WJEC (England) Biology AS-level

2.2: Adaptations for gas exchange

Notes

The need for specialised exchange surfaces arises as the size of the organism, and its **surface area to volume ratio** increases. In the case of single celled organisms, the substances can easily enter the cell as the **distance that needs to be crossed over is short**. However, in **multicellular** organisms that **distance is much larger** due to **a higher surface area to volume ratio.** As a result of that, 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** or **folded membranes**, such as those of the mitochondria. An efficient exchange surface should also be **thin to ensure that the distance that needs to be crossed by the substance is short**. The exchange surface also requires a **good blood supply/ventilation** to maintain a **steep gradient**, for example that of the alveoli.

Mammalian gaseous exchange system

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 which **contract to raise and lower the ribcage** respectively. A structure called the **diaphragm separates the lungs from the abdomen area**.

The air enters through the **nose, along the trachea, bronchi and bronchioles** which are **structures well adapted** to their role in enabling **passage of air into the lungs**. The gaseous exchange takes plans **in the walls of the alveoli**, which **are tiny sacs filled with air.**

The trachea, bronchi and bronchioles which **enable the flow of air into and out of the lungs**. The airways are **held open with the help of rings of cartilage**, The shape of these rings is incomplete (i.e. 'C' shaped) in the trachea to **allow passage of food down the oesophagus** behind the trachea.

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 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 layers 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 lungs from collapsing** in the event of **pressure drop** during exhalation.
- **Ciliated epithelium** – present in bronchi, bronchioles and trachea, involved in moving mucus **along to prevent lung infection** by moving it towards the throat.
- **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** with the help of lysozyme which digests bacteria.
- **Smooth muscle** – their ability to contract enables them to play a role in **constricting the airway**, thus controlling its diameter as a result and thus **controlling the flow of air to and from alveoli.**
- **Elastic fibres** – **stretch when we exhale and recoil when we inhale** thus controlling the flow of air.

Ventilation

The flow of air in and out of the **alveoli** is referred to as ventilation and is composed of two stages; **inspiration and expiration**. This process occurs with the help of two sets of muscles, the **intercostal muscles and diaphragm**.

During **inspiration**, the **external intercostal** muscles contract whereas the internal ones relax, as a result causing the **ribs** to raise upwards. The diaphragm **contracts and flattens**. In combination, the intercostal muscles and diaphragm cause the volume inside the **thorax** to increase, thus lowering the pressure. The difference between the pressure inside the **lungs** and atmospheric pressure creates a gradient, thus causing the air to **enter the lungs.**

During **expiration**, the **internal** intercostal muscles **contract** whereas the external ones relax therefore **lowering** the rig cage. The diaphragm **relaxes** and raises **up**wards. This results in a combination of a decrease the volume inside the thorax, therefore increasing the pressure, forcing the air **out of the lungs**.

Spirometer

A **spirometer** is a device used to measure **lung volume**. A person using a spirometer breathes in and out of the **airtight chamber**, thus causing it to move up and down, leaving a **trace on a graph** which can then be interpreted.

Vital capacity – the **maximum volume of air** that can be inhaled or exhaled in a single breath. Varies depending on **gender, age, size as well as height.**

Tidal volume – the **volume of air** we breathe in and out at **each breath at rest.**

Breathing rate – the **number of breaths per minute**, can be calculated from the spirometer trace by counting the **number of peaks** or troughs in a minute.

The volume of air which is always present in the lungs is known as the **residual volume**. The **tidal volume** can be exceeded, in cases such as during exercise where the inspiratory reserve volume is reached in an attempt to amount of air breathed in. Similarly, the **expiratory reserve volume** is the additional volume of air that can be exhaled **on top of the tidal volume**.

Ventilation and gas exchange in bony fish and insects

Fish have a **small surface area to volume ratio** for gas exchange, apart from this they have an impermeable membrane so gases can't diffuse through their skin therefore fish need a specialised exchange surface**. Bony fish** have **four pairs of gills**, each gill supported by an **arch**. Along each arch there are multiple projections called **gill filaments**, with **lamellae** on them which participate in gas exchange. Blood and water flow across the lamellae in a **counter current direction** meaning they flow in the opposite direction.

The projections are **held apart** by **water flow**. Therefore, in the absence of water they **stick together**, thus meaning fish cannot survive very long out of water.

