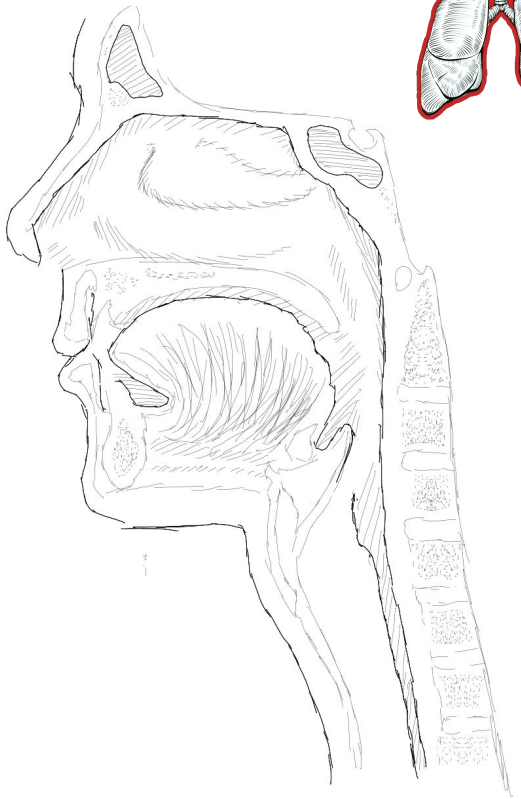
Mechanism of Pulmonary Ventilation



Editing File

Color Index:
-Main Text -Important -Notes
-Boy Slides -Girl Slides -Extra

Special Thanks to Hasan Alsughayir for the Sketch <3

Objectives

Male Dr: Thamir Al-Khaliwi
Female Dr: Aida Korish

01 List the muscles of respiration and describe their roles during inspiration and expiration.

02 Identify the importance of the following pressures in respiration: atmospheric, intra-alveolar, intrapleural, and transpulmonary.

03 Explain why intrapleural pressure is always sub atmospheric under normal conditions, and the significance of the thin layer of the intrapleural fluid surrounding the lung.

04 Define lung compliance and list the determinants of compliance.

05 Recognize the work of breathing, its types and the energy required for breathing.

06 Identify the concept of radial traction and its role in air trapping in emphysema.

Highly recommend these videos composed of 3 parts for this lecture

Mechanics of ventilation

- **Pulmonary Ventilation** : The physical movement of air into and out of the lungs.
- Air movement depends upon:
  Boyle's law which is : **P** x **V**= **K** **P1 x V1= P2 x V2**

Where **P**= pressure, **V**= Volume, **K**= constant

- The chest volume depends of movement of diaphragm and ribs

Respiratory muscles (muscles of breathing)

This table is mixed of male and female slide

Type	Active or passive process	Normal resting (inspiration or expiration)	Forced (inspiration or expiration)
Inspiratory Muscles (inspiration)	**Normal resting:** active **Forced:** active	1- diaphragm 2-external intercostal	Accessory muscles of inspiration + resting muscles contract to increase thoracic cavity size, for example: 1-Sternocleidomastoid/ elevate sternum 2-Scalene/ elevate first 2 ribs 3-Anterior serrati/ elevate many ribs 4-Pectoralis minor/ elevate 3rd to 5th ribs
Expiratory Muscles (expiration)	**Normal resting:** passive **Forced:** active	depends on the recoil tendency of the lung and needs **no muscle contraction**	Needs contraction of muscles of exhalation to increase pressure in abdomen and thorax for example: 1-Abdominal muscles 2-Internal intercostal muscles

Different pressures that affect respiration

1- Atmospheric pressure 2- Intra-alveolar (pulmonary) pressure 3- Intra-pleural pressure 4- Transpulmonary pressure

Intra-alveolar pressure (Intrapulmonary pressure)

