Physiology of Respiratory system

Lecture 1
Structure and function of the lungs

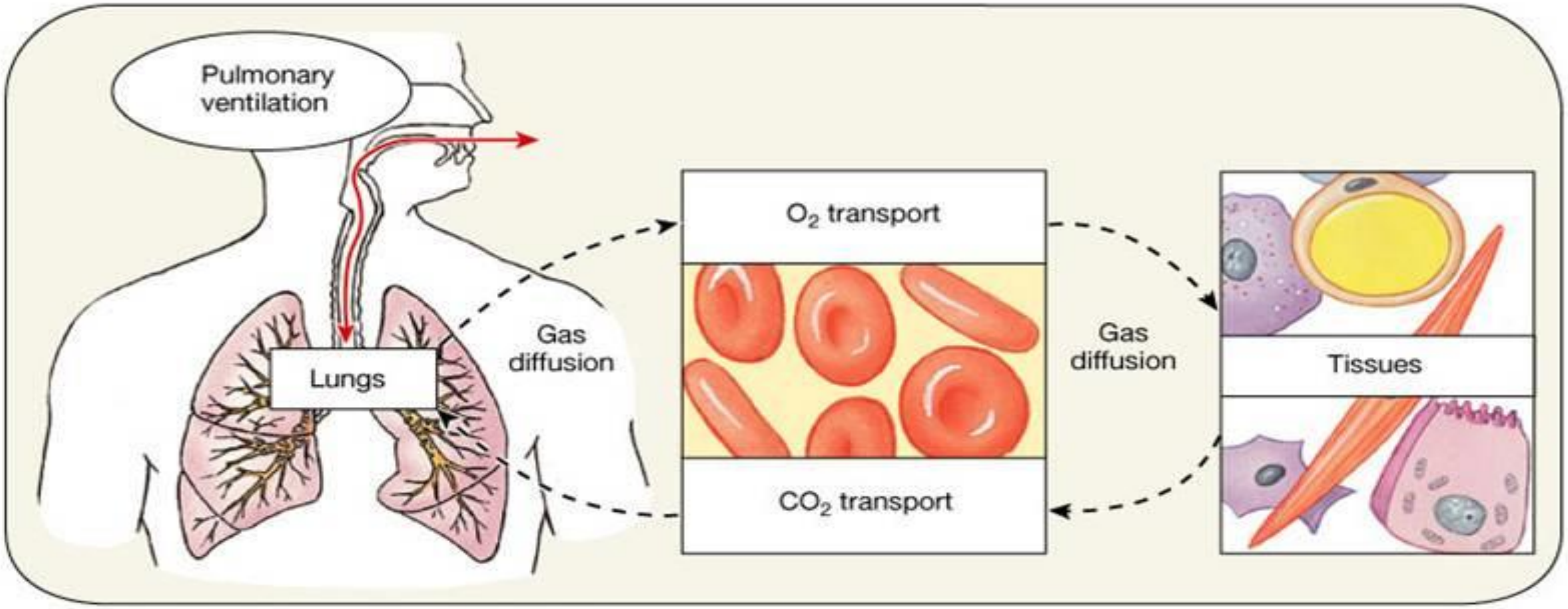
Textbook(s) and Readings:-

Respiratory Physiology The Essentials by John b. west. Ninth edition ,2011

Ganongg;s Review of Medical Physiology. 26rd edition

Lectures by John B. West, M.D., Ph.D

Types of respiration:



Functional structure of respiratory system

The respiratory system is made up of a gas-exchanging organ, the respiratory tract (the lungs) and a "pump" that ventilates the lungs. The pump consists of the chest wall; the respiratory muscles, which increase and decrease the size of the thoracic cavity; the areas in the brain that control the muscles; and the tracts and nerves that connect the brain to the muscles. The pluraEach lung is enclosed by a bilayered serous membrane

called pleura or **pleural sac. Pleura has two layers**

namely inner **visceral and outer parietal layers. Visceral**

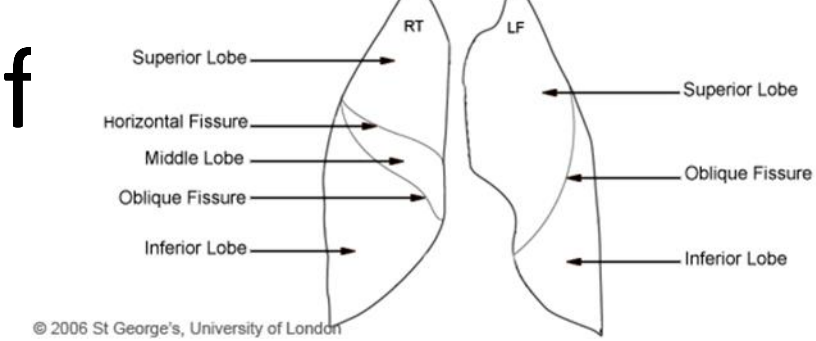
layer is attached firmly to the surface of the lungs.

At hilum, it is continuous with parietal layer, which is

attached to the wall of thoracic cavity.

At rest, a normal human breathes 12 to 15 times a minute. About 500 mL of air per breath, or 6 to 8 L/min, is inspired and expired. This air mixes with the gas in the alveoli, and, by simple diffusion, O_2 enters the blood in the pulmonary capillaries while CO_2 enters the alveoli. In this manner, 250 mL of O_2 enters the body per minute and 200 mL of CO_2 is excreted. Traces of other gases, such as methane from the intestines, are also found in expired air. Alcohol and acetone are expired when present in appreciable quantities in the body.

Gross anatomy of lung



Lungs are cone-shaped organs situated in the thoracic cavity. The left lung is divided by an oblique fissure into superior and inferior lobes. The right lung is divided by oblique and horizontal fissures into superior, middle and inferior lobes. Each lobe receives a secondary (lobar)

Both lungs have a central recession called the hilum at the root of the lung, where the blood vessels and airways pass into the lungs. There are also bronchopulmonary lymph nodes on the hilum. The lungs are surrounded by the pulmonary pleurae. The pleurae are two serous membranes; the outer parietal pleura lines the inner wall of the rib cage and the inner visceral pleura directly lines the surface of the lungs. Between the pleurae is a potential space called the pleural cavity containing pleural fluid.

Respiratory tract:

The first 16 generations of passages form the **<u>conducting zone</u>** of the airways that transports gas from and to the exterior. They are made up of bronchi, bronchioles, and terminal bronchioles. Inside the lungs, the secondary bronchi give rise to smaller bronchi called 'tertiary (segmental) bronchi', which in turn divide into smaller tubes called 'bronchioles'. Bronchioles branch repeatedly to form the terminal bronchioles that divide into respiratory bronchioles.

The remaining seven generations form the **<u>respiratory zones</u>** where gas exchange occurs; they are made up of respiratory bronchioles, alveolar ducts, and alveoli. These multiple divisions greatly increase the total cross-sectional area of the airways, from 2.5 cm^2 in the trachea to 11,800 cm^2 in the alveoli . Consequently, the velocity of air flow in the small airways declines to very low values.

Airways

Components of Respiratory zone

a. Respiratory bronchioles

b. Alveolar ducts

- i. Smooth muscle
- ii. Elastic and collagen fibers
- iii. Alveoli
- iv. Terminate into clusters of alveoli—alveolar sacs

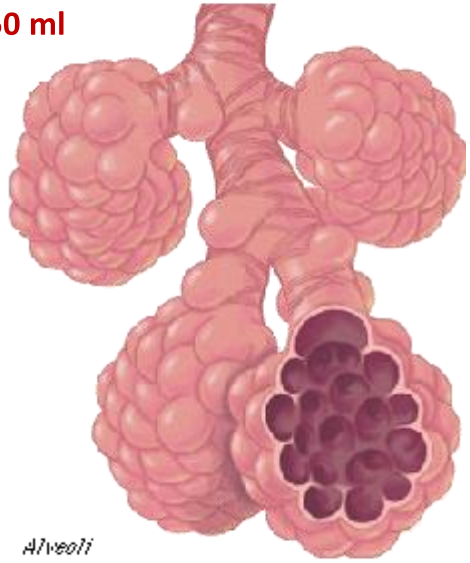
c. Alveolar sacs

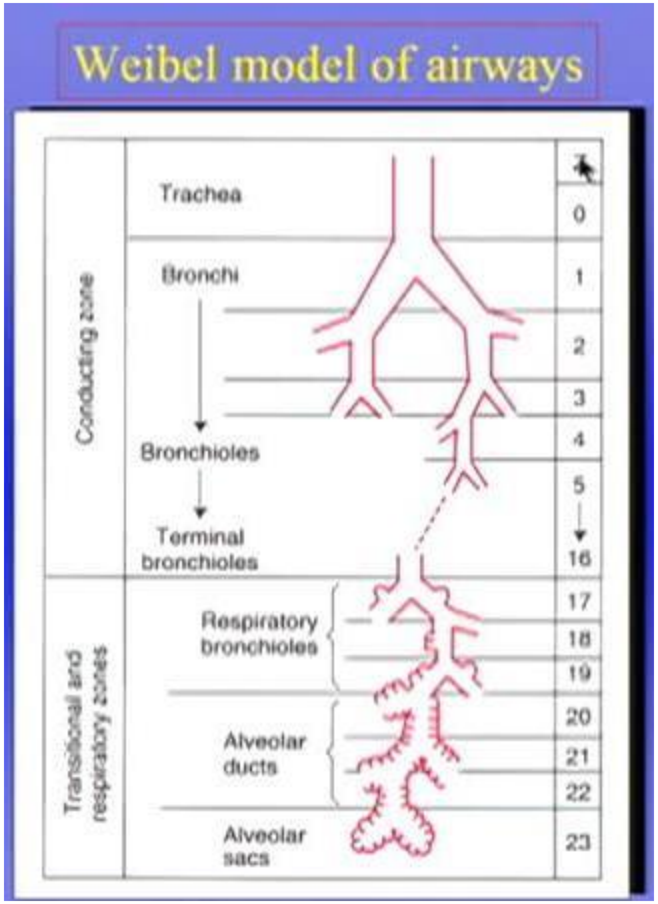
- i. Groups of alveoli

d. Alveoli

Volume of conducting zone is about 150 ml

volume of respiratory zone is 3 litters

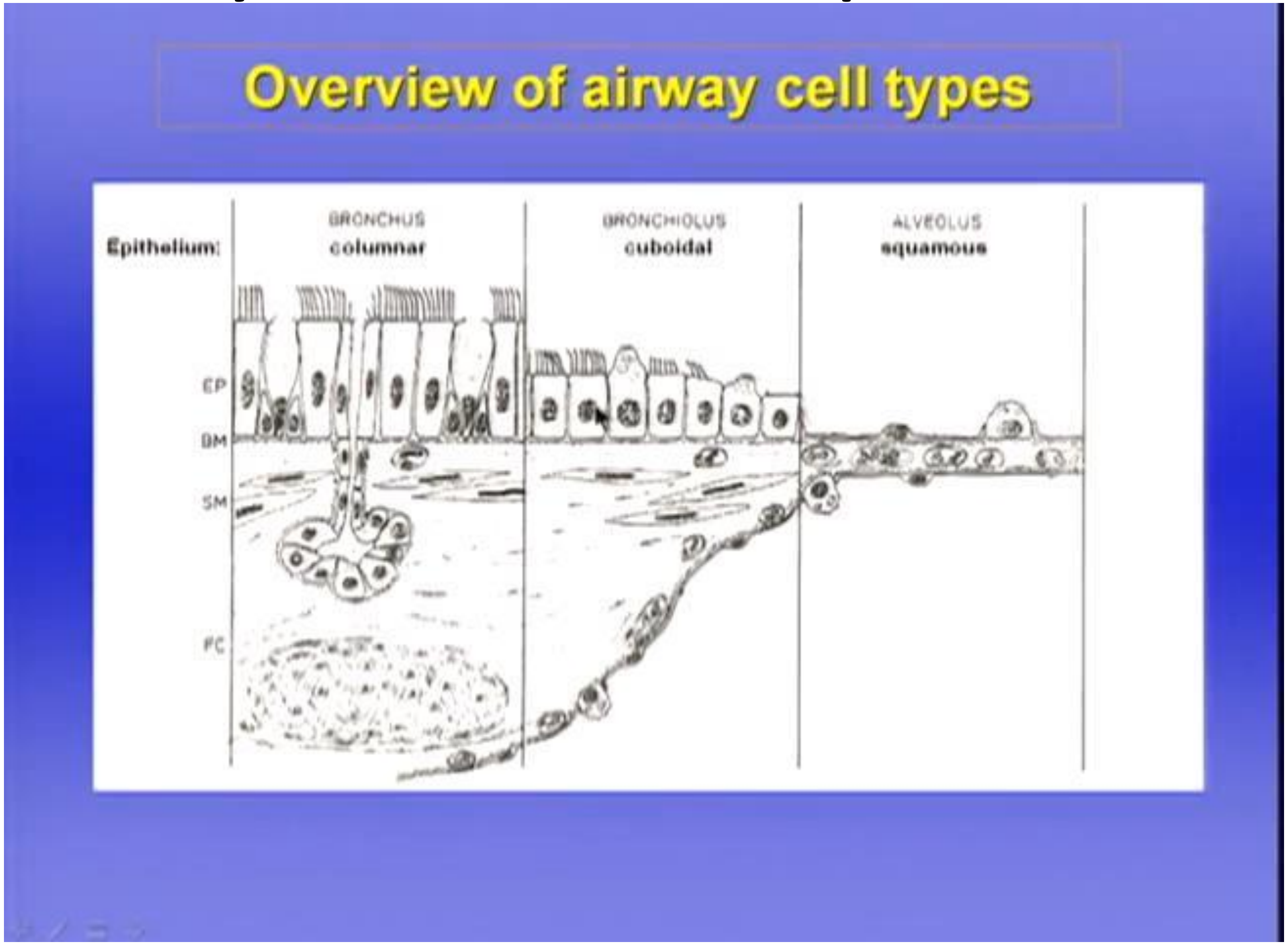




Microanatomy

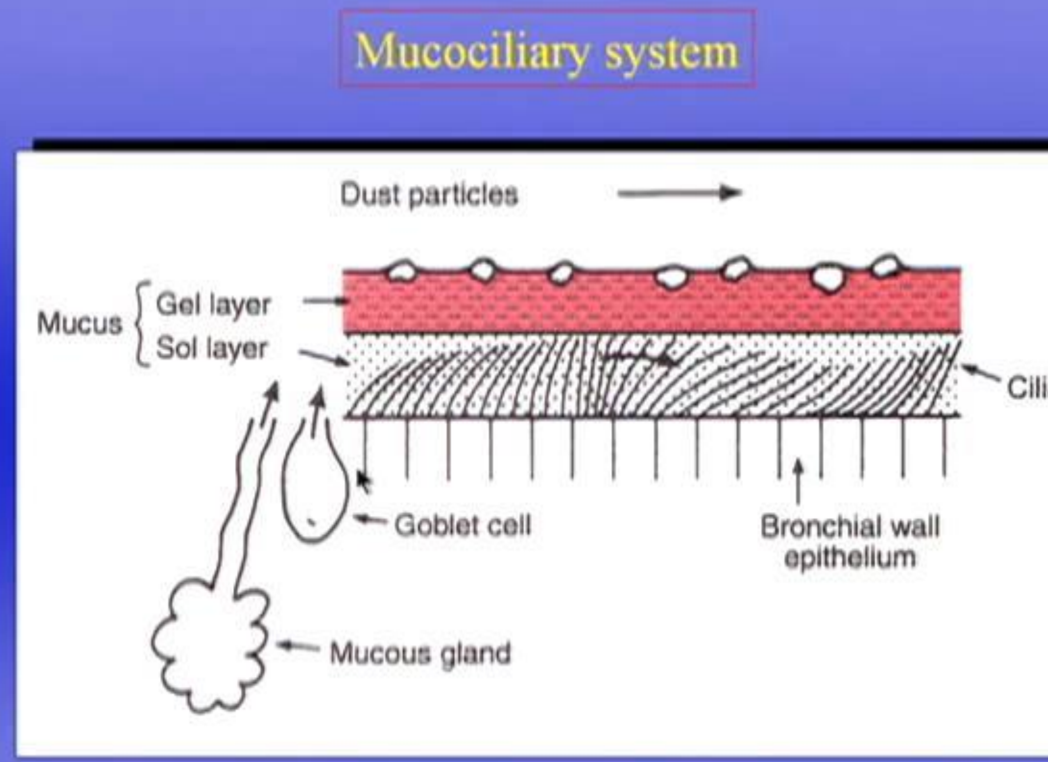
- The lung tissue contain:
- Respiratory airways (tract) which terminate in alveoli
- Parenchyma or the interstitial between alveoli
- Blood and lymphatic vessels and nerves

Cells within airway: the airways lined with epithelial cells



Airway wall

Cilia and Clara cells



Mucociliary system
Dust particles
Mucus
Gel layer
Sol layer
Cili
Goblet cell
Bronchial wall epithelium
Mucous gland

The epithelium of the respiratory passages from the anterior third of the nose to the beginning of the respiratory bronchioles is ciliated. The cilia are bathed in a periciliary fluid, a complex