Contents

Chapter 1

Week 2: Vegetative Morphology & Keys

The Nature of Leaves

Flowering plants are the culmination of an amazing cascade of evolutionary innovations. This laboratory aims to place them in the context of the diverse array of vascular plants and trace the evolution of some basic aspects of their morphology.

The first section of this laboratory aims to illustrate the less specialised organisation of the plant body found in the non-flowering plants and from which angiosperm morphology has been derived, while the latter part of the lab introduces the use of identification keys. The rest of the course concentrates on the flowering plants, and will consider form and function of the various organs of this group in more detail.

The purpose of many of the questions in this lab is to encourage you to look carefully at your material to see what is really there. Today's focus is on **leaves**, **buds**, and **stems**. In different species they make look very different. There are also some specialized terms for discussing different types of leaves; it's not necessary to memorize these terms but it is good to know they exist and where to find definitions when you need them.

In today's lab we will do a very brief tour of leaves across all the major groups of vascular plants from whisk ferns, ferns, gymnosperms, and finishing with the angiosperms.

A basal group of ferns: the whisk ferns

The earliest known vascular plants consisted of a system of cylindrical axes. The cortical tissues of the above ground parts had stomata and a cuticle and were photosynthetic, while the epidermis of the underground parts had no cuticle but produced hair-like outgrowths to aid absorption of water and minerals. Such plants are only known from the fossil record, but there are two living genera that approach this simple level of organisation. These are *Psilotum* and *Tmesipteris*, which are both "whisk ferns" and native to Australia.

Examine *Psilotum nudum*.

It consists of a stem system bearing small *microphylls*. The stem grows by a single apical "initial" rather than a meristem (a group of initials).

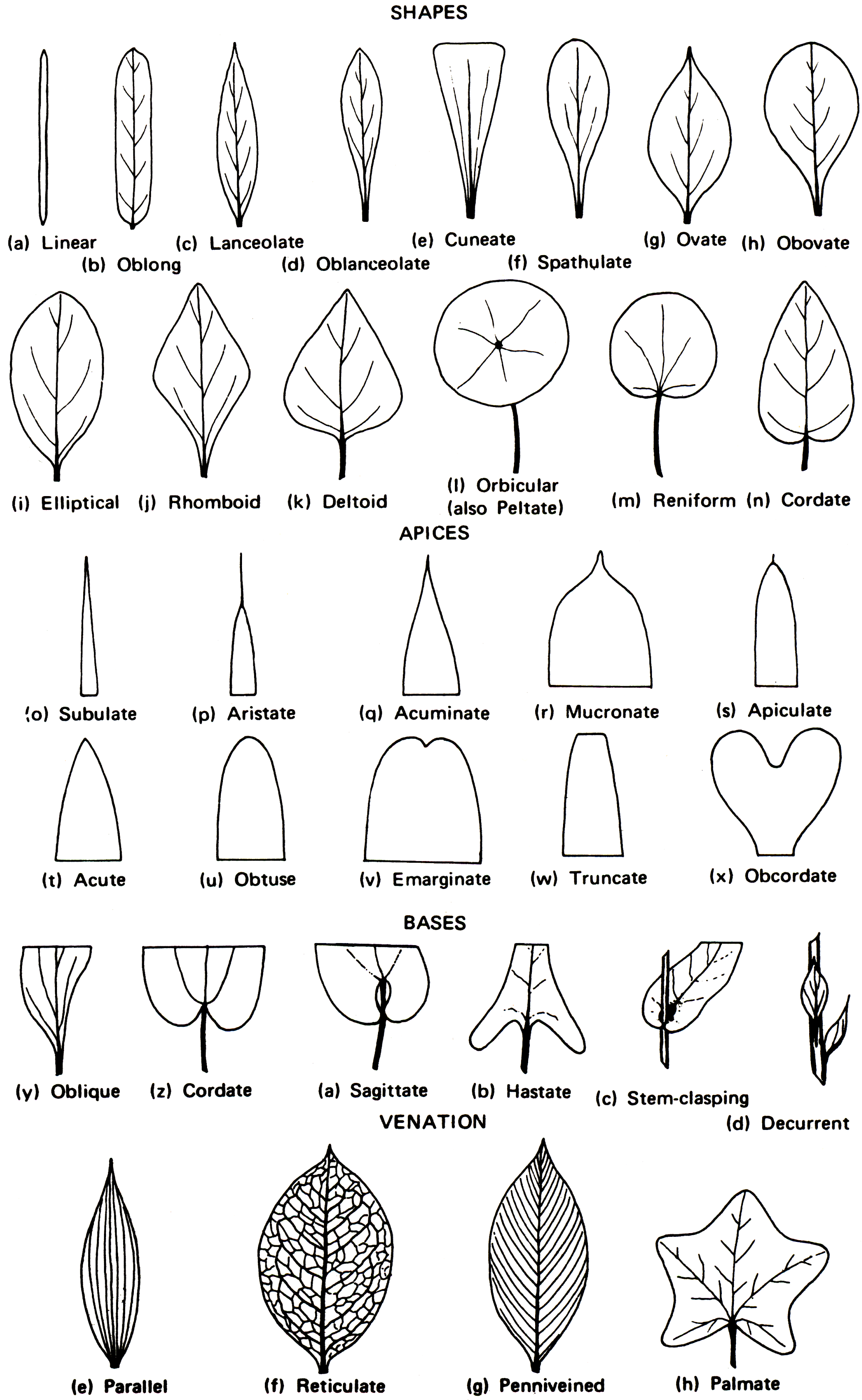

Fig. 2 Shapes, apices, bases and venation of leaves and leaf-like structures.

Figure 1.1: Terms for different leaf shapes. Figure from N.C.W. Beadle, O.D. Evans & R.C. Carolin (1982) Flora of The Sydney Region. Reed, Sydney.

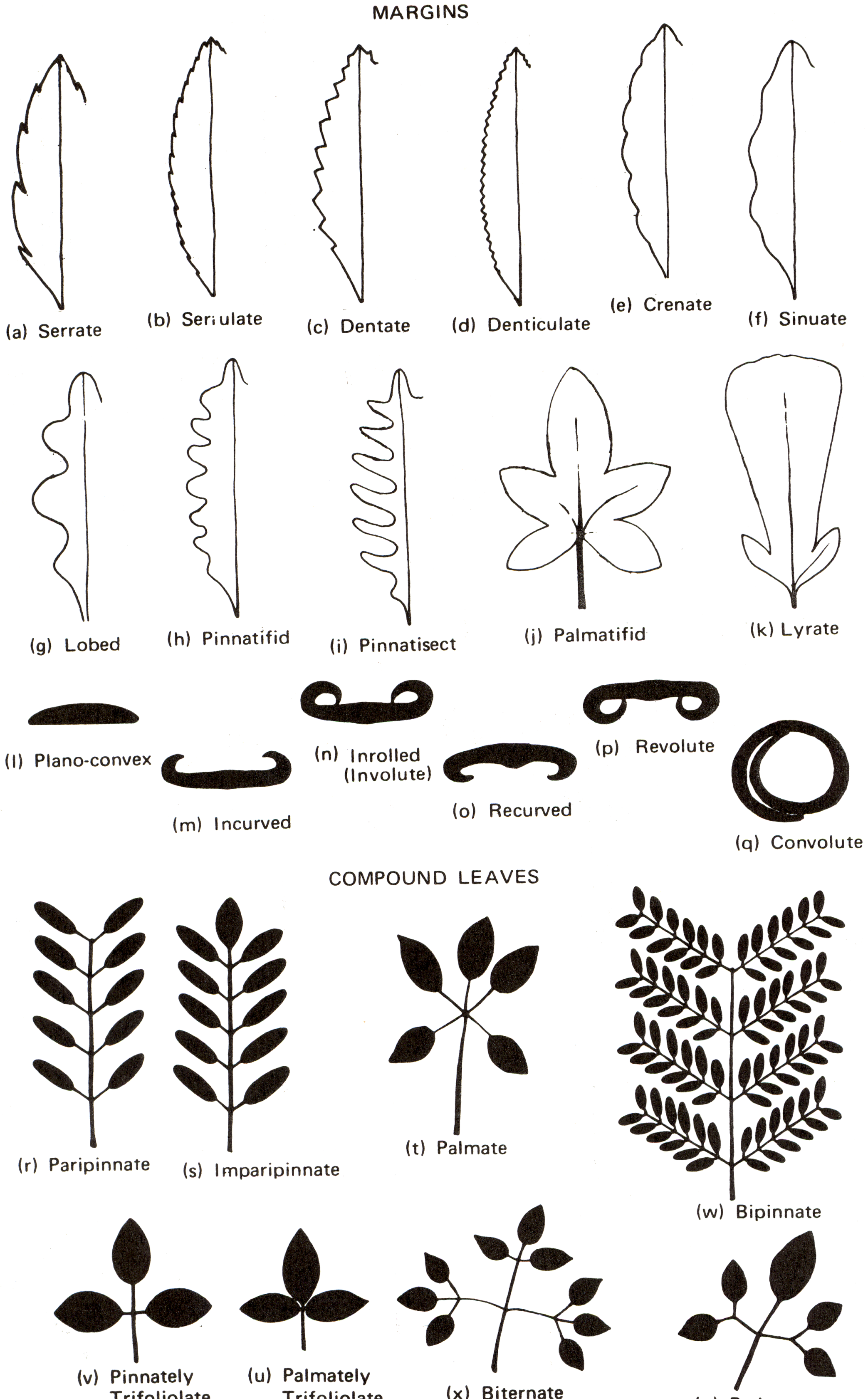

Fig. 3 Leaf-margins. Compound leaves.

Figure 1.2: Leaf arrangements; simple and compound leaves. Figure from N.C.W. Beadle, O.D. Evans & R.C. Carolin (1982) Flora of The Sydney Region. Reed, Sydney.

- Examine the branching of the stem. This type of branching, where there is no main axis bearing laterals, is termed **dichotomous**. It is the oldest form of branching in plants, and is still common in the algae. Can you distinguish a main axis bearing lateral branches, or are all branches of equal size and growth?

- Determine what, if any, relationship exists between microphyll and branch position. Does this plant have axillary buds? If there are no actual buds, from which point and in what manner do branches form?

- Are apical buds present? Check the definition of bud in the glossary.

- How do you think new aerial stems are produced from below ground?

- What would be the effect of browsing or pruning the tips of the aerial parts of the plant?

Ophioglossoid Ferns

Members of this group have roots, stems and leaves, but the latter are *megaphylls*, and are not homologous with the microphylls of the previous group. In the ferns there is no main root system, the roots being lateral organs borne on the stems (*adventitious* roots).

Examine *Lygodium scandens.*

The stem grows horizontally below the surface of the ground (it is a *rhizome*); only the leaves are visible. Each leaf grows for one year, climbing on other plants towards the light, but eventually dies back to be replaced by a new one the next year.

- Do the leaves show determinate or indeterminate growth?

- Note the growing apex of a leaf is coiled up to protect the initial cell that is responsible for the growth. All fern leaves uncoil at the apex like this why is this adaptive?

- Use the drawings in Figs.1.1. and 1.2 to identify the primary and secondary leaflets (*pinnae* and *pinnules*), and the primary and secondary *rachises*.

- How would you describe the primary branching in the leaf? Is there any evidence of dichotomous branching in these leaves?

- Note that the veins in the leaflets (pinnules) are in the form of an open system where the branches end blindly rather than joining to form a net.

- What, if any, part of *Psilotum nudum* would be homologous with the leaf of *Lygodium scandens*? Is any organ of the latter homologous with the microphylls of the former?

Examine *Gleichenia* sp.

Note the small fibrous adventitious roots that arise at any point along the stem, and the large divided (compound) megaphylls. These leaves uncoil during growth.

- Determine the relationship (if any) between leaf positions and branching of the stem. Does this species have axillary buds? How are branches initiated in the stem system?

- Use the diagrams in Fig. 1 to determine what type of branching is present in the leaf. How many orders of branching are there in a leaf? Identify the primary, secondary and tertiary rachises.

- Compare a one-year-old leaf with a two-year-old leaf. Is there any evidence of indeterminate growth in these leaves?

- Examine the apex of the rhizome (underground stem). Does this plant have an apical bud? Is there any protection of the growing apex?

Gymnosperms

These are seed plants without fruit or flowers. They are thought to have dominated the world's vegetation during the cooler and drier period that followed the Carboniferous.

Examine *Podocarpus elatus*

Podocarpus elatus (Plum Pine) is a conifer native to the closed forests of eastern Australia.

The leaves of conifers are also interpreted as megaphylls, i.e. as having evolved from a lateral branch that has become determinate in growth and flattened to enhance interception of light.

- Note the simple leaves that characterise the order. Are the leaves strictly determinate in growth? How are they arranged? What term(s) best describe the **phyllotaxis** (leaf arrangement)?

- Hold a leaf up against the light and examine the pattern of the veins with a hand lens. Can you detect any lateral veins branching from the midrib? These leaves have a continuous sheet of tracheid-like cells between the adaxial and abaxial mesophyll tissue that distributes water laterally through the lamina from the single midvein.

- Examine the pattern of branching of the stem. Look for axillary buds in leaf axils. Does this plant have axillary branching as in angiosperms or apical branching as in ferns?

Examine the growing apex closely. Rather than a naked apical meristem, this group has the meristem protected within a bud. Note that the bud consists of a meristem enclosed with embryonic leaves, but that these are themselves enclosed within a group of **bud scales**, ie., reduced and hardened leaves that protect the bud. When the apex starts growing next spring, the bud scales fall off (leaving scars where they were attached) and the new vegetative leaves expand as the stem grows out of the bud. The positions of previous **winter buds** can be seen at intervals down the stem. They appear as rings of scars where the bud scales were attached.

- Given that each winter bud marks the end of a year's growth, how old is the basal internode of the specimen you are examining?

Angiosperms – Flowering Plants

Fill in the appropriate information in Table 1.1 and 1.2 as you examine the angiosperms in the lab today.

There are many orders of flowering plants. All are characterised by the possession of a carpel, pollination at a distance from the micropyle of the ovule, and double fertilisation via a pollen tube. Like the previous two divisions their leaves are megaphylls, although there is some evidence that the megaphyll evolved separately in each group. Unlike conifers, the leaves of angiosperms may be simple or compound.

Examine *Abelia triflora*

Note that it has simple leaves with a short petiole, and that the laminas of these are mostly arranged in the one plane, spreading out either side of the stem. Note carefully how leaves are attached at successive nodes.

- Which term(s) (see Fig. 1.2) best describes the phyllotaxis (leaf arrangement) of Abelia?

- Using a hand lens and holding the leaf against the light, examine the venation pattern in the leaf lamina.

- Are there any free vein endings in the leaf? Which term best describes this pattern? How does this pattern differ from that in the leaflet of a fern?

- Examine the relationship between stems, leaves and branches. How do branches arise on the stem? Does this plant have axillary branching? Does each leaf axil contain a bud? How can you distinguish a branch of Abelia bearing two rows of simple leaves from a single pinnate leaf?

Examine the the pea seedlings (*Pisum sativum*) on your bench.

Each leaf is compound, consisting of a petiole terminating in a rachis bearing several pairs of rounded leaflets.

- Which term(s) best describes the form of these leaves (see Figs. 1.1 and 1.2).

- Identify the pair of large rounded stipules associated with each node, and resembling a basal pair of leaflets that are attached directly to the stem. Note how they enclose the apical bud of the main axis. What possible adaptive value could these stipules have?

- Which term(s) best describe the phyllotaxis (leaf arrangement - see Figs. 1.1 and 1.2).

- Does this plant have axillary buds?

Examine *Acacia elata* (Cedar Wattle).

How much constitutes a leaf? Look for axillary buds that may arise in the axils of leaves, but never in the axils of leaflets. Also look for the largest repeated unit of organisation. The leaf is the largest determinate unit of organisation, as distinct from the indeterminate stem system.

- Identify the petiole, rachis, primary leaflets (pinnae) and secondary leaflets (pinnules). Are the primary and secondary leaflets strictly paired?

- Is there a terminal leaflet on the primary rachis?

- Is there a terminal secondary leaflet on the secondary rachises?

- Which term(s) best describe the form of these compound leaves? (see Fig. 1.2).

- Are there stipules present?

- Look for the doughnut- or volcano-shaped glands (**nectaries**) that are a characteristic feature of the petiole and/or the rachis of *Acacia* species. What could be the adaptive value of such nectaries?

- Compare the form of these leaves with those of *Gleichenia*. In which respects do they differ? Which of these two forms of leaf most closely resembles a stem system? (ie., which is the more primitive megaphyll?) Which features of the *Acacia* do you consider to be advanced, and which do you consider primitive?

Examine specimens A, B, and C

In some angiosperms the process of adaptation has blurred the functional distinction between leaves and stems. Some such examples are considered below.

In each of specimens A, B and C, use your knowledge of the relationship between stems, leaves and axillary branches to work out what constitutes a leaf, and then enter in Table 1.1 the appropriate terminology from Fig 1.2 to describe the form and arrangement of the leaves.

In the following cases, some part of the plant has been modified to serve as an aid to climbing.

Examine the **tendrils** on the young pea plants supplied. Each tendril arises from near the end of a compound leaf, in the position in which you find a leaflet (CHECK THIS) on a leaf that has no tendril.

Hence, we can conclude that the development has been modified so that the tissues that normally develop into the leaflet grow into a tendril instead (ie., the tendril is a modified leaflet/pinna).

Now examine the tendrils on the branch of *Cissus* sp. Each arises on the stem opposite a leaf. This suggests that the plant originally had leaves in opposite pairs, and that one has been modified to form the tendril.

To check this explanation, find a node at which no tendril has been formed.

- Does this node bear a pair of leaves, or a single leaf?

This shows that our initial interpretation is wrong. The tendril cannot be a modified leaf.

- Is the tendril in the correct position to have arisen from an axillary bud?

If it is neither a modified leaf nor a modified axillary branch, it must in fact be a modification of the tip of the main axis.

In this species, each time a tendril is formed it uses up the apical meristem in the apical bud, so continued growth of the plant can only come from an axillary bud emerging from the axil between the last leaf and the tendril. As it grows, the axillary branch pushes the tendril to the side, and forms a continuation of the vertical axis of the plant. So the plant axis is formed by a new "side branch" at each node bearing a tendril. This pattern of growth is described as **sympodial growth**. Sympodial growth is also seen in some plants where the apical bud is used up to form a flower.

Examine specimens D, E and F

Determine in each case whether the climbing structure (tendril or claw) represents an apical bud, and axillary bud, a leaf or part of a leaf. Enter your answers in Table 1.2.

TABLE 1 Leaf morphology in angiosperms. For form of leaf write down the shape, apex, base, and veneation using the terms from Figure 1.1 and 1.2.

Species	**Form of Leaf**	**Arrangement of leaves**	**Stipules**
Abelia triflora			
Pisum sativum			
Acacia elata			
Specimen A			
Specimen B			
Specimen C			

TABLE 2 Modifications to aid climbing. For form of leaf write down the shape, apex, base, and veneation using the terms from Figure 1.1 and 1.2.

Species	Form of leaf	Modification to aid climbing	Organ modified
Specimen D			
Specimen E			

Check your answers with demonstrators / lecturers / classmates

Introduction to the use of an identification key

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**Plant identification is a key skill from this course.
 This skill is essential in a range of careers
 including consultancy, bush regeneration, government and research**
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Plant identification almost always is based on a key. The aims of this exercise are to learn how to use an identification key, and also to become familiar with a range of common vegetative features of plants. Use the preceding section and the glossary to understand all the terms in the key.

A key is a device that progressively eliminates possibilities until the identification is complete. At each step in the process it asks you to choose which of a pair of contrasting conditions or characters occurs in your specimen, and then directs you to the next appropriate choice depending on the condition chosen. It is important to realise that you do **not** have to use all the possible alternatives for any one specimen. The contrasting alternatives can be arranged in either of the following ways:

1. In **Bracketed Keys** the contrasting alternatives are placed together, usually under a single number. Each alternative directs you to the numbered alternative that should be examined next. Hence, the first alternative under number 1 might direct you to 2 (the second pair of contrasting conditions), while the second alternative under 1 may direct you to 13, omitting all the intervening pairs (2 to 12).

2. In **Indented Keys** the contrasting alternatives are marked with the same symbols (numbers or letters) and indented or inset the same distance from the left hand margin, but are not necessarily placed directly under each other; indeed, they can sometimes be on different pages of the book, so one has to search for the alternative. Commonly the first and second alternatives are distinguished as A and *A, B and *B, etc. Having decided which alternative best fits the specimen, proceed to the pair of alternatives that immediately *follows* the correct alternative (**downwards!**). Hence, if your specimen fits the second of two alternatives, say *B, ignore all the choices listed below B and go to the first choice listed under *B.

In **both** types, it is essential to -

1. always proceed downwards;
2. **read all alternatives carefully before** deciding which best fits the specimen, and check any unfamiliar terms in the glossary. **Never** decide that the first alternative is correct before you read the second of the contrasting pair!

Now turn to the key at the back of the lab manual. This is a key that uses only vegetative characters. The advantage of such a key is that it does not require you to have flowers or fruit, which are only on the tree in certain seasons. Use this key to identify at least two of the specimens.

Chapter 2

Week 3: Floral Morphology and Inflorescences

Reference: Raven, P.H., Evert, R.F. & Eichhorn, S.E. 2013. **The Biology of Plants 8^{th} edition** pp 478-492.

In this practical, we will examine the floral characters of typical angiosperms. In addition, we will introduce you to sufficient terminology that you can use identification keys based on reproductive characters.

The radiation of floral structure within Angiosperms has lead to a wide variety in both floral structures and inflorescences. In part this is due to chance evolutionary events and in part it is do to selection pressures that arise from a particular pollination mechanism.
Sometimes the pollinators are animals that are evolving themselves, meaning the evolution of floral structure can only be understood in the context of *co-evolution*–both the plant and the animal are evolving at the same time and in response to each other.

The floral diversity in angiosperms is staggering, but with some practice it's also useful—it can be of great assistance in plant identification. With a few terms and some practice.

Floral structure

As you will see, flowers are complex, highly specialised, and exhibit tremendous morphological diversity across taxa. Botanists have a number of ways of describing floral structure.

The basic floral structure comprises four **whorls**, each comprising 3-5 segments, but this varies greatly among species. A 'whorl' is a group of appendages arising from the same point on an axis. The identity of each floral whorl is determined by its position and function. The inner-most and upper-most whorl is the gynoecium, followed by the androecium, corolla and calyx (the outer-most and lowest whorl of the flower.

Important terms

Make sure you know these terms (consult the glossary at the back of the manual):

1. determinate and indeterminate growth
2. radial and bilateral symmetry
3. perianth, petal, corolla, sepal, calyx
4. ovary, ovule and ovum
5. carpel and gynoecium

Floral formula

A floral formula can express the number, fusion and insertion of floral parts.

The symbols used are as follows:

- **K** : calyx (sepals)
- **C** : corolla (petals)
- **P** refers to the perianth, when calyx (**K**) and corolla (**C**) are not different.
- **A** : androecium i.e. the number and arrangement of stamens and staminodes.
- **G** : gynoecium i.e. the number and arrangement of carpels.
- **G** $_{\underline{4}}$: a line under the number for G indicates a superior ovary
- **G** $_{\overline{3}}$: a line over the number for G indicates an inferior ovary
- ***** : radially symmetric flower ie. actinomorphic
- .|. : bilaterally symmetric flower ie. zygomorphic
- (5) signifies fusion of parts in the same whorl;
- $[C_5+A_5]$ or C_5+A_5 indicates fusion between the parts of different whorls.

For example, the floral formula:

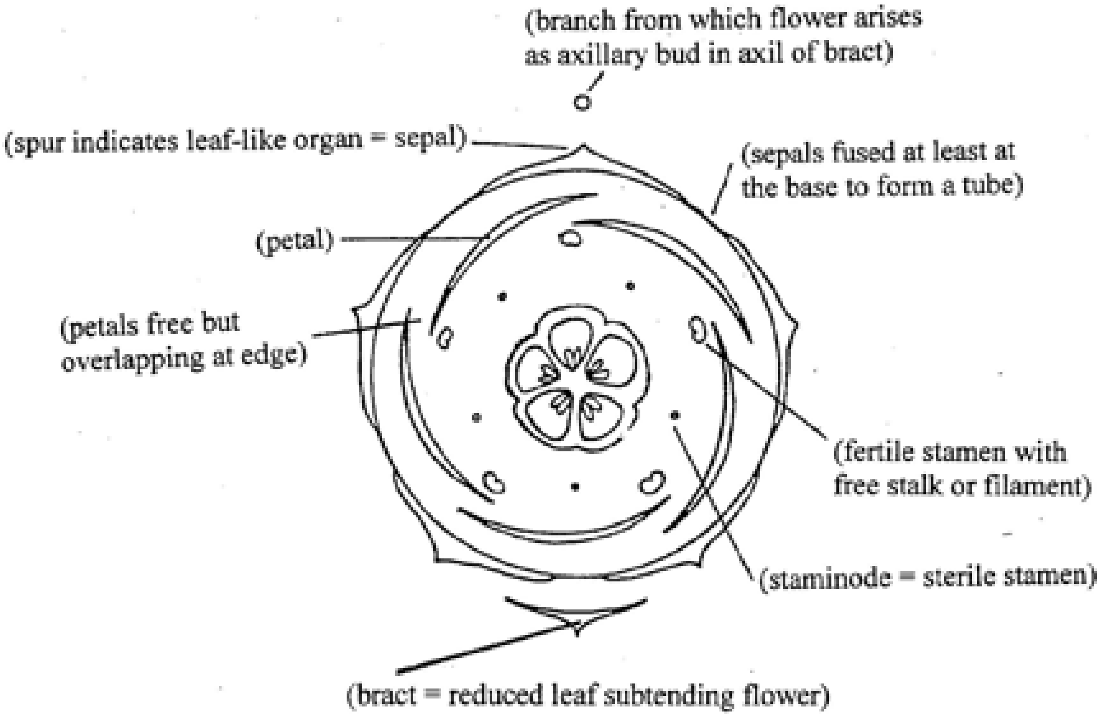
$* \ K_5 \ [C_{(5)} \ A_{5+5}] \ G_{(\underline{3})}$

signifies a radially symmetrical flower with 5 free sepals, 5 fused petals, 2 whorls each of 5 stamens that arise from the inside of the petals, and 3 fused carpels with a superior ovary.

Cut a longitudinal section through a flower to determine whether the ovary is superior or inferior. Cut a cross section through the basal part of the flower through the ovary to determine the number and arrangement of the carpels (locules). Then gently squeeze each section of the ovary. If the ovules pop out of one end then you can assume that they must be attached at the other end.

A floral diagram is a ground plan that can express number of parts, fusion and some of the symmetry, but not whether the ovary is superior or inferior. It helps to draw concentric circles for each whorl first in light pencil as a guide for the floral diagram. The position of the inflorescence axis and the subtending bract or leaf can also be shown. The figures and show examples of floral diagrams and floral formulae

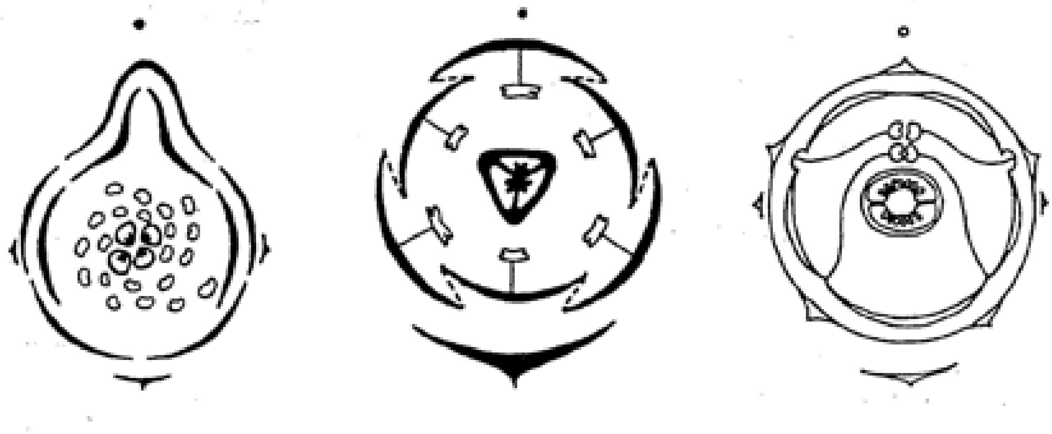
Floral Formula: $*K_{(5)}\ C_5\ A_{5+5}\ G_{\underline{(5)}}$



What feature is shown by the formula but is not in the diagram?

NB. In a completed floral diagram the parts of the flower are represented diagrammatically and do not need labels. Do not label the parts of your floral diagrams. Do give it a title.

Figure 2.1: A floral diagram of *Flindersia*, a rainforest tree of northern NSW. Note that each successive whorl is offset by the same angle. This alternation of whorls is a feature of virtually all flowers. There is an outer whorl of fertile stamens (the five lobed anthers between the petals) and an inner whorl of sterile staminodes (the five circles opposite the petals). Fusion is shown by joining parts with a line (as for the sepals). Note that the petals are shown to overlap, the stamens in the inner whorl are reduced and sterile, and the 5 locules show axile placentation. These points are not indicated in the formula.



·|· P_{5+4} A□ $G_{\underline{4}}$
A

∗ [$P_{(3+3)}$ A_{3+3}] $G_{(\underline{3})}$
B

·|· $K_{(5)}$ [$C_{(5)}$ A_{4}]$G_{(\underline{2})}$
C

Features shown in the diagrams A to C but not shown in corresponding floral formulae are:

A) There are two small bracts below the calyx, as well as the subtending leaf. There are only four tepals in the inner perianth whorl because the one opposite the subtending leaf has been lost during evolution. This loss, and the elaboration of the perianth on the upper side (towards the axis) have produced the zygomorphy. The numerous stamens and four free carpels are in a helical arrangement, rather than in whorls.

B) Dotted lines indicate fusion of all perianth parts at the base to form a single short tube, although their upper parts overlap. The solid lines represent the fusion of the outer whorl of stamens to the outer whorl of perianth, and the inner whorl of stamens to the inner whorl of perianth; this is also shown by the square brackets in the formula.

C) *Limnophila* sp. The two upper and three lower petals are more completely fused, so the corolla tube has an upper and lower lip. There are only 4 stamens because the one between the two upper petals has been lost; the remaining stamens, although attached to the lower half of the corolla tube, are positioned in pairs under the upper lip.

Figure 2.2: Examples of floral diagrams and floral formulae illustrating some variations in floral structure that can be shown in these ways.

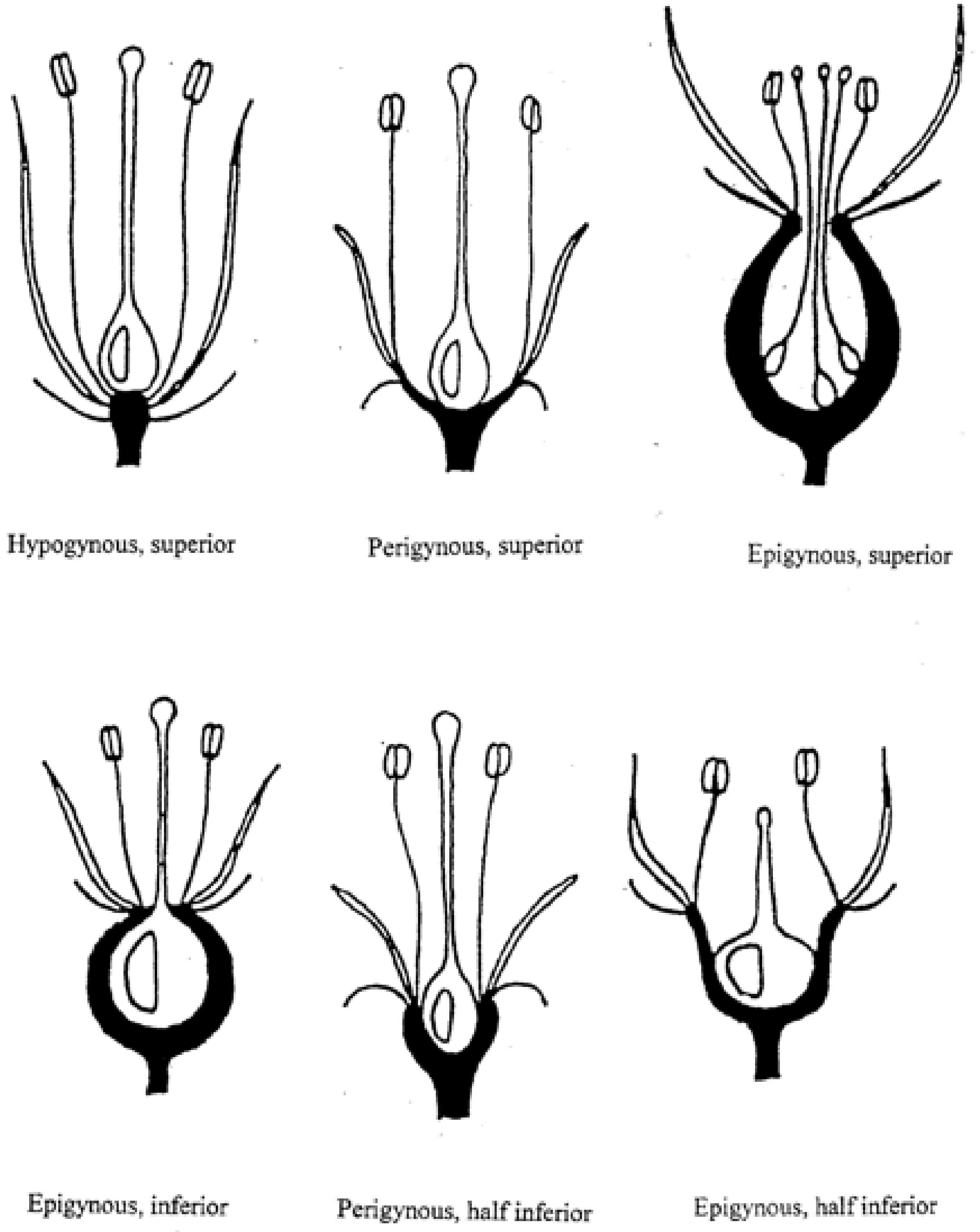
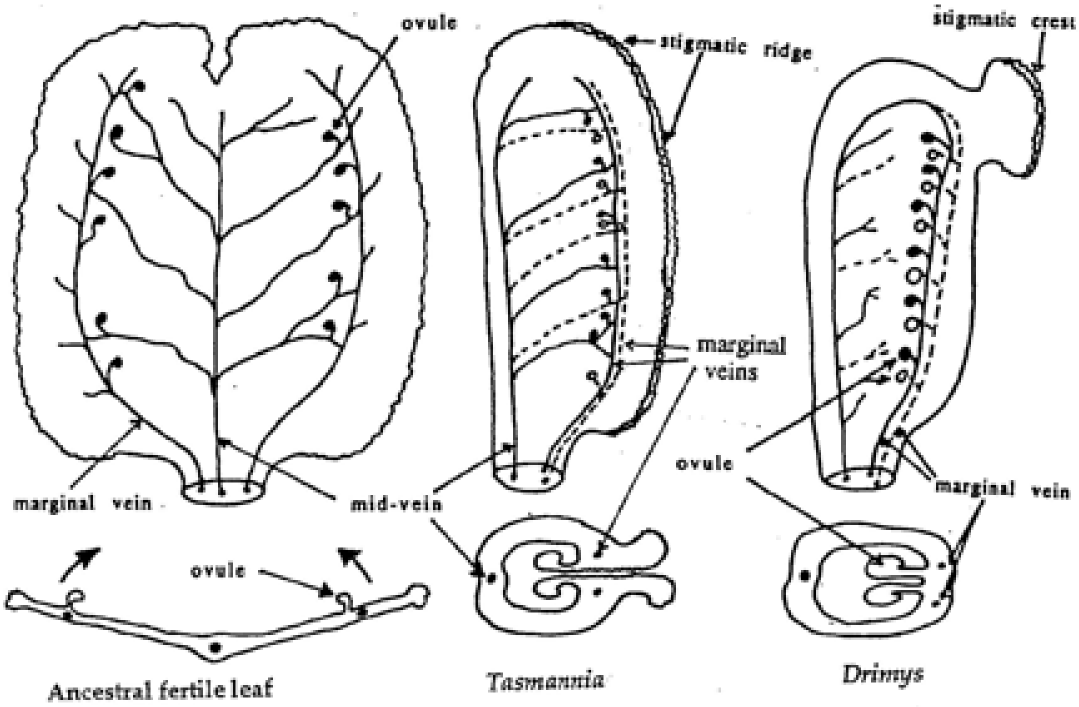


Figure 2.3: Terminology for describing the position of the ovary in relation to other floral parts. The hypanthium (shown in black) is an extension of the pedicel (flower stalk). For every new flower you examine, check if the calyx, corolla and androecium separate from the hypanthium above (epigynous), level with (perigynous) or below (hypogynous) the gynoecium. Also check if the ovary fused to the hypanthium only at its base (superior), for its basal portion (half-inferior) or for its entire length (inferior).



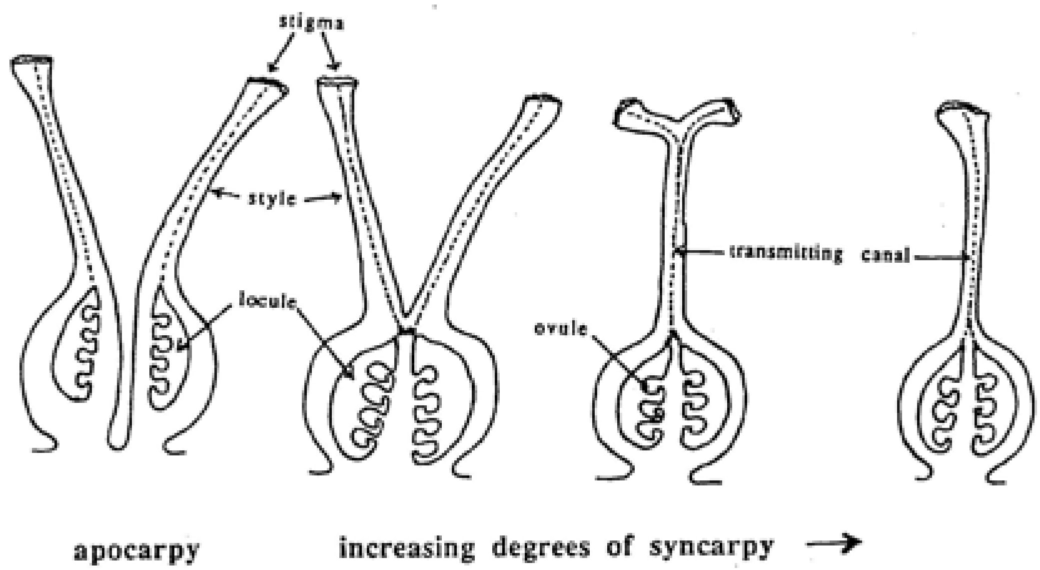


Figure 2.4: Carpels in basal angiosperm lineages and one hypothesis for the evolution of syncarpy

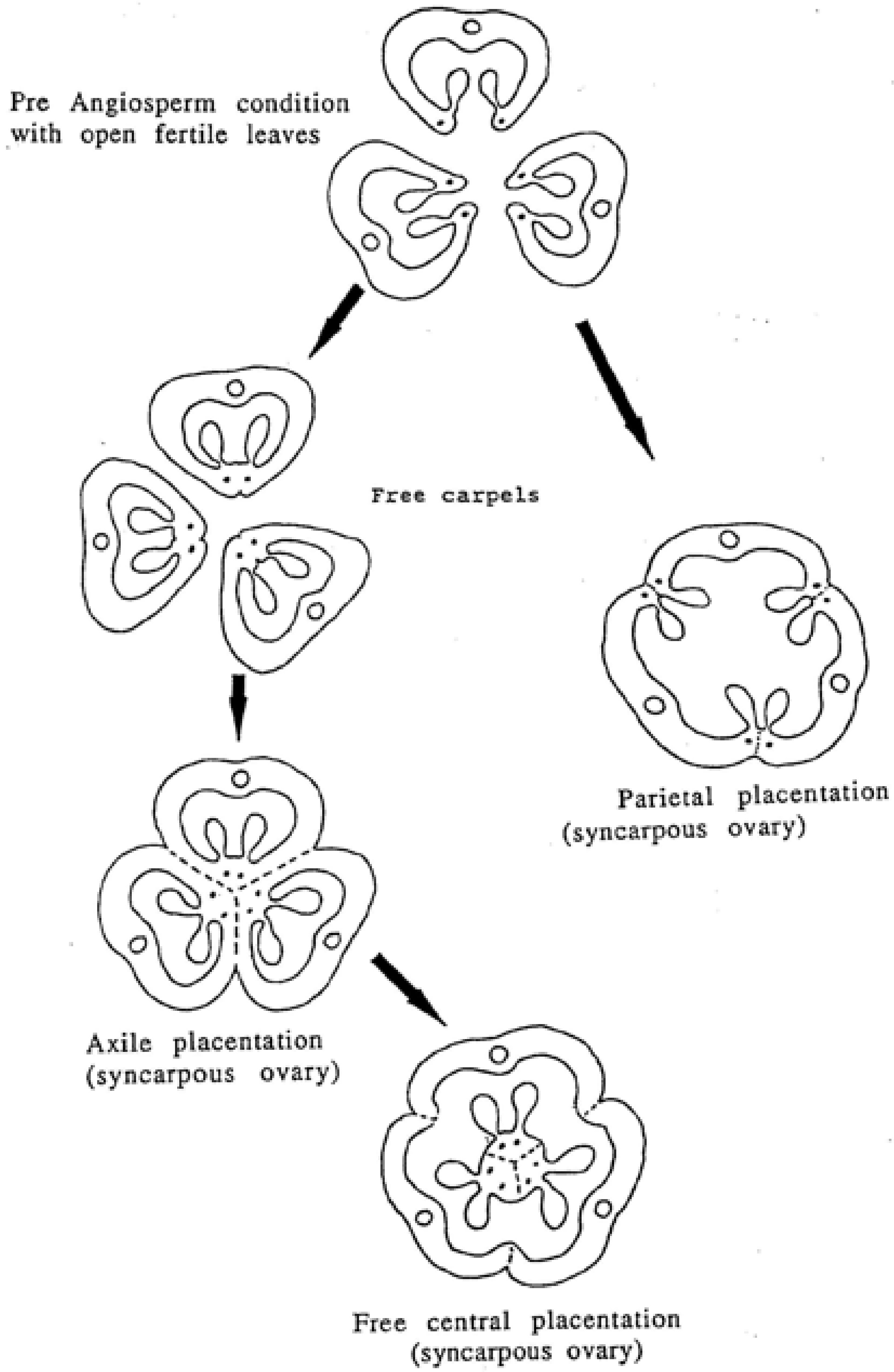


Figure 2.5: Evolution of different types of placentation in the ovary of angiosperms by different patterns of carpel fusion

