4.2 PULMONARY FUNCTION TESTS

Lung Function Tests

Pulmonary function tests

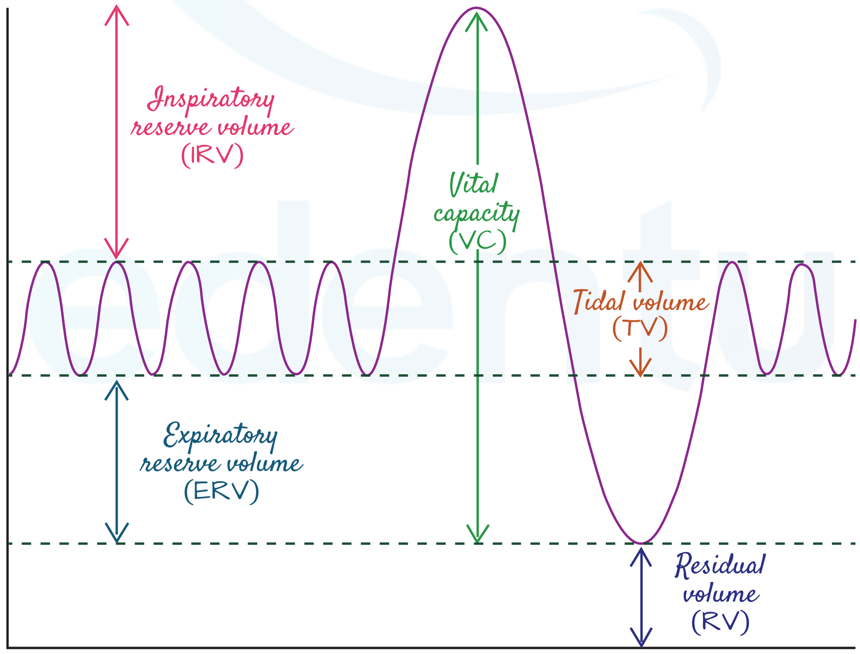
Based on volume of air that flows into or out of lungs. Static lung function tests include static lung volumes and static lung capacities.

Dynamic Lung Function Tests

Dynamic lung function tests are based on time. Dynamic lung function tests are useful in determining the severity of obstructive and restrictive lung diseases.

Lung Volumes

- Static lung volumes are of four types:
  - Tidal volume (500 mL (0.5 L))
  - Inspiratory reserve volume (3,300 mL (3.3 L))
  - Expiratory reserve volume (1,000 mL (1 L))
  - Residual volume (1,200 mL (1.2 L))



Tidal volume (TV)

- Volume of air breathed in and out of lungs in a single normal quiet respiration.
- Normal Value – 500 mL (0.5 L).

Inspiratory reserve volume (IRV)

- Additional volume of air that can be inspired forcefully after the end of normal inspiration.
- Normal Value – 3,300 mL (3.3 L).

Expiratory reserve volume (ERV)

- Additional volume of air that can be expired out forcefully, after normal expiration.
- Normal Value – 1,000 mL (1 L).

Residual volume (RV)

Volume of air remaining in lungs even after forced expiration. It helps to aerate the blood in between breathing and during expiration and maintains the contour of the lungs.

Normal Value – 1,200 mL (1.2 L)

Lung Capacities

- Static lung capacities are of four types
  - Inspiratory capacity
  - Vital capacity
  - Functional residual capacity
  - Total lung capacity.

Inspiratory Capacity (IC)

- Maximum volume of air that is inspired after normal expiration (end expiratory position). It includes tidal volume and inspiratory reserve volume.

$$
\begin{aligned}
IC &= TV + IRV \\
&= 500 + 3{,}300 \\
&= 3{,}800 \text{ mL}
\end{aligned}
$$

Vital Capacity (VC)

Maximum volume of air that can be expelled out forcefully after a deep (maximal) inspiration.

