

Gas Exchange

9.1 The Gas Exchange System

- The lungs are in the thoracic cavity (chest) cavity surrounded by the pleural membranes, which enclose an airtight space. This space contains a small quantity of fluid to allow friction-free movement as the lungs are ventilated by the movement of the diaphragm and ribs.

2 major adaptations of gas exchange surfaces:

- Large surface area.
- Thin - This facilitates a short diffusion pathway.
- In single-celled organisms, gases are absorbed and released by diffusion across their outer body surface. They have;

- A large surface area: The average human adult has around 480-500 million alveoli in their lungs. This equals a surface area of 40-75m². This enormous surface area increases the space available for oxygen and carbon dioxide to diffuse.
- A short diffusion pathway
- A thin surface: only 1 cell thick. Gases have a very short diffusion distance and so gas exchange is as quick and efficient as possible.

Hence they do not require a system for gas exchange.

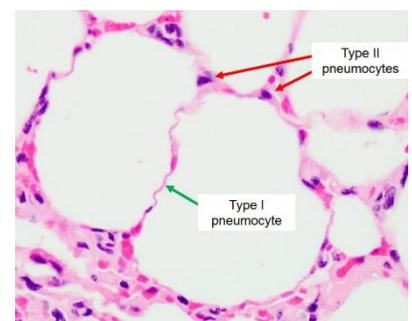
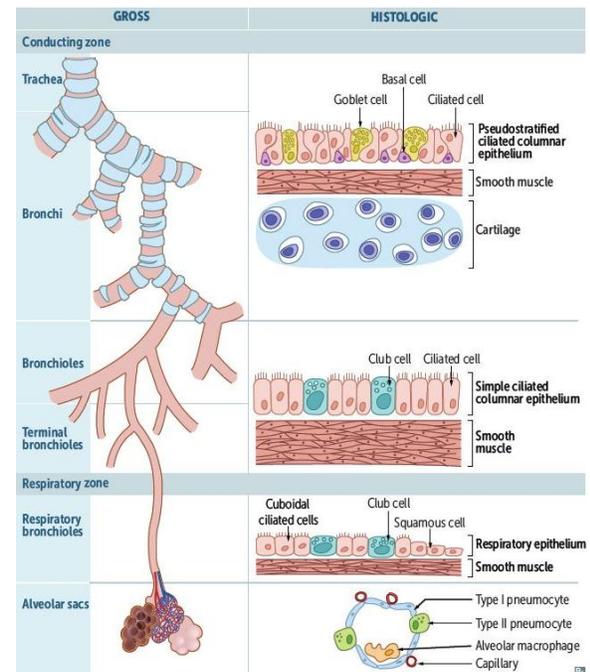
Stratified Epithelium: A stratified epithelium is made up of more than one layer of cells.

Pseudostratified Epithelium: A pseudostratified epithelium is made up of closely packed cells that appear to be arranged in layers because they're different sizes, but there's actually just one layer of cells.

Type 1 pneumocytes are alveolar cells that line the alveolar surface. They are flat and thin.

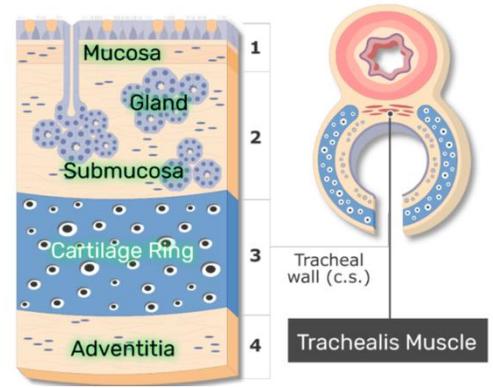
Type 2 pneumocytes are alveolar cells that secrete surfactant proteins to reduce surface tension. They are cubic in shape.

