MEDICINE
KING SAUD UNIVERSITY

Physiology Team 436

Revised by
شوق الأحمري & طراد الوكيل

Respiratory Ventilation

RESPIRATORY BLOCK

Red: very important.
Green: Doctor's notes.
Pink: formulas.
Yellow: numbers.
Gray: notes and explanation.

Physiology Team 436 – Respiratory Block Lecture 3

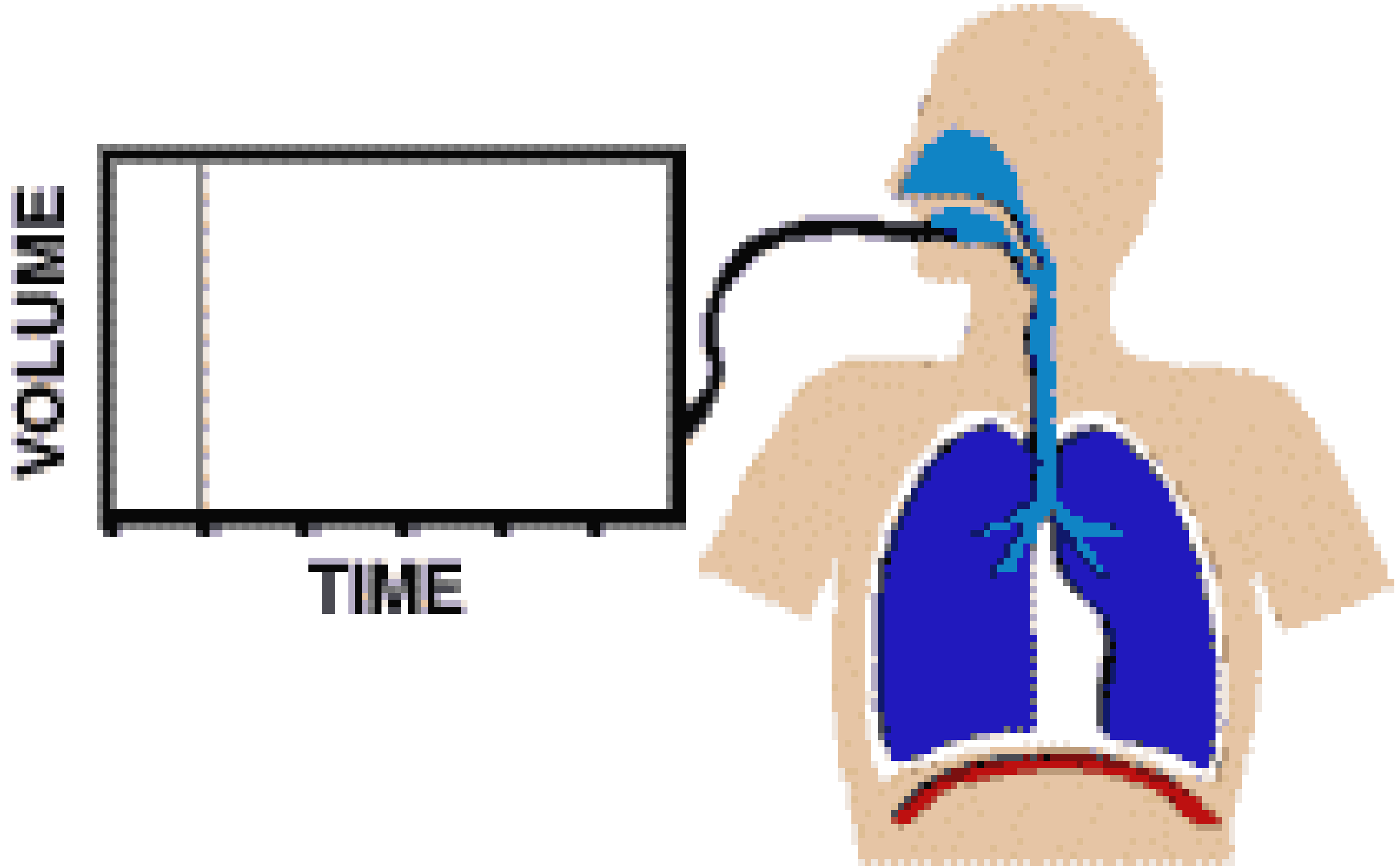
Lecture: If work is intended for initial studying.
Review: If work is intended for revision.

Objectives

- Define the various lung volumes and capacities and provide values for each.
- Define ventilation rate, their typical values and their measurement alveolar.
- Describe FEV_1 and its role in differentiating obstructive and restrictive lung diseases
- Describe the types of dead space and State a volume for the anatomical dead space.
- Define the term minute ventilation and state a typical value.
- Distinguish minute ventilation from alveolar ventilation.

ONLY IN MALES' SLIDES

PULMONARY / LUNG VOLUMES AND CAPACITIES



Animation

ONLY IN MALES' SLIDES

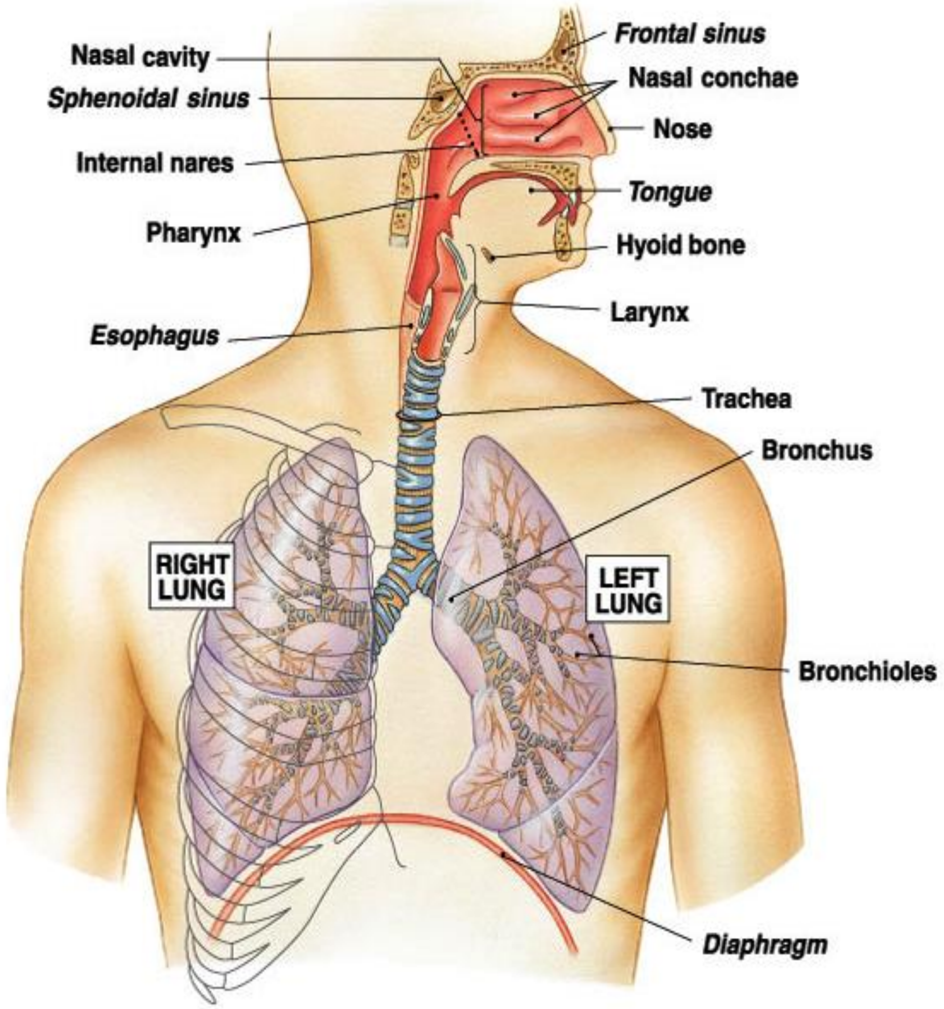
RESPIRATORY SYSTEM

Upper Respiratory Tract:

