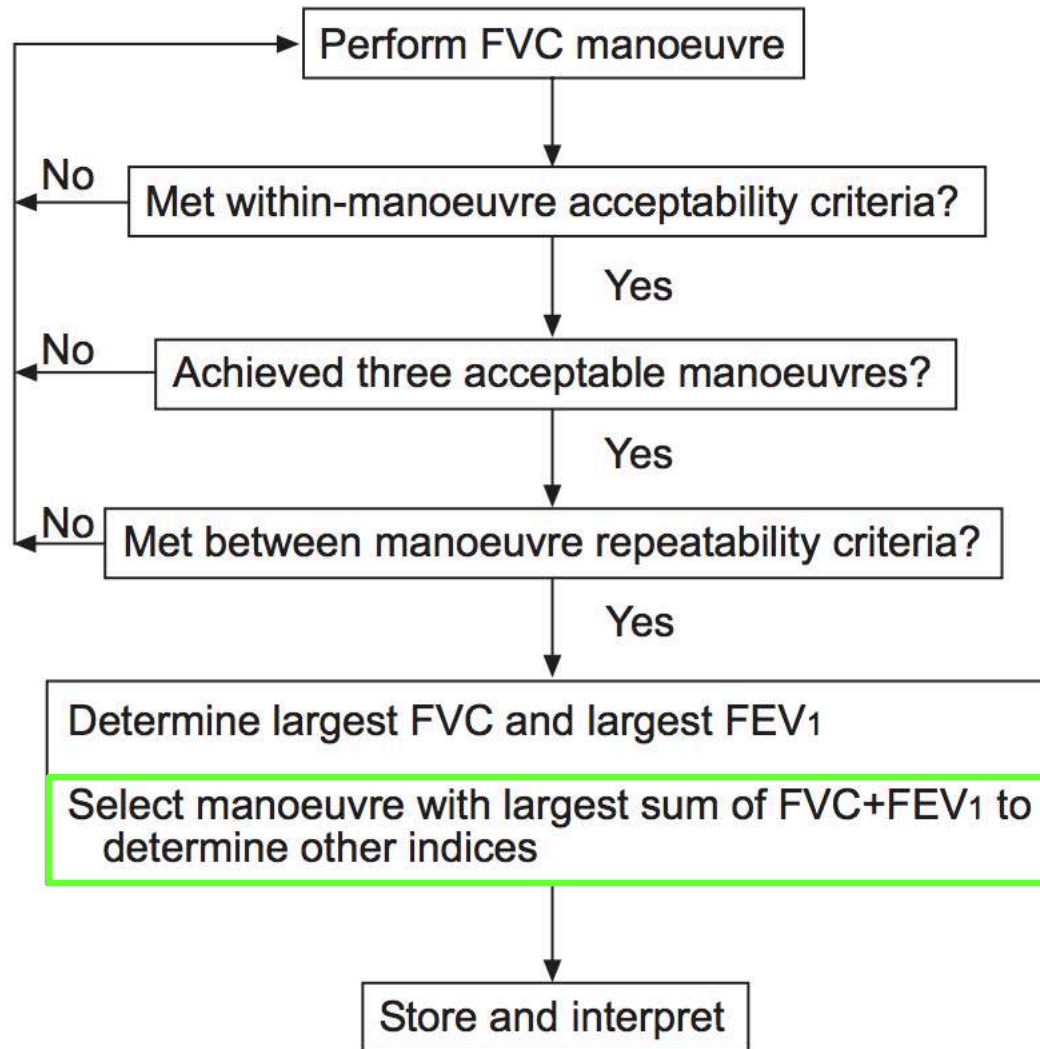
**Test result selection**

FVC and FEV<sub>1</sub> should be measured from a series of at least three forced expiratory curves that have an acceptable start of test and are free from artefact, such as a cough (*i.e.* “usable curves”). The largest FVC and the largest FEV<sub>1</sub> (BTPS) should be recorded after examining the data from all of the usable curves, even if they do not come from the same curve.

pg. 326

pg. 325

# Q 2



## Q 2

- A patient performs 3 acceptable FVC efforts, with the following results from each effort:

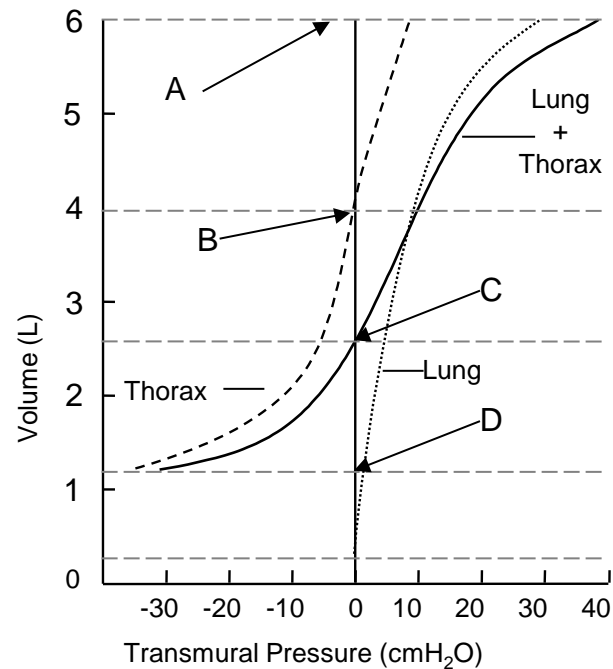
	1	2	3
<b>FEV<sub>1</sub> (L)</b>	3.25	3.35	3.10
<b>FVC (L)</b>	4.15	4.00	4.20

According to ATS/ERS guidelines, which spirometric values should be reported from which efforts?

- A - ~~FEV<sub>1</sub>, FVC and FEF<sub>25-75</sub> from effort 2~~  
*FVC from effort 2 not the highest*
- B - ~~FEV<sub>1</sub>, FVC and FEF<sub>25-75</sub> from effort 3~~  
*FEV1 from effort 3 not the highest*
- C - ~~FEV<sub>1</sub> from effort 2, FVC and FEF<sub>25-75</sub> from effort 3~~  
*effort 3 not highest sum of FEV1 + FVC*
- D - FEV<sub>1</sub> from effort 2, FVC from effort 3, FEF<sub>25-75</sub> from effort 1  
*FEF<sub>25-75</sub> from largest sum of FEV1 and FVC which is effort 1*

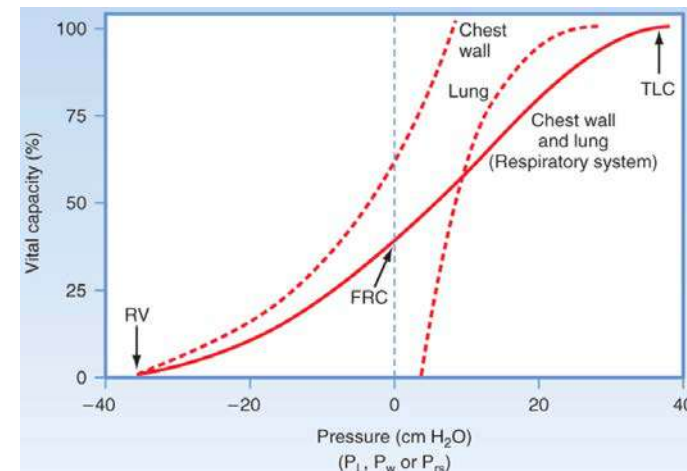
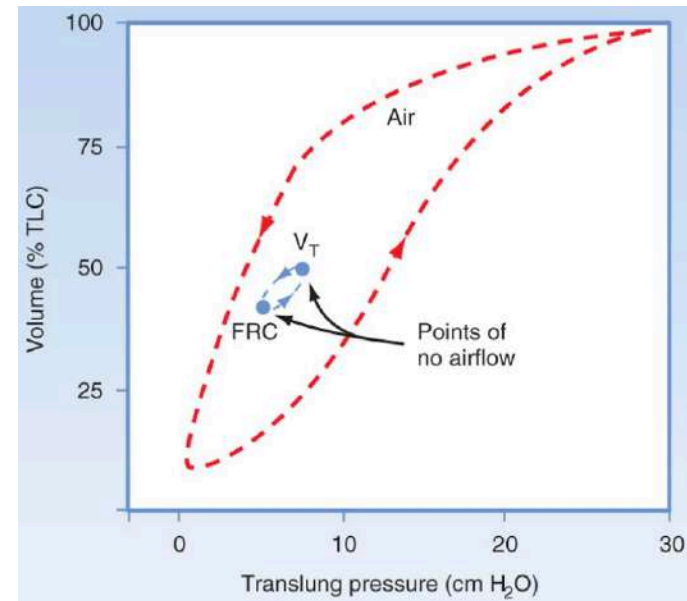
# Q 3

- In the figure provided, which arrow indicates the resting volume of the thorax?

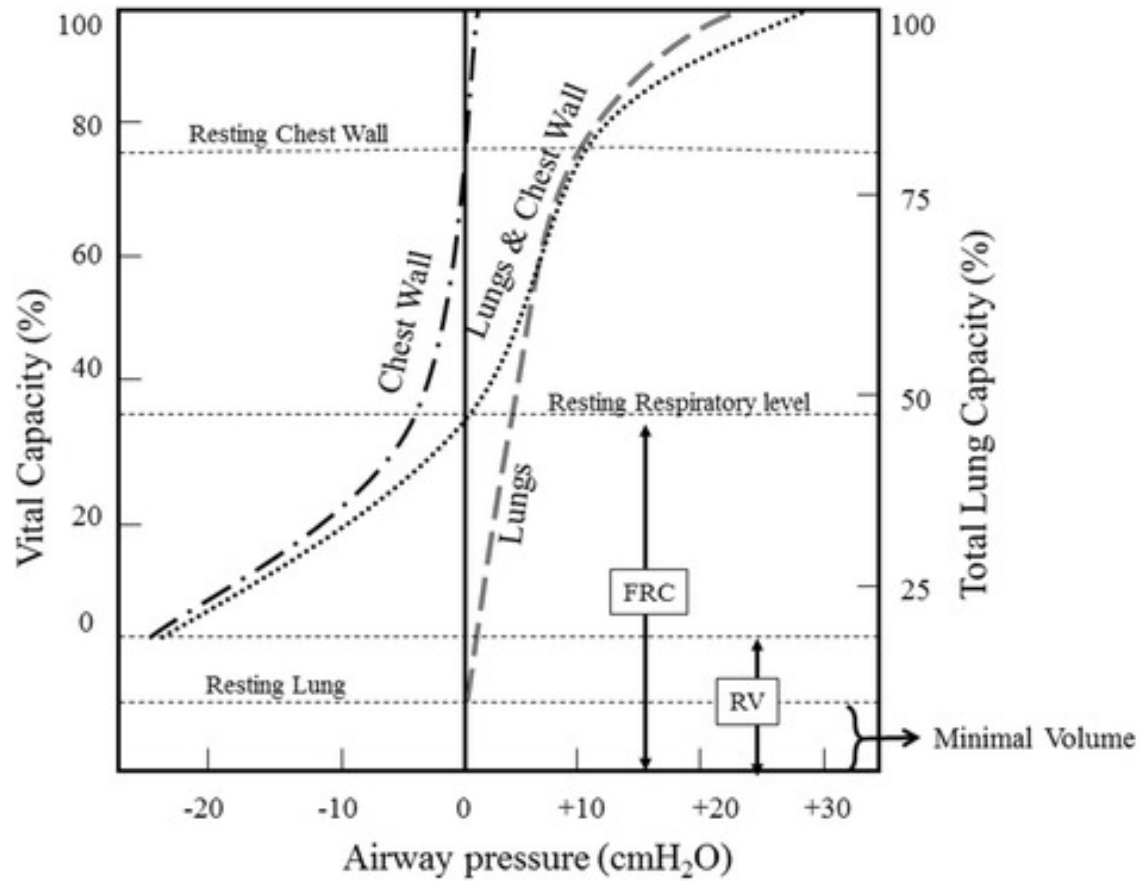


# Q 3

- Pressure is equal to zero when the system (Chest wall and Lung) is resting
  - neither inflating ( $\uparrow$  volume) nor deflating ( $\downarrow$  volume)
- Lung and Chest Wall system is rested when
  - $P_{alv} = P_{atm}$
  - Lungs at FRC
- $P_{alv} = P_{atm}$ 
  - inward recoil tendency of the lungs is equal to the outward recoil tendency of the chest wall
- $P_{alv} > P_{atm}$  = expiration
- $P_{alv} < P_{atm}$  = inspiration

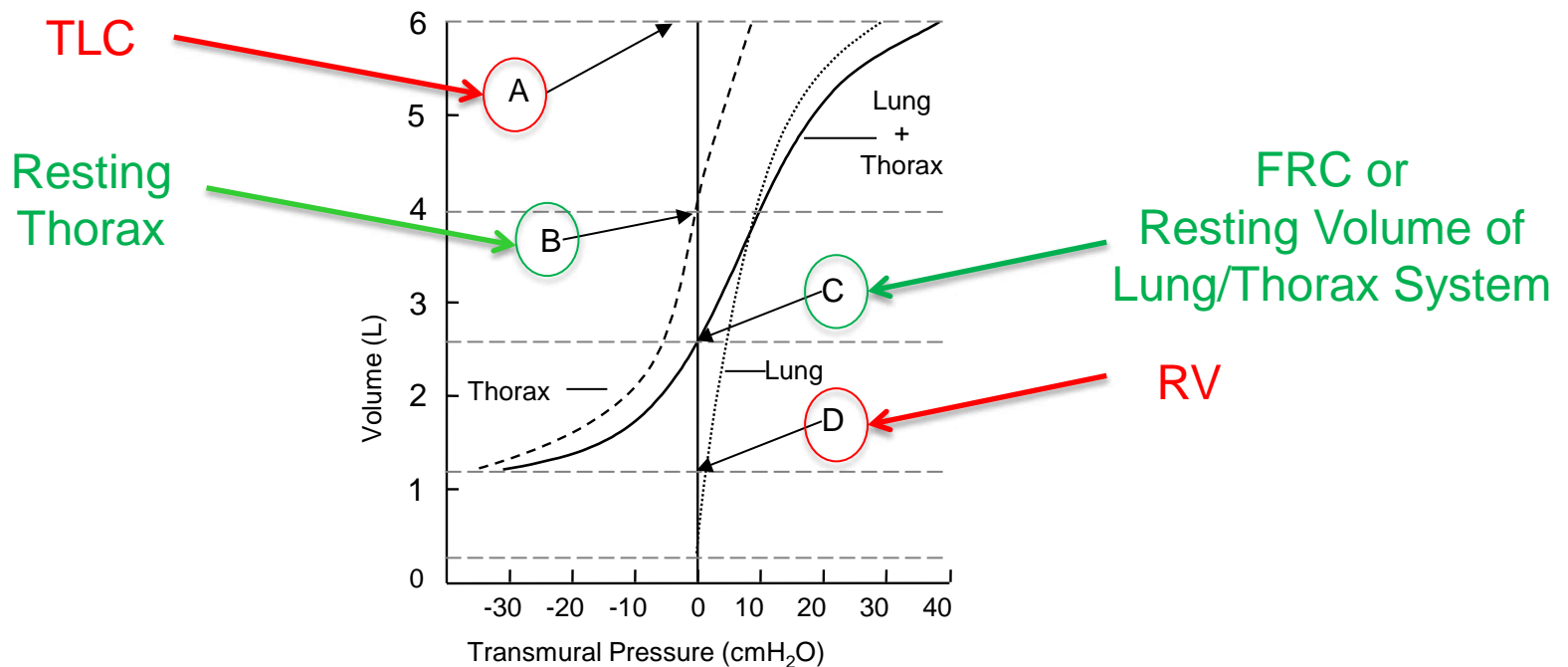


# Q 3



# Q 3

- In the figure provided, which arrow indicates the resting volume of the thorax?



