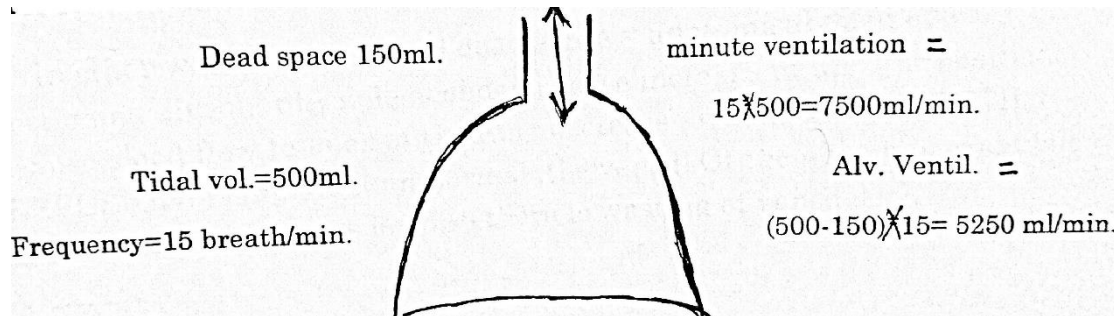


RESPIRATORY SYSTEM

VENTILATION: -

The ventilation of the lung depending on the depth of each breath (tidal vol.) and the number of breath per unit time (respiratory frequency) or resp. rate. Both of them can vary over a wide range depending on the body's requirement.



If we assume tidal volume = 500ml and there are 15 breaths/min. then total vol. leaving the lung each min is $500 \times 15 = 7.500 \text{ ml/min.}$ this is known as the minute ventilation or total ventilation or pulmonary ventilation.

Not all the inspired air reaches the alveolar compartment where gas exchange occurs. Of each 500 ml inhaled 150 ml remain behind in the anatomical dead space thus $(500 - 150) \times 15 = 5.250 \text{ ml/min.}$ this is known as alveolar ventilation.

The minute ventilation can easily be measured by having the subject breathe through a valve box which separates the inspired from the expired gas and collecting all the expired gas in a bag.

Tidal vol. (T.V) \times RESP. FREQ = minute ventilation. Rapid breathing causes inadequate ventilation whereas slow deep breathing results in adequate ventilation. Usually the rate of respiration (frequency) increases in exercise, fever or it may decrease in other abnormal conditions.

Dead space:-

There are two type of dead space:

1-anatomical dead space & 2 physiological dead space.

Normally they are identical but in lung disease it is not identical
The anatomical dead space is the volume of airways // the mouth & nose and the alveoli
The physiological is the anatomical dead space plus volume of inspire gas which ventilate alveoli which receive no pulmonary capillary blood flow, or some of the alveoli which are over ventilated or alveoli which receive blood but not ventilated i e, inequality of blood flow and ventilation of the lung (alveolar dead space).

In other ward physiological dead space = anatomical dead space un functioning alveoli. physiological dead space increase in upright position because blood flow to apex of the lung decrease when $V_A \setminus Q$ (VENTIL / PERFUSION) is higher than normal, the ventil. Of the alveoli is great but the alveolar blood flow is low so there is wasting of ventilation.