1. Nose.
2. Pharynx and associated structures.

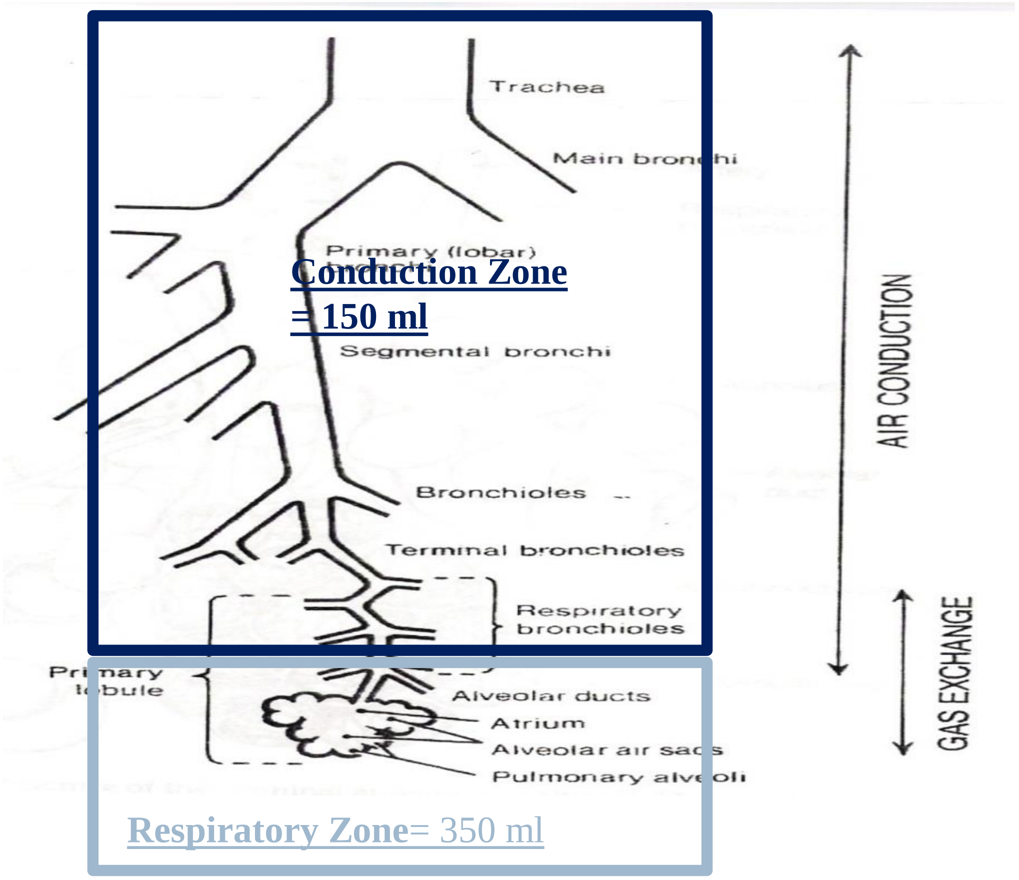
Lower Respiratory Tract:

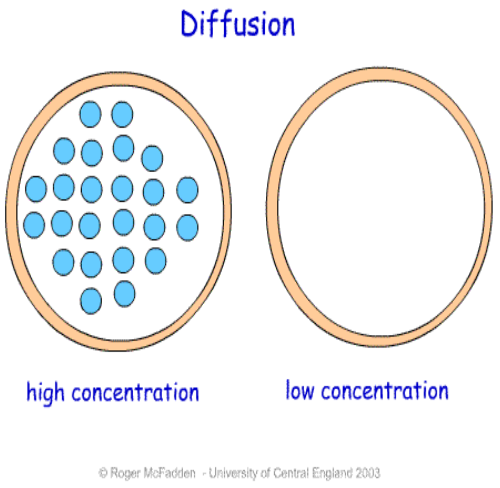
1. Larynx.
2. Trachea.
3. Bronchi.
4. Lungs.



Zones of the Respiratory Tract

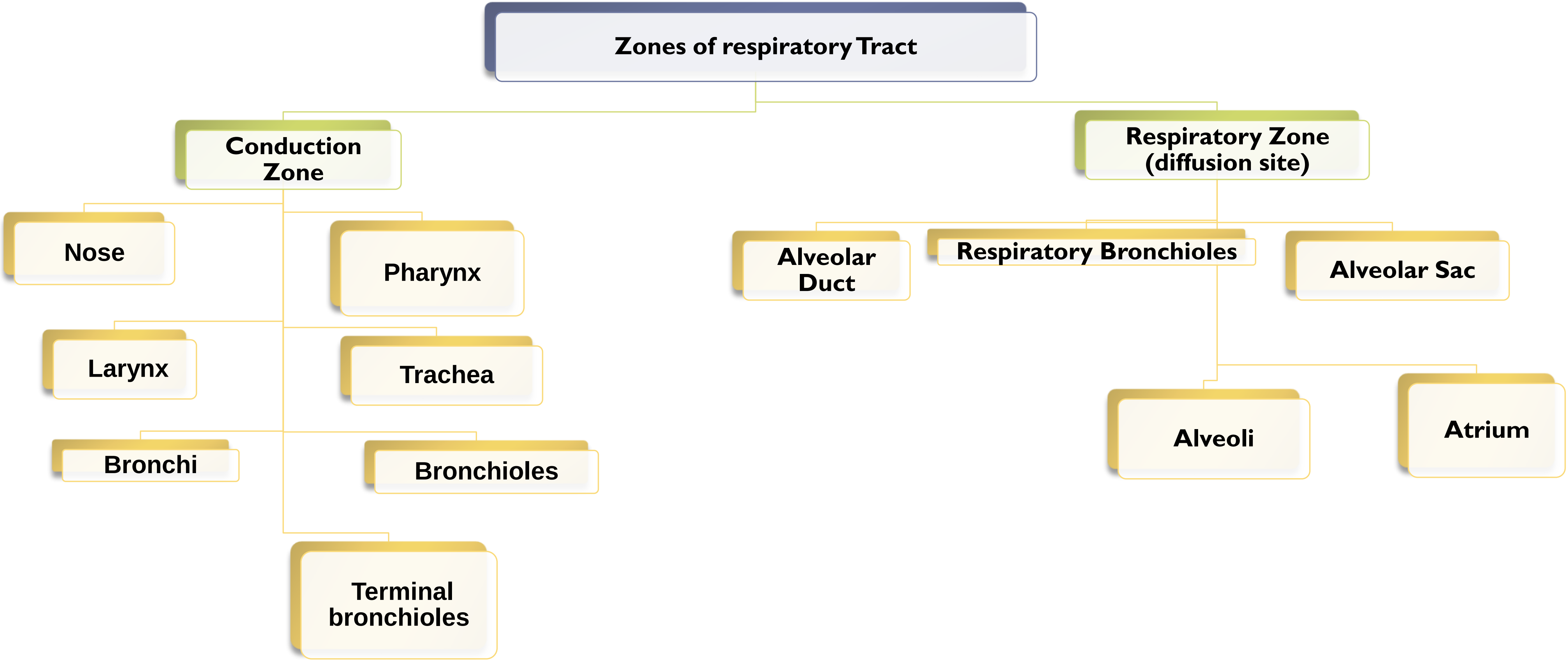
Tidal volume (500 ml) = Conductive zone (150 ml) + Respiratory zone (350 ml)





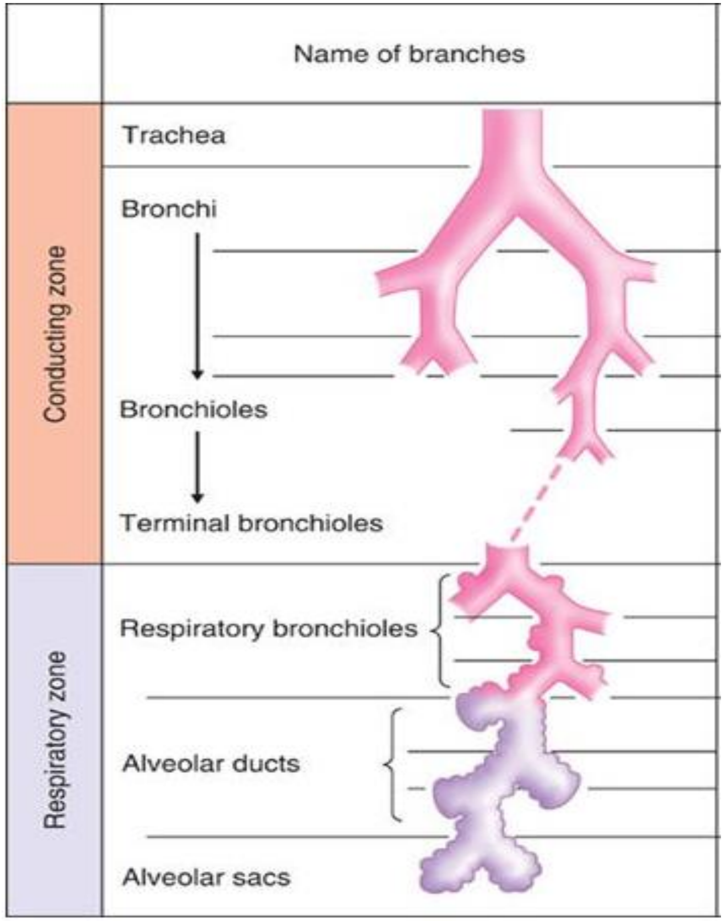
Gas diffuses in (respiratory zone) from higher concentration (higher pressure) to lower concentration (lower pressure).

