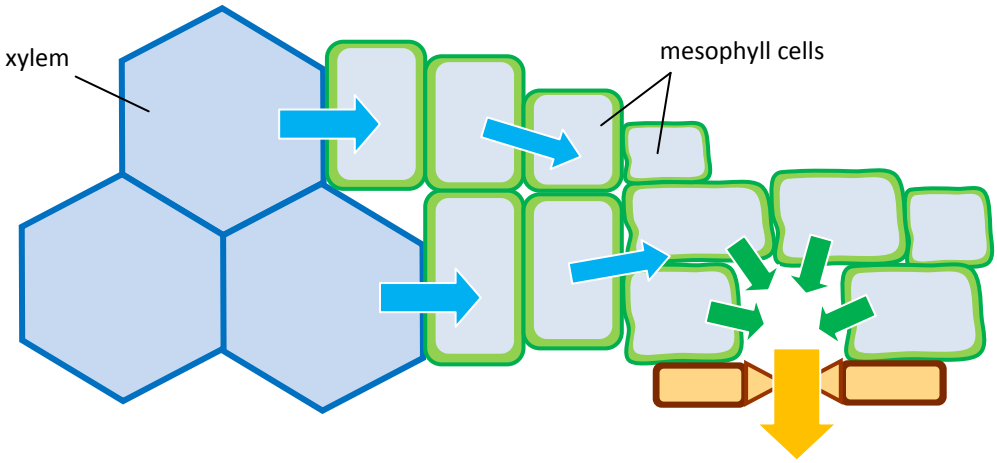
2.13 Transpiration

The loss of water vapour from (mainly) the leaves of a plant

Transpiration is an inevitable process of photosynthesis. This is because during photosynthesis, the stomata are opened in the leaves for gaseous exchange to happen – this allows water to be lost through the leaves.

Water enters the leaves through xylem vessels (see 2.12 Water Uptake and Movement Up the Stem) and passes to the mesophyll cells by *osmosis*. Water evaporates from the surface of the mesophyll layer cells, forming water vapour. The spongy mesophyll cells have large air spaces in between them where this vapour can collect, making the **water vapour potential** rise. Once the water vapour potential inside a leaf is higher than outside the leaf, the water molecules will **diffuse** (not osmosis – but diffusion) out of the leaf.



So we can summarise transpiration as involving three simple processes:

- **osmosis** from the xylem vessels to the mesophyll cells (➡)
- **evaporation** from the surface of the mesophyll cells into intercellular air spaces (➡)
- **diffusion** of water vapour through the stomata (➡)

As water leaves the xylem in the leaf, it must be replaces from below. Water moves up the xylem from the roots to replace the water which has been lost. This constant movement of water due to the loss and replacement of water via transpiration is called the **transpiration stream**.

The rate of transpiration can be measured using a **potometer**. This device measures the water uptake in a plant using a cut shoot, so it is not an exact measure of the transpiration rate – but because approximately 99 per cent of water taken up is lost by transpiration, it does give a reasonable estimate of water loss.

Factors Affecting Transpiration Rate

There are a large number of both plant (*internal*) and environmental (*external*) factors which affect the rate of transpiration, as shown in the table:

Plant Factors	Environmental Factors
Number of leaves (and area of leaves)	Light intensity
Density and distribution of stomata	Temperature
Thickness of waxy cuticle	Wind speed
Specialised adaptations	Humidity

Key:

Blue means that as this factor increases, transpiration rate also increases

Pink means that as this factor increases, transpiration rate decreases

When the rate of transpiration is too high, i.e. more than the rate of water uptake, the plant cells will lose their turgidity and non-woody plants will wilt and die. The leaves of woody plants will also wilt and die.

XEROPHYTES

There are a number of plants which are particularly well-adapted to living in certain conditions. These plants are known as **xerophytes**. Their adaptations help to reduce water loss from their leaves:

- they have smaller leaves, often even like needles, reducing surface area so less water is lost through transpiration
- they have a very thick waxy cuticle (for example, holly leaves)
- densely packed spongy mesophyll reduces the air spaces, so transpiration happens at a slower rate
- some are able to close the stomata when water availability is low
- many have hairs on the surface of their leaves to trap a layer of air close to the surface: this air becomes saturated with moisture and will reduce the water potential gradient from inside the leaf to outside, therefore reducing the rate of transpiration
- rolling the leaves so that the lower epidermis is not exposed to the atmosphere can trap air that becomes saturated
- **pits** containing stomata at their base also trap air that can become saturated with water vapour, reducing the water vapour potential gradient and therefore reducing water loss
- cacti and other succulents have specialised water-storing facilities
- there may be either very long roots to increase water uptake or very short roots to exploit overnight moisture

The image below shows a cross-section of **marram grass**. This plant is specialised for living in sand dunes, where conditions are particularly harsh. Any water which is available drains away quickly, the sand is often salty, and the leaves are often exposed to very windy conditions. Some of the xerophytic features above are shown below: