Respiratory conditions and surface tension

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LEARNING OBJECTIVES

- Hypoventilation
- Hyperventilation
- Hypercapnea
- Eupnea
- Hypopnea
- Hyperpnea
- Surface tension
- Surfactant
- Atelactasis
- Describe the composition of the pulmonary surfactant and its path physiology in respiratory distress syndrome of the new born.

Pulmonary ventilation

- Pulmonary ventilation is a cyclic process by which fresh air enters the lungs and an equal volume of air leaves the lungs. It is the volume of air moving in and out of lungs per minute in quite breathing. It is also called respiratory minute volume(RMV).
- Normal value of pulmonary ventilation is 6000ml(6 liters/minute).
- Pulmonary ventilation is the product of tidal volume(TV)and the rate of respiration(RR).It is calculated by the formula
- Pulmonary ventilation=tidal volume x respiratory rate

  =500ml x 12/min

  =6000ml/min.

Hypoventilation

- Hypoventilation is **breathing that is too shallow or too slow to meet the needs of the body.** Hypoventilation occurs when respiratory centers are suppressed, or by administration of some drugs. If a person hypo ventilates, the body's carbon dioxide level rises. This causes a buildup of acid and too little oxygen in the blood.

Hyperventilation(over ventilation)

- Hyperventilation is **rapid or deep breathing**, usually caused by anxiety or panic.
- Hyperventilation is a condition in which minute ventilation exceeds metabolic demands. Example is exercise.
- This over breathing, as it is sometimes called, may actually leave the person feeling breathless.

hyperventilation

Air to air

First Aid for Hyperventilation

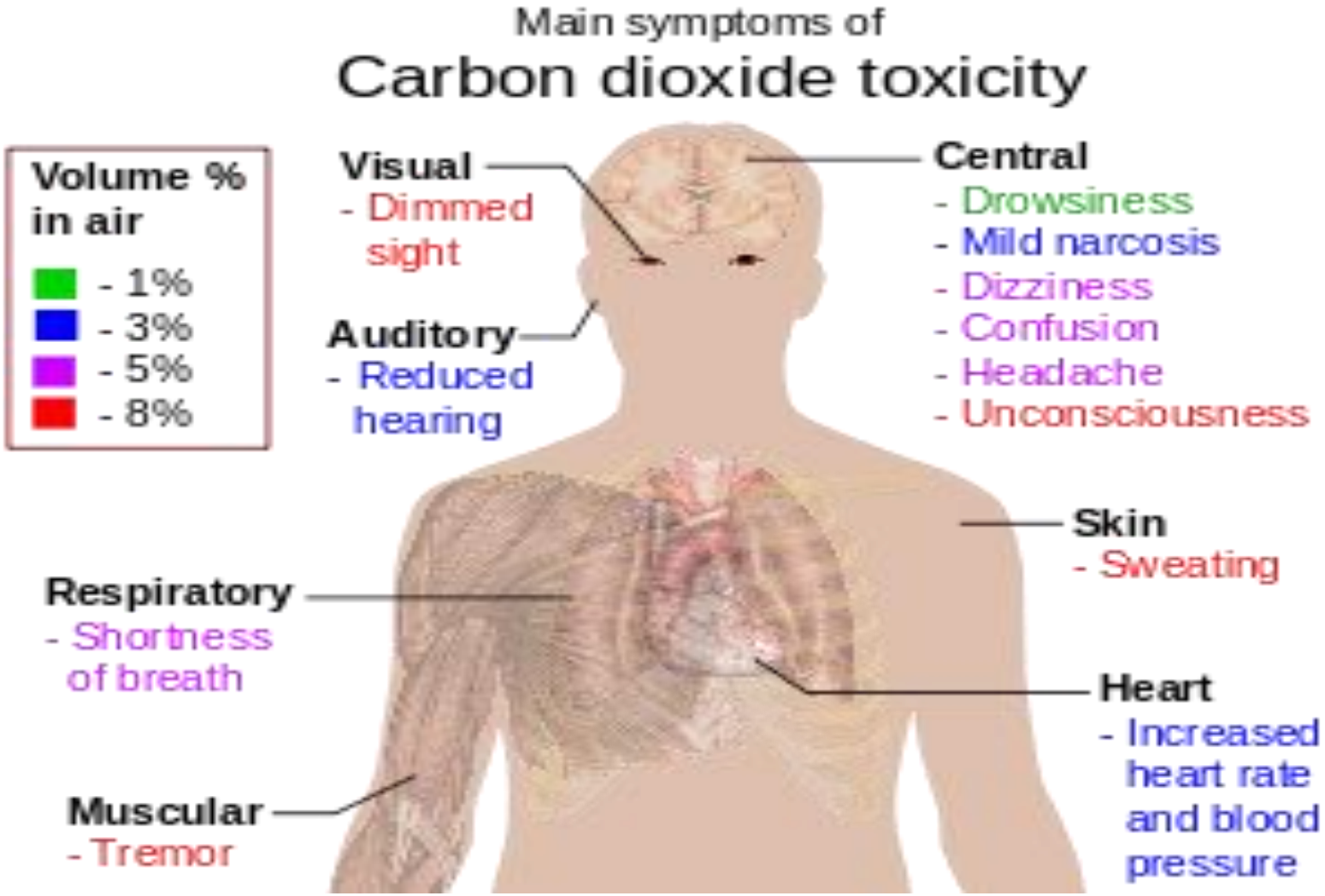
The symptoms of respiratory alkalosis include dizziness, tingling in the lips, hands or feet, headache, weakness, fainting, and seizures. In extreme cases it may cause carpopedal spasms, a flapping and contraction of the hands and feet.