mixture of proteins and polysaccharides secreted from specialized cells, glands, or both in the conducting airway. This combination allows for the trapping of foreign particles(in the mucus) and their transport out of the air way (powered byciliary beat).

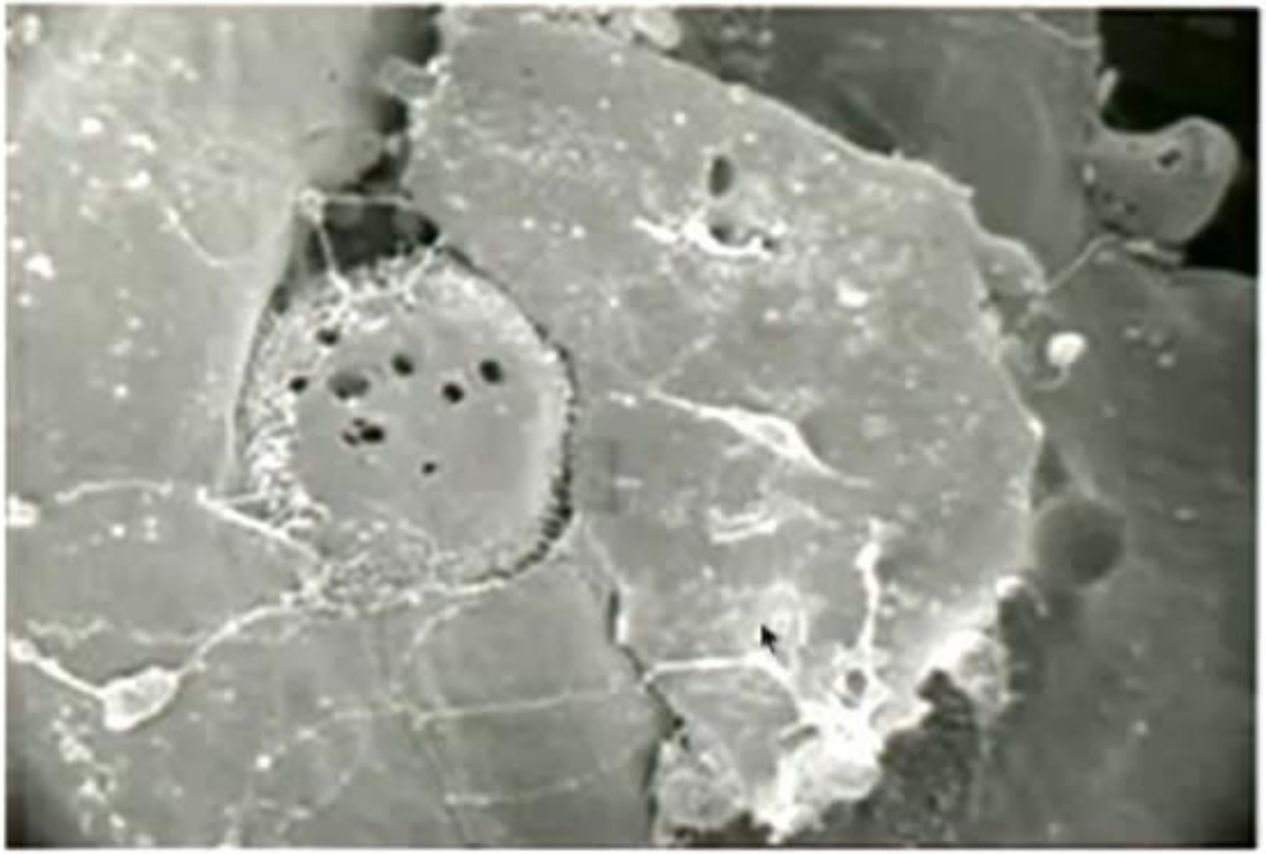
The ciliary mechanism is capable of moving particles away from the lungs at a rate of at least 16mm/min. When ciliary motility is defective, as can occur in smokers, nor as a result of other environmental conditions or genetic deficiencies, mucus transport is virtually absent. This can lead to chronic sinusitis, recurrent lung infections, and bronchiectasis. Some of these symptoms are evident in cysticfibrosis

Epithelial cells in the conducting air way can secrete a variety of molecules that aid in lung defense. Secretory immunoglobulins(IgA), collectins (including surfactant protein, defensins and other peptides and proteases, reactive oxygen species(ros), and reactive nitrogen species. The sesecretions can act directly as antimicrobials to help keep the airway free of infection.

Alveolar wall cells:

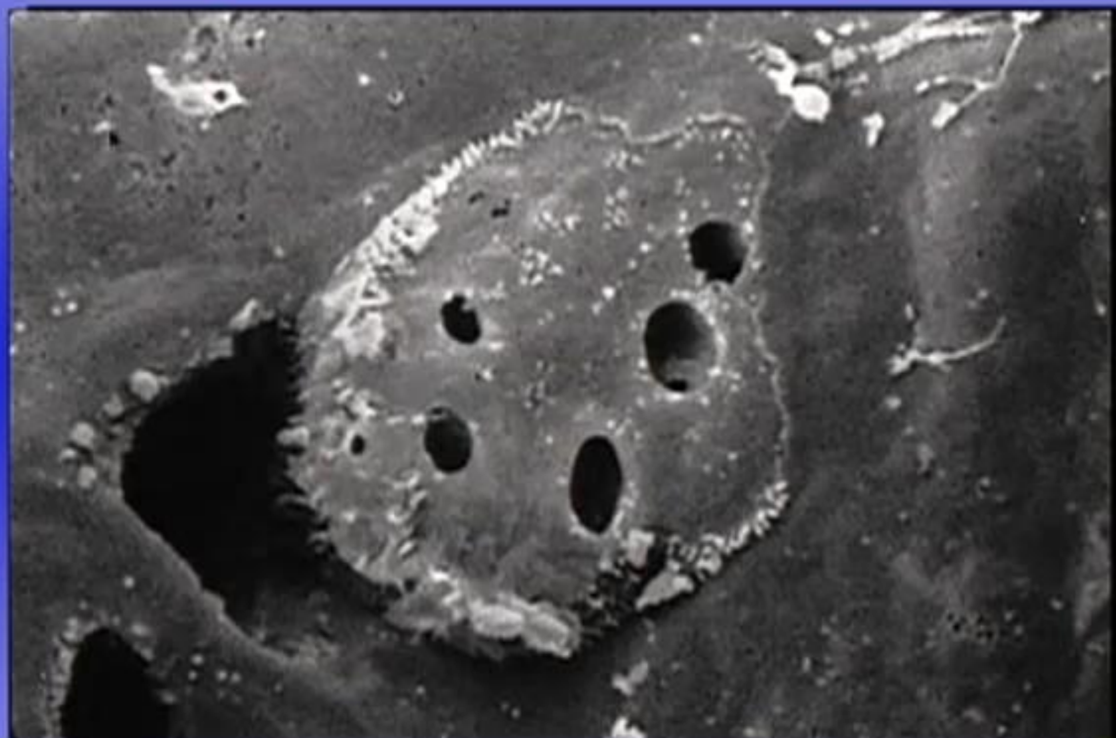
- Two types of alveolar cells: type I and type II alveolar cells (also known as pneumocytes).Types I and II make up the walls and septa of the alveoli. Type I cells provide 95% of the surface area of each alveoli and are flat ("squamous"), and Type II cells are larger and generally cluster in the corners of the alveoli and have a cuboidal shape
- Alveolar macrophages have an important immunological role. They remove substances which deposit in the alveoli including loose red blood cells that have been forced out from blood vesels