VC includes inspiratory reserve volume, tidal volume and expiratory reserve volume.

$$
\begin{aligned}
VC &= IRV + TV + ERV \\
&= 3{,}300 + 500 + 1{,}000 \\
&= 4{,}800 \text{ mL}
\end{aligned}
$$

Variations of Vital Capacity

Physiological Variations

- Sex: In females, vital capacity is less than in males
- Body built: Vital capacity is slightly more in heavily built persons
- Posture: Vital capacity is more in standing position and less in lying position

⇨ Athletes: Vital capacity is more in athletes

⇨ Occupation: Vital capacity is decreased in people with sedentary jobs. It is increased in persons who play musical wind instruments such as bugle and flute.

Pathological Variations

⇨ Asthma, Emphysema, Weakness or paralysis of respiratory muscle, Pulmonary congestion, Pneumonia, Pneumothorax, Hemothorax, Pyothorax, Hydrothorax, Pulmonary edema and Pulmonary tuberculosis.

Functional Residual Capacity (FRC)

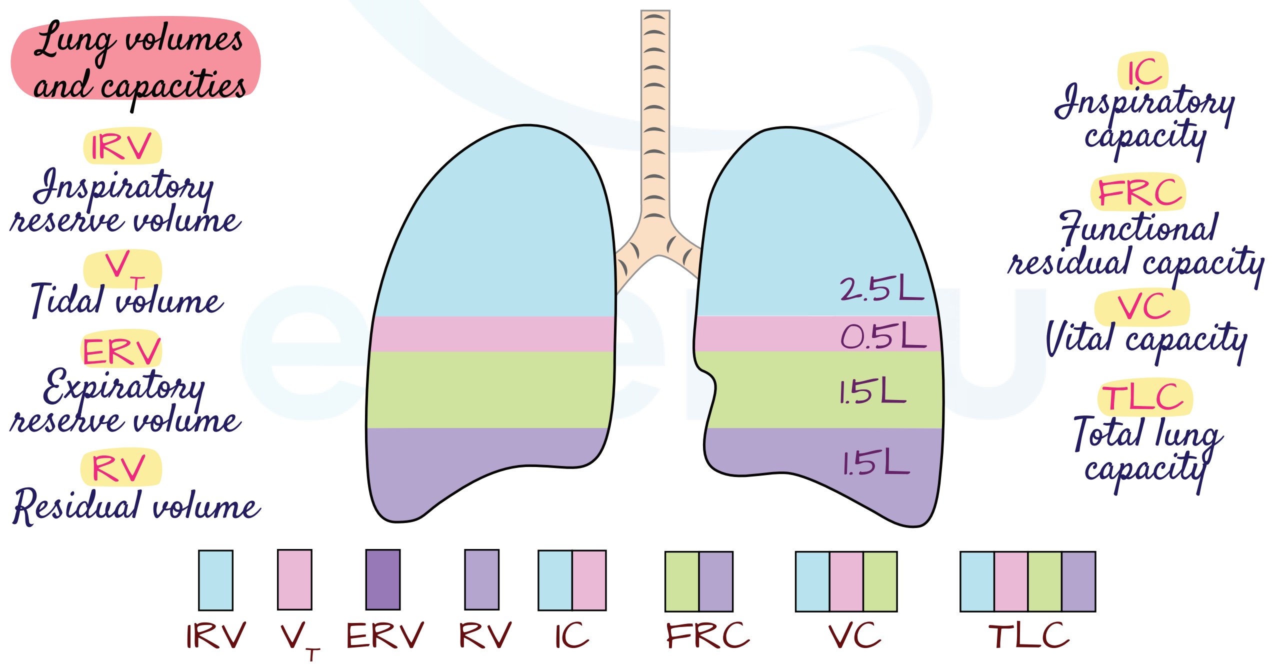
⇨ Volume of air remaining in lungs after normal expiration (after normal tidal expiration). Functional residual capacity includes expiratory reserve volume and residual volume.

$$\begin{aligned} FRC &= ERV + RV \\ &= 1{,}000 + 1{,}200 \\ &= 2{,}200 \text{ mL} \end{aligned}$$

Total Lung Capacity (TLC)

