Functional Organization of Respiratory System

Editing File

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

Special Thanks to Hasan Alsughayir for the Sketch <3

Male Dr: Ahmed Alsobeah
Female Dr: Aida Korish

Objectives

01 Discuss the functions of the respiratory system, including non-respiratory functions, like the metabolic functions, the protective functions like clearance mechanism by mucus and cilia, the production of surfactant and its physiological significance.

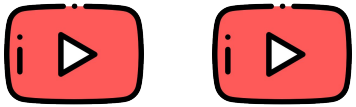
02 Describe the structures and functions of the conductive and respiratory zones of airways.

03 Distinguish the difference between internal and external respiration.

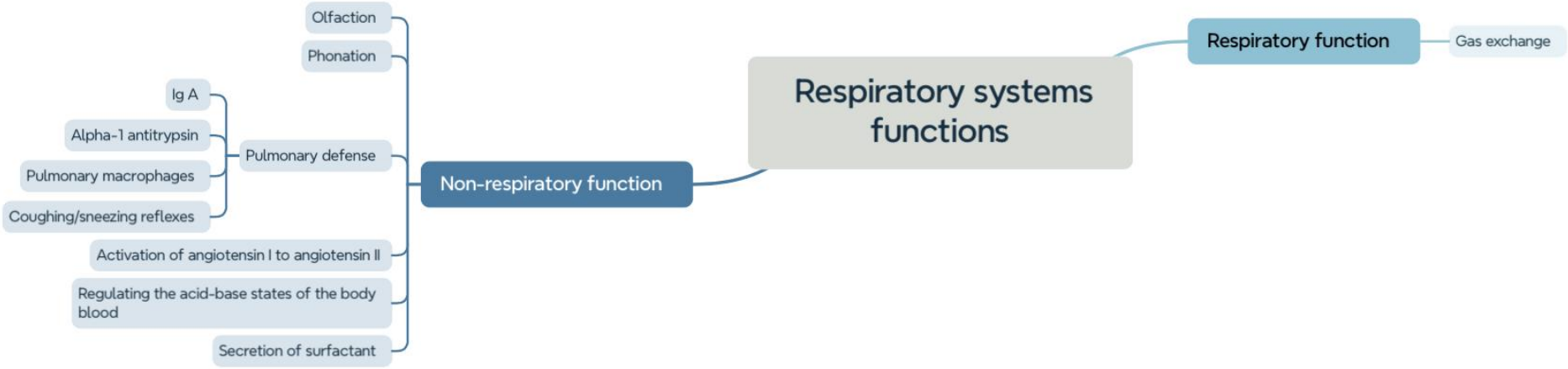
04 Identify the cells lining the alveoli and discuss their functions and the concept of surface tension.

05 Identify the innervation of the respiratory passages and the determinants of airway resistance.

Helpful videos from Ninja nerd



Functions of the Respiratory System



Functions of the Respiratory System

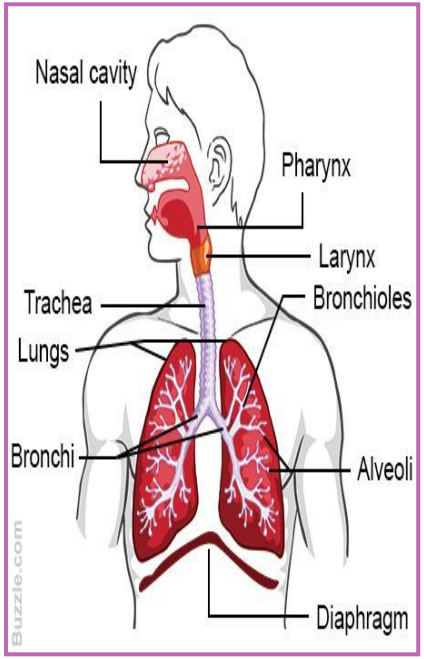
- **Respiratory function:**
  The main function is to provide O2 to the tissues and remove CO2 through : **gas exchange.**

- **Non respiratory functions:**

1- Olfaction: sense of smell by the receptors in roof of nose.

2- Phonation: is the production of sounds by the movement of air through the vocal cords.

3- Regulating the acid-base status of the body by washing out extra carbon dioxide from the blood.



