Australian Plants Society NORTH SHORE GROUP

Ku-ring-gai Wildflower Garden

Topic 4: **LEAVES and STEMS**

Did you know that,

- If there is no light, there is no chlorophyll, no photosynthesis and no complex life on Earth.
- In vascular plants, the common site for photosynthesis is in the leaves.
- Plant growth is all about placing leaves in light. To do this plants have sensors for light and gravity.
- In the absence of flowers, many plants can be identified from their leaves.

Introduction

Leaves are the organs which absorb light from the sun and convert it into chemical energy (sucrose and starch) required for the normal growth and function of plants. This process of converting solar energy into chemical energy is called **Photosynthesis** and it is the most important process in the maintenance of Life on Earth.

Stems position the leaves to expose them to the sun. They contain vessels which transport water and minerals from the roots and sugars from the leaves.

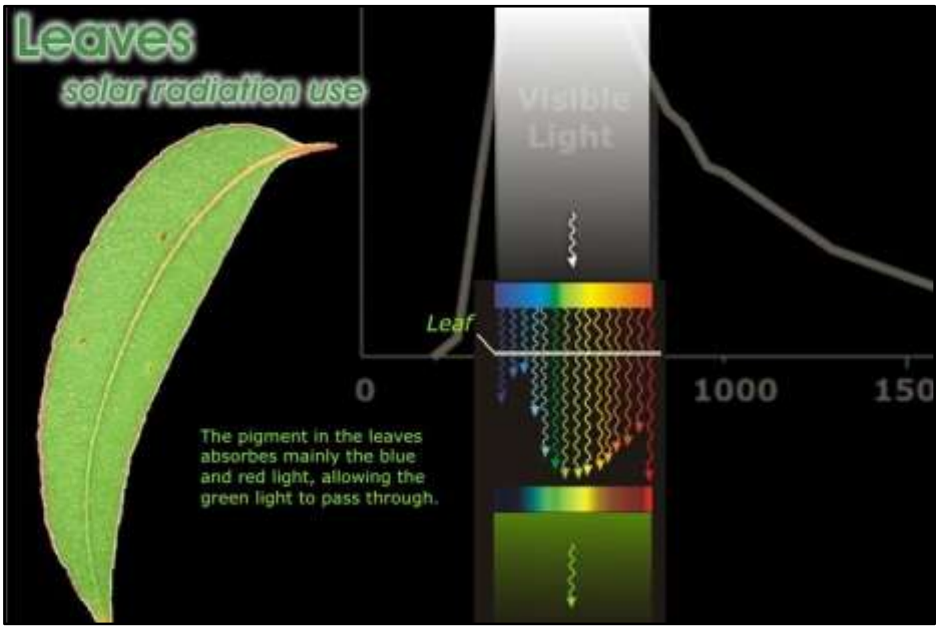
Photosynthesis

The process of photosynthesis evolved first in cyanobacteria about 2.5 billion years ago. Land plants arose about 2 billion years later, then it took about a further 40 million years before wood, stems and leaves evolved. During this latter period, and beyond, falling levels in atmospheric carbon dioxide levels may have been an important factor in the evolution of the leaf. While leaves continued to evolve into many forms and shapes and even though the carbon dioxide in the atmosphere had plummeted more than tenfold over this period, the fundamental processes of photosynthesis remained the same.

