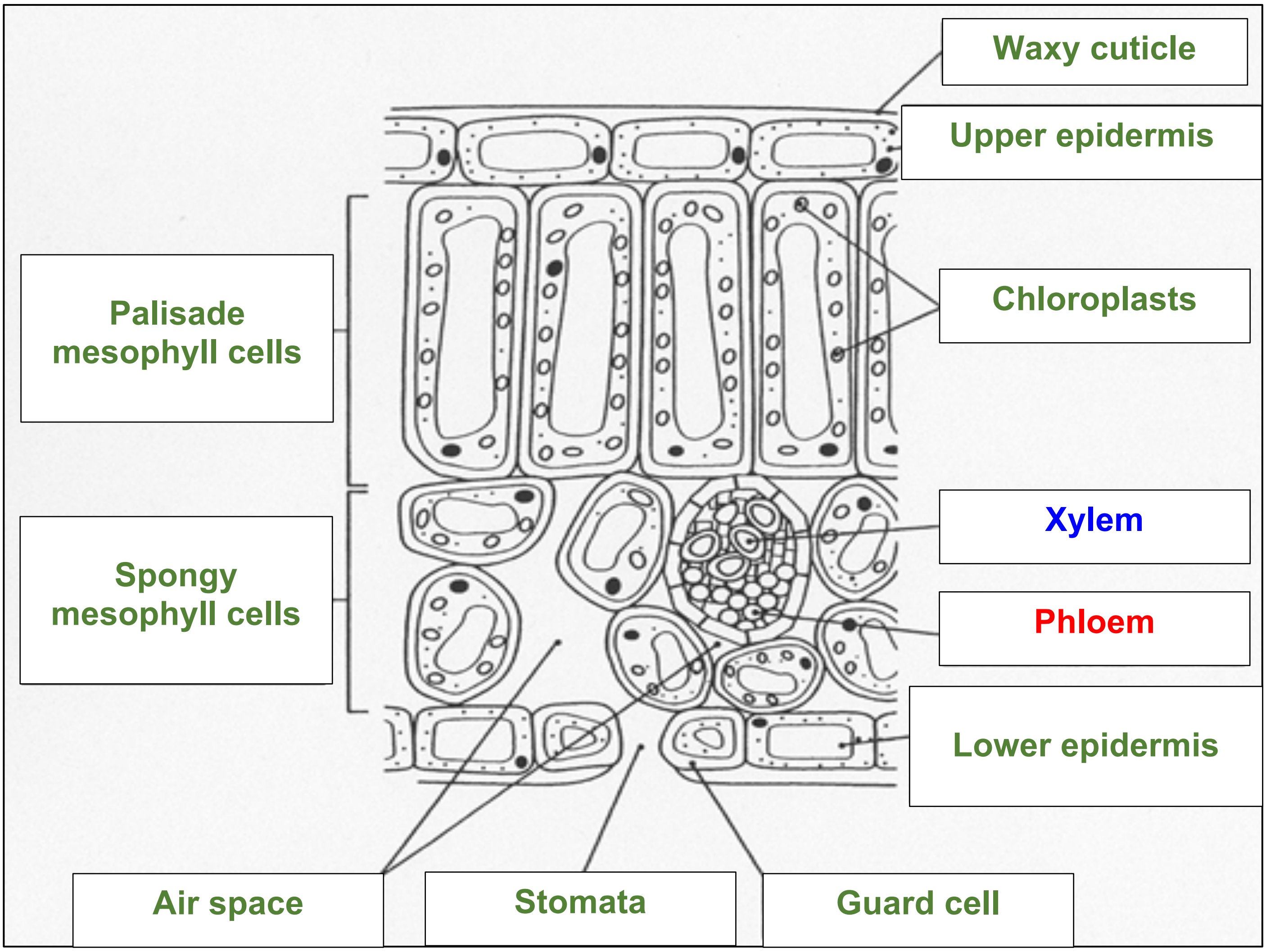
A. LEAF STRUCTURE



WAXY CUTICLE	• **Waterproof** and **prevents water** from **evaporating** out of the leaf.
UPPER EPIDERMIS	• Single layer of cells with **no chloroplasts**. • **Thin** and **transparent** for **maximum light penetration**.
PALISADE MESOPHYLL CELLS	• These cells contain **many chloroplasts**. • They are **near the leaf surface** and are **packed close together** to **absorb more light**. • Where most **photosynthesis** takes place.
CHLOROPLASTS	• These **trap light energy** and convert it into **chemical energy** and make leaves look green.
SPONGY MESOPHYLL CELLS	• Have **air spaces** between them. • For **fast diffusion** of **gases** in and out of the leaf.
XYLEM	• Transports **water and minerals** to the leaf.
PHLOEM	• Transports **dissolved sugar/sucrose** away from the leaf.
LOWER EPIDERMIS	• The **bottom layer** of a leaf.
STOMATA	• **Holes** that let gases in and out of the leaf.
GUARD CELLS	• These cells **control** the **opening** and **closing** of **stomata** in the lower epidermis.

B. TRANSPIRATION

The **EVAPORATION** of **WATER VAPOUR** at the **SURFACE** of the **MESOPHYLL CELLS**

Followed by the **DIFFUSION** of **WATER VAPOUR** through the **STOMATA**

- Transpiration is the inevitable consequence of **gas exchange** in the leaf.
- Plants transport **water** from the **roots** to the **leaves** to **replace losses** from **transpiration**.

C. HOW WATER MOVES UP THE XYLEM TO THE LEAVES

- Light causes stomata to open;
- (Causing) evaporation of water molecules;
- From spongy mesophyll cells;
- (Causing) tension/ low/negative pressure / suction / pulling force in xylem vessels;
- (At leaf)) water is drawn out of the xylem cell walls by adhesion;
- Hydrogen bonds make water molecules cohesive/stick together;
- Adhesion causes water molecules to stick to the cell walls/cellulose of the xylem;
- (So) continuous water column/transpiration stream produced (in xylem);
- (So) water travels from roots to leaves in xylem vessels;

