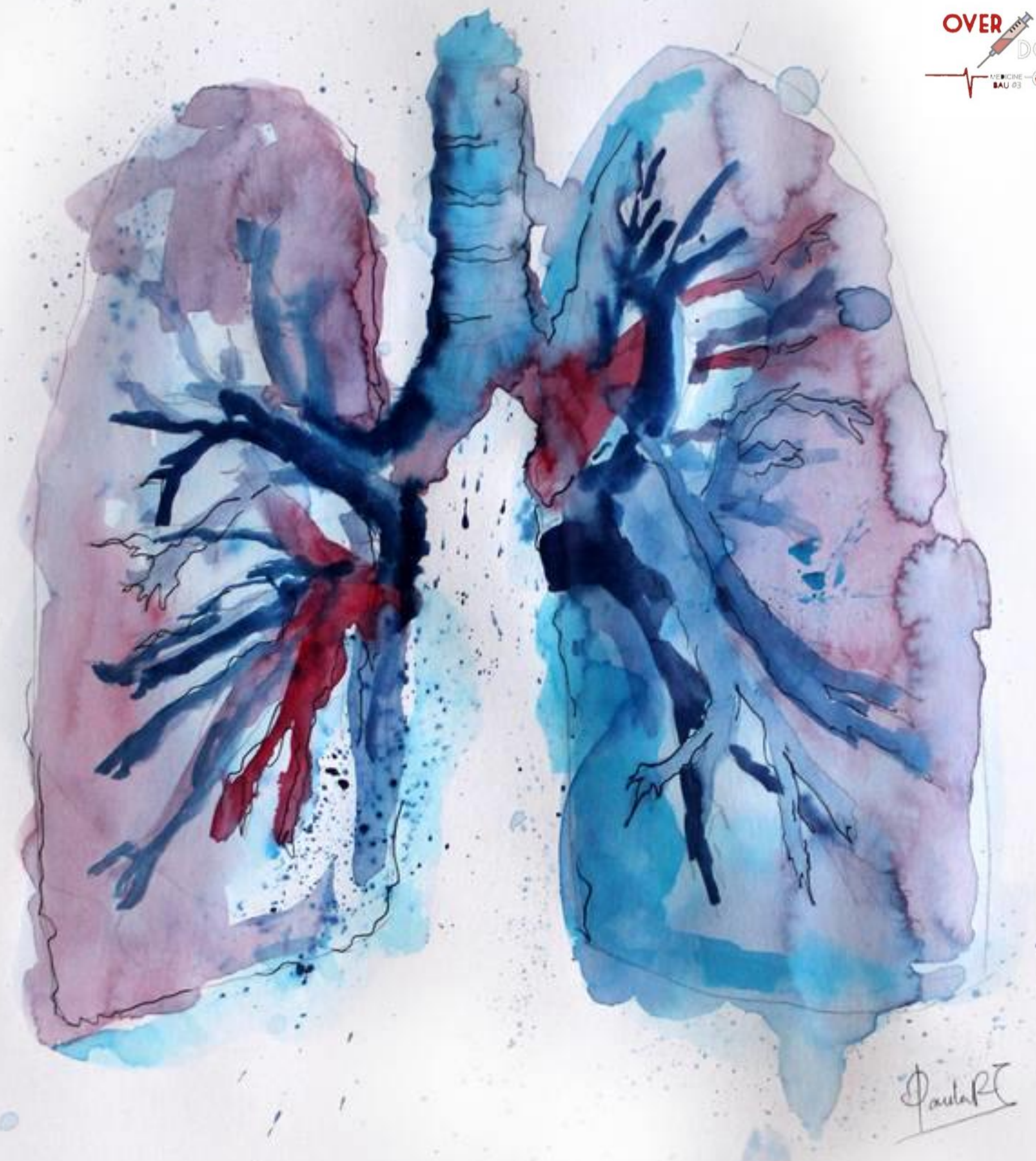

THE RESPIRATORY SYSTEM

Sub-system: Physiology
Lecture Title: Pulmonary Volume 1
Lecture Date: 31-10
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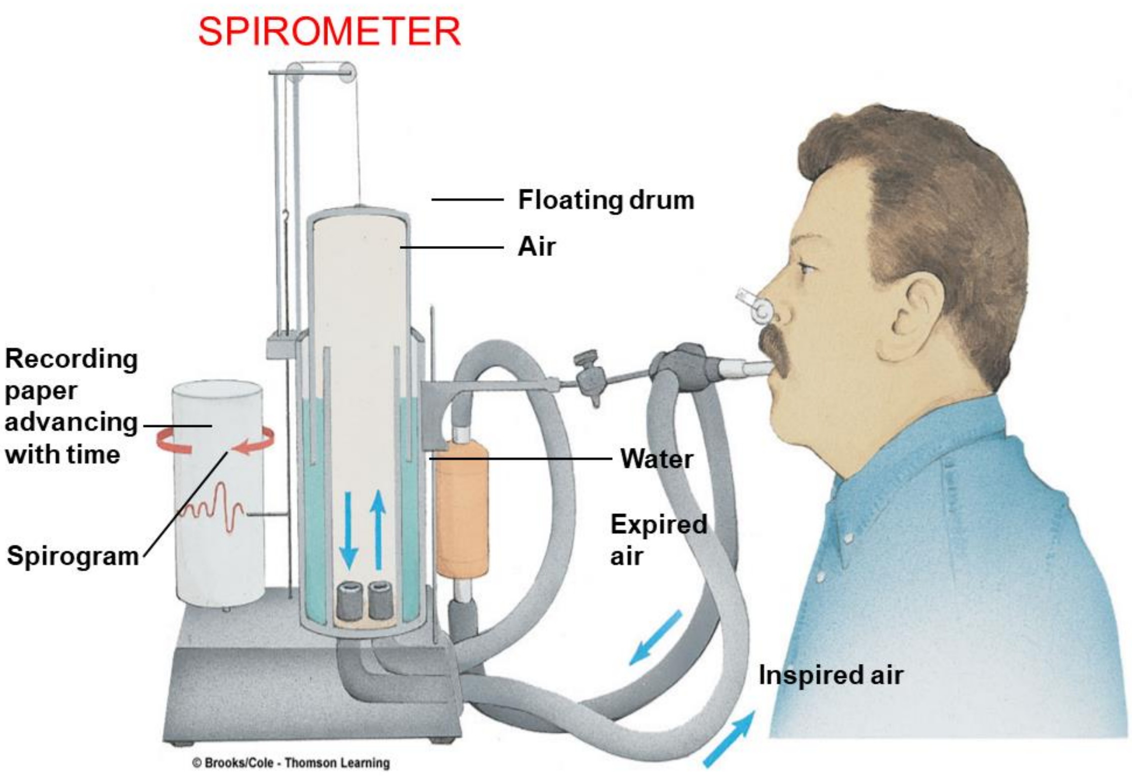
LUNG VOLUMES

- There are different parameters that assist the functions of the Inhalation Process as inspiration, expiration, and exchange and so on. These parameters are called Lung volumes.
- Lung Volumes are used to assess the functions of the lung; clinically, if any patient has a problem with the respiratory system, one of the most important things to perform is the lung volumes or the respiratory tests.

- ## Spirometer :
  - It is a device that measures the volume of air breathed in and out; it consists of an air-filled drum floating in a water-filled chamber and it's used to assess and monitor the functions of the patient's lung by measuring the lung volumes.
  - As a person breathes air <u>in and out</u> of the drum through a connecting tube, the resultant <u>rise and fall</u> of the drum RESPECTIVLEY and these are recorded as a spirogram (like the ECG) , which is calibrated to the magnitude of the volume change.
  - NOTE: There is one way for breathing by using the mouth only while closing the nose.



- This figure below represents a normal spirogram of healthy young adult male including lung volumes, and we'll discuss each part of it.