Cont.


Zones of respiratory Tract
Conduction Zone
Nose
Pharynx
Larynx
Trachea
Bronchi
Bronchioles
Terminal bronchioles
Respiratory Zone (diffusion site)
Alveolar Duct
Respiratory Bronchioles
Alveolar Sac
Alveoli
Atrium

Cont.

Tidal volume 500 = 150 (Conduction Zone) + 350 (Respiratory Zone)



Tidal Volume (Vt): Normal amount of air we inspire and expire.

The conducting zone: Structures form a continuous passageway for air to move in and out of the lungs.

Respiratory zone:

-Is found deep inside these thin-walled structures; allows inhaled oxygen (O2) to diffuse into the lung capillaries in exchange for carbon dioxide (CO2).

- It occupies the space distal to the terminal bronchioles start from the respiratory bronchioles down to the alveolar sacs.
- Where gas exchange takes place.
- Two thirds of the tidal volume is lost here.
- Volume ≅ 350ml/min

Dead Space

- Parts of the respiratory tract not participating in gas exchange:

Anatomical Dead Space:

- Tracheo-bronchial tree (the air-conducting system) down to respiratory bronchioles.
- Normally 2ml/kg or 150ml in an adult, roughly a third of the tidal volume is lost here.
- No gas exchange

Alveolar Dead Space:

Non-perfused alveoli

perfused: supply (an organ or tissue) with a fluid by circulating it through blood vessels or other natural channels.

Physiologic Dead Space:

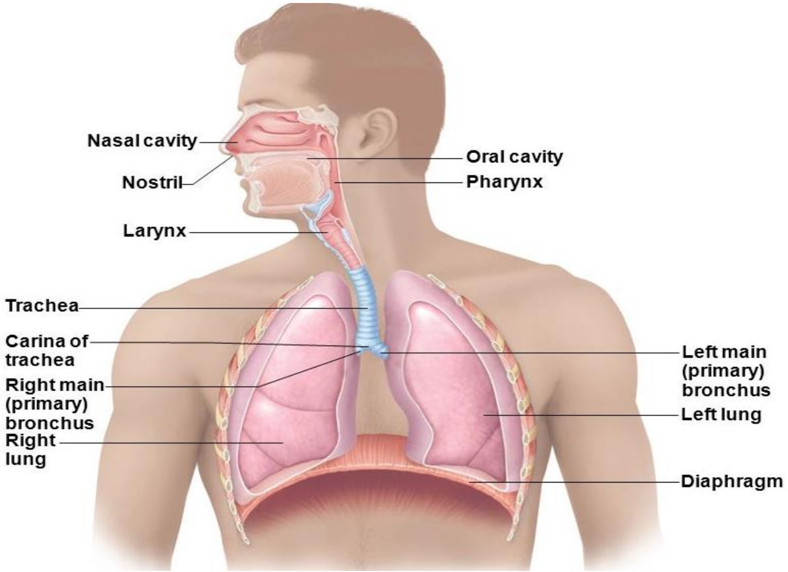
Anatomical Dead Space+ Alveolar Dead Space

- No diffusion in "Anatomical Dead Space" is normal
- No diffusion in "Alveolar Dead Space" (nonfunctioning alveoli) is pathological due to edema or fibrosis

Extra: dead space is the volume of air which is inhaled that does not take part in the gas exchange, either because it (1) remains in the conducting airways, or (2) reaches alveoli that are not perfused or poorly perfused. In other words, not all the air in each breath is available for the exchange of oxygen and carbon dioxide.

Diffusion occurs only in alveoli. If there is no diffusion in alveoli, it is due to pathological reasons.

Pollution and Disease Pattern



The larynx and carina are very sensitive to dust particles. Terminal bronchioles and even the alveoli are also sensitive to chemicals such as sulfur dioxide or chlorine gas.

Air expelled at velocities ranging from 75 to 100 miles / hour [Guyton] 965 Km (600 miles / hour) [Ganong]

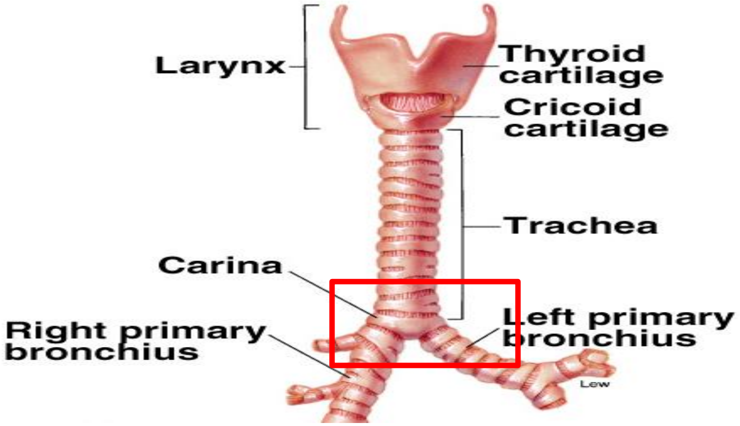
Dust particles with an aerodynamic diameter of:

10 μm = nose and pharynx.

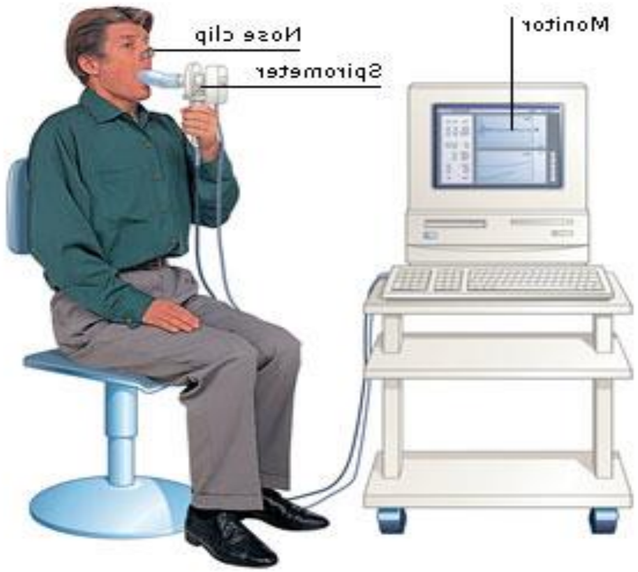
2-10 μm = tracheo-bronchial tree

0.1-2 μm within the alveoli.

Particles smaller then 0.1 μm remain in the air stream and are exhaled.



Spirometers



Spirometer:

An apparatus for measuring the volume of air inspired and expired by the lungs. A spirometer measures ventilation, the movement of air into and out of the lungs. (More in lecture #4)

Important Note:

Spirometers are **NOT** used for measuring the: 1. Residual Volume, 2. Functional Residual Capacity, and 3. Total Lung Volume (**Capacity** not volume according to Guyton).

