



Topic 7 THE PLANT KINGDOM

The Plant Kingdom

The plant kingdom in all its adaptive manifestations, will colonise virtually any location on land and sea, provided there are nutrients, water and sunlight and it is not too cold. Greenness is to be found in abundance in the forests of Africa and SE Asia but not on the summits of Kilimanjaro and Kinabalu, both located at the Equator – the first because it is too cold and the other because glaciation is so recent that no soil exists. There is greenness about most of the Australian deserts but not with the dry sand-seas of the Sahara. At home we are surrounded by gardens, reserves and parks. The world *is* green.

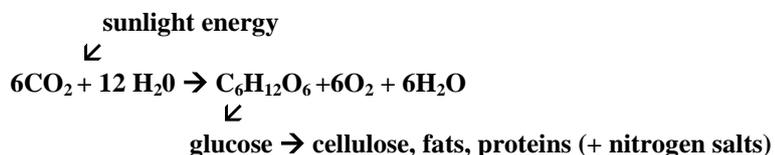
What is a Kingdom?

The primary groupings of living matter with the same basic characteristics - by living is meant that the organism is able to reproduce itself. Five Kingdoms are generally recognised - in order of their appearance on earth:

Bacteria (*Monera*) - **Protists** (*Protista*) - **Fungi** (*Mycota*) - **Plants** (*Plantae*) - **Animals** (*Animalia*)
(see Appendix for the scientific detail and terms relating to the Kingdoms)

What is unique about the Plants Kingdom?

Plants grow by making their *own* food – by photosynthesis: ***'the synthesis of complex organic materials by plants from carbon dioxide, water and inorganic salts using sunlight as the source of energy, facilitated with the aid of the catalyst chlorophyll'***. *Chloro* – green, *phyll* – leaf, the font of plant greenness.

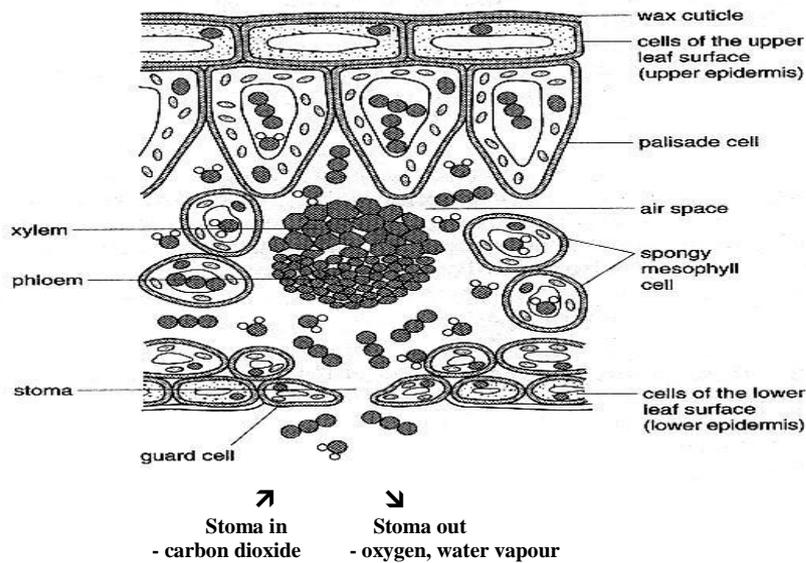


Important note – this process is reversed in animal respiration and food intake and in burning fossil fuel, i.e. CO₂ is *generated*.

The chlorophyll is contained in distinct chloroplasts within leaf cells and is excited by sunlight and so provides the driving energy for the complex multi-stage process, only outlined above. Carbon dioxide is absorbed by the leaves directly from the atmosphere whilst water and nutrients come from the soil. The products oxygen and water are transpired directly by the leaves whilst the organic material is transported within the plant for building blocks.