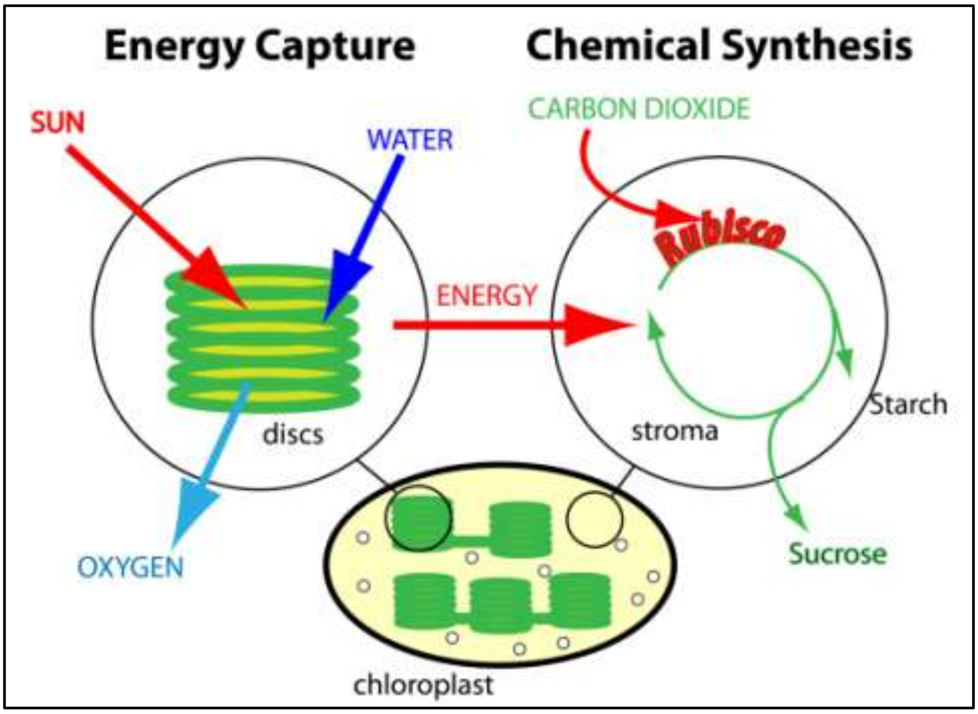
Photosynthesis consists of two processes, the energy capturing process - light dependent and the process of chemical synthesis which is independent of light.

Energy capture

Visible light from the sun is captured by pigments, which provide the energy to split water into hydrogen and free oxygen (released into the atmosphere) and create other energy rich compounds. The latter are used to drive the chemical synthesis step. The main pigment used to absorb the light energy is chlorophyll (green), but other pigments such as carotenes (yellow to orange) are normally present combined with chlorophyll in a light harvesting complex to increase the amount of light being absorbed. The colour of a leaf will be determined by the absolute and relative amounts of the pigments present.



Schematic image of light absorption by leaves (Evans, 2004)



Schematic representation of the two major activities involved in photosynthesis.

Chemical Synthesis (The Calvin Cycle)
The energy obtained from light is used to incorporate carbon dioxide from the atmosphere into a sugar, sucrose, an energy source available to all cells in the plant. The first step in this cycle is not very efficient and may explain why the efficiency of the leaf in converting sunlight into sucrose is 3-6%, compared to silica based solar panels >20%, and dye-based solar panels >8%. This step involves the capture of carbon dioxide by a very large and clunky enzyme Rubisco. While other processes in photosynthesis are flying along in femto to pico seconds, this enzyme lumbers along at milliseconds to seconds. Furthermore when plucking molecules from the air it can

confuse oxygen for carbon dioxide. So in order that photosynthesis proceeds at a reasonable rate, there is a lot of this enzyme in the leaf. It is estimated that it constitutes about 60% of leaf protein, and is believed to be the most abundant protein on Earth.

Other types of Photosynthesis

Around 30 mya a more efficient form of photosynthesis evolved. This is called C4 photosynthesis (the original form is C3). It is believed to have occurred when grasses migrated from shade beneath forest canopies to increased exposure to sunlight in open environments. It most commonly occurs in monocots (many grasses) and accounts for about 30% of carbon fixation.

Another form of photosynthesis "CAM" (crassulacean acid metabolism) has arisen as an adaptation of hot and especially dry conditions. In such plants, eg cacti, stomata open at night to allow carbon dioxide entry, when it is stored as an acid. During the day the stomata are closed and carbon dioxide is released to be used in a normal photosynthetic pathway.

The Growth and Form of Plants

Growth

Plant growth is greatly affected by light and gravity and to a lesser extent by touch and chemicals. Photoreceptors and gravity detectors in the growth shoots, guide the growth towards light, and in the absence of light usually directly upward against the pull of gravity. Of course in the absence of light chlorophyll will not be synthesised, photosynthesis will not occur and the plant will die.

Growth occurs from the growing tips of plants. A rope tied around the trunk of a tree will remain at the same height above the ground (until the rope breaks as the trunk expands laterally).

