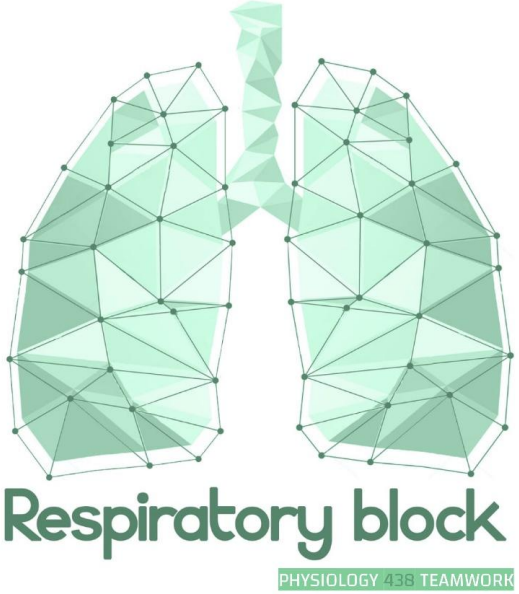
Respiratory ventilation



- Red: important
- Black: in male / female slides
- Pink: in female slides only
- Blue: in male slides only
- Yellow: notes
- Gray: extra information
- Textbook: Guyton + Linda

Editing file

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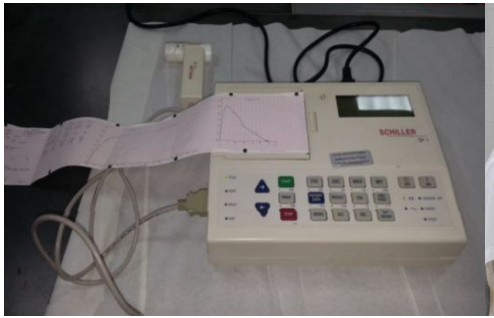
Objectives

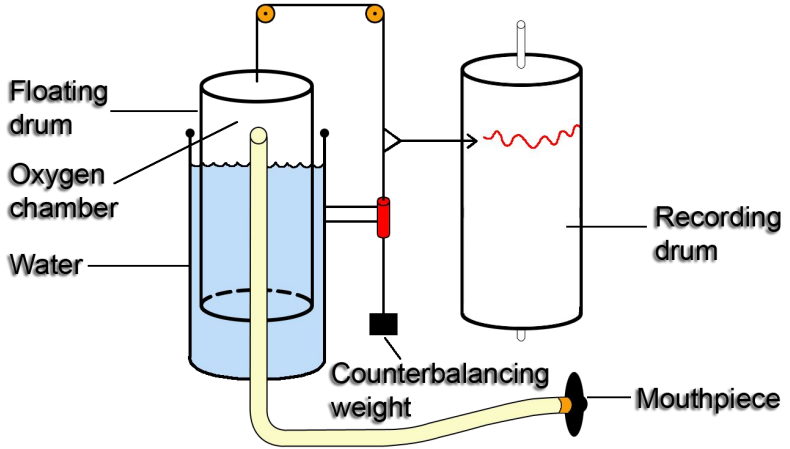
1. Define the various lung volumes and capacities and provide typical values for each.
2. Define ventilation rates, their typical values, and their measurement.
3. Describe FEV1 and its role in differentiating obstructive and restrictive lung diseases.
4. Describe the types of dead space. State a volume for the anatomical dead space.
5. Define the term minute ventilation and state a typical value.
6. Distinguish minute ventilation from alveolar ventilation.

Spirometer: EXTRA INFO

From Guyton:

The spirometer consists of a drum inverted over a chamber of water, with the drum counterbalanced by a weight. In the drum is a breathing gas, usually air or oxygen;a tube connects the mouth with the gas chamber. When one breathes into and out of the chamber, the drum rises and falls, and an appropriate recording is made on a moving sheet of paper.





Pulmonary volumes and capacities:

Pulmonary volumes (by using spirometer):

"all values are based on an average 70 kg male"

1

Tidal volume (TV)

is the volume of air **inspired or expired** with **each normal breath** = **500ml** in young adult man.

