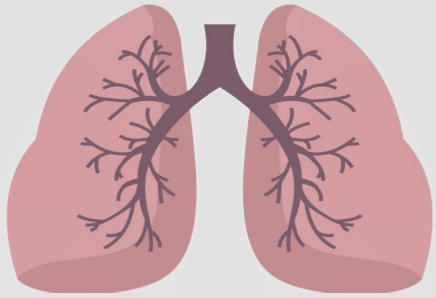
Mechanics of pulmonary ventilation



Respiratory Block

Physiology 439 team work

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

Editing file

@physiology439

Objectives :

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

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

03 Explain why intrapleural pressure is always subatmospheric 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

Mechanics of breathing

1

Pulmonary Ventilation : the physical movement of air into and out of the lungs

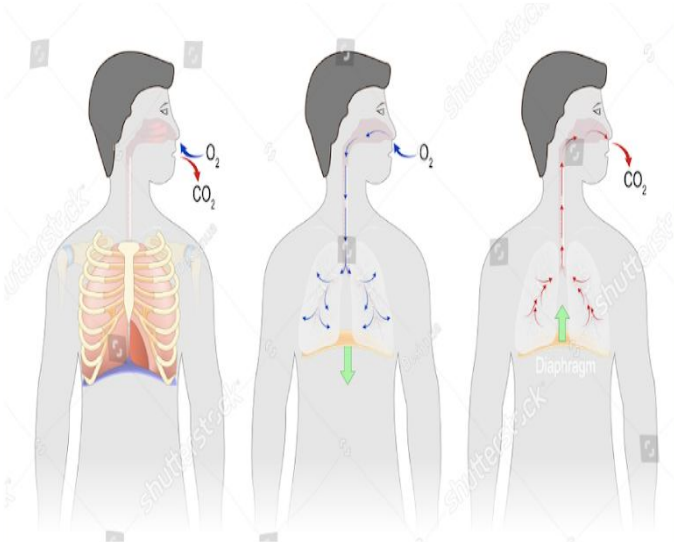
2

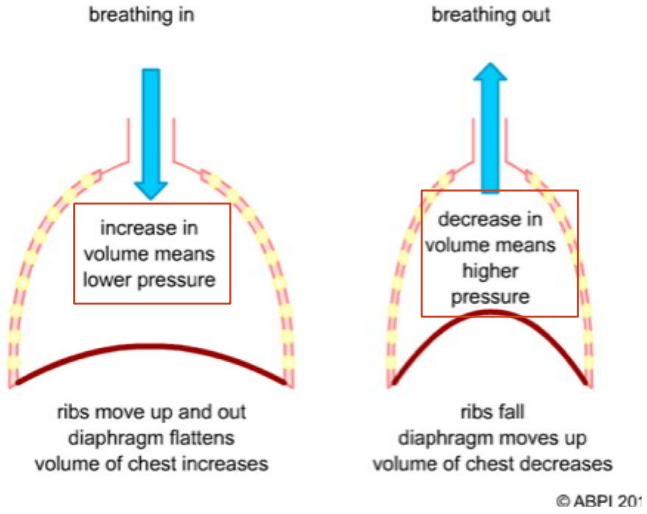
Air movement depends upon :
Boyle's Law:
PxV=K
P1xV1=P2xV2

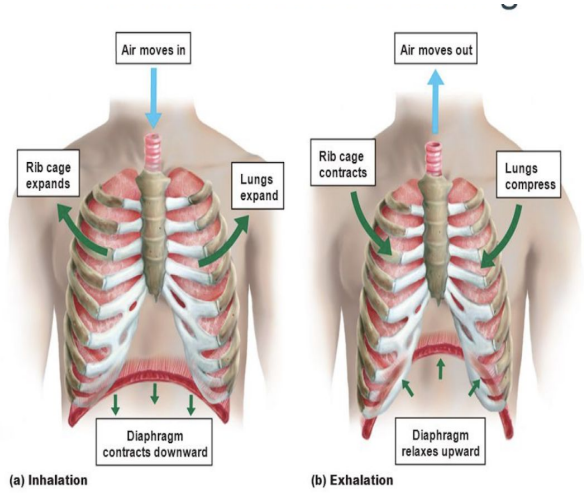
P= pressure , V= volume, K= constant

3

Volume depends on movement of diaphragm and ribs







Respiratory muscles

	Inspiratory muscle	Expiratory muscle
During resting	Diaphragm and external intercostal	It is a passive process that depends on the recoil tendency of the lung and need no muscle contraction
During forced	**Accessory muscles** e.g Sternomastoid, anterior serratus, scalene muscles contract in addition to the muscles of resting inspiration	It is an active process and need muscles contraction the abdominal muscles and the internal intercostal muscles
Deep forceful breathing	During deep forceful inhalation accessory muscles of inspiration participate to increase size of the thoracic cavity -Sternomastoid: elevate sternum -Scalene: elevate first two ribs -Anterior serrati: elevate many of the ribs -Pectoralis minor: elevate 3rd , 4th and 5th ribs	-Expiration during forceful breathing is an active process - Muscles of exhalation increase pressure in abdomen and thorax: (Abdominal muscles and Internal intercostal)

Different pressures that affect respiration

- **Atmospheric pressure**
- **Alveolar pressure**
- **Intrapleural pressure**
- **Transpulmonary pressure**