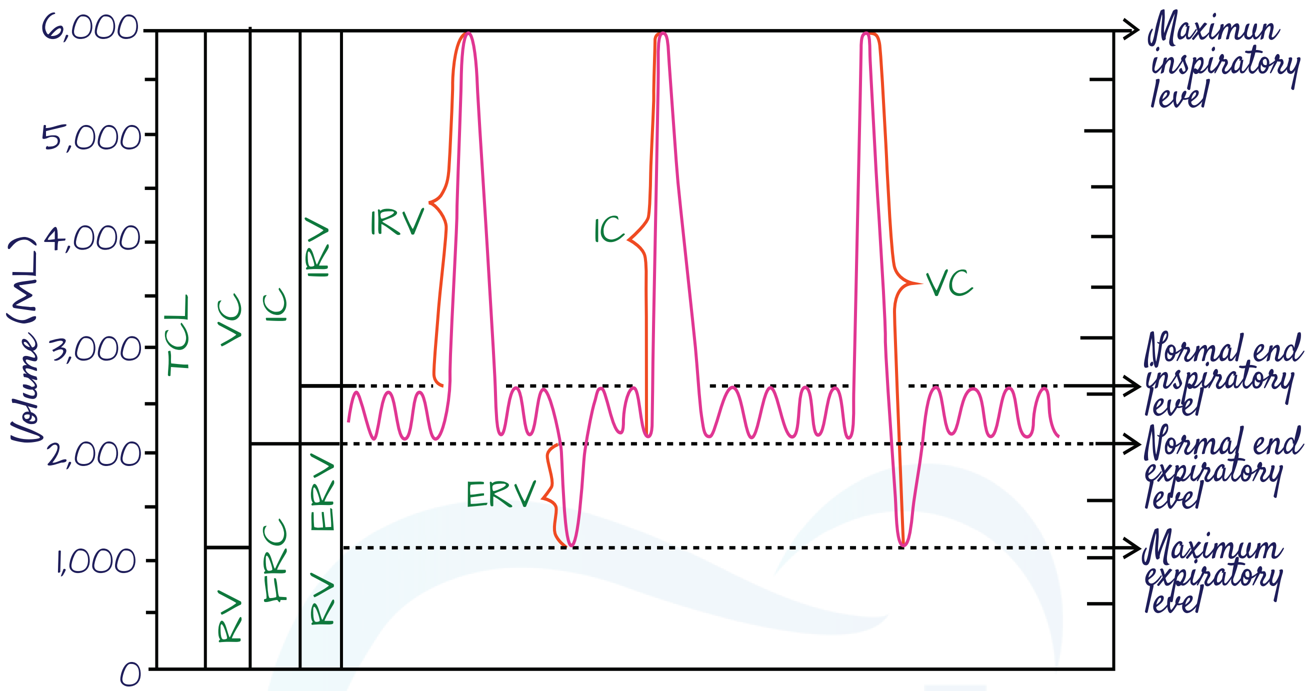
Volume of air present in lungs after a deep (maximal) inspiration. It includes all the volumes.

$$\begin{aligned} TLC &= IRV + TV + ERV + RV \\ &= 3{,}300 + 500 + 1{,}000 + 1{,}200 \\ &= 6{,}000 \text{ mL} \end{aligned}$$



Spirogram

⇨ Spirogram is the graphical record of lung volumes and capacities using spirometer. Upward deflection of the spirogram denotes inspiration and the downward curve indicates expiration.



