Respiratory ventilation (Assessment of lung function)

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Learning objectives

- **By the end of the lecture you should be able to: -**

1-Define the various Lung Volumes and capacities and provide typical values for each.

2-Define ventilation rate, their typical values, and their measurement.

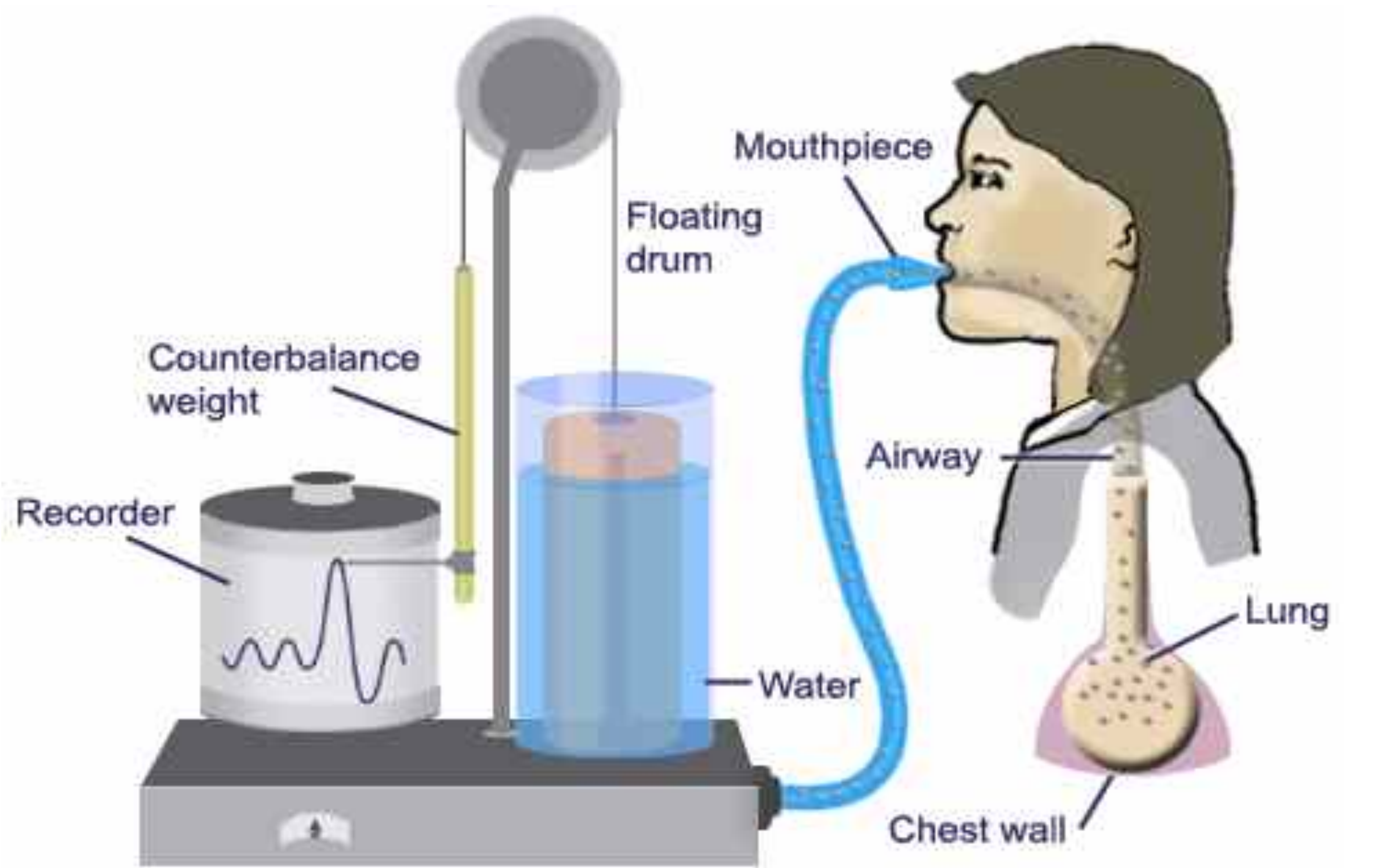
3- Describe FEV1 and its role in differentiating obstructive and restrictive lung diseases.

