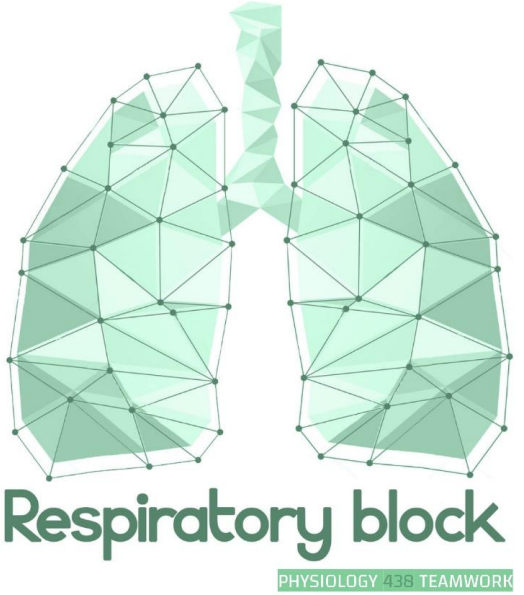
Mechanics of breathing



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

Editing file

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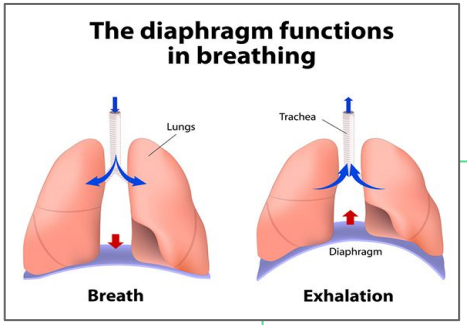
Objectives

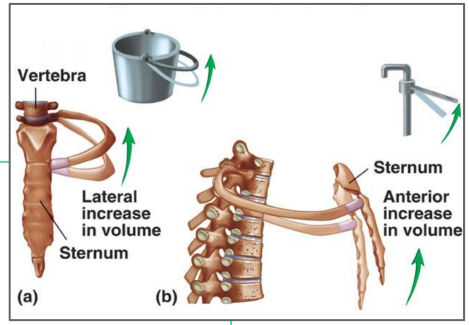
1. List the muscles of respiration and describe their roles during inspiration and expiration.
2. Identify the importance of the following pressures in respiration: atmospheric, intra-alveolar, intrapleural, and transpulmonary.
3. Explain why intrapleural pressure is always subatmospheric under normal conditions, and the significance of the thin layer of the intrapleural fluid surrounding the lung.
4. Define lung compliance and list the determinants of compliance.

Male's slides only

lungs can be expanded and contracted:



downward and upward movement of the diaphragm to lengthen or shorten the chest cavity

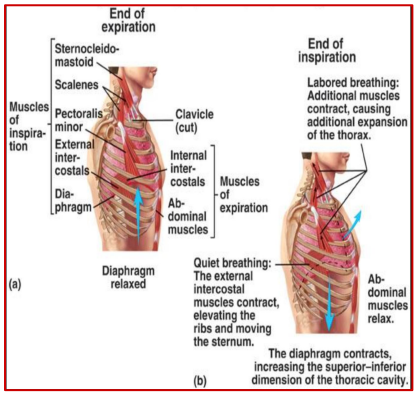


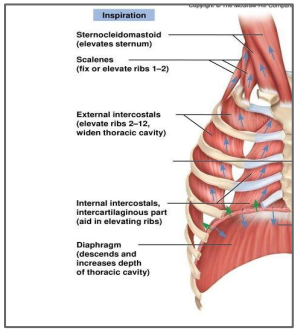
by elevation and depression of the ribs to increase and decrease the anteroposterior diameter of the chest cavity

Respiratory muscles:

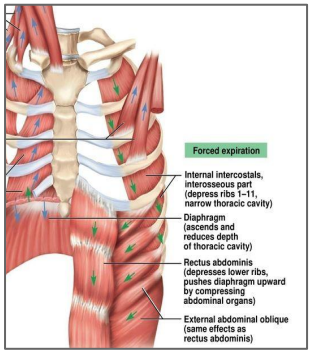
- Inspiratory muscles
  (resting- forced)
- Expiratory muscles
  (forced expiration- muscles that depress the rib cage)