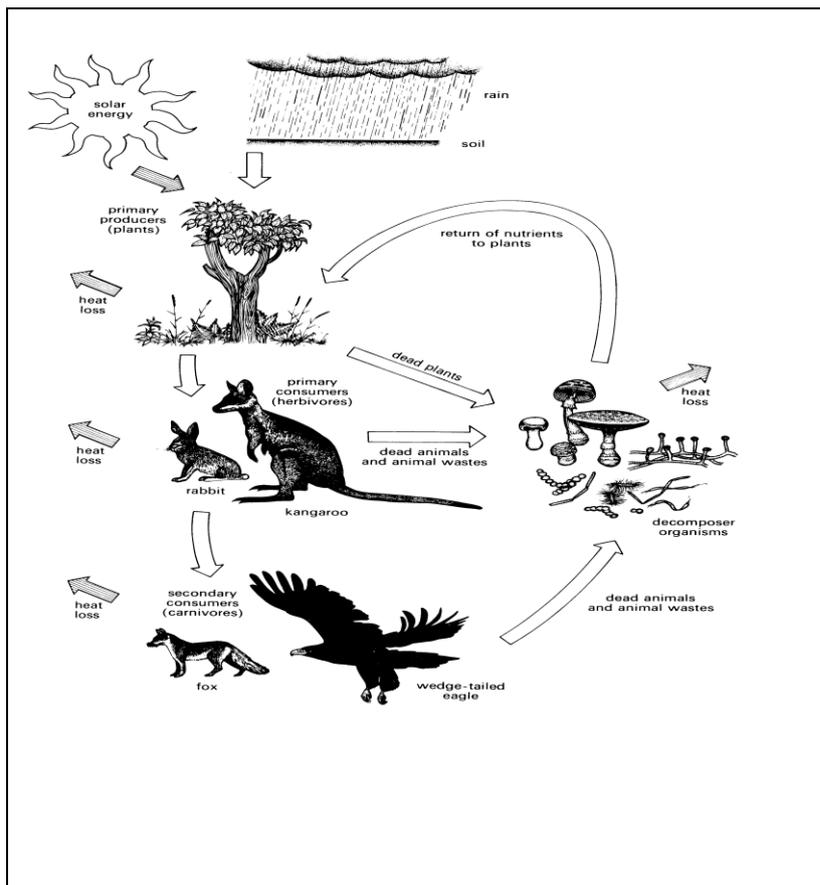
Photosynthesis and Plants are the Staff of Life

Sunlight is the energy source that drives the Earth's environment and sustains all (or nearly all) living organisms. But ***it is greenness – chlorophyll and photosynthesis – that provides the nutritional underpinning of life***. Plants are able to covert inorganic materials into the building blocks of plants – animals are all dependent on plants (*producers*) for nutrition and their building blocks in turn, either directly as herbivores (*primary consumers*) or indirectly as carnivores (*secondary consumers*) or omnivores, as are many humans. In any ecosystem, both on land and in water and in the seas, the food chain may be complex with many trophic (*nutrition*) layers of producers and consumers but ending in a closing or recycling link when dead and waste matter is decomposed by members of other kingdoms, fungi and bacteria is decomposed by members of other kingdoms, fungi and bacteria.



After Morton Jenkins (2003)

CROSS-SECTION OF A LEAF The chloroplasts are in meso-leaf cells. The xylem and the phloem are the vascular system within the structural elements, leaf venation, twigs, branches, roots, of a vascular plant ; the former takes up the water and nutrients from the soil and the latter distributes the manufactured 'food' down the plant.



AUSTRALIAN EXAMPLE OF TROPHIC LAYERS

Note that there will be many primary and secondary trophic layers involved in the food chain with different types of insects and birds. The decomposers - bacteria and fungi - feed off the dead plant material and recycle nutrients back into the soil.

After Harry Recher et al (1981)

The Place of the Plant Kingdom in Evolution

The Earth formed about 4.6 billion years ago – around 3.8bya the first organisms came into being - about 2.7bya the simple life - form bacteria evolved forms with chlorophyll, together with the first nucleate cell organisms, and through the subsequent photosynthesis Earth acquired free oxygen, the necessary precursor for respiration and, of course, animals. The Cambrian evolutionary explosion at about 0.5bya when life-forms that we are familiar with started – the animal kingdom, then came the kingdoms of fungi and plants, on land as well as in the water habitats of the organisms from which they evolved – *Homo sapiens* came out of Africa to start to populate the whole world a mere 85 thousand years ago, arriving in Australia only about 20 thousand years later!