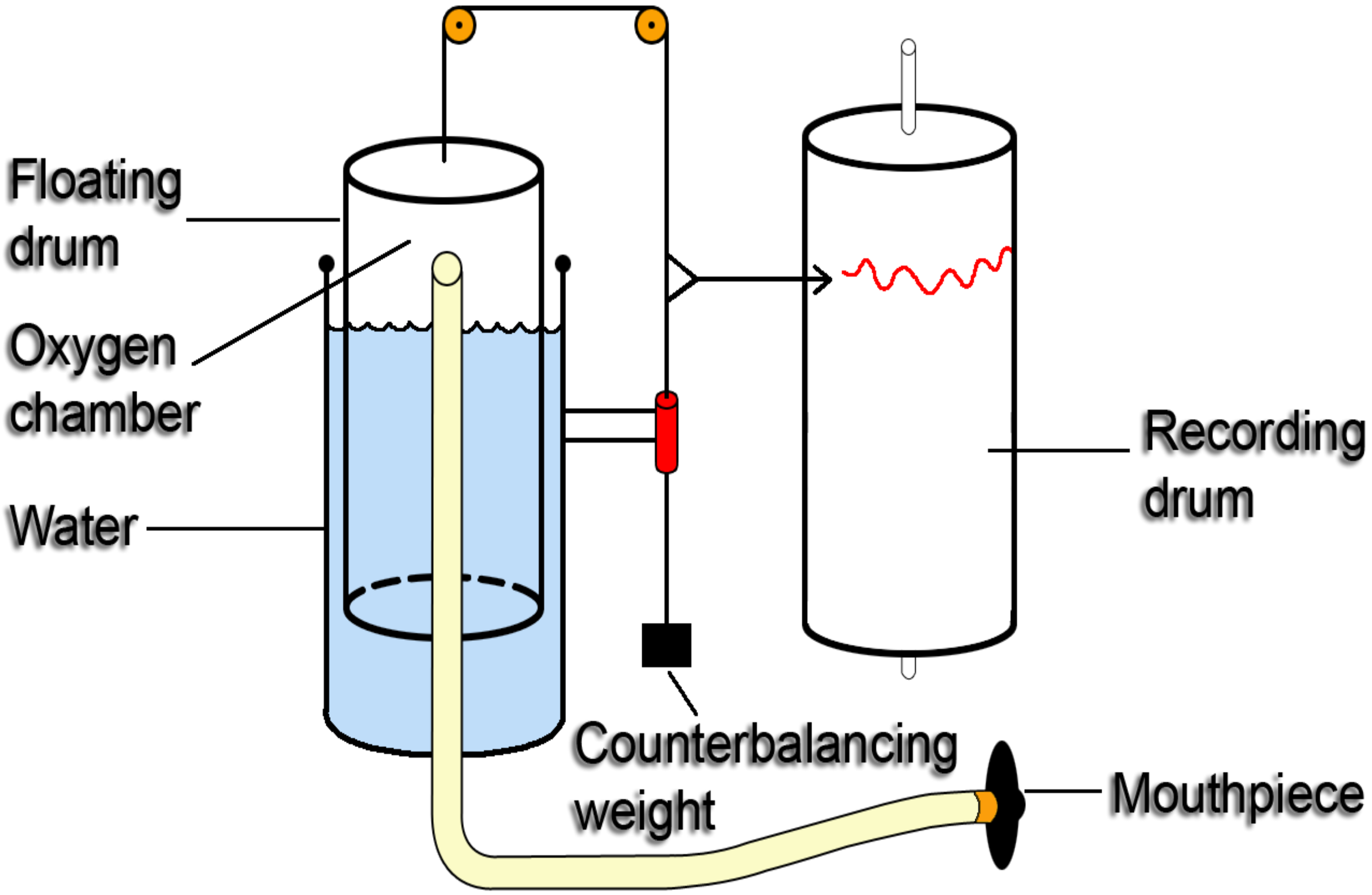
The Residual Volume is the only volume that cannot be measured by the spirometer

Spirometer

- Again: we use the spirometer to measure the lung volume and lung capacity, Except:

1. Residual volume.
2. Functional residual capacity (FRC)
3. Total lung volume (capacity).

- The floating drum contains either oxygen or normal air.
- Counterbalancing weight contains a pen that will move to draw when the patient breath in or out.



مهم السلايد

Physiological Conditions and Pulmonary Volumes and Capacities

- Age: Pulmonary capacities/Vol keep on increasing until the age of 35 then begins to decrease after the age 35.
- Gender: All lung volumes and capacities are about 20 to 25% less in women than in men.
- Height: Height increase, increases pulmonary Vol/Cap.
- Weight: Weight increase (obesity), decreases pulmonary Vol/Cap.
- Ethnic group (race عرق)
- Exercise: Increases pulmonary Vol/Cap .All lung volumes and capacities are greater in athletic persons than in small and asthenic persons.
  Asthenia: physical weakness or lack of energy.
- Posture: Pulmonary Vol/Cap while standing is higher than while sitting.
- Pregnancy: Decreases pulmonary Vol/Cap.
- Diurnal variation, seasonal, climate.
- Customary activity.
- Geographical location.
- Health: If the patient is normal or has lung diseases.

Pulmonary Volumes and Capacities

Lung Volumes

- Tidal volume: [VT]
- Inspiratory reserve volume [IRV]
- Expiratory reserve volume [ERV]
- Residual volume [RV]

Lung Capacities

- Vital Capacity [FVC]
- Inspiratory capacity (IC)
- Functional Residual Capacity [FRC]
- Total lung capacity [TLC]

➢ Capacity equals the sum of 2 or more volumes.

Physiological variations in lung volumes

Lung volumes	Male	Female
Tidal volume	500	500
IRV	3000	2000
ERV	1100	700
Residual volume	1200	1100
TLC	5800	4300

الجدول مطلوب

Pulmonary Volumes (by using spirometer)

- **Tidal volume: [VT]** Volume of air inspired or expired in each normal breath; value = 500 ml or 0.5 L *in young adult man.*

- **Inspiratory reserve volume [IRV]:** It is the extra volume of air, that can be inspired forcefully, beyond the normal tidal volume value= 3000 ml or 3 L.

Volume of air inspired by maximal inspiratory effort after normal tidal inspiration. (سعة الرئة)

- **Expiratory reserve volume [ERV]:** It is the extra volume of air that can be expired forcefully beyond the normal tidal volume. Value = 1100 ml or 1.1 L

Volume of air expired by maximal expiratory effort after normal tidal expiration.

Forcefully: with applying force.

Beyond: after.

Residual = متبقي

- **Residual volume [RV]:** It is the volume of air still remaining in the lungs after a forceful expiration.
- Value= 1200 ml.

This volume keeps the lung from collapsing .سبحان الله

Pulmonary Capacities

- **Functional Residual Capacity [FRC]**

This is the amount (volume)of air that remains in the lungs at the end (after)of normal expiration.

- FRC = the expiratory reserve volume ERV 1100 ml + the residual volume: RV 1200 ml = 2300 milliliters.

- **Forced Vital Capacity [FVC]**

The maximum amount of air that a person can expel forcefully from the lungs after taking a deep inspiration. Or it is the volume of air expired by a maximal expiratory effort after maximal inspiration.
The vital capacity is the sum of the
= (tidal volume + inspiratory reserve volume + expiratory reserve volume) = 500 + 3000 + 1100= 4600 ml

Inspiratory Capacity

The volume of air inspired by a maximal inspiratory effort after normal expiration = 3500ml = inspiratory reserve volume + tidal volume.

Notice the difference between the **FRC** & **RV** , that **FRC** amount of RESIDUAL air in lungs in NORMAL expiration BUT **RV** in FORCEFUL expiration.

The person is asked to inspire as deeply as possible and then to breathe out as hard and as fast as he/she can. The expiration is continued until he/she 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.**

Simply: It is **the maximum** amount of expiration that the person can do until an **obligatory (uncontrolled) stoppage of the expiration.**

Note: That based on the FVC the **electronic spirometer** calculate the different volumes and then **diagnose the disease.**

- The capacity comprises of more than one volume.
- All lung capacities and volumes in females are 20% - 25% less than in males.