4- Describe the types of dead space. State a volume for the anatomical dead space.

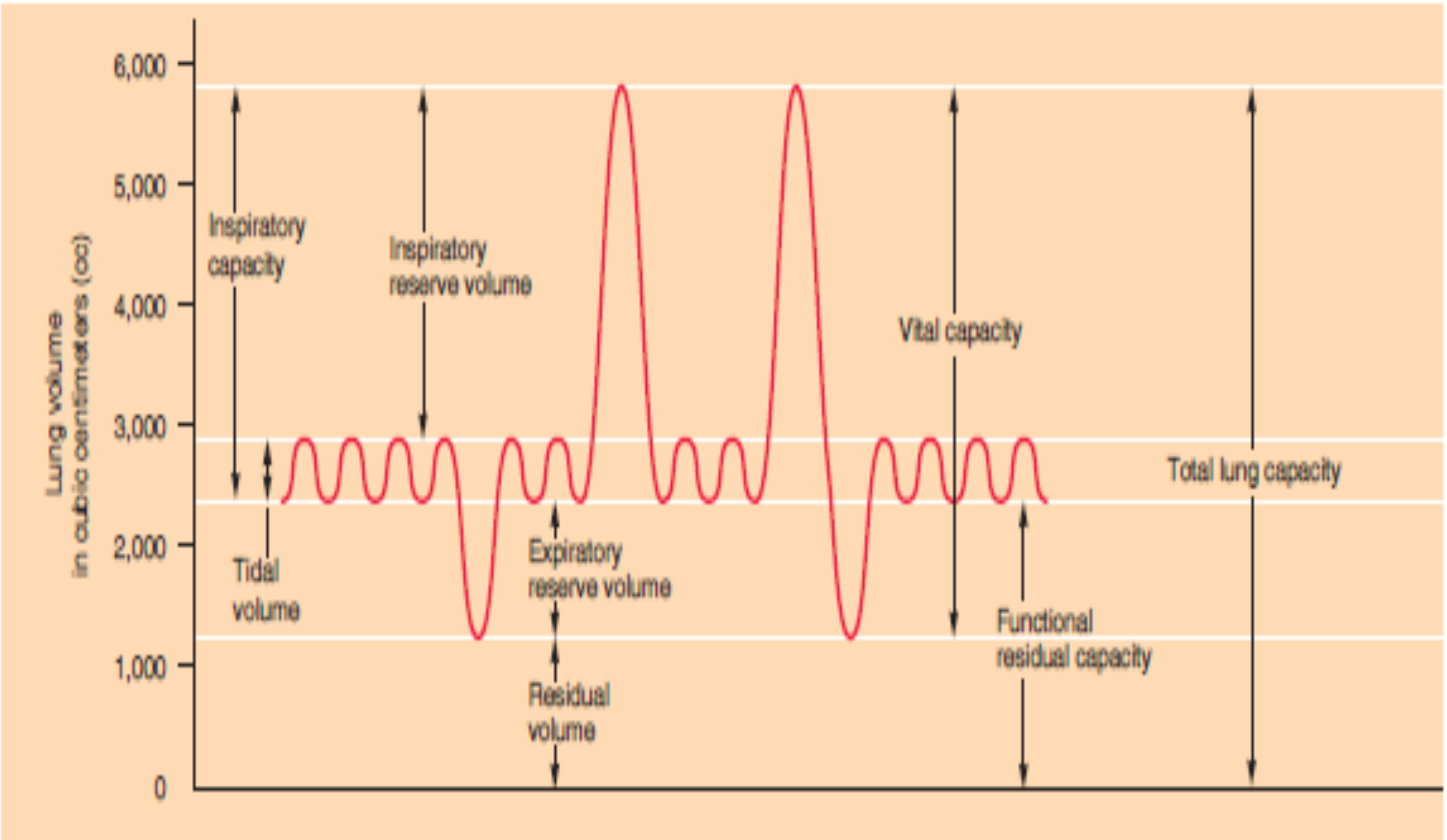
5- Define the term minute ventilation and state a typical value.