Alveolar macrophage with types I and II epithelial cells

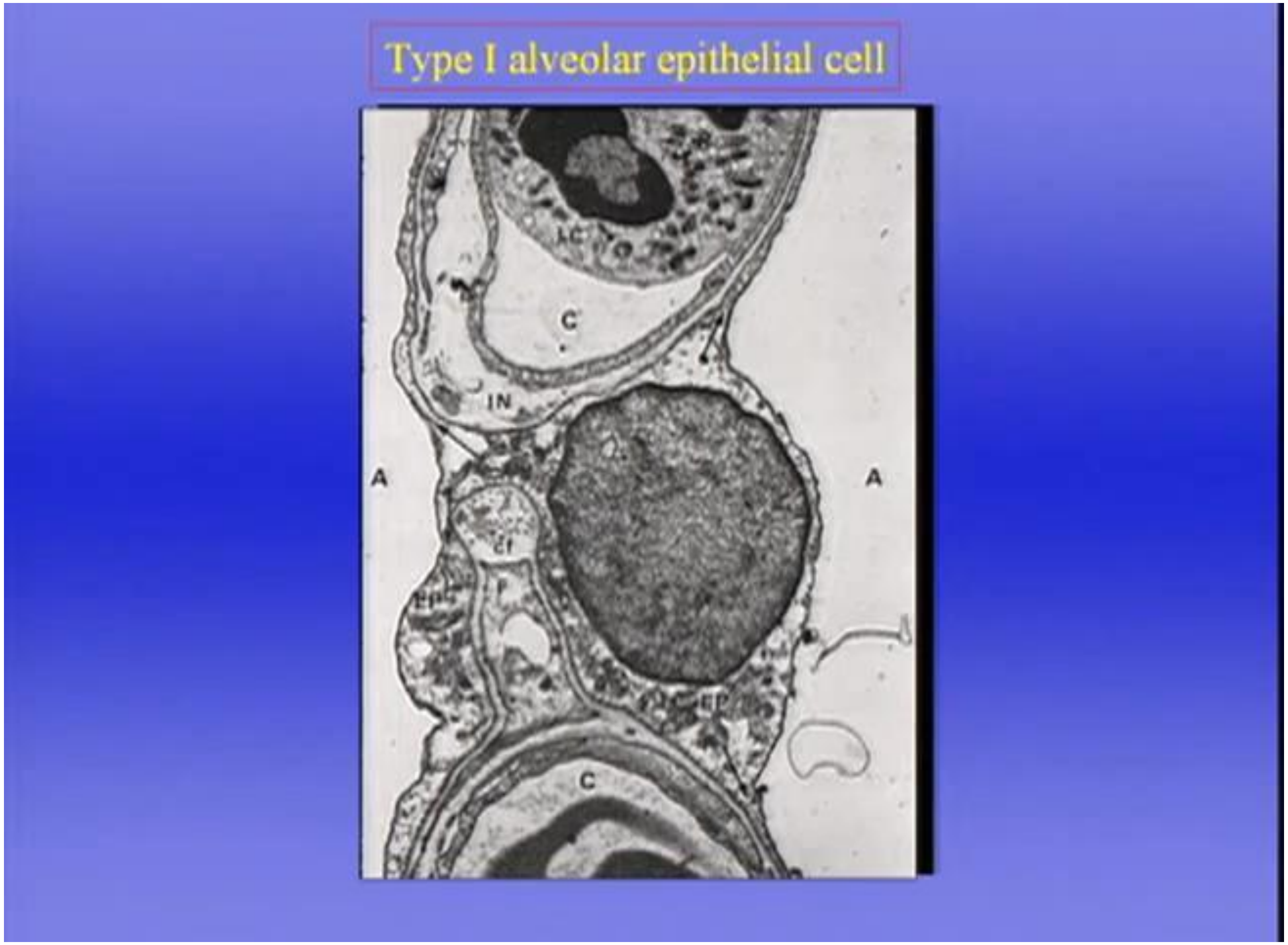


Goblet cell

Type II alveolar epithelial cell

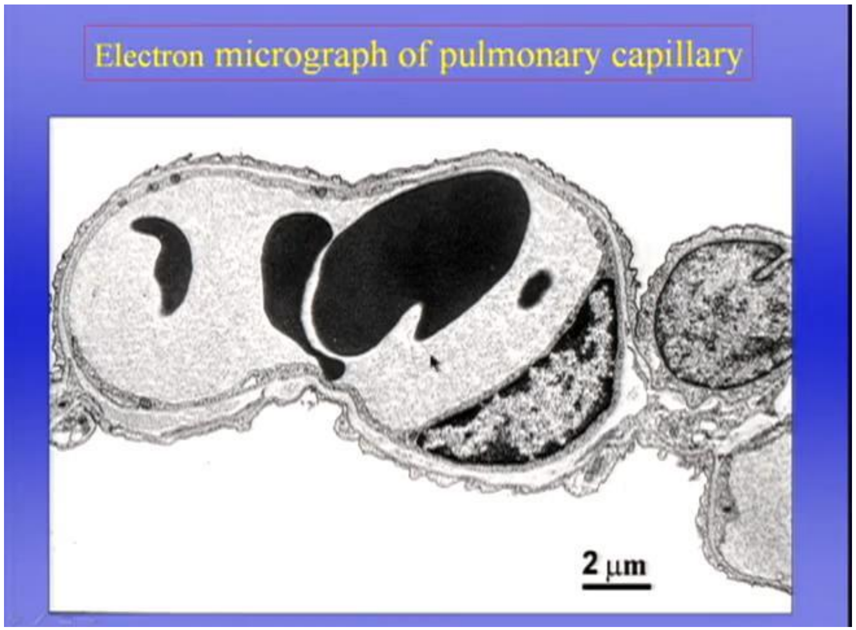


Alveolar wall



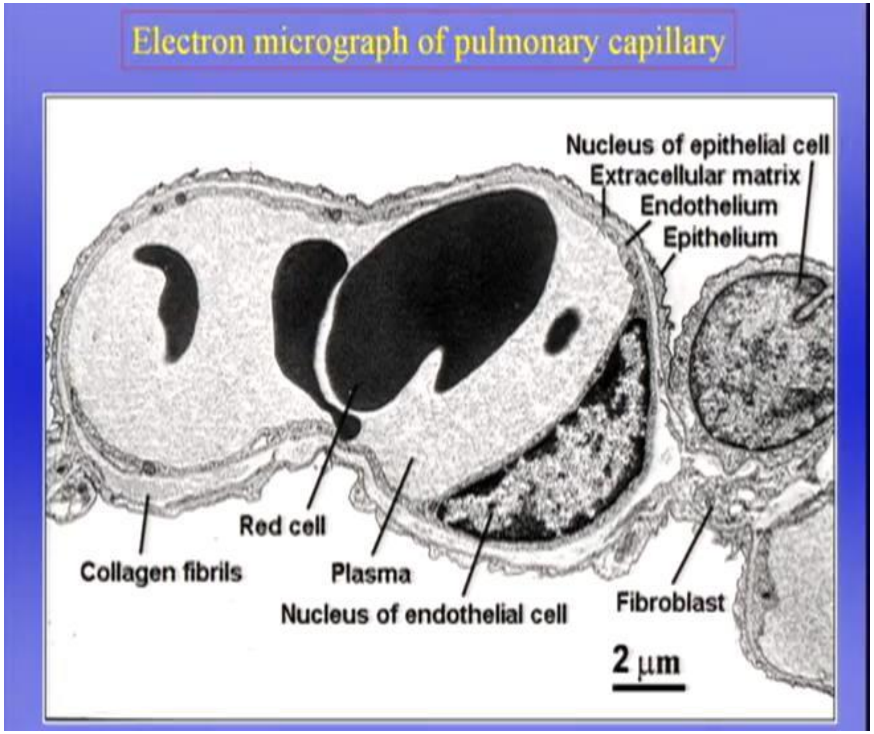
Alveolar macrophage in the corner of an alveolus

Blood gas barrier



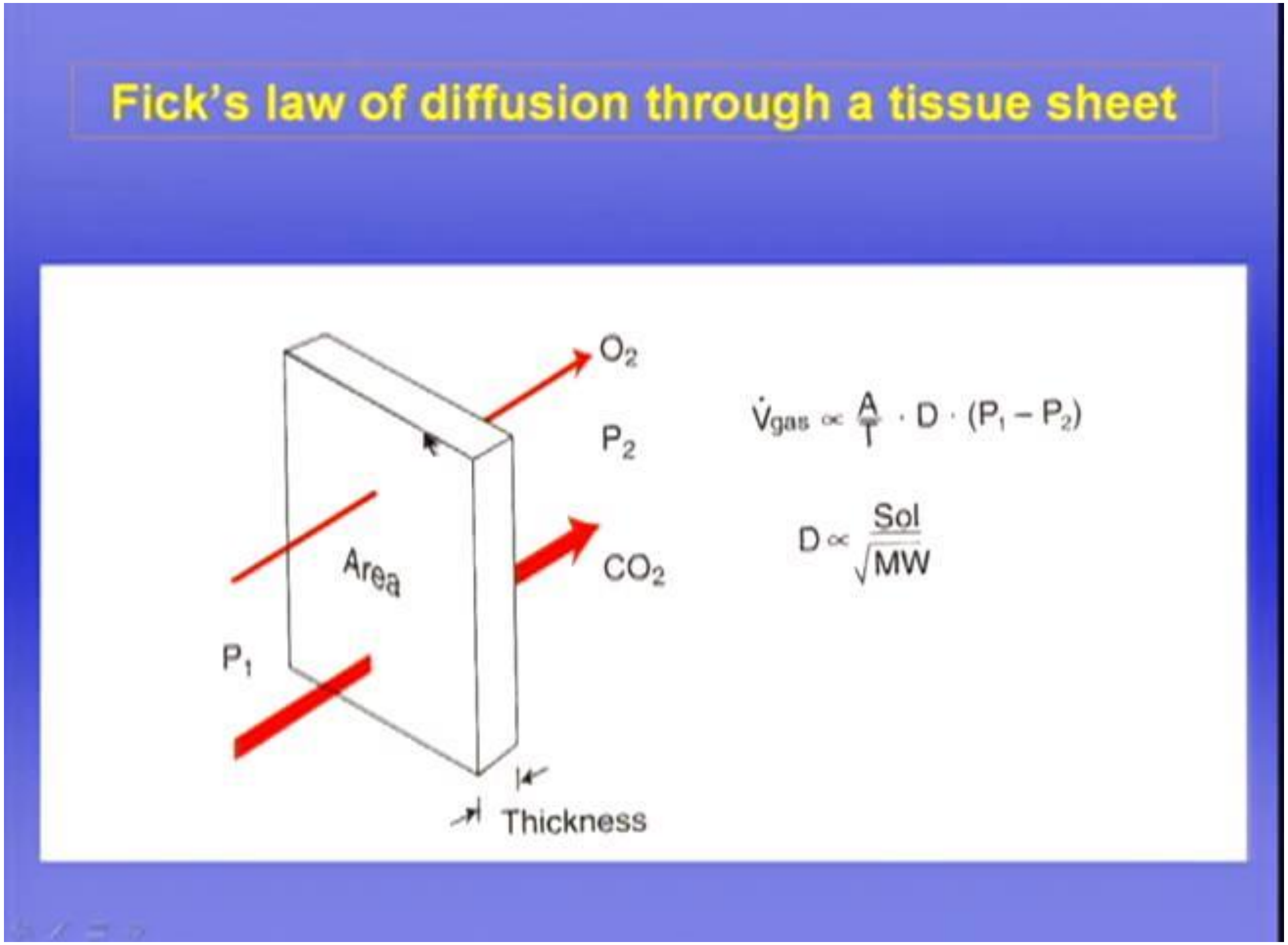
- 1. A layer of fluid lining the alveolus and containing surfactant that reduces the surface tension of the alveolar fluid
2. The alveolar epithelium composed of thin epithelial cells
3. An epithelial basement membrane
4. A thin interstitial space between the alveolar epithelium and the capillary membrane 5. A capillary basement membrane that in many
- places fuses with the alveolar epithelial basement
- membrane
- 6. The capillary endothelial membrane

Very thin Blood-Gas barrier



The diameter of a capillary segment is about 7 to 10 mm, just large enough for a red blood cell.
The lengths of the segments are so short that the dense network forms an almost continuous sheet of blood in the alveolar wall, a very efficient arrangement for gas exchange.