Pulmonary: related to the lungs

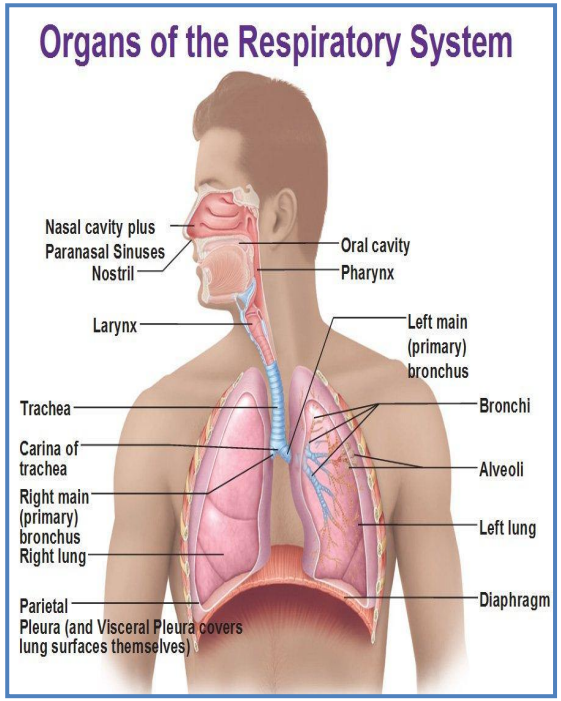
Cont on Functions of the Respiratory System

4- Pulmonary defense: The respiratory mucous membrane has muco-ciliary barrier filter and it secretes:

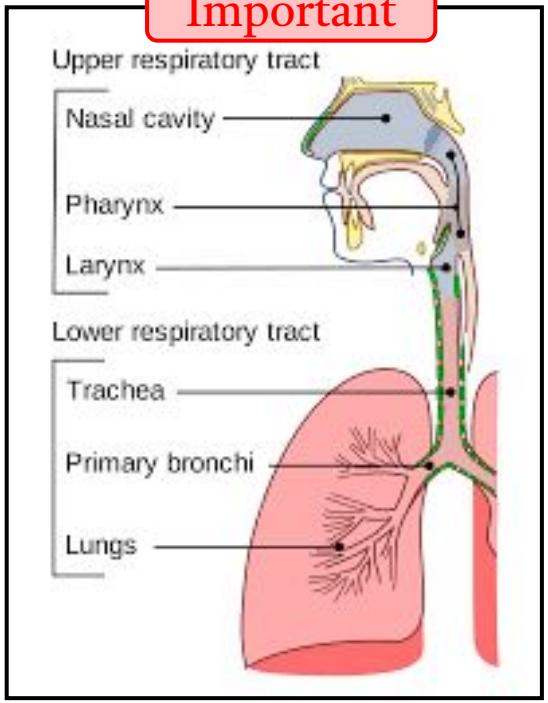
- Immunoglobulin A (IgA) .
- Alpha-1 antitrypsin (protects the lungs from the action of trypsin, elastases, proteases secreted by the bacteria) (Trypsin -> Breaks down proteins of the lung)
- The pulmonary macrophages in the alveoli: engulf smaller foreign particles which pass through the mucociliary barrier filter.
- Cough reflex: initiated by slight foreign matter irritation of bronchi and trachea. -
- Sneezing reflex: like the cough reflex, it applies to the nasal passageways instead of the lower respiratory passages.

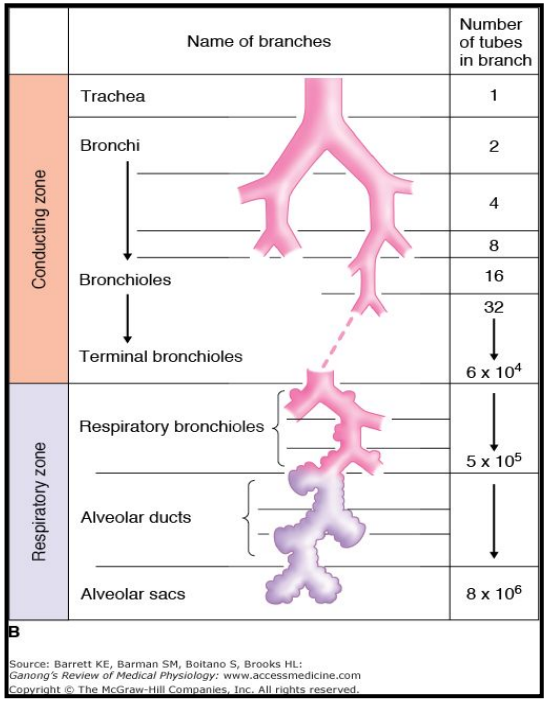
5- Activation of Angiotensin I to angiotensin II with the help of angiotensin converting enzyme (ACE) formed by the lungs. **Angiotensin:** blood pressure regulator.

