Lecture 18. General characteristics of the respiratory system. Pulmonary ventilation

Functions of respiratory system

Respiratory system is one of the eleven systems of the human organism , that plays important role in maintaining homeostasis .

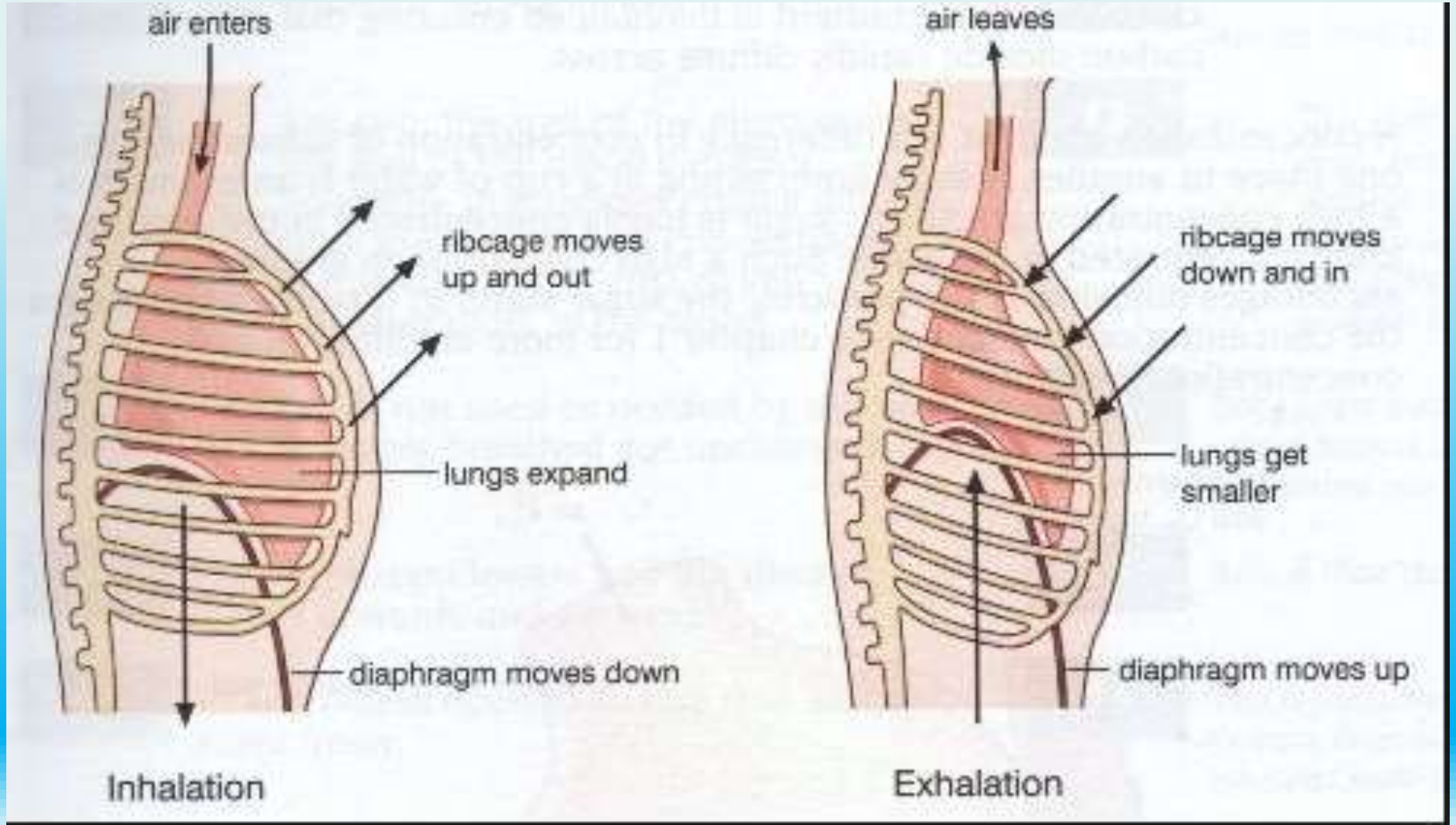
- Supplying the cells with needed oxygen to produce energy and getting rid of carbon dioxide :

- * Vocalization , or sound production.
  * Participation in acid base balance .
  * Participation in fluid balance by insensible water elimination (vapors).
  * Facilitating venous return .
  * Participation in blood pressure regulation : Lungs produce Angiotensin converting enzyme (ACE) .
  * Immune function : Lungs produce mucous that trap foreign particles , and have ciliae that move foreign particles away from the lung.
- They also produce alpha 1 antitrepsin that protect the lungs themselves from the effect of elastase and other proteolytic enzymes

