RESPIRATORY SYSTEM

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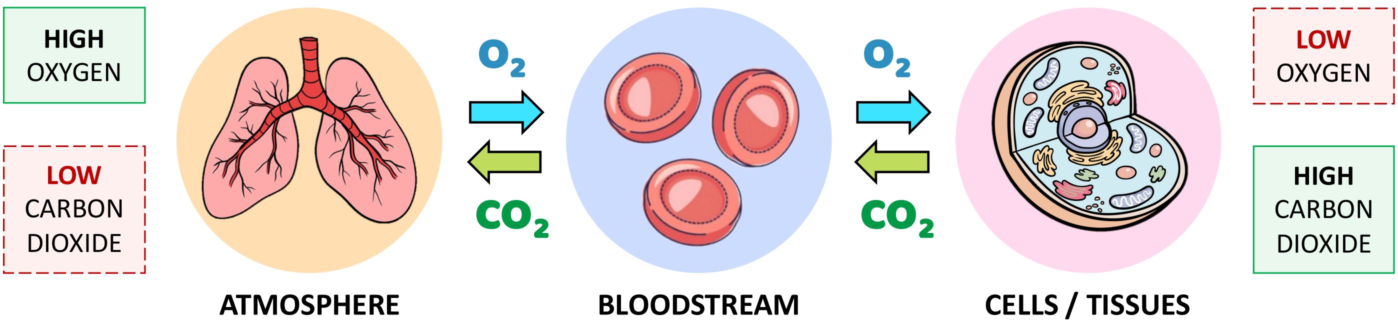
GAS EXCHANGE

Gas exchange is a vital function in all living organisms as it facilitates the interchange of materials required for metabolic reactions. Oxygen is required for aerobic respiration, whereby cells produce large amounts of chemical energy (ATP). Carbon dioxide is a by-product of this process and excess levels must be removed from the organism. In unicellular organisms, gas exchange can be achieved via simple diffusion across the membrane surface. However, multicellular organisms encounter challenges to achieving adequate levels of gas exchange. In larger organisms, the distance from the centre of the organism to the exterior is greater. This means that diffusion distance is greater for certain tissues, necessitating a greater gradient to ensure adequate exchange. Additionally, larger organisms have smaller surface area : volume ratios. This means they have a reduced capacity to exchange gases relative to the increased demand for gases by the tissues. Larger organisms therefore require specialised respiratory system to optimise the exchange of vital gases.



RESPIRATORY SURFACES

Respiratory systems perform **ventilation** by continually cycling fresh air from the atmosphere. This maintains a suitable concentration gradient for gas exchange. The respiratory surfaces of these systems all possess certain key qualities that optimise the transfer of the respiratory gases:

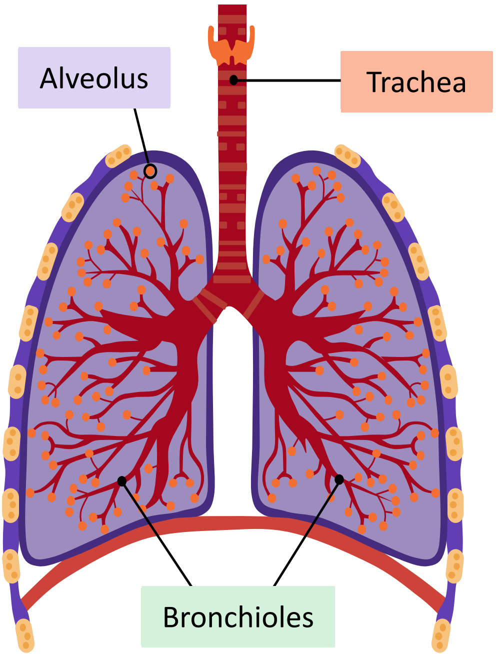
- **Surface area** – Must be large to facilitate sufficient gas exchange
- **Moist** – Gases will diffuse more readily when dissolved in solution
- **Absorptive** – The surfaces must be suitably permeable to the gases
- **Rich blood system** – They are connected to a dense blood network
- **Thin tissue layer** – Diffusion distance is minimal to optimise exchange

Examples of respiratory systems include **gills** (for water) and **lungs** (for air)

Mnemonic: SMART

LUNGS

The mammalian respiratory system is composed of two spongy structures called lungs. Air is inhaled via the mouth or the nose and travels down an airway called the **trachea**, until it bifurcates into two **bronchi** which connect to the lungs. Each bronchus then divides into many smaller airways called **bronchioles** that end in a cluster of air sacs called **alveoli** – which function as the site of gas exchange with the bloodstream. The rapid branching of the bronchioles act to greatly increase the available surface area for gas exchange in the lungs. Alveoli are composed of specialised cells called **pneumocytes**. Type I pneumocytes are extremely flat and are optimised for gas exchange (thin cells will possess a minimal diffusion distance). Type II pneumocytes are cuboidal in shape and release **pulmonary surfactant** (a fluid which reduces the surface tension in alveoli to prevent the air sacs collapsing).

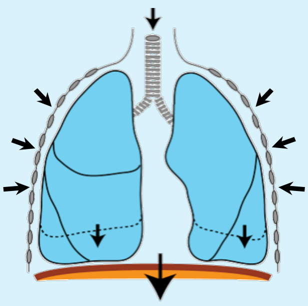


VENTILATION

Ventilation is mediated by sets of antagonistic muscles which change the volume of the thoracic cavity. **Inhalation** occurs when the volume within the chest is increased – causing the pressure within the lungs to become less than atmospheric pressure, so air will move into the lungs to equalise the pressure differential. This expansion in the thoracic cavity is caused by the contraction and flattening of the diaphragm, and also by the contraction of the external intercostal muscles (which function to pull ribs upwards and outwards). **Exhalation** occurs when the volume in the chest is decreased – causing the pressure in the lungs to become more than the atmospheric pressure, so air will move out of the lungs to equalise the pressure difference. This reduction in the volume of the thoracic cavity is caused by the relaxation of the diaphragm (which then curves upwards) and the contraction of the internal intercostal muscles (which pull ribs down and inwards). Additionally, abdominal muscles can contract to push abdominal contents upwards and forcibly expel air.

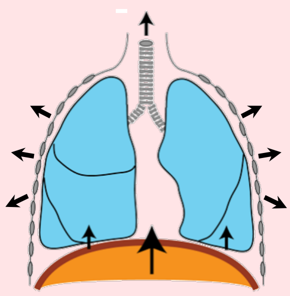
Inhalation:

- Diaphragm flattens
- External intercostal muscles contract
- Ribs pulled upward
- Chest gets larger



Exhalation:

- Diaphragm curves
- Internal intercostal muscles contract
- Ribs pulled inward
- Chest gets smaller



LUNG CAPACITY

Lung volumes can be used as a measure of respiratory fitness:

1. **Total lung capacity** – Maximal volume of air the lungs can hold
2. **Residual volume** – Volume of air always present in the lungs
3. **Vital capacity** – Maximal volume of air that can be exchanged
4. **Tidal volume** – Volume of air exchanged via a normal breath
5. **Inspiratory reserve** – Air inspired after a normal inhalation
6. **Expiratory reserve** – Air expired after a normal exhalation