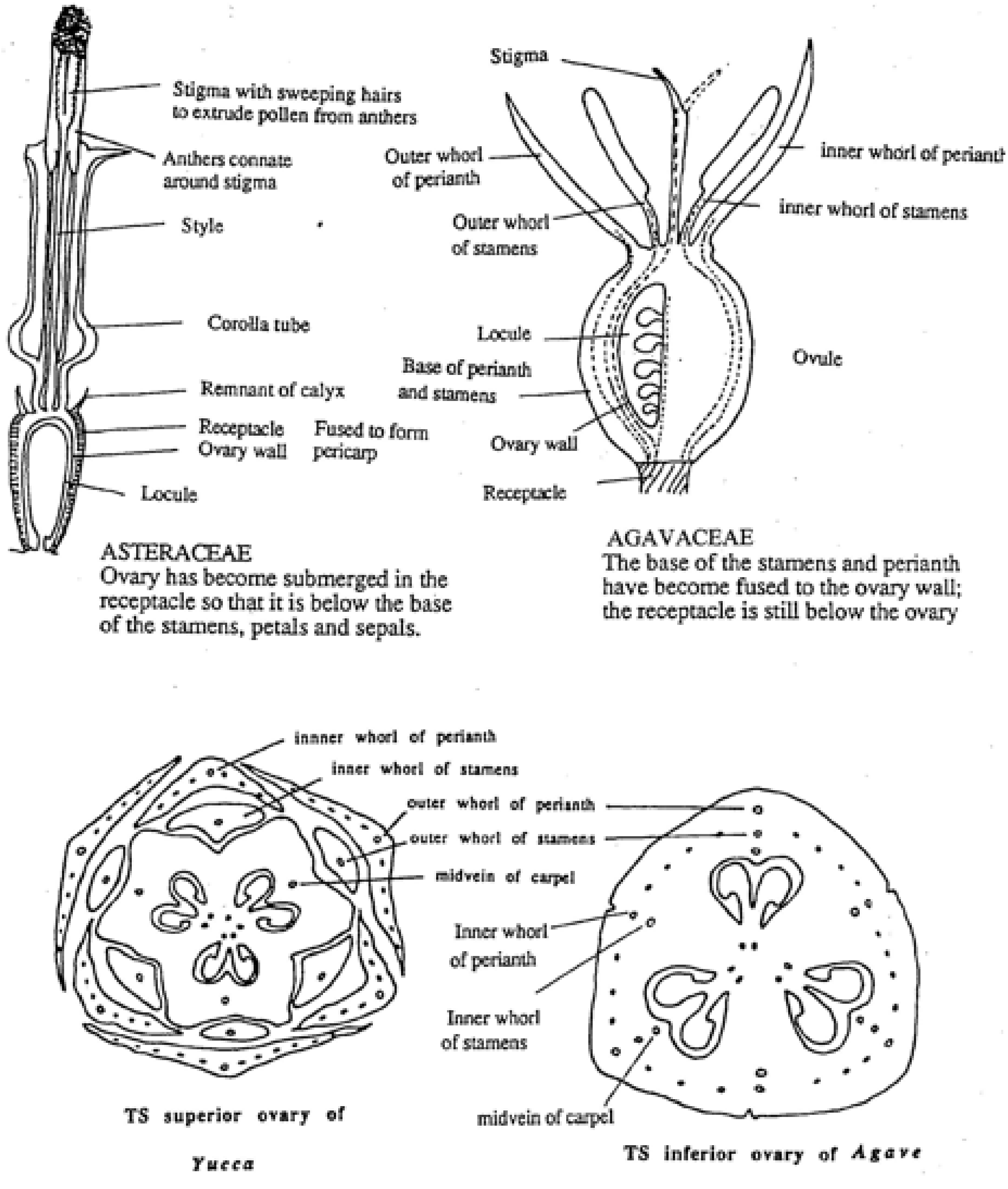


Figure 2.6: Vertical sections of flowers indicating two different ways in which an inferior ovary may have evolved. The lower row shows sections of the ovary of two related species, both members of the Agavaceae. In *Agave*, the vascular traces to the whorls of perianth and stamens can be identified in the outer layers of the ovary tissue.

Inflorescences

Species in which the flowers arise singly in the axil of leaves on ordinary vegetative branches are usually considered to have the primitive flower arrangement. Mostly, specialised flowering branches called inflorescences are produced. There is considerable variation in the pattern in which flowers are borne on inflorescences. The more an inflorescence differs from an ordinary vegetative branch, the more highly evolved it is usually considered.

- The inflorescence on *specimen A* is said to be *anthotelic* (ending in a flower), because the growing apex of the inflorescence axis is used up to form a flower, and subsequent growth is from lateral branches. The pattern of branching and the length of the internodes within the inflorescence are used to define sub-types (see figures). Which sub-type of the anthotelic inflorescence is this?
- *Specimen B* has a *blastotelic* inflorescence (ending in a branch or vegetative bud). The apical bud of the inflorescence axis is not used to form a flower, and so the inflorescence is potentially indeterminate: ie. it could continue to grow indefinitely. Hence these inflorescences often do not have such a precisely defined size as anthotelic ones. When the axis of the inflorescence reverts back to vegetative growth at the end of the flowering season, the inflorescence becomes *intercalary* rather than *terminal* on the plant (ie. within a branch, rather than on the end of a branch). Which of the sub-types of the blastotelic inflorescence is this (see figures)?
- A mixture of branching patterns may occur within the one inflorescence. These are described in order of branching eg. a raceme of cymes - the cyme is the terminal form (see figures). Describe the inflorescence in specimens *C, D* and *E.* Record each in the form of a line diagram, as in Fig 3.9. Note carefully whether the flowers are sessile or have a peduncle.

Diversity of floral traits

Examine the floral structure of the specimen provided.

Perianth.

- How many whorls of perianth are present? If there is more than one whorl, do they alternate in position as in Fig 3.1? Are they differentiated into calyx (sepals) and corolla (petals)?

- How many parts are present in each whorl?

- Are the petals free from the base or are they fused into a tube? Do they arise from the base of the ovary or from above the ovary? Is the ovary **superior** or **inferior** (see figures)? Would you describe the flower as hypogynous, epigynous or perigynous?

Androecium - the male part of the flower comprising one or more stamens, each with an anther and filament

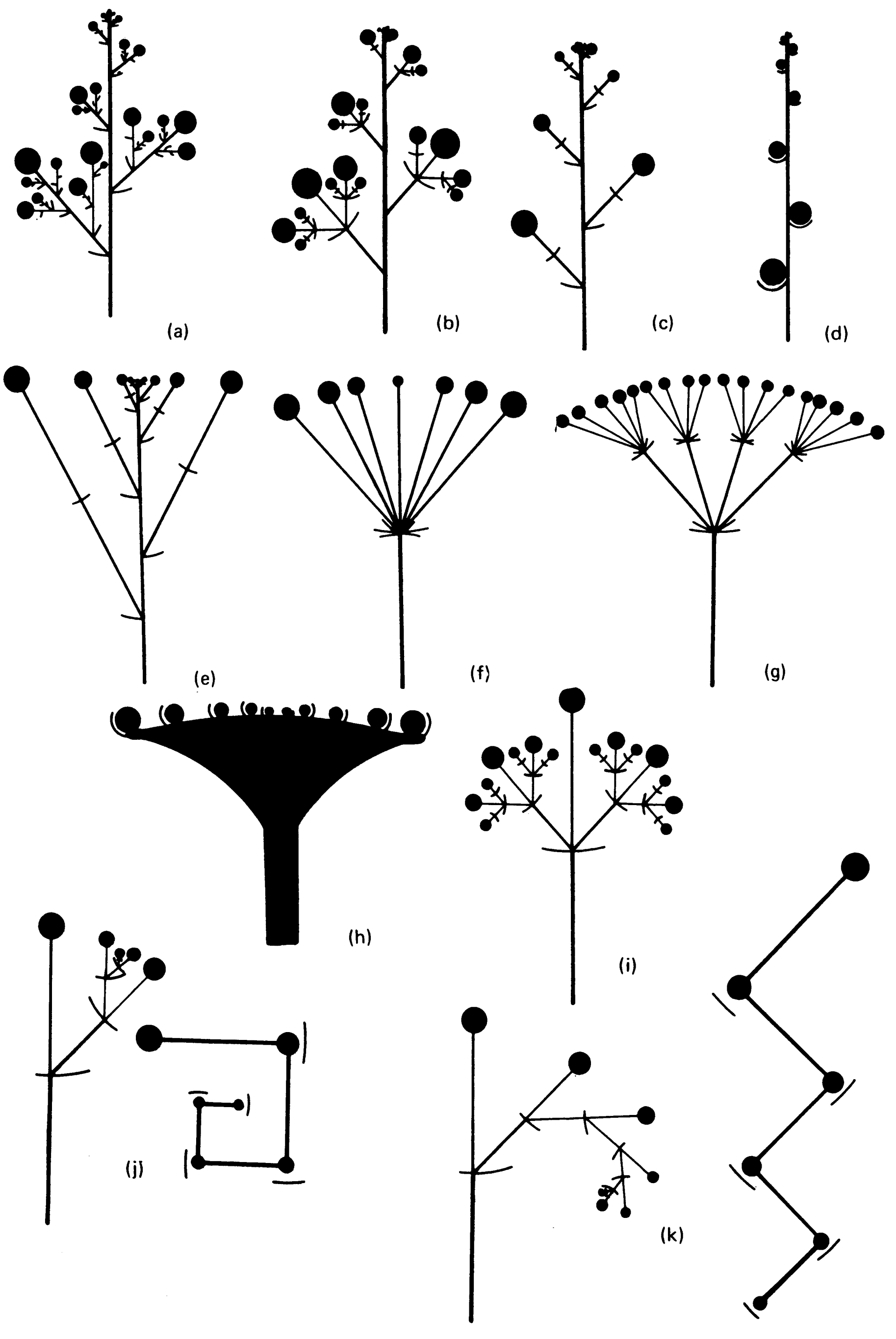


Fig. 4 Inflorescences. (a) Panicle (b) Thyrse (c) Raceme (d) Spike (e) Corymb (f) Simple Umbel (g) Compound Umbel (h) Capitulum (Head) (i) Dichasium (j) Monochasium—bostryx (k) Monochasium—cincinnus.

Figure 2.7: Types of inflorescences. The sequence in which the flowers open is indicated by size of the circles representing the flowers; largest opens first, smallest opens last. Figure from N.C.W. Beadle, O.D. Evans & R.C. Carolin (1982) Flora of The Sydney Region. Reed, Sydney.

- Does the number of stamens relate readily to the number in each perianth whorl, or is it very large and variable from flower to flower? Can you determine a constant number of stamens for the flower?

- Do the stamens arise from a rim-like extension of the receptacle at the top of the ovary by individual stalks, from the top of a staminal tube formed by fusion of the stalks (see figures), or from some distance up on the inner surface of the petals? The stamens may appear to be all on the one whorl, but often we can distinguish inner and outer whorls by their position in relation to the petals (see Figures).

Symmetry. Study the symmetry of the flower from above.

- Is there more than one axis of symmetry? Are the parts of each whorl all of the same size? What type of symmetry is shown: **radial** or **bilateral**?

Gynoecium - the female part of the flower comprising one or more carpels, each with an ovary, style and stima. Note the single style arising in the centre of the flower. The structure of the ovary is often seen more clearly in developing fruits. Cut the ovary transversely with a razor blade and examine the cut surface with a hand lens. Make certain you have cut through the centre of the ovary, and not above or below it. You should be able to see several ovule-containing regions (**locules**) separated by thin radial walls. The ovules will appear to radiate from the **placenta**. Otherwise, if you gently squeeze the ovary, the ovules will pop up from the surface, but some will remain attached to the placenta. Is the placenta on the outer wall or at the centre of the ovary? How many locules and placentas are there? Use this information to determine the number of carpels in the gynoecium.

- Is the flower **apocarpous** or **syncarpous** (see figures)? Which term in that figure describes the placentation?

Now determine the position of the locules in relation to the other parts in the flower. Does the centre of each locule lie opposite a sepal or in between two sepals (ie., opposite a petal)? Note the pattern of alternating whorls of floral parts (sepals, petals, stamens and carpels).

Floral diagram. Draw enough concentric circles for the whorls of perianth and stamens, making the diameter of the inner one at least 4 cm so as to leave plenty of room in the centre to draw in the gynoecium later. Draw in the perianth on the outer whorls, following the most appropriate example in the flower figure.

Draw in the stamens as lobed anthers (to distinguish them from sterile **staminodes**; see figures), making certain to position each stamen correctly with respect to the perianth members. If the stamens are fused with the perianth, join the anther to the appropriate perianth part (inner or outer) by a straight line (see figures).

Draw the gynoecium in the centre of your floral diagram. Use **two lines,** one for the outer wall of the ovary and another for the walls that divide the locules. Show some ovules attached to the placenta in each locule of the ovary (see figures).

- Cut a second flower of the specimen vertically along a diameter that divides the flower symmetrically. Note how the ovary is positioned in the flower with respect to the receptacle and point of attachment of the stamens, etc. Would you describe the flower as **hypogynous**, **perigynous** or **epigynous** (see figures)?

- Now summarize the floral structure in a floral formula.

Identifying unknown plants

The following summarises the way you should proceed to identify any unknown specimen. First determine if the plant is a monocotyledon or a dicotyledon. If the specimen is a monocotyledon, have a closer look if it has modified/reduced flowers and/or spikelets, go to the family key to determine if it belongs to **CYPERACEAE** or not. If the specimen has well developed flowers, use the full family key for monocotyledons to determine in which family the specimen belongs.

If the specimen is a dicotyledon, first check whether it belongs to one of the major families or subfamilies you should recognise. Only if it does not belong to one of these families should you use the key to families. Otherwise, go direct to the key to genera in the family you have recognised.

- Hold a leaf up to the light and examine with a X10 lens for the presence of translucent oil glands.
  - If oil glands are present the specimen belongs to... **MYRTACEAE** or **RUTACEAE**
  - If the ovary is superior, it belongs to.................................. **RUTACEAE**
  - If the ovary is inferior, it belongs to................................**MYRTACEAE**

  If the leaves are compound, it must be a member of Rutaceae. Simple leaves occur in both families.

If there are no oil glands in the leaves, then continue through this key.

- Examine the inflorescence. Is it a capitulum? That is, does it consist of many small tubular flowers without sepals, but the whole cluster surrounded by numerous bracts resembling sepals.
  - If so, it belongs to.. **ASTERACEAE**.

  Check that the ovary is inferior, the corolla is tubular, and the anthers are connate and epipetalous to confirm the identification.

If the inflorescence is not a capitulum, then -

- Are the flowers in dense heads without an involucre of surrounding bracts? Are the stamens the main display of the flowers? Does the plant have bipinnate leaves or phyllodes? Look for the marginal gland. Is the fruit a legume or pod?
  - If "yes" is the answer to all these questions, the specimen belongs in........**MIMOSOIDEAE.**

If these features are not present, then -

- Examine a flower externally. Are both sepals and petals present or is there only one perianth whorl?
  - If there is a single perianth whorl of 4 parts, it is........**PROTEACEAE**.

  Check that there are 4 stamens opposite the perianth parts to confirm the identification.

If this does not apply, then -

- Is the flower radially symmetric and does it have a tubular corolla?
- If so, are there small bracts resembling sepals below the calyx?
  - If so, it belongs to...................................... **ERICACEAE**.

  Check leaf venation and for epipetalous stamens to confirm the identification.

- If the flowers are zygomorphic, do they have a 'standard', a 'keel' and 2 'wings'? Is the fruit is a legume or pod developed from a superior ovary?
  - If so, the specimen belongs in the ....**FABOIDEAE**.

  Compound leaves and stipules are common in this subfamily.

If none of these features apply, then go to the family key.

Get used to using these key characters to recognise the large Australian dicotyledon families. This skill will be tested in the practical exam. It will frequently enable you to avoid having to wade through the family key because you can go directly to the generic key in that family.

Introduction to the use of the Key to Plant Families

Use The key to some Australian Plant families found at the end of the lab manual to identify the specimen supplied to family level.

First, examine the flower and construct a floral formula for it. Drawing a floral diagram or a vertical cross-sectional diagram may help. Check this with a demonstrator, so that you are sure you have interpreted the flower correctly, **before proceeding to the key.**

It is essential to read **both** alternatives carefully before deciding which one fits the specimen. Check every unfamiliar term in the *Glossary* at the back of this book. At each stage, one alternative must fit the specimen. If neither is correct, you must have made a mistake in an earlier choice, so check each preceding choice.

Always proceed **downwards** in the key. Chose the correct alternative of a pair and then go to the **next pair below the correct one**. Proceed until the chosen alternative is linked to the name of a family.

When you have a family name for the specimen, check with a demonstrator

If time permits, identify one of the other specimens provided.

You should practice using this key whenever you have an opportunity. It is a valuable botanical skill and **the use of such keys *will* be tested in this course**.

Plant Identification and Family Descriptions

We will examine the key traits and features of some of the **major Australian plant families** throughout this course.

Chapter 3

Week 4: Important Plant Families in Australia and the World

There are >300,000 Angiosperms and >350,000 vascular plants, so we use families as the filing cabinet to put all this diversity in. There are 416 flowering plant families by the most recent assessment (Angiosperm Phylogeny Group IV 2015). Most working botanists will know around 100 of these families. (Not all families are present everywhere.) In this class we'll teach your first 10 families. We will split one of these into two sub-families that look very different. Some are important in the Australian flora, and others are on the global scale and especially for agriculture.

The important concept to consider first is that some traits are variable within some families, but good diagnostic characters for other families. So the key traits for different families are different. Moreover it's the particular combination of traits that makes an family identification accurate.
Categories of traits that help were covered in detail in the previous two labs, so there are not new terms to learn today, but use this opportunity to review those terms. The terms also are crucial for working your way through plant ID keys.

Start filling out the trait data for the families below by looking at the specimens. There is also details for many of these families are provided in the back of the lab manual (Plant Identification and Family Descriptions, and the Key to Australian Plant Families). As throughout this course, feel free also use the abundant plant resources on the web for Australian and global families (see links on Moodle). The key skill in this course is connecting the plants you see in front of you to resource material.

One note about names: modern botanical rules state that families should be named after a "type" genus and end in "-aceae". (Animal families end in -idae.) That is the Proteaceae is named for the "type" genus Protea (which is found in South Africa and florist shops). Because this was the first genus of the family it becomes the type genus. Before these names were introduced there was a bit more chaos in naming of plant families. (And there are still a few hold-outs around that want to stick to old names.) We've included the old names below as some of the reference books and field guides still use the old names.

Table 3.1: Proportion of Australian species within each of the major families.

Family	Percent of the Australian Flora	Percent of the World flora
Fabaceae	12.0	7.0
Myrtaceae	9.3	1.7
Asteraceae	8.0	9.4
Poaceae	6.5	3.3
Proteaceae	5.6	0.3

Figure 3.1: A notable Australian genus

Myrtaceae

How will you recognize members of this family?

Example species

Rutaceae

How will you recognize members of this family?

Example species

Fabaceae sub-family: Faboidea aka Papilionaceae

How will you recognize members of this family?

Example species

Fabaceae sub-family: Mimosoideae

How will you recognize members of this family?

Example species

Proteaceae

How will you recognize members of this family?

Example species

Ericaceae aka Epacridaceae

How will you recognize members of this family?

Example species

Poaceae aka Gramineae

How will you recognize members of this family?

Example species

Brassicaceae aka Cruciferae

How will you recognize members of this family?

Example species

Apiacеae aka Umbelliferae

How will you recognize members of this family?

Example species

Asteraceae aka Compositae

How will you recognize members of this family?

Example species

Chapter 4

Week 5: Flowering Plant Diversity

In this lab, we will be examining the history of plant diversity. *Phylogenetics* is the study of diversity through time. In this lab we will do a practical introduction to the basics of phylogenetics and how it relates to what we've been studying this term.

First some history: seed plants are about 375 Million years old (Silvestro et al. 2015). The age of angiosperms is a subject of much recent debate but probably the most recent common ancestor of all angiosperms lived between 150 and 200 million years (Stephens 2001).

The following paragraph is an excerpt from an influential paper (Davies et al. 2004):

> Charles Darwin described the rapid rise and diversification within the angiosperms as an abominable mystery. Angiosperms are regarded as one of the greatest terrestrial radiations of recent geological times. The major lineages originated 130-90 million years ago (mya), followed by a dramatic rise to ecological dominance 100-70 mya. Approximately 250000 extant species have been recognised, although estimates vary, and the final number might be double this. Within the group, sister clades can differ in species richness over several orders of magnitude. Darwin attempted to identify a single causal explanation for the rapid diversification of angiosperms but described his own efforts as wretchedly poor.

Through recent research, we have come a long way in understanding the evolutionary relationship among orders and families of flowering plants. The figure shows a phylogeny of flowering plants (a tree showing how flowering plant orders are related to one another).