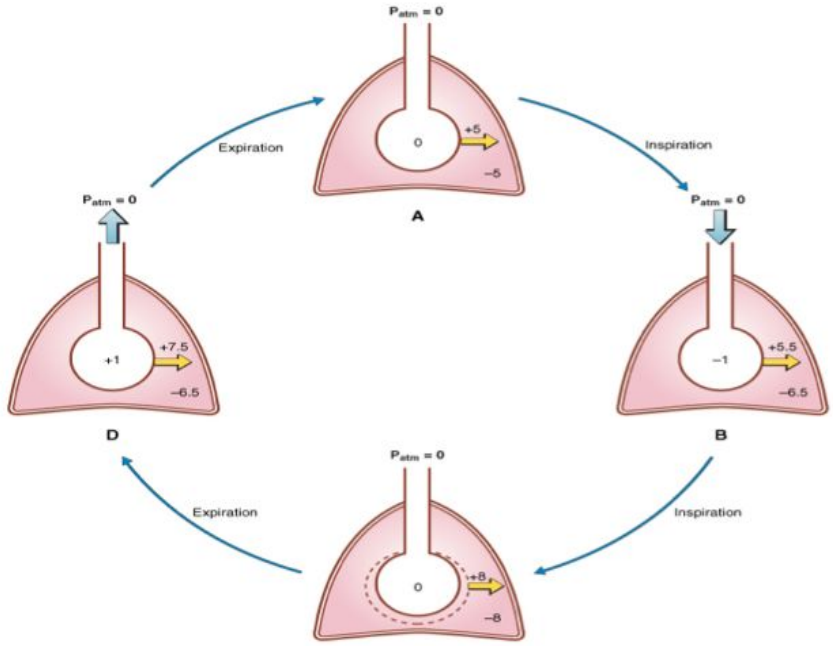
Intra-alveolar pressure (intrapulmonary pressure)

Between breaths:
0 mmHg
(Zero pressure)
"We also called it pause "

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

At the end of inspiration:
0 mmHg and air stops flowing.

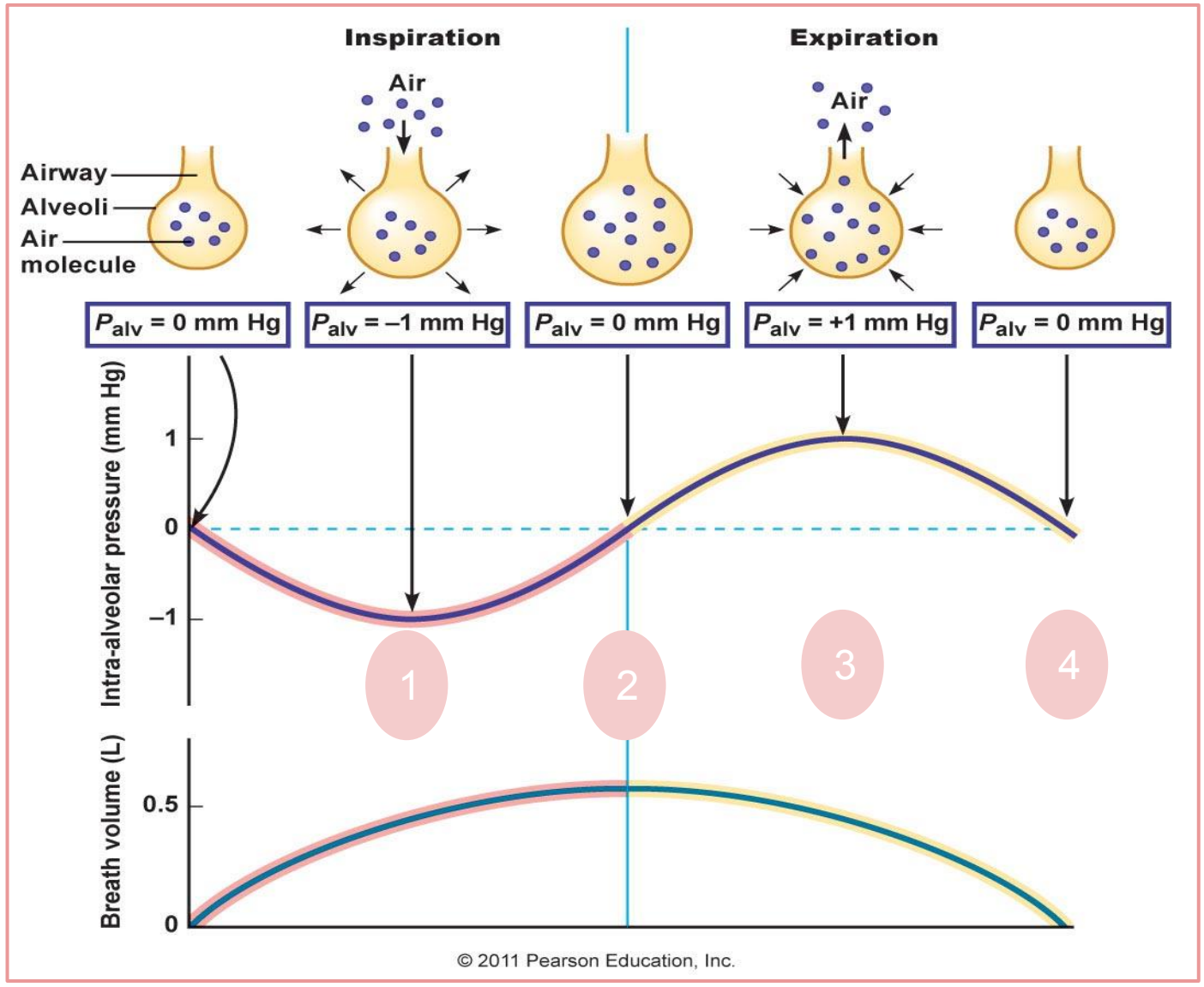
During expiration:
+1 mmHg
and air flows out of the lungs.