Tropism	Stimulus	Response	Examples
Gravitotropism	Gravity	Positive	Primary roots
		Negative	Shoots, leaves
		Plagiotropism	Axillary branches, some leaves etc
Phototropism	Light	Positive	Shoots, leaves
		Negative	Tendrils etc
Heliotropism	Light	Follow sun	Leaves
Thigmotropism	Touch	Positive	Tendrils, vine stems

The basic responses of plants that determine their growth form (from Atwell et al 1999)

Form

While much of the form of plants is determined by its DNA, all plants are to a lesser or greater degree opportunistic in their growth, because the purpose of stem growth is to place the leaves in a space where they will be exposed to the sun. It can be expected that tall plants would provide good examples of less opportunistic growth (less variable form) and short plants, especially understory plants, good examples of more opportunistic growth (more variable forms). An example from a plant in the KWG that is a tall plants of more determined form, is the Australian conifer *Araucaria bidwillii,* and from a short plant of more opportunistic form, is the heath plant *Woolsia pungens*, a native of the KWG. A general description of plant forms is provided in Topic No. 12

Araucaria bidwillii

Woollsia pungens

Branching patterns of stems may be quite distinctive or not. A plant in KWG that exhibits elements of distinctive branching patterns is *Ceratopetalum gummiferum*.

Plants with woody (lignin containing) stems are common amongst Australian native plants, because they do not wilt during dry periods. Plants with non-woody stems are referred to as herbs. The lignification of stems which provides stiffness and chemical stability, also enables plants/trees to grow to heights of 115m. The height of trees seems to be limited by the properties of water and the elements of the tree's vascular system.

Since trees may take many decades to reach their mature height, their stem or trunk needs to be strong and well protected. The external layer of bark serves this latter function, where generally the level of protection is determined by the thickness of the bark/outer layers.

The Functions Stems
Broadly the stems of plants serve two principal functions, to provide structural support for the leaves, and to provide a plumbing system for transport of sugars from the leaves to other parts of the plant, the phloem vessels and to transport water and minerals from the roots to the leaves, the xylem vessels. These vessels are present in the leaves as vascular bundles, and visible as veins.

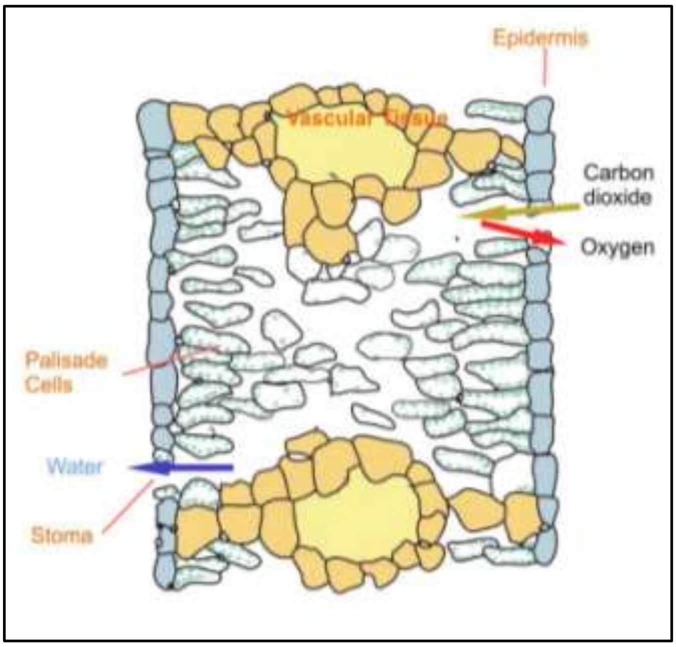
The Leaf

Leaf Form and Structure
Leaves arise from a stem, typically as a flat green structure. They may have a stem (petiole) or not (sessile). Usually there is a small bud in the angle between the parent stem and the leaf/leaf stem (axillary bud). Vascular tissues from the stem grow through the leaf and are visible as veins.

Leaves in which the blade is mostly held in a horizontal plane are usually greener on the upper surface (discolourous), while those in which the blade is generally held in a vertical plane are equally green on both sides (concolourous).

The surface layer of cells (epidermis) and waxes (cuticle) create a barrier to water and gas exchange. However it is perforated by small pores (the stomata) controlling the passage of gases and the loss of water vapour from the plant.

Pendulant concolourous *Eucalypt* leaves, diagram representing a transverse section.



Beneath the epidermis are cells rich in chloroplasts (palisade cells), the main site for photosynthesis, cells for storage of photosynthates (spongy cells) and the vascular tissue.