And its relation to lung volume

Pictures in the video is better for understanding than the slide

Definition : the pressures in all parts of the respiratory airways

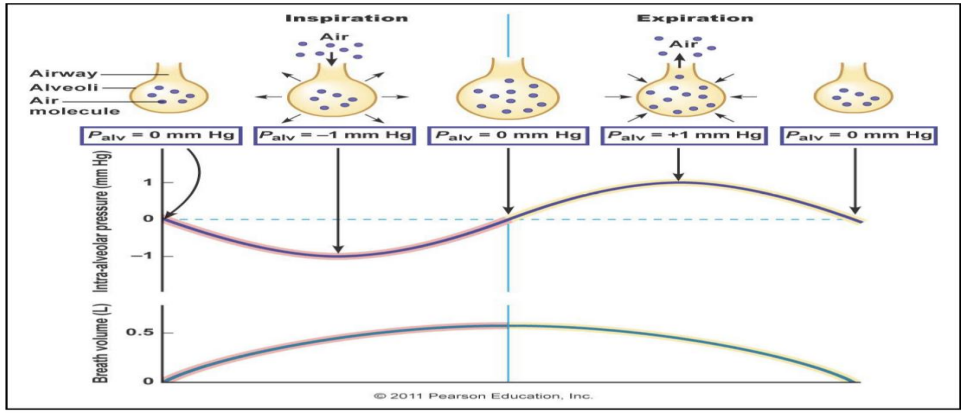
01 Between breaths: zero pressure

02 During inspiration: (-1 mmHg) and air (tidal volume) flows from **outside** to **inside** the lungs

03 At the end of inspiration=zero pressure and air flow stops

04 During expiration=(+1 mmHg) and air flows out of the lungs

Relation between intra alveolar pressure and lung volume

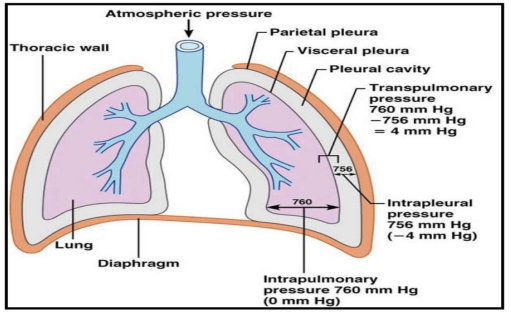


The more u increase the pressure the less the volume becomes

They are inversely proportional to each other if one increases the other decreases according to Boyle's law

Intrapleural pressure (IPP)

negative pressure in the pleural fluid



Definition: the pressure of the fluid in the thin space between the lung pleura and chest wall pleura

- Pressure in the pleural space is normally slightly negative with respect to atmospheric pressure at the end of normal expiration (-5cmH2O)

Values of IPP :

- Resting position (between breaths)(at rest) =(-5cmH2O) which is the amount of suction required to hold the lungs open to their resting level.
- Full resting inspiration it becomes more negative= (-7.5cmH2O)(-8cmH2O)

What causes the negativity of the IPP?

01 The lung's elastic tissue causes it to recoil, while that of the chest wall causes it to expand. Because of these two opposing forces the pressure in the pleural cavity becomes negative.

02 The pleural space is a potential space (empty) due to continuous suction of fluids by lymphatic vessels.

Presence of air in the pleural cavity (pneumothorax), Fluid (pleural effusion), blood (hemothorax), Pus (pyothorax) all lead to loss of the negativity of the pleural cavity and collapse of the lung.

🩺 Doctor said:IF values come they won't ask accurately like asking in SAQ what's the number and if it comes MCQ it will be same or close to the number.

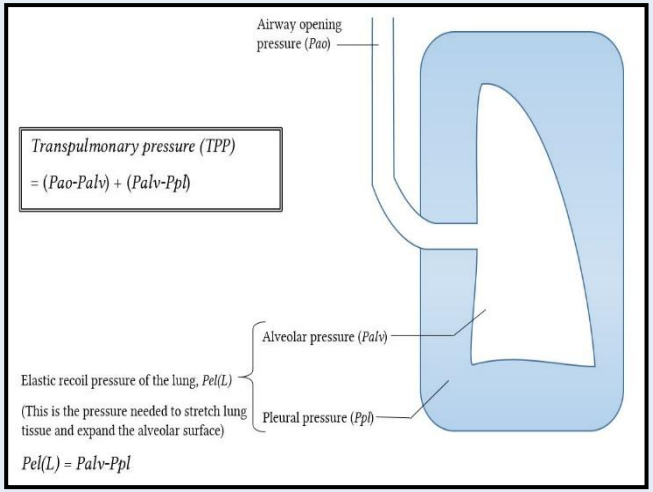
Transpulmonary pressure (TPp) (Extending Pressure)