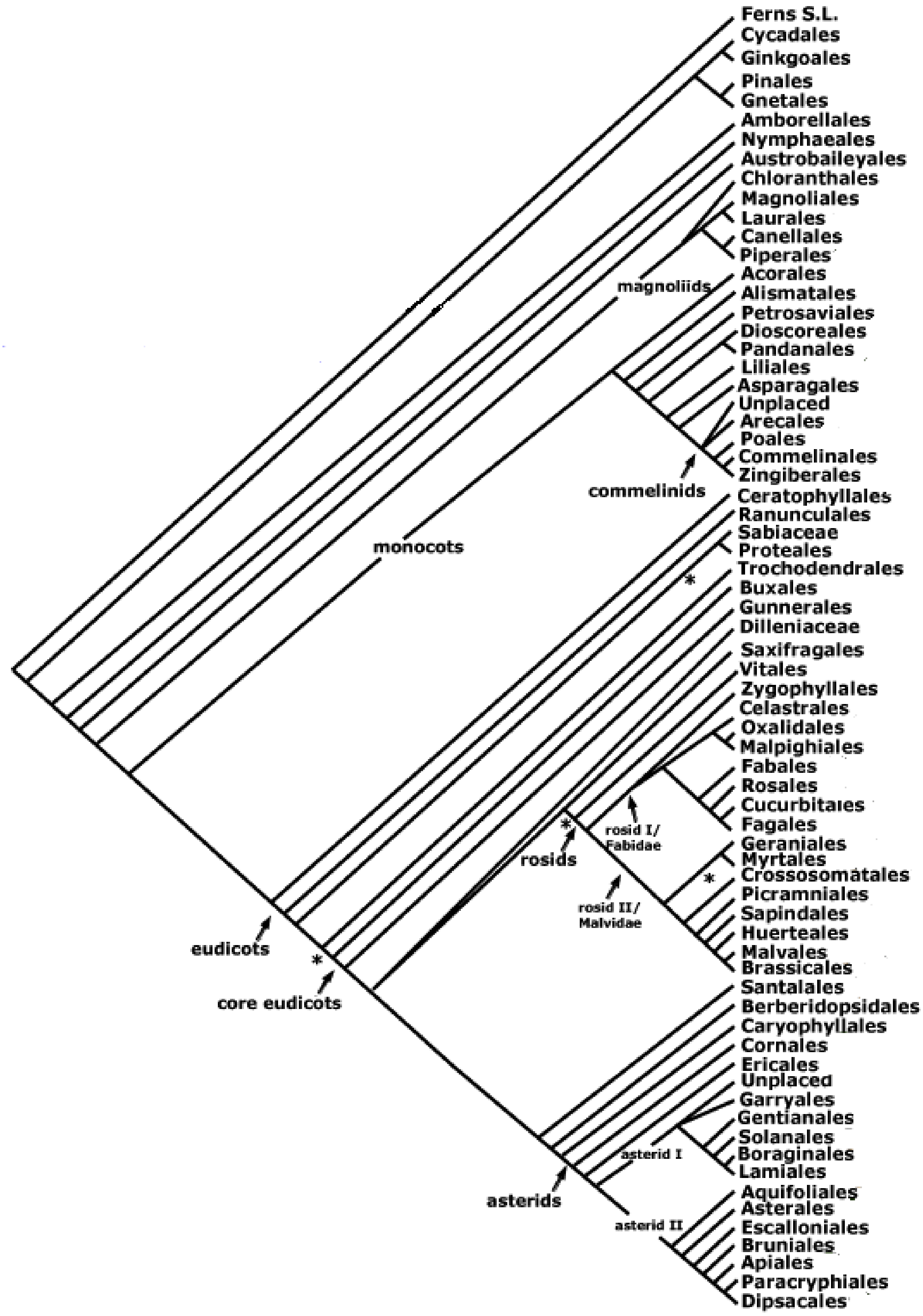


Figure 4.1: The evolutionary relationships among the orders of vascular plants. From http://www.mobot.org/MOBOT/research/APweb/

Make sure you know the key terms:

1. **Most recent common ancester**
2. **Clade** (a group of organisms that contains all descendents from a common evolutionary ancestor; **taxon** (plural: taxa) is a synonym of clade)
3. **Speciation rate** (units of number of species per million years)
4. **Extinction rate** (units of number of species per million years)
5. **Net diversification rate** (units of number of species gained or lost per million years)
6. **Sister group**–Sister groups or "sister taxa" are just what they sound like–two groups the diverged from each other, with each being the other's closest relative. Gymnosperms are angiosperms closest relative and vice versa. The ferns are sister to the seed plants. Fagales (the oak order) and Cucurbitales (the cucumber order) are sister groups. However, this gets more complicated as some taxa do not have accepted names. Rosales is sister to Cucurbitales + Fagales, which is a group that does not have its own name.
7. **Monophyletic** a group of organisms that contains all descendents from a common evolutionary ancestor; primates is one example of a monophyletic group that contains *you*. If a plant family is found not to be monophyletic, taxonomists break it up to try to create monophyletic plant families. This is usually why taxonomy changes through time. For example the *Acacia* species in Australia and the *Acacia* species in Africa are not monophyletic and taxonomists are currently in the process of breaking them up into two different genera.
8. **Paraphyletic** (hard to explain in words see figure)
9. **Family** in plants these all end in -*aceae*; every family is in an order; in plants families *usually* have diagnostic features
10. **Order** in plants these end in -*ales*; unlike families orders are so internally diverse that there are usually not diagnostic features

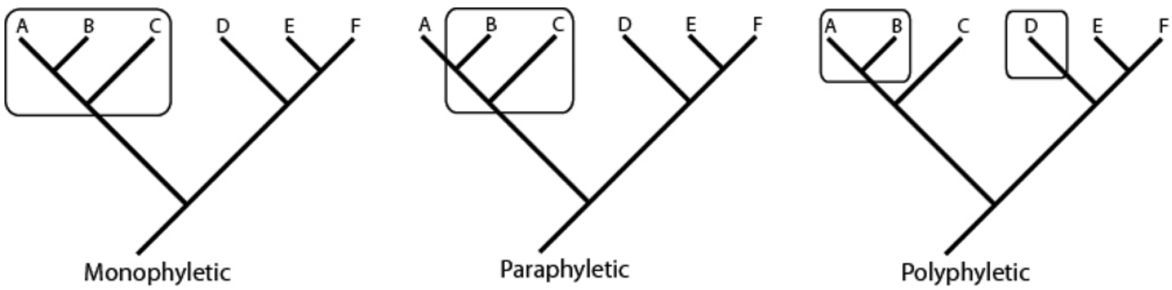


Figure 4.2: A way to talk about phylogenies

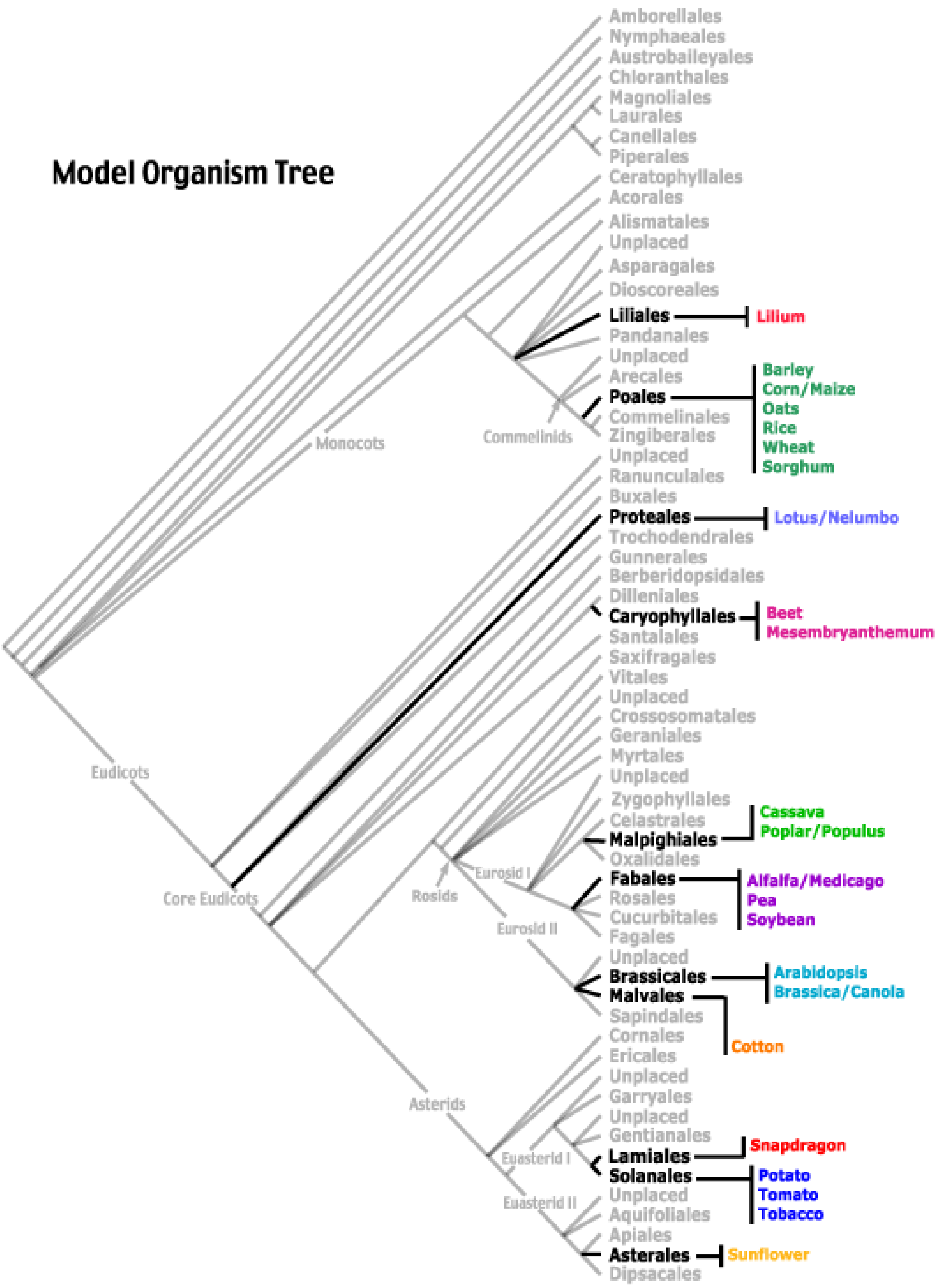


Figure 4.3: Here is a phylogeny with the model organisms (usually food plants) highlighted

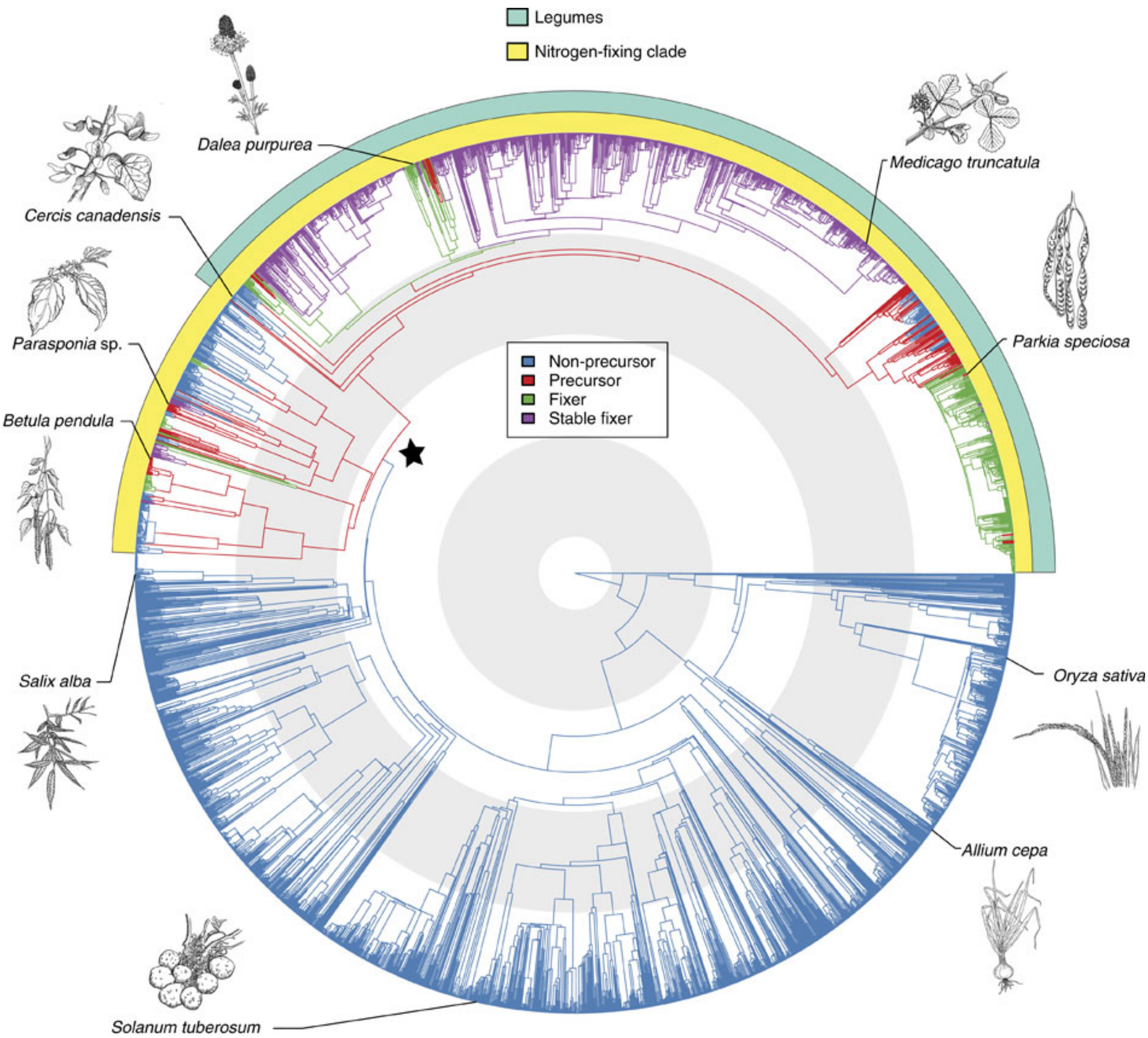


Figure 4.4: Here is another phylogeny of the angiosperms with specific species at the tips highlighted. The grey doughnuts each represent 50 Million Years so you can see the scale of plant evolution. Phylogeny from Werner, Cornwell et al. 2014.

Phylogenies can be in different units

There are three key types, so learn to check this when you "read" a tree:

1. No units at all. These are commonly used just to show the shape (ie branching structure) of a tree. The model organism tree above is like this.
2. Time. These are called time-trees and have units of (millions of) years. The Werner et al. tree above is a time-tree. These are almost always "dated" fixed to certain dates using information from fossils.
3. Molecular evolution. In these tree the units are derived directly from the number of changes in the organisms genes. The Smith et al. 2008 trees are an example.

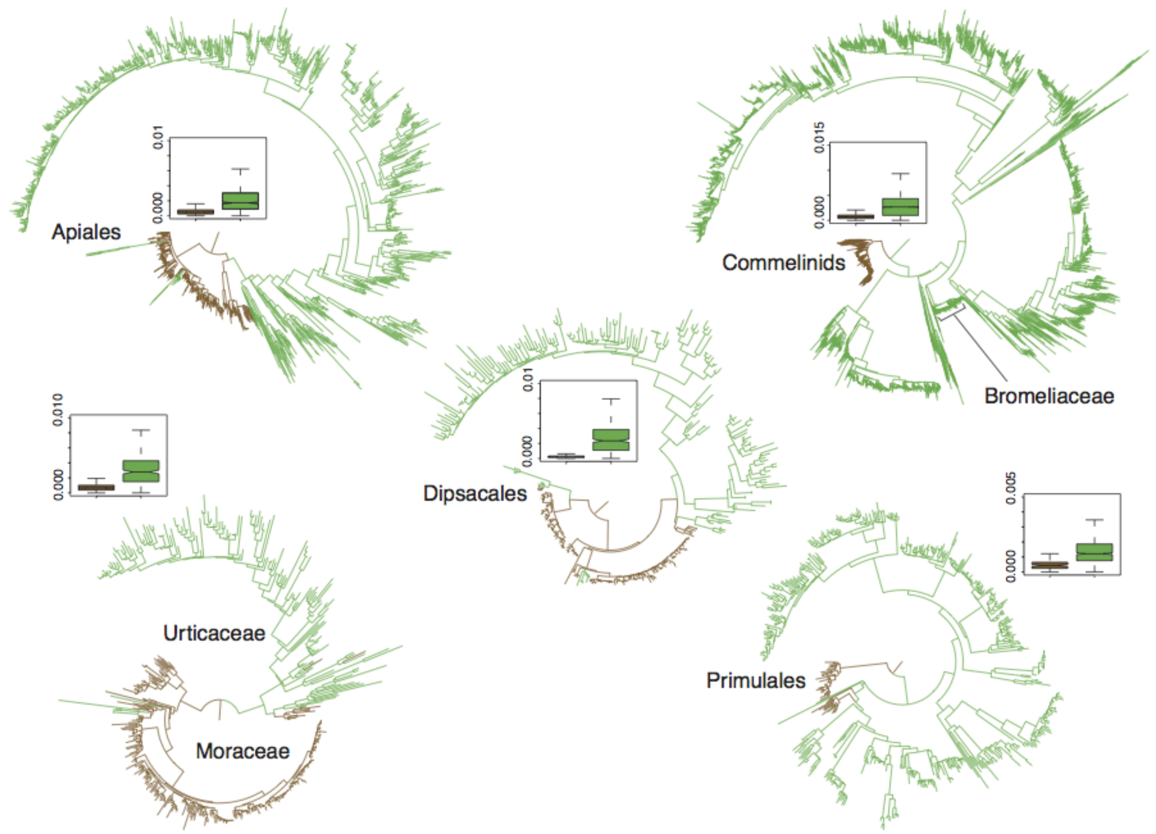


Figure 4.5: Smith et al. 2008 trees

Branching structures represent the flow of more than just evolution. Any idea or design concept often can be represented using a tree. Here is a fun example, note that it is also a time-tree, that is the y-axis is in units of years:

Three key web resources that curate data on flowering plant diversity:

The Atlas of Living Australia: (http://www.ala.org.au/)

and

The Angiosperm Phylogeny Website: (http://www.mobot.org/MOBOT/research/APweb/)

and

The Plant List: (http://www.theplantlist.org/)

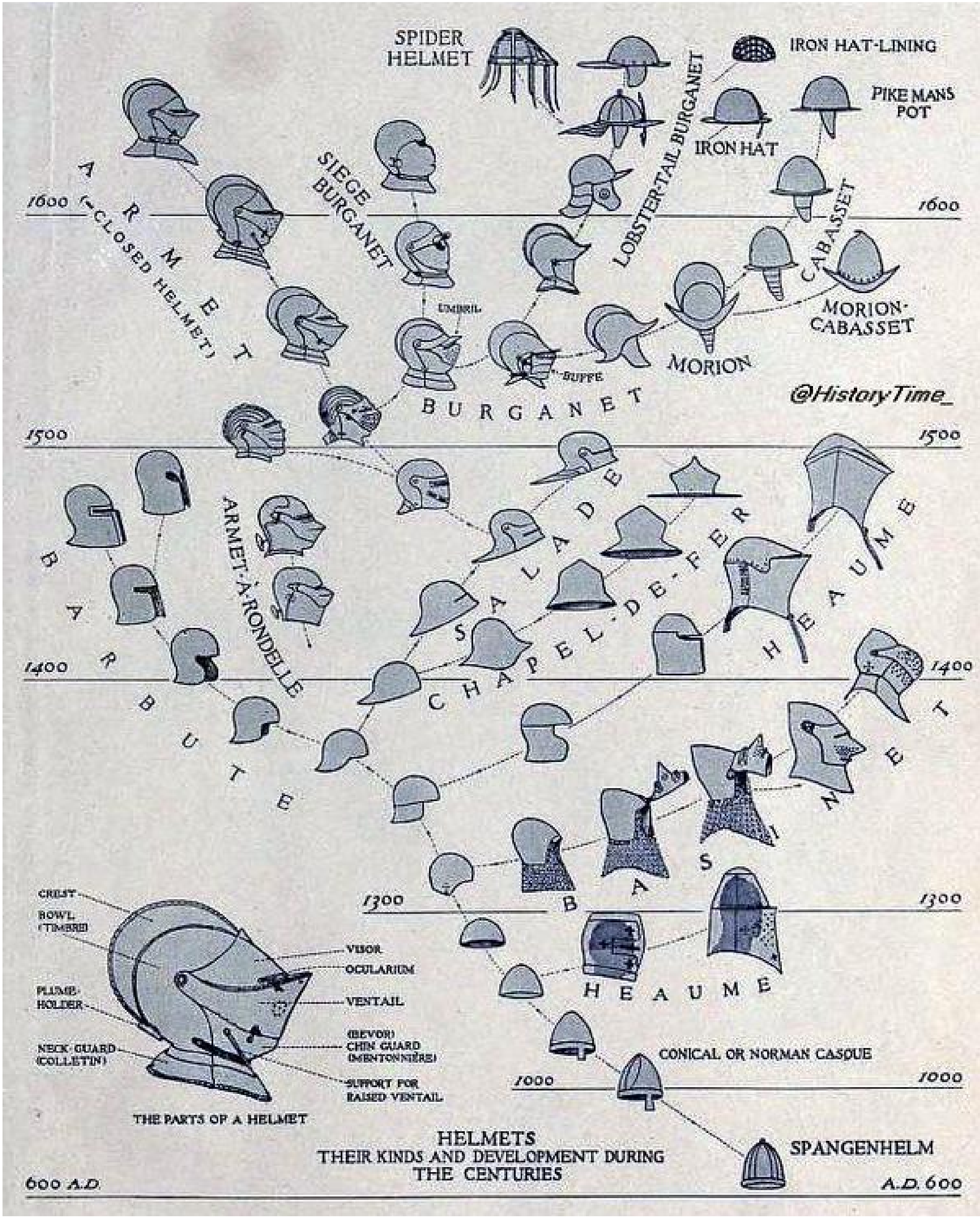


Figure 4.6: Medieval helmet designs changing through time

You will now use these two web resources (and anything else you can find on the web) to build a powerpoint slideshow (4-6 slides!).