Cont. Pulmonary Capacities

- **Total Lung Capacity [TLC]:**

This is the maximum volume to which the lungs can be expanded with the greatest possible inspiratory effort. Or it is the maximum volume of air that can be accommodated in the lungs.
It is the sum of all pulmonary volumes.
(Tidal volume + Inspiratory + Expiratory reserved volume + Residual volume) or (vital capacity + residual volume)
= 500 + 3000 + 1100 + 1200 = 5800 ml

- **Forced Expiratory Volume in one second (FEV_1):**

This is the volume of air expelled during the first second of a forced expulsion after a maximum inspiration.
This is a very useful volume to test for the diagnosis of obstructive lung diseases, such as: emphysema and asthma in which FEV_1 is significantly reduced.
It is 80%-90% of the vital capacity. FEV_1 = 3680 ml.

- **Forced Expiratory Ratio (FEV_1/FVC):** (Normally it is about 80% in the first sec.)

The forced expiratory ratio is a sensitive index in differentiating **obstructive** from **restrictive** pulmonary disease (when vital capacity is abnormal). It is decreased in obstructive lung disease

e.g: bronchial asthma, emphysema and is normal or increased in restrictive lung diseas e.g: interstitial pulmonary fibrosis .

Minute Respiratory Volume

The volume of air breathed in or out of the lungs each minute = respiratory rate x tidal volume = 12 X 500ml = 6000ml/min or 6 L/min.

Minute Respiratory Volume could rise to almost 200 L/min or more than 30 times normal , if the Respiratory Rate (RR) rises from 12 to 40, Tidal Volume (VT) rises from 500ml to 4600 ml (RR x VT = 4600* x 40 = 184000 ml = 184 L almost 200 L) in young adult man (under stress/excitation).

***4600 is just an example**

Note

REMEMBER ALL THESE 3 PARAMETERS HAVE CLINICAL SIGNIFICANCE:

*Forced Vital Capacity [FVC].

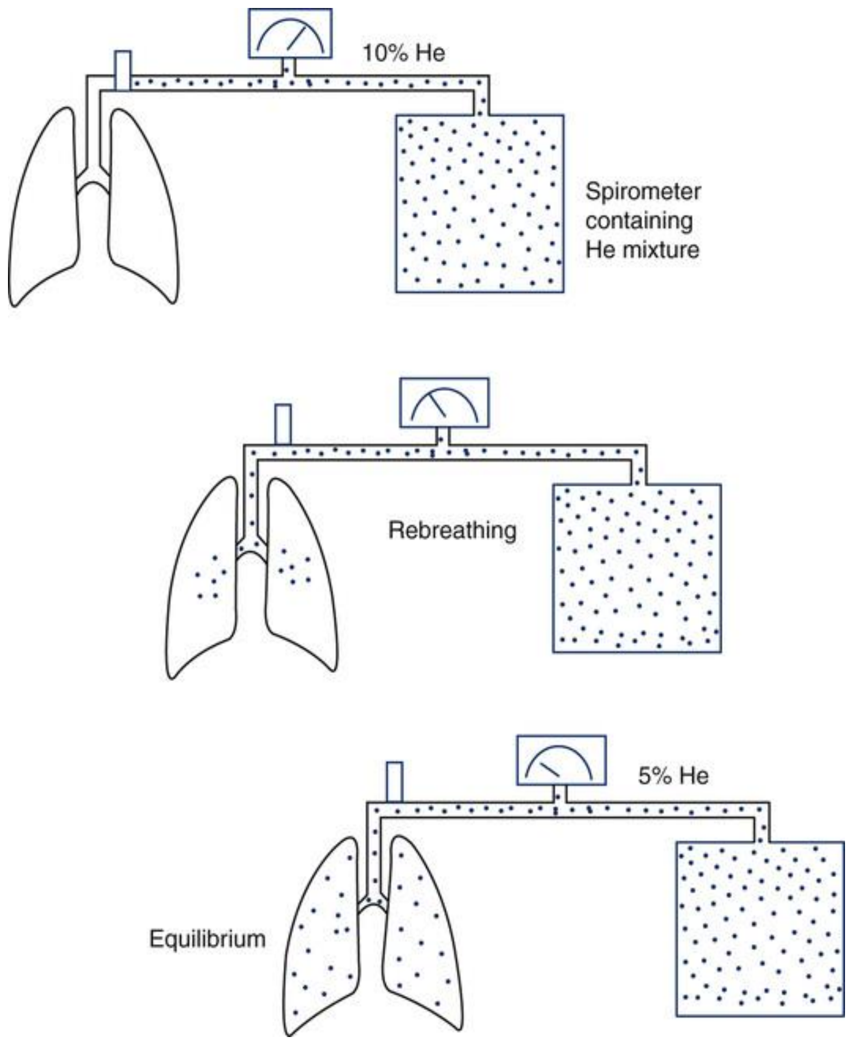
*Forced expiratory volume in one second (FEV1).

*Forced expiratory ratio.

ONLY IN FEMALES' SLIDES

Closed Circuit Helium Dilution Method

- Used to measure the residual volume.
- The patient breathes a known volume of air by a spirometer that contains a known concentration of helium. With each breathe the helium will be diluted with the air.



- The equation is applied when a sample is drawn with constant concentration.

Ci \ i= initial
Cf \ f= final

FRC: Functional Residual Capacity

- We use Closed circuit Helium Dilution to determine FRC, RV, and TLC.
- **C1xV1 = C2xV2**

C1: concentration of Hi in spirometry

V1: volume of air in the spirometry.

C2: Final concentration of helium

V2 :Volume of spirometry+ FRC

FRC = (Ci He (C1) - 1) x Vi Spi (V1)
Cf He (C2)

Note

شرح للشريحة السابقة

If we calculate the FRC we can also calculate the residual volume and the total lung capacity:

Simply:

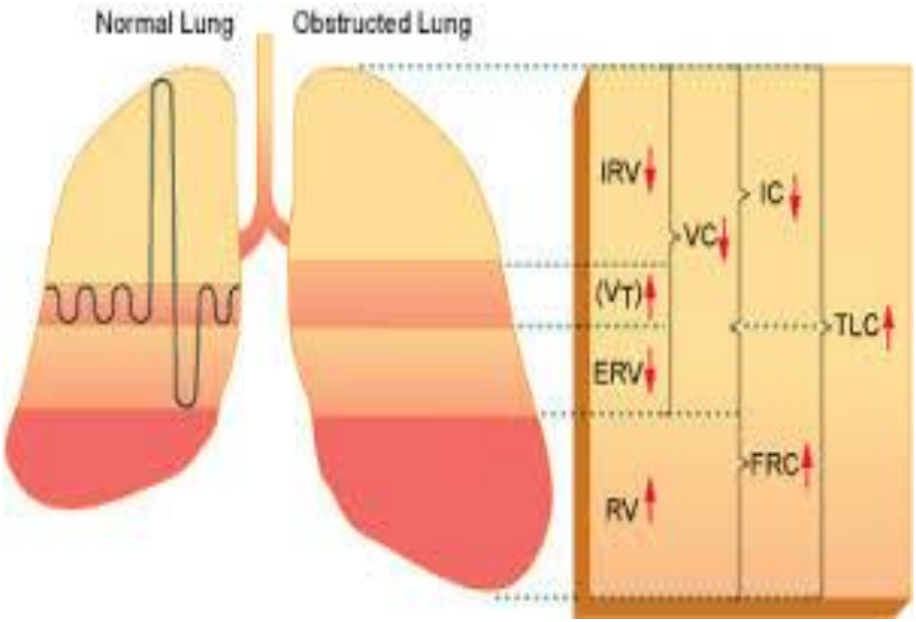
1. FRC= $\frac{(C1 - 1)}{C2}$ X (V1)