Relation between **intra-alveolar** pressure and **lung volume**

The values of Intra-alveolar pressure in the diagram indicate the difference between **INTRA-ALVEOLAR** pressure and **ATMOSPHERIC PRESSURE**
Not the exact values of P-alv

1. Increase in volume
   ⇩
   Decrease in pressure
2. Atmospheric pressure = alveolar pressure
3. Decrease in volume
   ⇩
   Increase in pressure
4. Atmospheric pressure = alveolar pressure



Intrapleural pressure

مهم نعرف قاعدتين قبل دراسة هذا الضغط
اولًا: أي سطحين يقتربون لبعض بيولّدون ضغط موجب، واي سطحين يبتعدون بيولدون ضغط سالب
ثانيًا: الصدر دائمًا يندفع للخارج، والرئة للداخل
للخارج والداخل > يبتعدون عن بعض > ضغط سالب
وش الفائدة منه؟ لو كان مو موجود الرئة بيحصل لها Collapse

The site of intrapleural pressure: pleural space (Between the visceral pleura and parietal pleura)

The values of pressure:

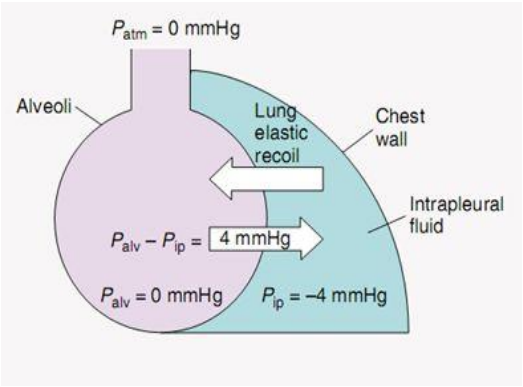
- During **resting position** (between breaths) it = **-5cm H2O(-4 mmHg)** .
- During **resting inspiration** it becomes more –ve = **-8 cm H2O**, **-7.5 cm H2O**

(Notice that the values are **negative** with respect to atmospheric pressure at the end of normal expiration)

What are the causes of negativity ?

1

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**.



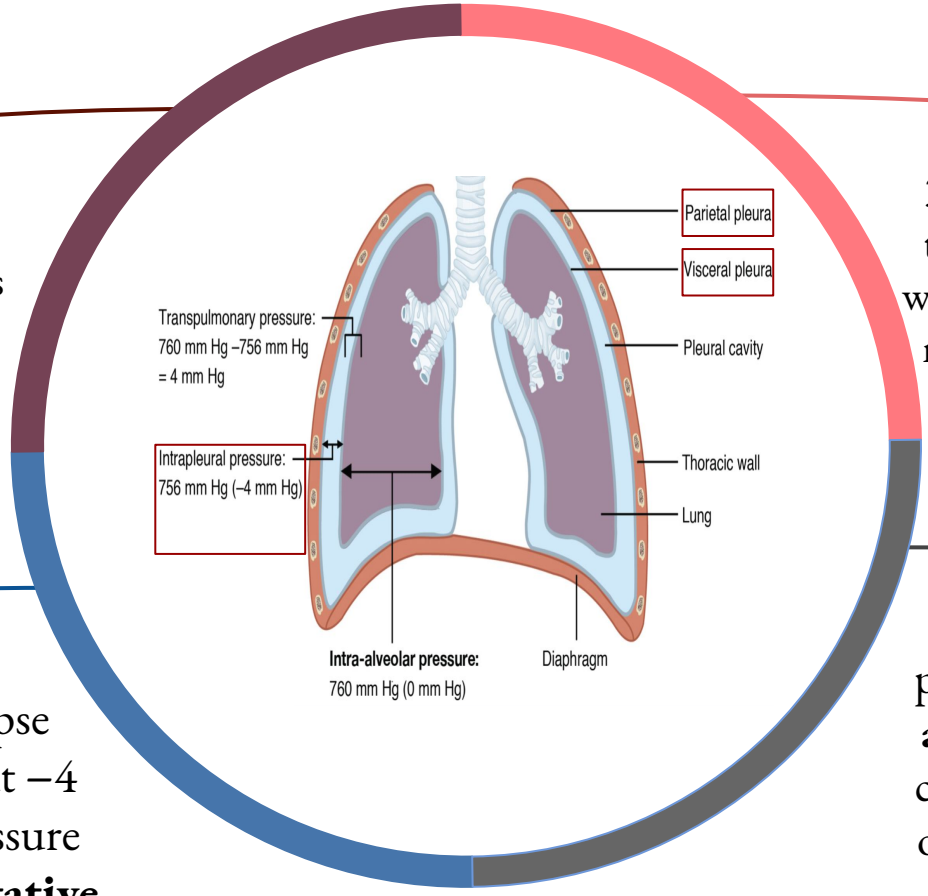
2

The pleural space is a potential space, (empty space) due to continuous suction of fluids by lymphatic vessels.
(which is also the basis of the negative pressure found in most tissue spaces of the body).