Forced Expiratory Volume Or Timed Vital Capacity

Definition

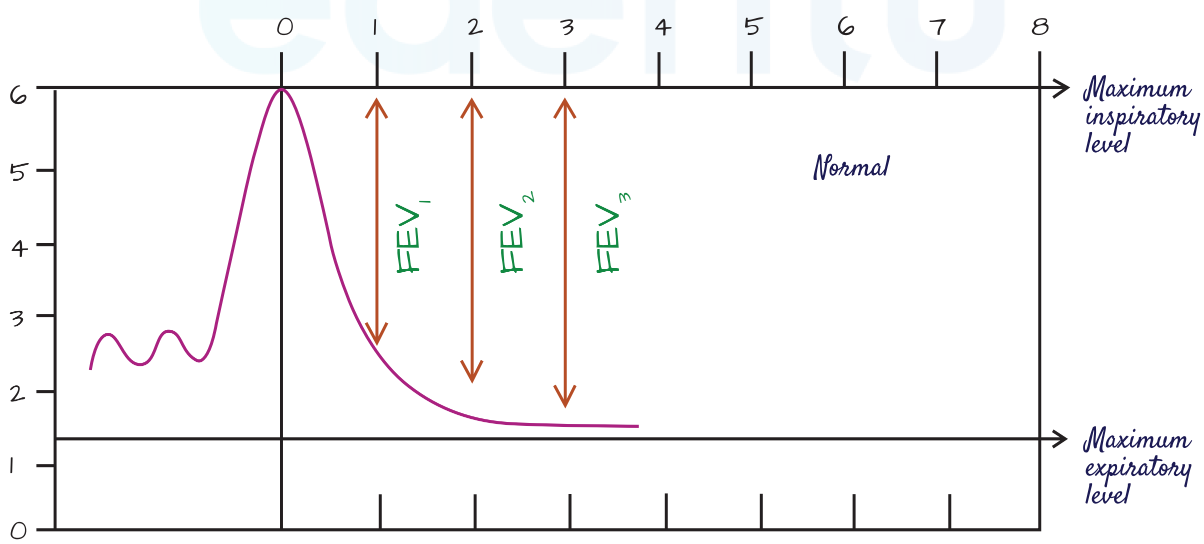
✓ Forced expiratory volume (FEV) is the volume of air, which can be expired forcefully in a given unit of time (after a deep inspiration).

⇨ It is also called timed vital capacity or forced expiratory vital capacity (FEVC). It is a dynamic lung volume.

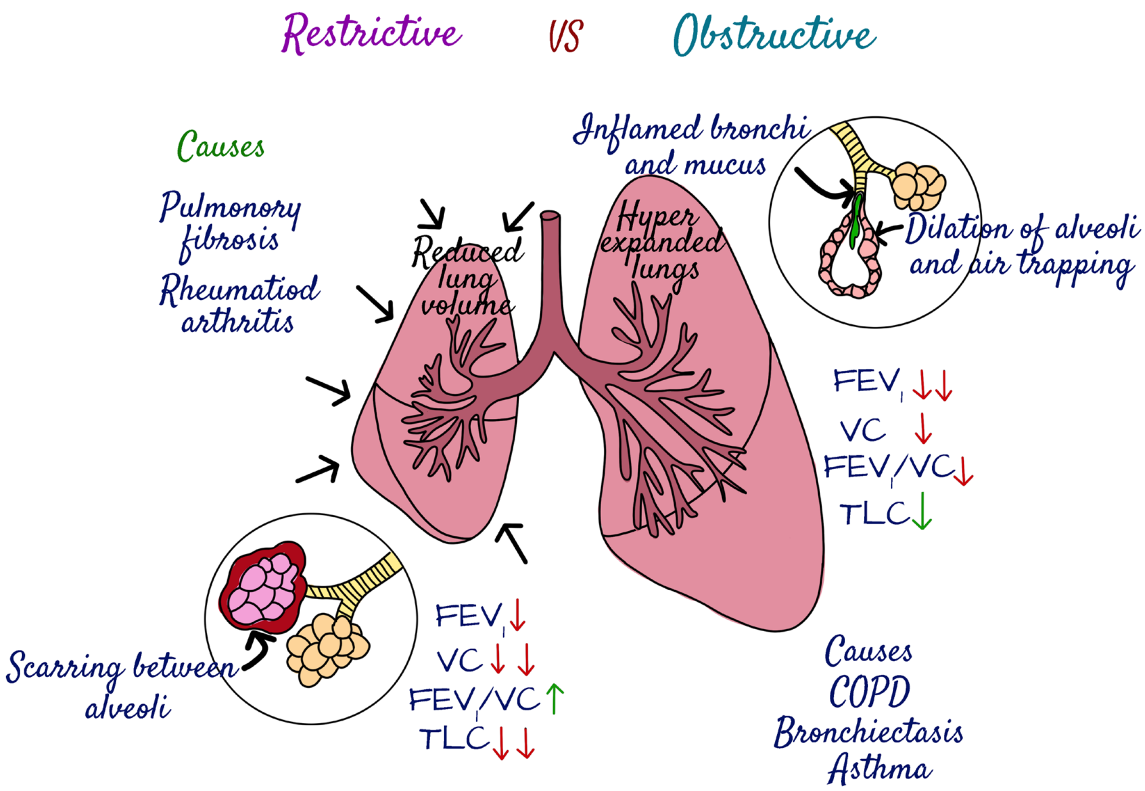
- FEV_1 = Volume of air expired forcefully in 1 second – 83% of total vital capacity
- FEV_2 = Volume of air expired forcefully in 2 seconds – 94% of total vital capacity
- FEV_3 = Volume of air expired forcefully in 3 seconds – 97% of total vital capacity

