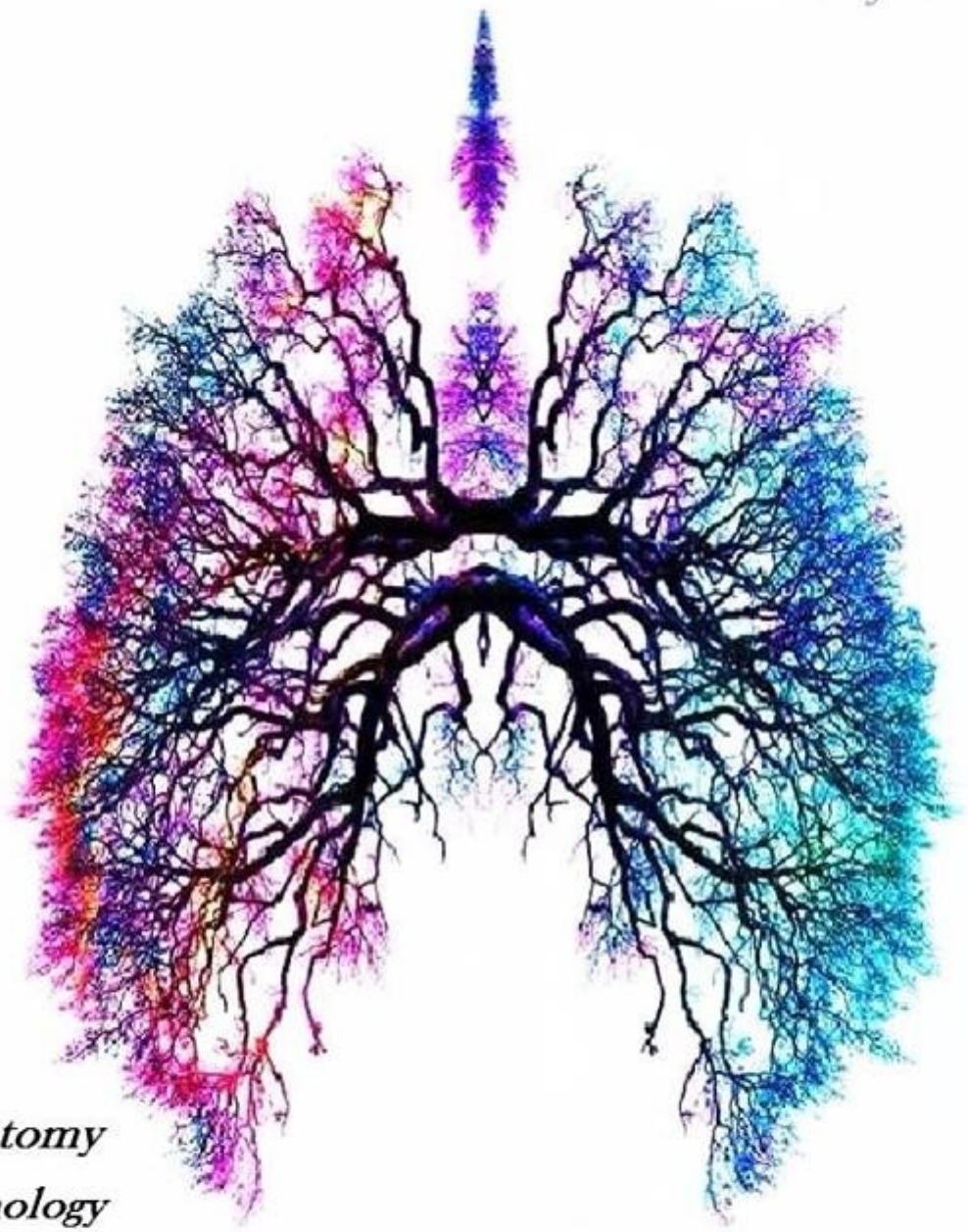
RESPIRATORY SYSTEM

Cover by: Aseil Khatib



- ○ Anatomy
- ○ Pathology
- ● Physiology
- ○ Pharmacology
- ○ Microbiology
- ○ PBL

Dr Name: Yanal Shafagoj
Lecture # 3
Done By: Hamza Awni

Sheet ■
Slide □
Other □

Dead spaces and ventilation

بسم الله الرحمن الرحيم

- Hello everyone, this sheet was written based on section one record, mostly these topics are based on understanding so it will probably be easy, but I wrote it according to the record and you all know the lecture was jumping from topic to another so thing are not very organized and I tried as much as possible to organize it.