Leaf Arrangement (phylotaxy)
The arrangement of leaves on the stem is normally a highly determined character. The three basic arrangements are,

1. *Alternate*, very common, when leaves are in an alternate arrangement along the stem, ie neither 2 nor 3 (and often very confusing).
2. *Opposite*, when two leaves are attached to the stem at the same level.
3. *Whorling,* when three or more leaves are attached to the stem at the same level, ie in a whorl.

(Evans 2004)

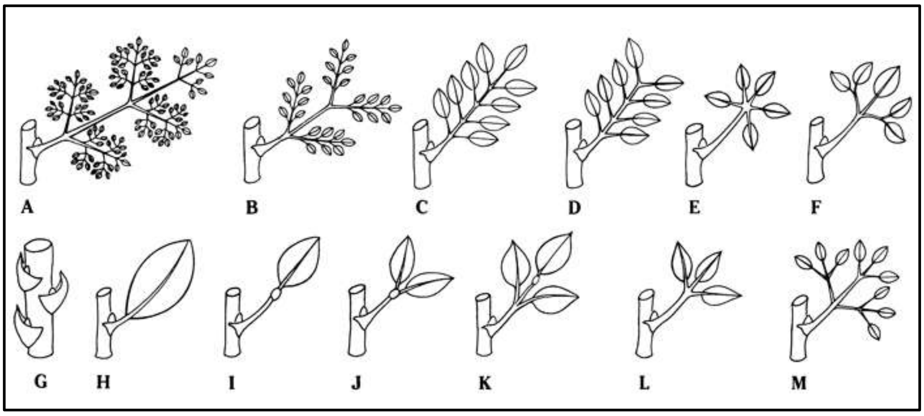
Leaf Shape and Size
The bulk of leaves in Australian plants are small in area, ie length <5 cm. Some plants with LARGE leaves in KWG are the Gymea Lily and Tree Ferns.

While the leaf as a solar panel might be expected to have a lamina or plate-like form, there are many conditions affecting it shape and form.

Some of these and the adaptations are,

Intense solar radiation, vertical orientation, thinness of leaf blade, stiffenning
Shade, increased size and thinness
Dryness, reduced surface area, stomata in pits, hairs,
Wind, reduced size,
Herbivores, toxins, spines, hairs, reduced size, "bitten" shape

As leaves have evolved to accommodate this range of conditions, it is less surprising to find that they occur in many forms from flat to cylindrical and from simple to highly divided (compound),



Simple leaves (G & H), Compound leaves (A-F & I-M). Taken from Plantnet glossary

The shapes of leaves are as variable as one's imagination, from round to narrowly linear, from smooth to highly incised margins.

Other Leaf Characteristics
These include, texture (fleshy, soft, leathery, hard), odour, the veination, presence of spines etc

Other photosynthetic organs
Particularly under dry conditions, leaves may be reduced to vestigial non-functional forms (scale on *Casuarina*) and their role taken over by other parts of the plant.
eg leaf stems, called phyllodes as in many *Acacias.* stems, called cladodes as in *Casuarina.*

Variations of leaf form within a plant
Leaf shape and size often varies with the one plant.
eg juvenile leaves are often larger, leaves in shade may be larger and thinner,

Young leaves are often red due to the presence of an anthocyanin pigment. It is believed that this pigment may have a role in protecting young growing leaves from the harmful effects of UV radiation.

Young leaves on *a Callistemon*

Identifying Plants using leaves
In the absence of flowers leaf characteristics can often be used in the identification of plants. However as leaf morphology can vary greatly within a Genus, these are less helpful in recognising plant groupings.

Some leaves found in KWG
See the table "Leaves from KWG"

References

Atwell, B.B., *et al* (1999) "Plants in Action". Macmillan Education Australia.
Evans, T. (2004) "Mandalay to Albany"
Mager, S & G. Burrows. "Botanical Field Guide". Second Addition.
Plantnet http://plantnet.rbgsyd.nsw.gov.au/

Acknowledgements

Acknowledgments: These notes contain hyperlinks to materials, including images, illustrations, plant descriptions and a glossary from PlantNET, with the courtesy of The Royal Botanic Gardens & Domain Trust, 2011.
For general access to PlantNET see also http://plantnet.rbgsyd.nsw.gov.au/

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