Ventilation is required to maintain a **continuous unidirectional flow**. Ventilation begins with the fish opening its mouth followed by **lowering the floor of the buccal cavity**, thus enabling water to flow into it. Afterwards, fish closes its mouth, causing the **buccal cavity floor to raise**, thus increasing the pressure. The water is forced over the gill filaments by the **difference in pressure** between the **mouth cavity and opercular cavity**. The operculum acts as a **valve and pump** and lets water out and pumps it in.

Insects do not possess a transport system therefore **oxygen needs to be transported directly to tissues undergoing respiration**. This is achieved with the help of **spiracles**, small openings of tubes, either bigger **trachea** or smaller **tracheoles**, which run into the body of an insect and supply it with the required gases.

The leaf

The structure of angiosperm leaf is as following:

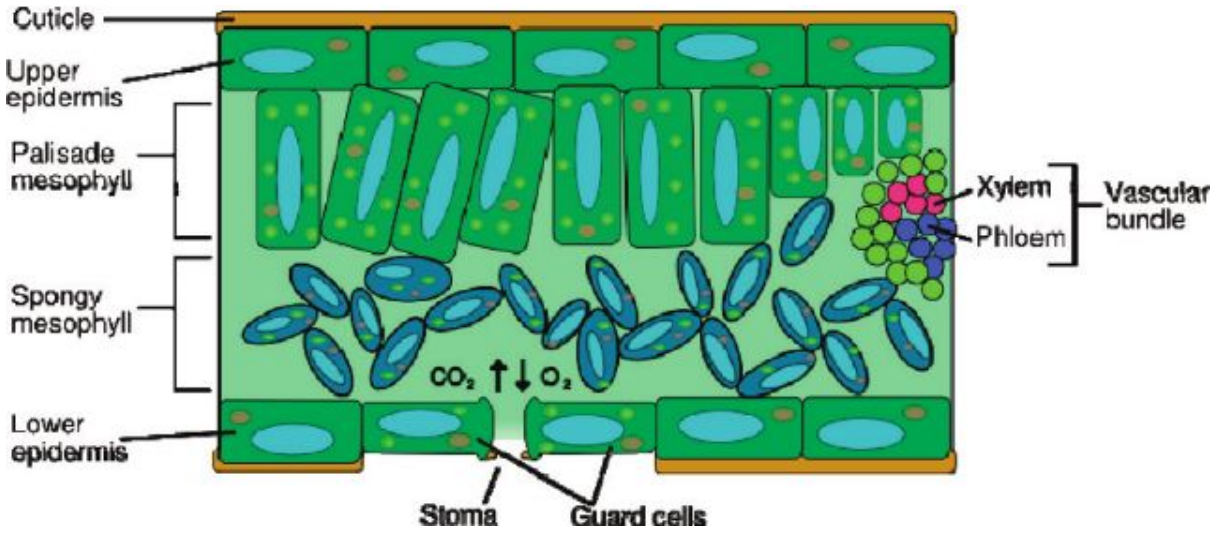

Figure 1 ResearchGate

Leaf structures and their function:

- **Upper epidermis** is a waxy, waterproof layer known as cuticle which prevents excessive evaporation of water, it has no chloroplasts thus allowing light to pass through the outer layer easily.
- **Palisade mesophyll** is the main site of photosynthesis; palisade cells contain a large number of chloroplasts for photosynthesis.
- **Spongy mesophyll** contains **air spaces** which are connected to outer atmosphere through stomata and facilitate the gas exchange between mesophyll and atmosphere, also the site of photosynthesis.
- **Lower epidermis**, contains **guard cells** which control the opening and closing of the **stomata.**

Stomata and guard cells play an important role in gas exchange:

- **Stomatal aperture** is regulated in response to the requirements for uptake of carbon dioxide for photosynthesis and conserving water.

- Stomata have **daily rhythms** of opening and closing and respond to changes in environmental conditions to allow diffusion of carbon dioxide and regulate water loss by **transpiration.**

- **Guard cells** control the opening and closing of the stomata by either inflating to allow water and gas exchange or deflate to prevent water loss.

- Stomata **inflate** when turgidity caused by increase in potassium ions occurs, thus decreasing the water potential, thus causing water to enter the guard cells.

- Stomata close following an **excess water loss**, usually in response to drop in light levels and lower rate of photosynthesis.