CAIE Biology A-level

Topic 9: Gas exchange

Notes

The need for specialised exchange surfaces arises as the size of the organism increases, and its **surface area to volume ratio** decreases. In the case of **single-celled organisms**, the substances can easily enter the cell as the diffusion distance is short. However, in **multicellular organisms,** that distance is much larger due to a lower surface area to volume ratio. As a result of this, multicellular organisms require **specialised exchange surfaces** for efficient gas exchange of **carbon dioxide and oxygen**.

Features of an efficient exchange surface include **large surface area**, for instance, the **root hair cells** in plants or **folded membranes** in the mitochondria. An efficient exchange surface should also be **thin** to ensure the diffusion distance is short. The exchange surface also requires a **good blood supply/ventilation** to maintain a steep gradient, for example, the capillaries in the alveoli.

Mammalian gaseous exchange system

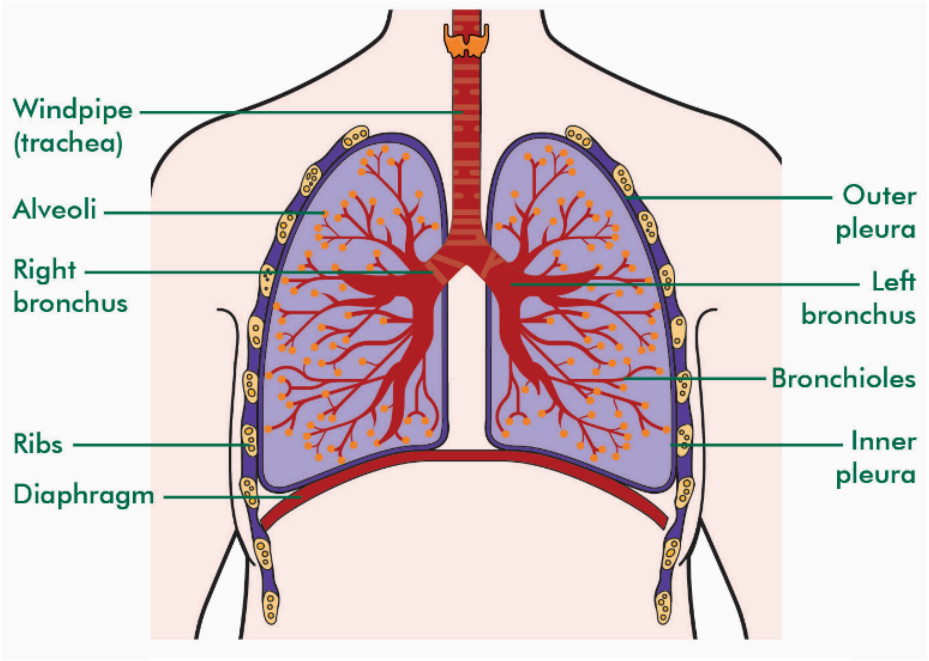


Figure Macmillan – The Lungs

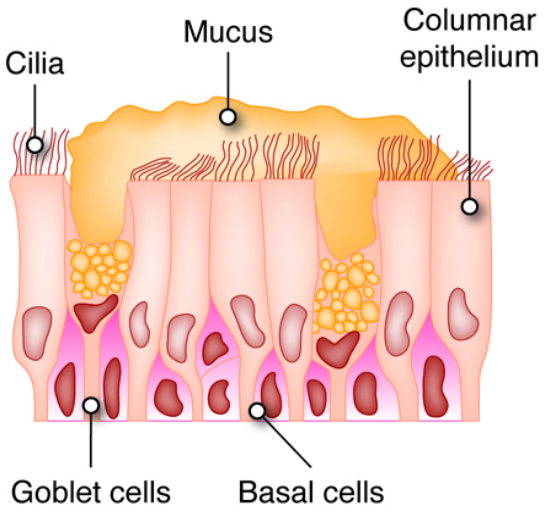
The **lungs** are a pair of structures with a **large surface area** located in the **chest cavity** with the ability to **inflate**. The lungs are surrounded by the **rib cage** which serves to protect them. A lubricating substance is secreted to prevent the friction between rib cage and lungs during inflation and deflation. **External and internal intercostal muscles** between the ribs work antagonistically to raise and lower the ribcage. A structure called the **diaphragm** separates the lungs from the abdomen area.

The air enters through the nose and passes along the **trachea, bronchi and bronchioles**, which are structures well adapted to their role in enabling passage of air into the lungs. The airways are held open with the help of rings **of cartilage** in the trachea to allow passage of food down **the oesophagus** behind the **trachea.**

The gaseous exchange takes place in the walls of **alveoli**, which are tiny sacs filled with air and surrounded by **capillaries**. Capillaries have a constant flow of blood which carries blood away from the area of diffusion as it becomes oxygenated to maintain the **concentration gradient**. The oxygen that is inhaled moves from the alveoli into the blood. At the same time, carbon dioxide is also removed from the capillaries to the alveoli which again maintains a steep concentration gradient. The alveoli also have a thin layer of surfactant that reduces surface tension, preventing collapse, keeping them inflated.