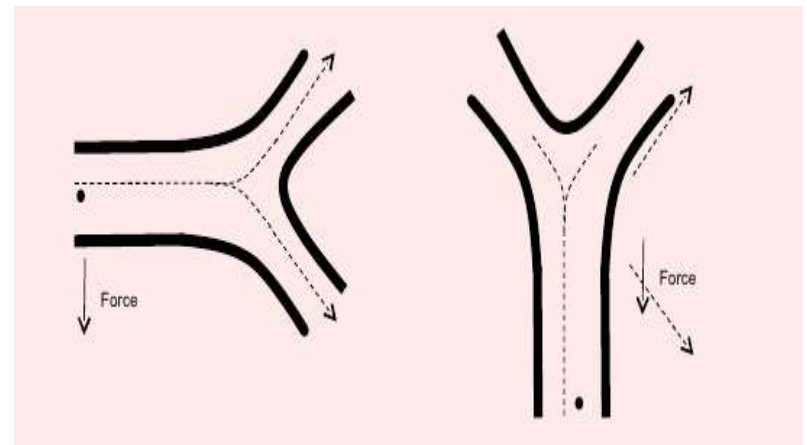
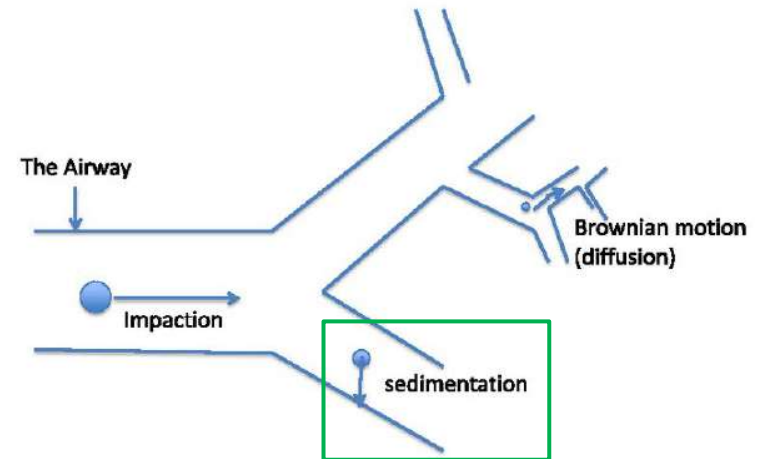
## Q 4

- Which of the following is NOT a mechanism for aerosol deposition in the lung?
  - A - Rotational inertia
  - B - Sedimentation
  - C - Brownian movement
  - D - Impaction

# Q 4

- **Sedimentation**

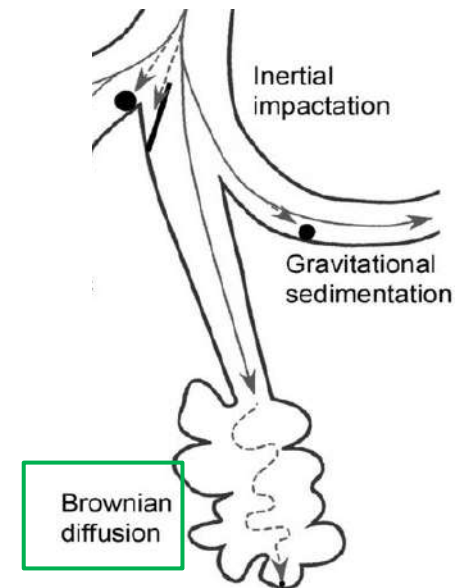
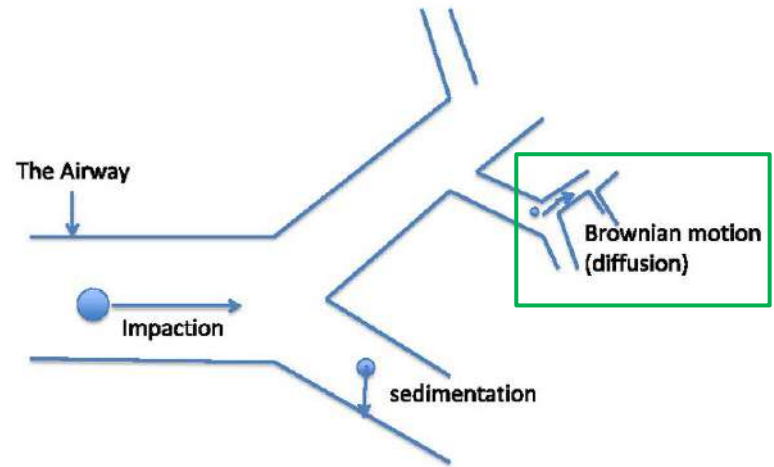
- gravitational force acting on a particle overcomes the total force of air resistance
- particles with sufficient mass are deposited due to the force of gravity when they remain in the airway for a sufficient length of time
- mainly in last 5 bronchial generations
  - air speed is slow
  - residence time is longer