Apnea

- means temporary arrest of breathing. Apnea occurs after hyperventilation due to lack of carbon dioxide. During hyperventilation more carbon dioxide is washed out. So partial pressure of carbon dioxide in the blood decreases and the number of stimuli to the respiratory centers also decreases leading to Apnea.
- During Apnea, carbon dioxide accumulates in the blood. When partial pressure of carbon dioxide increases, the respiratory centers are stimulated and respiration starts.
- Dyspea means difficulty in breathing.

Hypercapnia

- (from the *hyper* = "above" or "too much" and *kapnos* = "smoke"), also known as **hypercarbia** and **CO_2 retention**, is a condition of abnormally elevated carbon dioxide (CO_2) levels in the blood. Carbon dioxide is a gaseous product of the body's metabolism and is normally expelled through the lungs.
- Carbon dioxide may accumulate in any condition that causes hypoventilation, a reduction of alveolar ventilation (the clearance of air from the small sacs of the lung where gas exchange takes place).
- Inability of the lungs to clear carbon dioxide leads to respiratory acidosis.
- Eventually the body compensates for the raised acidity by retaining alkali in the kidneys, a process known as "metabolic compensation"


Main symptoms of
Carbon dioxide toxicity
Volume % in air
- 1%
- 3%
- 5%
- 8%
Visual
- Dimmed sight
Auditory
- Reduced hearing
Central
- Drowsiness
- Mild narcosis
- Dizziness
- Confusion
- Headache
- Unconsciousness
Skin
- Sweating
Respiratory
- Shortness of breath
Heart
- Increased heart rate and blood pressure
Muscular
- Tremor

Eupnoea

- is normal, good, unlabored breathing, sometimes known as *quiet breathing* or *resting respiratory rate*. In eupnea, expiration employs only the elastic recoil of the lungs.

Hypopnea

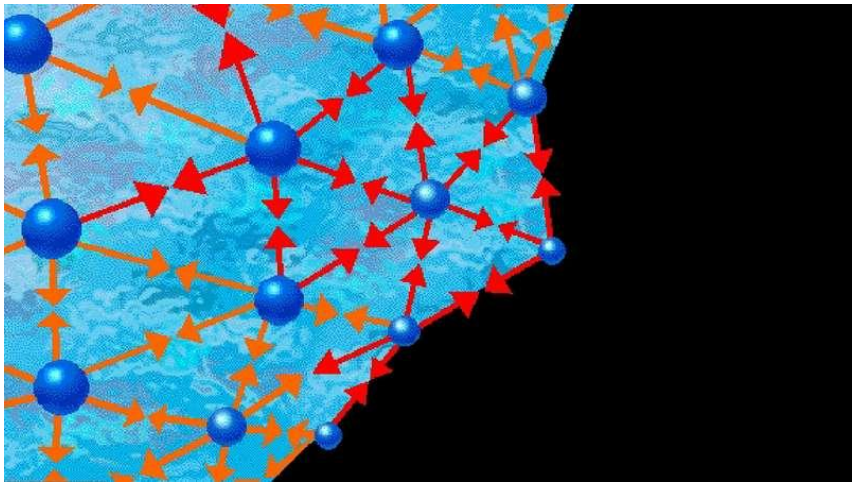
- is overly shallow breathing or an abnormally low respiratory rate
- is typically defined by a decreased amount of air movement into the lungs and can cause oxygen levels in the blood to drop. It commonly is due to partial obstruction of the upper airway.
- Hypopnea during sleep is classed as a sleep disorder. With moderate to severe hypopnea, sleep is disturbed such that patients may get a full night's sleep but still not feel rested because they did not get the right kind of sleep. The disruption in breathing causes a drop in blood oxygen level, which may in turn disrupt the stages of sleep.
- Daytime hypopnea events, however, are mostly limited to those with severely compromised respiratory muscles. As occurs in certain neuromuscular diseases

Hyperpnea

- (forced respiration) is increased volume of air during breathing. It can occur with or without an increase in respiration rate.
- It is characterized by deep breathing.
- It may be physiologic—as when required to meet metabolic demand of body tissues (for example, during or after exercise, or when the body lacks oxygen at high altitude or as a result of anemia)—or it may be pathologic, as when sepsis is severe.
- Hyperpnea is distinguished from tachypnea, which is a respiratory rate greater than normal, resulting in rapid and shallow breaths.
- Hyperpnea is also distinguished from hyperventilation, which is over-ventilation (an increase in minute ventilation), which involves an increase in volume and respiration rate, resulting in rapid and deep breaths.

Surface Tension

- The cohesive forces between liquid molecules are responsible for the phenomenon known as surface tension
- the tension of the surface film of a liquid caused by the attraction of the particles in the surface layer by the bulk of the liquid, which tends to minimize surface area.



Cohesion and Adhesion

- Molecules in the liquid state experience strong intermolecular attractive forces. When those forces are between like molecules, they are referred to as cohesive forces. For example, the molecules of a water droplet are held together by cohesive forces, and the especially strong cohesive forces at the surface constitute surface tension.
- When the attractive forces are between unlike molecules, they are said to be adhesive forces. The adhesive forces between water molecules and the walls of a glass tube are stronger than the cohesive forces lead to an upward turning meniscus at the walls of the vessel and contribute to capillary action.

Surfactants

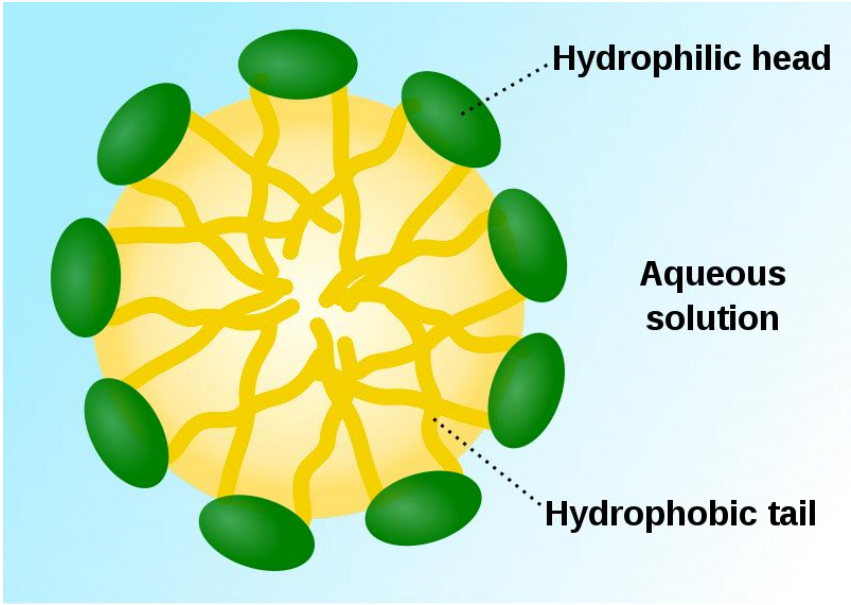
- are compounds that lower the surface tension (or interfacial tension) between two liquids, between a gas and a liquid, or between a liquid and a solid.

Surfactants

- Surfactants are usually organic compounds that are amphiphilic, meaning they contain both hydrophobic groups (their *tails*) and hydrophilic groups (their *heads*).
- Therefore, a surfactant contains both a water-insoluble (or oil-soluble) component and a water-soluble component.
- The water-insoluble hydrophobic group may extend out of the bulk water phase, into the air or into the oil phase, while the water-soluble head group remains in the water phase

surfactant

- surfactants form aggregates, such as micelles, where the hydrophobic tails form the core of the aggregate and the hydrophilic heads are in contact with the surrounding liquid.



Surfactant production

- The half life of surfactant is 30 hours.

Hyaline membrane disease (HMD), also called respiratory distress syndrome (RDS),

- **condition that causes babies to need extra oxygen and help breathing**.
- HMD is one of the most common problems seen in premature babies. The more premature the baby, the higher the risk and the more severe the HMD.
- Preterm labor is labor that begins early, **before 37 weeks of pregnancy**. Labor is the process your body goes through to give birth to your baby. Preterm labor can lead to premature birth. Premature birth is when your baby is born early, before 37 weeks of pregnancy. Baby needs about 40 weeks in the womb to grow and develop before birth
- Because many premature babies are born with low birthweight, Low birthweight is when a baby is born weighing less than 5 pounds, 8 ounces.