⇨ Vital capacity may be almost normal in some of the respiratory diseases. Decreased in some respiratory diseases (obstructive diseases like asthma and emphysema)

⇨ Slightly reduced in some restrictive respiratory diseases like fibrosis of lungs.



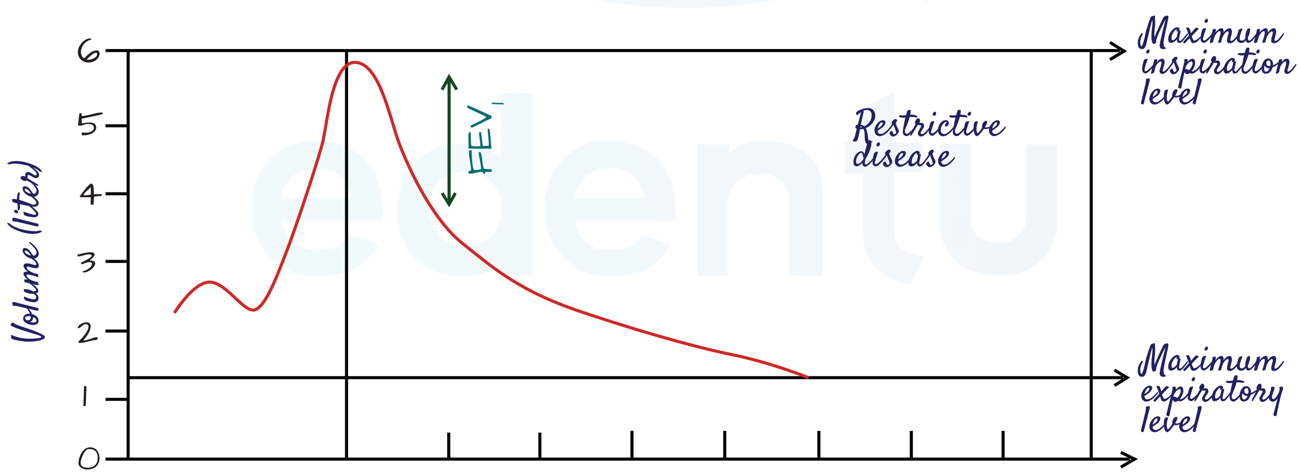
Restrictive And Obstructive Respiratory Diseases



