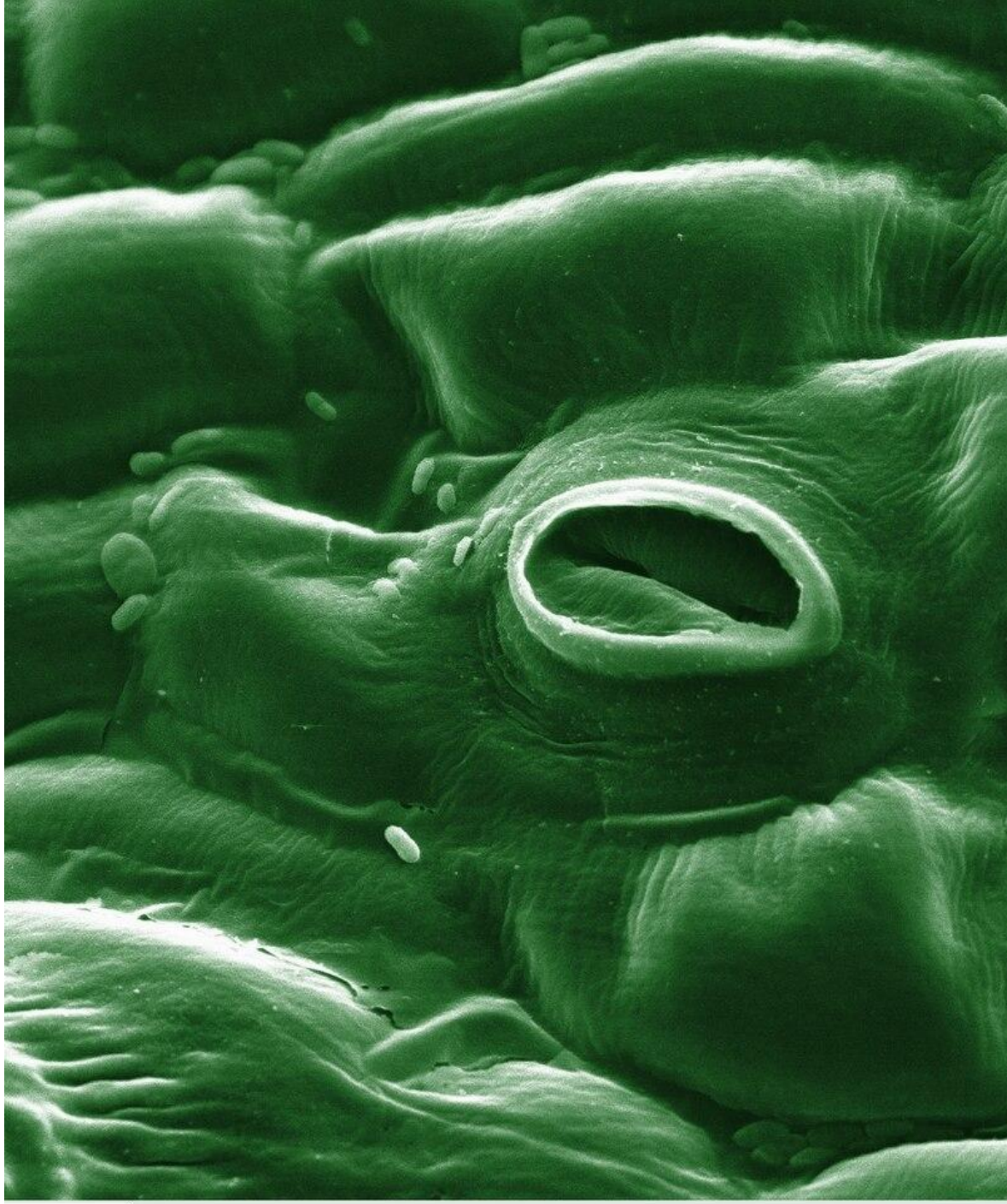
DP Biology – B3.1 Plant Systems

# Gas exchange in plants

- What adaptations let multicellular organisms exchange gases?
- How do flowering plants and mammals differ, and resemble each other, in gas exchange?

Plant statements B3.1.7–10, SL and HL. Textbook pp. 283–291.
Image: a stoma on a tomato leaf, coloured electron micrograph. Photohound, public domain.