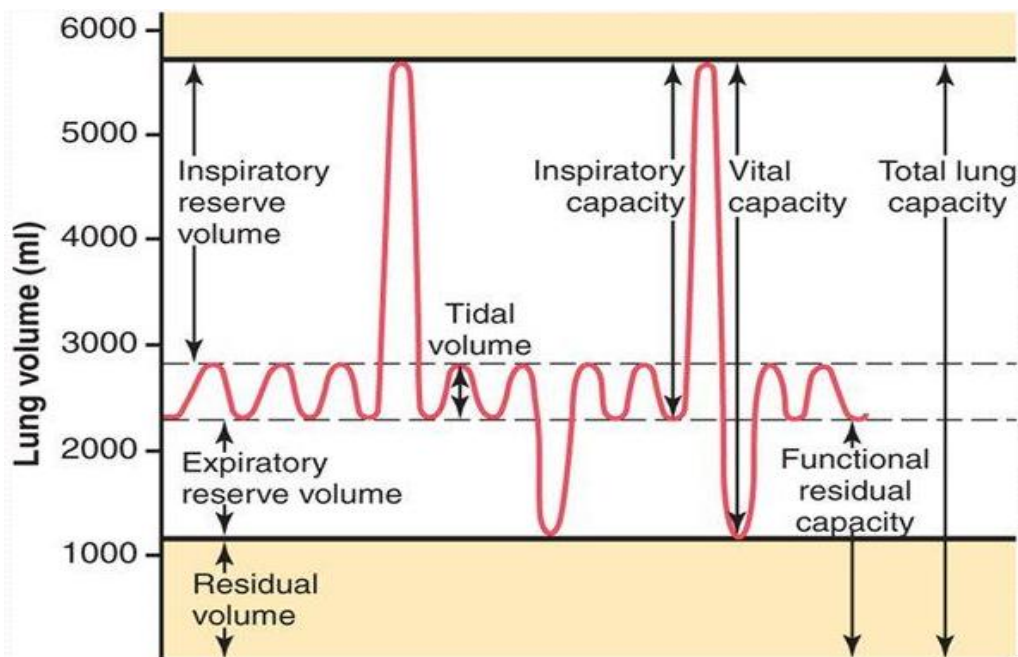


Figure (2-2): Lung volumes and capacities (Guyton and Hall, 2011).

Pulmonary Volumes & Capacities:

There are four lung volumes and four lung capacities as follow:

A. Lung Volumes:

1. Tidal volume: volume of air inspired or expired with each breath = 500 ml.
2. Inspiratory Reserve Volume: Extra volume of air that can be inspired beyond the normal tidal volume =3000 ml
3. Expiratory Reserve Volume: Volume of air that still expired by forceful expiration after the end of normal tidal volume =1100 ml.
4. Residual Volume: Volume of air still remaining in the lungs after maximum expiration =1200 ml.

B. Lung Capacities

1. Inspiratory Capacity: (inspired reserve volume + tidal volume)= 3500ml It is the greatest volume that can be inhaled after normal expiration.
2. Functional Residual Capacity (expiratory reserve volume + residual volume) =2300 ml., It is the amount of air remaining in the lungs at the end of normal expiration
3. Vital Capacity: (inspiratory reserve volume + tidal volume + expiratory volume) =4600 ml., It is the maximum expiration after maximum inspiration.
4. Total Lung Capacity: Maximum volume to which the lung can be expanded with the greatest possible inspiratory effort 5800 ml (Vital capacity + Residual volume)

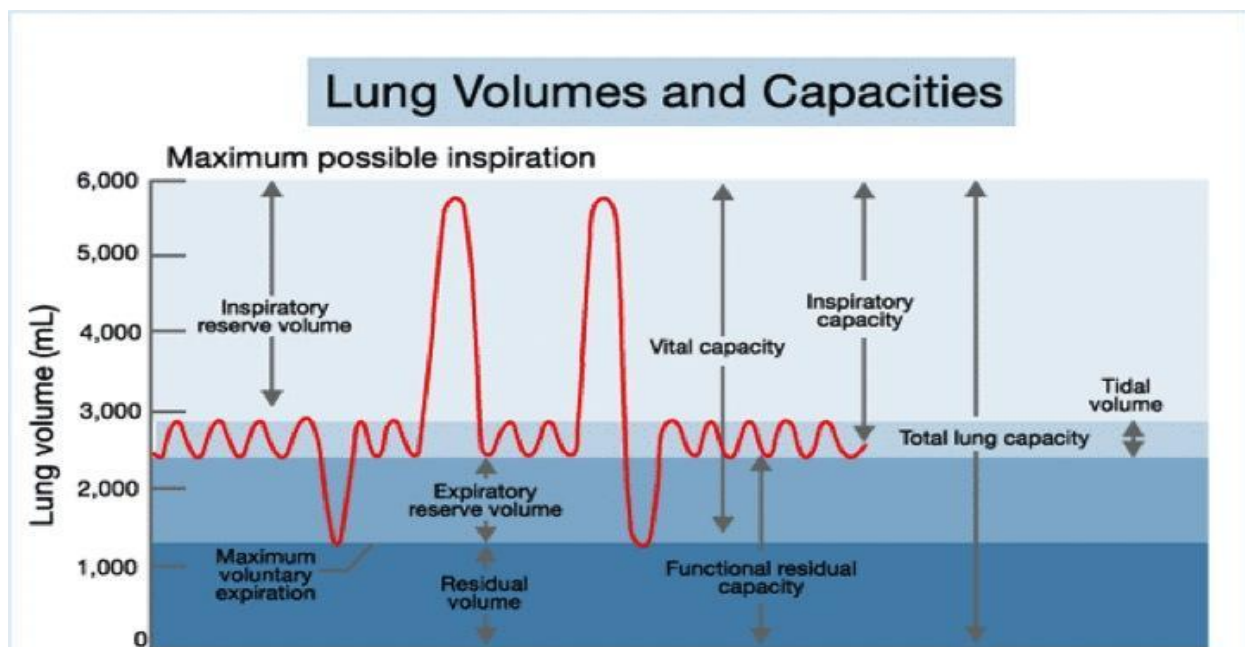
Significance of The Residual Volume:

