## *Activity 12A: Transpiration in plants*

1. Define transpiration, and explain how transpiration occurs.
2. Explain why plants need water.
3. Explain how transpiration helps plants.
4. Explain how stomata are formed.
5. **a.** Name the factors that increase transpiration, and explain how each increase is caused.
   **b.** Name the factors that decrease transpiration, and explain how each decrease is caused.
6. Explain the significance of CAM photosynthesis.
7. Compare and contrast the adaptations of mesophytes and xerophytes.
8. Compare and contrast the adaptations of mesophytes and hydrophytes.
9. Discuss diversity in transpiration in three named groups of plants. In your answer:
   - describe the structures associated with transpiration in each group
   - explain the ways the structures carry out the processes of transpiration
   - discuss why the systems in these three groups are different.

## Activity 12A answers: Transpiration in plants

1. Transpiration is the loss of water from the leaves of a plant. Water that leaves the xylem enters the air spaces of the leaf and surrounds the cell membranes. Water molecules *vaporise* in the air (rate increases with increasing temperature) and then *diffuse* out of the leaf, as they are more *highly concentrated* in the air in the leaf than the air outside the leaf.
2. Plants need water to keep cool, to keep cell membranes moist, for photosynthesis. Water is an essential raw material for the production of glucose in photosynthesis. Cell membranes need to be kept moist to allow gas exchange – $CO_2$ and $O_2$ need to dissolve in order to diffuse across the membrane. Plants need to keep cool because excess heat can denature enzymes needed for essential cell processes.
3. Transpiration helps the plant to keep cool and to draw water up the xylem from the roots to the leaves (transpiration pull) for photosynthesis. The plant is kept cool because the water takes heat from the cells as it vaporises. As water vaporises and leaves the leaf, it exerts a pull (force) on the column of water in the xylem that draws the water up the xylem (against gravity). Therefore, water constantly enters the leaves.
4. A stoma opens and closes as the guard cells that form it expand and contract by increasing or decreasing turgor pressure.

   Light receptors called *phototropins* cause $Na^+$ and $K^+$ ions to enter guard cells – solute concentrations increase, water is in lower potential in the guard cells than surrounding cells, water enters the guard cells. The increase in turgor pressure causes the thicker wall of each guard cell to expand less so the guard cells bend to form a stoma between them.
5. **a.** Increases in wind speed, air temperature, light intensity.

   Increasing wind speed increases the rate at which water vapour is removed from the leaf surface. Removal of water vapour keeps a high concentration between the inside and outside of the leaf, so the faster the vapour is removed, the faster the rate of transpiration. The higher the air temperature, the faster the vaporisation of

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water in the air spaces of the leaf, and the more rapid its diffusion through the air spaces and out of the leaf; therefore, the faster the rate of transpiration. Increasing light intensity increases air temperature (light, like heat, is a form of energy), with the same effects as have just been described.

**b.** Increases in humidity and soil moisture/water.

The more humid the air, the more water vapour it contains. Therefore, increasing the humidity reduces the concentration gradient for water vapour inside and outside the leaf. Therefore with increasing humidity, the rate of transpiration falls. The more water in the soil, the lower the concentration gradient between the soil and the root hairs, therefore less water enters the plant and the leaves, and so less is available for transpiration and the rate of transpiration falls.

**6.** CAM photosynthesis occurs in some xerophyte plants when the stomata close during the day and open at night. Therefore, the $CO_2$ needed for photosynthesis can only enter the leaves at night, and must be stored until daytime when it can be used to make glucose. This is an adaptation to conserve water in xerophytes, which live in dry, hot climates, as it allows the stomata to be closed during the higher temperatures of daytime (when transpiration is highest) but open in the cooler nights (when transpiration will be lowest).

**7.** *Comparisons* could include the following.

- Leaves are the photosynthetic organs in both groups (except cacti), and basic internal structure of the leaves essentially is the same (e.g. waxy cuticle, epidermis, mesophyll cells, guard cells and stomata).
- Root structure and function are essentially the same.
- The stem holds up leaves and flowers.
- Stomata function in the same manner and can close to conserve water when necessary; most stomata are found on the lower epidermis.

*Contrasts* could include the following.

- The waxy cuticle is much thicker in xerophytes.
- Leaves are often reduced in size in xerophytes (e.g. spines in cacti).
- Leaves are often very hairy in xerophytes.
- Stomata are often sunken in pits in xerophytes.
- There are fewer stomata in xerophytes, and these are often confined to the lower epidermis.
- Leaves may be rolled (lower epidermis on inside) in xerophytes.
- Roots can grow much longer/deeper into the soil in xerophytes (e.g. marram grass).
- Water storage tissue may be present in the stems of xerophytes (e.g. cacti).

**8.** *Comparisons* could include the following.

- Leaves are the photosynthetic organs in both groups, and basic internal structure of the leaves are essentially the same (e.g. epidermis, mesophyll cells).
- The stem holds up the leaves and flowers (the flowers are above water in hydrophytes).
- The roots anchor the plant.
- Gases enter and leave by diffusion, whether in water or in the air.

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*Contrasts* could include the following.

- Vascular and support tissues tend to be reduced in hydrophytes.
- Roots tend to be reduced in hydrophytes.
- Leaves and stems of hydrophytes tend to have large air spaces.
- The cuticle and stomata are absent in the leaves of submerged hydrophytes, and are present on the upper epidermis of floating leaves (e.g. water lilies).
- Hydrophytes obtain water (osmosis) and minerals (diffusion) from surrounding water.

**9.** Three clearly different taxonomic or functional groups (e.g. hydrophytes, mesophytes, xerophytes) need to be selected.

For *each* group, the *structures* associated with *transpiration* need to be *described fully and carefully using correct terms*, e.g.:

- the size, shape and location of leaves
- the location of stomata
- the presence and location of hairs
- the presence and structure of internal cell layers of leaves (e.g. cuticle and air spaces)
- stem specialisations (e.g. water-storage tissue)
- vascular tissue (xylem and phloem)
- root system and root hairs.

For *each* group, *how* these structures perform their particular function needs to be *explained*, e.g.:

- the need for water (gas exchange, photosynthesis, cooling)
- the transport of water (diffusion / transpiration pull / cohesion and adhesion)
- factors affecting transpiration and how water loss is reduced
- how and when stomata open and close
- CAM photosynthesis.

For *each* group, reasons for *differences* between the groups need to be *explained*, including the following.

- Habitat, e.g. adaptations to aquatic environment, arid environment and temperate environment.
- Size, e.g. the need for support and transport systems in large terrestrial plants, little need for these in plants living in a buoyant aquatic environment; aquatic plants are restricted in size, dependent on diffusion of substances from water.
- Life cycle, e.g. the need for aquatic plants to get their flowers above the water for pollination, the rapid flowering and seeding of desert plants to take advantages of short periods of heavy rain, and the shedding of leaves in autumn by deciduous plants.

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