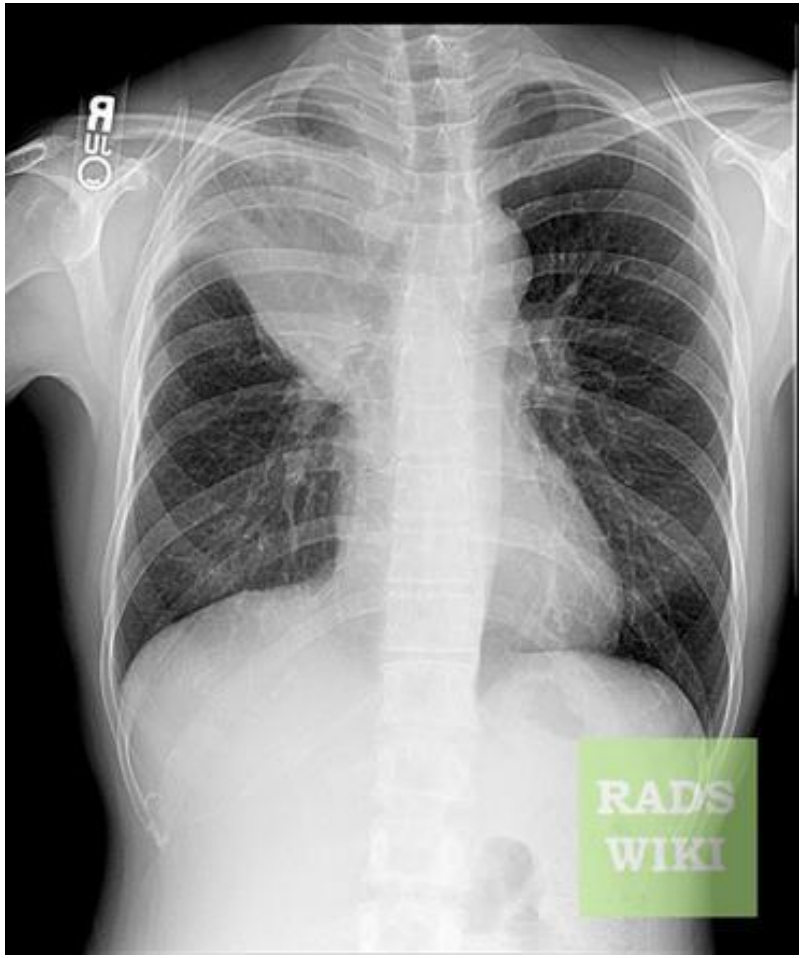
Pulmonary surfactant

- The human body produces diverse surfactants. Pulmonary surfactant is produced in the lungs in order to facilitate breathing by increasing total lung capacity, and lung compliance.
- **Lung compliance**, or **pulmonary compliance**, is a measure of the lung's ability to stretch and expand (dispensability of elastic tissue).
- In clinical practice it is separated into two different measurements, static compliance and dynamic compliance. Static lung compliance is the change in volume for any given applied pressure.Dynamic lung compliance is the compliance of the lung at any given time during actual movement of air
- In respiratory distress syndrome or RDS, surfactant replacement therapy helps patients have normal respiration by using pharmaceutical forms of the surfactants

Atelectasis

- is the collapse or closure of a lung resulting in reduced or absent gas exchange. It is usually unilateral, affecting part or all of one lung. It is a condition where the alveoli are deflated down to little or no volume, as distinct from pulmonary consolidation, in which they are filled with liquid. It is often called a *collapsed lung.*

- Atelectasis may be an acute or chronic condition. In acute atelectasis, the lung has recently collapsed and is primarily notable only for airlessness.
- In chronic atelectasis, the affected area is often characterized by a complex mixture of airlessness, infection, widening of the bronchi (bronchiectasis), destruction, and scarring (fibrosis).



composition of the pulmonary surfactant

- Pulmonary surfactant is a complex mixture of phospholipids (PL) and proteins (SP) that reduce surface tension at the air-liquid interface of the alveolus.
- It is made up of **about 70% to 80% PL, mainly dipalmitoylphosphatidylcholine (DPPC) called as LECITHINE.**
- **Phosphatidylglycerol,** cholesterol are about 10% each, whereas surfactant proteins SP-A to -D comprise 2-5%.
- SpA and SpD and variety of anti-inflammatory and antimicrobial substances and hydrophilic while SP-B and SP-C are hydrophobic. Surfactant proteins are vital components of surfactant, and the surfactant becomes inactive in the absence of proteins. Ions present in surfactant is mostly calcium ions.

- The epithelial surface of the alveoli is composed of alveolar type I and type II cells. Type I alveolar cells are **squamous extremely thin cells involved in the process of gas exchange between the alveoli and blood**. Alveolar type I cells comprise 96% of the alveolar surface area. These cells are extremely thin, thus, minimizing diffusion distance between the alveolar air space and pulmonary capillary blood.

- Type II cells are spherical pneumocytes which comprise only 4% of the alveolar surface area, yet they constitute 60% of alveolar epithelial cells and 10-15% of all lung cells.

Four major functions have been attributed to alveolar type II cells:

(1) synthesis and secretion of surfactant;

(2) xenobiotic metabolism;
Xenobiotic is a term used to describe **chemical substances** examples as plant constituents, drugs, pesticides, cosmetics, flavorings, fragrances, food additives, industrial chemicals and environmental pollutants

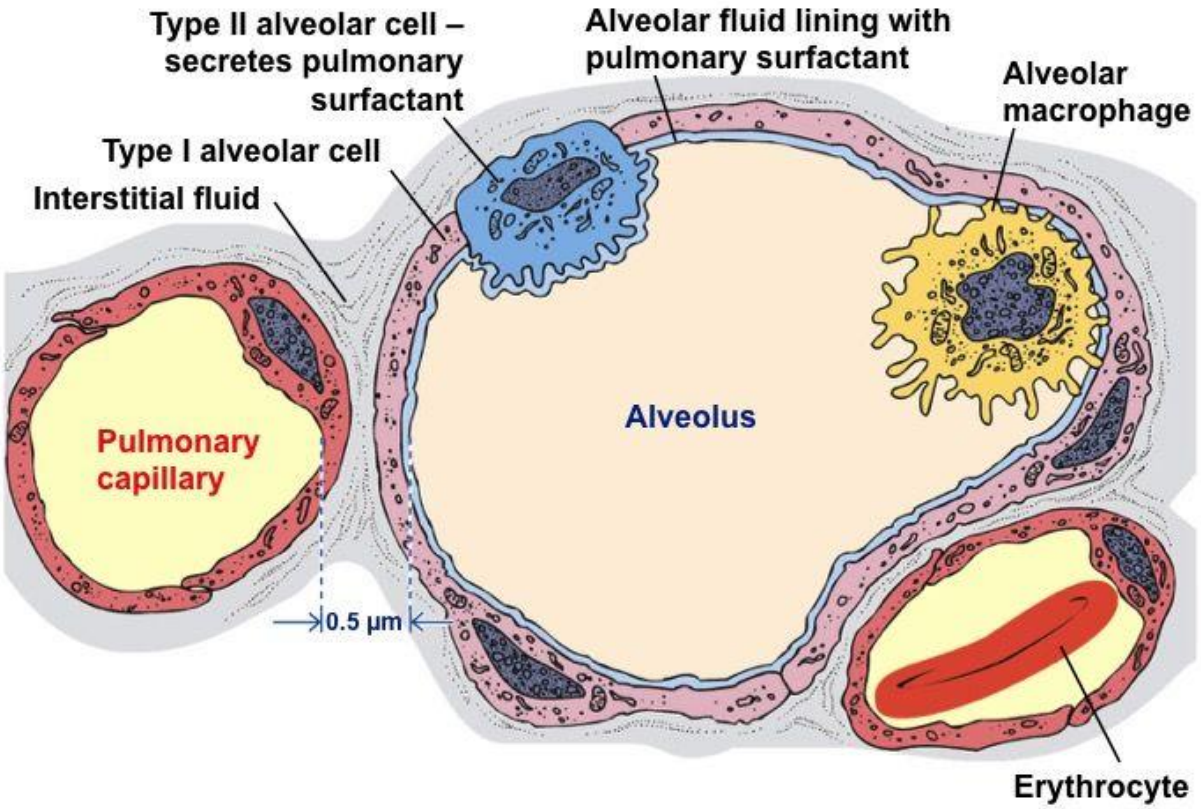
(3) transepithelial movement of water; and