It is the volume that can not removed even after forceful expiration, this is important because it proceed air in the alveoli

to ventilate the blood even between breaths. If no residual volume present the concentration of O₂ and CO₂ in the blood would rise and fall markedly with each respiration which is disadvantage to respiratory process.

Function of surfactant in general:

1. Decrease surface tension of alveoli
2. Increase the compliance of the lung.
3. Prevent transudation of fluid from capillary into the alveoli (prevent pulmonary oedema).
4. Contribute to the stability of the alveoli in the lung.



- 1- TV: al volume /500 ml
2. IRV: Inspiratory Reserve Volume =3000 ml.
3. ERV: Expiratory Reserve Volume =1100 ml
4. RV: Residual Volume =1200 ml.
 - a. IC: Inspiratory Capacity =3500 ml
 - b. VC(FVC): Vital Capacity (Forced Vital Capacity) =4600 ml

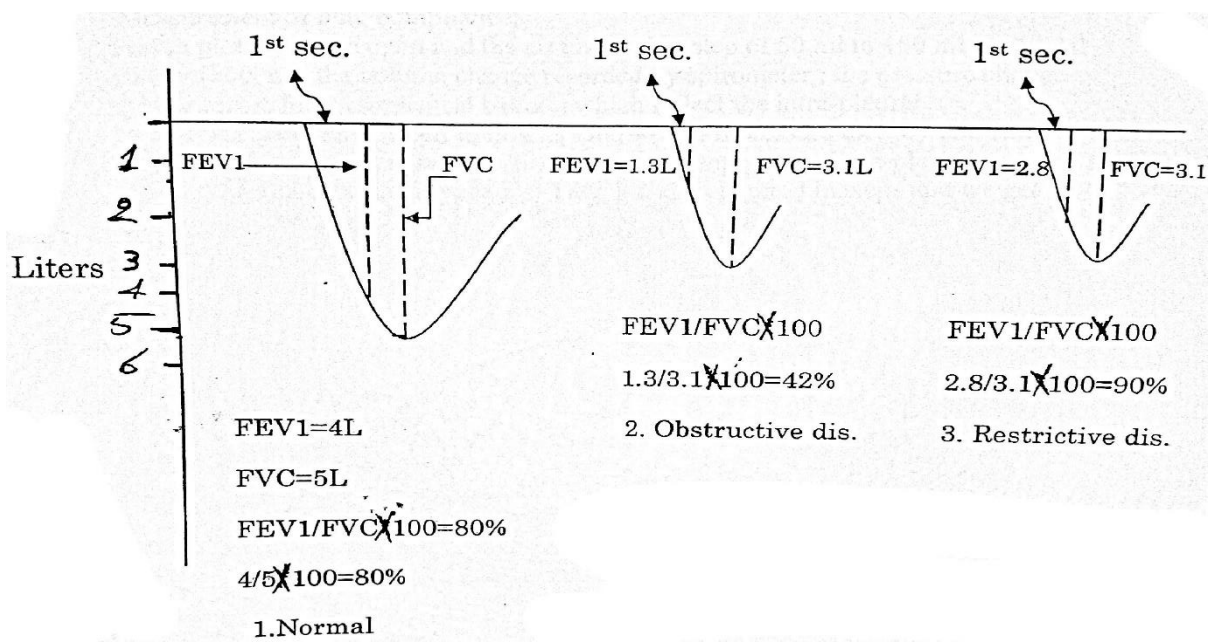
c. FRC: Functional Residual Capacity =2300 ml

d. TLC: Total Lung Capacity =5800 ml

Note: All pulmonary volumes and capacities are 20-25% Less in women than men and they are greater in large and athletic people than in small and asthenic people.