2

Inspiratory reserve volume (IRV)

is the extra volume "Maximal" of air that can be **inspired over and beyond the normal tidal volume** = **3000ml.**

3

Expiratory reserve volume (ERV)

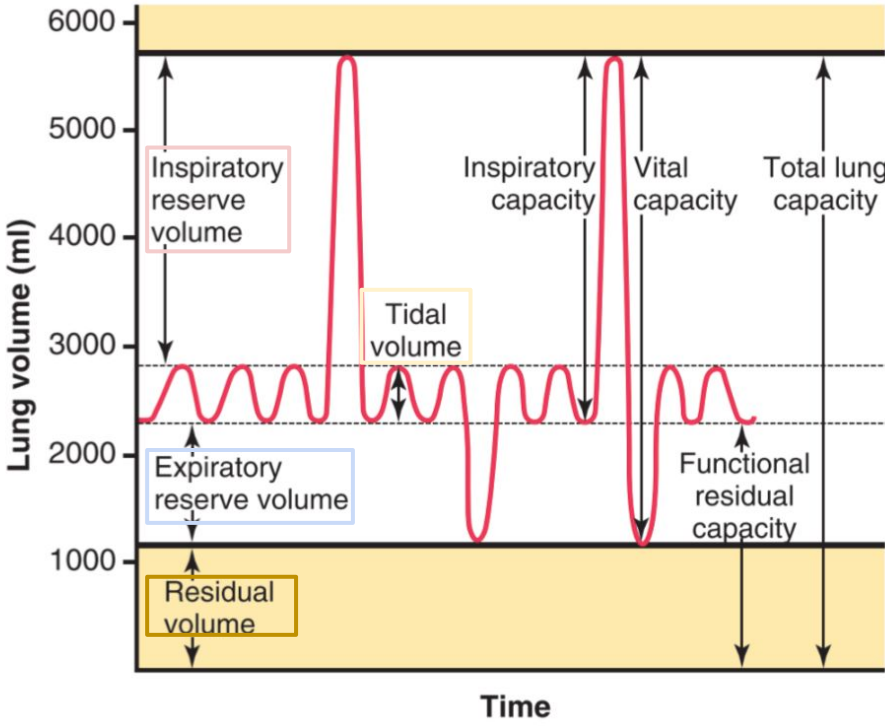
is the extra amount "Maximal" of air that can be **expired by forceful expiration** after the end of a **normal tidal expiration** =**1100ml**.

4

Residual volume (RV)

"not measured by spirometer"

is the volume of air that **still remain** in the lungs after the most forceful expiration = **1200ml**."even after forced expiration , some air will stay to prevent the lung collapsing"



The pulmonary capacities:

Volume is a single value while Pulmonary Capacities are a sum of two or more volumes

1-The functional residual capacity (FRC):

is the volume of air remaining in the lungs **after normal expiration.**

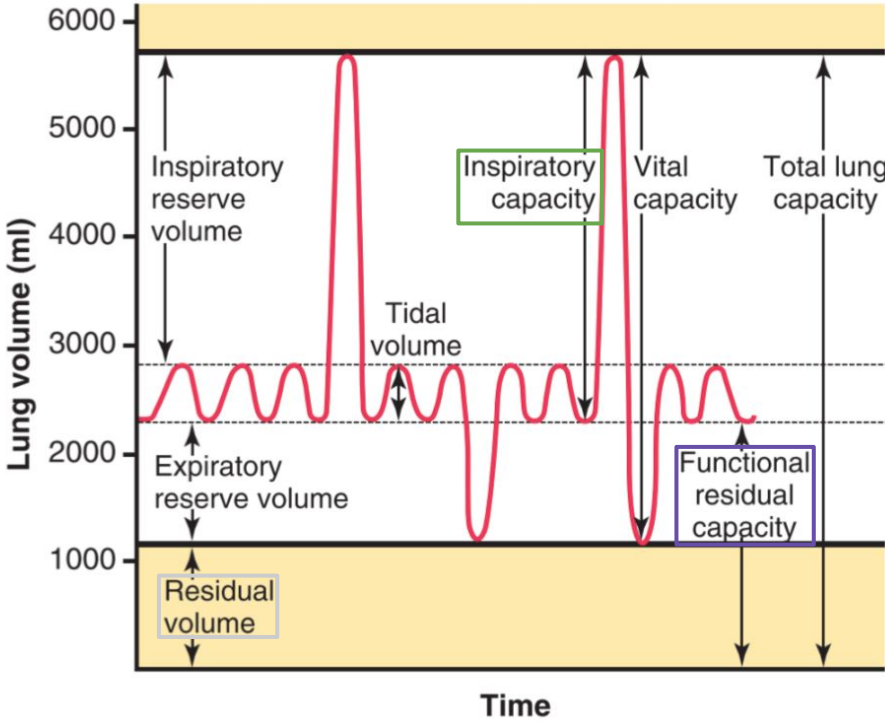
- *Equation*= expiratory reserve volume (1100)+ residual volume(1200) =**2300ml.**

