Electrocardiograms

We can monitor the electrical activity of the heart using an **electrocardiogram** (ECG) (see Figure 2). This involves attaching a number of sensors to the skin. Some of the electrical activity generated by the heart spreads through the tissues next to the heart and outwards to the skin. The sensors on the skin pick up the electrical excitation created by the heart and convert this into a trace.

The trace of a healthy person has a particular shape. It consists of a series of waves that are labelled P, Q, R, S and T.

- Wave P shows the excitation of the atria.
- QRS indicates the excitation of the ventricles.
- T shows diastole.

(see topic 3.2.5).

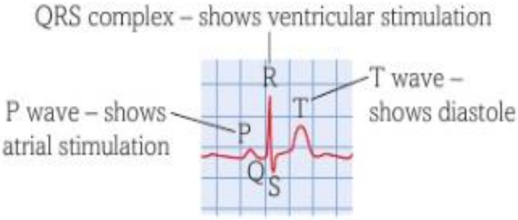

Figure 2 A normal ECG.

The shape of the ECG trace can sometimes indicate when part of the heart muscle is not healthy. The diagrams in Figure 3 show four abnormal ECG traces compared with a normal trace. Such traces can be used by medical professionals to diagnose heart problems.

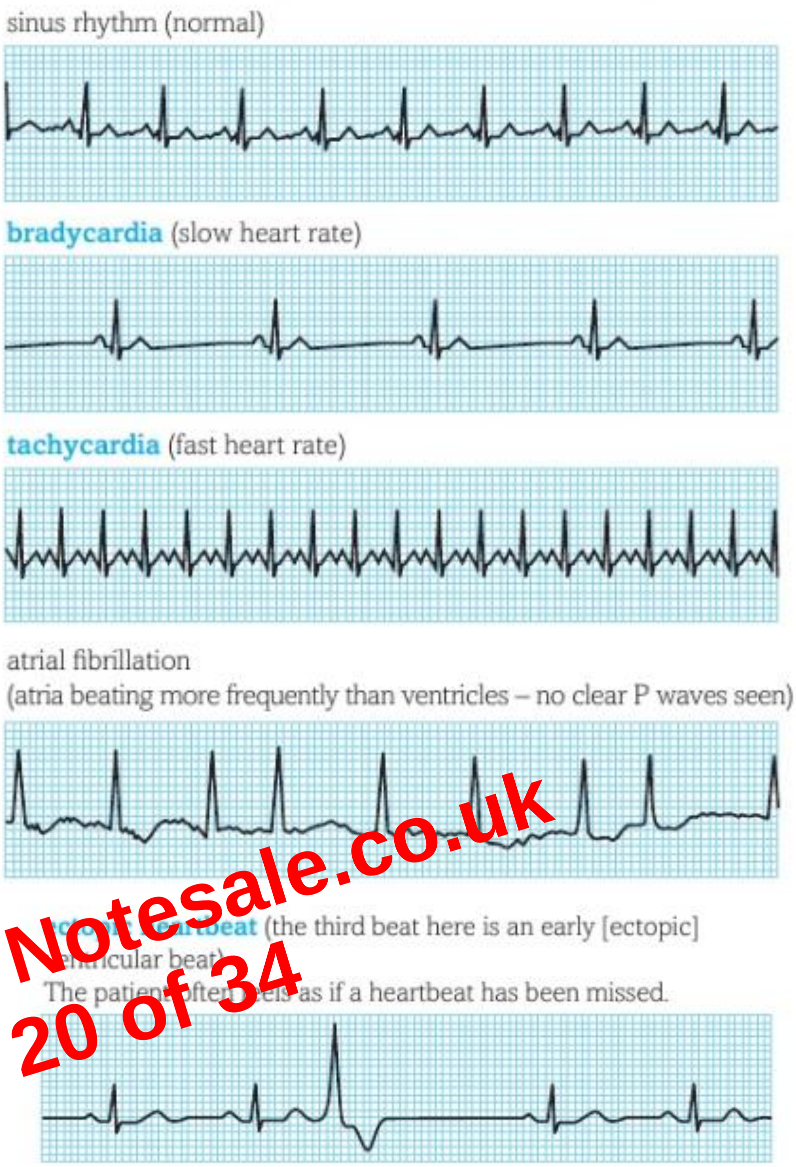

Figure 3 Abnormal ECGs, compared with a normal trace.

(i) <u>The role of haemoglobin in transporting oxygen and carbon dioxide</u>

<u>To include the reversible binding of oxygen molecules, carbonic anhydrase, haemoglobinic acid, HCO3- and the chloride shift.</u>

Transports of oxygen

Oxygen enters the blood in the lungs. Oxygen molecules diffuse into the blood plasma and red blood cells. Here, they associate with the haemoglobin to form oxyhaemoglobin.

Haemoglobin is a complex protein with 4 subunits. Each subunit contains a haem group that contains a single iron ion (FE2+). This attracts and holds 1 oxygen molecule. The harm group is said to have an affinity for (an attraction to) oxygen – the haemoglobin attracts and holds the oxygen. Each haem group can hold 1 oxygen molecule, so each haemoglobin molecule can carry 4 oxygen molecules.