Importance's of a thin blood gas barier

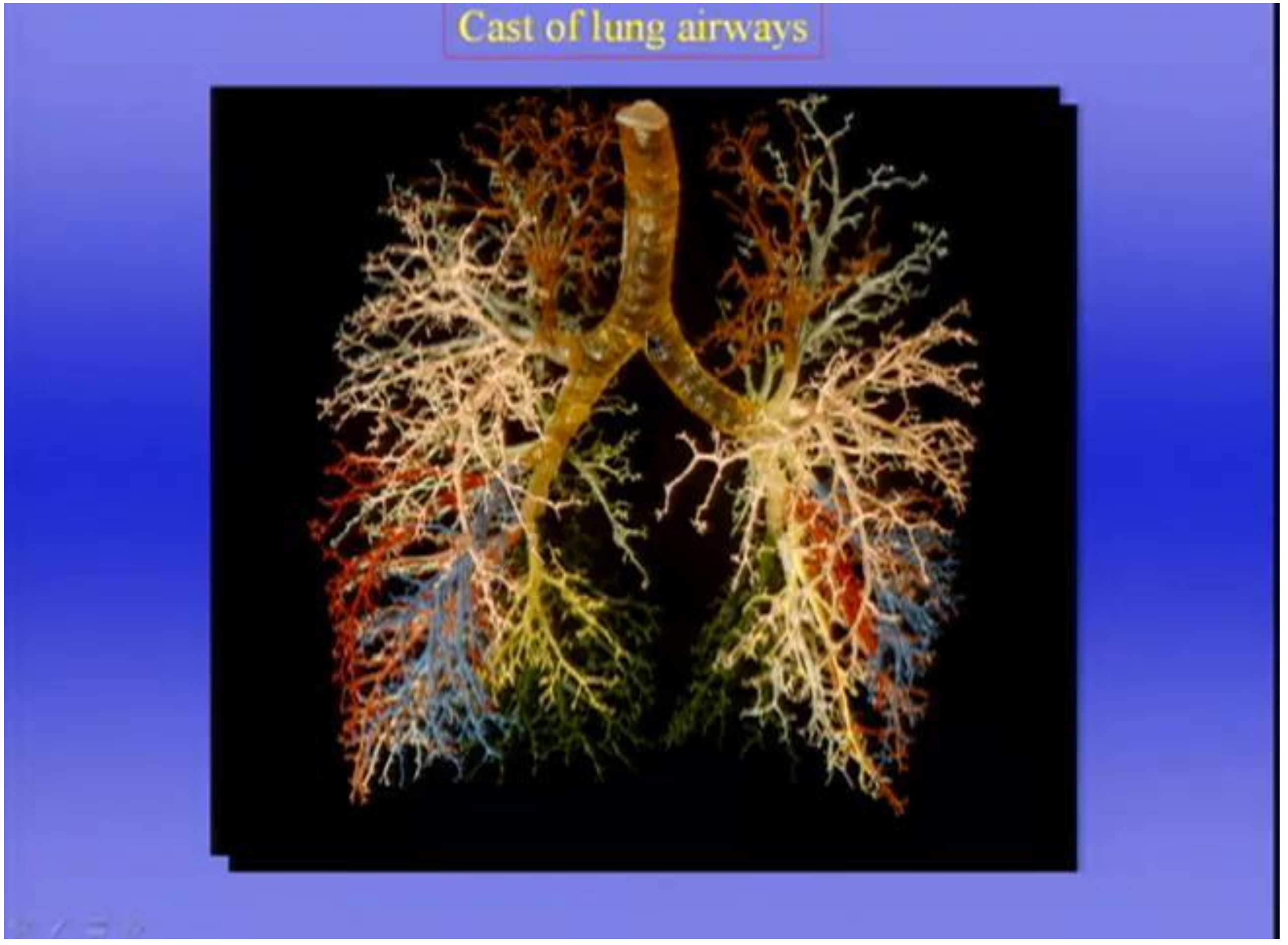


The extreme thinness of the blood-gas barrier means that the capillaries are easily damaged:

- Increasing the pressure in the capillaries to high levels
- inflating the lung to high volumes

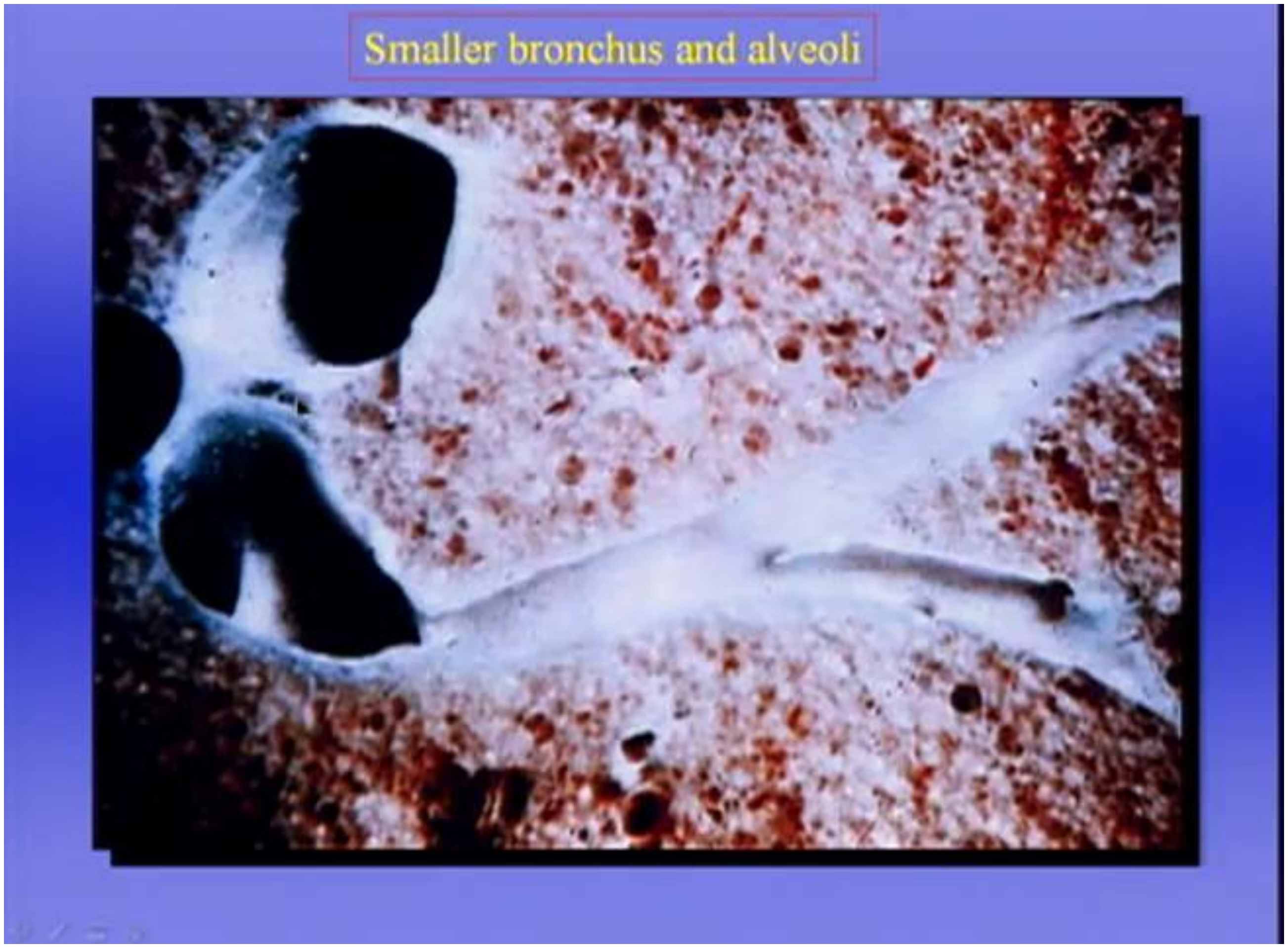
can raise the wall stresses of the capillaries to the point at which ultrastructural changes can occur. The capillaries then leak plasma and even red blood cells into the alveolar spaces.