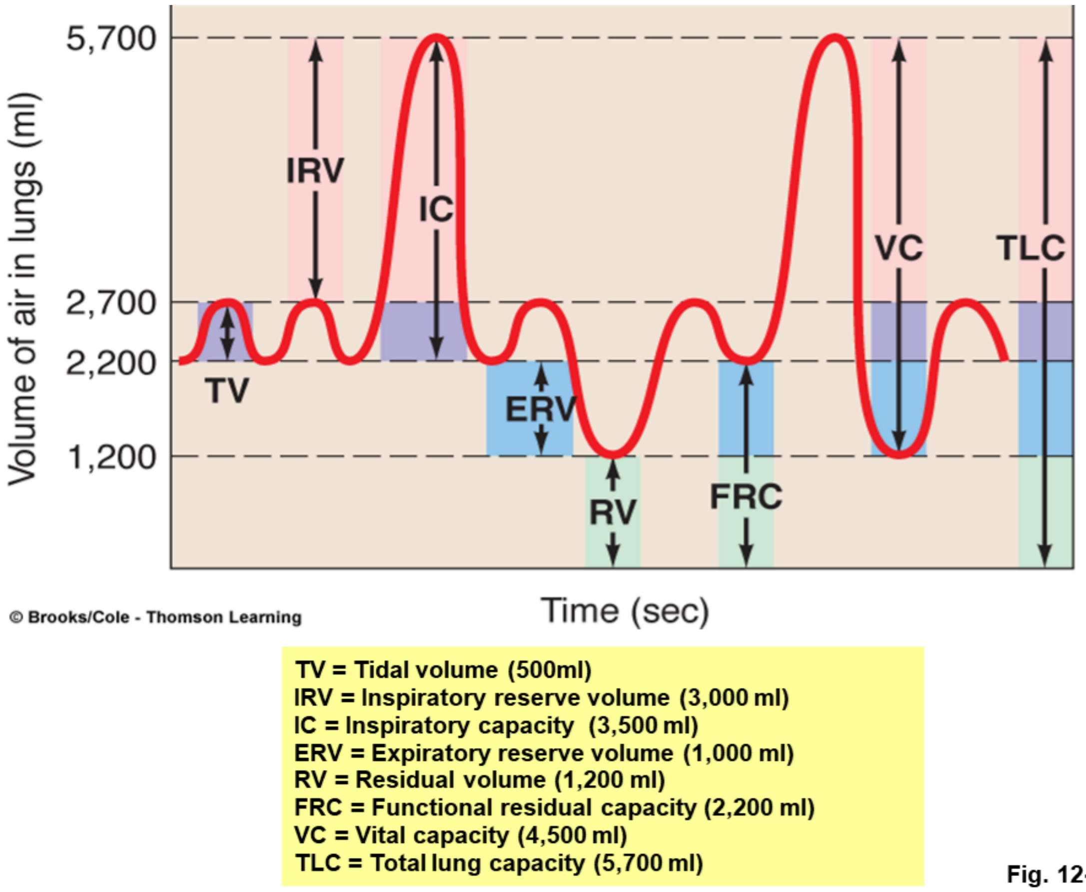
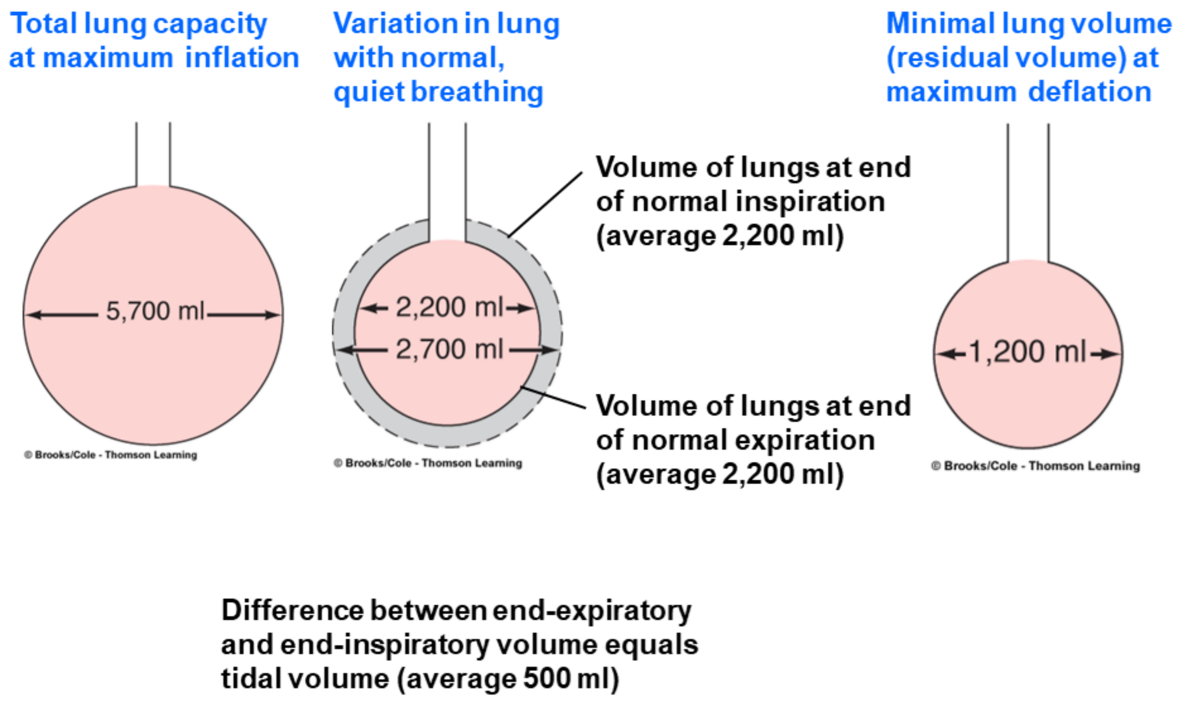