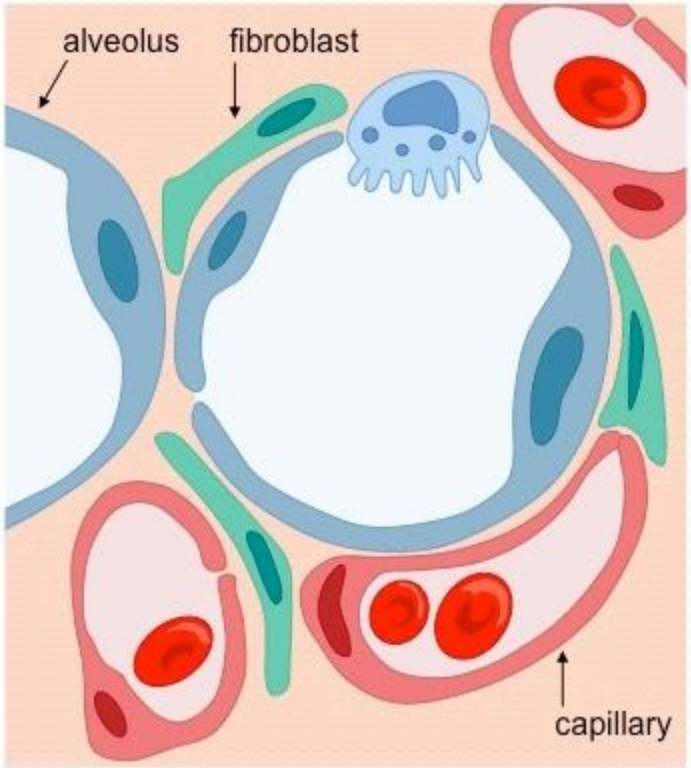
(4) regeneration of the alveolar epithelium following lung injury.

Therefore, alveolar type II cells play important roles in normal pulmonary function and in the response of the lung to toxic compounds which may cause lung damage

- type II cells also provide part of the initial antioxidant **A substance that protects cells from the damage caused by free radicals** defense by secreting glutatione, which is present in high concentration in alveolar fluid..

Type II alveolar cells are involved in the secretion of surfactant proteins.