The air ways



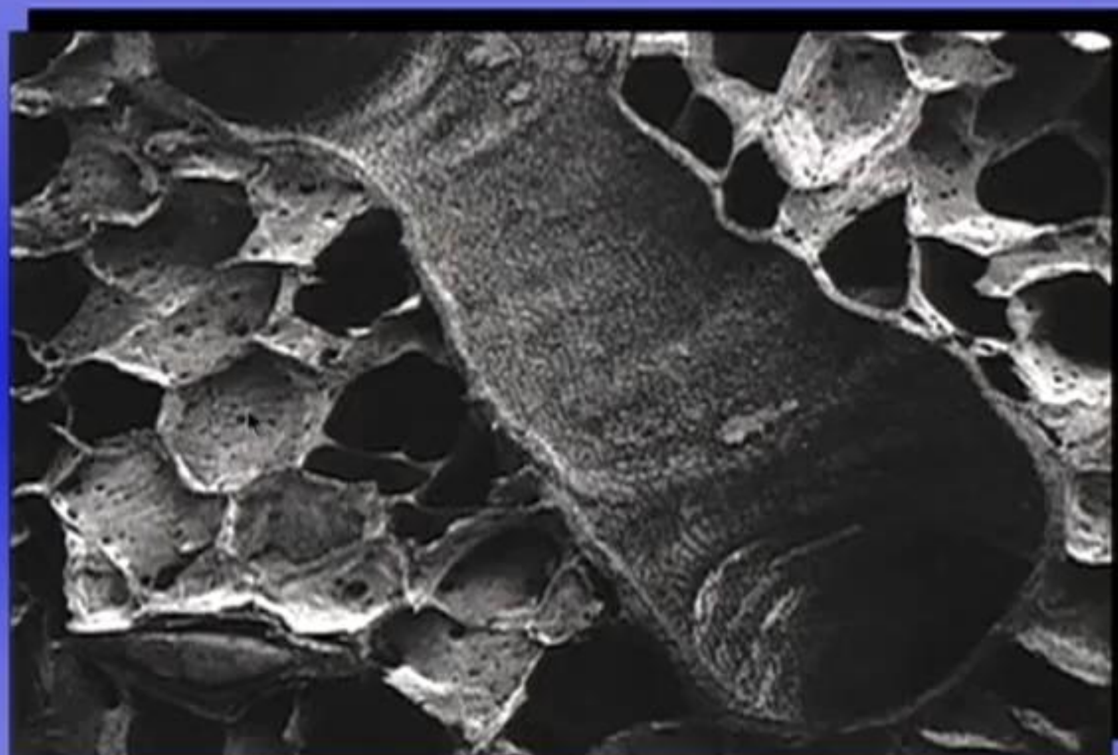

Airway Structure: Trachea and Major Bronchi

Large bronchus and blood vessels

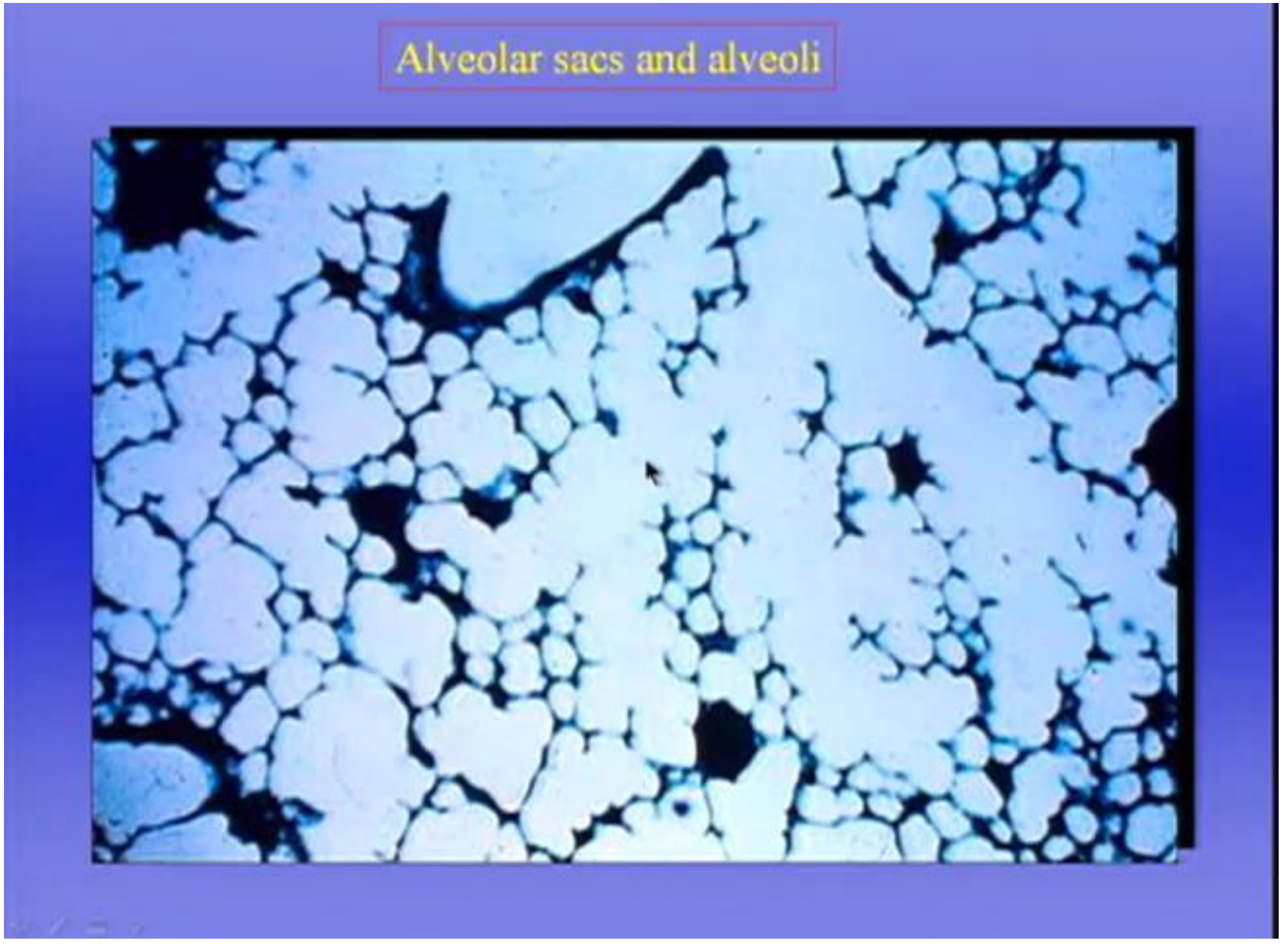

Smaller bronchus and alveoli


Airway, artery, vein and alveoli

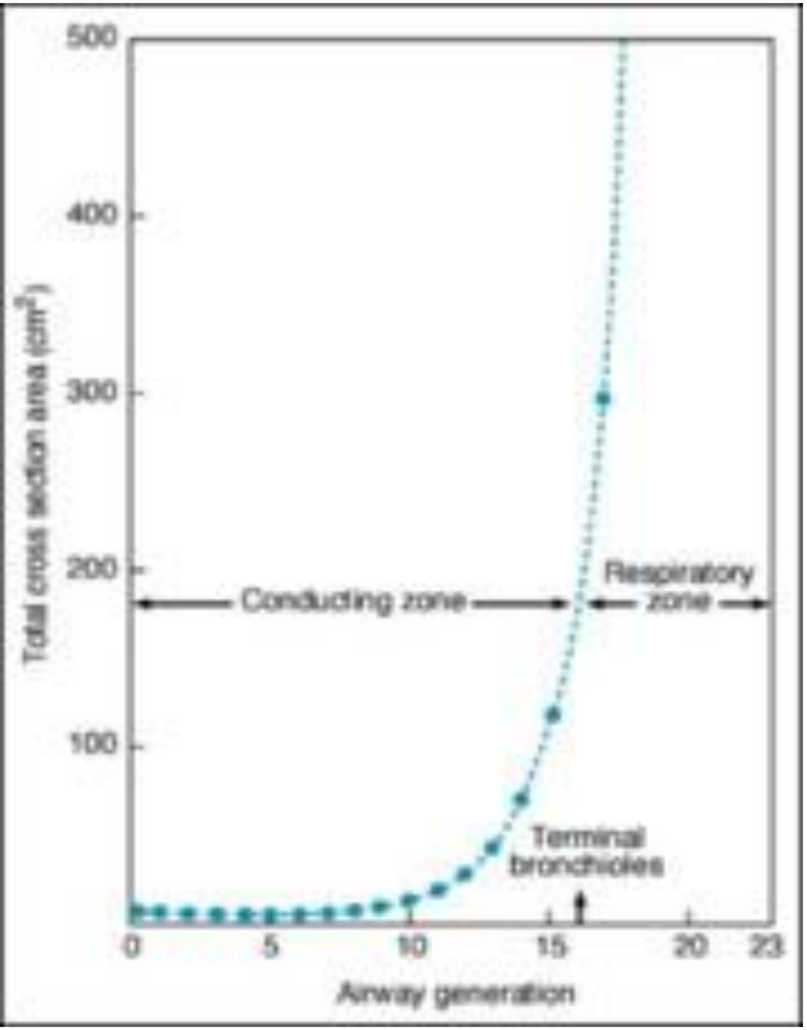
Scanning electron micrograph of small airway and alveoli




Alveolar ducts and alveoli


Alveolar sacs and alveoli

Total airway cross-sectional area as a function of airway generation.