6- Secretion of important substances like surfactant.


Organs of the Respiratory System
Nasal cavity plus
Paranasal Sinuses
Nostril
Oral cavity
Pharynx
Larynx
Left main
(primary)
bronchus
Trachea
Bronchi
Carina of
trachea
Alveoli
Right main
(primary)
bronchus
Right lung
Left lung
Parietal
Pleura (and Visceral Pleura covers
lung surfaces themselves)
Diaphragm

Important


Upper respiratory tract
Nasal cavity
Pharynx
Larynx
Lower respiratory tract
Trachea
Primary bronchi
Lungs


Name of branches
Number of tubes in branch
Conducting zone
Trachea
1
Bronchi
2
4
8
Bronchioles
16
32
Terminal bronchioles
6 x 10^4
Respiratory zone
Respiratory bronchioles
5 x 10^5
Alveolar ducts
Alveolar sacs
8 x 10^6
B
Source: Barrett KE, Barman SM, Boitano S, Brooks HL:
Ganong's Review of Medical Physiology: www.accessmedicine.com
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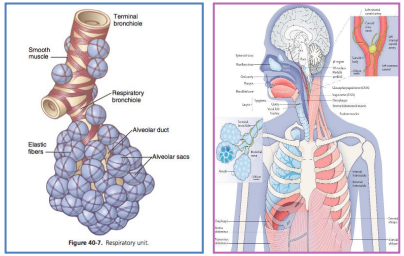
Organization of the Respiratory System

Respiratory system anatomically consists of:

1-Respiratory Passages (airways)

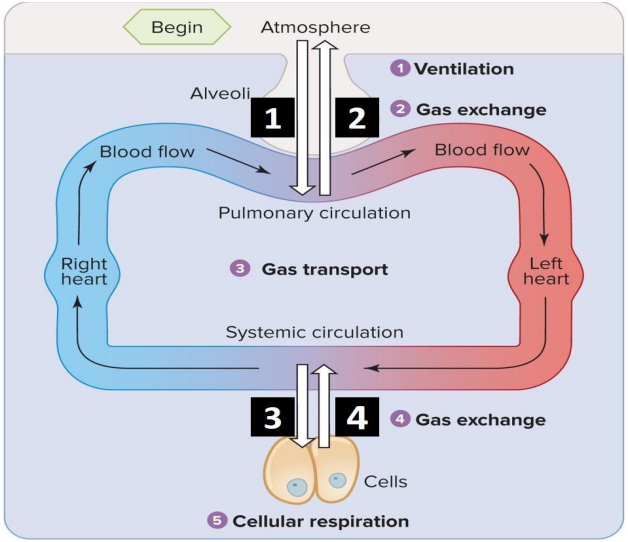
2-Respiratory Muscles

3-Respiratory Control Centers

zone	Conductive Zone (no gas exchange)	Respiratory Zone (Respiratory unit)
Contents of the zone	Starts from nose trachea to the end of terminal bronchioles.	Includes: Respiratory bronchioles, alveolar ducts, alveolar sacs, alveoli
Functions	- Help warming, humidification, filtration of inspired air. -Contains the olfactory receptors for smell sensation -Conducts the sound during speech. - Protective function by cough and sneezing reflexes.	gas exchange. 

External and Internal Respiration

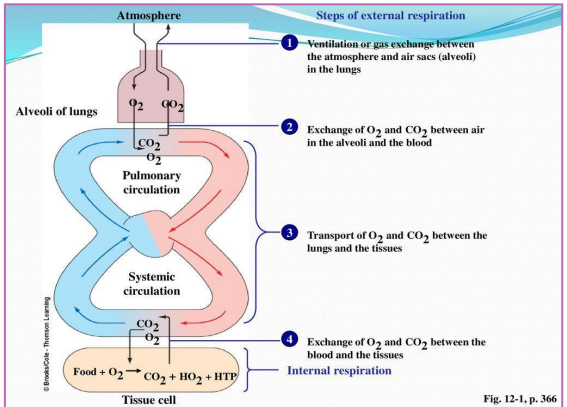
External respiration (level of the lung)	Internal Respiration (level of the cell)
(Gas exchange at the level of the alveoli), between the air in the alveoli and the blood in the pulmonary capillaries). Involves the absorption of O2 and removal of CO2 from the body as a whole.	The intake (utilization) of O2 by the tissue cells and the production of CO2 (gas exchange at the level of the tissues).