# Objectives for each class

| Class | Statements | By the end of the class, you can... |
|---|---|---|
| 1 | B3.1.7–8 | Explain how leaf structures are adapted to gas exchange, and draw a plan diagram of a leaf |
| 2 | B3.1.9–10 | Explain why gas exchange causes transpiration and what affects its rate, and determine stomatal density |

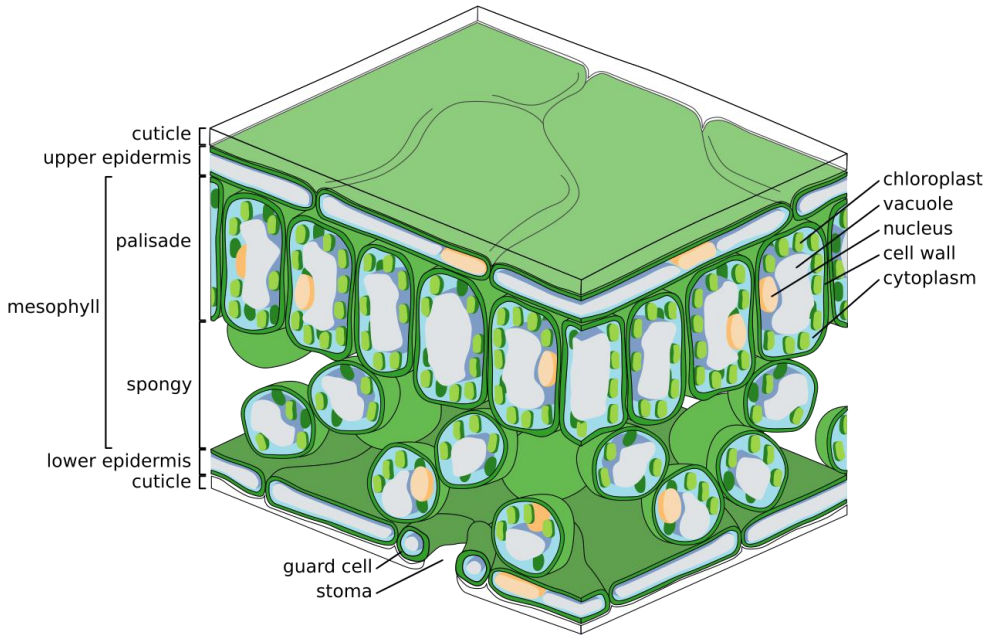
# Overview of this chapter

| Part | Statements | What it covers |
|---|---|---|
| **The leaf** | B3.1.7 | How its tissues are adapted to gas exchange |
| **Plan diagrams** | B3.1.8 | Where the tissues are in a dicot leaf |
| **Transpiration** | B3.1.9 | Why it happens, and what affects its rate |
| **Stomatal density** | B3.1.10 | Counting stomata from micrographs or leaf casts |

# Leaves need gas exchange too

B3.1.7

- Photosynthesis takes in **carbon dioxide** and releases **oxygen**
- Cell respiration does the reverse, all the time
- Gases diffuse through the air spaces inside the leaf
- Leaves are **flat and thin**, giving a large surface area-to-volume ratio and short diffusion distances




Tissues in a leaf. Zephyris, CC BY-SA 3.0.

## Key idea

The same surface that lets carbon dioxide in also lets water vapour out. Every adaptation of a leaf balances these two.