Female slide only

Cont. Of Intrapleural pressure
(Negative pressure in pleural fluid)

1- A **negative force** is always required on the outside of the lungs to keep the lungs **expanded**.
-This force is provided by negative pressure in the normal **pleural space.** (Between two pleura)

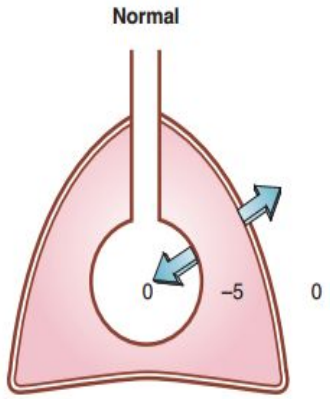


2- Because the normal collapse tendency of the lungs is about −4 mm Hg, the pleural fluid pressure must always be **at least as negative as −4 mm Hg** (- 5 cm/H2O) to keep the lungs expanded.
عشان نقاوم انكماش الرئة لازم تكون القيمة نفس قيمة سالبيتها أو اكثر

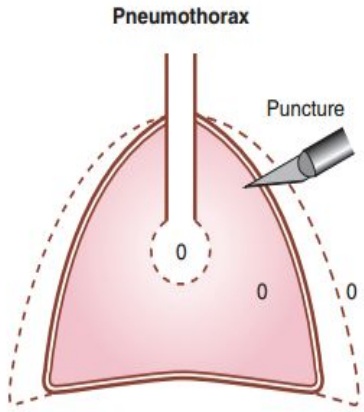
3-Actual measurements have shown that the pressure is usually about −7 mm Hg, which is a few millimeters of mercury more negative than the collapse pressure of the lungs.
Not that important*

4-The negativity of the pleural fluid pressure keeps the normal lungs **pulled against** the parietal pleura of the chest cavity, except for an extremely thin layer of mucoid fluid that acts as a lubricant.

What do you think will happen if someone got a stab at the lungs?



Normal Intrapleural pressure ; normal lungs

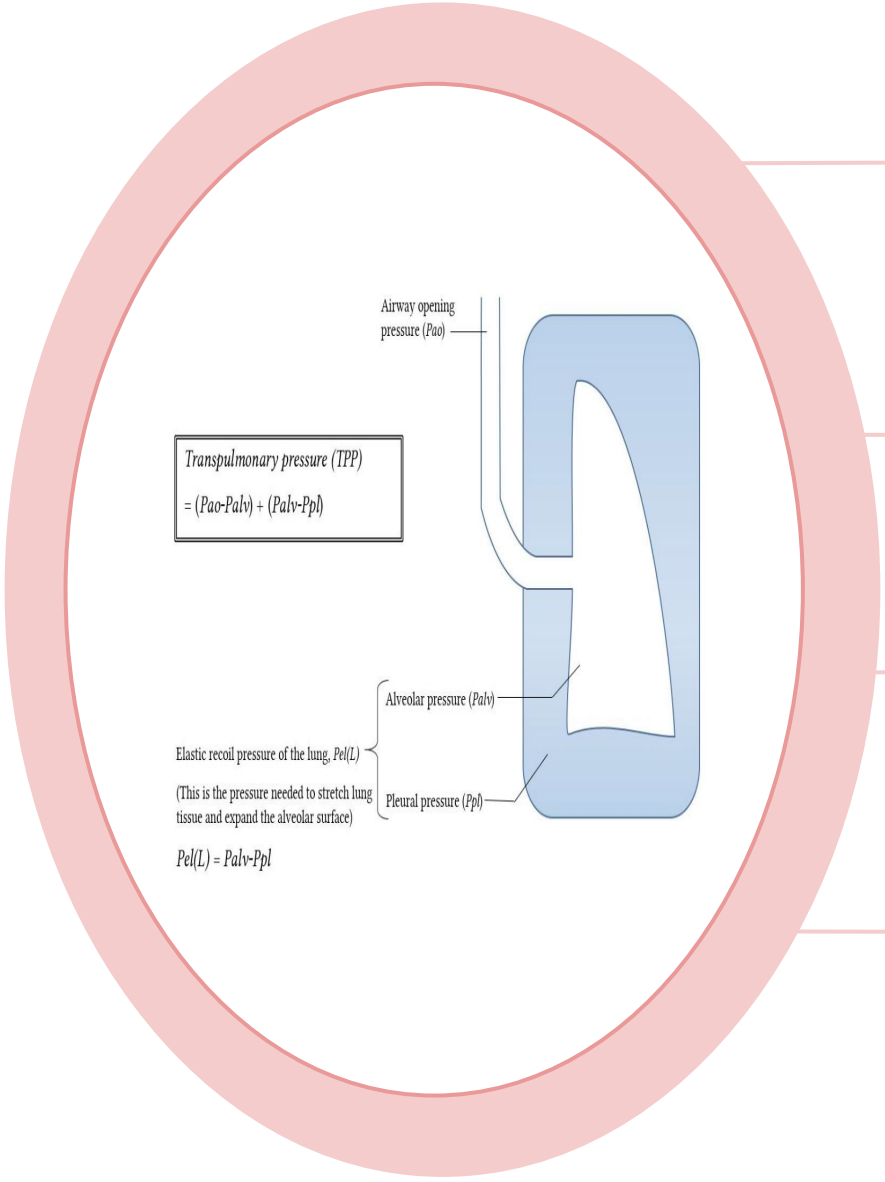


We already said that intrapleural pressure should be **"at least as negative as 4mmHg=5cm/H2O "** but in this case it will become ZERO! Causing the lung to collapse and chest wall to expand

Intrapleural pressure in a normal person and in a person with a pneumothorax. The numbers are pressures in cm H_20. Pressures are referred to atmospheric pressure; thus, zero pressure means equal to atmospheric pressure. The arrows show expanding or collapsing elastic forces. Normally, at rest, intrapleural pressure is-5 cm H_20 because of equal and opposite forces trying to collapse the lungs and expand the chest wall. With a pneumothorax the intrapleural pressure becomes equal to atmospheric pressure, causing the lungs to collapse and the chest wall to expand.