COHESION is water molecules **STICKING TOGETHER** by **HYDROGEN BONDING**

ADHESION is water molecules **STICKING TO** the **XYLEM WALL**

D. FACTORS THAT AFFECT THE RATE OF TRANSPIRATION

- The same factors that **dry clothes faster** on a **washing line** will **speed up transpiration**.

LIGHT

- Causes **stomata** to **open**
- (So) **transpiration** will be **faster**

TEMPERATURE

- Water molecules have **more kinetic energy**
- **Warmer air** can **hold more water vapour**
- (So) transpiration will be **faster**

WIND

- Water molecules are **blown away** from the **leaf surface**
- Means a **higher a water concentration gradient** between inside and outside the leaf
- (So) transpiration will be **faster**

HUMIDITY (=amount of water in the air)

- Lots of moisture in air = **high humidity**
- Means a **lower water concentration gradient** between inside and outside the leaf
- (So) transpiration will be **slower**

E. XEROPHYTIC ADAPTATIONS TO REDUCE TRANSPIRATION

- **Xerophytes** are plants that live in **hot**, dry places e.g. **cacti**.
- They have **adapted** ways of **reducing transpiration** to **reduce water loss**.
- Always remember to relate these points to **reducing transpiration** in exams.

ADAPTATION	HOW IT HELPS
THICK WAXY CUTICLE	• Impermeable so prevents evaporation of water from leaf surface • Increases the diffusion distance
SMALL/ NO LEAVES	• Less stomata/leaves = • Less surface area = • Less evaporation of water
FEW STOMATA	
SUNKEN STOMATA (IN PITS) SURROUNDED BY HAIRS	• Less exposed to the air = • Traps water vapour = • Reduced water concentration gradient = • Less evaporation of water
ROLLED UP EAVES	
CAM PHYSIOLOGY	• Stomata only open at night (when cooler) • Less evaporation of water
DEEP LONG-SPREADING ROOT SYSTEM	• A higher chance of finding water
LOWER GROWTH TO THE GROUND	• Less exposed to the wind and more shaded. • Less evaporation of water

F. HALOPHTIC ADAPTATIONS TO REDUCE WATER LOSS

- **Halophytes** are plants that live in **salty conditions (high salinity soils)**.
- They have **adapted** ways of **reducing water loss**.