- First of all **Lung Diseases**, which are classified to 3 types:

1. Obstructive diseases (70%) of total lung diseases, like Asthma and COPD
2. Restrictive diseases (20-25%), like Asbestosis and Fibrosis
3. Vascular diseases (5-10%), like pulmonary hypertension

- How do we differentiate between these diseases? We use PFT (Pulmonary function test).

- We said in the previous lecture, we have 4 lung volumes and 4 lung capacities. We use for example spirometer for measuring the volumes of air inhaled or exhaled, but if the air isn't moving (static), like **RV** (Residual volume) then we can't measure it, also if we can't measure **RV** then we can't measure **FRC** (Functional Residual Volume), **TLC** (Total lung capacity), anything including **RV**.

- We want to measure RV but can't do it by Spirometer, then how?
  First we have to measure FRC then we can measure RV, because FRC= ERV (Expiratory reserve volume) +RV, now ERV can be measured by spirometer.
  We ask the patient to breath from a closed bag which contains **non absorbable gas** (like **Helium**), this helium doesn't cross the membrane and go to the blood so it's non absorbable, the patient breathes beginning at FRC, he breathes many times until there is equilibrium of helium between lung and the bag which he breathes from (**Concentration of helium in Inspired air is the same as Expired air**) and we know the Vol. of the lung and the bag.
- Then we use this equation: ($V_1C_1=V_2C_2$)
  V_1= Vol. of air in the bag
  C_1= Initial Conc. Of helium in the bag
  V_2= V_1 +FRC
  C_2= Final Conc. Of Helium

- ⇨ V*C= total amount of helium

After the patient starts to breathe the helium, the total amount of helium remains the same because none of it crosses the membrane to the blood.

- ⇨ Usually, C2 is less than C1 because of dilution.

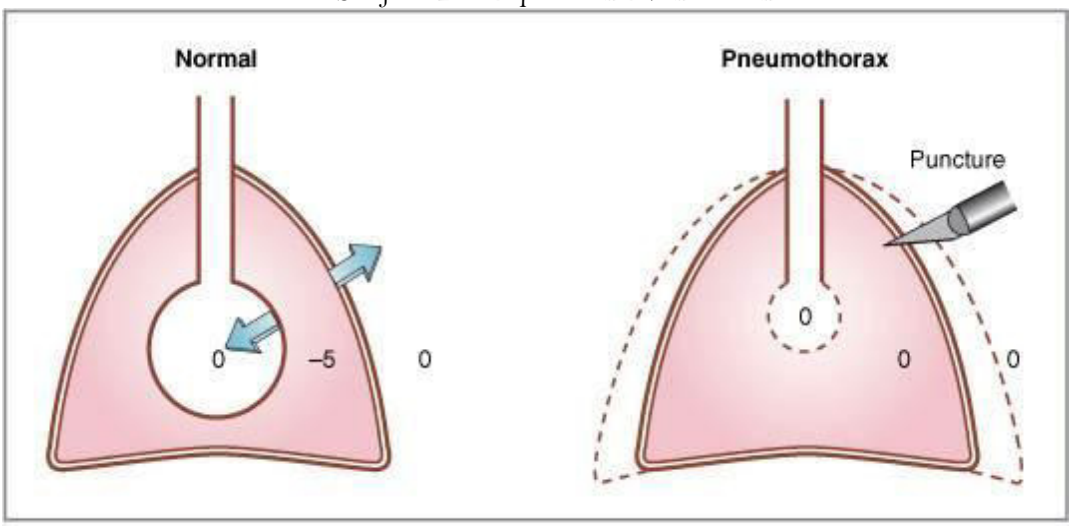
Now we rearrange this equation to measure FRC
>> V1C1= (V1+FRC)*C2
>> V1C1= V1C2+ FRC*C2 >>V1C1-V1C2= FRC*C2

$$>> FRC = \frac{V1C1 - V1C2}{C2} \gg FRC = V2 * \frac{C1 - C2}{C2}$$

- This is known as the **Helium Dilution method**, Measure FRC then RV.