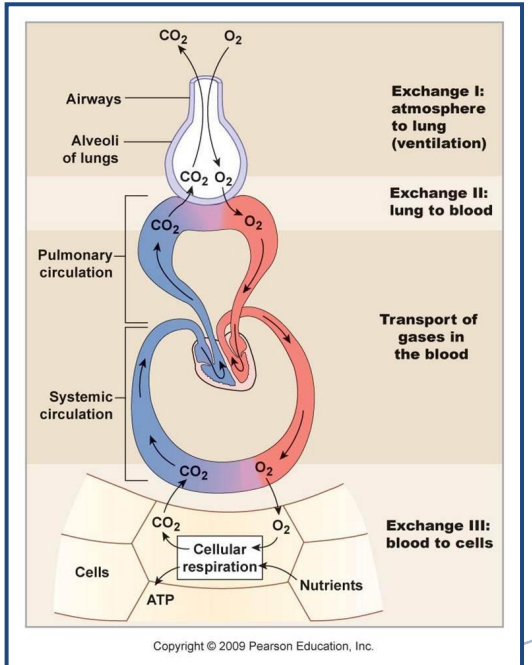


💡 Extra Info from 443:
Pulmonary artery is the only artery that contains deoxygenated blood because it's a continuation of the venous circulation.
A: 1st point of gas exchange in alveoli → external.
B: 3rd point of gas exchange in tissues → internal.

Major Functional Events During Breathing

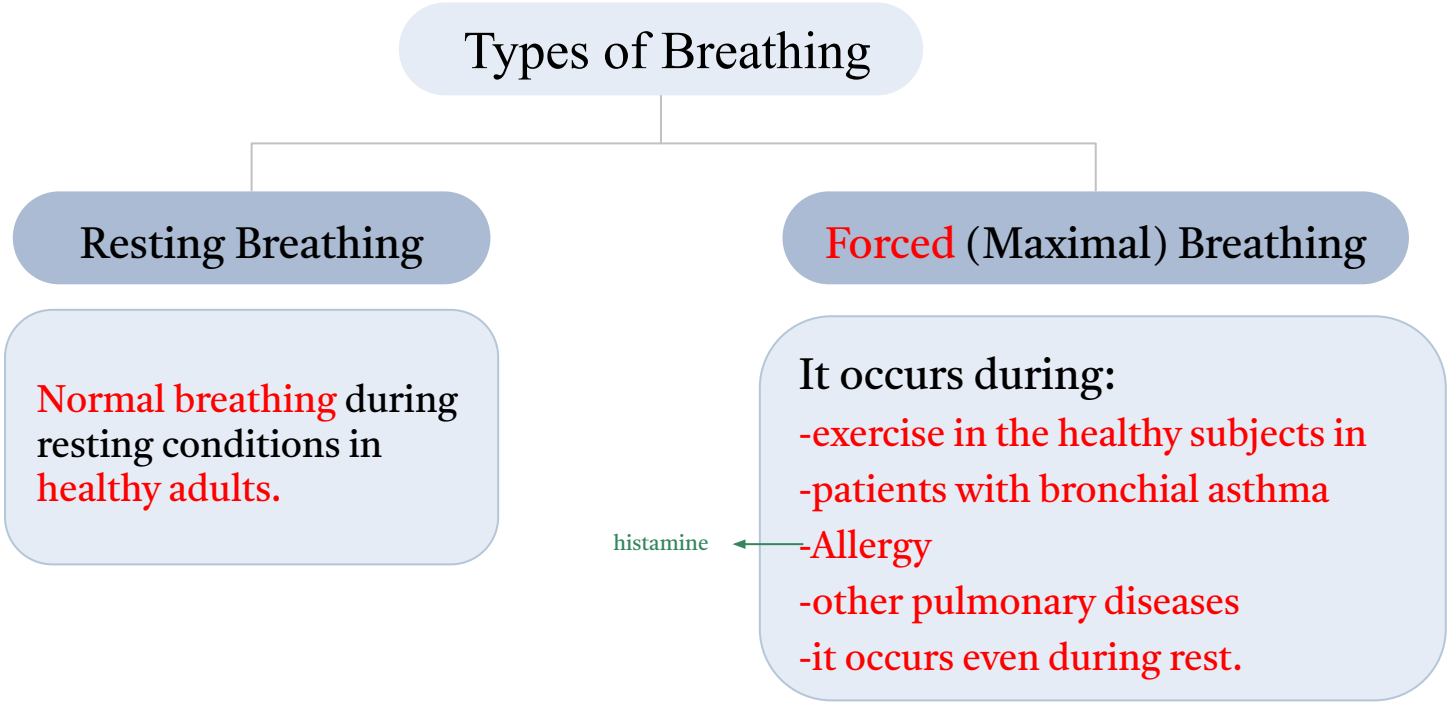
1- Pulmonary ventilation. *L2*
2- Diffusion of O2 and CO2 between the alveoli and the blood. *L4*
3- Transport of oxygen(O2) and carbon dioxide(CO2) in the blood and body fluids to and from the body's tissue cells. *L5*
4- Regulation of ventilation Control of breathing. *L8*