Make sure to cite the source for all data in your slideshow

Here are the steps to producing this slideshow:

1. Find one native plant species that is found close to somewhere you know well, e.g. your home. Pick a species that you like, since you'll proceed to do some research on it. Everyone should pick a different species. Don't pick the same one as your neighbor. (Include in the slideshow the latitude and longitude of the species observation from ALA).
2. Which state(s) is this species found in (check ALA)?
3. Which family is this species in?
4. Write down the traits of the flower (or plant) that would allow you to tell that the plant is in this family.
5. Which order is this species in?
6. The number of species in this genus in the world (check the plant list).
7. The number of species in this genus in Australia.
8. The number of species in this family in the world. (Is this family relatively diverse or species poor? Is this number of species relatively high or low?)
9. The number of species in this family in Australia. (Is this family relatively diverse or species poor? Is this number of species relatively high or low?)
10. The sister family(s) of your plant's family (check the phylogenies on APWeb).
11. Modeled on the pictures of phylogenies in the lab, draw a phylogeny (with lines in powerpoint or whatever drawing program you like) that contains your plant species, *Zea mays*, *Solanum tuberosum*, *Eucalyptus regnans*, *Pisum sativum*, and *Pinus radiata*. (Remember phylogenies don't have to contain all the species–it's OK to draw a phylogeny of just a few to show the relationships among those 6 species.)
12. Place picture of each plant at the "tip" of the phylogeny (ALA or google image)
13. Remember a phylogeny is a representation of history. How long ago was the most recent common ancester of all the species in your phylogeny? Place a rough scale bar (in millions of years) on your phylogeny (hint: look for dates/ages on APWeb)
14. Calculate the net diversification rate for your species' family. This is the total number of species in the family (get the number of "accepted" species from the plant list) divided by the age of the family.

Upload your slideshow on moodle

Chapter 5

Week 6: How to be a tree

This week's class is incredibly important – understanding how plants actually grow (and no, it's not like what you see in the movies!).

We need colour pictures to fully capture tissue types, so we will give you a hand out in class that explains this week's material.

This week we do sectioning and staining and we will use the compound microscope for the first time, and this is a rather complicated piece of equipment. These are important practical skills for botany specifically and biology in general. Read the following instructions before you start the practical work in the lab.

Sectioning and Staining

Plant structure is studied most often by cutting thin sections of the plant and examining them stained or unstained with the light microscope. The plant material to be sectioned may be living or 'fixed', which means that the material has been treated with a carefully chosen chemical that gels cell proteins and preserves intracellular structure with as little distortion as possible of the living state.

Sectioning can be done by hand with a razor blade, or by using a mechanical cutting device (a microtome) that holds the material and advances it a section-thick distance after each slice of the knife. Usually for microtome sectioning material is first impregnated with wax or plastic which is then solidified around and within the tissue to strengthen it during cutting. On hardening, a 'block' is formed with the specimen 'embedded' within a matrix of supporting material. Both tissue and embedding matrix are sectioned together and the extra support allows thinner sections to be cut, resulting in better resolution of tissue structure.

Sectioning By Hand

You will require:

1. a Petri dish or watch glass with a 0.5 cm depth of water;
2. a small paint-brush;
3. a *new* razor-blade (carefully protect its cutting edge all the time).

Hold the material with your left (or non-dextrous) hand so that the plane of cutting will be horizontal. The aim is to cut smoothly and fairly quickly producing dozens of sections from which a few are chosen: it is worth noting that it is often the incomplete sections with thin 'running-out' edges that provide the best study. The razor blade surface should be wet with one or two drops of water to prevent the newly-cut sections from drying out. When several sections mount up on the blade they are swept carefully off with the wet paint-brush into the water in the Petri dish.

Do not let the material dry out at any stage.

Staining Schedules

Place the staining solution in a watch glass. Prepare a second watch glass about 2/3 full of distilled water ready for rinsing. After staining the specimen for the appropriate time transfer it to the rinse solution. Note that staining times are usually critical, but sections can often be held in rinse water for several hours without damage.

All stains should be treated as potential carcinogens and you should take care not to stain yourself. To protect skin and clothes from accidental staining please wipe up any spills immediately.

Schedules for the stains you will use are outlined below.

Mounting Sections

Always place a cover-slip over the section before examining it under the microscope. Sections can be mounted either in water or 50% glycerol. The advantage of glycerol is that it evaporates less quickly. However, if the preparation is drying out an additional drop of mounting solution can be added easily without removing the cover-slip, by carefully touching the drop (on a needle, pencil or pipette) against the edge of the cover-slip and allowing the liquid to flow under the cover-slip.

(Plastic-embedded sections are often mounted in oil or other non-aqueous media, rather than water: this gives improved resolution.)

Staining Schedules

- *Toluidine Blue* (MULTIPLE STAIN)

Toluidine Blue is a very important dye that distinguishes lignified from unlignified walls. It is a positively charged dye which stains negative groups. Lignified walls stain blue and unlignified walls stain pink or purple. The pectin and hemicellulose fractions of the wall stain pink. Cellulose does not stain.

More detailed staining reactions are given below:

Cell Chemical Group That Staining Structure Reacts With Colour

1. cytoplasm (phosphate groups in nucleic acids) purple
2. nucleus (phosphate groups in DNA) blue
3. cell walls (COOH groups in some unlignified carbohydrates e.g. pectin) pink
4. lignified walls (phenols) green to blue (turquoise blue)
5. some vacuoles (phenols) deep dark blue

Staining Schedule

1. Wash section in distilled water (5 min.).
2. Transfer to a drop of toluidine blue in a watch glass.
3. Leave until you can see differentiation of pink and blue tissue (seconds to minutes).

4. Transfer to distilled water in a second watch glass for a few seconds to wash out excess stain. Check stain. If OK, then
5. Transfer to a clean dry slide in a drop of glycerol. Cover with a clean cover-slip, lowered gently from one side to exclude air bubbles.

Safranin and Fast Green

Many prepared slides are stained with these two dyes. Safranin (red) is preferentially retained in lignified, suberized, or cutinised walls, as well as in regions rich in DNA or RNA (ie. nuclei), whereas Fast green stains protein (and, particularly, primary walls). Both stains are also fast (ie. permanent) on clothing and to a lesser extent on fingers, so should be used with care, and any spills mopped up with paper towel.

Iodine in KI (STARCH)

- Iodine stains starch grains bright purple to blue-black.
- Wash briefly in distilled water.
- Transfer section to a drop of iodine on a slide.
- Leave for 2-5 minutes.
- Blot off the stain and add a drop of glycerine.
- Cover with a cover-slip, lowered gently from one side to exclude all air bubbles.

Note: Although Iodine is widely used as a disinfectant, some people are highly allergic to it. Treat all stains with care and do not allow them to come in contact with your skin.

Light Microscopy

Olympus Microscope

Operating procedure

1. Place the microscope in a comfortable position on the bench.
2. Check that on/off switch (right hand side of base) is in the off position and the brightness control is at zero.
3. Plug in and switch on at the centre of the bench.
4. Turn on microscope lamp and increase brightness control until you can see some light coming through the condenser.
5. Make sure the 4x objective is in position.
6. Place specimen slide on stage and hold in position with stage clip. THE SPECIMEN SHOULD NEVER BE VIEWED WITHOUT A COVERSLIP.
7. Position specimen under 4x objective using mechanical stage controls.
8. Focus. Adjust brightness control if necessary.
9. Make interpupillary and diopter adjustments (see below).

10. Swing in desired objective. Re-focus.
11. Check that condenser height is optimum (should be raised above image of ground glass screen).
12. Close iris diaphragm to 2/3 (70%) of the exit pupil of objective (see below).
13. Fine focus and observe.

Correct setting up of the microscope *will be examined* in the practical examination.

How to correct interpupillary distance and diopter settings

1. Hold the knurled dovetail slides of the right and left eyepiece tubes with both hands and put the tubes together, or pull them apart laterally, whichever is required, while looking through the eyepieces with both eyes, until perfect binocular vision is obtained.
2. Rotate the tube length adjustment ring on the right eyepiece tube to match your interpupillary distance setting, which is given on the scale above and left of the right hand eyepiece.
3. Look at the image through the right hand eyepiece with your right eye and focus on the specimen with the coarse and fine adjustment knobs.
4. Next, looking at the image through the left eyepiece with your left eye rotate the tube length of this eyepiece to focus on the specimen without altering the coarse and fine adjustment knobs.

Automatic pre-focussing

This lever (inside ring of left hand focusing knob) locks the microscope at a particular coarse focus position to prevent further upward travel of the stage by means of the coarse adjustment knob. It prevents damage to objectives as a result of focusing the specimen slide up through the objective lens. It does not restrict fine focusing.

Aperture iris diaphragm

The lever on the condenser controls the aperture iris diaphragm adjustment. The iris diaphragm should be adjusted to match the numerical aperture of the objective in use in order to get the best result. However, since the image usually lacks contrast a compromise is made and the diaphragm is stopped down to about 70% of the objective numerical aperture.

Remove the eyepieces: the circle of light represents the exit pupil of the objective. Adjust the diaphragm using the condenser lever until the iris impinges on the exit pupil by about 1/3. This should always be done when objectives are changed.

Dos and don'ts

1. If lenses are dirty you may clean them, but only with either a blower brush or a fresh piece of lens tissue - NOT KLEENEX. (Xylene, alcohol or ether may be used in small amounts as a cleaning fluid.)
2. When carrying the microscope, keep it upright so that the eyepieces do not fall out. USE BOTH HANDS.
3. The tension on the coarse focus can be altered by rotating the innermost ring on the right-hand focus adjustment knob.
4. DO NOT TWIST THE TWO COARSE ADJUSTMENT KNOBS IN OPPOSITE DIRECTIONS SIMULTANEOUSLY AS THIS WILL CAUSE DAMAGE.
5. Do not spill water, oil or acid on the mechanical stage or any other part of the microscope. Oil or water between the slide and stage causes friction so that the slide will not move easily.

Calibration of the microscope and making measurements

Simple calibration calculations are usually on the board at the front of the lab.

All microscopes are equipped with a micrometer eyepiece. This contains a glass graticule with a scale engraved at the centre. It has been inserted into the eyepiece and should be visible when you look through the microscope.

The value of the micrometer eyepiece changes as the magnification changes and it should be calibrated for each objective with a stage micrometer. The stage micrometer scale is usually 1.0 mm long, subdivided into 100 X .01 mm (10 m) divisions. To calibrate the eyepiece micrometer you need to determine the number of divisions on the stage micrometer that corresponds to a chosen number of divisions of the eyepiece micrometer.

The relationship is: $M = \frac{S \times V}{E}$

M is the value (in mm or m) of *each* eyepiece micrometer unit to be determined.

V is the value of each stage micrometer unit (usually 0.01 mm).

S & E are the numbers of units on the stage and eyepiece micrometers, respectively, that correspond.

Once the value of M has been determined for a particular magnification, the eyepiece micrometer may then be used in the same way as a ruler.

The measurement is actually made by carefully lining up the two scales and counting the number of divisions in each that corresponds. The calibration should be done for each objective and the value recorded for future reference.

Botanical drawing

In this course we are not asking you to produce works of art (or imagination), but accurate representations of what you can see down the microscope. You are all capable of this - the principal requirements are practice and a sharp pencil (preferably HB).

There are two types of drawing, and *each should be accompanied by a scale:

High Power Drawing

This should be an accurate drawing of a small number of cells. It should show details of cell outline and as much internal structure as is discernable. For example, if you are drawing a cell with chloroplasts, you should draw them in the correct position to the correct size, shape and number: they should not be drawn as a vague collection of squiggles around the edge of the cell. Cell walls, if accurately represented, will rarely have breaks in them.

Thick cell walls should be represented by a double line, and thin cell walls by a single line. You can use the distance between the two “double” lines to indicate wall thickness. Each cell should be enclosed by a completed line. See these points in the example below. Note how the thick walls of the epidermis, collenchyma and fibres are separated from intercellular space.

Constructing a scale

A scale must be of a rounded-off length (eg. 10 m, 50 m, 100 m, or 0.5mm or 1mm) that readily allows the viewer to calculate the real size of the whole structure and its parts.

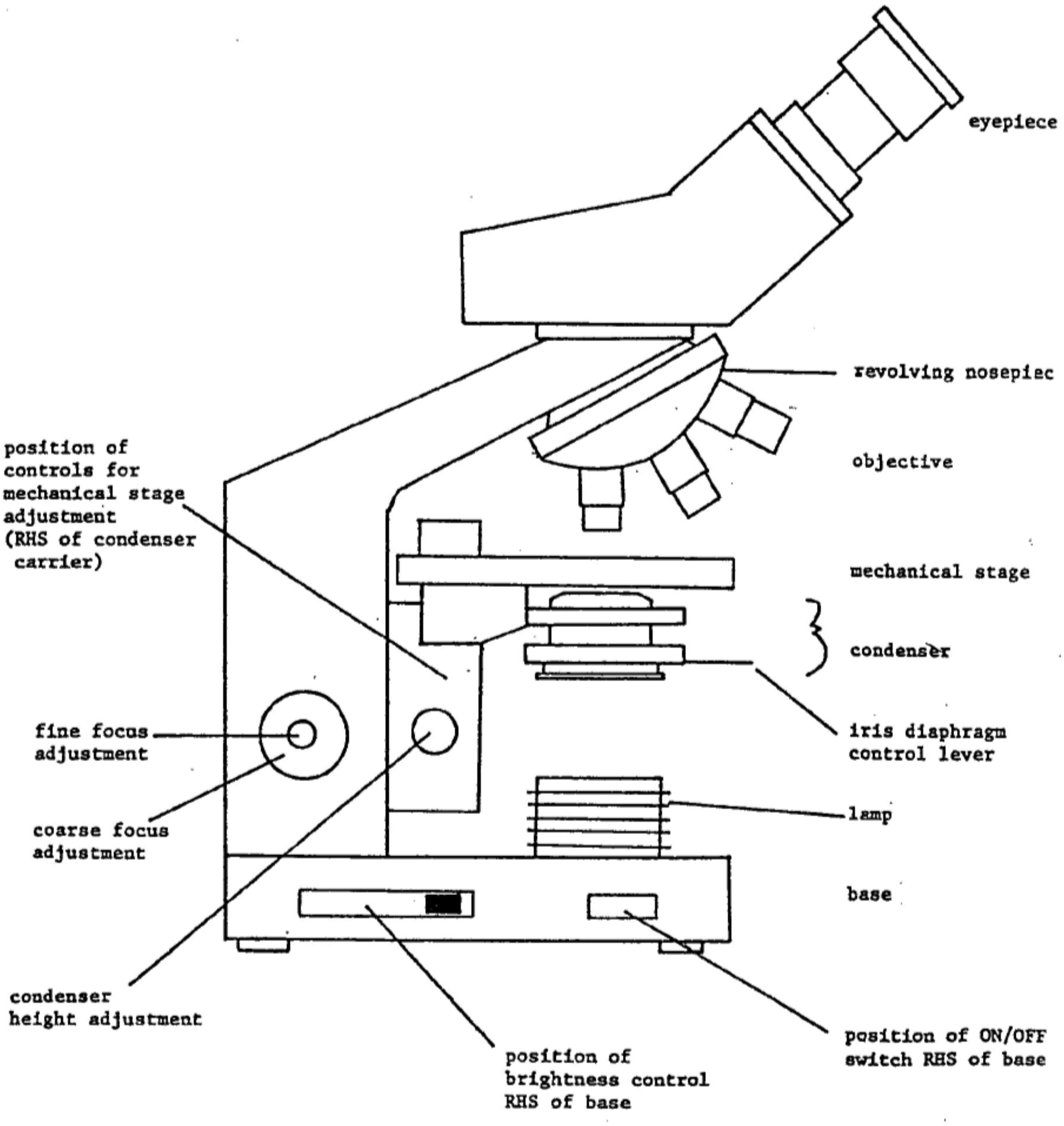


Figure 5.1: Diagram of a light microscope

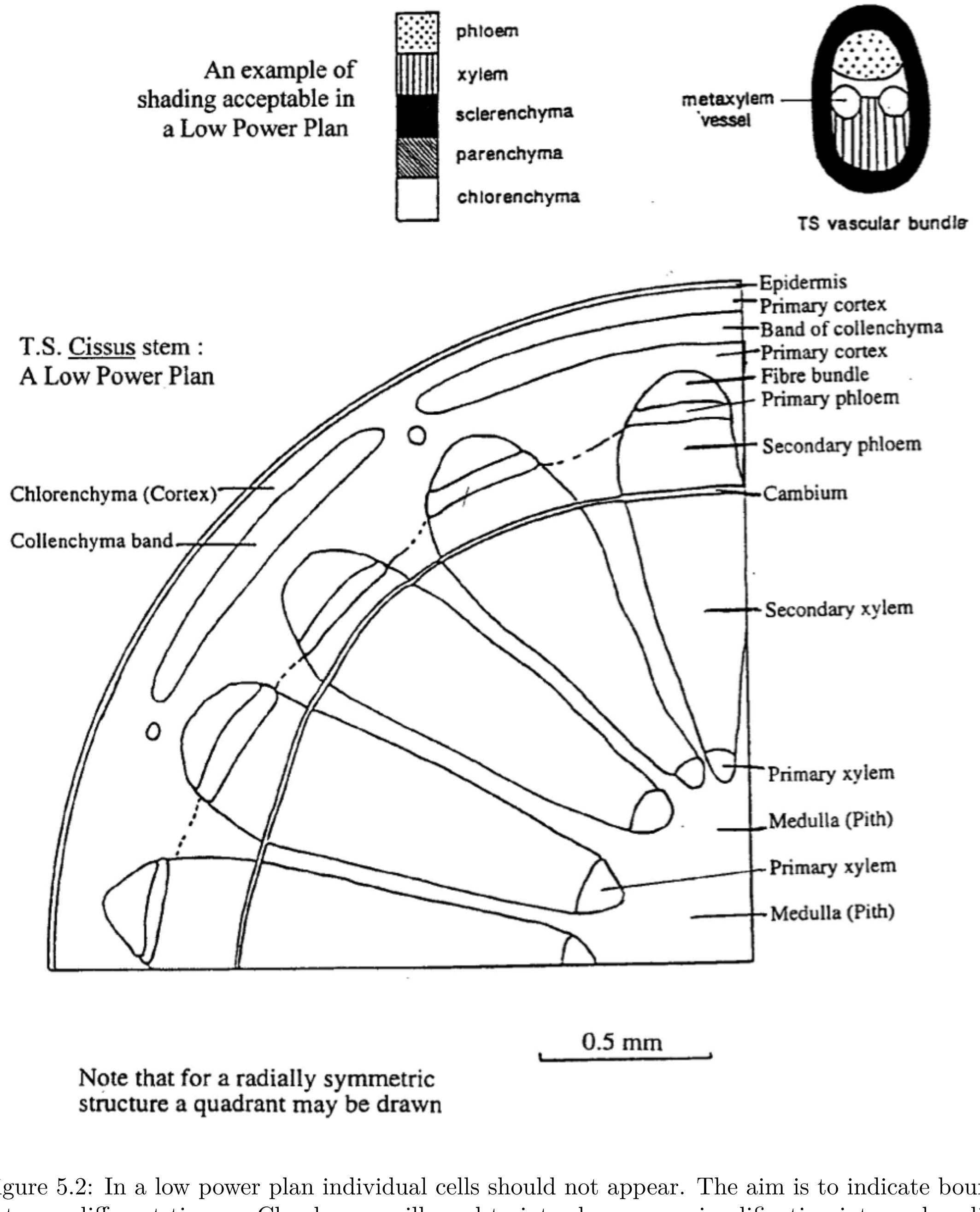


Figure 5.2: In a low power plan individual cells should not appear. The aim is to indicate boundaries between different tissues. Clearly you will need to introduce some simplification into such a diagram. For example, boundaries with many small scale convolutions may be portrayed as a straight line and diffuse boundaries by dotted lines.