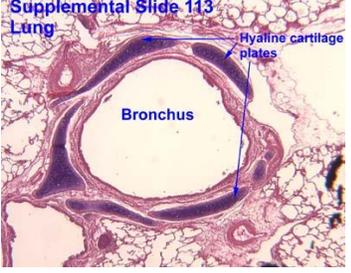
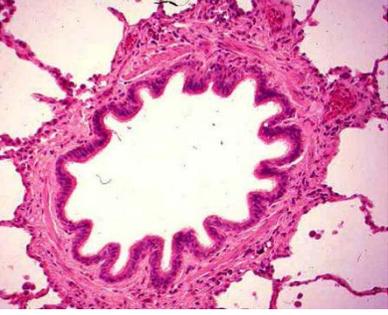
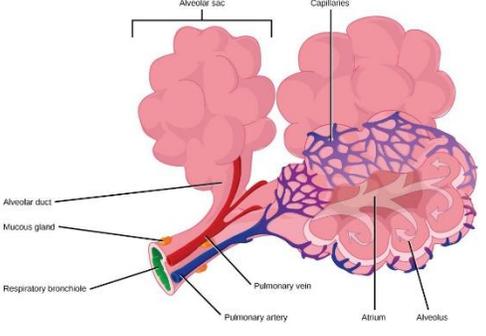
Surfactant Protein: are produced by Type II alveolar epithelial cells. They are located on mucosal surfaces & are critical for lung



homeostasis and maintenance of surface tensions. They recognize and bind bacterial, fungal, and viral pathogens.

Structure in Thorax	Description
<p>Trachea</p>	<p>This airway leads from the mouth and nose to the bronchi. The trachea is lined with mucus-secreting goblet cells and cilia. The cilia sweep micro-organisms and dust away from the lungs.</p> <p>Trachea begins from larynx and extends upto the level of 5th thoracic vertebra. It bifurcates forming 2 bronchi which enters the thoracic cavity just in front of the oesophagus.</p> <p>The wall is strengthened by incomplete C shaped cartilage rings. These rings will not allow the tracheal wall to collapse and allows the air to flow without obstruction.</p> <p>Apart from cartilages, the wall is made out of smooth muscles and connective tissues.</p> <p>The cavity is lined by ciliated epithelium.</p> <p>In the trachea and bronchi, the mucus is produced by the goblet cells of the ciliated epithelium.</p> <p>The upper part of each goblet cell is swollen with mucin droplets which have been secreted by the cell.</p> <p>Mucus is a slimy solution of mucin, which is composed of glycoproteins with many carbohydrate chains that make them sticky and able to trap inhaled particles.</p> <p>The rest of the goblet cell, which contains the nucleus, is quite slender like the stem of a goblet.</p> <p>Mucus is also made by mucous glands beneath the epithelium.</p>
<p>Lungs</p>	<p>Humans have two lungs, both of which are a central part of the breathing system and where gas exchange takes place.</p>



<p>Bronchi</p>	<p>"Bronchi" is the plural of "bronchus". At the base of the trachea are two bronchi (singular: bronchus), which subdivide and branch extensively forming a bronchial 'tree' in each lung. The left and right bronchi are at the bottom of the trachea and are similar in structure, but narrower. The bronchi lead to bronchioles.</p>	 <p>Supplemental Slide 113 Lung Hyaline cartilage plates Bronchus</p>
<p>Bronchioles</p>	<p>These are narrow tubes (less than 1mm) which carry air from the bronchi to the alveoli. As they are so narrow, they have no supporting cartilage and so can collapse. Each bronchus divides many times to form smaller bronchioles. Terminal bronchioles divide to form even narrower respiratory bronchioles that supply the alveoli with air. Bronchioles are surrounded by smooth muscle, which can contract or relax to adjust the diameter of these tiny airways.</p>	
<p>Alveoli</p>	<p>The main site of gas exchange within the lungs. These are tiny sacs with many structural adaptations to enable efficient gas exchange, such as their thin walls and large surface area to volume ratio. In humans, gas exchange occurs in alveoli. The walls of alveoli contain elastic fibres which stretch during inspiration and recoil during expiration to help force out air. The alveoli have extremely thin walls, each consisting of a single layer of squamous epithelial cells no more than 0.5 μ thick. Pressed closely against the alveoli walls are blood capillaries, also with very thin single-celled walls. Oxygen and carbon dioxide molecules diffuse quickly between the air and the blood because the distance is very small.</p>	 <p>Alveolar sac Capillaries Alveolar duct Mucous gland Respiratory bronchiole Pulmonary vein Pulmonary artery Atrium Alveolus</p>
<p>Capillary network</p>	<p>An extensive network of capillaries surrounds the alveoli and are an exchange surface between the lungs and the blood. During gas exchange, oxygen diffuses from the alveoli and into the capillaries, while carbon dioxide diffuses the other way and is exhaled.</p>	