Pneumothorax:
اللي صاير فيه ان الهواء دخل المنطقة اللي مفروض تصير منطقه فاضيه
ف بتالي اثر على الضغط الموجود في المنطقة "intraplural pressure" وصار ال pressure اللي كان نيقتف يساوي الضغط الجوي و هذي مشكلة !! ليه؟
بيصير صعوبه في الinspiration لان الlung أخذت الوضع المريح لها وصار لها collapse والchest صار Expand

Transpulmonary pressure (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 (the recoil pressure).

It prevents lung collapse.

The bigger the volume of the lung **the higher** will be its tendency to **recoil**.

زي البلونة المتفوخة بقوة، بيرجع منها الهواء بقوة

The atmospheric pressure is 760 mmHg

Summary

Pressure	During rest	During inspiration	During expiration
Intra-alveolar pressure	(0 cmH20) 760 mmHg	(-1cmH2o) 759 mmHg	(+1cmH2o) 761 mmHg
Intrapleural pressure	(-4 mmHg) 756 mmHg -5cmH2o	(-5mmHg) 755 mmHg -7.5cmH2o	(just for your information) -6.5 mmHg according to Linda
Transpulmonary pressure **TPp = Palv-Ppl**	TPp= 0 - (-5)= +5 cmH2o	TPp= -1 - (-7.5)= +6.5 cmH2o	(just for your information) TPp= +1 -(-6.5)= +7.5 mmHg

The Intra-alveolar pressure is normally zero (i.e . atmospheric) during the pause. At the start of inspiration, it decreases to about -I mmHg due to lung expansion. This allows the entry of about 500 ml of atmospheric air into the lungs and as a result, it increases Gradually till it becomes atmospheric again by the end of inspiration.
On the other hand, at the start of expiration, it rises to about +1 mmHg due to lung recoil. This moves 500ml of air outwards from the lungs and as a result, it decreases gradually till becoming atmospheric again by the end of expiration .

During expiration. Intrapleural pressure increases, becoming less -ve, which helps the lung to recoil. As a result, the intrapulmonary pressure increases to about +1 mmHg leading to entry of about 500 ml of air (tidal volume)

Transpulmonary pressure:
Is the pressure that prevents lung from collapsing. A newly born infant normally requires a transpulmonary pressure of About + 60 mmHg at the first breath to expand his lungs
.

Compliance of the Lung (CL)

Definition

The extent to which the lungs will expand for each unit increase in the transpulmonary pressure.

In other words: it's the measure of the lungs ability to stretch and expand.

-Transpulmonary pressure = Alveolar pressure - pleural pressure

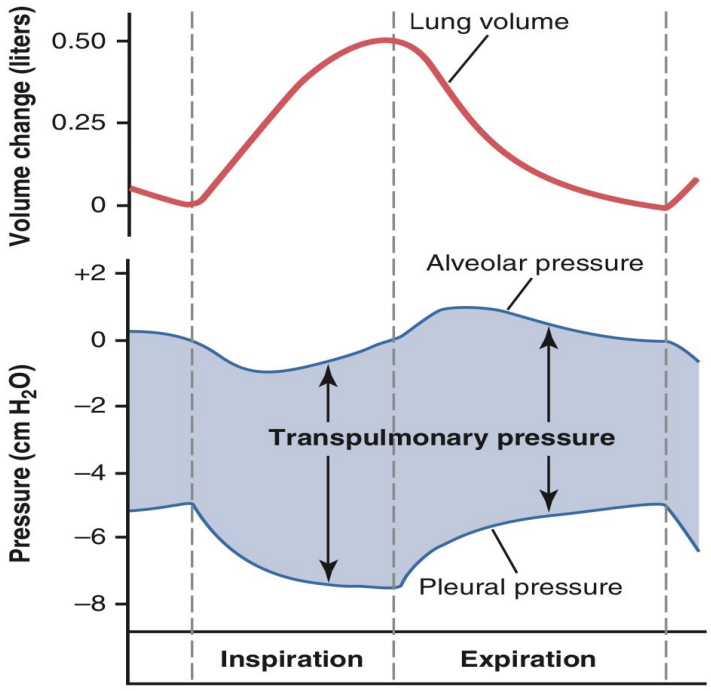


Figure 38-2. Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing.

i.e the ratio of the change in the lung volume produced per unit change in the distending pressure.