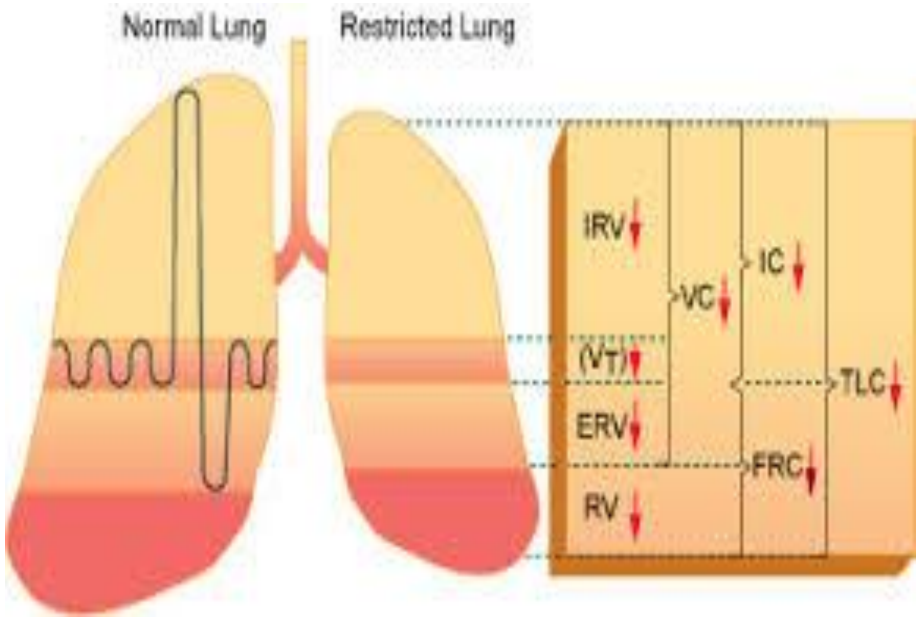
1. RV= (FRC) – (expiratory reserve volume)
2. TLC= (vital capacity) + (RV)

المعادلات من سلايد 14-15

-يعني نستعمل الاف ار سي عشان نطلع ال الار في , ونستعمل الار في عشان نطلع التوتال لنق كابيسيتي.

Obstructive and Restrictive Diseases

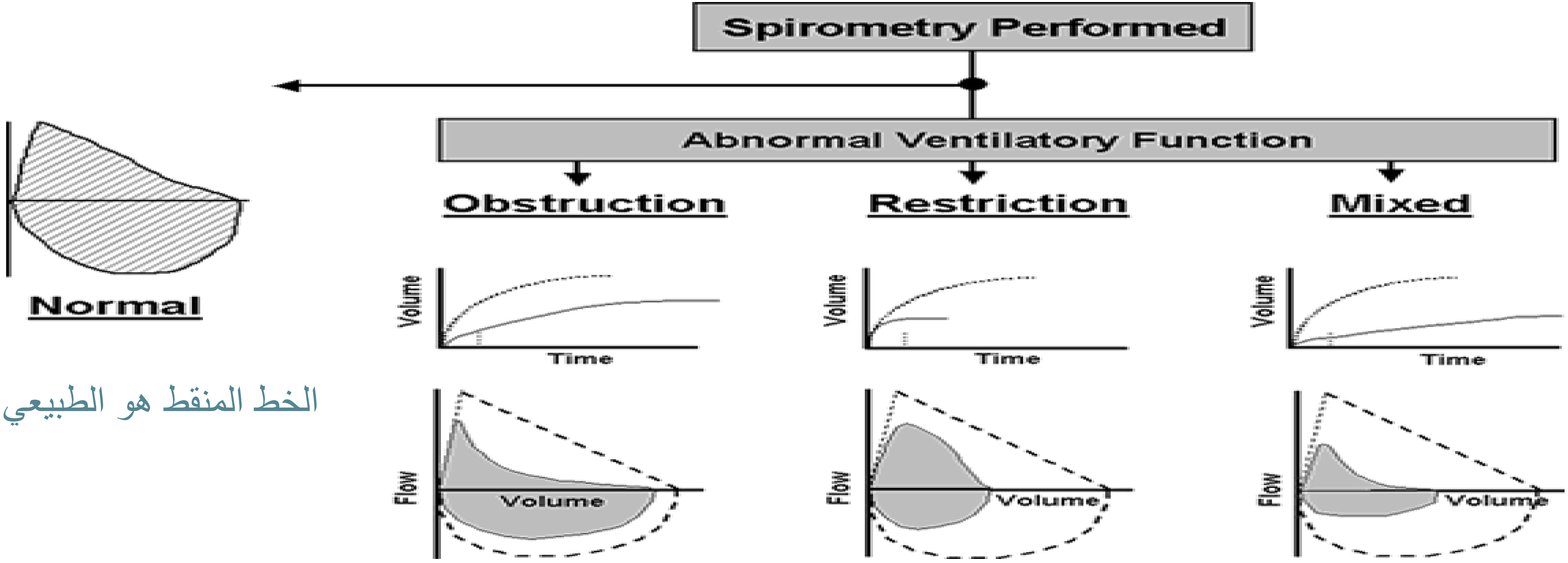




Obstructive disease causes **airway obstruction leading to decrease in airflow into and out of the lungs and trapping of air inside the lung (that is why RV, FRC** TLC are increased)

Restrictive disease restrict expansion of lungs causing decrease in lung volume (notice the decrease in amount of air according to all parameters)

Difference Between Obstructive and Restrictive Disease

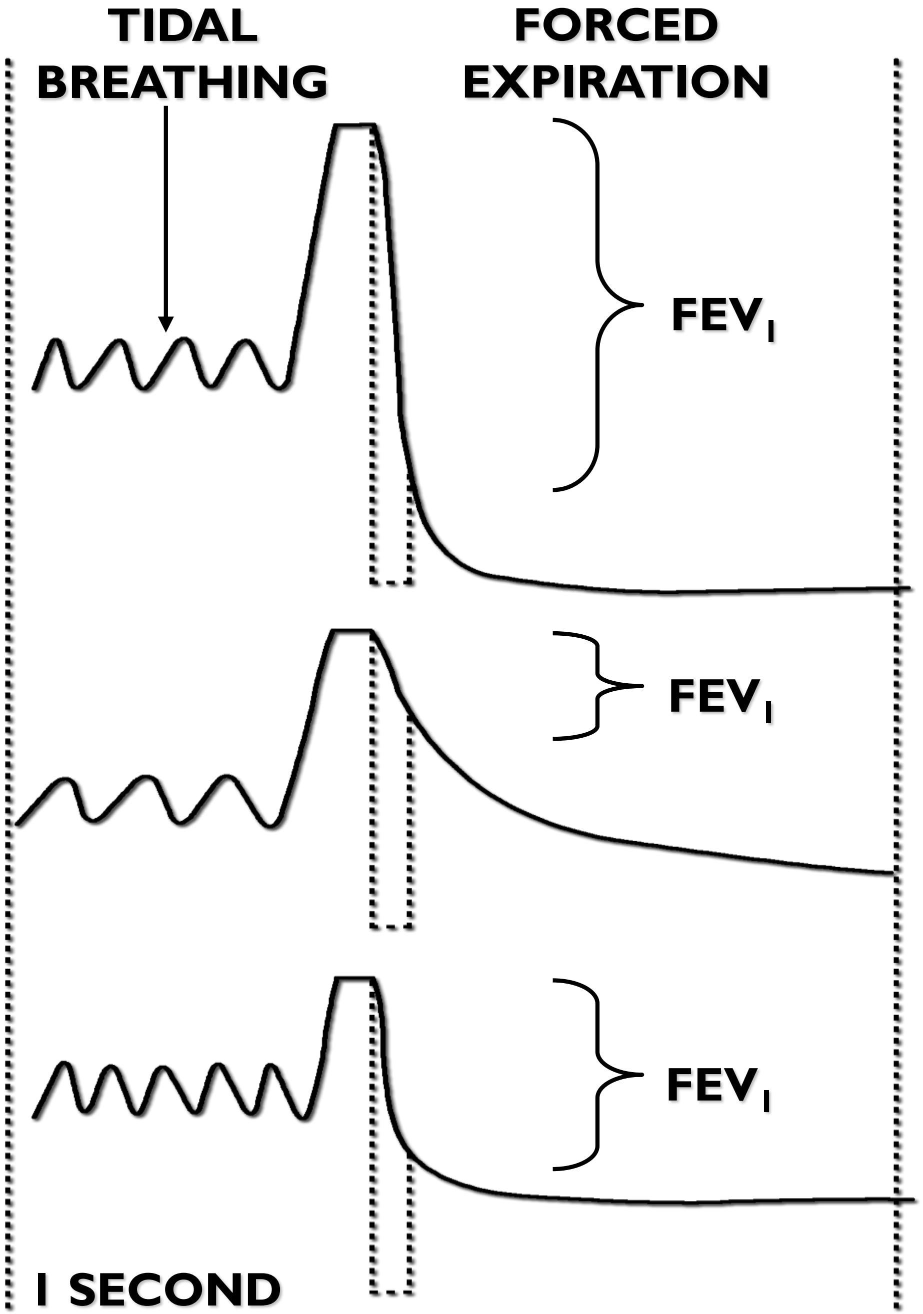


الخط المنقط هو الطبيعي

In Obstruction:
-Prolongation in time, due to increased airway resistance.