★





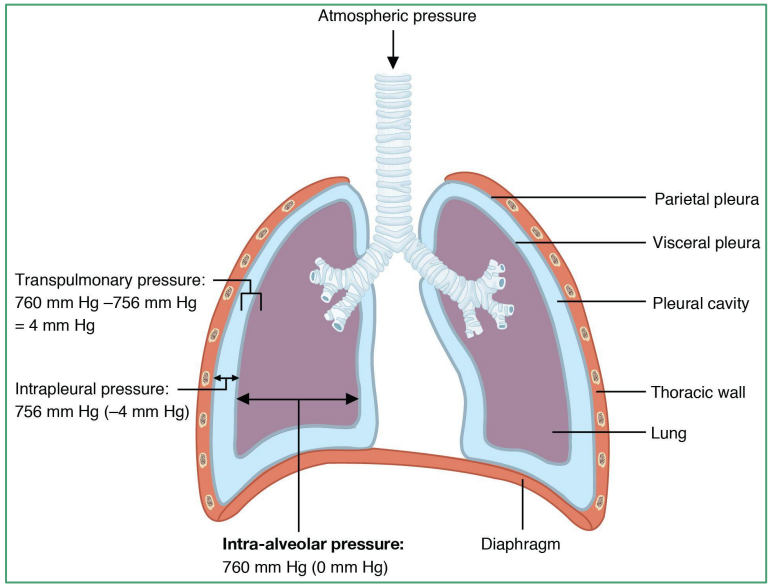
respiratory muscles



Inspiratory muscles	Expiratory muscles
- During resting inspiration, the muscles are 1- diaphragm 2- external intercostals.	Resting expiration is a passive process that depends on the recoil tendency of the lung and needs no muscle contraction.
- During forced inspiration the Accessory muscles of inspiration participate to increase size of the thoracic cavity	However, forced expiration is active and need contraction of the 1- Abdominal muscles . 2- internal intercostal muscles.
e.g/ •Sternocleidomastoid – elevate sternum • Scalene – elevate first two ribs • Pectoralis minor – elevate 3rd-5th ribs also, anterior serratus contract in addition to muscles of resting inspiration.	Muscles of exhalation increase pressure in abdomen and thorax

Pressure changes in the lungs during breathing

Air will flow from a region of high pressure to one of low pressure-- the bigger the difference, the faster the flow



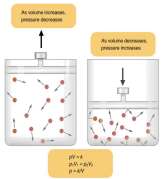
Extra information: (we advise you to read it after studying the lecture)

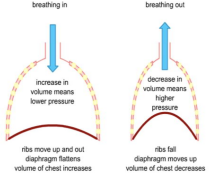
At rest: you're not breathing, yet.
The lung's recoil (elasticity) is forcing the alveoli to shrink (collapse).
The intrapleural pressure (about -5 cmH2O) will apply a force in the opposite direction in order to reach equilibrium.
the alveoli is connected to the atmosphere, so its pressure is equal to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

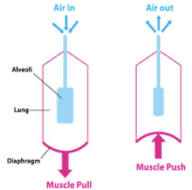
Inspiration:
The diaphragm contracts. The intrapleural pressure decreases to -8 — -7.5. The alveoli expand because the force acting outward (pressure) is greater than the force acting inward (recoil).
Remember Boyle's law? Yeah highschool… Increased volume causes a decrease in pressure in the alveoli.
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 ON 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.