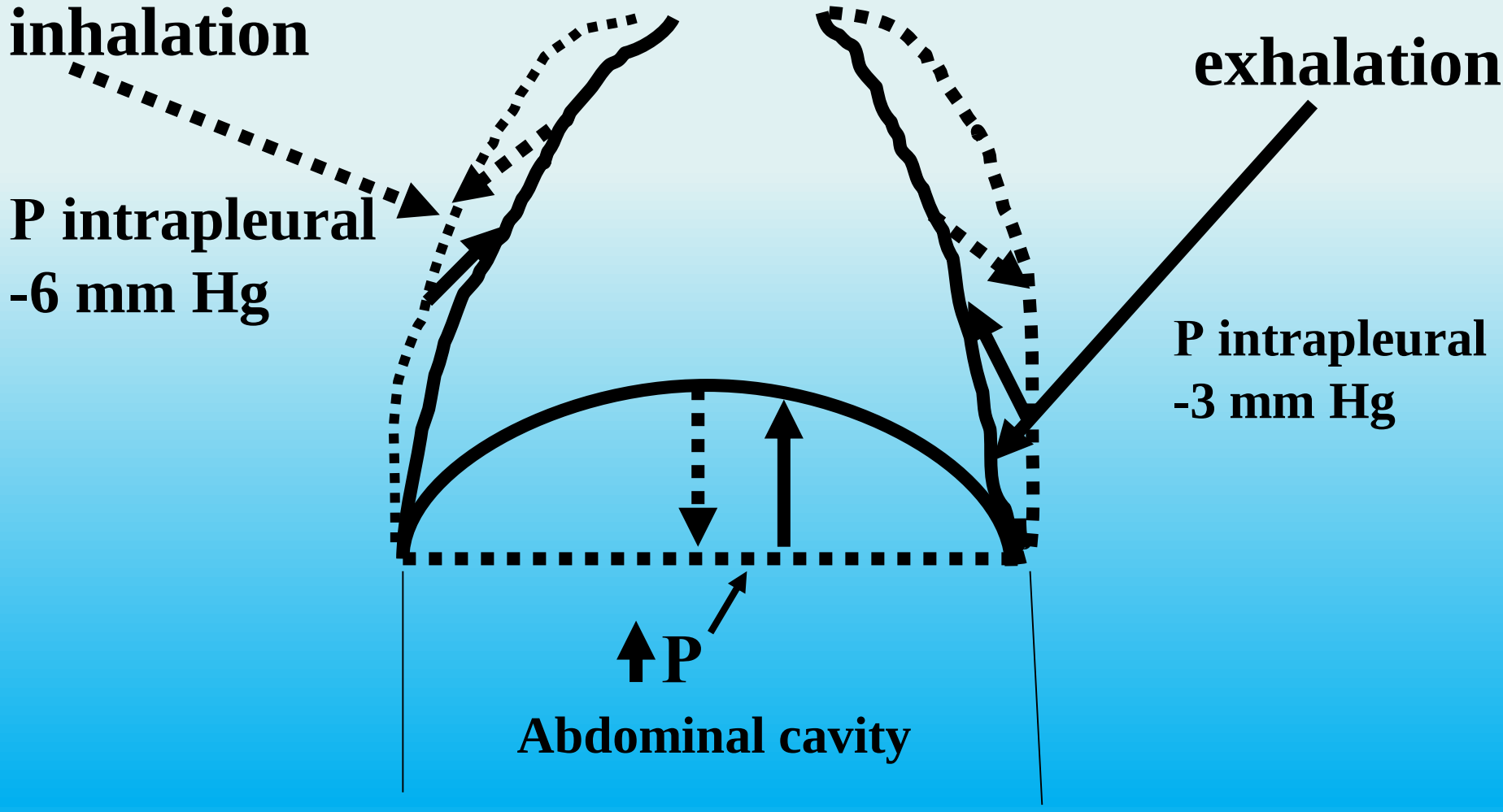
Processes in respiration

- (1) external respiration (pulmonary ventilation);
- (2) exchange of gases in the lungs between alveolar air and blood of lung capillaries;
- (3) blood gas transport;
- (4) exchange of gases in the tissues between the blood in capillaries of systemic circulation and tissue cells;
- (5) internal respiration (biological oxidation on cell mitochondria).

Changes in the position of diaphragm & chest during breathing.



Diaphragm & thoracis cavity movements



Inspiratory muscles

For usual

- muscular part of the diaphragm
- external intercostals & intercartilarginous parts of the internal intercostal muscles

- For forced inhalation:
- the scalenus, the major and minor pectoralis , the serratus anterior, trapezius, rhomboidei & the levatores scapulae muscles

Inhalation mechanism (active)

- **Stages:**
- 1) muscle contraction
- muscular part of the diaphragm
- external intercostals & intercartilarginous parts of the internal intercostal muscles
- 2) the volume of the thoracic cavity increases
- 3) the pressure in the pleural cavity becomes lower than atmospheric.
- 4) The lungs are stretched, the pressure in them also becomes below atmospheric.
- 5) Air is sucked into the lungs and fills the alveoli until the pressure in the lungs is equal to atmospheric

- *For forced inhalation: the scalenus, the major and minor pectoralis , the serratus anterior, trapezius, rhomboidei & the levatores scapulae muscles*.