Fig. 12-14b, p. 37

- Lung volumes :
  1. Tidal Volume (TD) : The volume of air which can be inspired or expired per one breath in normal conditions.
     - Normally it's about 0.5 liter, but this amount can increase or decrease significantly.
     - For example, during exercise it's significantly increased, while during rest or sleep, it's decreased, and this obviously depends on the metabolism process of how much the body needs oxygen.
     - This means that more metabolism, more oxygen need, more ventilation and vice versa.
     - So tidal volume represents the difference between volumes at the end of normal inspiration phase (≃2700 ml) VS the end of normal expiration phase (≃2500 ml) which equals ≃500ml (0.5 liter).



- The amount of tidal volume in the respiratory system is similar to the stroke volume in the cardiovascular system.
  - ✓ Stroke volume= is the difference between end-diastolic and end-systolic volumes; it is the volume ejected with each heartbeat.
    Cardiac Output = Stroke volume * Heart rate
  - ✓ The same thing here, Tidal volume= is the difference between end-inspired and end-expired volumes per one breath.
    Pulmonary Ventilation = Tidal volume * Respiration rate.
- Normally, the respiration rate equals (12 breaths per min), so roughly the pulmonary ventilation rate or the breathing rate equals about 6L/min during rest.

2. Inspiratory Reserve Volume (IRV) : the volume of air which can be inspired after a normal inspiration (2700 ml) , which means taking a Deep Inspiration, and this normally equals (3000 ml).

3. Inspiratory Capacity (IC): This represents the amount of Tidal and Inspiratory reserve volumes together, and normally it's equal to (3500 ml).

4. Expiratory Reserve Volume (ERV) : The additional volume which can be expired after a normal expiration, which means full expiration, and this normally equals (1000ml).

5. Residual Volume (RV): The minimum volume of air which stays in the lung after maximum expiration and it's normally equal to (1200 ml).
   - This amount of volume can't be expired under any condition, or else the lung will collapse.

6. Functional Residual Capacity (FRC): The capacity of volume presented in the lung after a normal expiration, which include the residual volume in addition to the expiratory reserve volume, and this normally equals (2200 ml).

7. Total Lung Capacity (TLC): Volume of air which presents in the lung after maximum inspiration, which normally equals (5700 ml).

8. Vital Capacity (VC): is the maximum amount of air a person can expire from the lungs after a maximum inspiration. It is equal to the sum of inspiratory reserve volume, tidal volume, and expiratory reserve volume, and normally equals (4500 ml).
   - The maximum expiration after a deep inspiration takes time (3-5 seconds), the volume of the vital capacity in the first second is called FEV1 or forced expiratory volume.
   - This value is important in lung function tests for patients who have Chronic Obstructed Pulmonary Disease (COPD) to find out the differences between obstructive disease and restrictive disease.
   - FEV1 normally equals 80% of the vital capacity (4500 ml) , and if it is less, then there is a problem.
   - Considering the severity of the disease:
     - ✓ 60-80% - Mild
     - ✓ 40-60% - Moderate
     - ✓ Less than 40% - Severe

- Note : Keep in mind that lung volumes as in CVS is related to surface area of the patient, including height and weight.
- More built patient, More lung volume changes.

- Using the Spirometer, there are some parameters we can measure easily (as TD then IRV, then ERV) and some other is calculated or predicted (as FRC, RV).
- For example, FRC= ERV+RV, here we have two variables (FRC and RV) , firstly we measure <u>ERV</u> using the spirometer, then by using Helium Dilution Method we can calculate <u>FRC</u>, and finally concluding the <u>RV</u>.