- If we try to empty the lung, we can't go below **RV**, you can say that the lung is a balloon, the balloon is **Elastic, so is the lung**, same as the balloon, the lung tries to empty itself, to contract, to shrink, to go to its resting state, **Resting Volume**, which means that the lung loses its tendency to collapse.

- The lung as we said is **Elastic and will Recoil**, try to collapse, but that doesn't happen in the normal body, why? Because the lung is surrounded by Negative pressure (inflation or opposing force) that pull it and try to expand it (It's the negative pressure in the pleural cavity), but it also doesn't expand, lung is trying to collapse and the negative pressure pull the lung, the lung is in static balanced state because of these two forces. **What** will happen if the lung isn't surrounded by this Negative pressure anymore, like if we take it outside the body (**In Vitro**), or if the pleural cavity is exposed to atmospheric air by stab wound or gunshot, or if the chest cage is opened during surgery?
Of course with nothing preventing the lung from collapsing, pleural pressure isn't -ve anymore, there's no inflation pressure, and it will collapse and reach Resting volume where it loses its tendency to collapse.



© Elsevier. Costanzo: Physiology 3E www.studentconsult.com

- The first one is normal balanced lung. The second one is punctured >> Lung collapses, no –ve pressure to cancel the Elastic force of the lung.

- The **Resting volume** of the lung also known as **Minimal volume** = 150mL

- Again, we want to empty our lungs but we can't go below RV, we can't reach Minimal volume (150mL), we can only reach RV, but we also can reach the Minimal volume if the collapsing forces of the lung is extremely high or there's no –ve pressure surrounding the lung anymore.

- As we all know, things are in harmony between the heart and the lung, the heart cardiac output to the lung equals (5L/min) ejected from Right Ventricle, and ventilation from outside, so you need Air+ Blood, how much is the ventilation?
  Ventilation= **Tidal volume** or VT (0.5L) inhaling *12 breaths/min
  =6L/min, it's called **Respiratory Minute Ventilation**
  However this isn't true because from the 500mL VT we inhale, 150mL remains in the **Anatomic Dead Space** (ADS), these 150mL never reach the alveoli, only 350mL reach the alveoli so **alveolar ventilation** (renewal of alveolar air), it is 350mL*12= 4.2L totally reach alveoli/min.

- The doctor said that we don't know for sure if that's true or not, said he'll repeat again and went to another topic. **Lung** has an apical and basal regions, the blood usually face difficulty reaching the apical region due to gravity, like in people standing, so **Perfusion** (which is blood flow) to the apical area is less than that of the basal area where perfusion is more, so apex is under-perfused and base is over-perfused, **however this isn't the Point!!!!!**

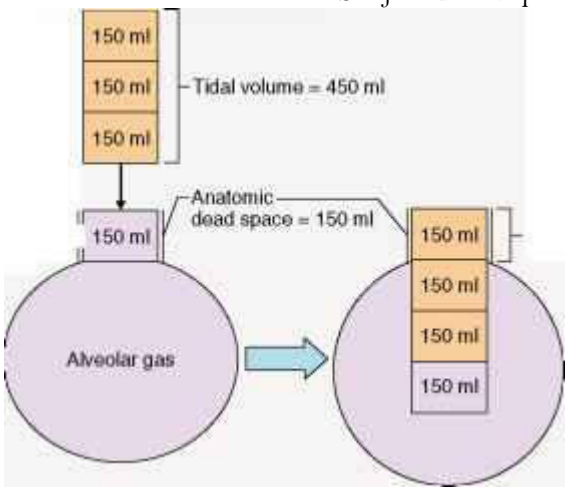
- In **ventilation, (500mL, hypothetically)** reach the apical area but there's no blood reaching it (**No perfusion**), so the ventilation/perfusion ratio (V/Q ratio) in this area= infinite, it's like you're dividing the ventilation on **zero**.