Restrictive Respiratory Disease

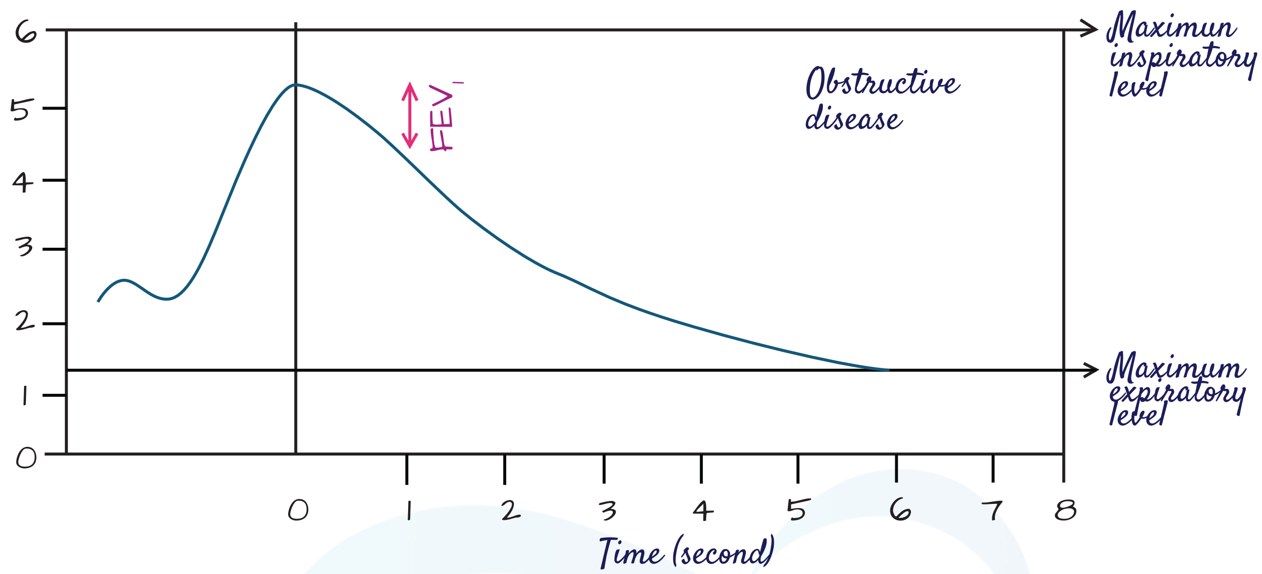
⇨ Restrictive respiratory disease is the abnormal respiratory condition characterized by difficulty in inspiration. Expiration is not affected.

⇨ Restrictive respiratory disease may be because of abnormality of lungs, thoracic cavity or/and nervous system.



Obstructive Respiratory Disease

⇨ Obstructive respiratory disease is the abnormal respiratory condition characterized by difficulty in expiration.



Type	Disease	Structures involved
Restrictive respiratory diseases	• Polio myelitis • Myasthenia gravis • Flail chest (broken ribs) • Paralysis of diaphragm • Spinal cord diseases • Pleural effusion	• CNS • CNS and thoracic • Thoracic cavity • CNS • CNS • Thoracic cavity
Obstructive respiratory diseases	• Asthma • Chronic bronchitis • Emphysema • Cystic fibrosis	Lower respiratory tract
	• Laryngotracheobronchitis • Epiglottis • Tumors • Severe cough and cold with phlegm	Upper respiratory tract

Respiratory Minute Volume

➩ Respiratory minute volume (RMV) is the volume of air breathed in and out of lungs every minute. It is the product of tidal volume (TV) and respiratory rate (RR).

$$\text{RMV} = \text{TV} \times \text{RR}$$
$$= 500 \times 12$$
$$= 6{,}000 \text{ mL}$$

➩ Normal respiratory minute volume is 6 L

➩ Increased – in physiological conditions such as voluntary hyperventilation, exercise and emotional conditions.

➩ Reduced – in respiratory diseases.

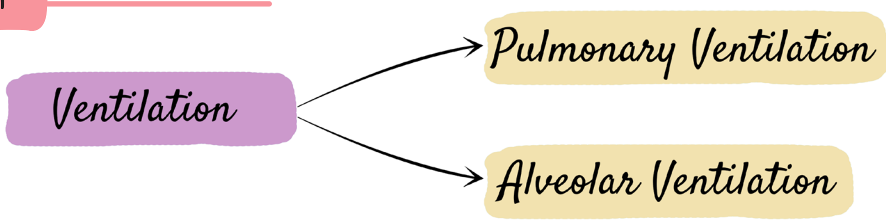
Maximum Breathing Capacity or Maximum Ventilation Volume

- Maximum breathing capacity (MBC) is the maximum volume of air, which can be breathed in and out of lungs by forceful respiration per minute.
- It is also called maximum ventilation volume (MVV)
- In healthy adult male, it is 150 to 170 L/minute and in females, it is 80 to 100 L/minute.