- Determination of FRC using Helium Dilution Method :
    1. a spirometer is filled with air that is mixed with a known initial concentration of helium
    2. Then we ask the patient to expire normally (not maximum expiration) so the lungs now will only have FRC left in lungs.
    3. Then the patient begins breathing from the spirometer which contains the mixture of helium and air.
       *before breathing, we know the initial volume of the spirometer with the initial concentration of the helium.
    4. After a short time of breathing from the spirometer, there will be a mixture between the lungs and the spirometer, so we'll have a new concentration (which is the final conc of helium) and a new volume
    5. helium becomes diluted by the FRC
    6. After knowing the FRC, we can now calculate the RV

FRC = ((CiHe / Cf He) -1) Vi spir.

RV = FRC - ERV .
TLC=FRC+IC .

CiHe= Initial concentration in spirometer.
Cf He= Final concentration in spirometer.
Vi spir= Initial volume of spirometer.

*We also can predict the final volume by this equation of 4 parameters:

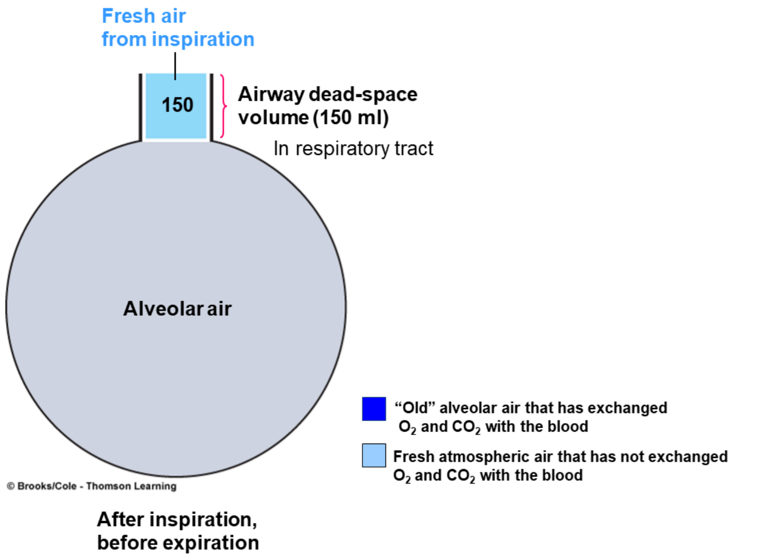
Initial conc * Initial vol = Final conc * <u>Final vol</u>

- ## Dead Space volume:
  - We already know that the breath inspired by a person through the mouth or nose, travel through the respiratory tract by larynx, trachea, bronchi, bronchiole, terminal bronchiole until they reach the alveoli where the exchange process of gases occur.
  - Anything between the air way between nose or mouth till the terminal bronchiole in the respiratory tract is called Dead Space Volume or anatomical dead space volume, and this part isn't involve in gas exchange process.
  - Dead space volume doesn't change by inspiration or expiration, the volume is the same, but the composition of dead space volume is different in inspiration from expiration.
  - The composition of Anatomical Dead Space Volume after a normal inspiration is filled with the Atmospheric Air from the air round, and after a normal expiration, its composition becomes filled with Alveolar Air from the air in the lung.
  - So we conclude that not all of the Tidal volume (which equals 500 ml) goes to the alveoli, part for it stays in the anatomical dead space which equal $\simeq 150$ ml
  - Thus the air that is actually involved in the exchange process is the Tidal volume 500ml – Dead space volume 150ml = 350 ml
  - Now we have two important concepts :