Alveolar Cells

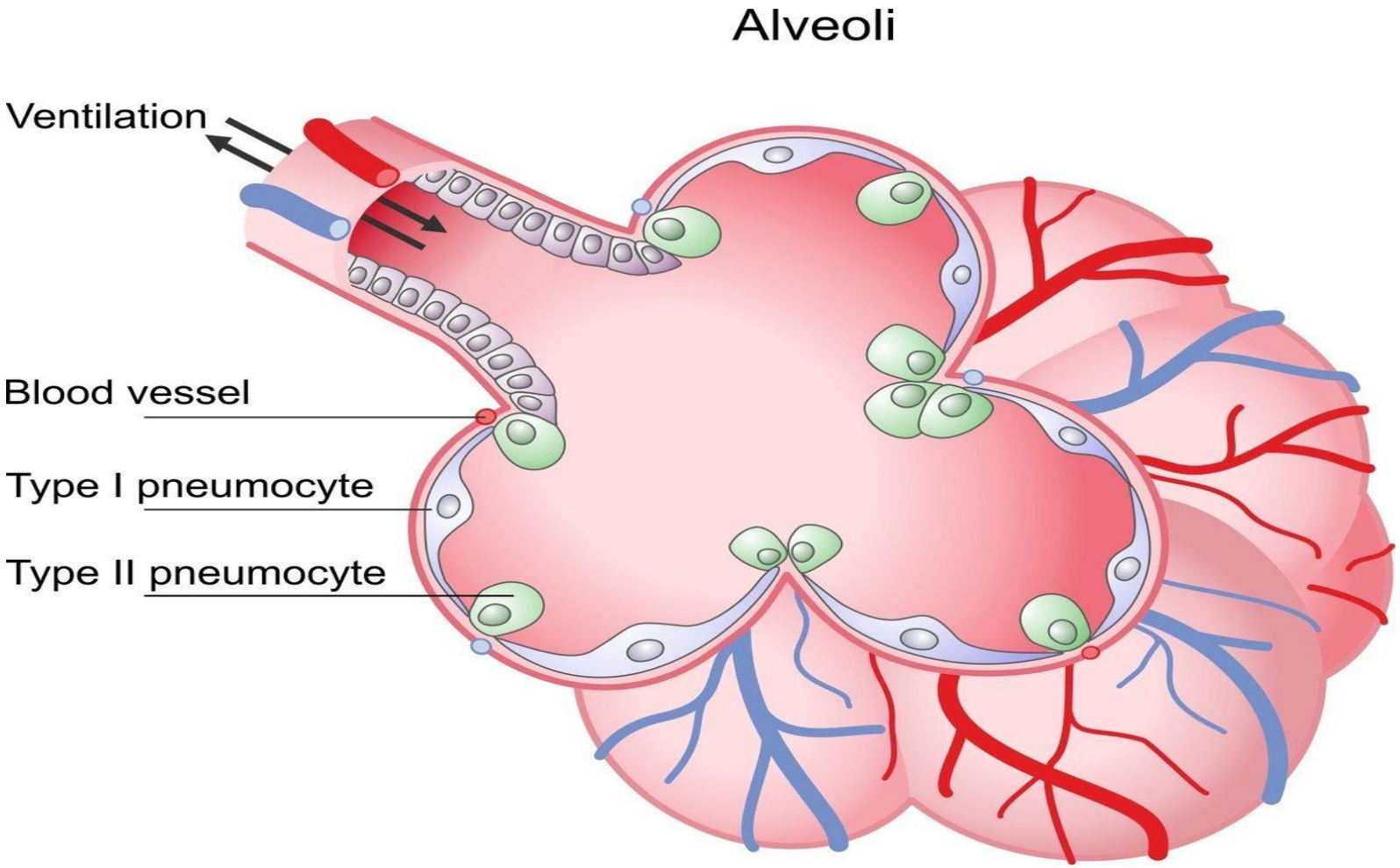
Type I Pneumocyte

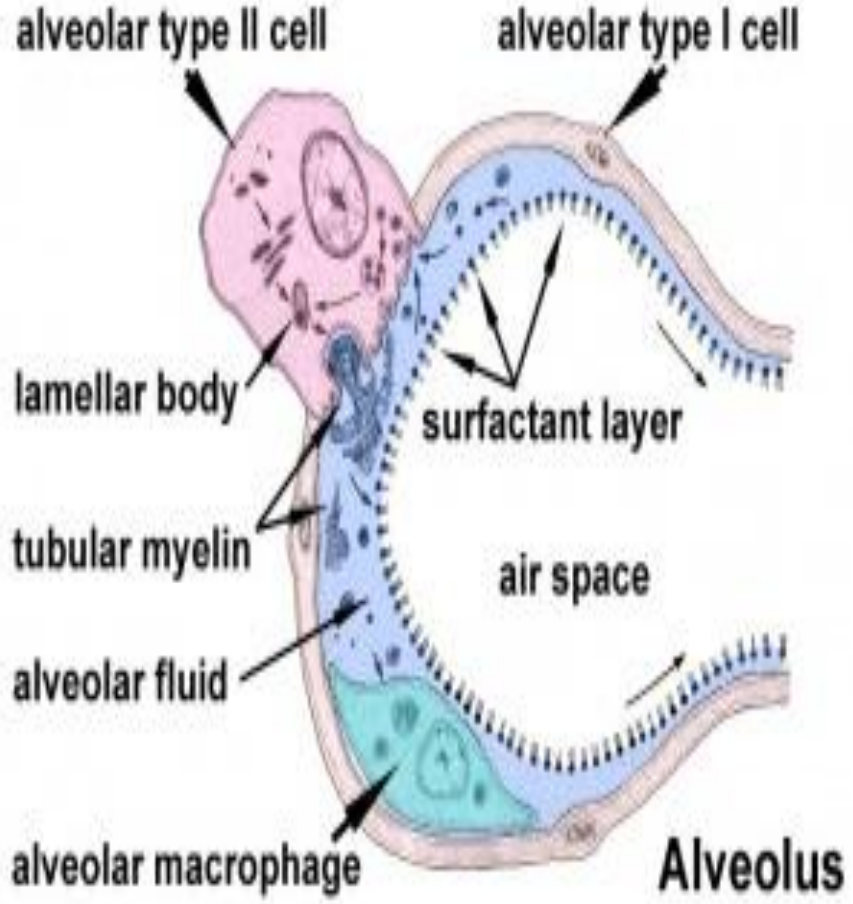
- Squamous and extremely thin
- Cover ~95% of alveolar surface
- Involved in gas exchange