- So you are wasting your ventilation, air goes to an area where there's no gas exchange because there's no blood flow (Perfusion), this is known as **Wasted Ventilation.** So first you've wasted 150mL in ADS on which you have no control of (you have no choice). Also the remaining 350mL will be subdivided into:
    1. Alveolar wasted volume: the region in the lung that is ventilated but not perfused i.e. ventilation/perfusion ratio is high.
    2. Alveolar ventilation.

- There is a new definition know as Physiologic dead space (PDS), which equals Anatomic dead space + Alveolar wasted volume (from the remaining 350mL). If the alveolar wasted volume= 0 (i.e. all alveoli are ventilated and perfused), then PDS=ADS, and if it's more than zero, then PDS > ADS.

- Back to V/Q ratio, we don't like to have the ratio very high or very low, such as if there's perfusion but no ventilation, **it is wasted perfusion** (No gas exchange), there is effort on the heart pumping blood but with no air so it's useless.
    - ⇨ So we don't want any of the ventilation perfusion mismatches to happen.

- Again back to ADS and PDS, when talking about the composition of air in the ADS, imagine that I have **two ADS Volumes**, one is in **ADS at the end of inspiration** and the other is in **ADS at the end of expiration**, the first one is composed of the same air as the outside air (fresh air) because it never reached the alveoli and never did any gas exchange, and the second one is part of the 350mL of alveolar air inside, the question is, why did I call the 2nd one (which is an alveolar air), why did I call it ADS? Because when we expire the air, the first part of air to go outside is the 150mL in ADS which never reached the alveoli, **we exhale and the alveolar air inside take the place of the 150mL of the ADS when we finish exhaling**, it's the alveolar air from the previous breath. It's something like this:



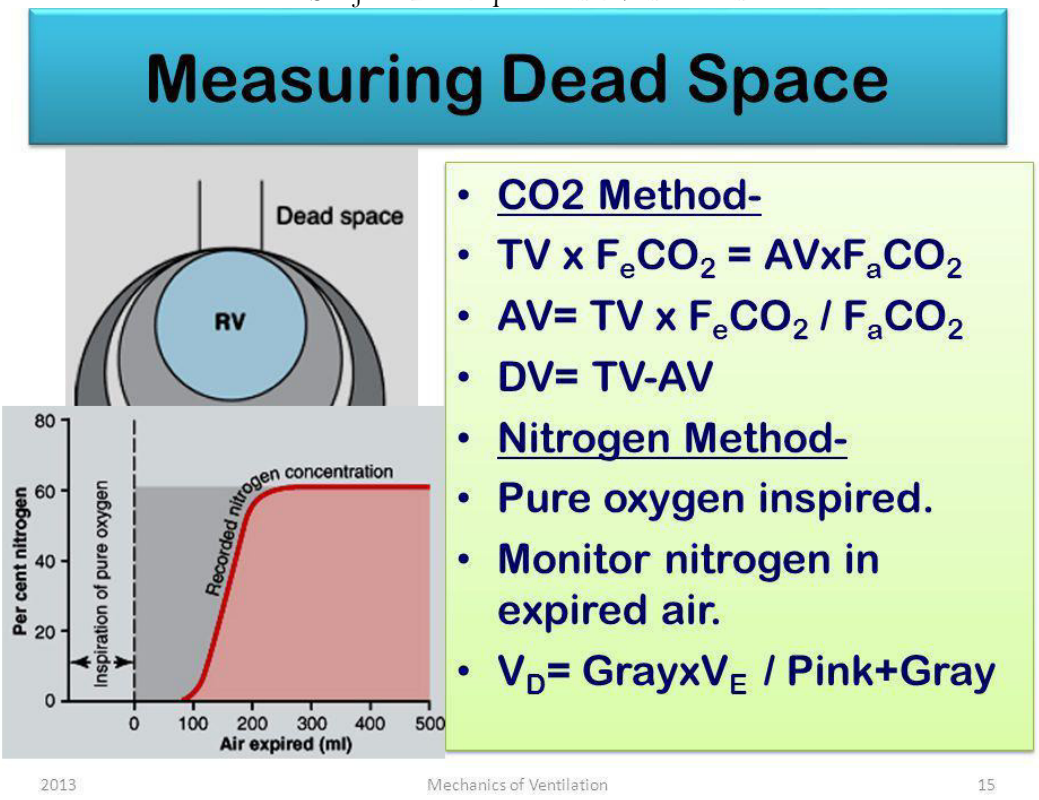
- So **at the end of inspiration** ADS air is the same as the outside air which means P_{O_2}=150 mmHg and P_{CO_2}= zero, and **at the end of expiration** the ADS air is the alveolar air that was inside so P_{O_2}= 100 mmHg and P_{CO_2}= 40mmHg.
  When we analyze the expired air, 150mL from ADS + 350 from alveolar air, 150mL where P_{CO_2}= zero, and the 350mL where P_{CO_2}= 40 mmHg.
  So P_{CO_2} in the next expired air = $\frac{150*0+350*40}{500} = 28$ mmHg