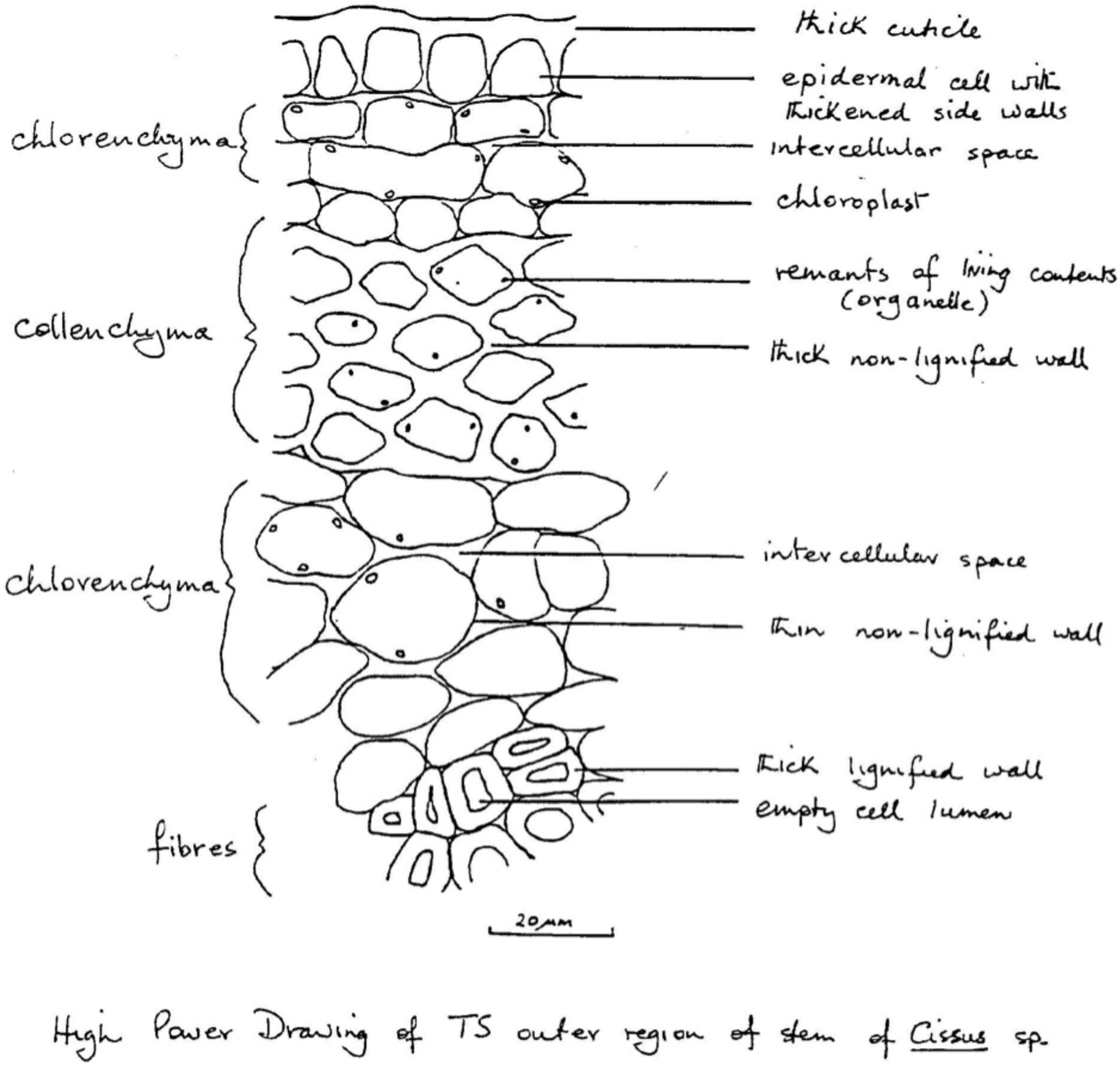


Figure 5.3: An example of a good high power drawing

STEPS:

1. Measure (on the section) an *easily recognisable part* of the drawing using the ocular micrometer eg. the radial diameter of a vascular bundle = 54 units on the X4 objective
2. Calculate the actual size: (ie. multiply occular units by the length each represents on the objective used) eg. 54 x 25 =1350 m (or 1.35mm)
3. Measure the size of *the same part* on the drawing (ie. the diameter of the same bundle) eg. 76mm
4. Since 76mm on the drawing represents 1350m on the section, what distance on the drawing equals 1mm (1000m) on the section?

1 m = *76* therefore 1000m = *76* x1000 = 55.9mm

1350 1350

5. Draw a scale line 56mm long below the drawing and label it 1mm (ie.1000m).

General points

1. Make drawings large.
2. All drawings should have a heading stating organ, species and plane of section.
3. All drawings should be in pencil. It is also highly desirable that labels should be in pencil so that corrections can be made easily and neatly.
4. Labels should appear to the side of a drawing and not be written across it. A *straight* line, and not an arrow, should connect the label to the area it refers to - the labels should be arranged in such a way that the lines do not cross. Labels should give detailed information about composition of structures where possible, based on staining reactions, eg. lignified wall.
5. It is usually not necessary to use cross-hatching or stippling to indicate particular tissue types in low power diagrams. If you must clarify your drawings by cross-hatching, make sure it is neat and does not cross the boundary line of the tissue. An example of the use of shading is given on page 12.
6. The scale of all drawings should be indicated (see instructions for constructing a scale above).
7. In labelling a drawing a certain amount of interpretation is necessary. Under some circumstances, interpretation of certain features of transverse sections may require confirmation from longitudinal sections.
8. While drawing you should be constantly altering the plane of focus of the microscope in order to clarify details. You should also be prepared to change the objective: to a higher power to help the interpretation of fine detail; to a lower power to appreciate the relationship of what you are drawing to the structure of the whole organ.
9. In this course we hope to improve your skills of observation and interpretation. In some exercises it will be left to you (with advice from your demonstrator) to decide what sections to cut, what stains to use and how to present the evidence. Drawings alone may be inadequate to record some observations; supplement by notes or tables when appropriate. It is not desirable to include too many notes in the labels.

Chapter 6

Week 7: Leaf economics

In this class, we will examine some of the evolutionary constraints that have influenced the shape and structure of angiosperm leaves.

Even casual observation of the plants around us reveals an incredible diversity of form and architecture, for example even in the leaves of quite closely-related native plants such as members of the Acacias or Banksias. What evolutionary forces have generated such diversity? Why is there not a single 'best' shape and structure for a leaf?

One way to imagine these problems is to think of alternative investment strategies. On one hand, a plant may have evolved a strategy of investing considerable amounts of organic molecules to manufacture robust leaves, resistant to physical and herbivore damage. Alternatively, another species may have evolved a 'throw-away' strategy, investing relatively little carbon in each leaf, but replacing leaves frequently.

We will examine these questions by analysing the relationship of **leaf mass per unit area**, (**LMA**, the dried weight of a leaf divided by its area) to **leaf longevity** (how long the leaves of each species last on the plant).

Exercise 1. LMA versus leaf longevity

1. Take one leaf from each of seven angiosperm species. The leaves have been pressed and dried in an oven to remove all water.
2. Measure the area of each leaf. Record in units of m^2.
3. Weigh each leaf, in grams, on the electronic balance
4. For each leaf, divide mass (g) by area (m^2) to calculate LMA ($\frac{g}{m^2}$). Put your data for each leaf on the whiteboard.
5. Plot LMA on the X-axis, against leaf longevity on the Y-axis (you can do this by hand, or using a computer).

SPECIES	Leaf lifespan (years)	LMA
Eucalyptus umbra	2.06[1]	
Syncarpia glomulifera	1.91[1]	
Acacia suaveolens	2.45[1]	
Hakea dactyloides	3.45[1]	
Lambertia formosa	2.48[1]	
Pimelia linifolia	1.06[1]	
Ocimum basilicum	0.12[2]	
Platanus × acerifolia	0.67[2]	

[1] From Wright and Westoby (2002) New Phytologist 155:403-416

[2] Pers. obs. A. Moles.

Figure 6.1: Plot LMA on the X-axis, against leaf longevity on the Y-axis

6. Why do you think the points fall where they do, and not elsewhere on the graph?

7. Would you expect deciduous species to have higher, or lower LMA than evergreen species? Why?

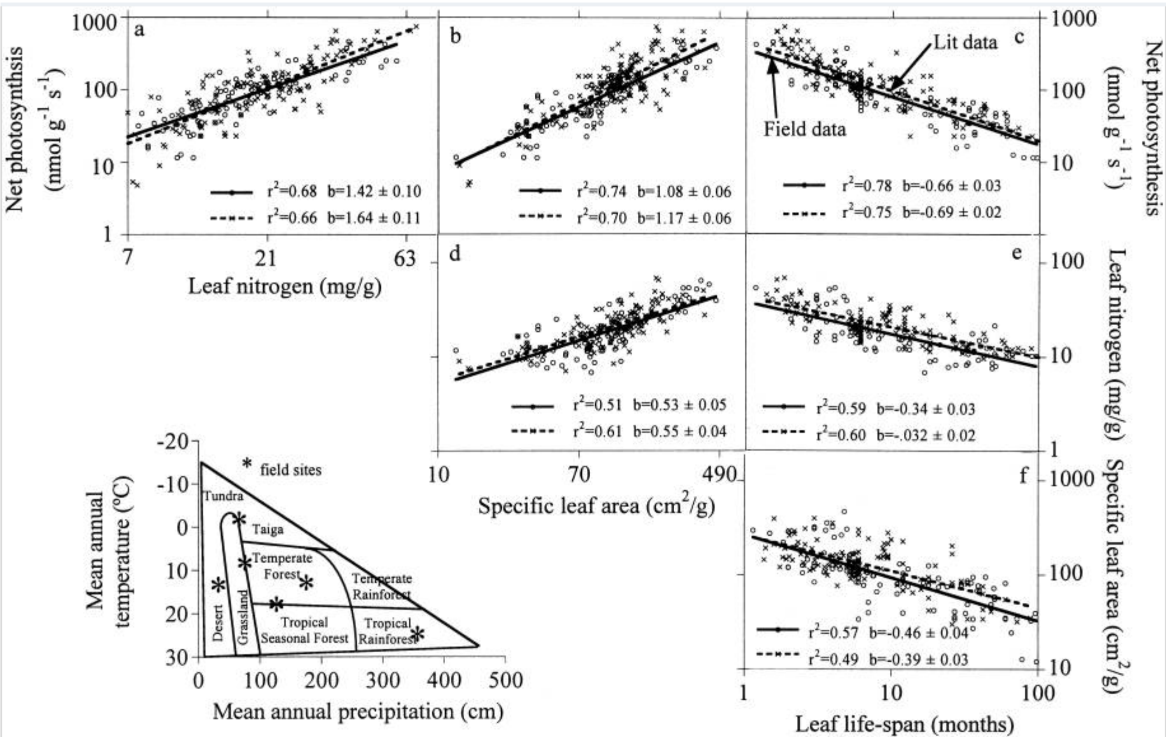


Figure 6.2: The figures below show the relationships between leaf lifespan, photosynthetic rate, leaf nitrogen concentration, and specific leaf area (the inverse of LMA) across species from around the world. From Reich, P. B., Walters, M. B., and Ellsworth, D. S. (1997) From tropics to tundra: Global convergence in plant functioning. PNAS 94:13730-13734.

Exercise 2. Leaf structure and function

There are virtual sections of leaves available on Moodle (in the resources folder).

What does a high LMA leaf look like inside?

Look at the images of *Doryphora sassafras* and *Banksia serrata*.

1. Which species has an LMA of 70?
2. Which species has an LMA of 352?
3. What differences can you see between the high and low LMA leaves?

Adaptations to arid environments

Plants lose a lot of water through their leaves. Many Australian plants have to deal with regular droughts or consistently arid environments. As a consequence, these plants have many adaptations to limit water loss. Following the link on moodle, open the images for each of these plants and list the adaptations to water loss that you can see.

1. *Banksia serrata*

2. *Correa alba*

3. *Hakea terretifolia*

4. *Atriplex* sp

Chapter 7

Week 8: Fruits and edible botany

Fruits and seeds play an essential role in the reproduction of most plants. As well as being reproductive structures they also have functions in the dispersal of plants, and, in many cases, survival through periods of adverse conditions. In this practical you will look at germination in seeds and you are provided with an introduction to some of the diversity of fruits found in the Angiosperms.

A range of fruits is provided. Using the Key and descriptions try to identify the type to which each fruit may be assigned.

Determine whether each fruit is a simple, aggregate or multiple fruit. If simple, try to find out whether it was the product of a superior or inferior ovary.

Try to determine the number of carpels incorporated into each fruit, and the placentation of their ovules. For this it may be necessary to start your investigations by taking a transverse section through the fruit (a longitudinal section is rarely informative). In many cases fusion and abortion of parts during development obscures the picture which can only be resolved if a full developmental sequence from flower to fruit is available. For example, a coconut is developed from a tricarpellary ovary in which two of the locules have aborted.

Fruit Types

> "... it may be right to say that there are as many sorts of fruits as there are major groupings of genera. This means thousands of kinds, and indeed, several hundred specialised names have already been proposed; the result is another specialist language in the babel of science, through which the student must break." - E.J. Corner 1964 'The Life of Plants'

The strict definition of a *fruit* would be that it is the product of the post-fertilizaton development of a pistil. However, it is more convenient to adopt a functional concept and include as part of the fruit tissues of extra carpellary origin so that the fruit is the post-fertilization development of the flower. [In some books you will find fruit containing tissues of extra carpellary origins referred to as "false fruit". Thus the strawberry (not a berry but an aggregate fruit) is said to be a false fruit because the fleshy part is derived from the receptacle. Even the fruits of *Eucalyptus* are sometimes called false because, derived from a half inferior flower, the cup of the fruit is extra carpellary. For most purposes making the distinction between true and false fruits is unnecessary.]

Several classifications of fruit types have been proposed of varying complexity. The terminology is, unfortunately, not necessarily consistent between classifications. Many of the names of fruit types refer to specialised forms produced by particular families; some of these special types are of great economic importance so that the names are widely known, many other special names can be conveniently ignored.

An artificial classification of fruits:

Simple fruit: a fruit derived from a single pistil or from a single carpel disseminated singly.

Aggregate fruit: a fruit derived from many free carpels of a *single* flower.

Multiple fruit: a fruit derived from the carpels of many individual flowers crowded together on the same axis.

Simple Fruits

A simple fruit is derived from the ripening of a simple or compound ovary in a flower with only one pistil. Note that there may be more than one carpel and more than one seed within a simple fruit.

A fruit is **dry** when the pericarp is papery, leathery or woody at maturity and **fleshy** if the pericarp becomes succulent or fibrous. Dry fruit may be **dehiscent** if the pericarp splits, or opens by means of pores, to shed the seeds and **indehiscent** if the pericarp does not open.

Fleshy fruits are virtually all indehiscent.

Dry dehiscent fruits

FOLLICLE - product of a single superior carpel containing one or many seeds and splitting down one side of the fruit only - e.g. *Telopea* (waratah), *Xylomelum* (woody pear).

LEGUME - product of a single superior carpel containing many seeds and splitting at maturity along both sides (along the carpel margins and the median-vein). Dehiscence is often explosive, ejecting the seeds. This is the characteristic fruit of the Leguminosae (Fabaceae).

CAPSULE - fruit developed from a number of fused carpels which open along a number of

sutures or by pores, e.g. *Eucalyptus.* A **siliqua** is the capsule characteristic of the Brassicaceae–it is a capsule that has two valves (from two fused carpels) which separate from a persistent central partition (septum) to which the seeds are attached.

Dry Indehiscent fruits

ACHENE - product of a single superior carpel with one seed which is free from the pericarp except at the placenta, e.g. *Ranunculus.* A **cypsela** is an achene derived from an inferior ovary; the term appears to be restricted to the Asteraceae.

SAMARA - a winged achene; the wing is an extension of the pericarp and presumably assists in dispersal, e.g. *Fraxinus* (ash). The fruit of the sycamore often given as an example of a samara is really a schizocarp (q.v.).

CARYOPSIS - product of a unilocular, superior ovary with one seed, but the wall of the ovary (pericarp) and the seed coat (testa) are fused together; characteristic of the family Gramineae.

NUT - one-seeded fruit with a hard, woody pericarp, e.g. *Quercus* (acorn), *Corylus* (hazelnut). Most of the nuts of commerce are not true nuts but are the seeds or stones of fruits.

SCHIZOCARP - usually the product of several joined carpels which separate when ripe, but each carpel remains indehiscent. Each carpel contains one seed, free from the pericarp except at the placenta, e.g. *Geranium*, the *Apiaceae*, *Acer.* The separate segments are called **mericarps**. In a sense schizocarps are intermediate between dehiscent and indehiscent fruits.

LOMENTUM - formed from a single carpel with many ovules, that separates into a number of one-seeded sections - found in a number of Fabaceae.

Fleshy fruits

DRUPE - the pericarp is differentiated into three zones: an outer *epicarp*, a middle succulent or fibrous *mesocarp* and an inner lignified *endocarp*; the endocarp and the contained seed(s) form the *pyrene* (stone). Most commonly formed from a single superior carpel as in *Prunus* spp. (peaches, cherries, etc.), but multicarpellary origins occur, e.g. *Lantana* and sometimes the drupe is pseudomonomerous through abortion, e.g. *Cocos* (coconut).

BERRY - pericarp two-layered, lacking the woody endocarp; usually a many-seeded fruit formed from a number of fused carpels (inferior or superior), e.g. *Musa* (banana), *Cucurbita* (pumpkin); sometimes one-seeded, e.g. *Phoenix* (date), (many so-called "berries" - strawberry, blackberry, raspberry, are not berries).

A **POME** is a particular kind of berry characteristic of certain members of the Rosaceae (apples, pears) - the five inferior carpels are free on their inner edges (the hole in the core) and their outer walls and the enlarged enclosing receptacle forms the flesh of the fruit. Pomes, and berries in general, are often yummy.

Aggregate fruits

An aggregate fruit is derived from many free carpels of a *single* flower; the carpels are not joined together, i.e. each pistil contains one carpel. Often the carpels are held together by a persistent floral receptacle which itself may be elaborated to form a substantial accessory part of the fruit.

1. *Receptacle tissue not fleshy*, e.g. *Rubus* (raspberry, blackberry) where the individual fruits are small drupes borne on a non-succulent receptacle.

2. *Receptacle tissue fleshy*, e.g. *Fragaria* (strawberry) where the individual fruits are achenes borne on a succulent receptacle and *Rosa* (the rose) where the rosehip consists of achenes enclosed in a fleshy cup-shaped receptale (a *hip*).

Multiple fruits

Multiple fruits are derived from many pistils or carpels of *many individual flowers crowded together on the same inflorescence* axis. The inflorescence axis and frequently also the basal parts of all floral segments as well as the floral receptacle and pedicel are necessarily incorporated in the fruit)

e.g.:*Syncarpia* (Turpentine) has a fruit formed from a fused cyme with seven capsules. *Ananas* (pineapple) fruit is a number of fused berries and the axis of the inflorescence (a spike), the bases of the subtending bract and the flower stalks have all become succulent.

Chapter 8

Week 9: Regeneration ecology: plant population structure and dynamics

In this exercise, we will compare plant population structure between plant species with different life histories and use the data to make inferences about the dynamics of populations exposed to periodic bushfires.

You will need: hat and sun protection, sturdy footwear, insect repellent, notebook, pencil. Wet weather gear in case of rain. Old/field clothing which you don't mind getting dirty with charcoal or soil.

Location: Small bush track opposite 12 Grose Street, La Perouse. Bus # L94 from UNSW. Part of this site was burnt about 2 years ago. The other part has been unburnt for approximately 20 years.

Time: Be on site by 1.30 pm for a briefing about the exercise. We will finish at 5.30 pm.

Activity: You will work in pairs, taking turns to search quadrats, count plants and record the data. Two pairs (4 people) will work together, sampling adjacent quadrats (i.e. one quadrat each, side by side).

Locate sampling points: Select a random number between 5 and 60 to pace out your steps along the track. Then select a second random number between 2 and 20 to pace into the bush on the burnt side of the track. At the location of your last step, lay out two 1 x 1 m2 quadrats side by side (one quadrat for each pair of students).

Record the data: Read this first and think about how to lay out your data sheet. Record the date, location and names of data collectors. For the five species described below, count the number of individuals present in the quadrat and for each one, measure its height and whether or not it has evidence of reproductive material (flowers or fruit). If there are more than 10 individuals in the quadrat, a sample of 10 height measurements is sufficient. If there are more than 20 individuals in the quadrat, you can estimate the total by counting in multiples of 10. Count live and dead individuals of each species separately.

Select a second quadrat in the burnt area using the same method and repeat the sampling. Now repeat the procedure to sample two quadrats on the unburnt side of the track. In a break from data collection, we will discuss some of the other plants to be seen in the vicinity.

Research questions:

For each species,

1. Are the standing plants killed by fire or can they survive and resprout? What is the evidence supporting your answer?
2. Is there likely to be a seed bank from which seeds are able to germinate after fire? If so if the seedbank likely to be stored in the plant canopy or in the soil? Wat is the evidence supporting your answer?
3. When the data are pooled, compare the size distributions of plant populations between the burnt and unburnt sites. Are they different? If so, how and why?
4. Use the height data to identify putative age classes for each species. Which are likely to be the youngest and oldest plants for each species in your data set? How old might they be?
5. Are there differences in reproduction: i) between species, ii) within species between burnt and unburnt sites?
6. How might fire affect the life history processes (survival, growth and reproduction) of each species?

A handout with color pictures of the species will be provided for identification purposes

Chapter 9

Week 10: How to make friends with other organisms – Root Structure and Function

Reference: Raven Biology of Plants. ch 24.

Introduction

Plants invest significant carbon captured in photosynthesis into their root systems. Roots have four functions:

1. Resources uptake
2. Anchorage
3. Transport
4. Storage

The last three of these functions are always done by the plant itself. The first one, resource uptake is often done via symbiotic partners.

Although the branching patterns and size of roots vary greatly with different species and in different conditions, the morphology and anatomy of all root systems is fundamentally similar.