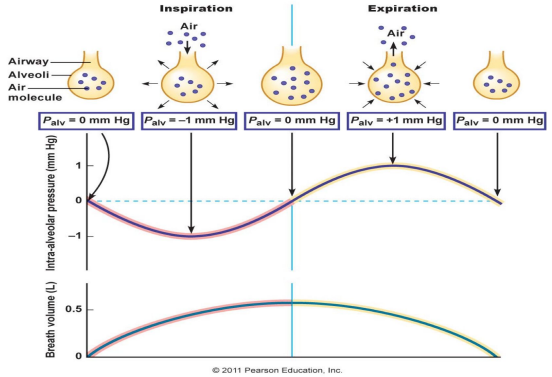




Intra-alveolar

During inspiration	end of inspiration	Between breathes	During expiration
= (-1 mmHg)	= zero	= zero (760 mmHg)	= (+1 mmHg)
air (tidal volume) flows from outside to inside the lungs.	air flow stops.		air flows out of the Lungs

Relation between Intra-alveolar pressure and lung volume

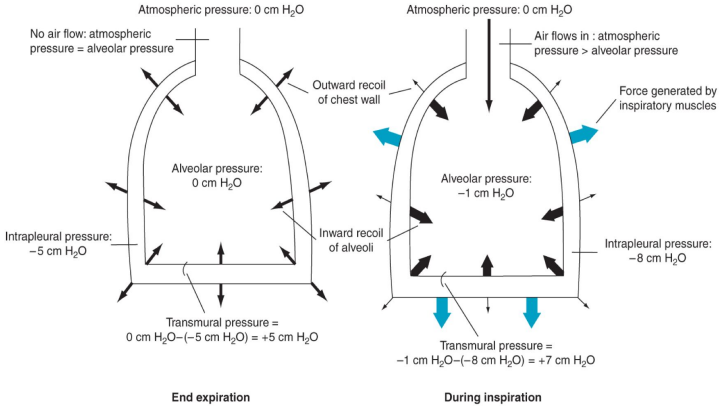


From Linda

The volume of air inspired in one breath is the **tidal volume (TV)**, which is approximately **0.5 L**. Thus, the volume present in the lungs at the end of normal inspiration is the functional residual capacity plus one tidal volume.

(We will go with the details in next lectures so don't worry and just know TV mean)

★



If diaphragm and external intercostal muscle contract they will produce space for air and the pressure will decrease by 1 mmHg (-1 mmHg = 759 mmHg) "the volume increase"

Because of the difference of the pressure between the intra-alveolar and atmospheric pressure the air will **enter** the lungs (inspiration)

The opposite thing is correct for expiration except that the intra-alveolar pressure will increases by 1 (+1 mmHg= 761 mmHg) which makes the air **move out** of the lungs

Intrapleural pressure (IPP)

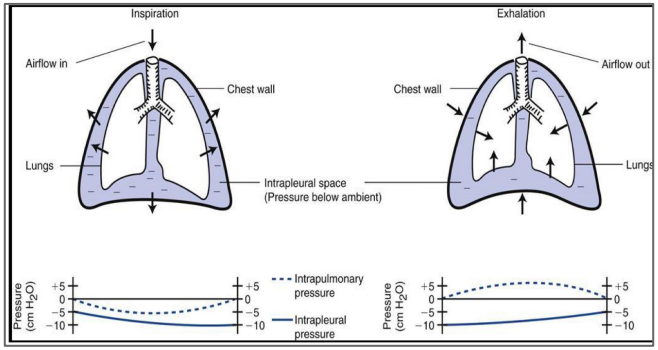
Pressure in the pleural space is negative with respect to atmospheric pressure at the end of normal expiration (-5 cmH_2O).

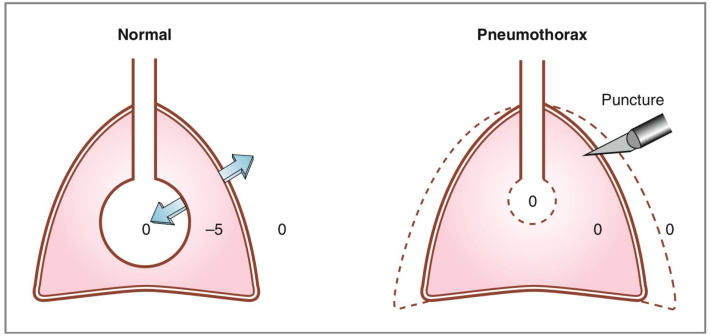
- **Why negative??:**

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) due to continuous suction of fluids by lymphatic vessels.