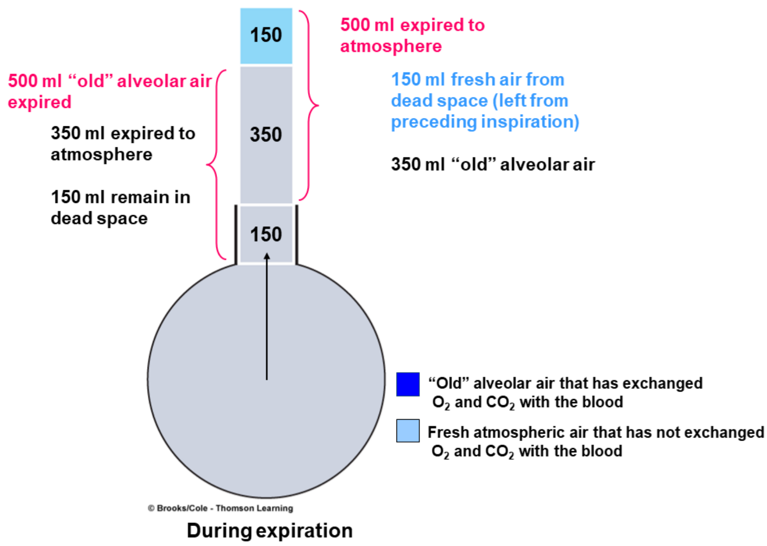
1. Pulmonary or respiratory ventilation : The total amount of air inspired or expired into respiratory passages each minute (all air in the lung including dead space volume which is not involved in exchange)
   Pulmonary ventilation = Tidal vol * Respiratory rate
   = 500 ml * 12/min = 6000ml/min
   (Low 1.5 L/min fatal). (high value like 200 L/min is fatal).
2. Alveolar Ventilation: The amount of air utilized for gaseous exchange every min.
   Alveolar ventilation = (Tidal vol – dead space) * Respiratory Rate
   = 350ml * 12/min= 4200ml/min

- Note: if we want to examine the alveolar air (in other words concentration of alveolar air or composition of alveolar air),we will take a sample from the last part of expiration which is called (end tidal volume).

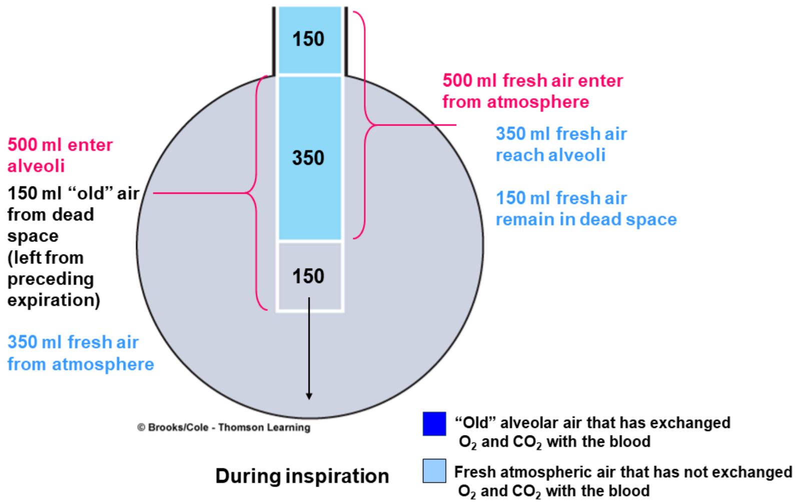
- The diagram below showing alveolar space (in gray) and dead space (respiratory tract) (in blue means fresh air) during inspiration.



- *The numbers in the figure represent ml of air.* Fig. 12-18a, p. 382



The numbers in the figure represent ml of air. Fig. 12-18b, p. 382



The numbers in the figure represent ml of air. Fig. 12-18c, p. 382

- Measurement of Dead Space Volume using fowlers method:
  1. We take a deep breath of 100% O_2, so the dead space will be filled with pure O_2 excluding any other gases
  2. Then we ask the patient to expire in a nitrogen meter that is capable of analyzing nitrogen concentration.
  3. The first portion recorded in the meter is the pure oxygen, representing the dead space volume which is roughly 150ml in a normal adult (this value depends on the built of the patient).
  4. Then the nitrogen concentration starts to rise until a plateau is reached, so we conclude that once the nitrogen start to rise, alveoli air appears.

- يعني الخلاصة : عشان نحسب حجم ال dead space بنطلب من المريض يتنفس هواء مشبع بال O_2 فقط الي رح يعبي ال dead space, ثم بنطلب منه ينفخ بجهاز النيتروجين ميتر الي رح يحسبلي النيتروجين أول ما يطلع من ال alveoli الي بتحتوي على مجموعة غازات (نيتروجين>أكسجين>بخار ماء>ثاني أكسيد الكربون).