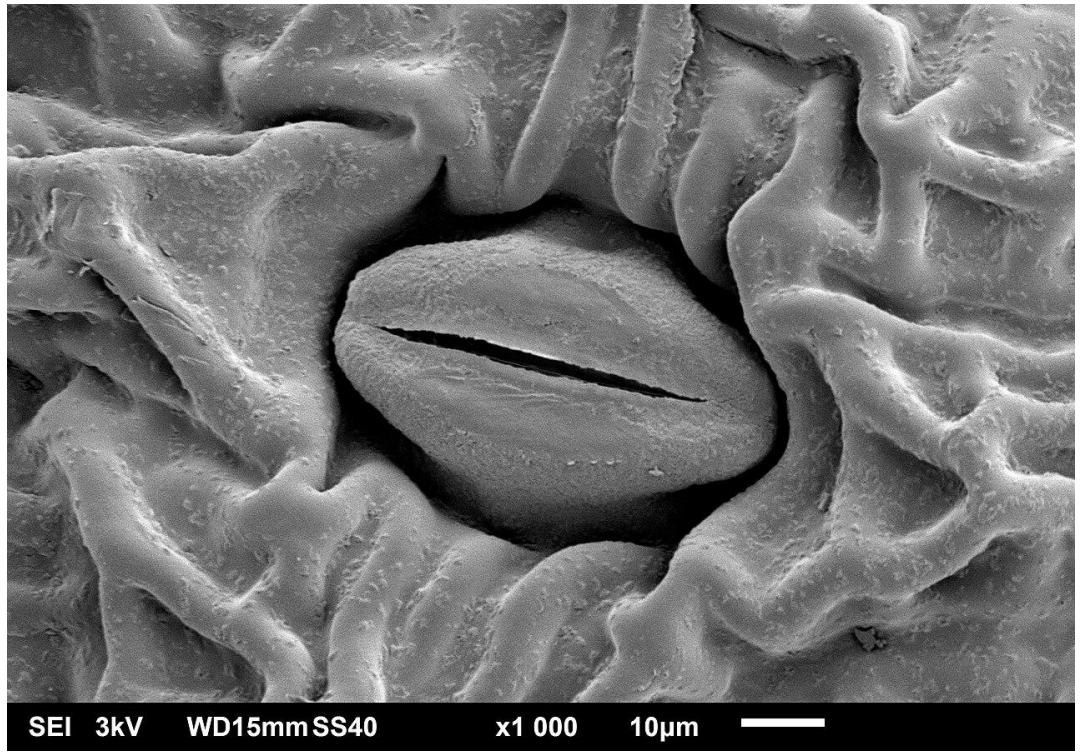
# How leaf structures help

B3.1.7

| Structure | Adaptation |
| --- | --- |
| **Waxy cuticle** | Largely impermeable barrier, so gases and water vapour must pass through stomata, where the flow is controlled |
| **Epidermis** | Thin and transparent. Most pores are in the lower epidermis, where it is shaded and cooler, reducing water loss |
| **Air spaces** | Let gases circulate around loosely packed mesophyll cells and maintain gradients |
| **Spongy mesophyll** | Large, moist surface for gases to enter and leave cells |
| **Stomatal guard cells** | Open and close the pore to control gas exchange and water loss |
| **Veins** | Xylem brings water; phloem removes sugars, so gradients are maintained |

# Guard cells control the stoma






Stoma and guard cells on a leaf surface, electron micrograph. Judyta Dulnik, CC BY-SA 4.0.

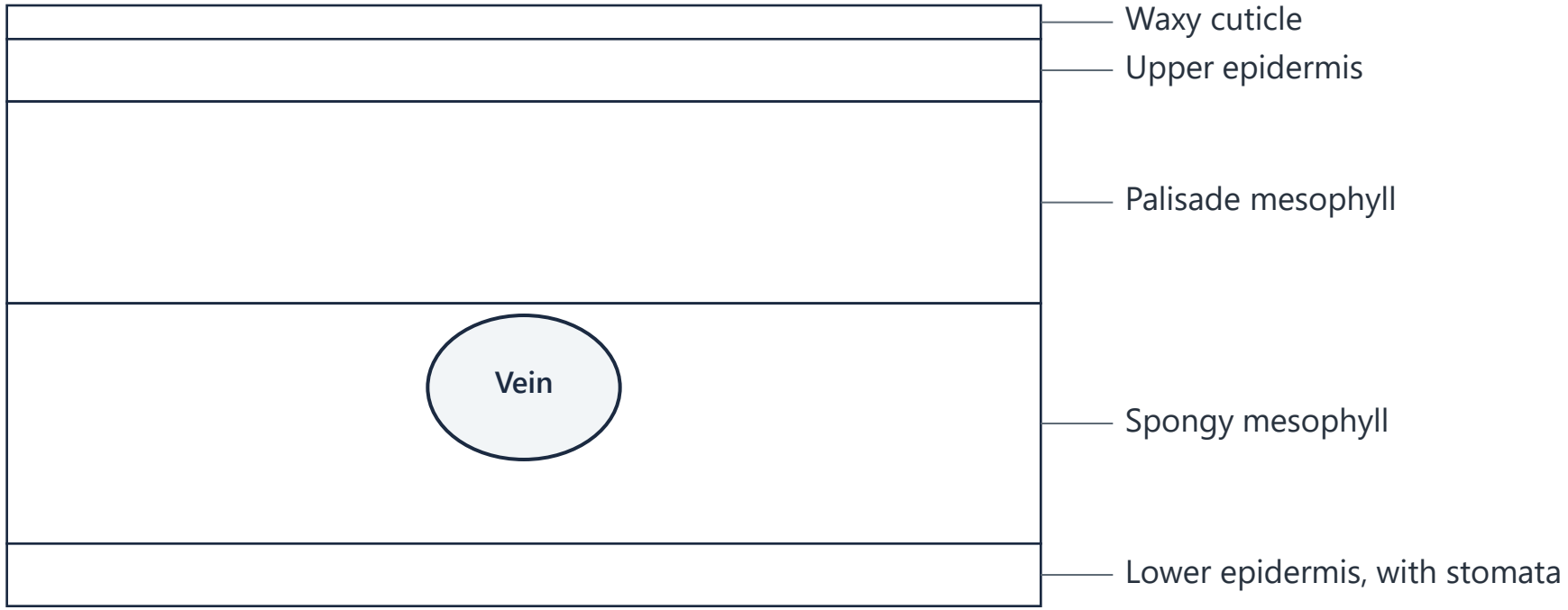
- Water enters the guard cells and they become **turgid**
- Thick inner walls make them curve apart, so the **pore opens**
- When they lose water they become **flaccid** and the **pore closes**
- Stomata usually open in daylight and close in the dark
- In very dry conditions, they close even in daylight