Peak Expiratory Flow Rate

- Peak expiratory flow rate (PEFR) is the maximum rate at which the air can be expired after a deep inspiration.
- In normal persons, it is 400 L/minute.
- Determination of PEFR rate is useful for assessing the respiratory diseases especially to differentiate the obstructive and restrictive diseases.
- Restrictive diseases, the PEFR is 200 L/minute and in obstructive diseases, it is only 100 L/minute.

Ventilation



Pulmonary Ventilation

Definition

✓ Pulmonary ventilation is defined as the volume of air moving in and out of respiratory tract in a given unit of time during quiet breathing. It is also called minute ventilation or respiratory minute volume (RMV).

- Normal value of pulmonary ventilation is 6,000 mL (6 L)/minute.
- It is the product of tidal volume (TV) and the rate of respiration (RR).

$$\begin{aligned}\text{Pulmonary ventilation} &= \text{Tidal volume} \times \text{Respiratory rate} \\ &= 500 \text{ mL} \times 12/\text{minute} \\ &= 6{,}000 \text{ mL/minute}\end{aligned}$$

Alveolar Ventilation

Definition

✓ Alveolar ventilation is the amount of air utilized for gaseous exchange every minute.

- Alveolar ventilation is different from pulmonary ventilation. In pulmonary ventilation, 6 L of air moves in and out of respiratory tract every minute.

- Normal value of alveolar ventilation is 4,200 mL (4.2 L)/ minute.

$$\begin{aligned}\text{Alveolar ventilation} &= (\text{Tidal volume} - \text{Dead space}) \text{ x Respiratory rate}\\ &= (500 - 150)\text{ mL} \times 12/\text{minute}\\ &= 4{,}200\text{ mL (4.2 L)/minute.}\end{aligned}$$

Dead Space

- Dead space is defined as the part of the respiratory tract, where gaseous exchange does not take place. Air present in the dead space is called dead space air.

Anatomical Dead Space

- Anatomical dead space extends from nose up to terminal bronchiole. It includes nose, pharynx, trachea, bronchi and branches of bronchi up to terminal bronchioles.

Physiological Dead Space

- Physiological dead space includes anatomical dead space plus two additional volumes (wasted ventilation). Wasted ventilation is the volume of air that ventilates physiological dead space. Wasted air refers to air that is not utilized for gaseous exchange.
- Volume of normal dead space is 150 mL.

$$\text{Dead space} = \frac{\text{Area without } N_2}{\text{Area with } N_2 + \text{Area without } N_2} \times \text{Volume of expired air}$$

Ventilation-Perfusion Ratio

- Ventilation¬ perfusion ratio is the ratio of alveolar ventilation and the amount of blood that perfuse the alveoli.
- Normal value of ventilation ¬perfusion ratio is about 0.84.
- Ventilation-perfusion ratio signifies the gaseous exchange. It is affected if there is any change in alveolar ventilation or in blood flow.
- In chronic obstructive pulmonary diseases (COPD), ventilation is affected because of obstruction and destruction of alveolar membrane.

Ventilation without perfusion = dead space

Perfusion without ventilation = shunt

$$\text{Ventilation–perfusion ratio} = \frac{\text{Alveolar ventilation}}{\text{Pulmonary blood flow}}$$

$$\begin{aligned}\text{Alveolar ventilation} &= (\text{Tidal volume} - \text{Dead space}) \times \text{Respiratory rate}\\ &= (500 - 150)\text{mL} \times 12/\text{minute} = 4{,}200\text{mL/minute}\end{aligned}$$

Blood flow through alveoli (Pulmonary blood flow) = 5,000mL/minute

Therefore,

$$\text{Ventilation-perfusion ratio} = \frac{4{,}200}{5{,}000} = 0.84$$

REMARKS