6- Distinguish minute ventilation from alveolar ventilation.

Spirometry


Mouthpiece
Floating
drum
Counterbalance
weight
Airway
Recorder
Lung
Water
Chest wall

Spirogram



6,000
5,000
4,000
3,000
2,000
1,000
0
Lung volume
in cubic centimeters (cc)
Inspiratory
capacity
Inspiratory
reserve volume
Vital capacity
Total lung capacity
Tidal
volume
Expiratory
reserve volume
Residual
volume
Functional
residual capacity

Lung volumes and capacities

Four lung volumes:

1. Tidal volume (TV): volume of air inspired or expired with each normal breath (~500 ml).
2. Inspiratory reserve (IRV): extra volume of air that can be inspired over and above the normal tidal volume when the person inspires with full force(~3000 ml).
3. Expiratory reserve (ERV): maximum extra volume of air that can be expired by forceful expiration after the end of a normal tidal expiration (~1100 ml).
4. Residual volume (RV): volume of air remaining in the lungs after the most forceful expiration (~1200ml).

Pulmonary capacities

- Two or more lung volumes are described as pulmonary capacity:

1- Inspiratory capacity (IC):

amount of air a person can breathe in, beginning at the normal expiratory level and distending the lungs to the maximum amount.

IC= TV+ IRV= 500+ 3000= 3500 ml

2-Functional residual capacity (FRC):

amount of air that remains in the lungs after normal tidal expiration. Acts as a buffer against extreme changes in alveolar gas levels with each breath.

FRC= ERV+ RV= 1100+ 1200= 2300 ml

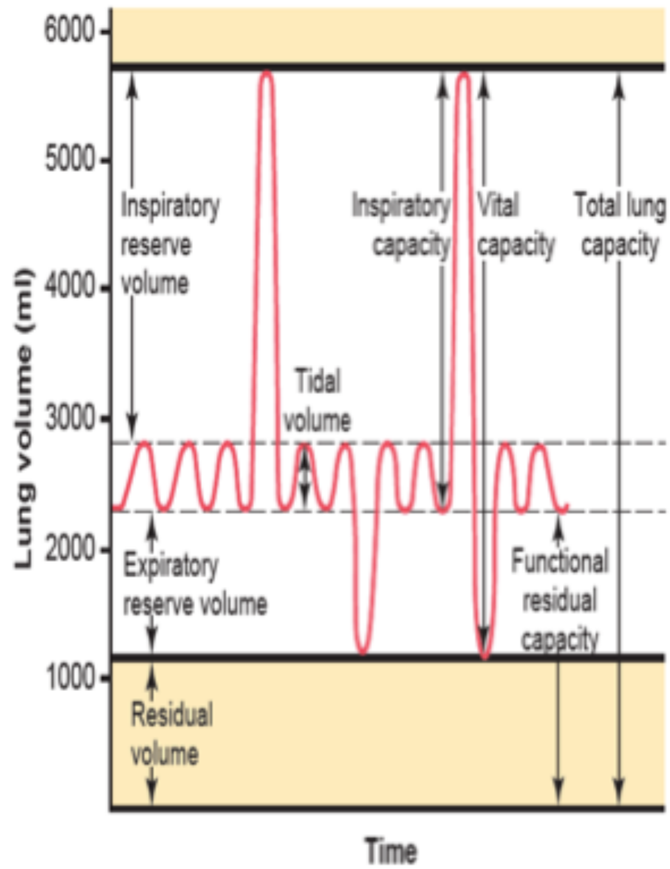
Cont… lung capacities

3-The vital capacity (VC):

maximum amount of air a person can expel from the lungs after first filling the lungs to their maximum extent and then recording expiring to the maximum extent.