For both lungs in adult = 200ml of air / cm H2O
For lungs and thorax together = 110 ml/cm H2O

نقص لأن مطاطية الثوراكس قليلة

Example

A thick rubber is considered to have a low Compliance
A thin rubber is considered to have a high compliance

Rubber = مطاط

CL = Change in Volume / Change in Pressure

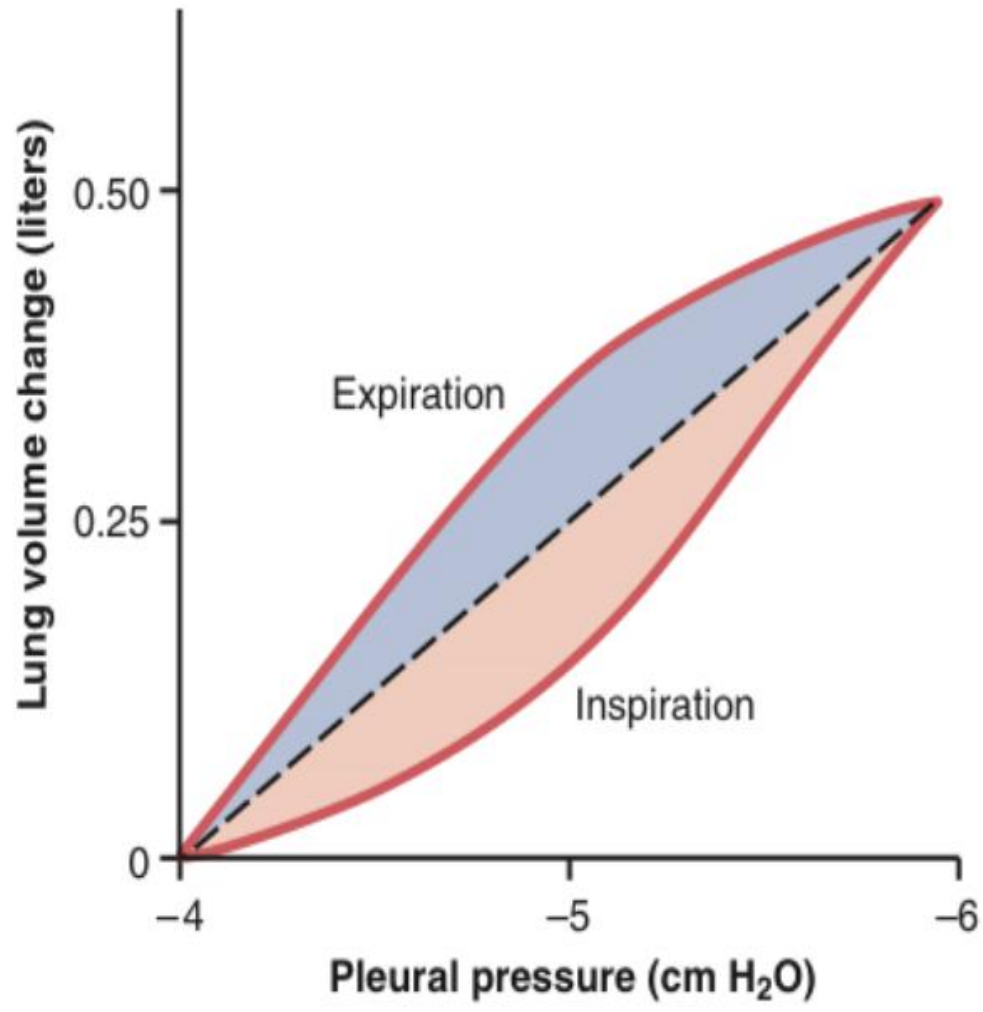
Imagine we have tissue A and tissue B. if we increase the pressure in both by +1 mmHg, and tissue A increases its volume more than B. Then we conclude that the compliance of A is higher that B

Helpful video

Lung compliance diagram

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

⅓ is due to the elastic forces of the lung tissue itself (elastin, collagen).
⅔ of the elastic forces caused by surface tension of the fluid that lines inside walls of the alveoli and other lungs air space.

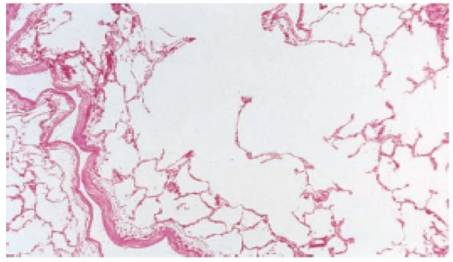


This is a Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone

Diseases affecting the lung compliance

Increase in lung compliance:

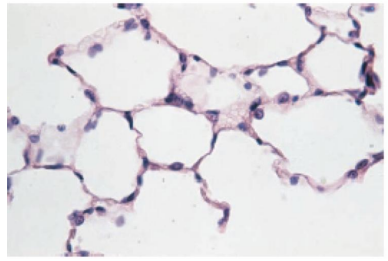
Emphysema increases the compliance of the lungs because it destroys the alveolar septal tissue rich with elastic fibers that normally opposes lung expansion.