Types of Breathing

Respiration (breathing) could be described as either:



cells in alveoli

in short, Type I do the main job of gas exchange and take up the majority of surface area, Type II and macrophages maintain the alveoli by surfactant and phagocytosis of dust particles, bacteria and foreign bodies

Type 1 Alveolar epithelial cells

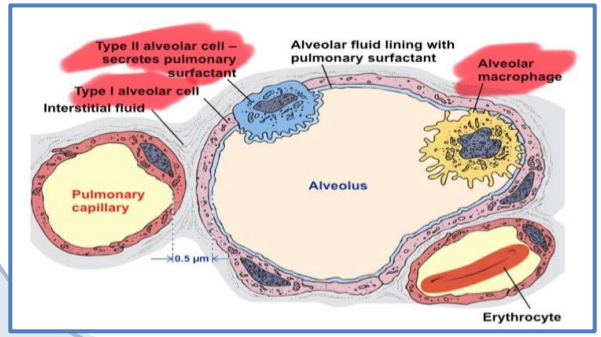
Type I pneumocytes: Participate in the respiratory membrane , across which gas exchange takes place.

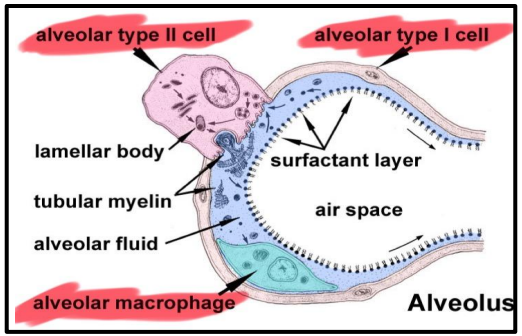
Type 2 Alveolar epithelial cells

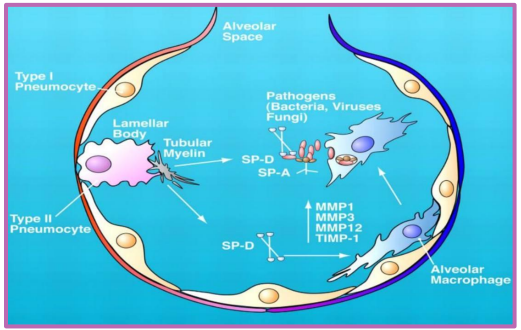
Type II pneumocytes: 10% of the surface area of alveoli, secrete surfactant

Alveolar Macrophages: Engulf the foreign bodies that reach the alveoli

surfactant decreases surface tension between particles of water in the alveoli, which helps in stopping the lung from collapsing







Innervation of Lungs and Bronchi

- Is by autonomic nerves.

Parasympathetic	Sympathetic
Parasympathetic stimulation releases acetylcholine -> causes Constriction of Bronchi. -Irritation of the epithelial membrane of respiratory passages by noxious gases / dust / cigarette smoke / bronchial infection irritate epithelial membrane of respiratory passageways → activates parasympathetic nerves to cause parasympathetic constrictor reflex, they may also act directly on the lung tissue to initiate local, non-nervous reactions that cause obstructive constriction of the airways. . - Bronchiolar Constrictor reflex -> when Micro emboli occlude small pulmonary arteries	Sympathetic stimulation releases epinephrine (adrenaline) -> causes dilation of the Bronchi.

Local secretory factors: Histamine, Slow reacting substances of Anaphylaxis (SRSA) released due to Allergy (e.g. asthma) → mast cells secrete them (local secretory factors) → bronchiolar constriction + increased airway resistance → forced breathing.

Thanks to 443 team!