## Common mistake

A stoma is the pore. Guard cells are the cells on either side of it, so do not use the two words as if they mean the same thing.

# Plan diagram of a dicot leaf

B3.1.8




Schematic plan diagram of a transverse section.

### Plan diagram

Show the tissues as regions. Do not draw individual cells or use shading.

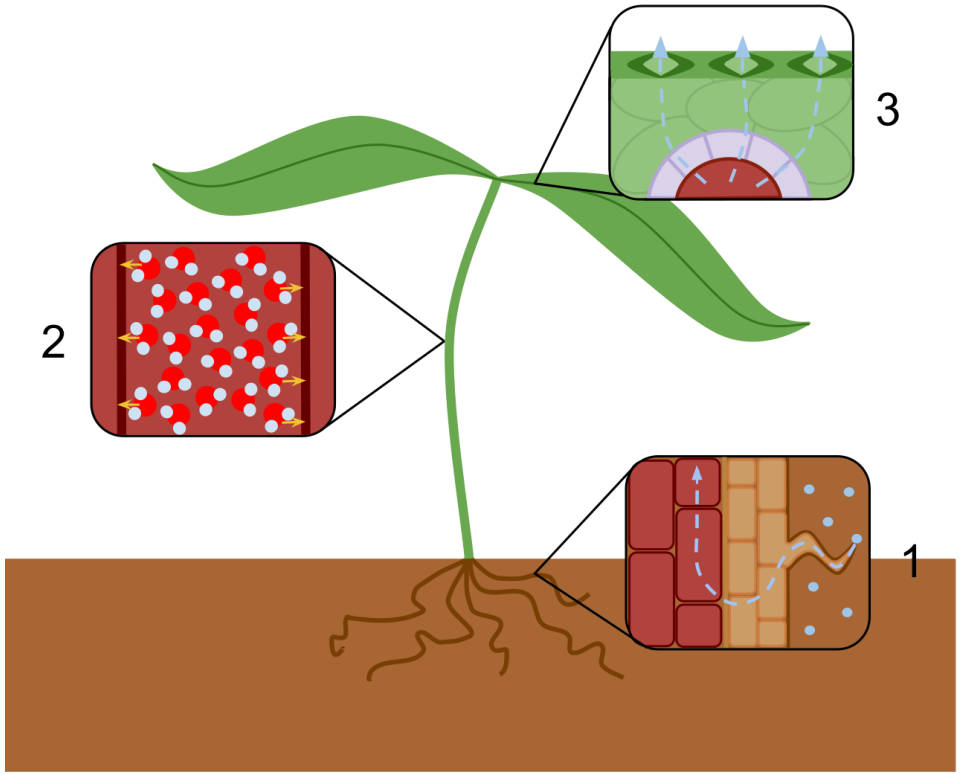
### Activity

Draw a plan diagram of a transverse section from a micrograph. Use clear, continuous lines, label each tissue and keep the proportions of the original. Label the waxy cuticle, epidermis, palisade and spongy mesophyll, xylem and phloem.

# Transpiration follows from gas exchange

B3.1.9

1. Stomata open so that carbon dioxide can enter
2. Water evaporates from moist cell walls into the air spaces
3. Water vapour diffuses out through the stomata, down its concentration gradient
4. This loss of water vapour from leaves is **transpiration**




Water moving through a plant. Laurel Jules, CC BY-SA 3.0.