3- Gravity: because the gravity try to pull pleural downward.

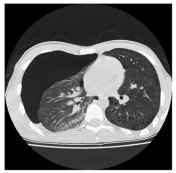




- During resting position between breathes it = (-5) cm H_2O.
- During resting inspiration it becomes more -ve (-7.5) cm H_2O.
- **Forced ventilation**

Insp.: -20 to - 40 cm H_2O

Exp.: + 30 cm H_2O



CT scan for pneumothorax (collapsing lung)

From Linda

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.

If someone got stabbed in the pleural space the lung will collapse because of the pressure differences between intrapleural pressure and atmospheric pressure and the air will move **in** to pleural space causing problems

Transpulmonary pressure (TPp) = (Extending Pressure)

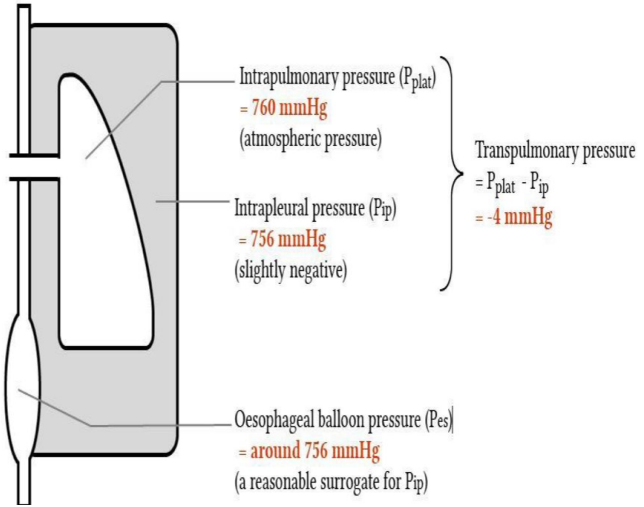
• The difference between the alveolar pressure (Palv) and the pleural pressure(Ppl).

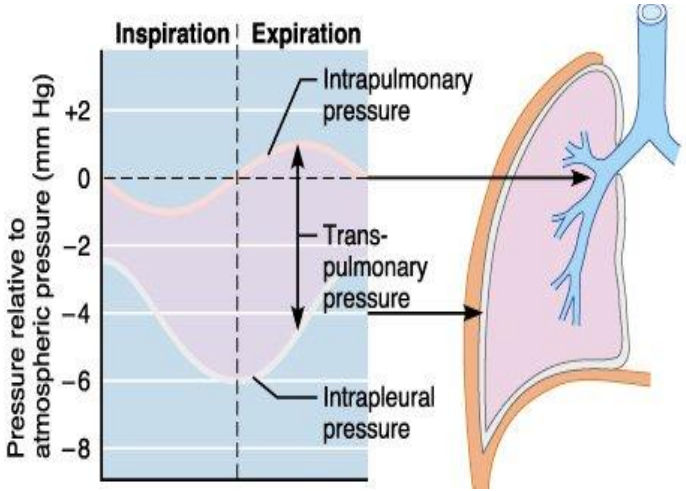
TPp = Palv-Ppl

• It is a measure of the elastic forces in the lungs that tend to collapse the lungs (the recoil pressure).

During rest (end expiration)
Palv=0 and ppl= -5 , so TPp= 0- (-5)= +5 mmHg
During inspiration
Palv=-1 and ppl= -7.5 , so TPp= -1 - (-7.5)= +6.5 mmHg
So, we conclude that As lung **volume increases**,the transpulmonary pressure increases too