Exhalation mechanism

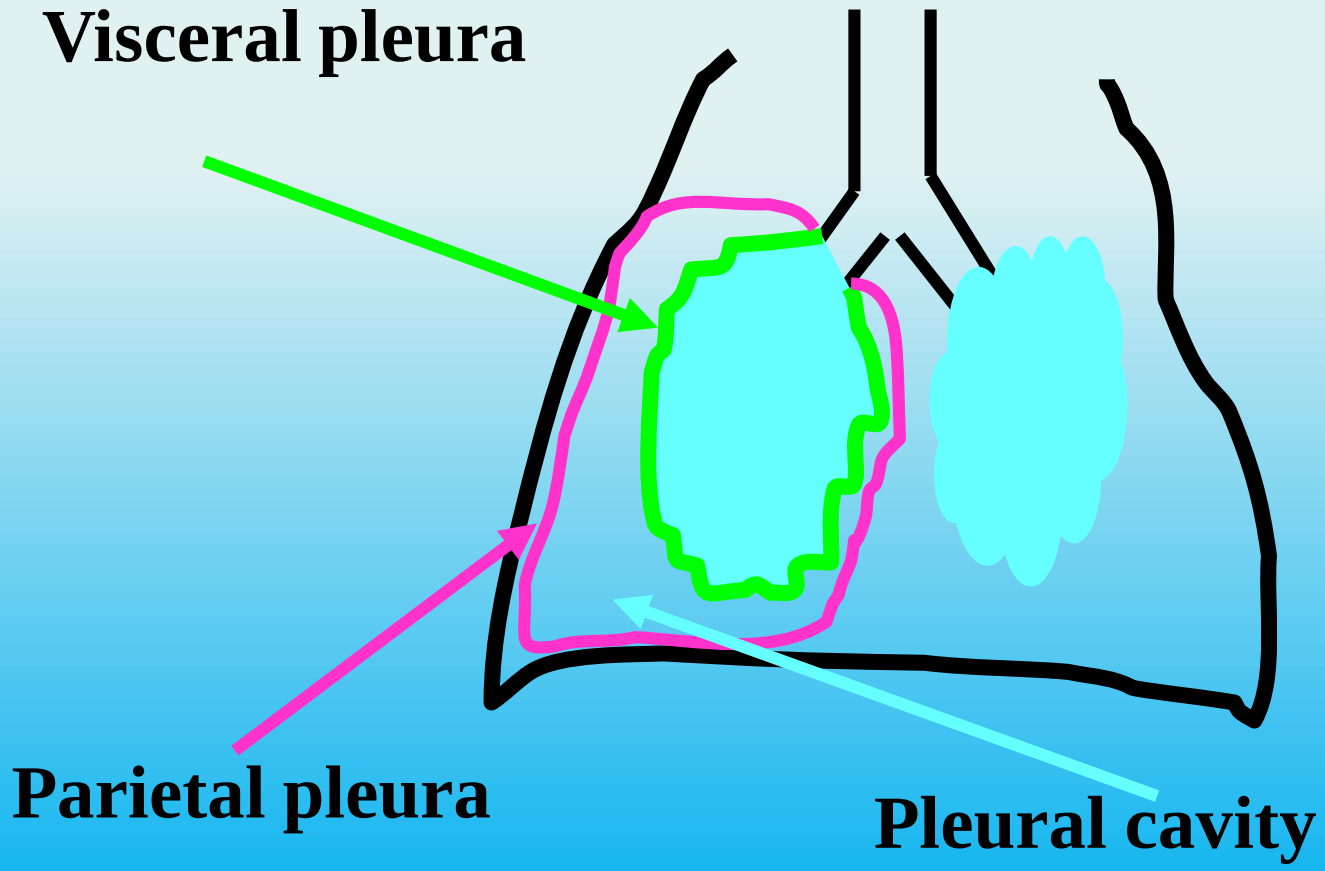
Usual expiration is passive

Stages:

- 1) The respiratory muscles relax
- 2) the lungs decrease in volume (under the action of elastic traction of the lung tissue)
- 3) the volume of the thoracic cavity decreases,
- 4) the pressure in the pleural cavity increases and together with the elastic recoil force become higher than the intrapulmonary.
- 5) the alveoli are compressed, the pressure in them becomes more atmospheric and the air is expelled from the lungs.

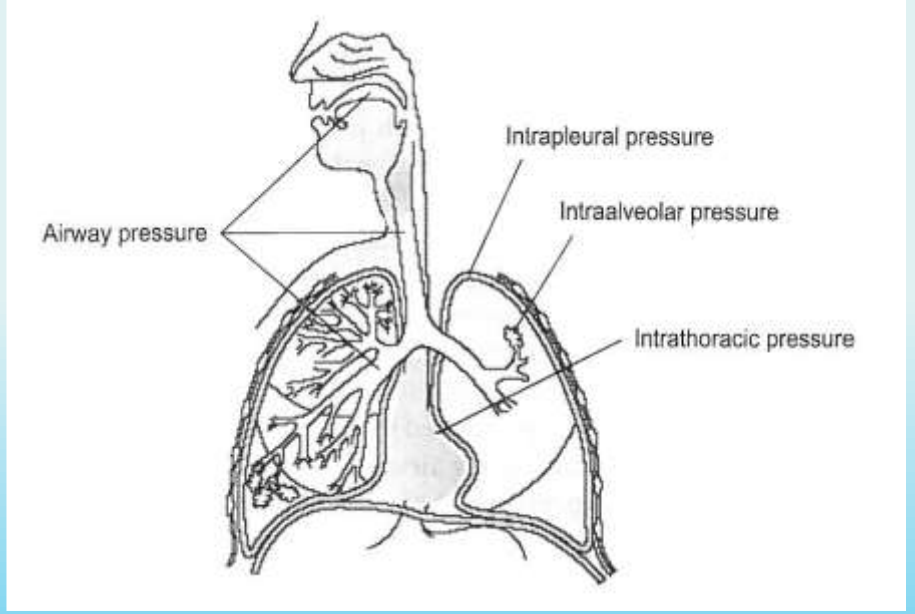
Forced exhalation is provided by the contraction of the abdominal muscles & ***internal intercostal muscles***

