Functions
Effective absorption of O₂ from the air and excretion of CO₂ to the air (= gas exchange)

Remember Fick’s Law: \[ \text{Diffusion} \propto \frac{\text{surface area} \times \text{concentration difference}}{\text{distance}} \]

Structure

Nasal Cavity
- hairs and mucus trap much of the dust and small particles like bacteria
- the wet surface moistens the air
- the rich blood supply warms the air

Mouth Cavity
Air entering via the mouth is not cleaned, moistened or warmed as well

Epiglottis
- protects the trachea against the entry of food and drink by
  - a reflex action
  - the opening of trachea is closed by the epiglottis during swallowing

Trachea
- a channel for air to flow to and from the bronchi
- its mucus lining traps dust and bacteria
- the beating of cilia on its surface move the mucus to the pharynx for swallowing
- the C-shaped rings of cartilage support the wall of the trachea keeping it permanently open
- **Bronchus** - one goes to each lung - similar in structure to the trachea but narrower

Bronchioles (many branches)
- a narrow open tube for air to flow in and out of the alveoli
- inflammation = bronchitis

Alveoli
- Sites of gas exchange in close extensive contact with blood capillaries
- Large Surface Area: \((90\text{m}^2)\) from 700 million alveoli.
- Good blood supply

Pleural Membranes
- surround and protect the lungs, lining the thoracic cavity
- ‘glues’ the lungs to the chest wall and diaphragm
- permits smooth moving of lungs across chest wall and diaphragm during breathing

Ribs
- protective bony cage around the lungs and heart;
- play a role in breathing (intercostal muscles)
**Diaphragm**
- a broad sheet of muscle between the thoracic and abdominal cavities
- its contraction is responsible for 75% of the air drawn into the lungs

**Intercostal Muscles**
- changes the shape and volume of the rib cage during breathing
- **external intercostals contract** to breathe in – ‘**inspiration**’
- **internal intercostals contract** during forced breathing out – ‘**expiration**’
- responsible for 25% of the inspired air

<table>
<thead>
<tr>
<th>Gas + %</th>
<th>Inspired Air</th>
<th>Expired Air</th>
<th>Alteration</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78%</td>
<td>76%</td>
<td>No real change.</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.8%</td>
<td>15.3%</td>
<td>Reduced by about a quarter</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>0.04%</td>
<td>4.2%</td>
<td>Increased by about a hundred and five times</td>
</tr>
<tr>
<td>Water Vapour</td>
<td>1.2%</td>
<td>6.1%</td>
<td>Increased about five times</td>
</tr>
</tbody>
</table>

**Note:** > 250cm³/day of water is lost from the body due to breathing.

**The Breathing Mechanism**

**Inspiration**
- An active process because it involves muscle contraction.
- The diaphragm and external intercostal muscles contract.
- The contracting diaphragm flattens and stretches the elastic lungs downward.
- The contracting intercostals pull the ribcage up and out causing the elastic lungs to stretch.
- The expansion of air causes a drop in air pressure in the lungs.
- The air in the lungs is at a lower pressure than the air outside, so air enters the lungs.

**Expiration**
- A passive process because it does not involve muscle contraction.
- The diaphragm relaxes, and the internal intercostal muscles contract (forced breathing).
- The lungs recoil elastically reducing their volume – a passive process.
- The volume of air in the lungs decreases causing an increase in the air pressure.
- Air flows from higher to lower pressure so the air flows out of the lungs.
- **Note:** the elastic recoil of the lungs pulls up the adhering diaphragm and ribcage.
**Carbon Dioxide and Breathing**

- Carbon dioxide blood level controls the rate and depth of breathing.
- Normal breathing is controlled subconsciously by the medulla oblongata in the brain.
- ↑ in blood CO$_2$ stimulates the medulla, sending nerve impulses to the breathing muscles.
- The diaphragm and external intercostal muscles contract, so air is breathed in.
- Nervous feedback from the inflating alveoli causes the medulla to switch off its stimulation.
- Inspiration stops and the lungs recoil causing expiration.
- Rapidly rising levels of CO$_2$ increase the rate of breathing.
- Exercise increases the production of CO$_2$ leading to an increase in the breathing rate.

**Gas Exchange Adaptations**

- Gas exchange is by diffusion so these adaptations enhance diffusion. (Fick’s Law)
- **Large surface area**: 90m$^2$ — 700 million alveoli
- **Good blood supply** - 40 billion capillaries.
- **Permeable surfaces**: the cell membranes are freely permeable to O$_2$ and CO$_2$.
- **Thin walls**: the distance between the air and the blood is two cells wide.
- **RBC’s only just fit capillaries** thus distance for diffusion minimised
- **Moist surface of alveoli**: enhances the uptake of O$_2$.
- **Elastic alveoli walls**: efficient filling with air and recoil enhances emptying.
- **Slow capillary blood flow**: time for complete oxygenation and excretion of CO$_2$.