The basic structure of all roots is similar to that of a primary root covered in the first year course. We will assume that you have remembered this knowledge. Otherwise the reference above will help.

Since all roots have an essentially similar plan we will focus mostly on root specialisations which enhance root survival and nutrient acquisition.

First we will examine how lateral branches are produced. They are ENDOGENOUS - that is, in contrast to stems, they are initiated deep inside root tissues.

Root morphology

The initiation of lateral roots

Lateral roots are initiated early in development in broad beans (*Vicia faba*). Cut transverse sections of root tissue through a young emerging lateral root and down the root where no lateral root has yet emerged and stain with toluidine blue.

- From which tissues are lateral roots initiated?

- Think about the vascular connections in roots. Where is the xylem in a root compared to in a stem?

When is a root not a root?

Aerating roots are an example of specialised roots with an atypical resource uptake function.

Here we will examine the pneumatophores - aerating roots that emerge from the dense, anoxic mud in mangrove swamps.

Use the following questions to conduct an investigative exercise into the differences between mangrove pneumatophores and a typical primary root.

- Is there an obvious root cap?

- What strange thing does the root tip do when it emerges from the mud?

- What is the primary function of a pneumatophore? What adaptations do pneumatophores have that allow them to carry out this function?

Strategies for enhancing Plant Nutrition

Root nodules: symbiotic fixation of Atmospheric nitrogen

Cut and stain sections of the legume root nodules and also examine the demonstration sections. Determine, and make drawings to illustrate, the nature and distribution of the micro-organisms involved.

In what ways does infection alter the morphology of the infected root? (You will need to compare infected and non-infected roots in each case.)

Proteoid or Cluster roots

Examine the proteoid roots and determine their morphology.

Mycorrhizas

There are two types of mycorrhizal associates: ectomycorrhizal fungi and arbuscular mycorrhizal fungi. Both principally trade the plant P for sugars. Ectomycorrhizal fungi also can trade N to the plant for sugar. The fungi involved are called ectomycorrhizal fungi and arbuscular mycorrhizal fungi. One plant and fungus symbiosis together is called a mycorrhyza (plural: mycorrhizas).

Arbuscular mycorrhizas are found in almost all vascular plants. They create a structure **inside** a cortical cell to exchange materiel with the plant; these tiny tree-like structures are called arbuscules.

Ectomycorrhizas found in specific families across the plant tree of life, including Myrataceae and Fabaceae. They create a net-like hyphal structure **outside** the plant root where exchange occurs.

Some species, including Eucalyptus spp., have both types of mycorrhizas. Examine the fixed material of the *Eucalyptus* roots and identify the characteristic appearance of ectomycorrhizal root systems

Chapter 10

Week 11: The plants around us: mapping the campus flora

This is an on-going project in which BIOS2051 students map the flora of sections of the UNSW campus. The aim is to generate an interactive map that will allow users to access information on all of the amazing plants around us.

The jobs for the class of 2017 will be to map the location and identity of unidentified trees on a section of campus, The mapping will be done in class time (starting today).

We will use the information you provide as the basis for an app something like the one available at Sydney University (http://campusflora.sydneybiology.org/).

The overall aims of this project are to:

1. Produce a real-life product that the community can use, and that you can be proud of.
2. Address plant-blindness the fact that most people wander around the world without noticing all the different sorts of plants they pass.
3. Increase your familiarity with many of the online botanical information resources, the primary literature, the herbarium, and the fact that there are interesting stories associated with many of the plants around you.
4. Reinforce what you have learned so far about plant identification, and help you to learn more about plant families.

PART A) MAPPING THE PLANTS ON CAMPUS

The class will be divided in to small groups. Each group will need at least one smart phone or tablet (but not every person needs one). We will divide a map of campus in to sections, and each group will be responsible for mapping 5 unidentified species above 15-cm dbh (diameter at breast height) in one map section.

We will establish a help station that you can come to for help with plant identification, to borrow pole pruners, or for any other questions.

You will need to:

1) Download a GPS app. For android, we suggest GPS Simple. For Iphone, we suggest Easy-GPS-coordinates-compass. Whatever you use should be in decimal format (degrees, minutes seconds are likely to cause conversion errors), should have at least 5 decimal places on degrees or 3 decimal places on minutes, and should have an estimate of the accuracy of your location.

When you take readings, make sure the accuracy is within ~5 m (preferably less). If you are in a corner surrounded by many buildings, you might not be able to get an accurate reading in this case, do your best, and locate the tree on google maps back in the lab to get more accurate coordinates. We will correct all of these based on aerial photographs in Google Earth/Maps.

2) For each group we have printed aerial photographs with the target plants circled.
Each group should collect their target photographs from the instructors.

3) Go to your section of campus that corresponds to your photograph (take secateurs, plastic bags, pen and paper, and your phone with you), and systematically map the circled trees. For each individual plant, you will need to record:

Latitude

Longitude

Species identity

If you arent sure what species a plant is, give it a placeholder name, and take a specimen and helpful photographs that will allow an expert (Frank!) to identify the species.

3) Enter the data in the Google spreadsheet: link on Moodle

Chapter 11

Week 12: Plant-animal interactions - herbivory

Today we're going to have a look at one of the most important interactions between plants and animals: herbivory. We will start by estimating the amount of herbivore damage experienced by plants growing in Sydney. Next, we will look at the different strategies plants use to reduce the amount of damage they receive, and test the efficacy of four types of plant defences.

Exersize 1: How much herbivory do plants experience at UNSW?

Work in pairs.

Step 1: Each pair should choose two species from the selection in the lab.

Step 2: Go outside (but stay on campus). Find a specimen of one of your species, and haphazardly select a branch to sample (try not to look at the state of the leaves when you do this).

Step 3. Locate the second and third fully expanded leaves on your branch, and estimate the level of damage as a percentage of leaf area removed (see Figure 1). Record data for each leaf separately, using Table 1, below. If you see a leaf scar where a leaf used to be, record 100% herbivory.

Step 4: Repeat step 3 for five branches (10 leaves) on each of five plants.

Step 5: Enter your data on the Google Sheet link on moodle.

Table 11.1: **Percent leaf area damaged for Species 1.** Enter data for each individual leaf in a separate box. Don't worry about keeping data from the different branches separate. The extra rows are just in case you need them.

Species 1:										
Plant 1										
Plant 2										
Plant 3										
Plant 4										
Plant 5										
extra row										
extra row										
Average herbivory:										

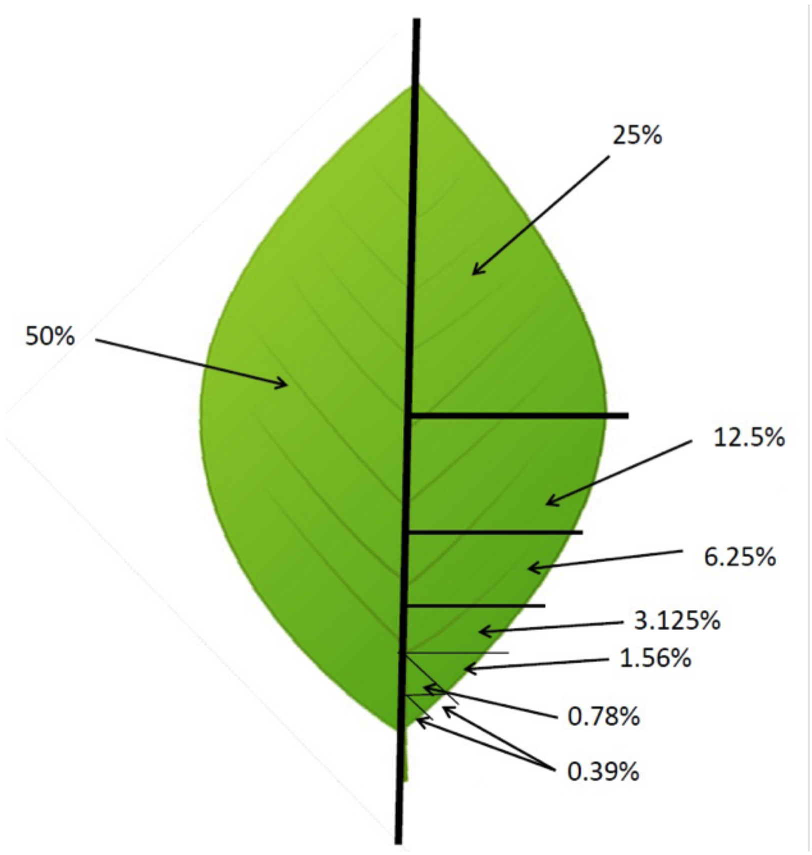


Figure 11.1: .A handy way to figure out what percentage of your leaf area is damaged. Take your leaf, and imagine halving it. That's what 50% damage looks like. Halve one of the halves. That's what 25% damage looks like – and so on. Don't get too hung up on whether a leaf has lost 1.39 or 1.45% of its area – it's more important to sample a lot of leaves than to measure each one to the 18th decimal place.

Table 11.2: **Percent leaf area damaged for Species 2.**

Species 2:										
Plant 1										
Plant 2										
Plant 3										
Plant 4										
Plant 5										
extra row										
extra row										
Average herbivory:										

Calculate the average herbivore damage across the study species. Does this seem like a lot of damage?

What sorts of damage has our study missed?

How could you improve the methods if you had more time?

Exercise II: How well do plant defence strategies work?

1. Look at the samples of the species we have studied. How might these leaves be defended against herbivory? We will select four putative defences to study today (class discussion). List a few ideas here:

2. Choose a defence to study (please try to make groups of a roughly even size). Move so that you're sitting with your group.
3. Discuss the ways that your trait might influence herbivory, and come up with a testable hypothesis about the relationship between herbivory and levels of your trait, and write it in the report space on the following page.
4. Sketch the sort of graph you might use to present the data (not everybody needs to do it the same way).

5. Think of a practical way to quantify your trait.
6. Divide the tasks up among your group members, collect and collate data. Enter your defence data in the google sheet (add columns as appropriate).
7. Summarise the relationship between your defence mechanism and herbivore damage in a figure (use a computer to generate the graph).
8. As a group, summarise your study on a single powerpoint slide (please include the figure), and write up your study in the space below.
9. Two people from each group will summarise their results in a 2-minute presentation for the class. Take notes on the results of all groups.

BRIEF WRITE UP OF YOUR STUDY

Hypothesis:

Methods:

Results:

Chapter 12

Week 13: Revision, and practical test

Practical Test

The prac test will cover skills and knowledge gained during the course. As long as you have completed each class and revised the material, this test should be no problem. It is an open book test, and you can access the internet during the exam – though no, you can't contact people for help during the test!

Expect to be tested on plant identification, anatomy, diagram drawing, connecting botanical structures to ecological function.

–

After the practical exam finishes, there will be a 30 minute break before the revision session.

Revision

This will be an interactive class, in which we go over the topics that you would like more help with, to consolidate all the amazing stuff you have learnt this year, and to prepare for the final exam.

Please email Angela (a.moles@unsw.edu.au) with any questions that you have, or topics that you would like to revise. Questions are due by 5pm October 23 (so that she has time to write the content for class!).

Chapter 13

Long-term Assignments

The Plant Collection

See details at the end of the lab manual for plant collection guidelines. While the collection is not due until week 8, specimens take some time to both dry and identify. We suggest that you begin work on this project as soon as possible.

Plant Collection Guidelines

As part of this course, you will be required to produce a small herbarium style plant collection. Plant collections are used by scientists in much the same way as animal specimens in museums. Preserved plants in herbaria can be used as a reference and aid to plant identification, a record of extant and extinct populations, a record of the expansion of invasive species, a source of DNA for molecular biology studies, and a source of morphological and architectural data for regional and global comparative studies. The School of BEES has a herbarium consisting of about 50 000 preserved specimens and other botanical resources on the fourth floor http://www.bees.unsw.edu.au/research/facilities/herbarium. After the course is completed, you may keep your collection or you may choose to donate your specimens to our herbarium. Your specimens will either be incorporated into our collection or donated to other local or international herbaria.

Rules

There are a number of rules which apply to making a plant collection. Without a license, it is illegal (with potentially large fines) to collect any plant which is included on the schedule of the Threatened Species Conservation Act (see www.nationalparks.nsw.gov.au) or the Environmental and Biodiversity Conservation Act (see www.ea.gov.au) or which is a protected species on Schedule 13 of the National Parks and Wildlife Act (this includes, for example, all species of *Boronia* and all orchids). It is also illegal to collect plants from national parks, nature reserves, state recreation areas or any other protected area (this includes the Royal Botanical Gardens). Collections breaking any of these rules will not be accepted.

Here are the general guidelines for your collection:

1. Your collection will consist of FIFTEEN specimens from at least eight different plant families. A minimum of six of these must be woody species (trees or shrubs)
2. Only collect flowering plants (angiosperms), do not collect gymnosperms or ferns.
3. Your specimens should include at least one specimen displaying:
    - An inferior ovary

- A superior ovary
- Compound leaves
- Bilaterally symmetrical flowers
- Radially symmetrical flowers
- Cladodes
- Stipules

4. **Collect native or naturalised plants**. Horticultural plants are often difficult to identify and collecting them would not contribute to our knowledge base of the Australian flora. If you are looking for plants near gardens **Dont** collect plants that have been put there by people; **Do** collect plants (such as weeds) that arrived there on their own.

Collecting Instructions

1. Bring a note book, a pair of clippers, plant tags, and a large plastic bag with you when collecting. Optional: a GPS or smart phone that includes a GPS.

2. When you find a plant you wish to collect, make careful note of the habitat (e.g. woodland, park, grassy field, rock outcrop, etc), and the location. The location may be either the latitude and longitude from a GPS or the names of nearby oads, pathways, parks, and neighbourhoods. This information should allow another scientist to find the population as easily as possible. Also include the growth habit of the plant (tree, shrub, vine, herb, etc.), plant height (approximately), and the approximate size of the population.

3. Collect a sample of the plant. Make sure your specimen shows leaves, stem, and flowers and/or fruit. For smaller plants you may wish to collect the entire individual. Collect healthy looking plants. Specimens should be collected by making a clean cut off the stem (ripping branches off produces large wounds, which may be invaded by pathogens). Put your specimens in the plastic bag.

4. You may wish to try to identify the specimens while fresh. They should stay relatively fresh for a day or two if the bag is stored in a cool place (your refrigerator).

5. Arrange your plants on newspaper and stack in the plant press. We will demonstrate this in the lab. Try to press your plants as soon as possible after collection (although called a press, the aim is to provide a means of drying plants, not to squash them as flat as possible).

6. Dry your plants. This can be done by different methods. We have some drying facilities in the herbarium you can use. If they are pressed correctly, your plants should dry in any well ventilated area. Remember to replace the news print and blotting paper on your specimens regularly, this will minimize the drying time. Large irregular structures (like Banksia inflorescences) may need to be sliced before pressing.

7. Display each specimen on a completed herbarium sheet. We will show you examples of mounted specimens.

8. Submit a spreadsheet documenting the distribution of character states amongst the specimens

Heres what we will be marking:

1. Complete and correct identification. This includes family name, genus, specific epithet and authority. Common names are not required.

2. Complete data. This includes habitat description, location, additional information for this specimen (e.g. height, growth form (e.g. tree or herb) population size estimate, flower or fruit colour), your name, collection date, and specimen number. *We will supply labels for each of your specimens with space for the required information.*

3. Complete specimen. Each plant must show flowers or fruit (preferably both), stem, and leaves. Press enough material to fill roughly half a folded sheet of news paper (Sydney Morning Herald size). Large herbs should be (where possible) folded, not cut. Woody plants should be trimmed so that critical characteristics are present.

4. Diversity. Plants displaying the character states listed in part 3 (above) should be included. Eight separate families must be represented within your collection. There will likely be bonus marks where each specimen represents a different family. A minimum of six specimens must be woody species.

Plant Biography Project

During the first lecture (week 2), you will be randomly assigned two species for which you will write plant biographies.

The goals for this project are:

- To build your skills in communicating scientific information, and to practice giving constructive feedback to your peers.
- To reinforce your understanding of plant families, learn interesting things about plants, and learn where to find information about plant taxonomy, distribution and ecology.
- To develop the content that will populate our campus flora app (see prac manual for further explanation).

There are three assessable components of the plant biography project:

1) FIRST PLANT BIOGRAPHY (Due Mon 24th August)

Prepare the plant biography for one of your two assigned plant species (detailed instructions below). We understand that it might not be possible to take pictures of your study species at this time of the year (e.g. if they are deciduous), so you can omit the pictures for this version. Herbarium specimens are not due until October.

Your biography must be uploaded to Moodle.

We will allocate each plant biography to three randomly selected students from the class. These people will give you anonymous feedback on your assignment. Your grade will be calculated based on the scores these three people give you. If you believe that one of your scores is unfair, you can click to flag it in Moodle, and we will check it.

2) FEEDBACK ON PEER ASSIGNMENTS (Due Friday 4th Sept)

Scientists spend a lot of time reviewing other scientists work, and giving their colleagues feedback on their work. We have designed this part of the assignment to give you the opportunity to develop your skills in giving constructive feedback. We hope that reading plant biographies for three additional species will also increase the amount of interesting plant knowledge you pick up. Finally, thinking about what you like (or dont like) about how others have done things is a fantastic way to improve your own work.

We expect you to upload at least 100 words of constructive feedback for each of the three biographies you review, in addition to assigning a grade. Use the marking schedule below to allocate marks, and to guide your feedback. We take plagiarism seriously if you find any evidence of plagiarism (e.g. sentences copied directly from other sources), please let Will or Angela know.

Together, the first plant biography and feedback on peer assignments are worth 10% of your grade for Flowering Plants. The peer assessments are important - if you do not submit feedback on peer assignments, you get 0 for the whole first plant biography assignment.

3) FINAL VERSIONS OF PLANT BIOGRAPHIES (Due Friday 16th October)

Revise your first plant biography in light of the comments from your peers, and prepare your second biography. Both need to be complete (ie, they should include pictures), and you need to include herbarium specimens for your species in your plant collections.

Upload completed biographies for both of your species on Moodle.

The final versions of your plant biographies are worth 10% of your grade in Plant Ecology (5% per species). They will be marked by Will and/or Angela.

WHAT TO INCLUDE IN YOUR PLANT BIOGRAPHY

The plant biographies (one for each species) can each be up to 500 words (not including references). They must include:

- Species name (binomial)
- Common name (if it has one)
- Family
- Order
- Pictures of the species highlighting important characteristics (you can use the georeferenced information from the google sheet (link above) to find your species on campus). Take photographs both at a distance, and close ups showing leaves, reproductive structures etc. *The pictures should be your own (not taken from the internet).* We understand that the species may not have leaves during winter, so pictures are not compulsory for the first version of your biography (due in August). However, we do expect that you will have found the plant and taken pictures by the time the final version is due in October.
- Link to a map showing where in the world the species naturally occurs (e.g. information from GBIF or the Atlas of living Australia),
- Link to a map showing where in the world the family naturally occurs.
- Links to species descriptions (from the Flora of Australia or the flora of NSW)

We would also like you to include information such as:

- **Ecological background of the species**, including finding at least one scientific paper about the species or its family (use Google Scholar or Web of Knowledge). Some ideas:

- Interesting biotic interactions (e.g. if you had a *Ficus*, you could write about the special interaction between figs and their pollinating wasps figs cant form without wasps living inside them, so are off the menu for strict vegetarians),
- Chemical and physical defences (e.g. Solanaceae tend to have interesting alkaloids like nicotine),
- Is the species, or its relatives useful/edible/noteworthy? (e.g did you know that black tea is made from a type of *Camellia* those ugly plants with pink flowers that you see near the coffee cart?).
- Any interesting biogeography or palaeoecology? (e.g. *Nothofagus* has a classic Gondwanan distribution)

- Include citations to the primary scientific literature wherever possible for all information [follow the reference format for the *Journal of Ecology*]. We need you to do more than cherry pick the Wikipedia entry.

- **Evolutionary (phylogenetic) history of the species.** What is known about the distribution, ecology and history of the genus or family?

- **Historical information** e.g. The *Agathis australis* (Kauri) on the biology lawn was planted by the Queen.

- **Translations of the scientific name** (to help people get past all those long latin words)

- **Ethnobotanical information**, such as traditional uses of plants

- **Conservation issues** (if any) of the species (or closely related species)

- **Something creative**. Here are some ideas:
  - If you have a *Banksia* species, take pictures of the leaves of every species of *Banksia* that you can find. Show the photos in the video about the evolution of leaf shape.
  - Find a good place with lots of flowers and pollinators and make a short film about flowers and bees.
  - Make a stop motion animation with drawings and a voice over explaining how plants grow.
  - Interview someone with traditional knowledge, historical knowledge, or with particular research or horticultural expertise on the species
  - Something else!

The more creative you are in writing these entries, the more fun our app will be.

Finally, we ask that you make a **herbarium specimen** for each of your species. These will be lodged in the UNSW herbarium, and the herbarium reference number can be included in the information in the species description, linking the online information to our impressive plant reference collection at UNSW. The herbarium specimens should be included in your plant collection add notes to your plant collection to indicate which specimens are of your plant biography species.