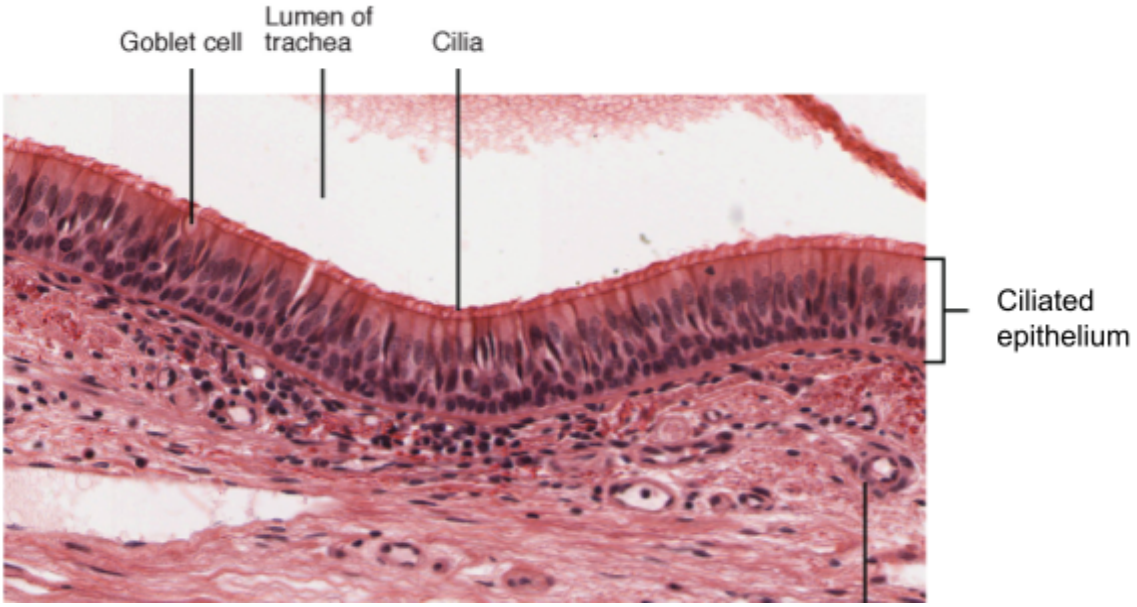
Trachea and bronchi are similar in structure, with the exception of size (bronchi are narrower). They are composed of **several layers** which together make up a thick wall. The wall is mostly composed of cartilage, in the form of incomplete C rings. Inside the surface of the cartilage is a layer of **glandular and connective tissue, elastic fibres, smooth muscle and blood vessels.** This is referred to as the '**loose tissue**'. The inner lining is an epithelial layer composed of **ciliated epithelium and goblet cells.**

The **bronchioles** are narrower than the bronchi. Only the larger bronchioles contain cartilage. Their wall is made out of smooth muscle and elastic fibres. The smallest of bronchioles have alveoli clusters at the ends.



Structures and functions of mammalian gaseous exchange system include:

- **Cartilage** – involved in supporting the trachea and bronchi, plays an important role in preventing the trachea and bronchi from collapsing in the event of pressure drop during exhalation.
- **Ciliated epithelium** – present in bronchi, bronchioles and trachea. Involved in moving mucus along the throat to prevent lung infection.
- **Squamous epithelium** – lines the alveoli and allows gas exchange to take place between the capillaries and the air in the lungs. It is thin with a large surface area for rapid diffusion.
- **Goblet cells** – cells present in the trachea, bronchi and bronchioles involved in mucus secretion to trap bacteria and dust to reduce the risk of infection.
- **Smooth muscle** – their ability to contract enables them to play a role in constricting the airway, thus controlling airway diameter and the flow of air to and from the alveoli.
- **Elastic fibres** – stretch when we inhale and recoil when we exhale, helping to control the flow of air.



Gas exchange between air in alveoli and blood in capillaries:

Gas exchange occurs in the **alveoli**, where air is brought into close contact with the blood in the surrounding **capillary network**. The air in the alveoli has a higher **partial pressure of oxygen** than the deoxygenated blood arriving in the capillaries. Hence, **oxygen diffuses** across the thin **alveolar epithelium** and **capillary endothelium** into the blood. At the same time, the blood has a higher **partial pressure of carbon dioxide**, causing **carbon dioxide** to diffuse from the blood into the alveoli to be exhaled.

The diffusion pathway is extremely short because both the alveolar and capillary walls are **one cell thick**, and their moist surfaces allow gases to dissolve before diffusing. The alveoli provide a very **large surface area**, and continuous **blood flow** maintains steep concentration gradients by bringing in deoxygenated blood and carrying away oxygenated blood. **Ventilation** constantly refreshes the air in the alveoli, maintaining these gradients, while **elastic fibres** and **surfactant** ensure the alveoli remain open and able to expand, allowing efficient diffusion.

Gas exchange is therefore a passive process driven by **pressure gradients**.