In Restrictive:
-Decreased total lung volume of air, due to the accumulation between alveoli (ex. Fibrosis).

In Mixed:
-Both obstructive & restrictive occur at the same time.



NORMAL

FEV_1 = 3.0L
FVC = 4.2L
FEV_1/FVC = 72%

OBSTRUCTIVE

Obstructive lungs have problems with expiration.

FEV_1 = 0.9L
FVC = 2.3L
FEV_1/FVC = 40%

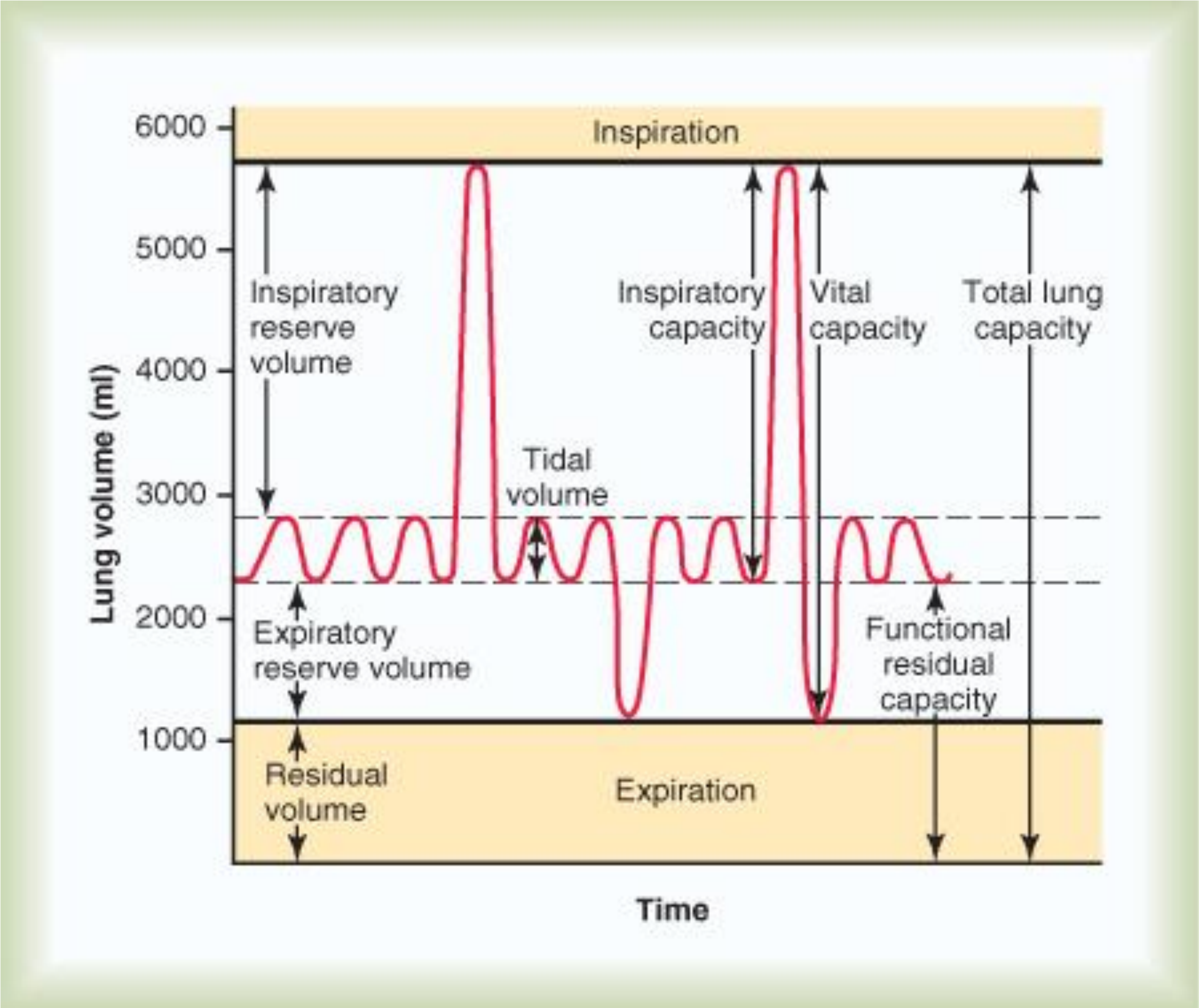
RESTRICTIVE

Mini curve.

FEV_1 =1.8L
FVC = 2.3L
FEV_1/FVC = 78%

- فرقوا بين أشكال الكيرف وقارنوه مع النورمال كيرف

Lung Volumes And Capacities (Spirogram)



- **Functional residual capacity =**

Residual volume (RV) + Expiratory reserve volume (ERV)

- **Inspiratory capacity =**

Tidal volume (VT) + Inspiratory reserve volume (IRV)

- **Vital capacity =**

Expiratory reserve volume(ERV) + Inspiratory reserve volume (IRV)+

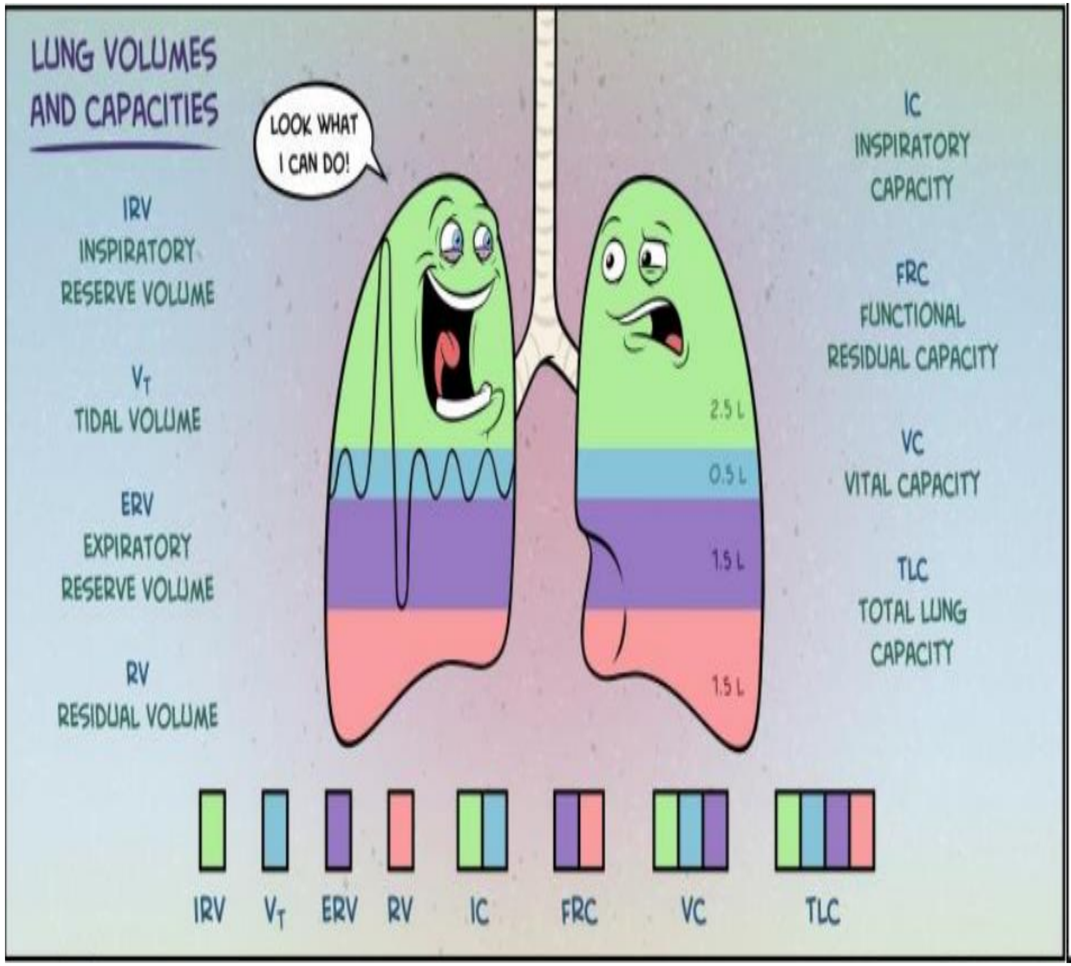
Tidal volume (VT)