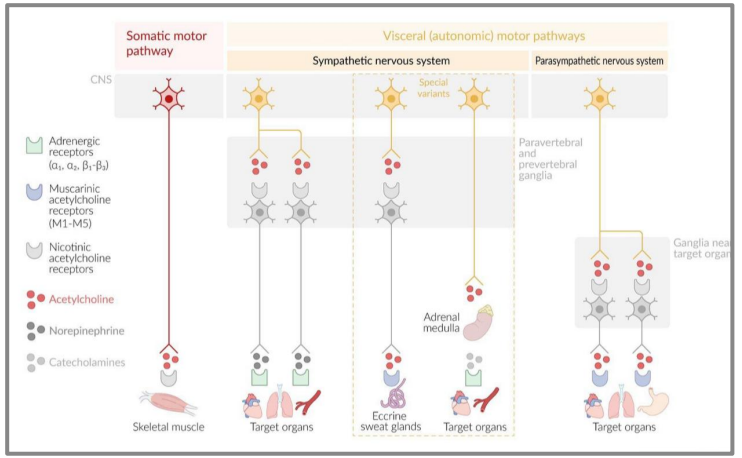
Extra

💡 Info from linda

The walls of the conducting airways contain smooth muscle. This smooth muscle has both **sympathetic** and **parasympathetic** innervations, which have opposite effects on airway diameter:

(1) Sympathetic adrenergic neurons activate β2 receptors on bronchial smooth muscle, which leads to relaxation and dilation of the airways. In addition, and what is more important, these β2 receptors are activated by circulating epinephrine released from the adrenal medulla and by β2-adrenergic agonists such as isoproterenol.

(2) Parasympathetic cholinergic neurons activate muscarinic receptors, which leads to contraction and constriction of the airways.
Changes in diameter of the conducting airways result in changes in their resistance, which produce changes in air flow.
Thus the effects of the autonomic nervous system on airway diameter have predictable effects on airway resistance and air flow. The most notable effects are those of β2-adrenergic agonists (e.g., epinephrine, isoproterenol, albuterol), which are used to dilate the airways in the treatment of asthma.



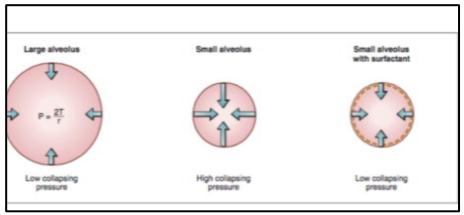
Surface Tension

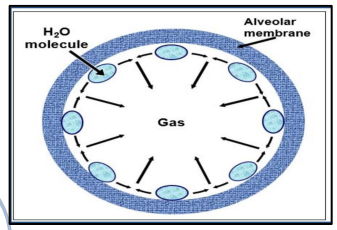
1. H_2O molecules at the surface of alveoli are attracted to each other by attractive forces that resist distension called: surface tension(التوتر السطحي).
2. Surface tension tends to oppose alveoli expansion(so it is a factor which collapses the lung).
3. Pulmonary surfactant reduces the surface tension of the fluid lining the alveoli(surfactant decreases surface tension therefore stopping lung collapse).
4. **Collapsing Pressure** is Caused by Surface Tension (of the fluid lining the alveoli) and is indirectly related to the size of alveoli (represented in the following equation)

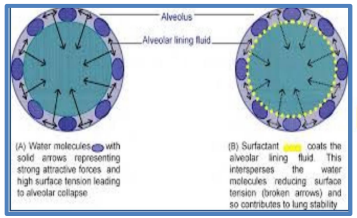
Important

(Law of Laplace)

$$\text{Collapsing pressure} = \frac{2 \times \text{surface tension}}{\text{radius of the alveolus}}$$







different way of explaining from costanzo 6th ed. page 202

Surface Tension of Alveoli

The small size of alveoli presents a special problem in keeping them open. This "problem" can be explained as follows: Alveoli are lined with a film of fluid. The attractive forces between adjacent molecules of the liquid are stronger than the attractive forces between molecules of liquid and molecules of gas in the alveoli, which creates a **surface tension.** As the molecules of liquid are drawn together by the attractive forces, the surface area becomes as small as possible, forming a sphere (like soap bubbles blown at the end of a tube). The surface tension generates a pressure that tends to collapse the sphere. The pressure generated by such a sphere is given by the **law of Laplace**: and this problem is solved by surfactant which will decrease surface tension, more in the next slide

$$P = \frac{2T}{r}$$

Surfactant

What is it?

Surfactant is a complex compound containing phospholipids especially dipalmitoyl phosphatidylcholine (DPPC or also called lecithin) and a number of Apo proteins.

What is its job?