Pleural cavity



Intrapleural Pressure

- At the end of a quiet expiration, the pleural pressure *(Ppl ,)* approximates —3 cm H2O.



The alveolar pressure *(PA)* is equal to atmospheric.
The difference *PA* - *Ppl* = 3cm H2O is the transpulmonary pressure *(PL).*

Factors forming negative pressure in the pleural cavity

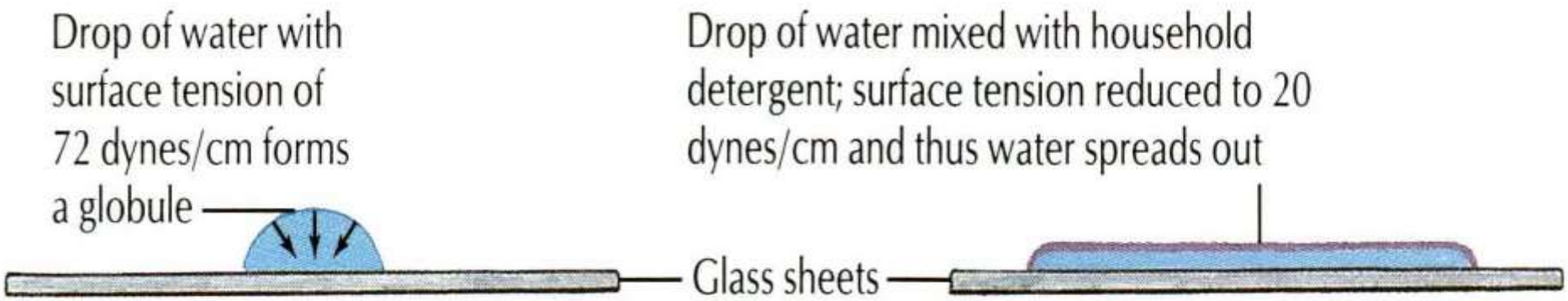
- **Hermeticized cavity (closed volume)**
- **In embrio thorasic cavity grows faster than lung parenhime**
- **Sucking force of parietal & visceral pleura**
- **Elastic recoil force**

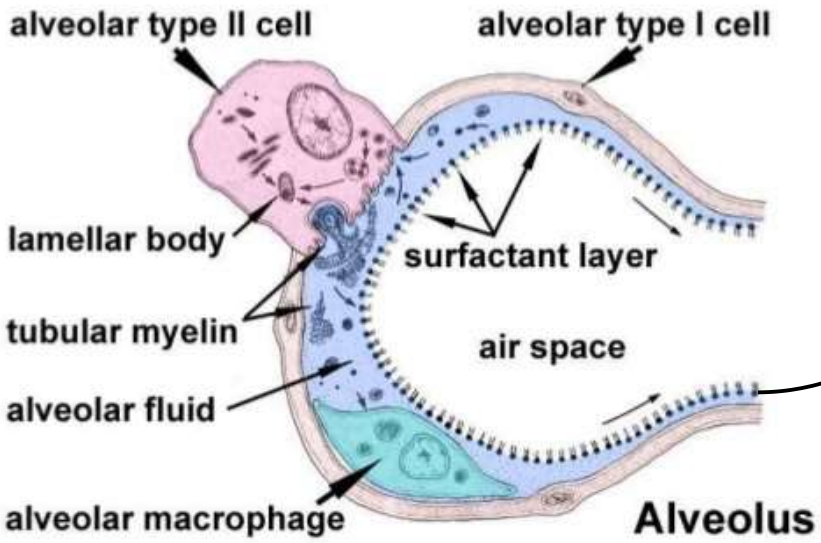
Elastic recoil force of the lungs

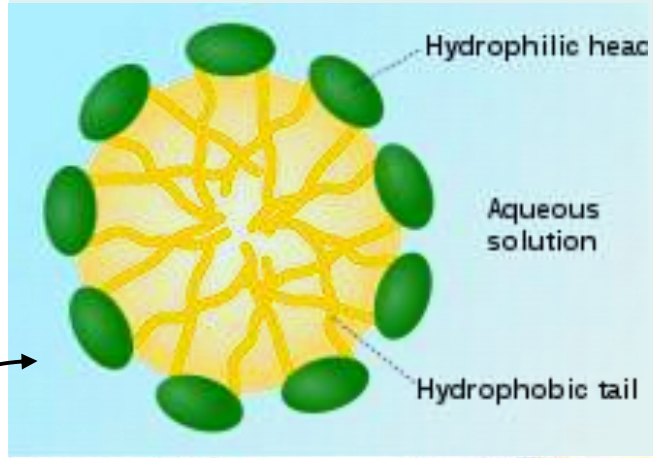
- (1) surface tension in the alveolar fluid film lining the alveoli
- (2) tissue elasticity of the alveolar walls due to the elastic fiber`s.