= TV+IRV+ERV =

500+3000+1100 =4600 ml



Cont… lung capacities

4-The total lung capacity (TLC): is the maximum volume to which the lungs can be expanded with the greatest possible effort

=TV+IRV+ERV+RV =500+3000+1100+1200= 5800ml.

- **All lung volumes and capacities** are 20-25% less in women than men. They are greater in large athletic people than in small asthenic people.

Average Pulmonary Volumes and Capacities for a Healthy Young Adult Man

Pulmonary Volumes and Capacities	Normal Values (ml)
Volumes	
Tidal volume	500
Inspiratory reserve volume	3000
Expiratory volume	1100
Residual volume	1200
Capacities	
Inspiratory capacity	3500
Functional residual capacity	2300
Vital capacity	4600
Total lung capacity	5800

Interrelations among pulmonary volumes and capacities

$$VC = IRV + VT + ERV$$

$$VC = IC + ERV$$

$$TLC = VC + RV$$

$$TLC = IC + FRC$$

$$FRC = ERV + RV$$

Determination of FRC, RV,TLC

Closed circuit Helium Dilution Method

$$C1 x V1 = C2 x V2$$

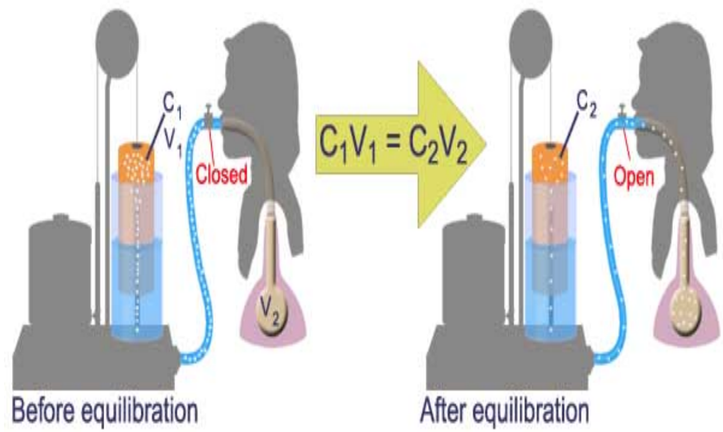
C1: concentration of Hi in spirometry

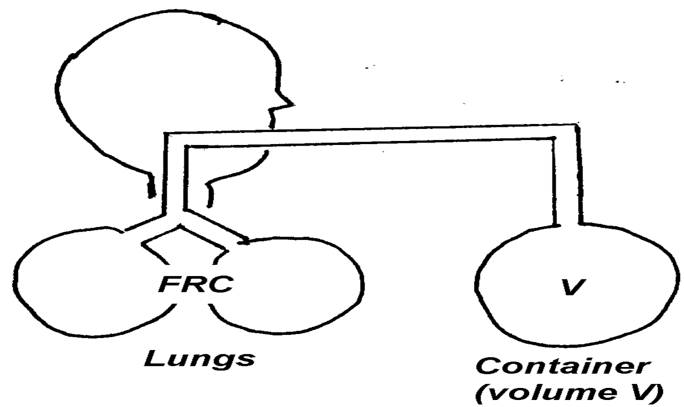
V1: volume of air in the spirometry.