THE EVOLUTIONARY TIMETABLE

Years before the Present	Evolution stage
4.6 billion	Earth formed
3.8 billion	First life-form
2.7 billion	Oxygenic cyanobacteria (First nucleates)
2 billion	Free O ₂ in atmosphere
570 million	<i>Cambrian</i> -the evolutionary explosion Animal, Fungi, Plant kingdoms
350 million	<i>Devonian</i> -Ferns –spores
300 million	<i>Carboniferous</i> -Gymnosperms –seeds
130 million	<i>Cretaceous</i> -Angiosperms –flowers, seeds dominant plant species
1.7million	First hominids
~ 60 thousand	<i>Homo sapiens</i> in Australia

The Plant Kingdom

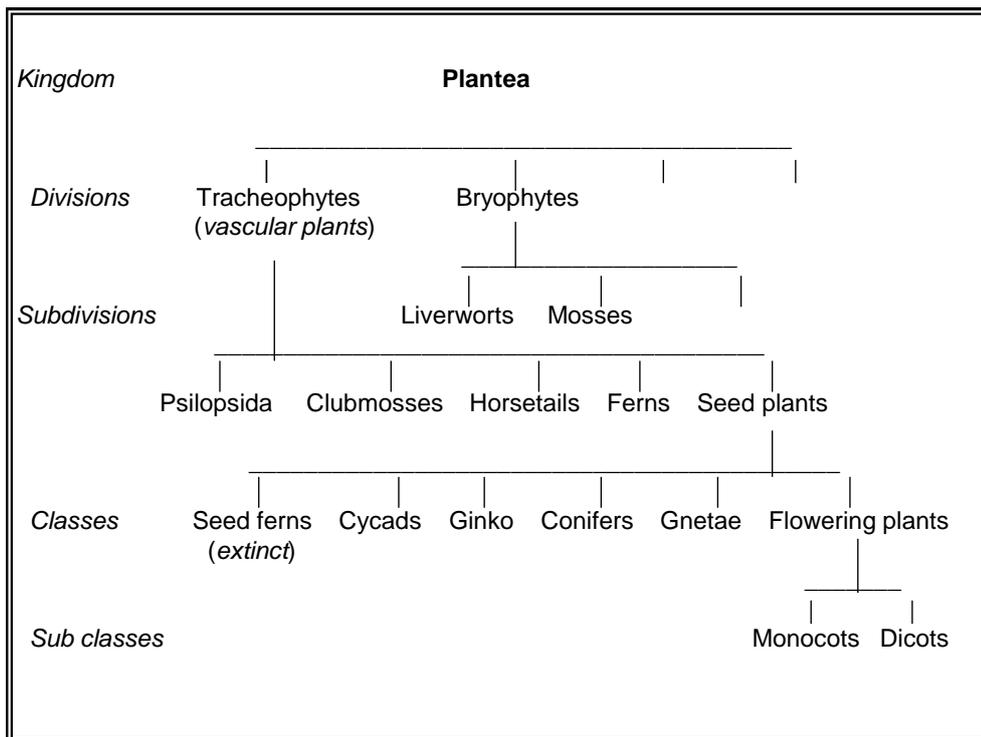
The diagram (p4) shows the arrangement of Plantae to *Class* level (see the Appendix for details of the classification within the Plant Kingdom). The Classes of flowering plants are in order of appearance in time. Flowering plants are by far the biggest Class, subclassed into dicots and monocots. Note that monocots are believed to be derived from dicots - thus it cannot be assumed that it is relatively ancient plants that are wind pollinated as are grass-like monocot plants.

Seed plants are of two basic groups - *Gymnosperms* where reproduction takes place in cones and the seeds, without an enveloping fruit, develop in the cone; Cycads and Conifers

Angiosperms where reproduction takes place in flowers and the seeds form in a fruit.

More ancient plants both vascular and non vascular reproduce by spores either on the undersides of the leaves or in sporangia at the tips.

Note that *lichens* are not true plants but a symbiotic union of *fungi and algae*.



Note: The layout given above is not exhaustive and common names, rather than scientific nomenclature, have been largely used.

Plant Kingdom relationships with other Kingdoms

Animals and Pollination - insects, birds, mammals are the necessary transposers of pollen for fertilisation (ancient plants, e.g. Casuarina and grasses are wind pollinated, some plants may be water pollinated). They are attracted to the flowers by scent and colour for the food inside - nectar. Many flowering plants have characteristics to allow only a single specialist pollinator.

Recycling of Material - fungi, bacteria, insects break down dead plant material and recycle nutrients into the earth

Take-up of Nutrients - fungi, bacteria form symbiotic relationships with plants to facilitate take-up of nutrients from the soil and receive nutrition in return.