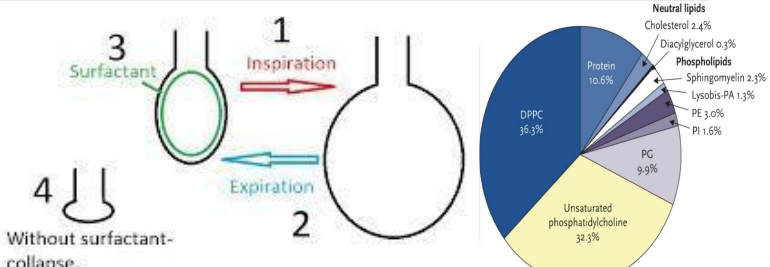
Surfactant reduces surface tension throughout the lung which causes the following:

1. reduces the effort required by the respiratory muscles to expand the lungs
2. prevents alveolar collapse
3. decreases airway resistance and decreases work of breathing.
4. Keeps the alveoli dry

💡Extra Info: so it prevents collapse and decreases workload of breathing

when (embryologically) does it start being made?

The earliest detection of surfactant in fetal alveoli begins between 6-7th month (24-28 Wk.) of intrauterine life, but could be delayed in others to wk. 35 of intrauterine life.



Surfactant Deficiency

What is it?

Surfactant Deficiency in premature babies causes respiratory distress syndrome of the newborn (RDS) (hyaline membrane disease).

How to fix this problem/disease

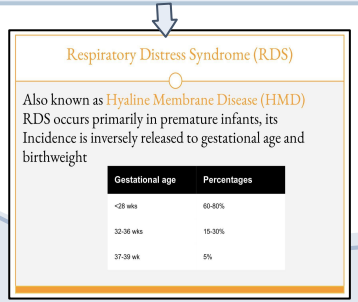
1. Prevention: Corticosteroid injection to the mothers **expected** to deliver prematurely. This will enhance the maturation of the baby surfactant.
2. Treatment: **After delivery the premature babies** are given inhaled surfactant. and continuous positive pressure breathing (PPB).

💡Extra Info: If the disease is Expected/possible then we call this prevention, if the disease the disease is guaranteed then we call it treatment

Risk factors

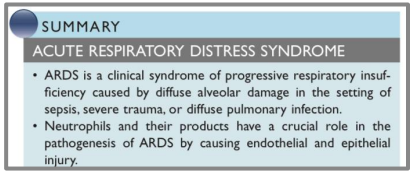
the following decrease the secretion of surfactant and cause adult respiratory distress syndrome (ARDS).

1. Smoking in adults
2. hypoxia(low tissue oxygen)/hypoxemia(low blood oxygen)



💡Extra Info: so causes of adult/acute respiratory distress syndrome in general are injury to the tissue leading to dysfunction (like smoking/lack of oxygen), quick disease summary from Robbins pathology 10th ed. page 497

i don't know why slides call it adult instead of acute, all sources call it acute, there is no "adult respiratory disease syndrome", also there is no mention of surfactant in robbins related to this diseases unlike RDS. ((DON'T Forget ARDS=/=RDS))



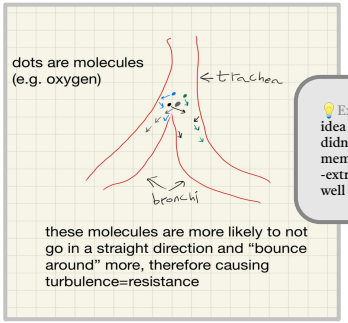
Resistance to Airflow in the Bronchial Tree

The greatest amount of resistance to airflow occurs in some of the:

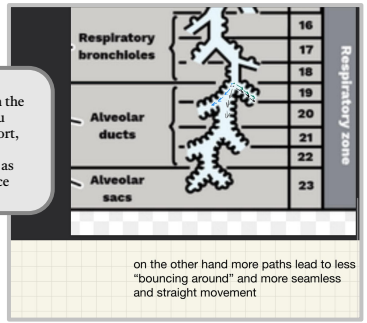
larger bronchioles

bronchi near the trachea

💡 The reason for this high resistance is that there are relatively few of these larger bronchi in comparison with the approximately 65,000 parallel terminal bronchioles.



💡Extra Info: these two images explain the idea behind the statement above (if you didn't get it just skip, not worth the effort, memorizing it is easier).
-extra reason from team 443 Dr. notes as well as to why trachea has less resistance



in some disease conditions, the smaller bronchioles play a far greater role in determining airflow resistance because of their small size and because they are easily occluded by:

1. Muscle contraction in their walls
2. Edema occurring in the walls
3. Mucus collecting in the lumens of the bronchioles.