# Q 4

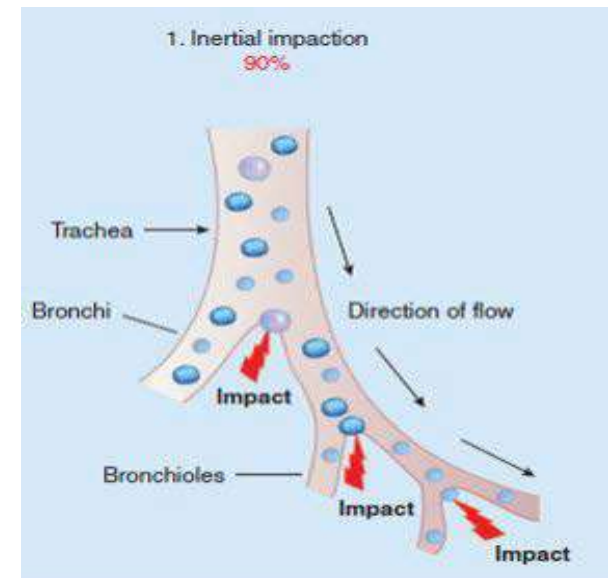
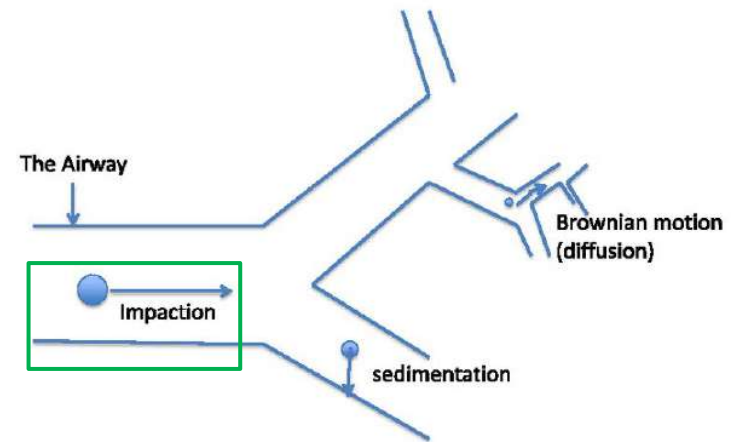
- **Brownian Movement/Diffusion**

- particles of an aerosol move erratically from one place to another in the airways
- “random walk”
- a consequence of Brownian diffusion
  - random motion of particles
  - Ancient Greek “πέ:δε:sis” – “leaping”
- particles smaller than  $0.5 \mu\text{m}$
- reach the alveolar spaces, where the air speed is practically zero
- these particles are generally not deposited
- expelled upon exhalation