- Now the P_{CO_2} in expired air is between (0-40) but it is closer to 40 why? Because the 350mL has more P_{CO_2}than the 150mL that was in the ADS.

- P_{CO_2} in expired air = 28 mmHg, and **after expiration** the P_{O_2}=100, P_{CO_2}=40, P_{H_2O}=47, P_{N_2}= the rest of the 760 mmHg.

- The doctor moved to another topic, here the doctor explains how we measure the dead spaces, we ask the patient to take single deep breath (one V_T) of pure O_2 meaning 100% O_2 (P_{O_2}= 760 mmHg in the inspired air), so at the end of inspiration the air in ADS is also pure O_2, but P_{O_2} in ADS equals 713, why? Because of the P_{H_2O} which equals 47, so P_{O_2}= 760-47=713, and there are NO CO_2 and NO N_2.

  Then we ask the patient to exhale through a hose connected to a machine that measures two things: The volume of air and Nitrogen content, the ADS has no N_2, which means that the amount of air exhaled with no N_2 in it represents the dead spaces. So if we plot the volume of exhaled air vs. N_2 content we will notice that at 150mL there's no nitrogen. After 150mL when the exhaled air becomes from the alveolar air, you can find N_2, but this doesn't go with the laws of physics, it is not accurate, not absolute, because there is always a transitional zone where there is mixing of gases which means there will be dilution. So the curve is like in the following picture:



- The method the doctor talked about is the picture below (Forget about the one above as the doctor didn't talk about it), as was written before we use N2 for measuring the dead space as it isn't present there so the area that has no nitrogen is the dead space with no gas exchange, and after this area is the area where nitrogen starts to appear (the machine measures the nitrogen content). This method is called: Nitrogen washout method.
  The ADS is measured by this method.

  What about the PDS?
- Another point is **the calculation of PDS Vol.** =

$$PDS = VT \times \frac{Pco2\ (arterial) - Pco2(mixed\ expired\ air)}{Pco2\ (arterial)}$$

Always remember that the arterial is the same as the alveolar.

In normal condition; Pa_{CO_2} = 40, PE_{CO_2}=28:

$\frac{40-28}{40} = \frac{12}{40}$ and PDS is a part of the VT, so PDS = 500mL*$\frac{12}{40}$ =150mL

⇨ As you notice PDS=ADS which means that there is no wasted Volume.