*FRC in normal expiration and **RV** in powerful expiration.

2-Inspiratory capacity (IC):

is the volume of air inspired by **a maximal inspiratory effort after normal expiration.**

- *Equation* =inspiratory reserve volume(3000) + tidal volume(500) =**3500ml**



The pulmonary capacities:

Volume is a single value while capacity Pulmonary Capacities is a sum of two or more volumes

3- Forced Vital Capacity (FVC):

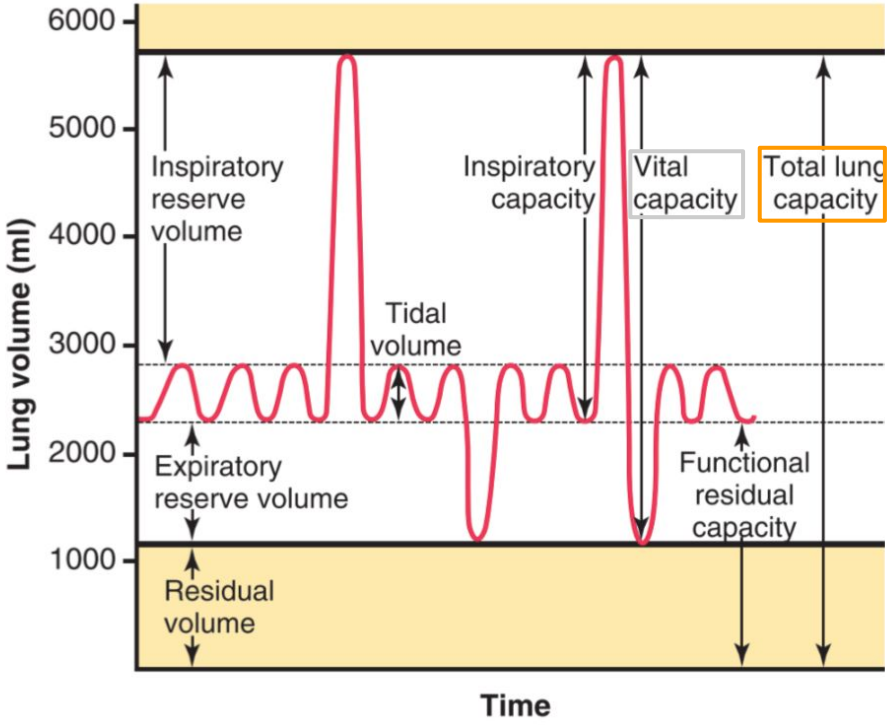
is the volume of air expired by a **maximal expiratory effort** after filling the lung to **maximal inspiration** then expiring to maximum extent. "Maximal inspiration with maximal expiration"

- *Equation*= tidal volume(500) + inspiratory reserve volume(3000) +expiratory reserve volume(1100) = **4600 ml.**