Seven generations form the transitional and respiratory zones where gas exchange occurs are made up of transitional and respiratory bronchioles, alveolar ducts, and alveoli. These multiple divisions greatly increase the total cross-sectional area of the airways,from2.5cm2in the trachea to11,800cm2 in the alveoli. Consequently, the velocity of air flow in the small airways declines to very low values. The transition from the conducting to the Note the extremely rapid increase in total cross-sectional area in the respiratory zone. As a result, forward velocity of gas during in spiration falls to a very low level in this zone.

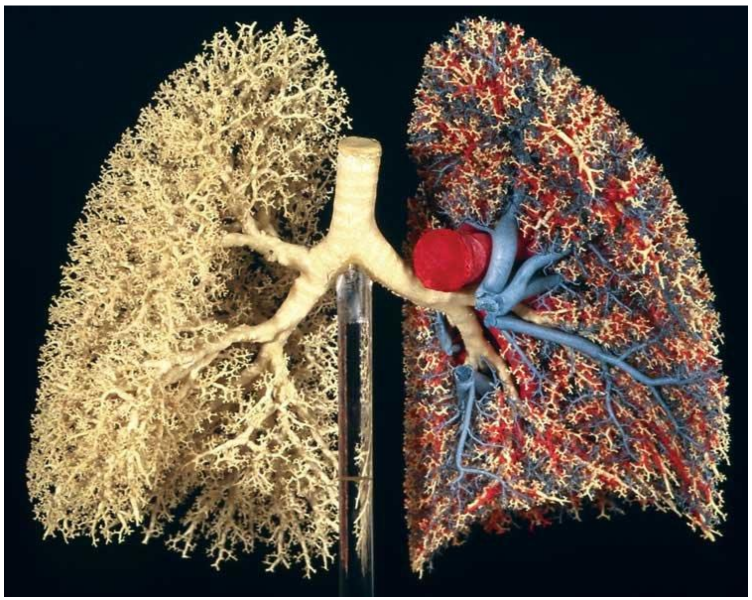
Stability of Alveoli

The lung can be regarded as a collection of 500 million bubbles, each 0.3 mm in diameter. Such a structure is inherently unstable. Stability of alveoli:

Surface tension of the liquid lining the alveoli, relatively large forces develop that tend to collapse alveoli. Fortunately, some of the cells lining the alveoli secrete a material called surfactant that dramatically lowers the surface tension of the alveolar lining layer

Blood supply of lungs

The blood vessels of the pulmonary circulation are the pulmonary arteries and the pulmonary veins.



The pulmonary artery receives the whole output of the right heart, but the resistance of the pulmonary circuit is astonishingly small. A mean pulmonary arterial pressure of only about 20 cm water (about 15 mm Hg) is required for a flow of 6 liter·min−1. This low pressure is due to the large cross-sectional area of the pulmonary circulation, which results in low resistance.

Lung Defense Mechanisms

1-They humidify and cool or warm the inspired air so that even very hot or very cold air is at or near body temperature by the time it reaches the alveoli.

2-Airway epithelial cells can secrete a variety of molecules that aid in lung defense. Secretory immunoglobulins (IgA), collectins (including Surfactant A and D), defensins and other peptides and proteases, reactive oxygen species, and reactive nitrogen species are all generated by airway epithelial cells. These secretions can act directly as antimicrobials to help keep the airway free of infection.

3- Airway epithelial cells also secrete a variety of chemokines and cytokines that recruit the traditional immune cells and others to site of infections.Various mechanisms operate to prevent foreign matter from reaching the alveoli. The hairs in the nostrils strain out many particles larger than 10 m in diameter. Most of the remaining particles of this size settle on mucous membranes in the nose and pharynx; because of their momentum, they do not follow the airstream as it curves downward into the lungs, and they impact on or near the **tonsils** and **adenoids,** large collections of immunologically active lymphoid tissue in the back of the pharynx. Particles 2 to 10 m in diameter generally fall on the walls of the bronchi as the air flow slows in the smaller passages. There they can initiate reflex bronchial constriction and coughing. Alternatively, they can be moved away from the lungs by the "mucociliary escalator." The epithelium of the respiratory passages from the anterior third of the nose to the beginning of the respiratory bronchioles is ciliated.

4-The pulmonary alveolar macrophages (PAMs) are another important component of the pulmonary defense system. Like other macrophages , these cells come originally from the bone marrow. Particles less than 2 m in diameter can evade the mucociliary escalator and reach the alveoli. PAMs are actively phagocytic and ingest these small particles. They also help process inhaled antigens for immunologic attack, and they secrete substances that attract granulocytes to the lungs as well as substances that stimulate granulocyte and monocyte formation in the bone marrow. When the PAMs ingest large amounts of the substances in cigarette smoke or other irritants, they may also release lysosomal products

FUNCTIONS OF THE LUNGS

Metabolic & Endocrine Functions of the Lungs

1- **They manufacture surfactant for local use.**

2-They also contain a fibrinolytic system that lyses clots in the pulmonary vessels. They release a variety of substances that enter the systemic arterial blood and they remove other substances from the systemic venous blood that reach them via the pulmonary artery.

3- Prostaglandins are removed from the circulation, but they are also synthesized in the lungs and released into the blood when lung tissue is stretched.

4-The lungs also activate one hormone; the physiologically inactive decapeptide angiotensin I is converted to the pressor, aldosterone-stimulating octapeptide angiotensin II in the pulmonary circulation. The reaction occurs in other tissues as well, but it is particularly prominent in the lungs. Large amounts of the angiotensin-converting enzyme responsible for this activation are located on the surface of the endothelial cells of the pulmonary capillaries. The converting enzyme also inactivates bradykinin. Circulation time through the pulmonary capillaries is less than 1 s, yet 70% of the angiotensin I reaching the lungs is converted to angiotensin II in a single trip through the capillaries. Four other peptidases have been identified on the surface of the pulmonary endothelial cells, but their full physiologic role is unsettled.

5-Removal of serotonin and norepinephrine reduces the amounts of these vasoactive substances reaching the systemic circulation. However, many other vasoactive hormones pass through the lungs without being metabolized. These include epinephrine, dopamine, oxytocin, vasopressin, and angiotensin II. 6-In addition, various amines and polypeptides are secreted by neuroendocrine cells in the lungs.

Nerve supply

- The lungs are supplied by nerves of the autonomic nervous system: A- parasympathetic nervous system occurs via the vagus nerve. When stimulated by acetylcholine, this causes constriction of the smooth muscle lining the bronchus and bronchioli, and increases the secretions from glands.[
- B- sympathetic tone from norepinephrine acting on the beta 2 receptors in the respiratory tract, which causes bronchodilation.
- C- The phrenic nerve to the diaphragm carrying nerve signals sent by the respiratory centres in the brainstem, along