C2: Final concentration of helium

V2 :Volume of spirometry+ FRC

$$FRC = \left(\frac{Ci\ He\ (C1)}{Cf\ He\ (C2)} - 1 \right)\ Vi\ Spi\ (V1)$$

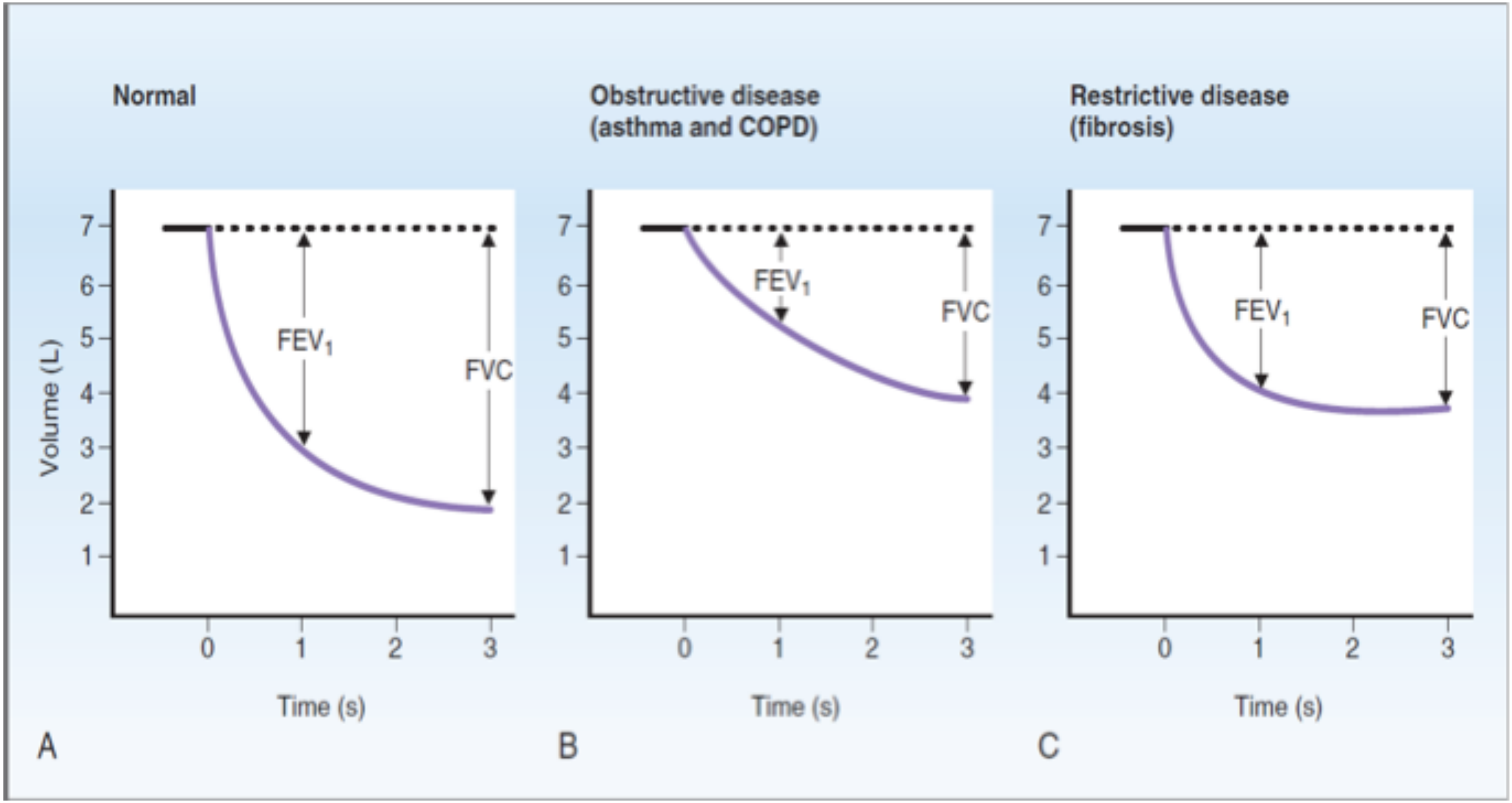




Forced Expiratory Volumes

- Volume of air that can be forcibly expired in the first second is called **FEV1.** The cumulative volume expired in 2 seconds is called **FEV2,** and the cumulative volume expired in 3 seconds is called **FEV3.**
- Vital capacity can be forcibly expired in 3 seconds, so there is no need for "FEV4."
- FVC and FEV1 are useful indices of lung disease. Specifically, the fraction of the vital capacity that can be expired in the first second, FEV1/FVC.
- In a **normal** person, FEV1/FVC is approximately 0.8, meaning that 80% of the vital capacity can be expired in the first second of forced expiration.
- In patients with obstructive lung diseases such as **asthma** and **chronic obstructive pulmonary disease (COPD),** both FVC and FEV1 are decreased, but FEV1 is decreased *more* than FVC is. Thus FEV1/FVC is also decreased, which is typical of airway obstruction with its increased resistance to expiratory air flow.
- In a patient with a restrictive lung disease such as **fibrosis,** both FVC and FEV1 are decreased but FEV1 is decreased *less* than FVC is. Thus in fibrosis, FEV1/FVC is actually increased or almost normal.