- Carbon, oxygen, hydrogen and nitrogen are the basic life elements
- But unlike the others *nitrogen*, although seemingly abundant, is *organically* in *very, very* short supply
- Plants take up nitrogen in amino acids (NH₂) through ←
 - fungi, i.e. *mycorrhiza* with ~ 90% of plants
 - bacteria, i.e. *rhizobium* with legumes
- The majority of plant structure is carbon based, cellulose and lignum indigestible to animals, and plants 'ration' nitrogen, in proteins, mainly to new growth, seeds. This could be a major limiting factor on the animal population and the need of animals to use bacteria to improve metabolism.

Photosynthesis - were chloroplasts originally bacteria?

What is the Message?

Plants, through photosynthesis, are the very staff of life though not the first Kingdom to come into being. Plants and the other Kingdoms do not exist in isolation but are interdependent.

Sources consulted

- * A M Young and Kay Smith, *A Field Guide to the Fungi of Australia*, UNSW Press (2005)
- * TCR White, *Why Does the World Stay Green? Nutrition and survival of plant eaters*, CSIRO Publishing (2005)
- * Walks and Talks Program - *Why is the World Green*, AF (2005)
- * Bill Bryson, *A Short History of Nearly Everything*, Black Swan (2004)
- * Stephen Oppenheimer, *Out of Eden, the peopling of the world*, Robinson (2004)
- * Andrew Parker, *In the Blink of an Eye: the most dramatic event in the history of time*, Free Press (2003)
- * Mary White, *Earth Alive! From microbes to a living planet*, Rosenberg (2003)
- * Morton Jenkins, *Biology, teach yourself* (2003)
- * Walks and Talks Program - *Plant Kingdom*, VW (1999)
- * Frank Salisbury and Cleon Ross, *Plant Physiology* (4th ed), Wadsworth Inc. (1992)
- * Alan Fairley and Philip Moore, *Native Plants of the Sydney Region*, Kangaroo Press (1989)
- * Harry Recher, Daniel Lunney and Irina Dunn, eds, *A Natural Legacy: ecology in Australia*, Pergamon Press (1981)
- * Macquarie Dictionary

Acknowledgement To Fred Langshaw who drew my attention to the book of Salisbury and Ross, surely the definitive work on Plant Physiology.

Appendix

The Five Kingdoms - Terminology

Living things are made up of cells and can reproduce themselves independently

1. MONERA > Bacteria – have *prokaryotic* cells, i.e. no cell nucleus or organelles. The generally little known bacteria kingdom contains about 60% of all living matter and is so essential in the functioning and well being of the biosphere, as well as being the evolutionary source of all plants and animals - see White's *Earth Alive!* for the full astounding story.

2. PROTISTA > Protists – have *eukaryotic* cells, i.e. nucleate cells – the three following kingdoms evolved from this early life form. Present day protists are algae and protozoa.

3. MYCOTA > Fungi – no chlorophyll, therefore incapable of photosynthesis – in symbiotic relationships with plants.

4. PLANTEA > Plants – have chlorophyll and use photosynthesis, taking energy from the sun to manufacture building blocks, taking in carbon dioxide and expelling free oxygen. Vascular plants have duct-like systems to transport water, nutrients and building blocks around the plant formed by the woody cell chains, the *phloem* and *xylem*. Other kinds of plants absorb necessary materials directly.

5. ANIMALIA > Animals – reverse metabolism to plants; taking plant or plant derivatives and oxygen to manufacture building blocks plus energy for movement and expelling free carbon dioxide.

Details of the classification within the Plant Kingdom

The **PLANT KINGDOM** has about 260 000 species grouped into two major Divisions with the vast number of species - about 230 000 - being flowering plants. By comparison the **ANIMAL KINGDOM** has about a very diverse range of invertebrates and vertebrates of about 1 000 000 known species grouped in some 36 Divisions with some 95% of species being invertebrates.

Plants probably evolved from ancestral green algae; they occur on land and in sea and fresh water and are characterised by :

- tough cell walls
- self feeding through photosynthesis
- remaining stationary

Classification of plants - refer to Plant Kingdom classification diagram

Divisions

BRYOPHYTES are the mosses and worts, relatively small plants that must grow in moist places on land for nutrition and reproduction. Some species can survive periods of drought, but only by becoming dormant and ceasing to grow. They have sperm cells with flagella that must swim to the egg cells and most lack vascular tissues. The bryophytes are thought by some botanists to have arisen from green algae. A young moss plant often closely resembles a green algal filament. As the plant grows it forms some branches (called rhizoids) that enter the ground and function like roots. Other botanists hypothesise that the bryophytes arose from true vascular plants by loss of structures as there are vestiges of vascular tissue and non-functional stoma guard cells in some bryophytes.