## Common mistake

Water vapour diffuses out of the leaf, not liquid water. Do not call this osmosis: the water is not crossing a cell membrane at this point.

# What affects the rate of transpiration

B3.1.9

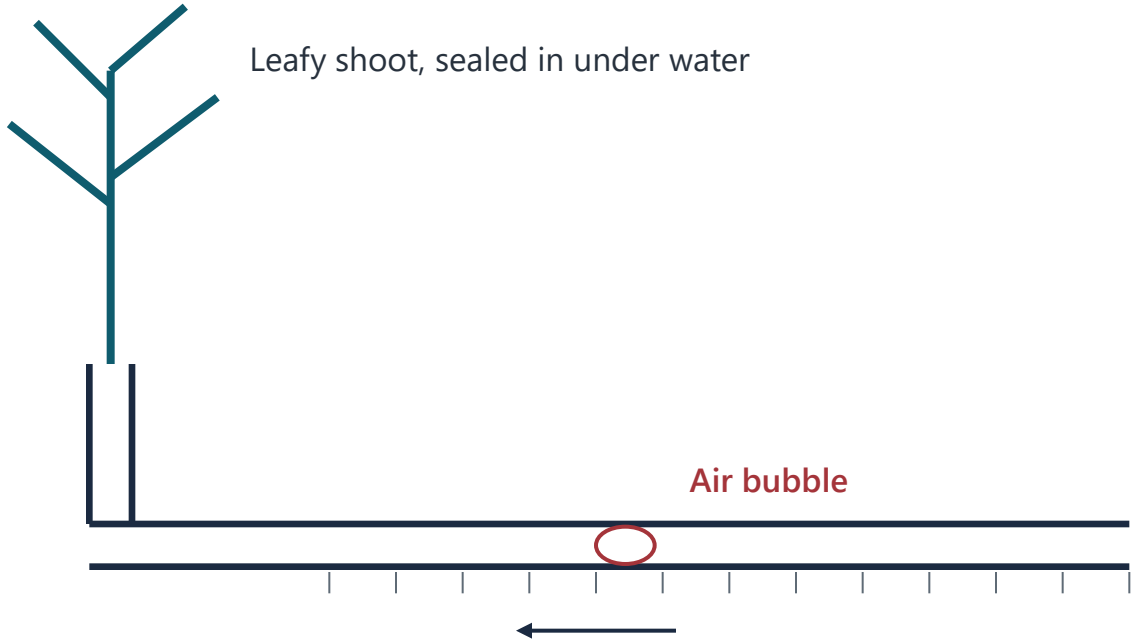
| Factor | Effect of an increase | Why |
|---|---|---|
| **Temperature** | Rate rises | More evaporation, so a greater concentration difference of water vapour |
| **Humidity** | Rate falls | Air outside holds more water vapour, so the gradient is smaller |
| **Wind** | Rate rises | Sweeps away water vapour near the stomata, keeping the gradient steep |
| **Light** | Rate rises | Stomata open for photosynthesis, and the leaf warms |

**Exam note**

When you explain any factor, refer to the concentration gradient of water vapour between the air spaces and the air outside.

# Measuring transpiration: the potometer

B3.1.9




Capillary tube and scale. The bubble moves towards the shoot.

Schematic, not to scale.