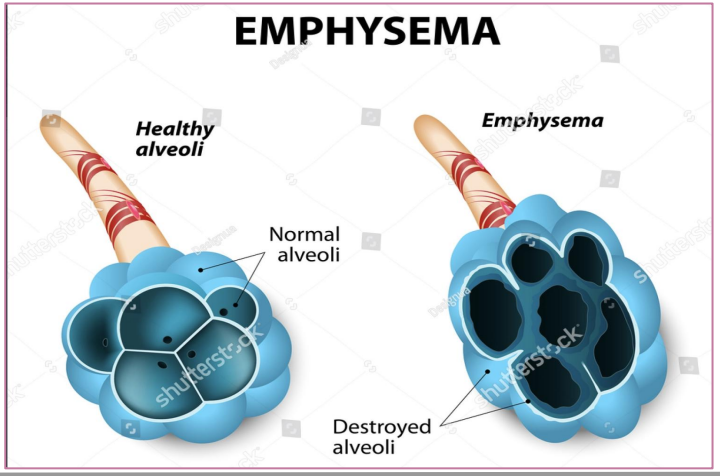
Reduce in lung compliance:

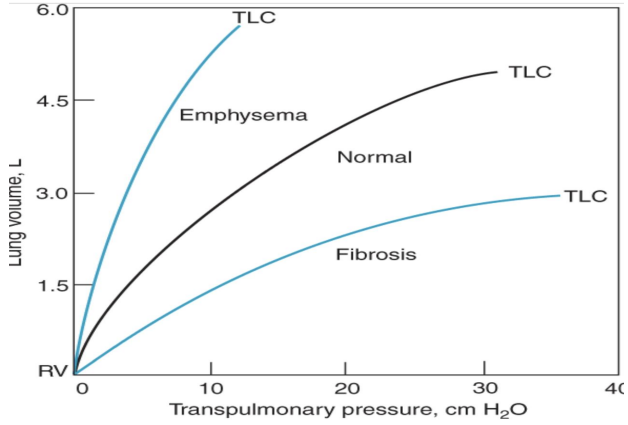
Lung compliance is reduced in pulmonary fibrosis, pulmonary edema, diseases of the chest wall (kyphosis, scoliosis, paralysis of the muscle, etc....).

This disease makes the compliance of the lung intense (strong), just like the thick rubber, the lung can't open easily, so the patient would have to use the accessory muscles.



Extra





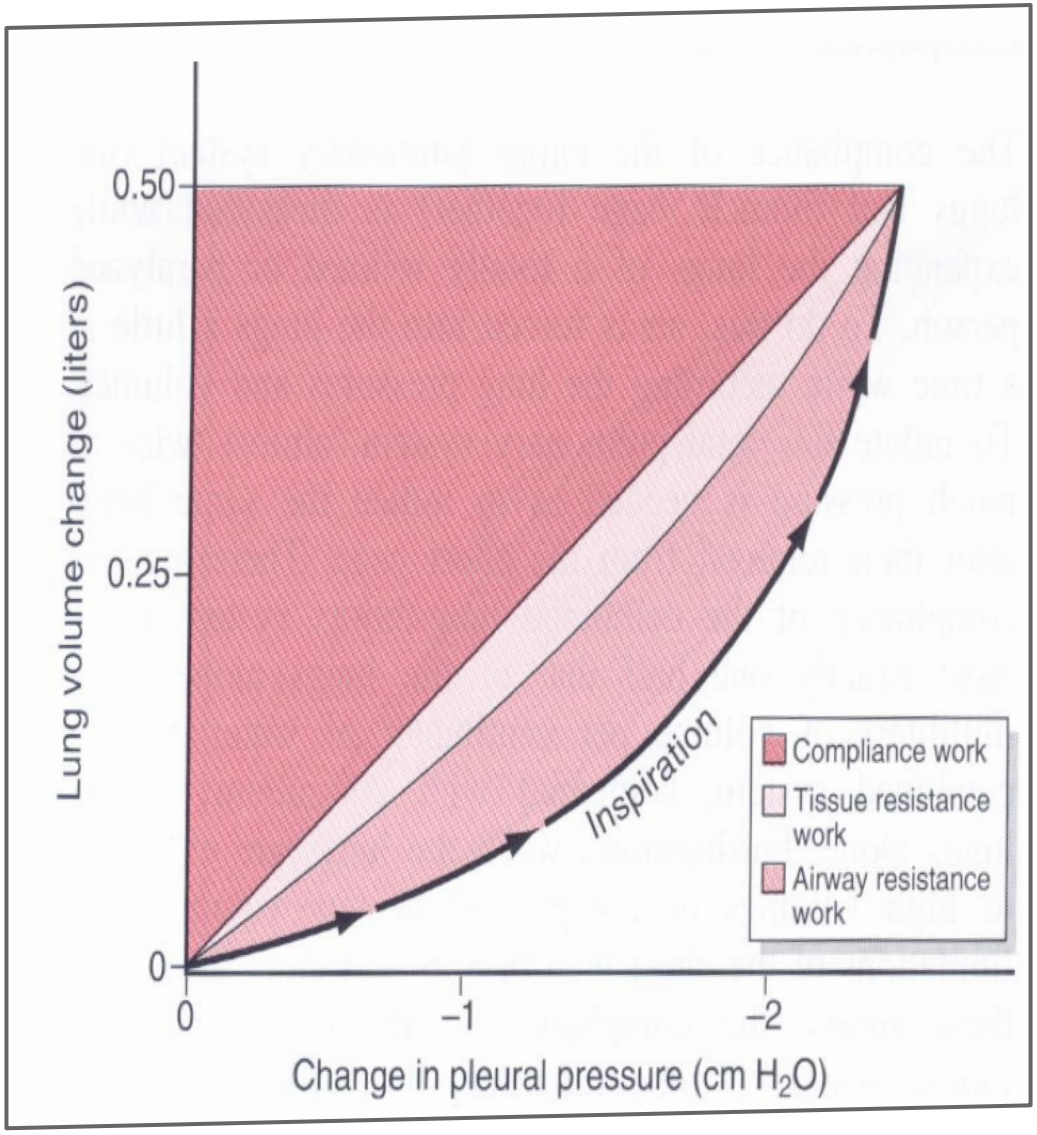
جالس يوضح العلاقة بين الLung volume و Transpulmonry pressure و هذا إيش ؟ الـ compliance

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%)



Energy required for respiration

3-5% of total energy expended by the body.