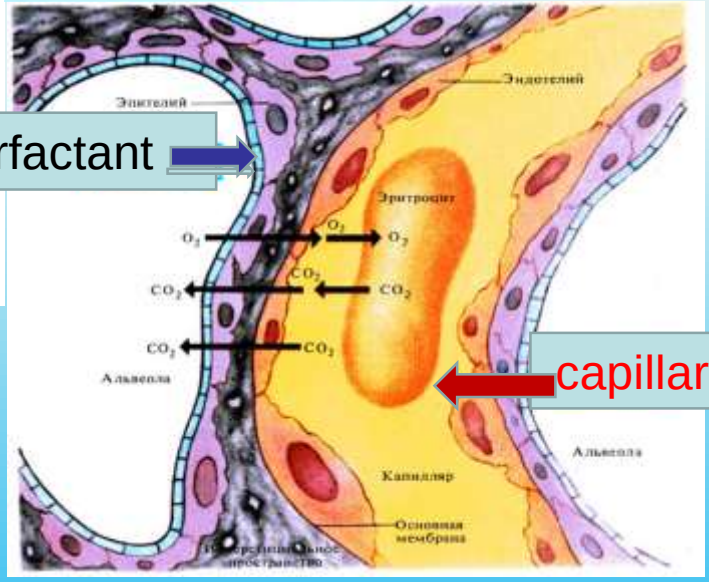
Surfactant

- Fats, mainly lecithin
- Produced by pneumocytes of II type



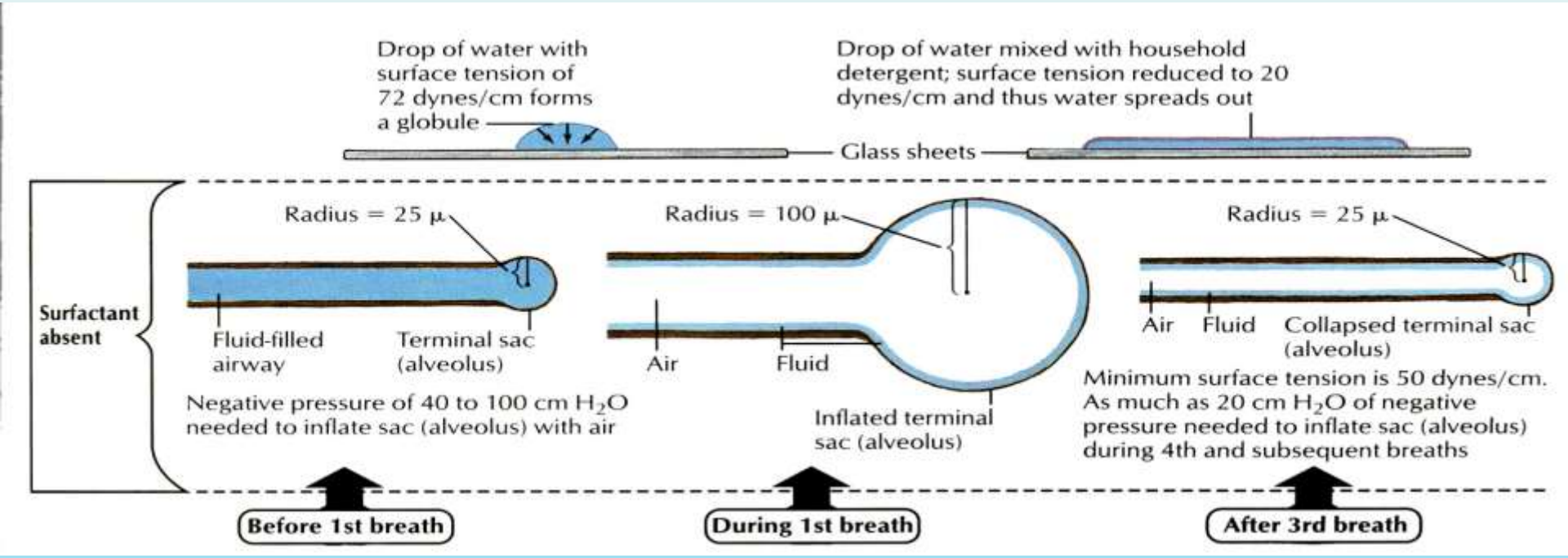


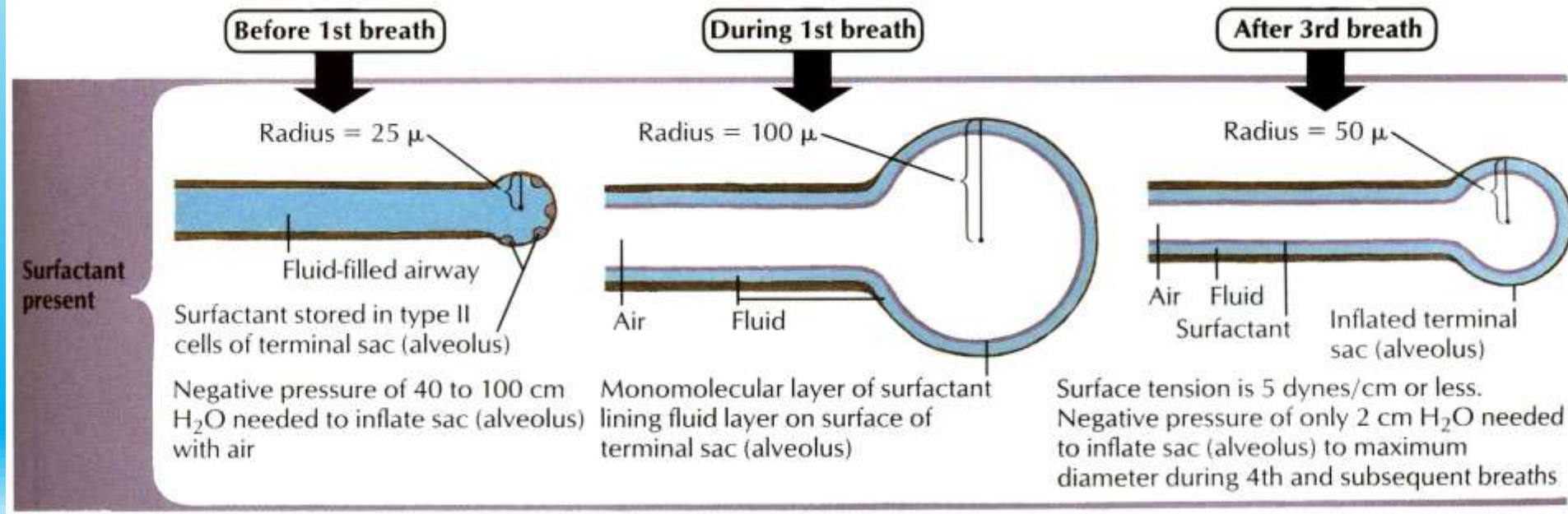


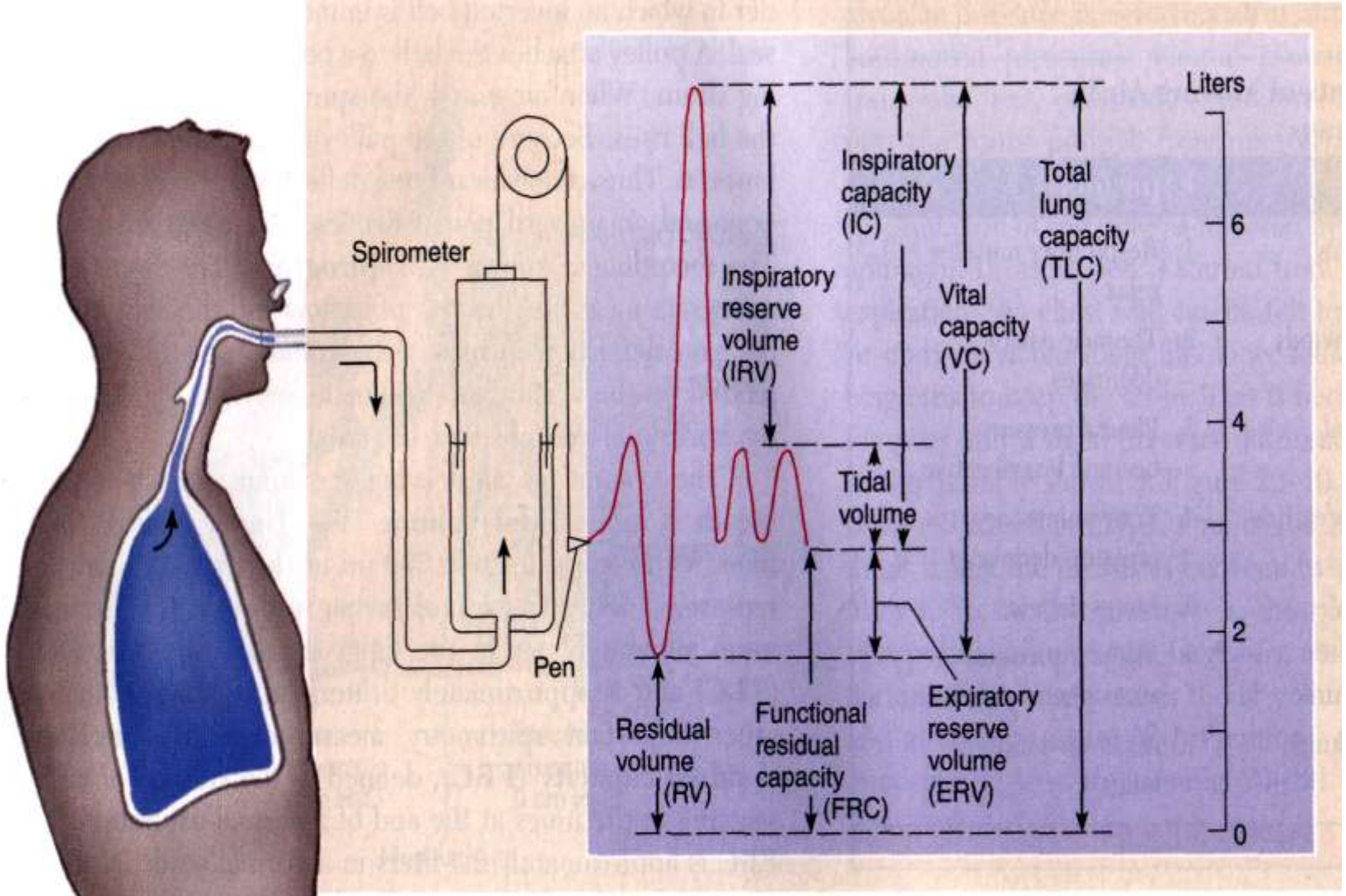


- ✓ reduce the surface tension in the alveoli,
- ✓ create the possibility of straightening the lungs during the first breath of the newborn,
- ✓ prevent the decline of terminal bronchioles, prevent overstretching of the alveoli,