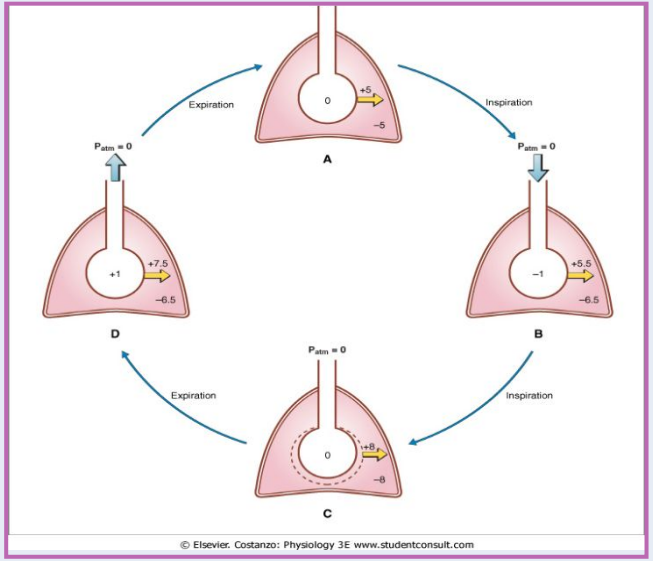
- The difference between the alveolar pressure (Palv) and the pleural pressure (Ppl).

  TPp = Palv - Ppl

- It is a measure of the elastic forces in the lungs that tend to collapse the lungs therefore (the recoil pressure).
- Importance: It prevents lung collapse.
- The bigger the volume of the lung the higher will be its tendency to recoil.
- e.g at total lung capacity (TLC) the recoil tendency of the lung is at its maximum and at the residual volume (RV)(Residual volume) it is the lowest.

Other names: Distending pressure/ Collapse pressure





Compliance of the lung (CL)

Helpful video

The extent to which the lungs will expand for each unit increase in the transpulmonary pressure is called the *lung compliance*

$$(CL) = \frac{(\Delta V)\ \text{(change in volume)}}{(\Delta P)\ \text{(change in pressure)}}$$

(CL): is the ratio of the change in the lung volume produced per unit change in the distending pressure (transpulmonary pressure Tpp).

CL is expressed in ml/cm H_2O.

- for both lungs alone in adult = 200 ml of air /cm H_2O increase in the Tpp.

  The compliance of the lung without the thoracic cage (which is a limitator) -> 200 ml of air/cm H2O (Double)
- for lungs and thorax together in adult = 110 ml of air/ each 1cm H_2O increase in the Tpp.

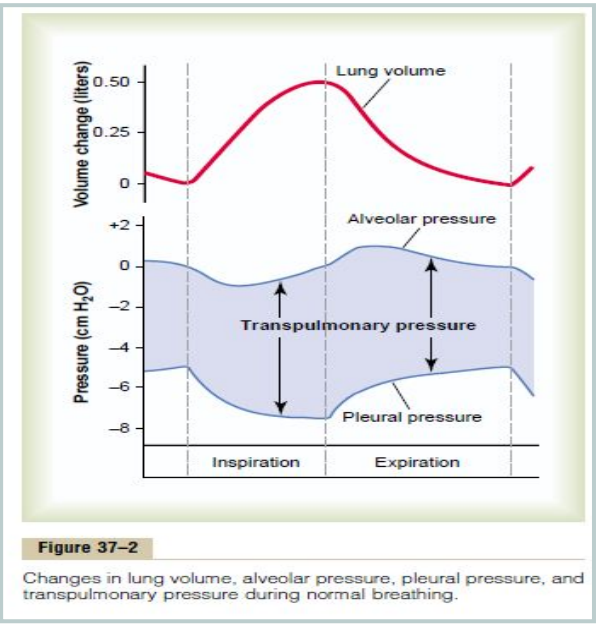


Figure 37–2

Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing.