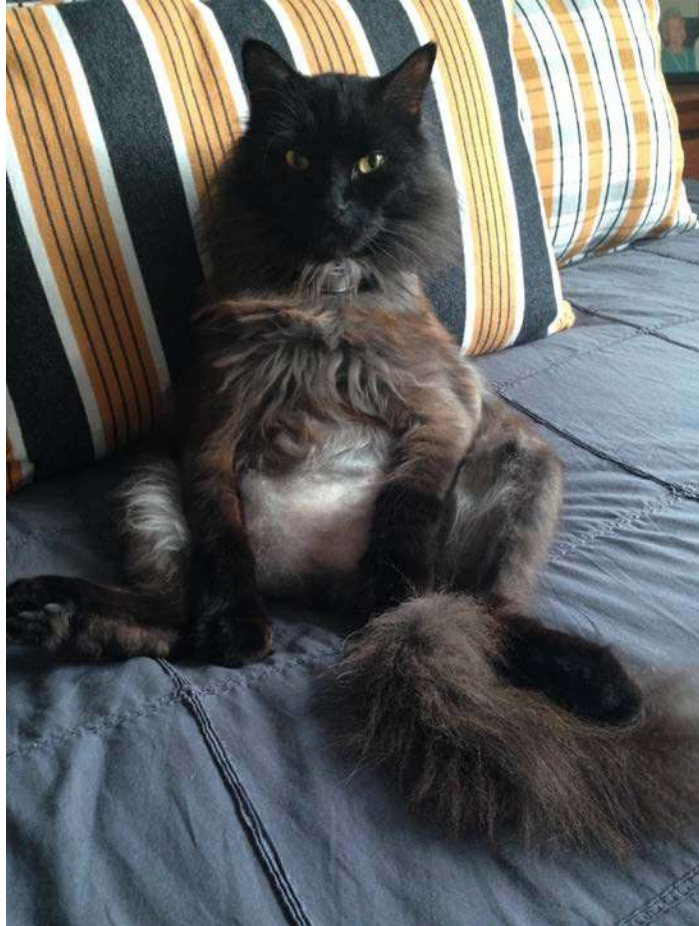


# Q 4

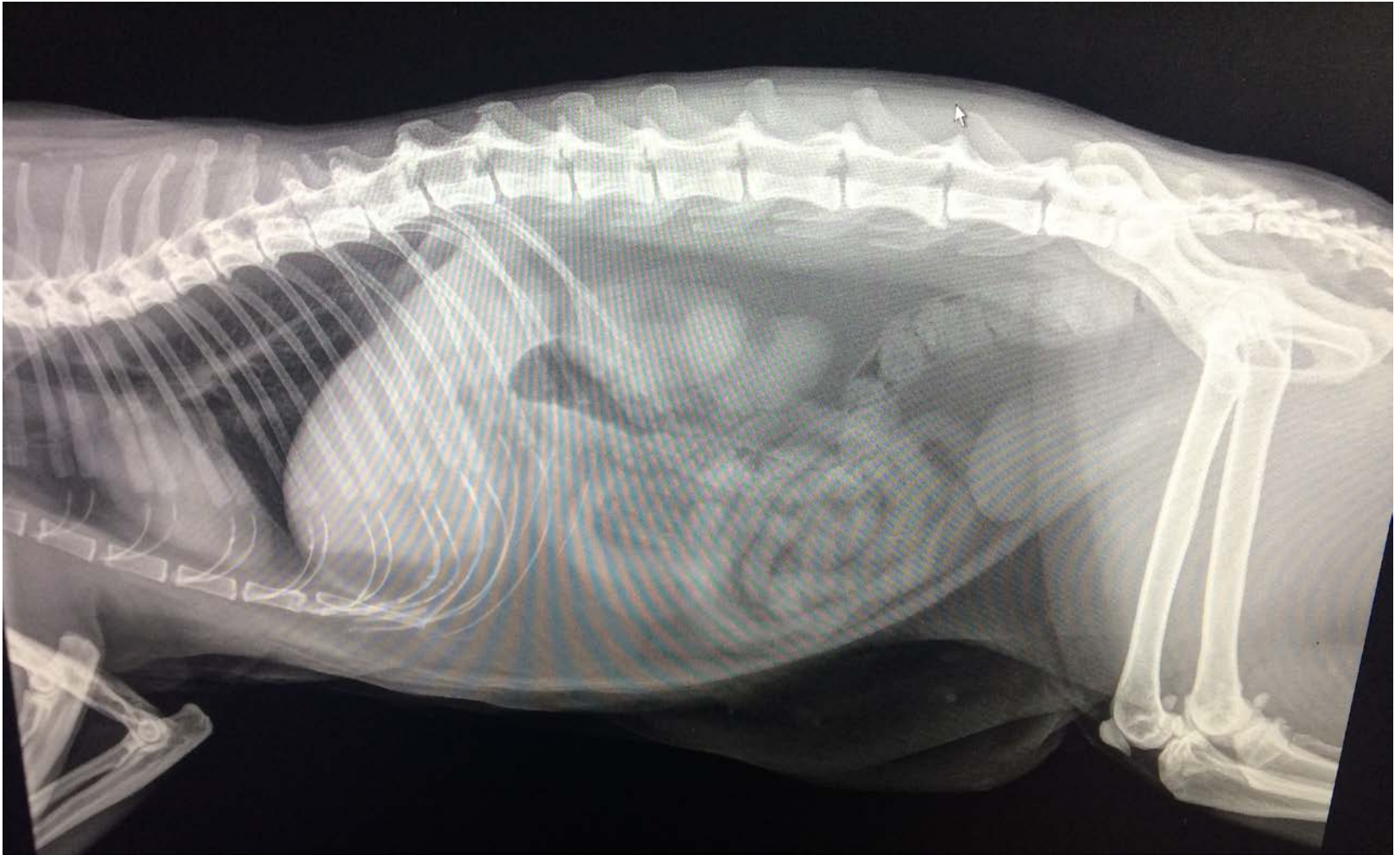
- **Impaction**
  - particles of an aerosol tend to continue on a trajectory when they travel through the airway
  - do not conform to curves of respiratory tract
- Particles with enough momentum (product of their mass and velocity) are affected at points where airflow suddenly changes direction, colliding with airway wall
- First 10 bronchial generations
  - High air speed
  - Turbulent air
  - Particles larger than  $10\mu\text{m}$  (retained in the oropharyngeal region)
  - Dry powder inhalers (DPI) or Metered-dose inhalers (MDI)



# Q 4



Q 4



Q 4



Q 4



# Q 4

- Which of the following is NOT a mechanism for aerosol deposition in the lung?