Lung Functional Test:

If the vital capacity (VC or FVC) is recorded on spirogram the volume of air expelled can be timed. Normally 80% of FVC (forced vital capacity) could be expired in the first second FEV₁. This test is very important in differentiation between obstructive and restrictive lung diseases i.e. subject inspire maximally and then expired maximally, the volume expired in first second is FEV₁ and total volume expired is FVC normally.



1-Normal lung function test- 80%.

2. Obstructive lung disease e.g. Bronchial asthma, Bronchitis, Emphysema =42%

3. Restrictive lung disease e.g. pulmonary fibrosis e.g. Tuberculosis(TB) 90%

Since the ratio is =90% due mathematical calculation, therefore this test is more significant in obstructive lung disease.

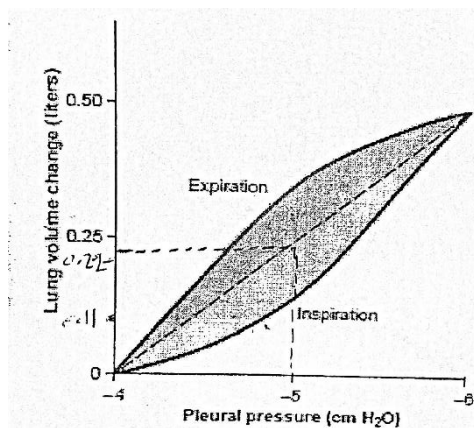
Compliance:

chest wall Several terms have been used to describe elastic properties of the lungs and it is either termed as stretchability or expansibility or distensibility. Compliance of the lungs and chest wall defined as the volume change per unit pressure change Compliance of the lungs

The change in lung volume per unit change in air way pressure $\Delta V / \Delta P$ Compliance of the lungs and chest wall pulmonary compliance) have a value of about 100-110 ml/cm H₂O pressure. i.e. every time the intra-pulmonary pressure is increased by 1 cm water the lung expand 100-110 ml. The lung when removed from the chest are almost twice as distensible as the lung and chest wall together, because the thoracic cage must also stretched when the lung are expanded. So that the compliance of the lung alone equal to 200-220 ml/cm H₂O pressure.

Measurement of lung compliance:

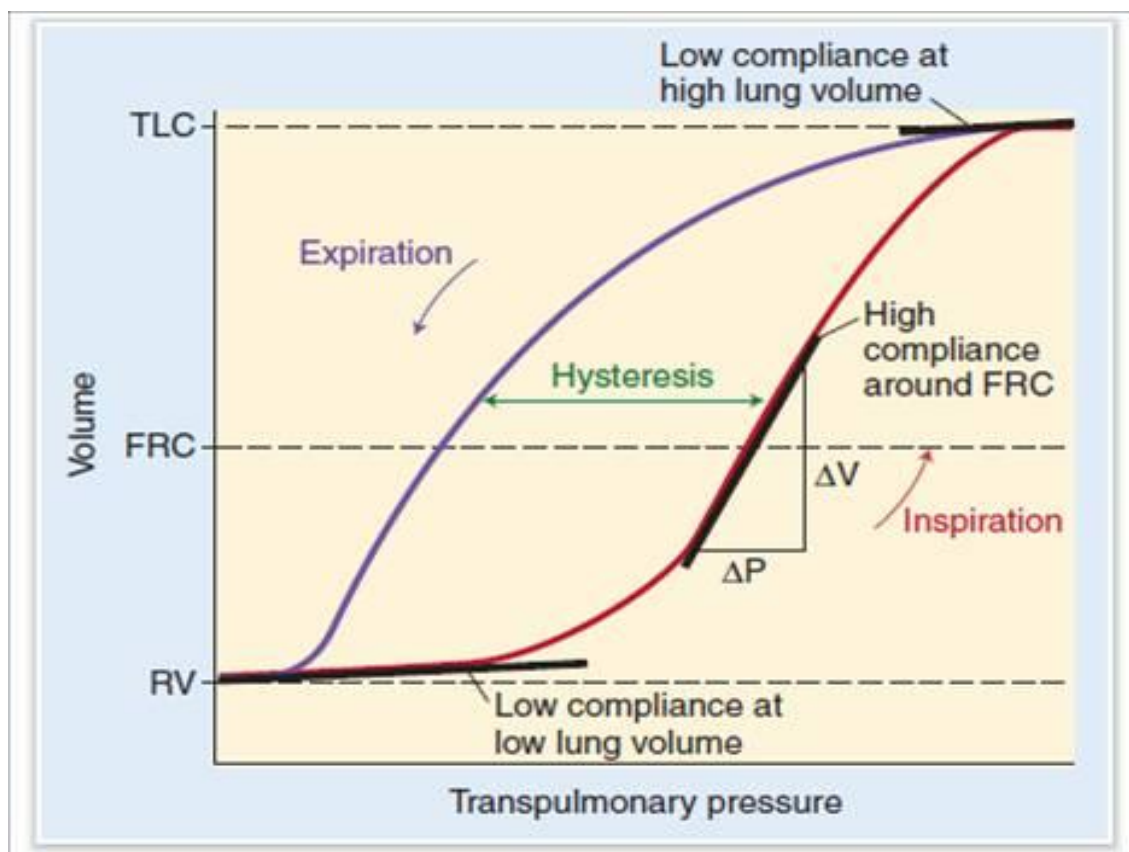
Person glottis remain open and the air inspired in step of 50 ml to 100 ml until tidal (500 ml) the volume change recorded by spirometer, the pressure change volume measure from intra esophageal balloon which reflect the intra-pleural pressure because its difficult to measure intra-pleural pressure directly and since esophageal contact to the intra-ple space so change in