Lung Compliance

The characteristics of the compliance diagram are determined by the elastic forces of the lungs. These can be divided into:

1. 1/3 is due to elastic forces of the lung tissue itself (caused by elastin & collagen fibers).
2. 2/3 of the elastic forces caused by surface tension of the fluid that lines the inside walls of the alveoli and other lung air spaces.

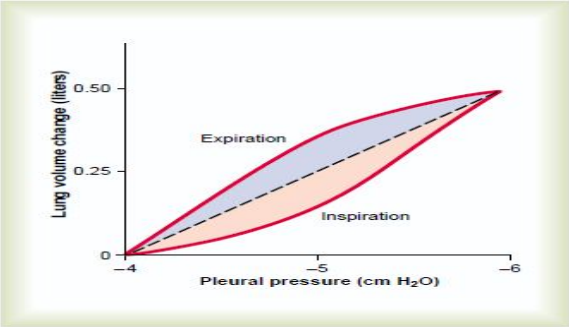


Figure 37–3

Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone.

Diseases that affect compliance of lung

Extra Info:
Kyphosis: تحدب الظهر
Scoliosis: (الجنف) ميلان العمود الفقري

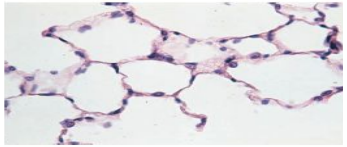
Lung compliance is reduced

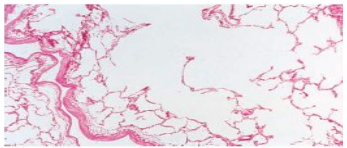
- pulmonary fibrosis
- pulmonary edema
- diseases of the chest wall : kyphosis, scoliosis, paralysis of the muscles, etc...

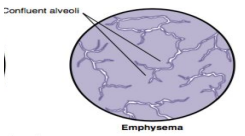
Lung compliance is increased

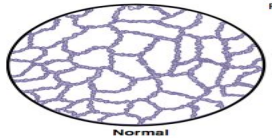
- Emphysema

because it destroys the alveolar septal tissue rich with elastic fibers that normally opposes lung expansion.









Work of inspiration can be divided into three parts:

1 Compliance work or elastic work:
Expand the lungs against the lung and chest elastic forces (65%).

2 Tissue resistance work:
To overcome the viscosity of the lung and chest wall structures (7%).

3 Airway resistance work:
Required to overcome airway resistance during the movement of air in the lungs (28%).

During pulmonary disease all 3 types of work are increased.