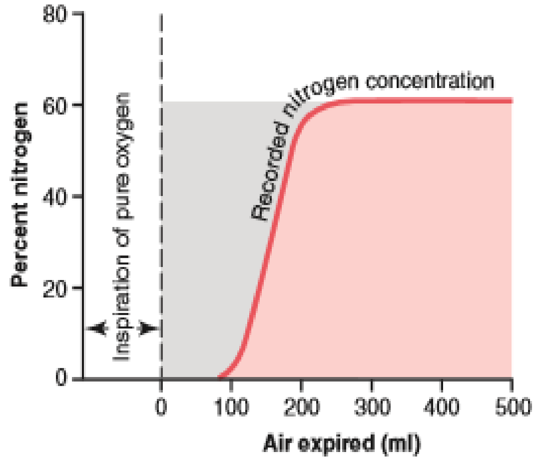


Figure 38-7. A record of the changes in nitrogen concentration in the expired air after a single previous inspiration of pure oxygen. This record can be used to calculate dead space, as discussed in the text.

- Note in slides not explained by the doctor :
  Physiological dead space = anatomical dead space + alveolar dead space Which means the anatomical dead space is only the dead space which is confined to the respiratory pathways, but the physiological also involves any alveoli that have poor perfusion of blood, so it doesn't exchange sufficiently. Dead space = No exchange
- Note: Most of the volumes are variables with emotion changing of the person, but the nearly constant volumes are: Residual volume, Dead space volume, and Total lung capacity.

▲ TABLE 12-2

Effect of Different Breathing Patterns on Alveolar Ventilation

BREATHING PATTERN	TIDAL VOLUME (ml/breath)	RESPIRATORY RATE (breaths/min)	DEAD SPACE VOLUME (ml)	PULMONARY VENTILATION (ml/min)*	ALVEOLAR VENTILATION (ml/min)**
Quiet breathing at rest	500	12	150	6,000	4,200
Deep, slow breathing	1,200	5	150	6,000	5,250
Shallow, rapid breathing	150	40	150	6,000	0

*Equals tidal volume × respiratory rate.
**Equals (tidal volume − dead space volume) × respiratory rate.

- **Functions of Respiratory Passageway :**

1. Main resistance to the airflow present in large bronchioles and bronchi
2. Sympathetic system dilate bronchioles, because in stress conditions (fight and flight), there must be dilation to increase ventilation and supply the body with O2.
3. Parasympathetic system constricts bronchioles.
4. Irritation of membrane passageways causes constriction as(smoking, dust, Infection)
5. Histamine and slow reactive substance of anaphylaxis secrete locally by the lungs by mast cells during allergic reaction as in Asthma. These cause bronchiolar constriction and we can hear the sound of breathing clearly because of this constriction.
6. Atropine relax respiratory passageway, used in patients with COPD or asthma.

- **Non respiratory functions of the Respiratory system:**
  1. It provides a route for water loss and heat elimination.
  2. It enhances venous return
  3. It contributes to the maintenance of acid-base balance.
  4. It enables various kinds of vocalizations.
  5. It defends against inhaled foreign matter.
  6. It modifies, activates, and inactivates materials passing through the circulatory system.

- ## Respiratory Reflexes :

1. Cough Reflex :
   A-Irritation of Bronchi and trachea by foreign matter
   B-Afferent impulses through vagus nerve to medulla, then automatic events trigger by neural circuit of medulla as follows
   I- Up to 2.5 lit air rapidly deep inspired
   II-Epiglottis and vocal cords closed
   III-Abdominal muscle and other expiratory muscles contract forcefully lead to increase the pressure rapidly as much as 100mmHg or more
   IV-Epiglottis and vocal cords open suddenly widely, so that under this high pressure in the lungs explode outward.
   Some velocity reach 75-100 Miles / hour, showing how fast and strong a cough reflex is to get rid of any foreign matter.
2. Sneeze Reflex:
   Very much like cough but irritation start in nasal passage way, the afferent pathway through 5th cranial nerve to medulla.
   Where the reflex is trigger and series of contraction similar to cough take place but the uvula is depress so large amount of air pass rapidly through the nose so helping to clear the nasal passageway of foreign matter.

- ## Some questions from serotonin students that may help clear any understanding :

1. Why do we use nitrogen and not CO2, even though CO2 is at higher concentrations than nitrogen?? The doctor answered you can actually use CO2, but nitrogen is a noble gas, so it will be more accurate to use nitrogen.

2. From where does nitrogen come if we inhaled pure oxygen?? The doctor said we have nitrogen in our alveoli

3. the dead space air stays inside? Doesn't change? The doctor said no its actually changed every time we take breathe
   *dead space air is the first to get in during inspiration and first to get out during expiration.

"Success is the sum of small efforts - repeated day in and day out"
Robert Collier