the intra-pleural pressure can be recorded from the esophagus). Then the air expired in steps and we get the following curve.

Figure: **compliance of the Lung**

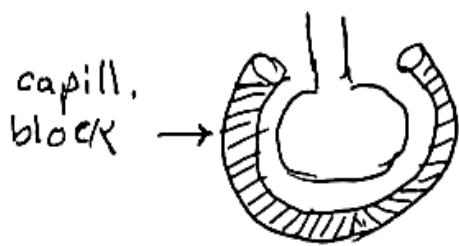
The curve show that inspiration different from expiration which is caused by the viscous properties of the lung i.e. the expansion of the lung and chest wall during inspiration is opposed by the elastic property of the lung that that is the recoil tendency of the lung. In addition inspiration need contraction of the inspiratory muscles (active process) while expiration is passive. The average compliance represented by dashed line in the figure, thus the volume increase 200-220 ml for change in intrapulmonary pressure by 1cm water. The trasnpulmonary pressure intra-pulmonary pressure (intra-Alveolar pressure) Intra-pleural pressure intrathoracic pressure) The type of curve known as hysteresis i e. not linear due to pressure of the non-elastic tissues in in addition to the fact that inspiration is active process) while expiration is passive process. Compliance of the



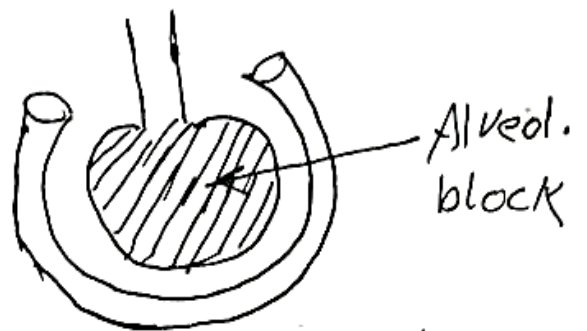
lungs decrease in lung fibrosis atelectasis and stiff lung. Where as it increase in emphysema and old age.

Figure 5-7: Pressure-volume (compliance) curve for a maximal breath. Compliance is low at both high and low lung volumes. Hysteresis is the phenomenon of the different path of the expiration curve compared to inspiration. TLC, total lung capacity; FRC, functional residual capacity; RV, residual volume.

unfunctioning alveoli either :