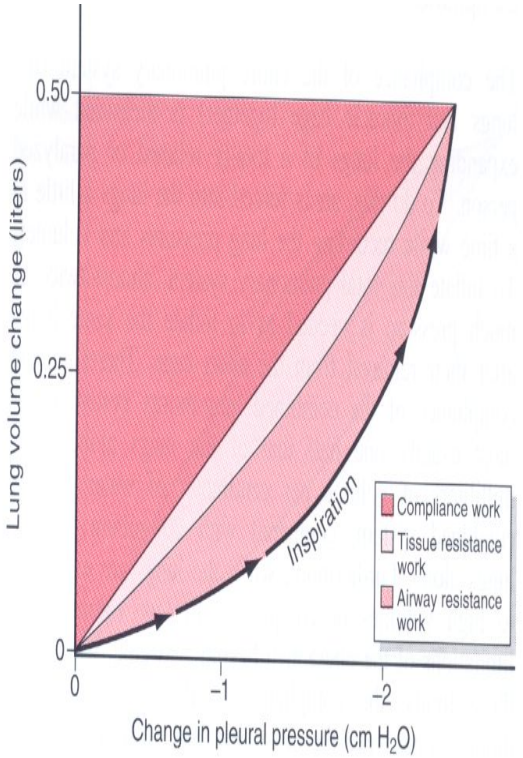


FIGURE 37-5

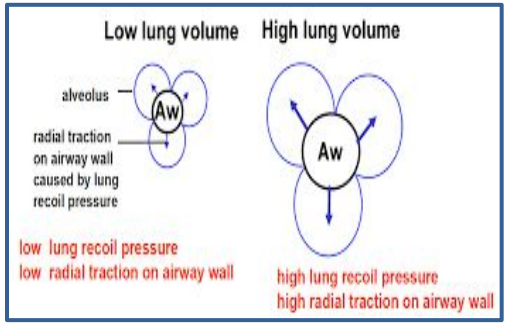
Energy required for respiration

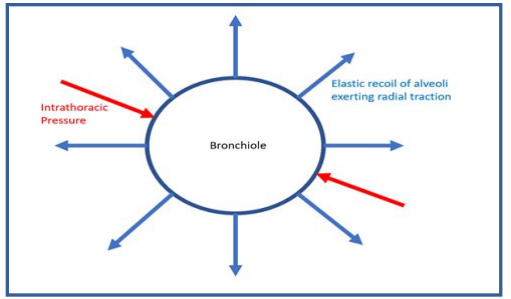
- 3-5% of total energy expended (used) by the body.
- Can be increased to 50 folds **during heavy exercise** especially if the person has any degree of **increased** airway resistance or **decreased** pulmonary compliance.
- One of the major limitations on the intensity of exercise that can be performed is the person's ability to provide enough muscle energy for the respiratory process alone.
- During **pulmonary diseases**, all the three types of work are increased.

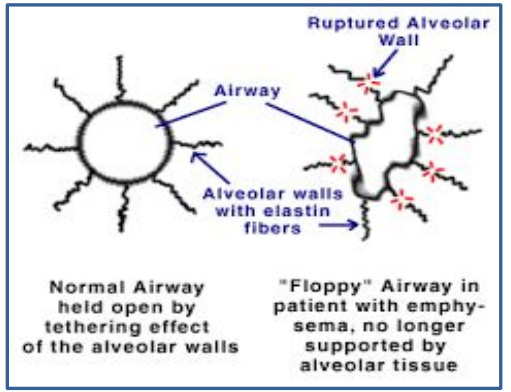
Radial Traction

🩺 Doctor said 443:
Q: Why is emphysema considered as a COPD?
A: Because of Radial traction

- **During inspiration**: With the increased volume, the intrathoracic pressure surrounding the smaller airways is reduced, allowing for **airway expansion.** As the radius of the airways increases, resistance to airflow is **lower** during this inspiratory phase.
- **In expiration**, the intrathoracic pressure **increases** due to the **lower** volume of the thoracic cavity. This pressure leads to narrowing of the smaller airways, so resistance is **higher** during expiration.
- In healthy lung tissue, the **elastic fibers** of the surrounding alveoli pull on the walls of small airways and hold them **open** – this force is called **radial traction.**
- The higher the elastic recoil of the lungs, the **greater** the radial traction will be.
- Radial traction helps to **prevent airway collapse** in expiration.

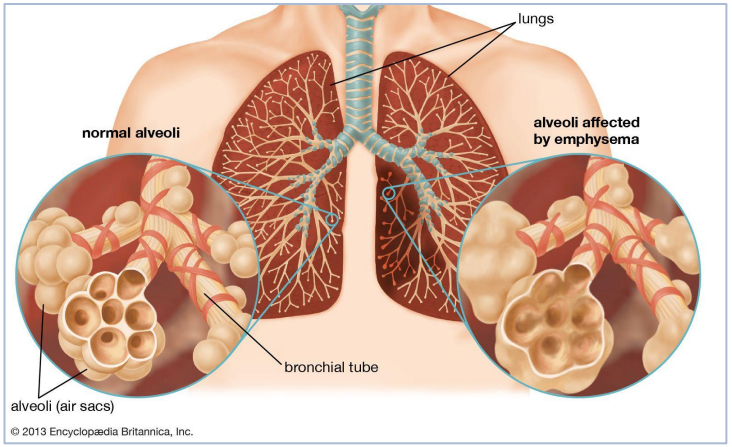






Clinical Relevance – Emphysema

- In **emphysema**, there is **destruction of elastin fibers** within alveoli. Therefore, there is less elastic recoil holding open the **smaller airways**, and thus reduced radial traction.
- This means that during expiration, when the intrathoracic pressure is greater, the smaller airways **collapse** very easily, trapping an **increased volume of air**.