- ✓ anti-edematous action, antioxidant action,
- ✓ provide up to 2/3 of the elastic resistance of the tissues of the adult lung and the stability of the structure of the respiratory zone,
- ✓ regulate the rate of absorption of O2 at the interface of the phases "gas-liquid",-
- ✓ regulate the intensity of water evaporation from the alveolar surface (regulation of water balance),
- ✓ have a bacteriostatic effect, opsonize bacteria,
- ✓ Clean the alveoli

Surfactant effects

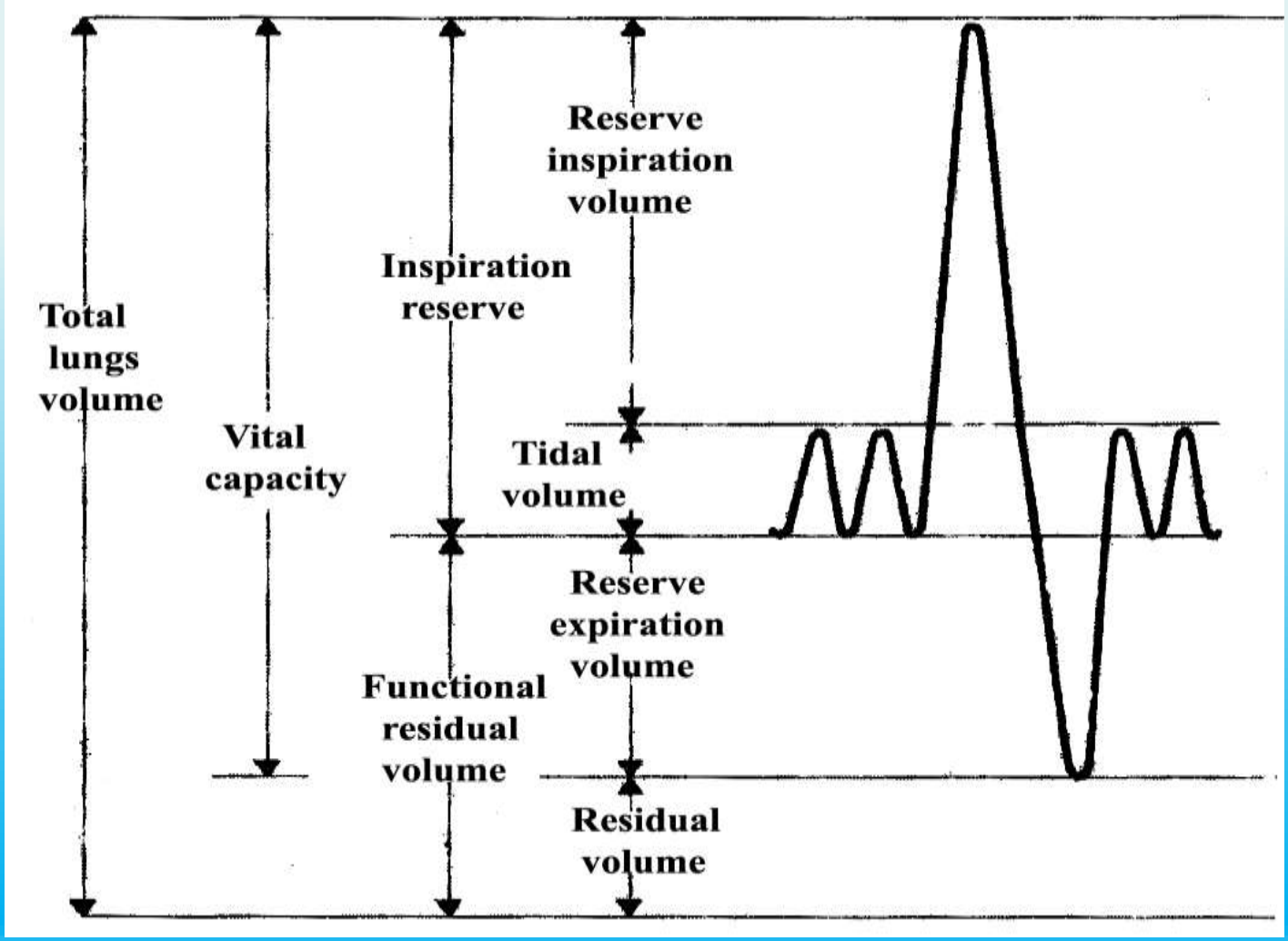






Lung volumes are measured by a spirometer. A cross-section of the spirometer is shown on the left. With inspiration, the pen shows an upward deflection on the spirogram, and with expiration, a downward deflection. On the right, a spirogram illustrating the different lung volumes is depicted. Note that the functional residual capacity (FRC), residual volume (RV), and total lung capacity (TLC) cannot be measured directly with a spirometer