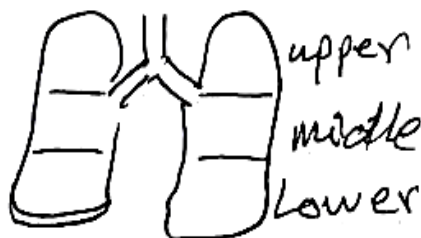
Ventilated but not perfused



Perfused but not ventilated

Both condition are
dead space

physiological dead space = anatomical
dead space



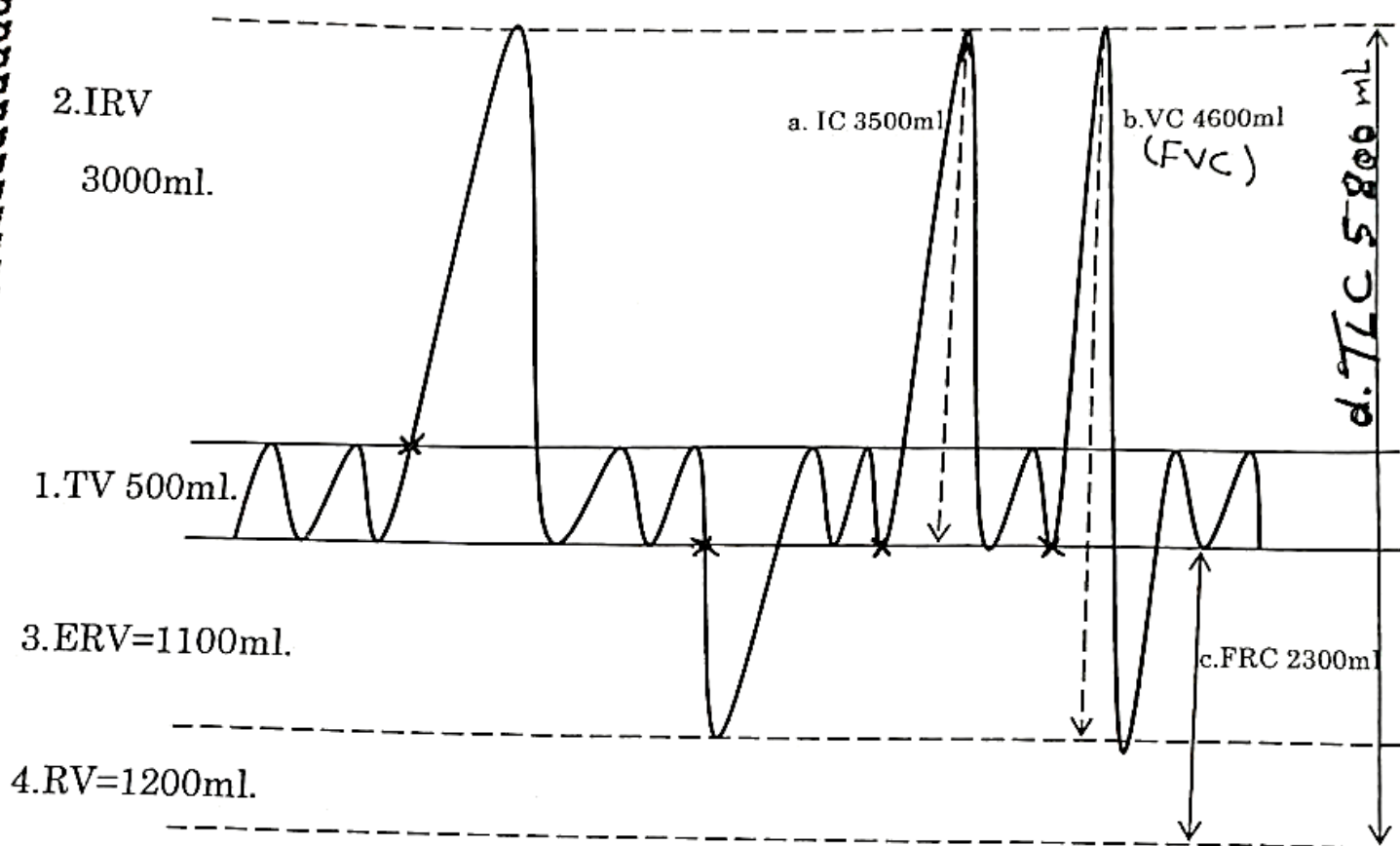
+
unfunctioning alveoli.

In standing position V_A/\dot{Q} (Ventil./Perfusion)
is increased

Transport of O_2 in the blood: a. In dissolved state 3%
b. In combination with (Hb) 97%

Transport of CO_2 in the blood:

- Dissolved state 7%
- Combination with Hb (Carbamino haemoglobin): 23%
- In form of bicarbonate ion (HCO_3^-): 70%



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- b. VC(FVC): Vital Capacity (Forced Vital Capacity) = 4600 ml.
- c. FRC: Functional Residual Capacity = 2300 ml.
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Note^①: All pulmonary volumes and capacities are 20-25% less in women than men and they are greater in large and athletic people than in small and asthenic people

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