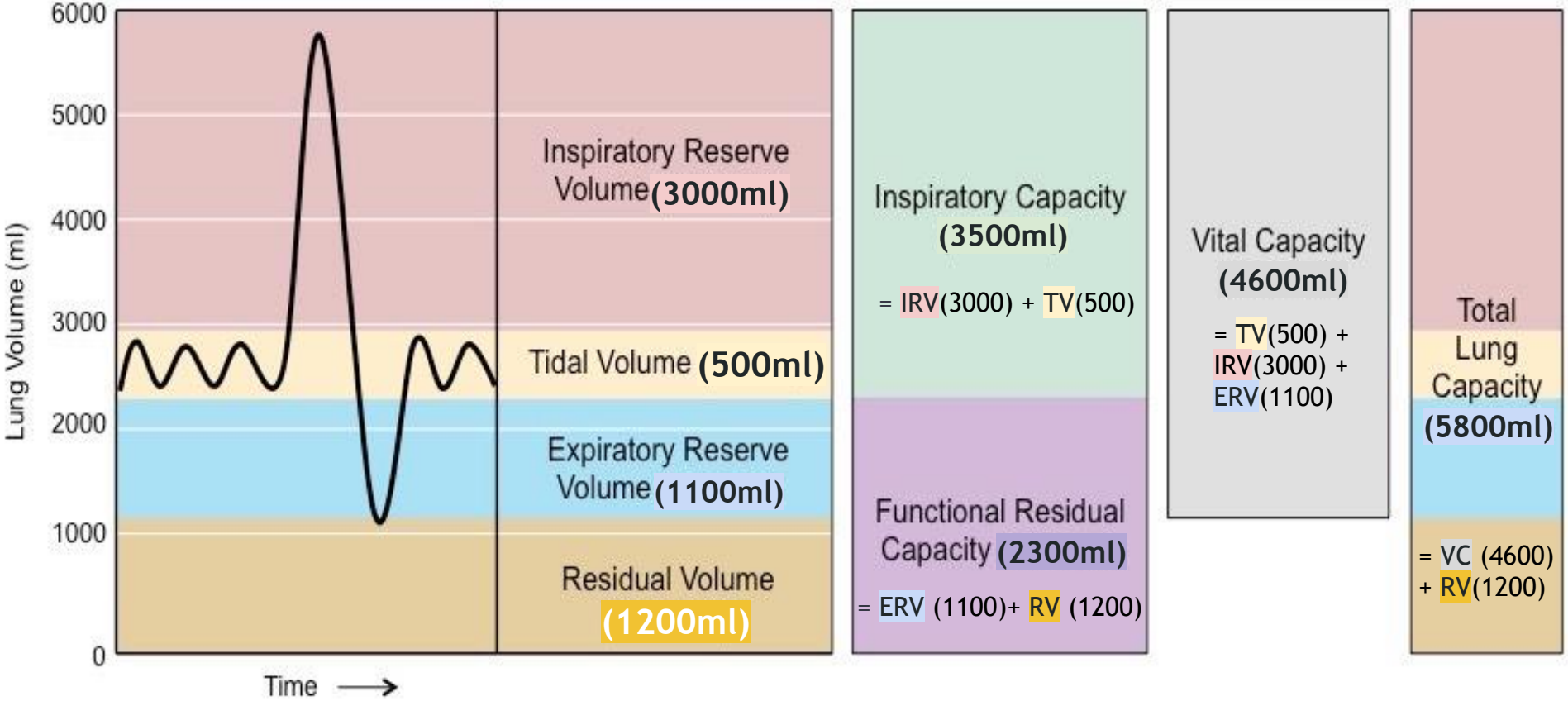
4-Total lung capacity (TLC) :

is the maximum volume of air that can be accommodated in the lungs.

- *Equation* = vital capacity (4600)+ residual volume(1200)=**5800ml**.
  "it is the sum of all pulmonary volumes"



Summary


6000
5000
4000
3000
2000
1000
0
Lung Volume (ml)
Time
Inspiratory Reserve Volume (3000ml)
Tidal Volume (500ml)
Expiratory Reserve Volume (1100ml)
Residual Volume (1200ml)
Inspiratory Capacity (3500ml)
= IRV(3000) + TV(500)
Functional Residual Capacity (2300ml)
= ERV (1100)+ RV (1200)
Vital Capacity (4600ml)
= TV(500) + IRV(3000) + ERV(1100)
Total Lung Capacity (5800ml)
= VC (4600) + RV(1200)