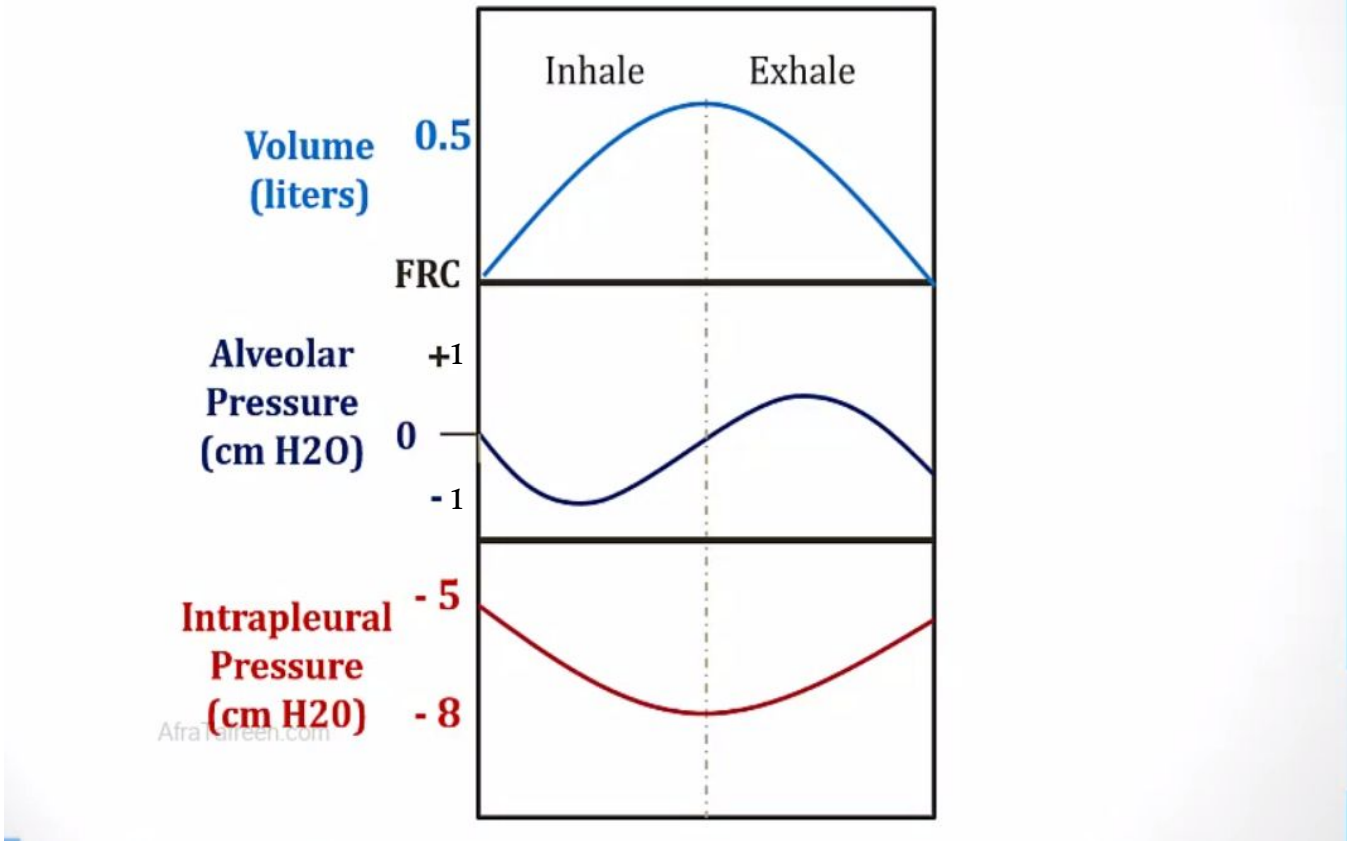
💡 Extra from Guyton:
Loss of lung tissue in emphysema leads to an increase in the compliance of the lungs and a decrease in the elastic recoil of the lungs. Pulmonary compliance and elastic recoil always change in opposite directions; that is, compliance is proportional to 1/ elastic recoil. The TLC, RV, and FRC are increased in emphysema, but the VC is decreased.

Summary Extra Slide From Team 348

Remember elasticity & alveolar pressure at each step.