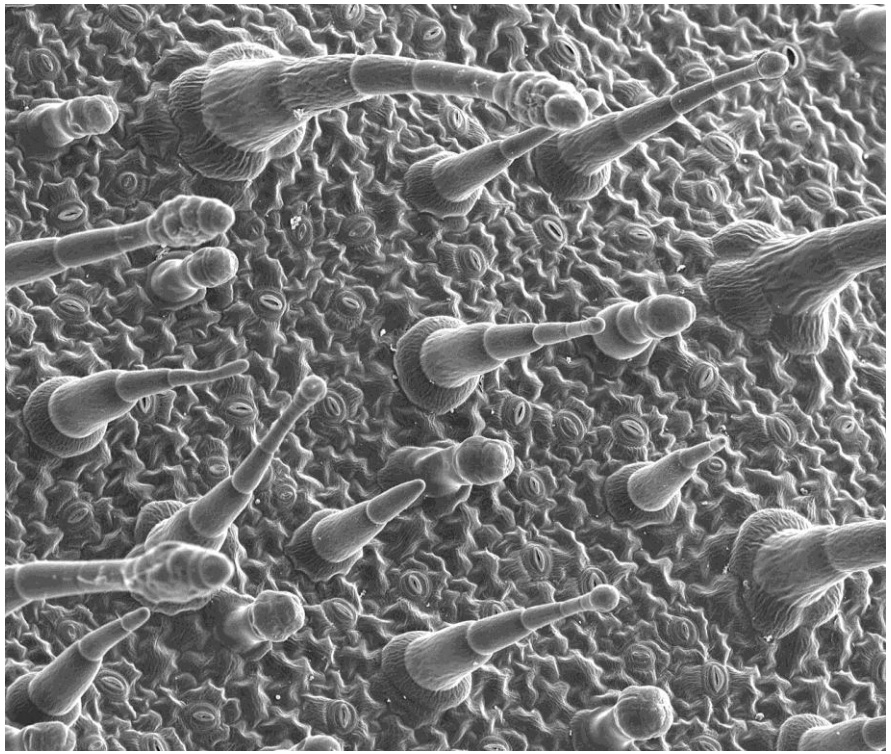
- Water lost from the leaves is replaced by water drawn up the stem
- The bubble moves along the tube as this happens
- **Rate** = distance moved / time
- Change one factor, such as wind from a fan or humidity from a plastic bag

## Common mistake

A potometer measures water uptake, not transpiration directly. A small amount of the water is used in the plant, though for a small shoot the difference is minor.

# Stomatal density

B3.1.10



Leaf epidermis, electron micrograph. Louisa Howard, Dartmouth, public domain.

- **Stomatal density**: the number of stomata per unit area of leaf
- Use a micrograph, or make a **leaf cast**
- Paint clear nail varnish on the underside; let it dry; lift it off with clear tape
- Count the stomata in a field of view, in several fields
- Area of field of view = 3.14 × $r^2$, and density = mean count / area

## Why it varies

More stomata can take up more carbon dioxide, but they can also lose more water. Density varies between species and between environments.

# Worked example: calculating density

B3.1.10

| Field of view | Stomata counted |
|---|---|
| 1 | 22 |
| 2 | 18 |
| 3 | 20 |

Invented values, for practice.

1. Mean count = (22 + 18 + 20) / 3 = 20
2. Field diameter = 0.4 mm, so r = 0.2 mm
3. Area = 3.14 × $0.2^2$ = 0.126 $mm^2$
4. Density = 20 / 0.126 = 159 stomata per $mm^2$

## Activity

Make leaf casts of the upper and lower surfaces of one leaf. Calculate the density for each surface. Explain the difference, and suggest how your results would differ for a plant from a dry habitat.

# Comparing leaves and lungs

| | Mammal lung | Leaf |
|---|---|---|
| **Surface** | Alveolar walls | Moist cell walls of mesophyll |
| **Large area from** | Many small alveoli | Air spaces around mesophyll cells |
| **Gas moved in** | Oxygen | Carbon dioxide (in the light) |
| **Gradient kept by** | Ventilation and blood flow | Photosynthesis, and air movement |
| **Water loss limited by** | Internal position of the lungs | Waxy cuticle and guard cells |

**Link**
This answers the second guiding question. See B3.1.1–6 for the mammal side.

# Check that you can explain

1. How each leaf structure is adapted to gas exchange
2. How guard cells open and close a stoma
3. How to draw a plan diagram of a dicot leaf
4. Why gas exchange in a leaf leads to transpiration
5. How temperature, humidity, wind and light affect the rate
6. How to measure rate with a potometer, and what it really measures
7. How to determine stomatal density

# Exit activity: 5 minutes

**On your own and without notes. Hand this in as you leave.**

1. Explain why gas exchange in a leaf leads to water loss.

2. Predict the effect of higher humidity on the rate of transpiration, and explain why.

3. A student counts a mean of 15 stomata in a field of view with an area of 0.15 $mm^2$. Calculate the stomatal density.

# Image credits

Tomato leaf stomate 1-color.jpg – Photohound – Public domain
Leaf Tissue Structure.svg – Zephyris – CC BY-SA 3.0
Stoma.jpg – Judyta Dulnik – CC BY-SA 4.0
Transpiration Overview.svg – Laurel Jules – CC BY-SA 3.0
Leaf epidermis.jpg – Louisa Howard (Dartmouth electron microscope facility) – Public domain

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