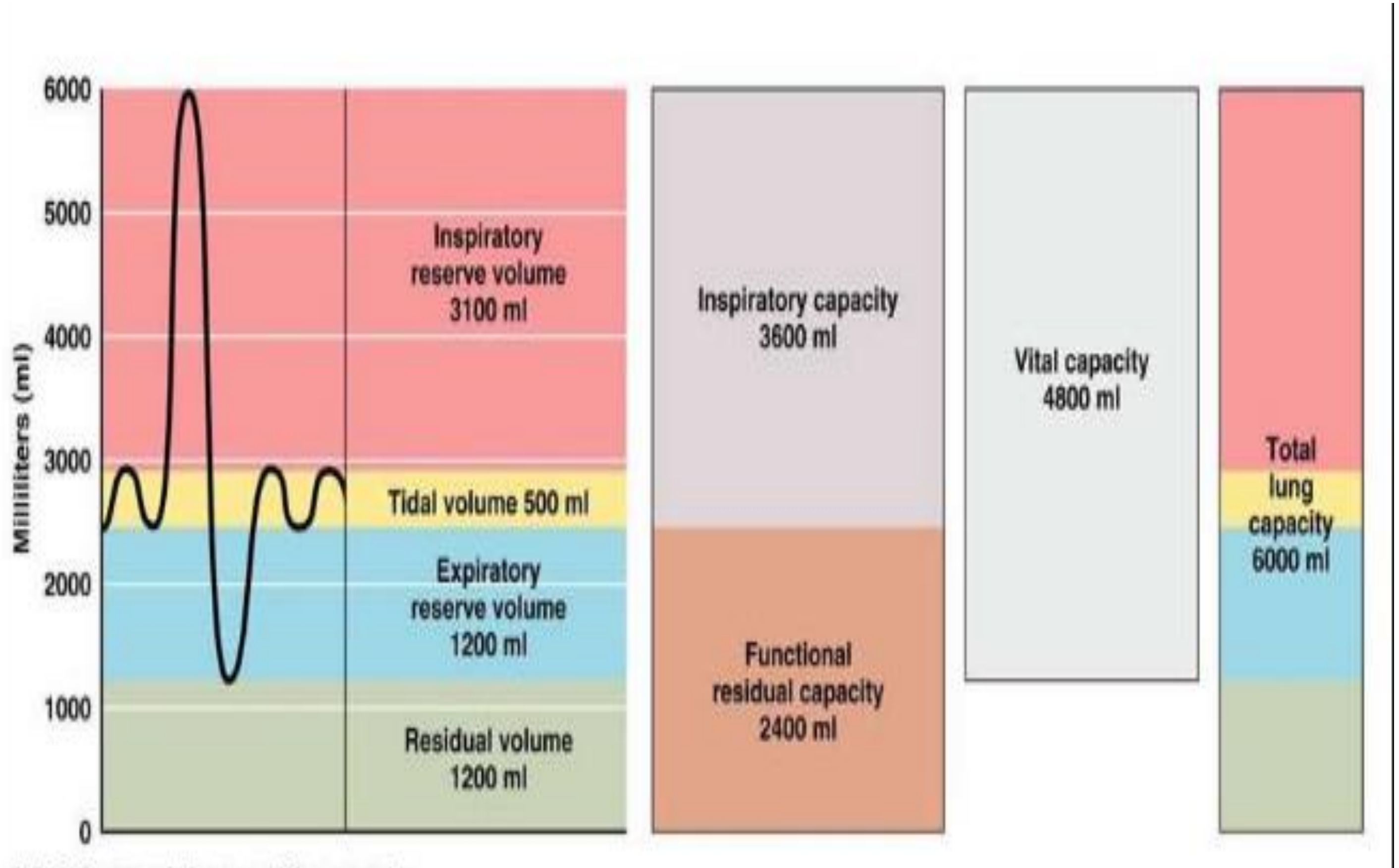
- **Total lung capacity =**

ERV +IRV + VT + RV

Spirogram: is the drawing of the spirometry. It is used for ease in describing the events of pulmonary ventilation, the air in the lungs has been subdivided in this diagram into four volumes and four capacities.

Summary Lung Volumes And Capacities





(a) Spirographic record for a male

Cont.

	Measurement	Adult male average value	Adult female average value	Description
Respiratory volumes	Tidal volume (TV)	500 ml	500 ml	Amount of air inhaled or exhaled with each breath under resting conditions
	Inspiratory reserve volume (IRV)	3100 ml	1900 ml	Amount of air that can be forcefully inhaled after a normal tidal volume inhalation
	Expiratory reserve volume (ERV)	1200 ml	700 ml	Amount of air that can be forcefully exhaled after a normal tidal volume exhalation
	Residual volume (RV)	1200 ml	1100 ml	Amount of air remaining in the lungs after a forced exhalation
Respiratory capacities	Total lung capacity (TLC)	6000 ml	4200 ml	Maximum amount of air contained in lungs after a maximum inspiratory effort: TLC = TV + IRV + ERV + RV
	Vital capacity (VC)	4800 ml	3100 ml	Maximum amount of air that can be expired after a maximum inspiratory effort: VC = TV + IRV + ERV (should be 80% TLC)
	Inspiratory capacity (IC)	3600 ml	2400 ml	Maximum amount of air that can be inspired after a normal expiration: IC = TV + IRV
	Functional residual capacity (FRC)	2400 ml	1800 ml	Volume of air remaining in the lungs after a normal tidal volume expiration: FRC = ERV + RV

(b) Summary of respiratory volumes and capacities for males and females

Minute Ventilation Rate and Volume

- **Respiratory rate:** Number of breaths taken per minute.
- **Minute ventilation:** Total amount of air moved into and out of respiratory system per minute.
- **Minute respiratory volume: MRV:** The total amount (volume) of new air that moves into the respiratory passages in each minute is called the minute respiratory volume.

Minute respiratory volume (MRV)= tidal volume x respiratory rate.

- **Rate of Alveolar Ventilation:**

Alveolar ventilation = respiratory rate X (Tidal volume – air in dead space)

Alveolar ventilation per minute is the total volume of new air entering the alveoli and other adjacent gas exchange areas (respiratory zone) each minute. **(Because 1/3 is lost in conductive zone.)**

Note

Rate of Alveolar Ventilation:

Normal tidal volume of **500 milliliters**

Normal dead space of **150 milliliters**

Respiratory rate of **12-18 breaths** per minute

What is the MRV and the rate of Alveolar ventilation for a patient with a respiratory rate of 12 breaths per minute?

- **MRV (tidal volume x respiratory rate)**

= 500 x 12 = 6000 L/minutes

(*it could rise to 200 L/min or more than 30 times normal if RR = 40 , TV* = 4600 ml in young adults man)

- **Alveolar ventilation (Va) = (respiratory rate x (Tidal volume – air in dead space))**

=12 x (500 –150)= 4200 ml/min = 4.2 L

UNITS MUST BE IN LITERS!

Quiz

- https://www.onlineexambuilder.com/respiratory-ventilation/exam-128128

Link to Editing File

(Please be sure to check this file frequently for any edits or updates on all of our lectures.)

References:

- Girls' and boys' slides.
- Guyton and Hall Textbook of Medical Physiology (Thirteenth Edition.)

Thank you!

اعمل لترسم بسمة، اعمل لتمسح دمعة، اعمل و أنت تعلم أن الله لا يضيع أجر من أحسن عملا.

The Physiology 436 Team:

Female Members:
Shroog Alsomali
Alaa Alaqeel
Aseel Alsulaimani
Laila Mathkour
Sondos Alhawamdeh
Elham Alami
Wateen Alhamoud

Male Members:
Waleed Alaskah
Omar Babteen
Fouad Fathi
Ali Alsubaie

Team Leaders:
Qaiss Almuhaideb
Lulwah Alshiha

Contact us:
Physiology436@gmail.com
@Physiology436