But if one area of the lung is ventilated but not perfused the air that comes from this area is actually like fresh air; it has high P_{O_2} and low P_{CO_2} because no exchange takes place. Thus when you exhale, the CO_2 in the expired air becomes less because it's mixed with part of the air that has no CO_2 so the P_{ECO_2} becomes 20 not 28, so PSD= 500* $\frac{40-20}{40}$= 250mL

⇨ Here, PSD>ASD and the wasted volume equals 250-150=100mL

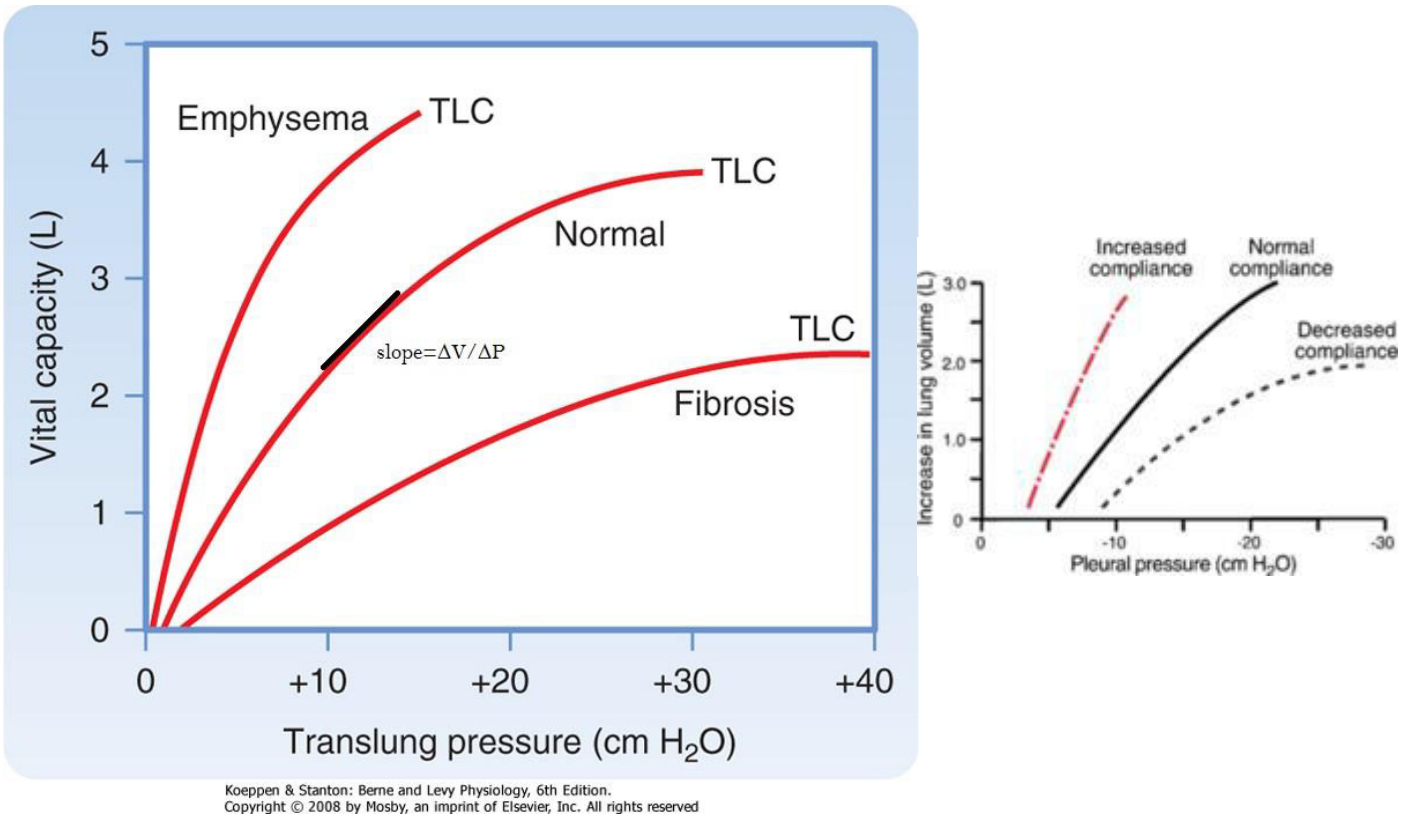
- Now we will discuss 2 lung diseases, emphysema and chronic bronchitis. Chronic bronchitis has a clinically based diagnosis; it is a productive cough for 3 months for 2 successive years, occurs usually in winter.