FVC and FEV1 in normal subjects and patients with lung disease



Minute respiratory volume

MRV = Respiratory rate x Tidal volume

= RR X TV

= 12 X 500 = 6L/min.

It could rise more than normal value if RR = 40,

= 40 X 500 = 20L/min.

Dead space and its effect on alveolar ventilation

Anatomical dead space:

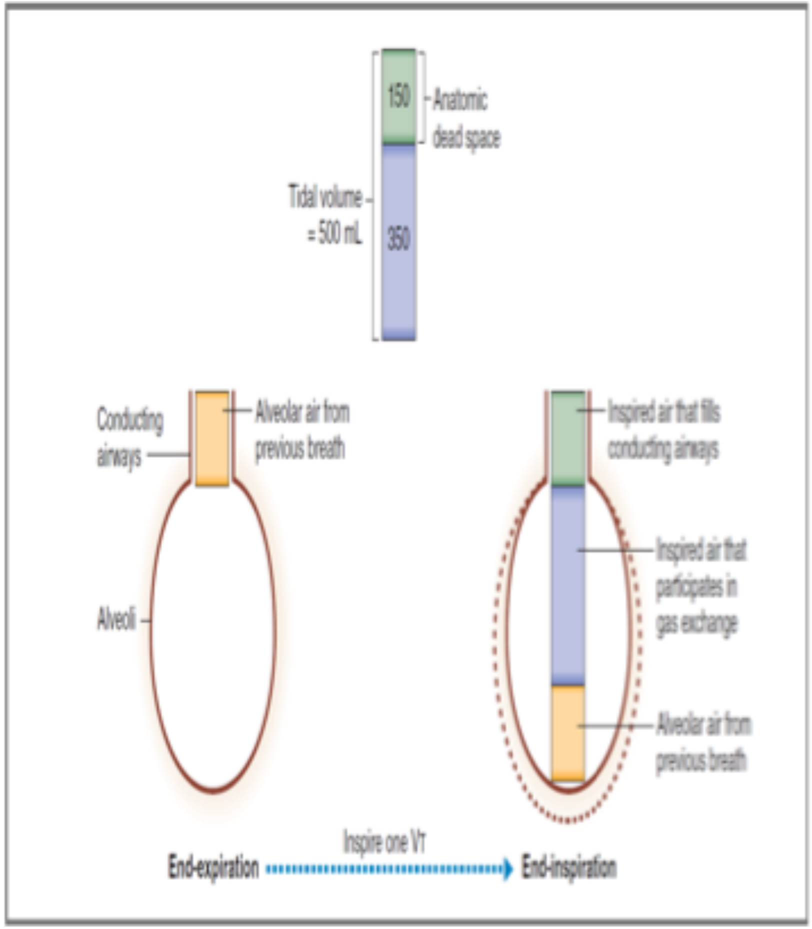
volume of air in the conducting respiratory passages (150 ml)=1/3 of tidal volume. On expiration, the air in the dead space is expired first.

Functional dead space:

alveoli that cease to act in gas exchange due to collapse or obstruction.

Physiological dead space:

summation of alveolar and



Alveolar ventilation

- **Rate of alveolar ventilation per minute:**

Is the total volume of new air entering the adjacent gas exchange area each minute.

= (TV - Dead space volume) x RR

= (500-150) x12 = 350x 12

= 4200ml/min

Alveolar ventilation is one of the major factors determining the concentrations of oxygen and carbon dioxide in the alveoli.