TRACHEOPHYTES are plants that have a system within them, similar to veins and arteries, which transports water, nutrients and other substances around the plant, called a *vascular* system. Other plants (Bryophytes) absorb these materials directly into the cells. The vascular system is formed from chains of woody cells called *phloem* and *xylem*.

Classes of TRACHEOPHYTES

REPRODUCTION BY SPORES

PSILOPSIDA are simple, branching plants that lack leaves and have no true roots, although they do have underground stems that bear unicellular rhizoids similar to root hairs. The stems carry out photosynthesis. Sporangia develop at the tips of some of the aerial branches. *Psilotum* and *Tmesipteris*, which both occur in Australia, are the only living genera.

CLUBMOSES (*Lycopsidea*) first appeared in the Devonian period, almost 10 million years after the first Psilopsida. During the late Devonian and the Carboniferous periods these were among the most dominant plants on land. Some of them were very large trees that formed the earth's first forests. They have true roots and true leaves. Certain leaves bear sporangia. Several species are found in Australia, and one in the Ku-ring-gai Wildflower Garden.

HORSETAILS vary from small creeping plants to scramblers reaching about 9 metres. The leaves are borne in whorls with jointed stems, and true roots. There are 25 surviving species of a genus that was widespread in Carboniferous times. The sporangia, spore-bearing tissues, are grouped into cones at the tips of fertile stems. They are no longer found in Australia.

FERNS are seedless, vascular plants which live in moist habitats and need water for reproduction. The stem is either underground (rhizome) or vertical, and the leaves have midribs. They reproduce by spores which are dependent on water to achieve fertilisation. The leaves unfold in a characteristic scroll.

REPRODUCTION BY SEEDS

GYMNOSPERMS are seed bearing, vascular plants, whose reproduction takes place in cones, not flowers, and seeds develop naked in the cone. Cycads and conifers make up the gymnosperms.

GINKGO BILOBA has lobed leaves and parallel veins. Reproduction takes place in cones where a naked seed develops and there are male and female trees. It is the only species in its Class, originating in China.

WELWITSCHIA (GNETA) is found only in south-west Africa. It is a remarkable woody plant, the sole member of its family. It has only two leaves which appear to be many when the two leaves have been split by wind action.

ANGIOSPERMS are vascular plants with flowers and fruits which enclose the developing seeds, The flowers have a great diversity of size and structure. Flowering plants are divided into monocots and dicots depending on whether the seeds have one or two cotyledons, the primary or rudimentary leaves of the plant embryo.

Evolution of land based plants from water based ancestors

Land based plants evolved from water plants and had to adapt to the new environment:

- *drying out*, plants have developed bark in trees and leaf cuticle surfaces to reduce moisture loss
- *gas exchange*, plants have evolved to either live in moist environments in which diffusion of gases, i.e. carbon dioxide, oxygen, in and out can take easily place (BRYOPHYTES) or have developed leaf structure with guard cells and stomata (TRACHEOPHYTES) - see Cross Section of a Leaf
- *support*, without the dense water medium plants evolved special support cells
- *circulation*, multi-cell plants evolved the transport structure to move materials about the plant, the phloem and xylem - Cross Section of a Leaf
- *reproduction*, in water the gametes, male sperms and female eggs, can be released into the water for fertilisation but on land the plants must live in a moist environment (BRYOPHYTES and FERNS) or develop a specialised delivery system, the pollen tube, to facilitate the sperm reaching the ovary, as in flowers.

Classification System - Kingdom, Division or Phyla, Class, Order, Family, Genus, Species.

- mnemonic:
Kings **P**lay **C**hess **O**n **F**lat **G**lass **D**iscs

Notes

(i) *Nuclei* and *organelles* are organic materials contained in separate membranes within a cell of an organism; a nucleus has the 'management' function and the organelles have their specific 'manufacturing' functions.

(ii) *pro* – before, *eu* – proper, *kary* – nut (nucleus)

(iii) Bacteria include *Cyanobacteria* that have chlorophyll and photosynthesis.

(iv) Viruses are parasitic and can only metabolise and reproduce inside a living host. They do not have the conventional cell structure and cannot reproduce by cell division – they are not regarded as living organisms.

(v) The Kingdom Protists contains a diverse group of living organisms that may have characteristics of both animals and plants. Algae range from the single celled to massive seaweeds.

Alec Fisher, West Pymble, April 2008 Copyright - not to be reproduced without permission.