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





Summary

The atmospheric pressure is 760 mmHg

Pressure	During rest	During inspiration	During expiration
Intra-alveolar pressure	(0 mmHg) 760 mmHg	(-1 mmHg) 759 mmHg	(+1 mmHg) 761 mmHg
Intrapleural pressure	(-5 mmHg) 755 mmHg	(-7.5 mmHg) 752.5 mmHg	(just for your information) -6.5 mmHg according to Linda
Transpulmonary pressure **TPp = Palv-Ppl**	TPp= 0- (-5)= +5 mmHg	TPp= -1 - (-7.5)= +6.5 mmHg	(just for your information) TPp= +1 -(-6.5)= +7.5 mmHg

pressure and volume relationships in a single respiratory cycle

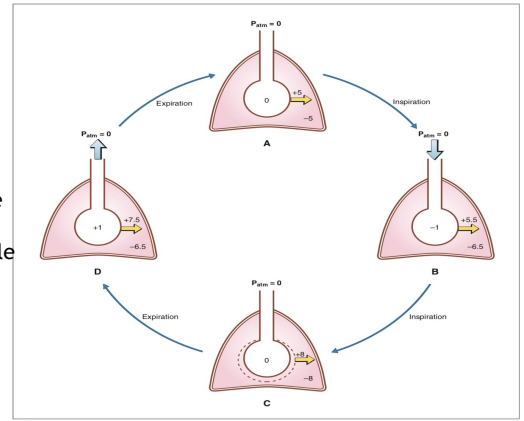


Figure 5-14 Pressures during normal breathing cycle. The numbers give pressures in cm H_2O relative to atmospheric pressure (P_{atm}). The numbers over the yellow arrows give the magnitude of transmural pressures. The *wide blue arrows* show airflow into and out of the lungs. **A**, Rest; **B**, halfway through inspiration; **C**, end of inspiration; **D**, halfway through expiration.

From Guyton

The lung is an elastic structure that collapses like a balloon and expels all its air through the trachea whenever there is no force to keep it inflated. Also, there are no attachments between the lung and the walls of the chest cage, except where it is suspended at its hilum from the mediastinum, the middle section of the chest cavity. Instead, the lung "floats" in the thoracic cavity, surrounded by a thin layer of pleural fluid that lubricates movement of the lungs within the cavity.

Compliance of the lung (CL)

It is the response of the lung to the pressure applied on it

Is defined as, the ratio of the change in the lung volume produced per unit change in the distending pressure.

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

$$CL = \frac{(\Delta V)}{(\Delta P)}$$

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

So, Cl is directly proportional to the volume, and inversely proportional to the pressure.

For both lungs in adult = 200 ml of air/cm H_20.

For lung alone without chest and ribs

For lungs and thorax together = 110 ml/cm H_20.

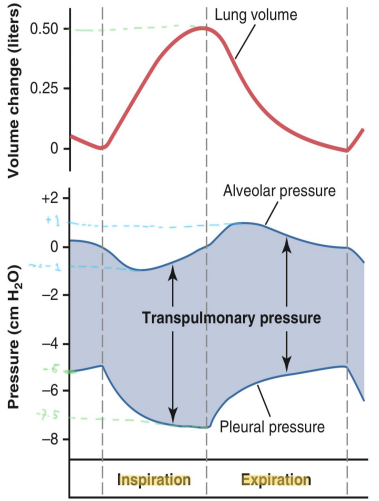


Figure 38-2. Changes in lung volume, alveolar pressure, pleural pressure, and transpulmonary pressure during normal breathing. Intrapleural pressure = pleural pressure (difference between slides and Guyton)

E.g. two rubber bands, thin and thick. The thin rubber band easily stretched, and is very distensible and compliant. The thick rubber band difficult to stretch and is less distensible and compliant.

Compliance of the lung (CL)

Female's slides only

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

(1) 1/3 is due to elastic forces of the lung tissue itself via elastin (collagen): is a highly elastic protein in connective tissue and allows many tissues in the body to resume their shape after stretching or contracting.