Lung Volumes



Lung Volumes

- The volume of air breathed in and out during quiet breathing is about 500 ml (from 300 to 800 ml) and is known as *the tidal volume.*

- The maximal volume of air that can be additionally inspired in deep inspiration is about 3000 ml. This is the *inspiratory_reserve volume.*

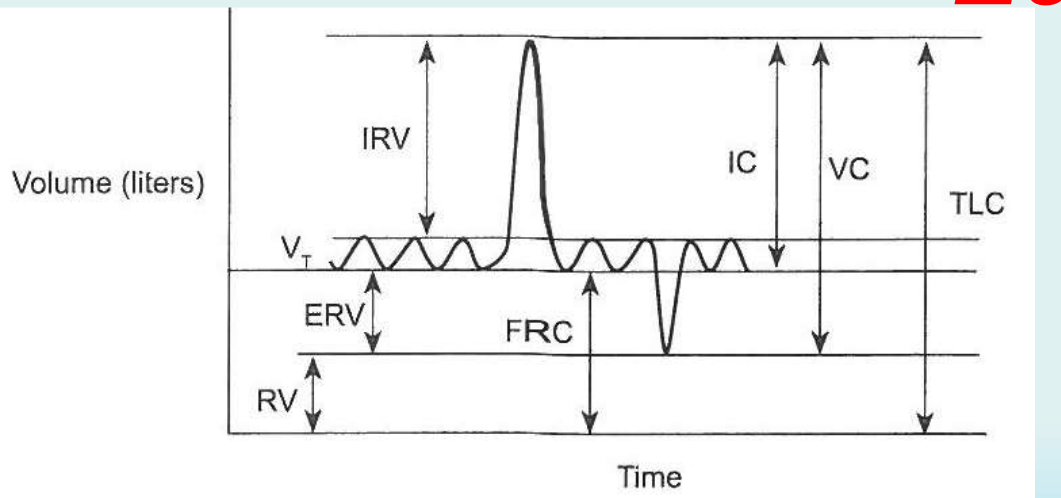
- The maximal volume of air that can be expired after quiet expiration is about 1300 ml and is called the *expiratory reserve volume.*

- The sum of these volumes is the *vital capacity of the lungs (VC):* 500 + 3000 + 1300 = 4800 ml The VC is slightly higher in the male (4000-5500 ml) than in the female (3000-4500 ml).

There is a formula for calculation of ***normal VCL for the men***: **height (cm) x 25** and ***for the women***: **height (cm) x 20**. Some kinds of sport (swimming, rowing) and professions increase VCL.

- A considerable volume of air (about 1200 ml) remains in the lungs after maximal expiration. It is called the *residual volume.*

Lung Capacities



Lung capacities include two or more lung volumes.

1. The *total lung capacity* (TLC) is the sum of all the volumes in the lungs. TLC is the volume of air that locates inside the lungs on the top of the deep forced inspiration. It is equal to appr. 6–8 liters of air.
2. The *vital capacity* (VC) equals the IRV plus the TV plus the ERV and is the amount of air that can be exhaled from the point of maximal inspiration. It is equal to appr. 4–5 liters of air.
3. The *functional residual capacity* (FRC) is the sum of the RV and ERV; it is the volume of air that remains in the lungs at the end of normal expiration. It is equal to appr. 2–3 liters of air.
4. The *inspiratory capacity* (IC) equals the TV plus the IRV. It is the amount of air a person can breathe in beginning at the normal expiratory level and distending the lungs to the maximal amount. It is equal to appr. 3.0-3.5 liters of air.

Lungs Dynamic Indexes

- **Forced expiratory volume (FEV_1) (Tiffno' test).**
- It is the volume of air that can be expired in one second following a maximal inspiration.
- It is normally 80 % of the **forced vital capacity (FVC)** and is expressed as:

$$FEV_1/FVC = 0,8$$

In restrictive lung disease such as fibrosis, both FEV_1 and FVC are reduced.

- In obstructive lung disease such as asthma, FEV_1 is reduced more than FVC so that FEV_1/FVC is decreased.
- **Coefficient of pulmonary ventilation** shows the part of air, which changes in the respiratory system during the one breathing cycle in state of rest:

- **CLV = (TV – DSV):FRC**; where TV – tidal volume, DSV – dead space volume, FRC – functional residual capacity;
  - CLV = (500-150):2500(ml) =1/7 (or 14 %).
- CLV shows, that only 1/7 part of air in lungs changes during one breathing cycle.