A - Rotational inertia

*Property of any object which can be rotated*

B - ~~Sedimentation~~

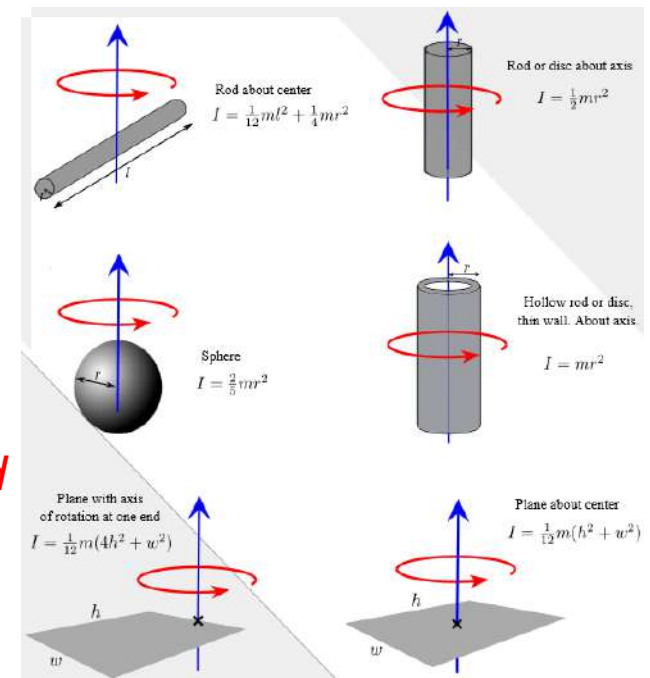
*Gravity, bottle of wine bottle*

C - ~~Brownian movement~~

*Small particles, "random walk" after finished*

D - ~~Impaction~~

*High flow, impact wall of airway, Panther*

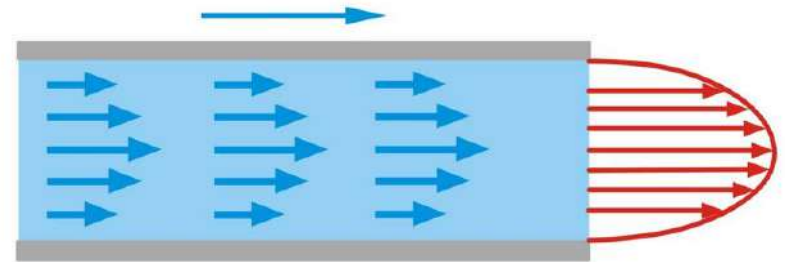


## Q 5

- Density is an important physical property of gases that affects resistance to what type of flow?
  - A - Laminar flow
  - B - Streamline flow
  - C - Turbulent flow
  - D - None of the above

## Q 5

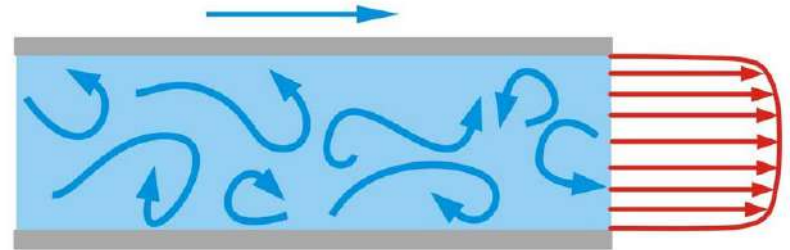
- Laminar/Streamline Flow
  - Moving in numerous, parallel layers
  - No disruption between layers
  - Flow at centre of airway 2x velocity of that at side of airway
  - Low flow rate
  - Small airways
  - Flow rate directly proportional to pressure gradient
    - Poiseuille Law
    - Increase pressure = Increase flowrate
  - Low Reynold's Number (Re)



$$Q = \frac{\pi Pr^4}{8\eta l}$$

# Q 5

- Turbulent Flow
  - Disorganised
  - Increases resistance to flow
  - High flow areas (during exercise, breath sounds in trachea),
  - Large diameter tubes, dense gas
  - Greater energy input required for a given flow
  - Flow rate proportional to square root of pressure gradient
  - To double the flow, the pressure must be quadrupled
  - High Reynold's Number (Re)
    - $>2000$



# Q 5

- Reynold's Number (Re)
  - Dimensionless number
  - Indicates whether flow will be laminar or turbulent
  - High number = turbulent flow
  - Low number = laminar flow
- According to equation, Re increases if –
  - ↑ velocity of gas (initial expiration)
  - ↑ diameter of tube (large airways)
  - ↑ density of gas (air less dense at altitude)

$$Re = \frac{\rho v D}{\mu}$$

$\mu$  = viscosity of the gas  
 $\rho$  = density of gas  
 $v$  = velocity of gas flow  
 $D$  = diameter of tube (airway)