Structure	Function
Ciliated epithelial cells	These cells line the trachea to the bronchi. Each cell has tiny projections called cilia, which sweep mucus, dust, bacteria and other microorganisms up and away from the lungs to the mouth, where they are swallowed and digested by stomach acid. They are distinctive due to their narrow cell bodies and hair-like cilia located along the apical layer.
Goblet cells	Goblet cells are embedded throughout the ciliated epithelium and are mucus-producing cells. The mucus they produce traps dust, bacteria and microorganisms. They lack a cilia & their nucleus is found towards their basal layer, with a large Golgi Apparatus & Mucus Granules found towards the apical layer.
Squamous Epithelium	It is made of thin, flat squamous cells.
Mucous glands	The mucous glands work with goblet cells in the trachea and bronchi to produce mucus.
Cartilage	Rings of cartilage line the trachea, or windpipe. Cartilage is a strong but flexible tissue and is essential for keeping the trachea open. Because of its flexibility, the cartilage can move & flex as we breathe.
Smooth muscle	Smooth muscle is muscle not under conscious control and is found in the walls of the bronchi and bronchioles. The cells of the smooth muscle are tightly packed & are found beneath the ciliated epithelium. It helps to regulate the flow of air into and out of the lungs by dilating and widening when more air is needed. They are not striated & don't show any stripes under a microscope.
Elastic Fibres	Elastic Fibres are found in the squamous epithelium of the alveolar walls. Elastic Fibres are a critical component of alveoli because they allow the tiny alveoli to stretch as they fill with air and recoil to help force air out. It is the elastic abilities of alveoli which enable them to have such a large surface area. In serious cases of COPD, such as advanced emphysema, the alveoli lose these elastic properties.

Airway	Number	Approximate Diameter	Cartilage	Goblet Cells	Smooth Muscle	Cilia	Site of Gas Exchange
Trachea	1	1.8 cm	Yes	Yes	Yes	Yes	No
Bronchus	2	1.2 cm	Yes	Yes	Yes	Yes	No
Terminal Bronchiole	48,000	1.0 mm	No	No	Yes	Yes	No
Respiratory Bronchiole	300,000	0.5 mm	No	No	No	A Few	No
Alveolar Duct	9×10^6	400 μm	No	No	No	No	Yes
Alveoli	3×10^9	250 μm	No	No	No	No	Yes

Gas Exchange in Alveoli:

- For Gas Exchange to take place rapidly, a steep concentration gradient must be maintained.
- This is done by breathing and by the movement of the blood.
- Breathing brings supplies of fresh air into the lungs, with a relatively high oxygen concentration and a relatively low carbon dioxide concentration. Blood is brought to the lungs with a lower concentration of oxygen and a higher concentration of carbon dioxide than the air in the alveoli.
- Oxygen therefore diffuses down its concentration gradient from the air in the alveoli to the blood, and carbon dioxide diffuses down its concentration gradient in the opposite direction.
- The blood is constantly flowing through and out of the lungs, so, as the oxygenated blood leaves, more deoxygenated blood enters to maintain the concentration gradient with each new breath.