The transport of water

The cell wall of a plant cell is permeable to water. The cell-surface membrane is selectively permeable. As a result, plant cells can contain mineral ions in solution which reduced the water potential inside the cell. The more concentrated the mineral ions, the lower the water potential. Water moves by osmosis from a cell with a higher water potential to a cell with a lower water potential because water molecules move down their water potential gradient. Similarly, water can enter a cell from its environment if the water potential in the cell is lower than the water potential in the environment. This is how root hair cells absorb water from the soil.

Pathways

Once in the plant, water can move across a tissue such as the root cortex by different pathways.

1) The apoplast pathway carries water between the cells through the cell walls – the water does not enter the cytoplasm or pass through cell-surface membranes
2) The symplast pathway takes water from cell to cell through the cytoplasm of each cell. Water often passes through plasmodesmata linking the cytoplasm of adjacent cells
3) The vacuolar pathway carries water through the cytoplasm and vacuole of each cell.

The **transpiration stream** is the movement of water from the roots to the leaves.

Remember that transpiration is the loss of water vapour from the leaf. The transpiration stream is the flow of water from the roots to the leaves to replace the water lost in transpiration

The transpiration stream

Water movement from the roots up to the leaves in the xylem is known as the transpiration stream. There are 3 mechanisms that move water up the stem: root pressure, adhesion or capillary action and transpirational pull. Root pressure and capillary action combined can only raise water by a few meters. Therefore, transpiration and the pull it creates are essential to move water all the way up a tall stem. Movement of water up through the xylem is by mass flow – a flow of water and mineral ions in the same direction. The three mechanisms that help move water up the stem are:

Root pressure

The action of the endodermis moving minerals into the medulla and xylem by active transport draws water into the medulla by osmosis. Pressure in the root medulla builds up and forces water into the xylem, pushing the water up the xylem. Root pressure can push water a few meters up a stem, but cannot account for water pushing to the top of tall trees.

Transpiration pull

The loss of water by evaporation from the leaves must be replaced by water coming up from the xylem. Water molecules are attached to each other by forces of cohesion. These cohesion forces are strong enough to hold the molecules together in a long chain or column. As molecules are lost at the top of the column, the whole column is pulled up as one chain. The pull from above creates tension in the column of water. This is why the xylem vessels must be strengthened by lignin. The lignin prevents the vessel from collapsing under tension.

Because the mechanism involves cohesion between the water molecules and tension in the column of water, it is called the cohesion-tension theory. It relies on the plant maintaining an unbroken column of water all the way up the xylem. If the water column is broken in one xylem vessel, then the water column can still be maintained through another vessel via the bordered pits.

Capillary action

The same forces that hold water molecules together also attract the water molecules to the walls of the xylem vessel. This is called adhesion. Because the xylem vessels are very narrow, these forces of attraction can pull the water up the sides of the vessel. It results in the water creeping up the xylem in a process called capillary action

- **Root pressure** is the pressure created by the action of the endodermis.
- **Adhesion** is the attraction between water molecules and the walls of the xylem.
- The **cohesion-tension theory** accounts for the movement of water up the xylem.
- **Cohesion** is the attraction between water molecules caused by hydrogen bonds.

(e) Adaptations of plants to the availability of water in their environment

To include xerophytes (cacti and marram grass) and hydrophytes (water lilies)

Xerophytes

Xerophytes are plants that are adapted to living in dry places. The following adaptations help them to reduce loss of water vapour:

- Thick, waxy cuticle on the leaves
- Smaller leaf area
- Automata in pits
- Hairy leaves
- Rolled leaves

Hydrophytes

Hydrophytes are plants that are adapted to living in water, such as water lilies. These plants have easy access to water, but are faced with other issues such as getting oxygen to their submerged tissues and keeping afloat- they need to keep their leaves in the sunlight for photosynthesis. The following adaptations help them to do this:

1) Leaves and leaf stems have large air spaces (to help them float so that they are in the air and can absorb sunlight)
2) The stomata may be on the upper epidermis (to gain carbon dioxide from the air and to allow gaseous exchange)

3) The leaf stem has many large air spaces (this helps with buoyancy, but also allows oxygen to diffuse quickly to the roots for aerobic respiration)

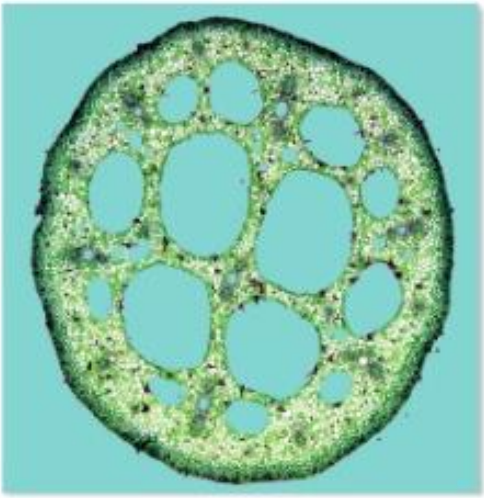

Figure 2 Transverse section of a water lily leaf stem, showing air spaces.