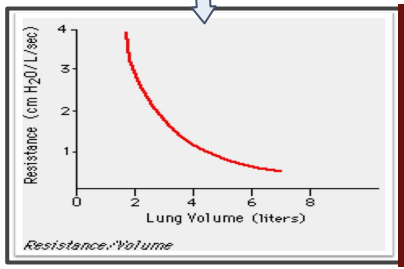
💡Extra Info: costanzo 6th ed. page 205

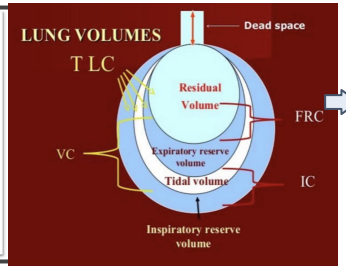
airway resistance. It would *seem* that the smallest airways would provide the highest resistance to air flow, based on the inverse fourth-power relationship between resistance and radius. However, because of their parallel arrangement, the smallest airways *do not* have the highest collective resistance. Recall that when blood vessels are arranged in parallel, the total resistance is less than the individual resistances and that adding a blood vessel in parallel decreases total resistance (see Chapter 4). These same principles of parallel resistances apply to airways.

- **Lung volume.** Changes in lung volume alter airway resistance, whereby decreased lung volume causes increased airway resistance (even to the point of airway collapse) and increased lung volume causes decreased airway resistance. One mechanism for the effects of lung volume involves the interdependence of alveoli—that is, alveoli tend to hold their neighbors open by radial traction or mechanical tethering. When alveoli are more inflated (higher lung volume), they pull on both adjacent alveoli and nearby bronchioles, pulling the bronchioles open and decreasing their resistance. Persons with asthma breathe at higher lung volumes and partially offset the high airway resistance of their disease (i.e., the volume mechanism helps to reduce airway resistance as a compensatory mechanism).

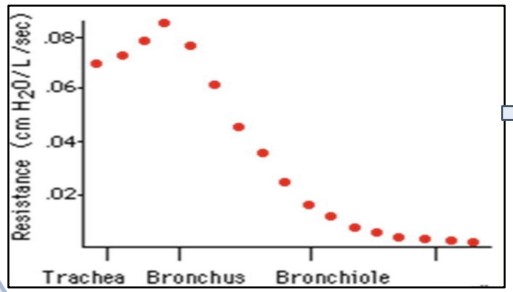
Resistance to Airflow in the Bronchial Tree

Airway resistance is inversely proportional to lung volume.
Airway resistance decreases as lung volume increase





443 note: Airway resistance is highest when the lung in resting positions and As low as possible when The long inflation يعني تكون الرئة أكبر ما يمكن



443 note:Airway resistance is lower in trachea than bronchi, why? Because trachea has more cartilaginous rings than bronchi that reduce contraction.

443:The resistance is higher in Bronchi than Terminal bronchioles, why? Bronchi has greater diameter but less branches and vice versa, therefore if we took the cross sectional area in comparison between the two bronchi would be approximately 2cm and Terminal bronchioles would be 40cm.

MCQs

Q1: What kind of antibody is found in the mucous of the respiratory tract			
A-IgM	B-IgA	C-IgG	D-IgE
Q2:One of the functions of the respiratory zone is			
A-heating the air	B-humidification of the air	C-conduction and movement of air	D-Gas exchange
Q3:One of the functions of the conducting zone			
A-heating the air and humidification	B-olfaction	C-Protection by coughs and sneezes	D- A+B+C

1-B 2-D 3-D

MCQs

Q4: The respiratory zone doesn't include			
A-alveoli/alveolar sacs	B-alveolar ducts	C-respiratory bronchioles	D-terminal bronchioles
Q5: When we expect premature delivery of a baby we give the mother			
A-inhaled surfactant	B-anti-oxytocin agents	C-corticosteroids	D-NSAIDS
Q6: Air resistance is highest in			
A-Trachea	B-Bronchi	C-Pharynx	D-Alveoli

4-D 5-C 6-B

click the image for 30 Anki cards/questions (high quality, ignore the typos xD)

you need to copy it to an anki program/app though

SAQs

Q1: Mention respiratory and non-respiratory functions of the respiratory system

Q2: Write the law of laplace

Q3: What is surfactant and what is the function of it?

A1: slide 3

A2: slide 14

A3: slide 15

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

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