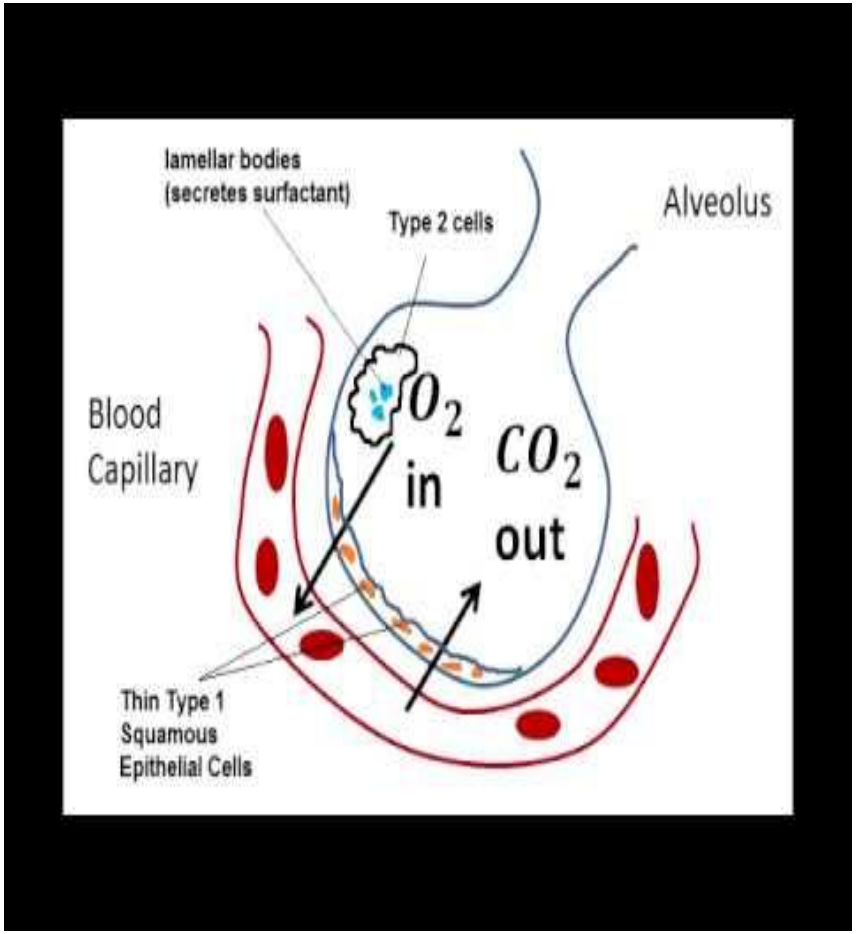
Type II Pneumocyte

- Granular and roughly cuboidal
- Cover ~5% of alveolar surface
- Secrete pulmonary surfactant

Type 2 alveolar cells are characteristic of a secretory cells.

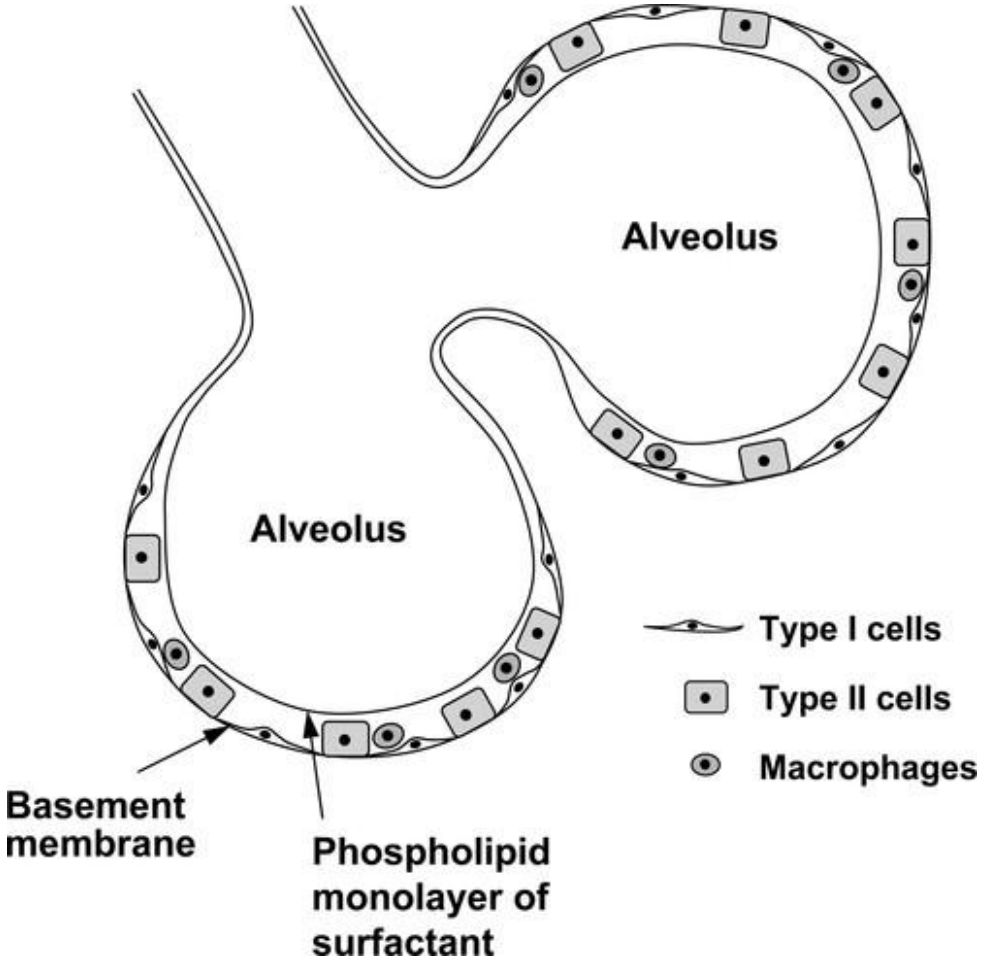



alveolar type II cell
alveolar type I cell
lamellar body
surfactant layer
tubular myelin
air space
alveolar fluid
alveolar macrophage
Alveolus


lamellar bodies
(secretes surfactant)
Type 2 cells
Alveolus
Blood
Capillary
O_2
in
CO_2
out
Thin Type 1
Squamous
Epithelial Cells

Formation of surfactant

- Initially surfactant is produced in the form of a precursor material called Tubular Myelin.
- Tubular myelin is a membrane bound organelle containing the immature surfactant.
- After formation it is released into the alveolar lumen by exocytosis.
- The tubular myelin is converted into the matured form of surfactant called the monomolecular film of phospholipids. Later it spread over the entire surface of alveoli.