How do they transpire?

Transpiration is the loss of water vapour from the surfaces of the leaves – but the water will not evaporate into water or into air that has a very high humidity. If water cannot leave the plant, then the transpiration stream stops and the plant cannot transport mineral ions up to the leaves. Many plants contain specialised structures at the tips or margins of their leaves called **hydathodes.** These structures can release water droplets which may then evaporate from the leaf surface.

Marram grass

Marram grass specialises in living on sand dunes. The conditions are particularly harsh, because any water in the sand drains away quickly, the sand may be salty and the leaves are often exposed to very windy conditions. Marram grass is a xerophyte – adapted to living in arid conditions.

The adaptions of marram grass include:

- The leaf it rolled longitudinally so that air is trapped inside – this air becomes humid, which reduces water loss from the leaf
- The leaf can roll more tightly in very dry conditions
- There is a thick, waxy cuticle on the outer side of the rolled leaf (upper epidermis), to reduce evaporation
- The stomata are on the inner side of the rolled leaf (lower epidermis), so they are protected by the enclosed air space
- The stomata are in pits in the lower epidermis, which is also folded and covered by hairs. These adaptations help to reduce air movement and therefore loss of water vapour
- The spongy mesophyll is very dense, with few air spaces – so there is less surface area for evaporation of water

leaves need every to grow, so the sugars are transported from the roots (now the source) to the leaves (now the stem).

KEY DEFINITIONS

assimilates: substances that have become a part of the plant.

sink: a part of the plant where those materials are removed from the transport system; for example, the roots receive sugars and store them as starch. At another time of year, the starch may be converted back to sugars and transported to a growing stem – so the roots can also be a source!

source: a part of the plant that loads materials into the transport system; for example, the leaves photosynthesise and the sugars made are moved to other parts of the plant.

translocation: the transport of assimilates throughout a plant.

Translocation occurs in the phloem, and is the movement of **assimilates** throughout the plant. Assimilates are substances made by the plant, using substances absorbed from the environment. These include sugars (mainly transported as sucrose) and amino acids. A part of the plant that loads assimilates into the phloem sieve tubes is called a **source**. A part of the plant that removes assimilates from the phloem sieve tubes is called a **sink**.

Active loading

Sucrose is loaded into the sieve tube by an active process. This involves the use of energy from ATP in the companion cells (see topic 3.3.2). The energy is used to actively transport hydrogen ions (H^+) out of the companion cells. This increases their concentration outside the cells and decreases their concentration inside the companion cells. As a result, a concentration gradient is created. The hydrogen ions diffuse back into the companion cells through special cotransporter proteins. These proteins only allow the movement of the hydrogen ions into the cell if they are accompanied by sucrose molecules. This is known as **cotransport**. It is also called secondary active transport, as it results from the active transport of the hydrogen ions out of the cell and moves the sucrose against its concentration gradient. As the concentration of sucrose in the companion cell increases, it can diffuse through the plasmodesmata into the sieve tube. Figure 1 shows this process.

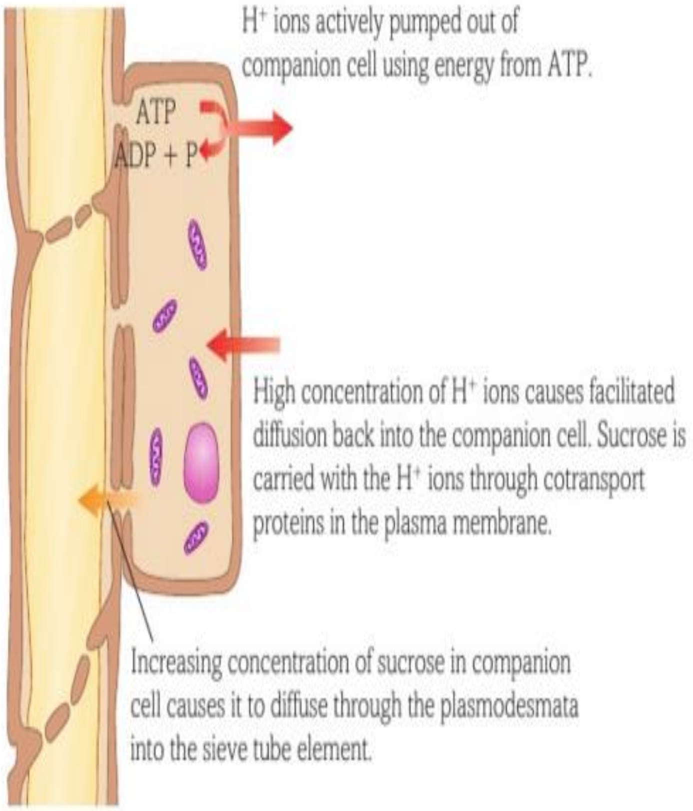

Figure 1 Active loading of sucrose into the sieve tube.