During pulmonary diseases all the three types of work are increased

Can be increased to 50 folds during heavy exercise especially if the person has a degree of increased airway resistance or decrease pulmonary compliance

One of the major limitation on the intensity of exercise that can be performed is the person's ability to provide enough muscle energy for the respiratory process alone

Extra information: (we advise you to read it after studying the lecture)

At rest: you're not breathing, yet.
The lung's recoil (elasticity) is forcing the alveoli to shrink (collapse).
The intrapleural pressure (about -5 cmH2O) will apply a force in the opposite direction in order to reach equilibrium.
the alveoli is connected to the atmosphere, so its pressure is equal to the atmospheric pressure. (We don't like big numbers so we say that Patm is equal to 0)

Inspiration:
The diaphragm contracts. The intrapleural pressure decreases to -8 — -7.5. The alveoli expand because the force acting outward (pressure) is greater than the force acting inward (recoil).
Remember Boyle's law? Yeah highschool… Increased volume causes a decrease in pressure in the alveoli.
The pressure changes from 0 to -1.
Air flows from the atmosphere (greater pressure) to alveoli (Less pressure). This is when we have the greatest amount of flow into the lungs.

At the END OF INSPIRATION (not expiration) , Air stops flowing. That's because pressure in the alveoli is equal to atmospheric pressure.
The pressure is back to 0.

Expiration:
The diaphragm relaxes. The intrapleural pressure rises back to -5 cmH2O. The Alveoli shrinks (Again, Boyle's law) the pressure in the alveoli increases to +1 because of the lungs recoil (elasticity). Air flows out to the atmosphere.
Remember: Elasticity & Alveolar pressure at each step.

Thanks to 438 physiology team

Summary

Lung volume depends upon movement of diaphragm & ribs.
Normal expiration is a passive process while forceful expiration is an active process.

The intra-alveolar pressure is zero (between breaths), -1 (during inspiration) and +1 (during expiration)
The intrapleural pressure is negative at resting position and becomes more negative at resting inspiration
The transpulmonary pressure = alveolar pressure - pleural pressure

compliance of lung(CL) refers to the lung expanding (increase in the transpulmonary pressure), it can be determined by the elastic forces of the lungs. (CL) is reduced by (pulmonary fibrosis, edema, kyphosis...), and increased by emphysema.

Energy required for respiration represents 3-5% of the whole energy expended by the body
It can be increased to 50 folds during heavy exercises .

Quiz

1-Which one of the following pressures affect respiration ?

A. Alveolar pressure
B. Transpulmonary pressure
C. Atmospheric pressure
D. All of them

2-Which of the following statements is true?

A) The change in the volume of the lungs with pressure is a measure of their compliance

B)The total compliance of the chest is determined solely by the compliance of the lungs

C) The recoil of the lungs assists inspiration

D) Pulmonary surfactant maintains a constant low surface tension in the alveoli

- **Key Answers :** 1-D,2-A,3-D,4D

Helpful quiz from 436 physiology team

3. A preterm infant has a surfactant deficiency. Without surfactant, many of the alveoli collapse at the end of each expiration, which in turn leads to pulmonary failure. Which set of changes is present in the preterm infant compared with a normal infant?
Alveolar Surface Tension - Pulmonary Compliance

A) Decreased - Decreased
B) Decreased - Increased
C) Decreased- No change
D) Increased - Decreased

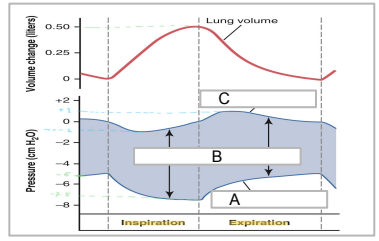
4-Contraction of the abdominal muscles is important in

A. Normal (quiet) inspiration.
B. Forced (maximum) inspiration
C. Normal (quiet) expiration
D. Forced (maximum) expiration.

SAQs

1- why pleural pressure is negative?

2- identify the letters.



Answers

1-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.

2- A(intrapleural pressure)

B(transpulmonary pressure)

C (intra-alveolar pressure)

Team leaders :

TeiF Almutiri

Abdulaziz Alkraida

Team Members

- Mishal Althunayan
- Basel Fakeeha
- Ibrahim altamimi
- Abdulaziz Alsuhaim
- Mohammad Alkatheri
- Basam alasmari
- Morshed Alharbi
- Ahmad Al Khayat
- Mohamed alquhidan
- Nawaf alghamdi
- Raed alntaifi
- Mishal alhamed
- Musab alamri
- Fayez altbaa
- Khalid altowijeri
- Mohammed alsalman
- Renad Alhomaidi
- Aseel alshehri
- Noura abdulaziz
- Yasmin Al Qarni
- Alaa Alsulmi
- Farah Albakr
- Muneerah alsadhan
- Sarah alobaid
- Farrah alsaid
- Noura almsaud
- Hessah alalyan
- Rema alhdleg
- Raghad alsweed
- Raghad asiari
- Ghadah alouthman
- Haya alanazi
- Asma alamri
- Rania Almutiri
- Yara alasmari

Reviewed by

- Ghadah alouthman
- homoud Algadheb

Contact us