FEV1/FVC ratio

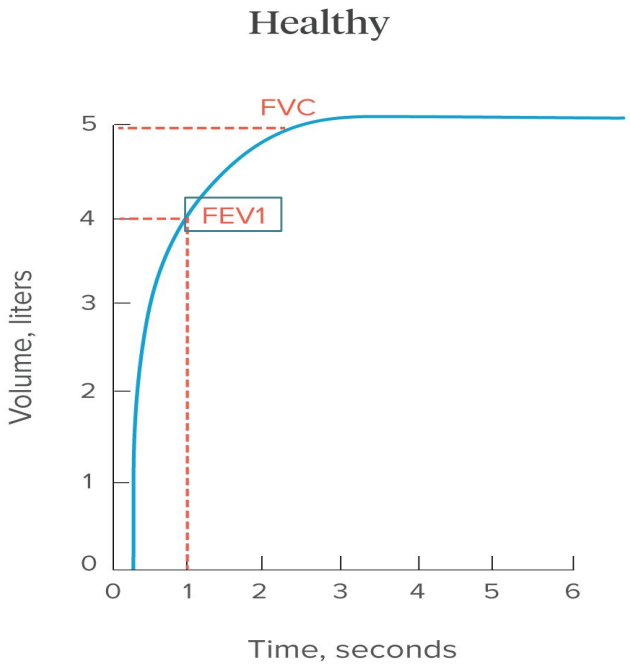
Forced Expiratory Volume in One Second (FEV1):

the volume of air expelled during the **first second** of a forced expulsion after a maximum inspiration.

It is obtained by: The person is asked to inspire as deeply as possible and then to breath out as hard and as fast as he can. The expiration is continued until he expired all the air out and thus forced vital capacity is obtained. During this process the volume of air expired in the first second is collected and is known as FEV1.
Also known as (Timed vital capacity).

It is very useful for diagnosis of obstructive lung diseases , such as emphysema and asthma
(in which FEV1 is significantly reduced) .

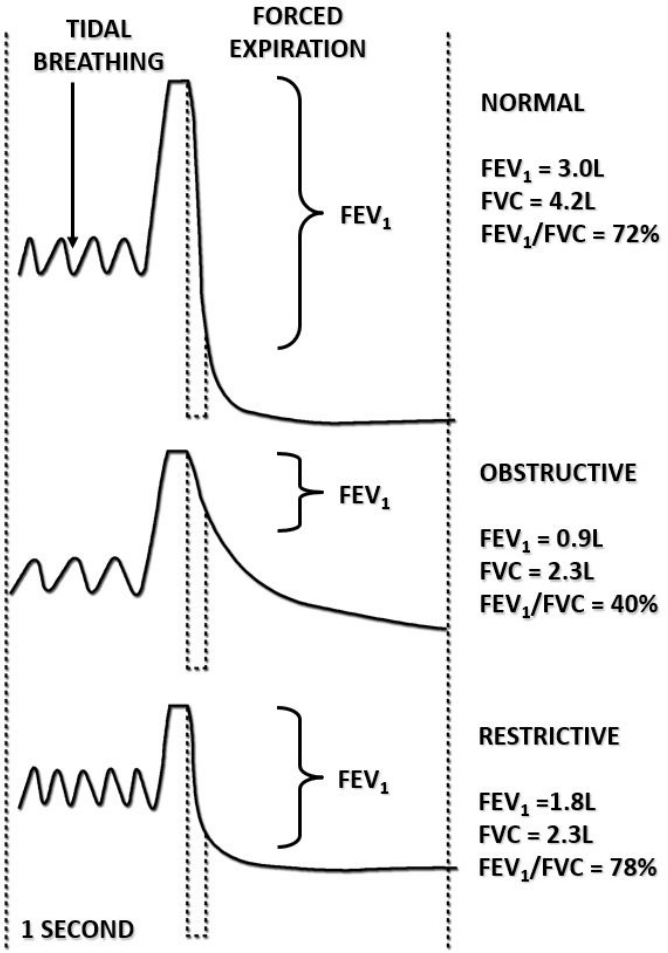
It is 80-90% of the vital capacity . FEV1 = **3680ml**



FEV1/FVC ratio: Conti..

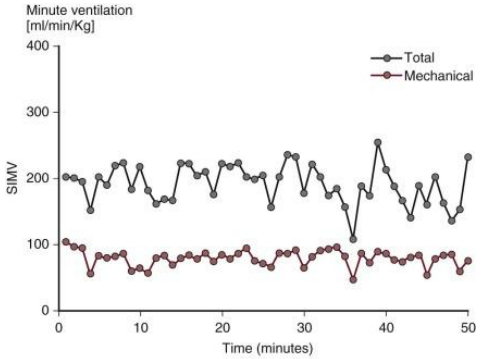
- Normally it is about 80%.”in first second”
- This ratio differentiates between obstructive and restrictive lung diseases.