  In emphysema, you need to use microscope. It has subtypes, one starts from the center, one starts from the periphery and one includes both.

  - How emphysema happens?

  The air ways (the bronchioles) are kept open by the elastic fibers (elastin) that stretch and keep them open. If the elastin is destroyed, they will shrink. So we lose the opening force (elastin/elastic fibers). Elastin is digested by elastase which is inhibited by antitrypsin (which is an anti-protease and elastase is a protease). Smoking inhibits antitrypsin so trypsin (proteases such as elastase) are free to act destroying elastin. Destroying elastin results in several problems one of them is that it causes obstruction since you lose the opening force.

- Inflation of the lung (inspiration) is an active process; you need to stretch the elastin. However, expiration is a passive process since the elastic fibers (elastin) try to recoil and bring the structure back to its resting state. So if you lose the elastin, it becomes easier to inflate i.e. the compliance of the lung increases. But the problem is that you have to use your muscles to deflate the lung because it's not passive anymore.
  (**Compliance** is how easy you can stretch, deform the structure, or change the volume by applying pressure. usually the volume can be changed by making the surrounding pressure more negative. If the lung is not compliant, high negative pressure must be applied to get the same change in volume. If it's compliant, little negative pressure is needed to be applied to get change in volume. So compliance is change in volume per unit change in pressure:
  $compliance\ (C) = \frac{change\ in\ volume\ (\Delta V)}{change\ in\ pressure\ (\Delta P)}$ (The slope of the curve)
  Check the following picture:



Too much compliance is bad because too much oxygen may cause oxygen toxicity and it'll cause problems. Also it's easy to inflate but difficult to deflate.

* In emphysema, there'll be too much air in the lung so TLC will become 7.0 L instead of 5.7 L, 7.0/5.7=120%

5.7 is the predicted TLC, each person has a specific predicted TLC depending on the age, gender…

7.0 L is the observed TLC.

* FRC and RV also increase as you can't exhale (there's air trapping).

- Again, lung diseases are of 3 types (patterns):
  1. Obstructive diseases (70%) of total lung diseases.
  2. Restrictive diseases (20-25%).
  3. Vascular diseases (5-10%).

* Obstructive pattern forms the majority and includes: chronic bronchitis, emphysema and bronchial asthma.

Bronchial asthma might become chronic in 5% of the cases.

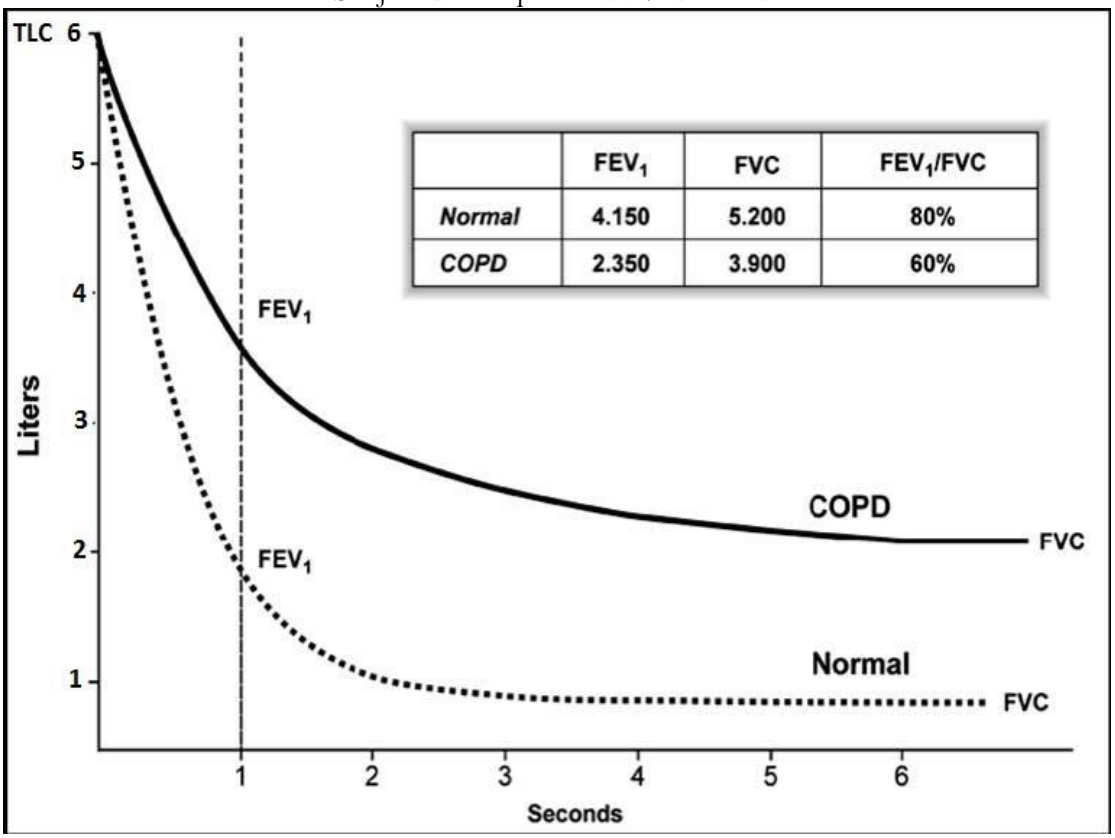
- We've talked about some pulmonary function tests such as volumes and capacities. However, these are not specific; they are not 100% diagnostic but they help in diagnosis; they only determine the pattern (family) of the disease (obstructive or restrictive).
  Restrictive is manifested by difficulty to inhale, TLC is low.
  Obstructive is manifested by difficulty to exhale, TLC is high.