At rest	• You're not breathing, yet. • Lungs recoil (elasticity) is forcing the alveoli to shrink (collapse). • Intrapleural pressure (-5 cmH2O) apply a force in the opposite direction to reach equilibrium. • Alveoli pressure is equal to the atmospheric pressure (Patm is equal to 0).
Inspiration	• Diaphragm contracts. • Intrapleural pressure decreases to -8 / -7.5. • Alveoli expand because the force acting outward (pressure) is greater than the force acting inward (recoil) increased volume → decrease in pressure in the alveoli (pressure changes from 0 to -1). • Air flows from atmosphere (greater pressure) to alveoli (less pressure) (greatest amount of flow into lungs).
At the end of inspiration (not expiration)	• Air stops flowing because pressure in the alveoli = atmospheric pressure (back to 0).
Expiration	• Diaphragm relaxes. • Intrapleural pressure rises back to -5 cmH2O. • Alveoli shrinks → pressure in the alveoli increases to +1 because of the lungs recoil (elasticity). • Air flows out to the atmosphere.

Great summary on pressure changes of normal breathing



MCQs

Q1: A 48-years old man came to the hospital with abdominal pain, examinations show that he had a hernia, what is the movement of the abdomen will be most affected?			
A- normal expiration	B- normal inspiration	C- forceful expiration	D- forceful inspiration
Q2: A 32-years old woman. came to the hospital complaining of difficulty in breathing. Tests show that she has pulmonary fibrosis, which of the following will be most affected?			
A- GIT	B- alveolar septa	C- ribs of chest	D- lung compliance
Q3:A 36-year-old man smoked 600 cigarettes per day for 20 years reports shortness of breath. The patient is diagnosed with chronic pulmonary emphysema. Which set of changes is present in this man compared with a healthy nonsmoker? (Pulmonary Compliance / Lung Elastic Recoil)			
A- increased / decreased	B- decreased / increased	C- increased / increased	D- decreased /decreased

1-C 2-D 3-A

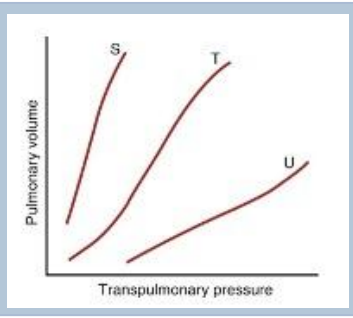
MCQs

Q4: The intrapleural pressure between breaths(at rest)			
A- (-8cmH2O)	B- (-5cmH2O)	C- (-7cmH2O)	D- (+4cmH2O)
Q5: Person injured his sternocleidomastoid which of the following will be lost			
A- forced expiration	B- normal inspiration	C- normal expiration	D- forced inspiration
Q6: If the intrapleural pressure was -6cmH2O and the alveolar pressure is +1cmH2O what is the transpulmonary pressure			
A- -7cmH2O	B- +7cmH2O	C- -5cmH2O	D- +5cmH2O

4-B 5-D 6-B

MCQs

Q4: The figure to the right shows three different compliance curves (S, T, and U) for isolated lungs subjected to various transpulmonary pressures. Which of the following best describes the relative compliances for the three curves?



A- S<T<U	B- S-T-U	C-S>T<U	D-S>T>U

4-D

SAQs

Q1: **Why is the intrapleural pressure negative ?**

Q2: Enumerate types of work of inspiration and what happens to them during pulmonary disease?

Q3: Why the lung compliance is increased in emphysema ?

A1: slide 6

A2: slide 10

A3: slide 9

Ahmad Addas

Ibrahim Albabtain

Leena Shagrani

Rimaz Alhammad

Abdulmohsen Alrahaimi


Abdulaziz Nasser

Abdullah Almarwan

Saud Alsaeed

Abdullah Almutlaq

Talal Alrobaian

Khalid Al Tameem

Zyad Alshuhail

Abdulaziz Alobathani

Moath Alabdulsalam

Omar Alattas

Khalid Alkanhal

Marwah Fal

Ghala Alyousef

Basma Al-ghamdi

Aljoharah Alyahya

Samiyah Sulaiman

Noreen Almarabah

Aram Alzahrani

Haya Alkhlaiwi

Layal Alkhalifah

Hessa Alamer

Aleen Muneif

Farah Aldriweesh

PHYSIOLOGY TEAM444

physiology.444ksu@gmail.com