Restrictive lung diseases	Obstructive lung diseases
Normal/increased	Decreases
FEV1 Decrease/normal	FEV1 decrease a lot
FVC Decrease a lot	FVC decrease/normal
TLC decrease	TLC increase
RV decrease	RV increase
e.g interstitial pulmonary fibrosis	e.g bronchial asthma, emphysema



The details will be taken in future lectures

Minute ventilation rate & volume



Minute respiratory volume (MRV):

- Total amount of air moved into and out of respiratory system **per minute.**
- *Equation*= respiratory rate x tidal volume = 12 X 500ml = **6000 ml/min.**

Respiratory rate"RR":
Number of breaths taken per minute.
[Approximately 12-18/ min]

- MRV could **rise** to 200 L/min or more than 30 times normal if RR = 40 TV = 4600 ml in young adults man.

★ All lung volume and capacity are about 20 to 25% less in women than in men and are greater in athletic people than in small and asthenic people.

Properties that affect volumes and capacities: Age , Gender , Weight , High , Race.

Closed circuit Helium Dilution Method:

$C_1 x V_1 = C_2 x V_2$

C_1: concentration of H_i in spirometry

V_1: volume of air in the spirometry.

C_2: Final concentration of helium

V_2 :Volume of spirometry + FRC.

$$FRC = \left[\frac{C_i\ HE\ (c_1)}{C_f\ HE\ (c_2)} - 1 \right] V_i\ (v_1)$$

-C_i= initial , C_f=final

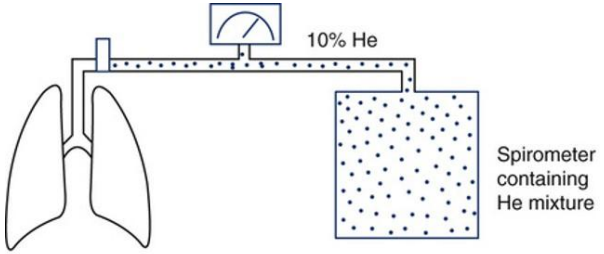
"This method is used to measure the Functional Residual capacity , Total lung capacity and Residual volume and the Helium Analyzer will helps to measure them.

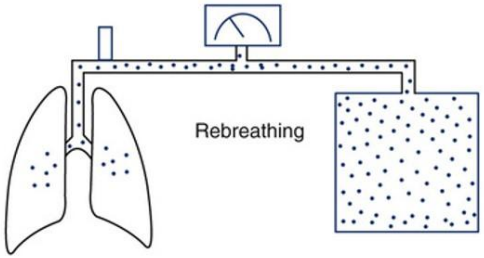
★ Why spirometer can't measure them?

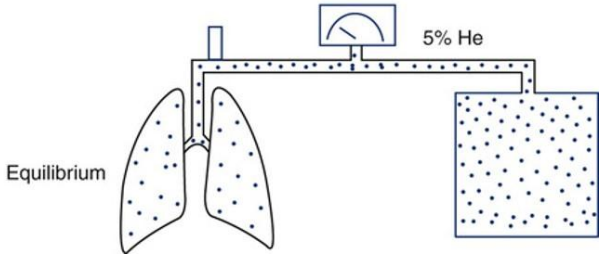
Because spirometer can ONLY feel the air that have been inspired or expired , and as we mentioned before the residual volume stay in the lung , so the spirometer can't feel it and the FRC + TLC depend on it."

How to use the results:

1. Residual volume = FRC - ERV
2. Total lung capacity = FRC + IC







Respiratory Zone VS Anatomical Dead Space

	Respiratory Zone	Anatomical Dead Space
Definition	From Guyton: It is the area where gas exchange occur , where air is in proximity to the pulmonary blood.	From Guyton: It is the amount of air that never reach the gas exchange area ,but fills respiratory passages where gas exchange does not occur.
Parts included	Occupies the space distal to the terminal bronchioles start from the respiratory bronchioles down to the alveolar sacs. Respiratory Bronchioles ⇨ Alveolar Ducts ⇨ Alveolar Sacs.	Occupies the air-conducting system down to the terminal bronchioles. "conductive zone" trachea ⇨ Bronchi ⇨ Bronchioles ⇨ Terminal Bronchioles
Gas exchange	Gas exchange takes place.	No gas exchange.
Volume	350 ml/min ⅔ of the tidal volume.	2ml/kg or 150 ml. ⅓ of the tidal volume.
Types	-	Anatomical dead space. Alveolar dead space (non perfused alveoli) . - Physiological dead space =anatomical+alveolar dead spaces.