- Now we'll talk about FEV1
  We ask the patient to fill his lung to the maximum (TLC ≅ 6L) then we ask him to empty his lung to the maximum (VC ≅ 5L). But as we ask him to empty his lung quickly and forcibly; this is called Forced Vital Capacity (FVC).

  - FVC is usually less or equal to VC.

  - VC is the volume of air that you can exhale followed by forced inspiration, firstly you fill your lung to the maximum then empty it to the maximum.

  If you do it fast and forcefully, some bronchioles might close and trap some air inside. So you might exhale most of the VC but not all of it. Thus FVC might be less than VC. However, in less than 5 seconds this will be finished.



	FEV_1	FVC	FEV_1/FVC
Normal	4.150	5.200	80%
COPD	2.350	3.900	60%

- Normally:
  - In the 1st second, you can exhale 4L (6 decreases to 2), this is called forced expiratory volume in the 1st second (FEV1):
  When you divide FEV1/FVC = 4/5= 80%
  i.e. normally, 80% of the VC can be exhaled in the 1st second.

  - These tests are done during expiration because the person who has increased airway resistance faces more problems during expiration not inspiration.

- In chronic bronchitis:
  - In the 1st second, the patient can exhale 3L; however, the FVC may stay almost normal or near to normal (5L):
  FEV1/FVC= 3/5= 60%

  - In more severe cases, the patient can exhale only 2L in the 1st second, so:
  FEV1/FVC= 2/5 = 40%

- So FEV1 can be used to **stage** COPD.
  (FEV1 is the volume of air which can be forcibly exhaled in the 1st second and normally it's 80% of FVC)

- FEV1 can be used to determine the severity of COPD:
  If FEV1/FVC equals:
  1. >80% normal
  2. 60-80% mild COPD
  3. 40-59% moderate COPD
  4. <40% severe COPD

- FEV1 can be used for:
  1. Diagnosis (there's obstruction or not)
  2. Staging (how much is the obstruction)
  3. Prognosis (to determine if the condition is reversible or not)
     For e.g. Asthma, is it reversible or not? We don't know, so we give the patient a bronchodilator, beta-2 agonist salbutamol, if FEV1 is improved by 12% or by 200mL, this indicates reversibility. If it's not improved, you may need to give the patient glucocorticoid.

❖ Hey guys hope you find it easy and short, and sorry the mess as this is my first time writing a sheet and I would like any kind of feedback.
❖ Finally dedication of course to all of you in this year and to my friends in section 2 next semester.