(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. (because of this we said surfactant is important)

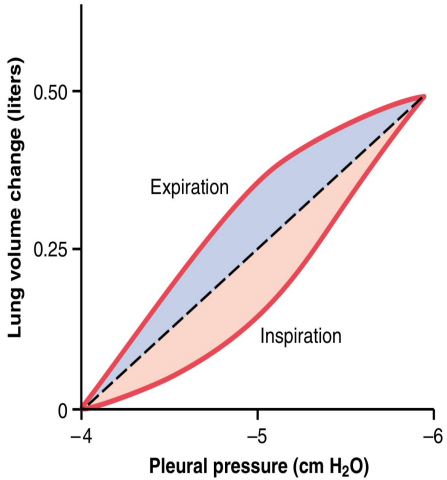


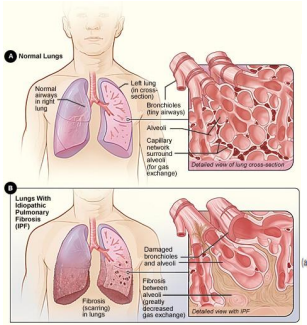
Figure 37-3 Compliance diagram in a healthy person. This diagram shows compliance of the lungs alone.

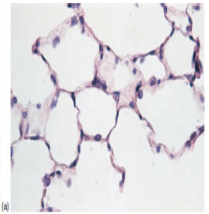
Diseases that affect compliance of lung

Lung compliance is **reduced**

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

destruction of elastic fibers **with** replacement of fibrous tissue (fibrosis)
Fibrosis is not as flexible as elastin, so the compliance will decrease





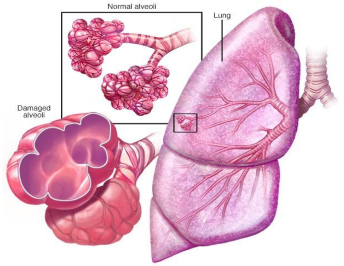
Lung compliance is **increased**

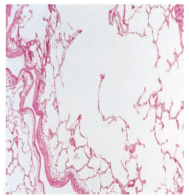
- Emphysema

Cause: it destroys the alveolar septal tissue rich with elastic fibers that normally opposes lung expansion

In these diseases destruction of elastic fibers **without** replacement.

Usually infect chronic smokers

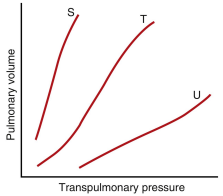




Quiz

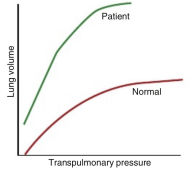
You don't understand why we chose those answers? Click here to read the explanations

1-The figure 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

2- The volume-pressure curves in the figure were obtained from a normal subject and a patient with a pulmonary disease. Which abnormality is most likely present in the patient?



A. Asbestosis
B. Emphysema
C. Mitral obstruction
D. Silicosis

3-A healthy, 25-year-old medical student participates in a 10-kilometer charity run for the American Heart Association. Which muscles does the student use (contract) during expiration

A. Diaphragm and external intercostals
B. Diaphragm and internal intercostals
C. Diaphragm only
D. Internal intercostals and abdominal recti

4-The pleural pressure of a normal 56-year-old woman is approximately −5 cm H_2O during resting conditions immediately before inspiration (i.e., at functional residual capacity [FRC]). What is the pleural pressure (in cmH_2O) during inspiration?

A. −7
B. +4
C. -3
D. +1

5- 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.	Increased	Decreased
C.	Unchanged	Increased
D.	Increased	Unchanged

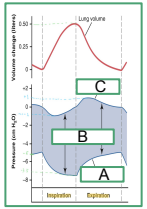
6- A 22-year-old woman has a pulmonary compliance of 0.2 L/cm H_2O and a pleural pressure of −4 cm H_2O. What is the pleural pressure (in cm H_2O) when the woman inhales 1.0 liter of air?

A. −6
B. −7
C. −8
D. −9

SAQ

1- why pleural pressure is negative?

2- identify the letters.



Answers

1- A- 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.

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

2- A(intrapleural pressure)

B(trans pulmonary pressure)

C (intra-alveolar pressure)

Key answers:

1-D 2-B 3-D 4- A 5-B 6-D

TEAM LEADERS

Elaf Almusahel

Omar Alshenawy

TEAM MEMBERS

Done by:

- Arwa Al Emam
- Deema almaziad
- May Babaeer
- Njood alali
- Noura Almazrou
- Noura Alturki
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