The rate of alveolar ventilation:

Alveolar ventilation per minute: is the **total volume of new air entering the alveoli** and other adjacent gas exchange areas **each minute**.

- **Equation=**

Va = Respiratory rate X (Vt – Vd)
= Respiratory rate X (Vtidal volume – Vdead space)
= 12 X (500 – 150) = 4200 ml

Form Guyton
The ultimate importance of pulmonary ventilation is to continually renew the air in the gas exchange areas of the lungs, where air is in proximity to the pulmonary blood. These areas include the alveoli, alveolar sacs, alveolar ducts, and respiratory bronchioles. The rate at which new air reaches these areas is called alveolar ventilation.

Male’s slides only

Pollution and diseases pattern

● Dust particles with an aerodynamic diameter of:	
○ 10 µm removed by:	➔ nose and pharynx.
○ 2-10µm removed by:	➔ tracheo-bronchial tree
○ 0.1-2µm removed by:	➔ within the alveoli.
● Terminal bronchioles and even the alveoli are also sensitive to chemicals such as:	➔ sulfur dioxide or chlorine gas.
● Cough Reflex	➔ Air is expelled at velocities ranging from 75 to 100 miles/hour.

Quiz

You don't understand why we choose this answer? Click here to read the explanations

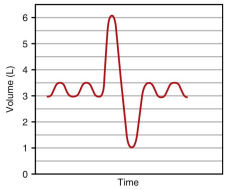
1-The various lung volumes and capacities include the total lung capacity (TLC), vital capacity (VC), inspiratory capacity (IC), tidal volume (TV), expiratory capacity (EC), expiratory reserve volume (ERV), inspiratory reserve volume (IRV), functional residual capacity (FRC), and residual volume (RV). Which of the following lung volumes and capacities can be measured using direct spirometry without additional methods?

	TLC	VC	IC	TV	EC	ERV	IRV	FRC	RV
A.	No	No	Yes	No	Yes	No	Yes	No	No
B.	No	Yes	Yes	Yes	Yes	Yes	Yes	No	No
C.	No	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
D.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes

2-A patient has a dead space of 150 milliliters, FRC of 3 liters, tidal volume (VT) of 650 milliliters, expiratory reserve volume (ERV) of 1.5 liters, total lung capacity (TLC) of 8 liters, and respiratory rate of 15 breaths/min. What is the residual volume (RV)?

A. 500 milliliters
B. 1000 milliliters
C. 1500 milliliters
D. 2500 milliliters

Use the below diagram for questions 3 and 4



3-Assuming a respiratory rate of 12 breaths/min, calculate the minute ventilation.

A. 1 L/min
B. 2 L/min
C. 4 L/min
D. 6 L/min

4-A 22-year-old woman inhales as much air as possible and exhales as much air as she can, producing the spirogram shown in the figure. A residual volume of 1.0 liter was determined using the helium dilution technique. What is her FRC (in liters)?

A. 2.7
B. 2.5
C. 3.0
D. 3.5

SAQ

1- A patient has a dead space of 150 milliliters, FRC of 3 liters, TV of 650 milliliters, ERV of 1.5 liters, TLC of 8 liters, and respiratory rate of 15 breaths/min. What is the alveolar ventilation (Va)?

2- what is the parts included in respiratory zone and anatomical dead space?

Answers

1- Va = Frequency × (TV - VD) = 15/min × (650-150)= 7500 ml/min =7.5 L/min

2- Respiratory zone : Respiratory Bronchioles, Alveolar Ducts and Alveolar Sacs.

Anatomical dead space: trachea,Bronchi, Bronchioles and Terminal Bronchioles

Key answers:

1-B 2-C 3-D 4-C

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