Alveolus
Alveolus
Type I cells
Type II cells
Macrophages
Basement membrane
Phospholipid monolayer of surfactant

Function of surfactant

- The surfactant reduce the surface tension in the alveoli of lungs and prevents the collapsing tendency of lungs.
- Surfactant acts by the following mechanisms.
- The phospholipids molecules in the surfactant has two portions. One portion of the molecules is hydrophilic. This portion dissolves in water and lines the alveoli.
- The other portion is hydrophobic which is directed towards the alveolar surface. This surface of the phospholipid along with other portion, spreads over the alveoli and reduce the surface tension.
- SP-B and SP-C play active role in this process.

Function of surfactant

- The surfactant is responsible for stabilizing of the alveoli, which is necessary to withstand the collapsing tendency.
- It plays an important role in the inflation of lungs after birth.
- Surfactant has role in defense within the lungs against infection and inflammation. The hydrophilic proteins SP-A and SP-D destroy the bacteria and viruses by means of opsonization. These two proteins also control the formation of inflammatory mediators. (An inflammatory mediator is **a messenger that acts on blood vessels and/or cells to promote an inflammatory response**. e.g prostaglandins)

Surfactant production

- Is identifiable in fetal lung as early as 16 weeks through its proper secretion begins after 24 weeks gestation and synthesized most abundantly after the 35 weeks of gestation.
- A massive secretion of surfactant that occurs at birth with the first breath requires prior massive synthesis of surfactant components by type II cells.

Respiratory distress syndrome

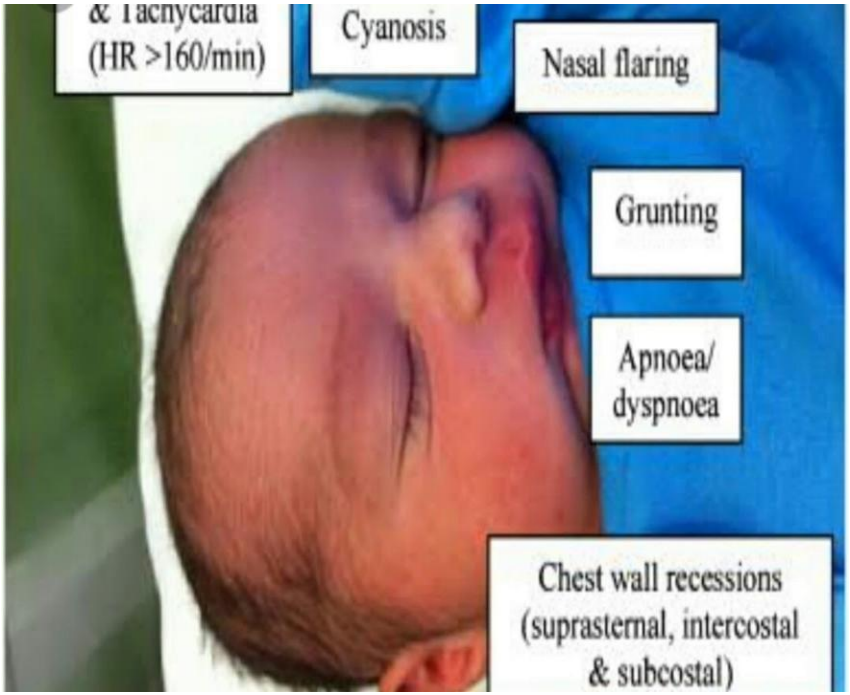
- Respiratory distress syndrome is caused by pulmonary surfactant deficiency in the lungs of neonates, most commonly in those born at < 37 weeks gestation.
- Risk increases with degree of prematurity. Symptoms and signs include **grunting respirations, use of accessory muscles, and nasal flaring appearing soon after birth**

Neonatal respiratory distress syndrome or hyaline membrane disease

- Surfactant plays a role in the inflation of lungs after birth. Neonatal respiratory distress syndrome is **caused by surfactant deficiency**, especially in the context of immature lungs.
- The deficiency of surfactant increases the surface tension within the small airways and alveoli, thereby reducing the compliance of the immature lung.
- Compliance is the ability the lungs and thorax to expand is called compliance it is the change in volume per unit change in pressure.
- Preterm labor is labor that begins early, **before 37 weeks of pregnancy**.
- Preterm labor can lead to premature birth.
- Term infants which numerically is represented as babies born at 37^{+0} to 41^{+6} weeks of Gestational age.

Neonatal respiratory distress syndrome

- When lungs have too little surfactant, the alveoli collapse after each breath the baby takes.
- The infants then have to struggle to take each breath and may become too exhausted to keep trying.
- Also, this lack of oxygen can cause acidosis, a buildup of acid in the blood, which can damage other body organs. An RDS baby needs help to survive.
- The fetus begins to produce surfactant at around 26 weeks, so babies born before 28 weeks are particularly susceptible to RDS



ARDS

- Adults usually develop ARDS due to an underlying condition such as heart disease, head and chest trauma, and sepsis. Tiny blood vessels in the lungs leak fluid into the alveoli, making breathing extremely difficult.