ADAPTATION	HOW IT HELPS
SALT EXCRETION	• Certain plant parts e.g. stem can contain **salt glands** that **actively** eliminate salt
ROOT LEVEL EXCLUSION	• Plant **roots** can be structured to **exclude 95%** of salt in solutions
CELLULAR SEQUESTRATION	• Halophytes can **accumulate** toxic ions and salts within the **cell wall** or **vacuole**
TISSUE PARTITIONING	• Halophytes can **concentrate salts** in particular **leaves**, which then **drop off**
ALTERED FLOWERING SCHEDULE	• Halophytes may **flower** at **specific times** (e.g. **rainy seasons**) to minimise salt exposure

G. MEASURING THE RATE OF TRANSPIRATION USING A POTOMETER

Transpiration is the evaporation of water vapour from the leaves.

Really, a potometer indirectly measures the rate of transpiration.

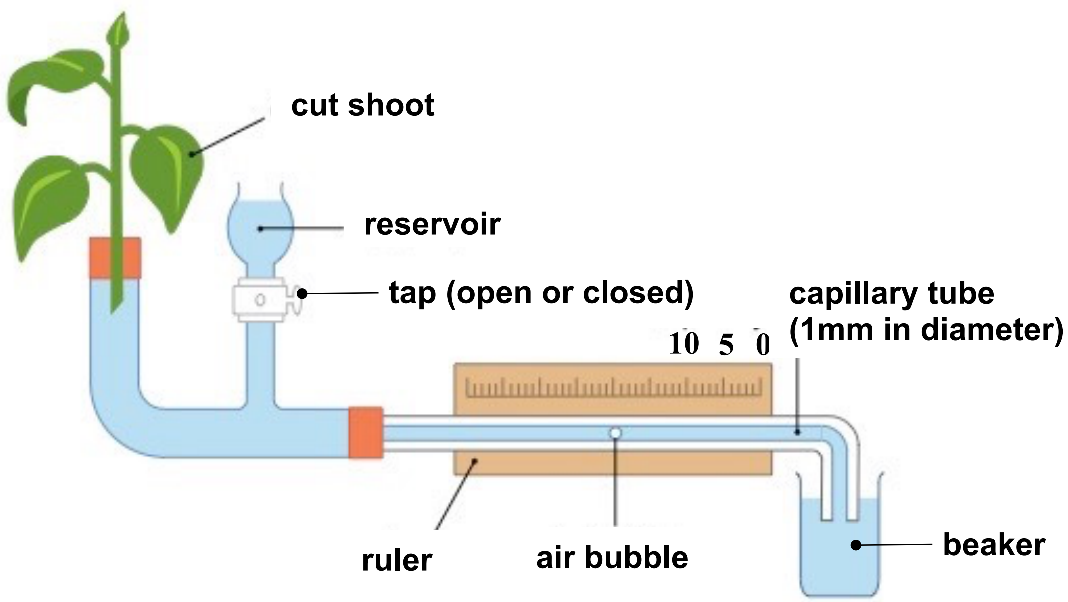
It directly measures the rate of water uptake.

We assume that water uptake = water lost through transpiration.

However, water is also used in photosynthesis and to make cells turgid for support.

Be aware of this limitation as it is often tested.

- Here is **one** type of potometer:



Preparation before using apparatus

1. Apparatus must be setup under water / Shoot must be cut underwater at an angle

- Prevents **air bubbles** from forming in the apparatus
- If cut in air, **air would enter the xylem** and **break** the **continuous water column**
- This would **prevent transpiration**
- Only **water** must enter the xylem

2. Seal all joints of the apparatus with petroleum jelly

- Petroleum jelly is **waterproof**
- It **prevents water** from **leaking out** of the apparatus
- It therefore **ensures** that all **water** can **only leave through evaporation** out of the **stomata**
- This makes the **results** more **accurate**

How it is used

- The **air bubble** is placed at **zero** (**0**).
- As the plant **transpires**, water will move from the **beaker** and **up** the **plant.**
- **Measure** the **distance moved** by the **air bubble** in a **fixed time**.
- **Open** the **tap** to **push the air bubble back to zero** so **repeats** can be done.
- This makes **results** more **reliable**.
- Used to **investigate** the effect of a **name factor** on the **rate of transpiration**.

Calculating the rate of transpiration

(a) Simplest way

Rate of transpiration = **distance** moved by air bubble in a **fixed time**

(e.g. 50 mm per hour)

(b) Better way

Rate of transpiration = **distance** moved by air bubble in a **fixed time** x **area** of **capillary tube**

(e.g. 0.26 mm^3 of water moved per minute)

- Area of a cylinder (capillary tube) = $\boldsymbol{\pi r^2}$, where **r** = **radius**