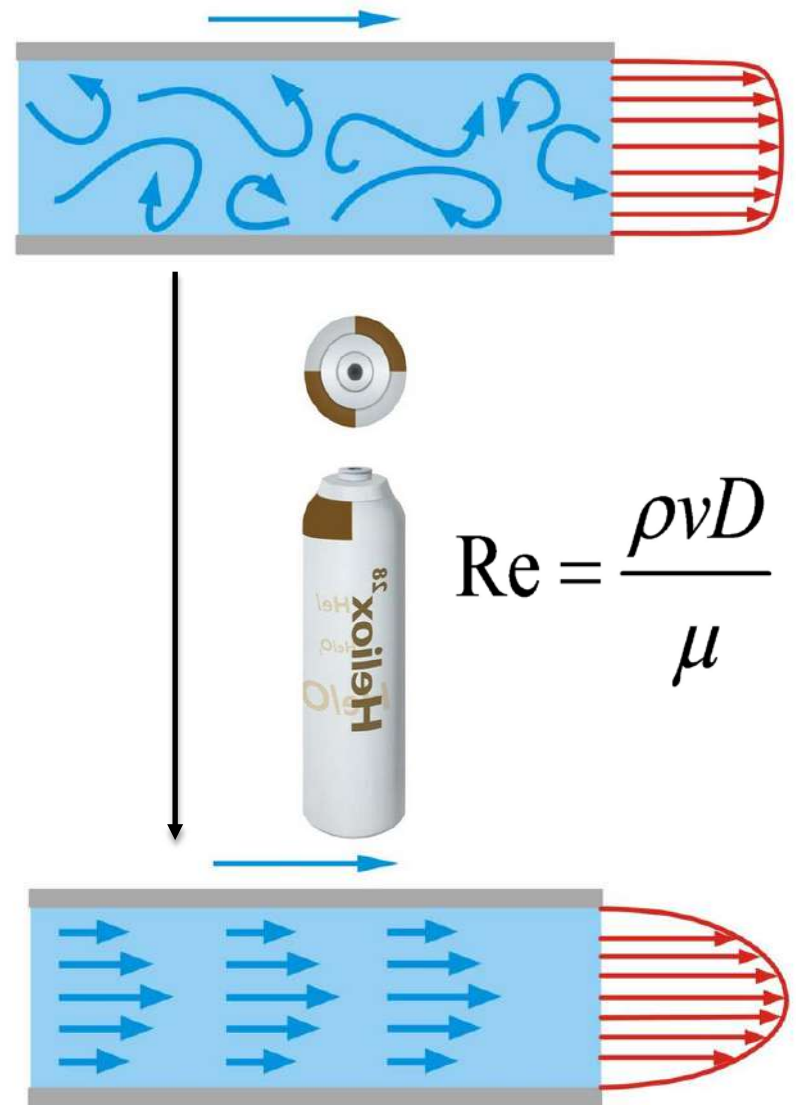
TABLE 6-4. Reynold's Numbers for Various Regions of the Tracheo-Bronchial Tree\*

Location	Diameter mm	Velocity 6 L/min	Velocity 60 L/min	Velocity 200 L/min
Nasal canal	5	400	4,000	12,000
Pharynx	12	800	8,000	24,000
Glottis	8	1,600	16,000	48,000
Trachea	21	1,250	12,500	37,000
Bronchi	17	910	9,100	27,300
Bronchi	9	700	7,000	21,000
Bronchi	6	570	5,700	17,100
Bronchi	4	190	1,900	5,700
Bronchi	1	35	350	1,050

\*Reprinted with permission from *Physiological Reviews* 41:314, 1961.

# Q 5

- Heliox
  - mixture of helium and oxygen
  - Helium is an inert gas
  - lower density than room air
    - 1.42g/L (O<sub>2</sub>) vs 0.17g/L (He)
- By substituting helium (He) for nitrogen (N<sub>2</sub>)
  - ↓ in density of the gas
  - ↓ in Re
  - more laminar flow
  - ↓ airflow resistance
  - ↓ work of breathing
  - ↓ dynamic hyperinflation
- Uses
  - Asthma, COPD exacerbations



## Q 5

- Density is an important physical property of gases that affects resistance to what type of flow?

A - ~~Laminar flow~~

*Poiseuille Law → laminar flow*

B - ~~Streamline flow~~

*AKA laminar flow*

C - Turbulent flow

*↑ density → ↑ Re = turbulent flow*

$$Re = \frac{\rho v D}{\mu}$$

D - ~~None of the above~~

## Q 6

- Airway Resistance ( $R_{aw}$ ) is measured in which of the following units?

A -  $L \text{ min}^{-1} \text{ mmHg}^{-1}$

B -  $\text{mmHg L}^{-1}$

C -  $L \text{ s}^{-1} \text{ cmH}_2\text{O}^{-1}$

D -  $\text{cmH}_2\text{O L}^{-1}\text{s}^{-1}$

# Q 6

- Airway Resistance ( $R_{aw}$ )
  - Ratio of driving pressure divided by flow through the airways
  - **Pressure/Flow**
  - Pressure required to achieve a flow of air with a velocity of  $1\text{L}\cdot\text{sec}^{-1}$

$$R_{aw} = \frac{\Delta P}{\cancel{\Delta Vol}} \times \frac{\cancel{\Delta Vol}}{\Delta \dot{V}} = \frac{\Delta P}{\Delta \dot{V}}$$

- Most common unit of pressure used for the lung
  - is centimetres of water ( $\text{cmH}_2\text{O}$ )
- Airway Conductance ( $G_{aw}$ )
  - Flow generated per unit of pressure across the airways
  - **Flow/Pressure**
  - Reciprocal of  $R_{aw}$
  - $1/R_{aw}$

## Q 6

- Airway resistance is measured in which of the following units?

A -  ~~$\text{L min}^{-1} \text{mmHg}^{-1}$~~

*mmHg not standard pulmonary nomenclature*

B -  ~~$\text{mmHg L}^{-1}$~~

*mmHg not standard pulmonary nomenclature*

C -  ~~$\text{L s}^{-1} \text{cmH}_2\text{O}^{-1}$~~

*$G_{aw}$  (reciprocal of  $R_{aw}$ ), flow/pressure*

D -  $\text{cmH}_2\text{O L}^{-1}\text{s}^{-1}$

*$R_{aw}$ , pressure/flow*