MARKING SCHEDULE

Assessment criteria	**Possible mark**	**Your mark**
Quality of content - Presents interesting, accurate, and complete set of information on the plant species. - Displays a good, well-rounded knowledge of the species. - Shows evidence of having read and understood relevant scientific literature. Must have gone beyond Wikipedia level. - Synthesised information from a wide range of sources (ie didn't just report what a paper/resource said, but integrated information and ideas from multiple data sources to provide a cohesive picture). - NO PLAGIARISM. Any plagiarism should be referred to Will or Angela.	**65**	
Presentation - Clearly written. Main text written in full sentences with proper punctuation and no spelling errors. Species names correctly formatted. - Good use of figures/tables and links to online resources. - Includes references to the sources of information, following the reference format for the *Journal of Ecology* for scientific references.	**15**	
Innovative content - Goes beyond summarising what others have written – does something new and creative.	**20**	
TOTAL	**100**	

Figure 13.1:

Chapter 14

Important Australian Families and Subfamilies

NB. The key characters for recognising the family are underlined in these notes.

Family Myrtaceae - The Eucalypt family.

A family of about 120 genera and 3,200 species (ranks 11th amongst the Angiosperms in number of species). It is worldwide in distribution, but is particularly well represented in Australia and Central America.

Habit: Woody plants, mostly trees and shrubs (no herbs).

Leaves: *Simple, entire and exstipulate*; mostly opposite, but many Australian members have alternate leaves. The mesophyll usually contains *translucent oil-glands*, so that the leaves are mostly fragrant when crushed.

Flowers: Actinomorphic with the sepals, petals and stamens arising from a receptacular cup that is fused to the sides of the ovary and mostly arises above it; hence the *ovary is half-inferior.* The perianth is 4-5-merous, while the *stamens are numerous* and often indefinite in number, providing much of the floral display.

Fruits: There are two basic kinds -

1. *A fleshy berry or drupe* - ovary 2 or more locular. This type characterises the sub-family Myrtoideae, which is widespread in the tropics; their leaves are always opposite. This is considered the more primitive (or less specialised) group in the family. In Australia its members are restricted to the closed forests of moister regions of the east and north.

2. A dry and often woody dehiscent structure with 1 or more locules *(a capsule*), or a dry unilocular indehiscent fruit (*an achene*). These types occur in the sub-family Leptospermoideae, which is mainly Australasian, and in which the leaves may be opposite or alternate. This sub-family is considered a specialisation that developed in Australia during the Tertiary in response to the increasing aridity of the continent. Some genera have spread to neighbouring regions in relatively recent time (eg., *Leptospermum* to New Zealand, *Melaleuca* to New Guinea and Malaysia, *Eucalyptus* to Timor, New Guinea and The Philippines).

Notes: An unusual feature of the family is that the stems and leaves have phloem on both sides of the xylem.

Important genera in Australia:

- *Syzygium* Gaertn. and *Acmena* DC, with fleshy fruits.
- *Eucalyptus* L'Herit.,
- *Corymbia* Hill & Johnson (previously included in *Eucalyptus*),
- *Angophora* Cav. (similar to eucalypts, but having sepals and petals in the flower, and always with opposite leaves)
- *Leptospermum* Forst. f. (Tea Trees)
- *Melaleuca* L. (Paperbarks - stamens fused into bundles in the flower) and
- *Callistemon* R. Br. (Bottlebrushes - stamens free), with woody capsules.

Family Rutaceae - the Citrus family.

The family includes 150 genera and 1,600 species, of which 40 genera and 335 species occur in Australia.

Habit: *woody* trees and shrubs.

Leaves: exstipulate, *often compound*, and contain *translucent oil glands* imparting an aroma when crushed.

Flowers: usually actinomorphic, and either *pentamerous* or *tetramerous*, with a *superior ovary* and *stamens up to twice as numerous* as the other parts -

* Kn Cn A2n-n G*(n)* where n = 4 or 5

There is a *nectariferous disc* surrounding the base of the ovary.

Fruits: berries or capsules.

Notes: similar to the Myrtaceae in having gland-dotted leaves, but can be distinguished by the superior ovary, and in many cases by the presence of compound leaves.

Important genera in Australia:

- *Boronia* Sm. (94 species - flowers tetramerous - many very attractive; all NSW species are protected);
- *Eriostemon* Sm. (33 species - Wax Flowers - flowers pentamerous);
- *Zieria* Sm. (25 species - flowers tetramerous with only one whorl of stamens).

Subfamily Faboideae: a subfamily within Fabaceae

(alternate name Papilionoideae)

500 genera, 12,000 species, worldwide in distribution. 59 m.y.o. (Lavin et al. 2005)

The alternative name Leguminosae is sometimes also applied to the Fabaceae. This traditional name is unusal because it is based on a morphological feature, the legume or pod, instead of a type genus. The name Fabaceae conforms to modern practices becasue it is based on a genus, *Faba.*

Habit: very variable, from trees to herbs and climbers.

Leaves: usually alternate, *often stipulate and/or compound.*

Flowers: *highly zygomorphic and pea-like*, though sometimes showing reduction in the size or number of the parts; sepals 5, connate at the base; petals 5, the adaxial one much enlarged and prominent (the "standard"), the two abaxial ones connate to form a "keel" enclosing the stamens and style and itself enclosed by the two lateral petals (the "wings"); stamens 10 or sometimes 9, often connate; carpel 1; ovary superior with marginal placentation.

Fruit: a *legume or pod splitting down both sides*; seeds non-endospermic, often large; embryo bilaterally symmetrical.

Notes: Many of the species are of economic importance as food or crop plants (*Vicia faba* L., Broad Bean; *Pisum sativum* L. Green Pea; *Medicago* L. spp., Clovers and Lucerne), timber (*Castanospermum australe* A. Cunn., Black Bean), and as a source of dyes (*Indigofera anil* L. and *I. tinctoria* L., Indigo) , medicines and oils. Most species have the capacity to form symbiotic relationships with nitrogen-fixing bacteria (root nodules).

Their seed protein contains the amino acid lysine, essential for human nutrition but absent from all other plant proteins; they are therefore important components of vegetarian diets.

Subfamily Mimosoideae, a sub-family within Fabaceae

The wattle subfamily

82 genera, 3335 species.

Habit: woody shrubs or trees.

Leaves: alternate, *bipinnate*, but often reduced to a *simple phyllode* in the adult, and often bearing *one or more nectaries on the petiole and rachis* (midrib of a compound leaf).

Inflorescence: crowded spikes or heads, often arranged in compound inflorescences.

Flowers: small, actinomorphic; calyx and corolla 4 or 5, inconspicuous; stamens long, numerous and showy; carpel 1; ovary superior with marginal placentation.

Fruit: a *legume splitting down both sides*; seeds non-endospermic, often bearing a brightly coloured aril (fleshy collar); embryo with 2 planes of symmetry.

Important genus:

- *Acacia* Willd., about 800 species endemic to Australia, also well represented in Africa, some in America. Contraversial genus.

Family Asteraceae, the Daisy family

(Alternative name Compositae)

1535 genera, 23,000 species; the largest family of dicotyledons; the family and many of the genera and even some species distributed worldwide, mainly in open communities. A relatively young family, Asteraceae probably has the highest rate of net diversification among all angiosperm families.

Habit: mostly herbs, often annuals (many desert ephemerals), a few shrubs and trees. Often in arid or semi-arid environments.

Inflorescence: a *capitulum* - a cluster of small sessile flowers seated on an expanded convex stem apex and surrounded by bracts (the *involucre*).

Flowers: calyx either reduced to a ring of scales or hairs, or absent; corolla connate, 5 (sometimes 4); stamens epipetalous, 5 (4), anthers connate in a tube surrounding the style; style splitting into 2 stigmatic lobes after emerging from the flower; the *ovary inferior, unilocular with a single ovule* attached basally.

Within the capitulum the flowers (florets) are often differentiated in the following ways:

- corolla asymmetrical, giving strap-shaped ray (or ligulate) florets;
- suppression of either or both sexes, giving separate male, female or sterile florets;
- reduction or differentiation of the pappus (calyx).

The most common condition is a ring of female or sterile *ray florets* (with a strap-shaped corolla) radiating outwards from the edge of the capitulum, and a central mass of bisexual tubular *disc florets*. However, the capitula of some species consist entirely of disc florets, while others are composed entirely of ray florets.

Fruit: a one-seeded, indehiscent achene (technically termed a *cypsela*), though rarely a drupe developing a fleshy outer layer as in *Chrysanthemoides* (Boneseed or Bitou Bush) a weed of coastal dunes. The ovary wall (pericarp) and seed coat (testa) fuse into a single layer during maturation of the fruit, and the pappus often develops into an aid to dispersal.

Notes: The family furnishes a few food plants (*Helianthus annuus* L., Sunflower; *H. tuberosus* L., Jerusalem artichoke; *Cynara scolymus* L., Globe artichoke; *Lactuca sativa* L., Lettuce; *Cichorium intybus* L., Chicory), many horticultural plants (*Chrysanthemum* L., *Dahlia* Cav., *Gerbera* Boehm., *Aster* L.) and weeds (*Soliva anthemoides* (Juss.) R.Br., Bindii; *Taraxacum officinale* Weber ex Wiggers, Dandelion; *Sonchus* L., Thistles).

Family Proteaceae, the Waratah family

1600 species in 80 genera; mostly, but not entirely, a southern hemisphere family with greatest diversity in the Cape Province of South Africa, south-western Australia and eastern Australia.

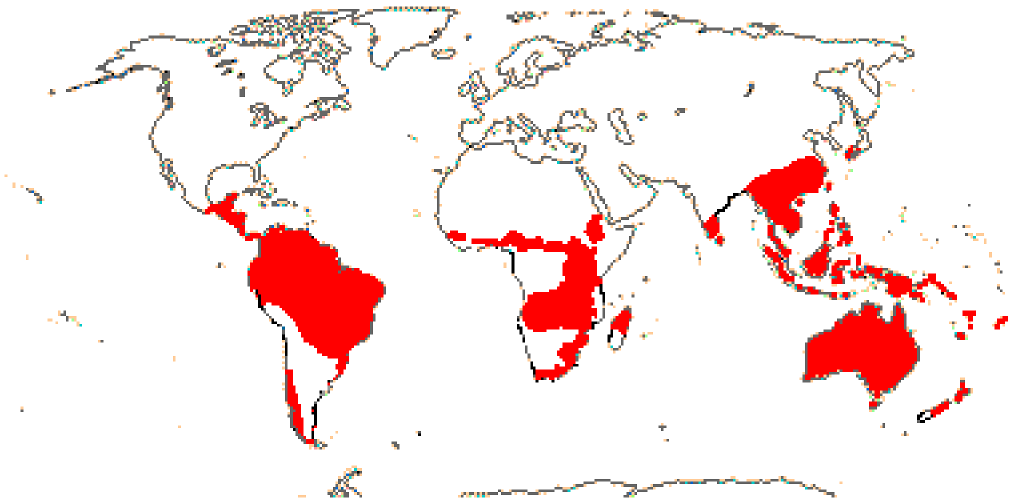


Figure 14.1: Range map for Proteaceae from Angiosperm Phylogeny Web (APWeb; www.mobot.org/MOBOT/research/APweb)

Habit: *Woody plants*, from great trees to dwarf prostrate undershrubs and trailing undershrubs.

Leaves: usually *hard or leathery with much sclerenchyma*, exstipulate, opposite or alternate, ranging from entire isobilateral leaves with sub-longitudinal venation to highly divided or strongly dorsiventral.

Flowers: *perianth monocyclic and tetramerous*, actinomorphic or zygomorphic, the segments showing varying degrees of fusion; *ovary monocarpellary with marginal placentation*; ovules numerous to 2; around the base of the ovary there may be up to 4 nectiferous glands, single or variously fused, alternating with the tepals.

[P(4) A4] G*1*

Fruit: a drupe, nut, achene or follicle.

Notes: Some of the large rain forest species are economically important in the timber industry; the wood has wide and deep rays and therefore yields "oak" figures on cutting - the silky oaks of commerce are *Cardwellia sublimis* F. Muell. and *Grevillea robusta* Cunn. Many species have massed flowers in showy inflorescences: e.g., the South African *Protea* and the Australian *Banksia*, *Telopea* and *Grevillea*.

The important genera around Sydney are:

- *Banksia* L.f., ca 50 species in Australia. Flowers compacted around the thick rachis of a spike, the inflorescence superficially resembling Bottlebrushes and Paperbarks (Myrtaceae). Perianth tube very narrow with slender stiff segments that have expanded concave tips containing the almost sessile anthers.
- *Grevillea* R.Br., ca 200 species throughout Malaysia, New Hebrides, New Caledonia and Australia.
- *Hakea* Schrad., ca 100 species in Australia. The fruits are woody follicles. Leaves isobilateral with sub-longitudinal venation, or terete, pungent-pointed needles.
- *Isopogon* R.Br. ex Knight (ca 35 species) and *Petrophila* R.Br. ex Knight (ca 40 species) are two closely related genera in which the flowers are in contracted cone-like spikes or heads. Drum sticks.
- *Persoonia* Sm., ca 70 species endemic to Australia; many species have isobilateral leaves with sub-longitudinal venation. The flower is actinomorphic and is borne singly in the axils of leaves or bracts. The fruit is a drupe. Geebungs.

Othere interesting species are:

- *Lambertia formosa* Sm., the Honey Flower or Mountain Devil.
- *Macadamia ternifolia* F. Muell., the Queensland Nut or Macadamia nut, is probably the only Australian plant species that has been taken into crop production.
- *Stenocarpus sinuatus* Endl., the Fire-Wheel Tree from northern N.S.W., is commonly planted around Sydney. A drawing of this species is on the cover of this manual.
- *Telopea speciosissima* R.Br., the Waratah, the state emblem of N.S.W.
- *Xylomelum pyriforme* Sm., the Woody Pear.

Family Ericaceae, the heaths

Formerly the southern hemisphere heaths were included in the family "Epacridaceae"; molecular evidence disproved the existence of Epacridaceae as a real evolutionary group and the southern heaths are now considered to be part of a globally distributed family, Ericaceae

A large globally distributed family with 126 genera and 4000 species. Boreal to warm temperate, also montane tropics, very rare in lowland tropics. The species are mainly in wet and dry heathlands and are common on the sandstone around Sydney and in the Blue Mountains. They are known as Native Heaths.

Habit: Typically *woody* small under-shrubs, shrubs, or sometimes trees.

Leaves: in Australia *usually small and crowded*, alternate, simple, entire, exstipulate with *palmate or longitudinal venation*.

Flowers: *radially symmetrical and pentamerous*, with few to many *imbricate bracts below the flower and often grading into the sepals*; *petals fused into a tube*; *stamens epipetalous*; ovary superior with 1-10 locules.

* K5 {C(5) A5} G*(1-10)*

Fruit: a capsule or drupe.

Chapter 15

Glossary

Abaxial: the side or face of a lateral organ (leaf or bract) turned away from the axis; the lower surface of a leaf

Achene: a dry, indehiscent fruit, formed from a superior ovary consisting of one carpel and containing one seed which is free from the pericarp

Actinomorphic: a radially symmetric flower

Acuminate: tapering to a point.

Acute: pointed; sharp

Adaxial: the side or face of a leaf or bract facing the axis on which it is borne; the upper surface of the leaf

Adnate: (1) organically fused to another but different kind of part, eg. stamens to petals; (2) anthers fused to the filament by their whole length

Adventitious: arising in irregular positions, as in roots arising on a stem. (cf. axillary - in defined positions)

Aestivation: the arrangement of petals and sepals in the unexpanded bud

Aggregate fruit: a fruit derived from many free carpels of a single flower (e.g. Blackberry). See multiple fruit

Alternate: arranged singly at different heights on the axis and in 2 rows longitudinally. Commonly also used to describe a spiral arrangement

Analogous: of structures showing an analogy

Analogy: structures showing a similarity that results from their adaptation to the same function or environment [cf. *homology*]; hence, similarity not resulting from inheritance from a common ancestor

Androecium: the stamens

Anthotelic: an inflorescence ending in a flower

Apocarpous: applied to a gynoecium which consists of several to many free or slightly coherent or basally connate carpels

Apomorphy: a derived state of a character. See *synapomorphy, pleisomorphy, autapomorphy.*

Appressed: pressed up against but not fused

Arborescent: growing to the size of a tree; resembling a tree in habit growth

Aromatic: possessing a strong smell, often spicy; eg. leaves when crushed

Autapomorph: a unique derived trait; a character that arose in the common ancestor of a taxon (species, genus etc.) and that is unique to the taxon; a unique *synapomorph* [*cf. synapomorph, symplesiomorph*]. Note that, since ancestral and derived are relative terms, the taxon must always be defined when this term is used; eg. companion cells in the phloem of angiosperms; calyptra formed by fusion of perianth whorls in the flowers of *Eucalyptus*.

Authority: name(s) cited after a binomial indicating the author(s) who first described and named it; usually only included at the first mention of the binomial in any article, or to distinguish between *homonyms*

Awn: bristle-like appendage, eg. one the end of a bract or fruit.

*Axil (*hence *axillary):* the upper angle between the axis and any organ which arises from it, especially a leaf or bract or bud (and the branch arising from it)

Axile: on the axis, .g. in axile placentation where the placentas and ovules are on the central axis of the ovary

Barbellate: bearing short stiff hairs, sometimes hooked, eg. on small dry fruits of Asteraceae

Basal: (1) (Radical) attached or grouped at the base, e.g. of leaves in a rosette; (2) of placentation, with the placenta at the base of the ovary

Berry: an indehiscent, succulent fruit having the pericarp differentiated into epicarp (skin) and pulp usually containing many (sometimes one) seeds

Bi: prefix signifying two or twice

Bilateral: having two sides

Bilateral symmetry: having 2 sides symmetrical about only one median diameter or axis

Bipinnate: twice pinnately divided

Bisexual: having both fertile male and female organs in the same flower; hermaphrodite

Blastotelic: an inflorescence ending in a branch or vegetative bud

Blade (Lamina): an expanded portion of a leaf

Bract: leaf-like structure, reduced leaf or scale which subtends an inflorescence or flower

Bracteate: having bracts

Bracteole: a small bract situated on the stalk or pedicel below a flower but not subtending it; usually paired in dicotyledons, one in monocotyledons

Bulb: a storage organ consisting of a short, usually underground stem surrounded by swollen fleshy leaf-bases and outer, dry protective leaf-bases. (eg. onion)

Bud: the structure from which shoot, leaf or flower develops; a meristem surrounded and protected by developing leaves and/or protective bud scales

Burr: a rough or prickly compound structure developed from a seed or fruit and associated appendages (bracts, perianth etc.)

Caducous: falling off early

Calyptra: the cap-like covering surmounting some flowers and consisting of connate perianth-segments

Calyx: the sepals of one flower, collectively

Campanulate: bell-shaped

Capitate: enlarged and globose at the tip; formed like a head

Capitulum: a head of sessile florets crowded together on a receptacle and often surrounded by an involucre

Capsule: a dry dehiscent fruit of two or more fused carpels which opens by splitting apart or by special valves as in *Eucalyptus*

Carpel: a unit of the gynoecium in which one or more ovules are enclosed. It is usually divisible into stigma, style and ovary

Cauline: borne on the more or less elongated portion of a stem, e.g. describing leaves (compare with *Basal*)

Ciliate: fringed with hairs

Circinnate: coiled from apex downward, as in developing fern fronds

Cladode: a stem which is specialised to carry out photosynthesis and on which the leaves are reduced to scales or absent (eg. *Casuarina)* [cf. *phyllode*]

Clathrate: resembling lattice-work; having raised and thickened lateral cell walls

Clavate: club-shaped

Cochlear: a type of perianth arrangement in which one petal is entirely outside and another is entirely inside the others

Coherent: attached to, but not fused with, another floral part of the same kind, easily separable; eg. coherent styles

Complementary tissue/cells: the loose packed tissue of a lenticel arising from the phellogen in woody plants

Compound leaf: a leaf divided to the base or mid-vein into leaflets

Compound head: an inflorescence made up of a number of heads arranged in a larger head

Compound umbel: an inflorescence in which several umbels are borne on stalks or peduncles radiating from the top of a stem

Compressed: flattened laterally

Cone: (1) a compact group of sporophylls (male or female) borne on a central axis. (2) the woody multiple fruit of *Casuarina*, made up of true fruits surrounded by woody bracts

Connate: organically fused to one or more members of the same whorl, as in fusion of petals to each other [cf. *adnate*]

Connivent: lying or standing side by side, but not touching or fused

Contorted: perianth parts twisted about each other and with overlapping edges in the bud

Contracted: narrowed or shortened

Convolute: rolled so that the margins overlap

Cordate: heart-shaped (often applied to bases only)

Corm: a short, swollen, upright, underground stem formed annually in the stem-base and in which food reserves are stored. It is surrounded by dry, protective leaf-bases

Corolla: the petals collectively

Corymb (hence *corymbose*): an inflorescence of stalked flowers in which all the flowers, although they originate at different levels on the stem, are ultimately borne at about the same level

Cotyledon: a seed-leaf of the embryo of a seed plant

Crenate: having the margin cut regularly into rounded teeth or lobes

Crisped: curled, very wavy or crumpled

Cyme (hence *cymose*): an inflorescence in which a flower terminates growth of the main axis, which is replaced by one or two axillary buds that later form flowers, the process being repeated throughout the inflorescence

Cypsella: characteristic fruit of the Asteraceae; like an achene but formed from an inferior ovary and therefore covered with other floral tissues outside the ovary wall

Deciduous: 1) of perianth parts - falling at maturity; 2) of trees - those trees with leaves which all fall at a certain season.

Decumbent: reclining growth from apex but with the summit ascending (applied to branches whose lower portions lie on or near the ground while the tips grow upwards)

Decurrent: extending downward beyond the point of insertion (applied to pinnae, leaves or petioles when they extend beyond their insertion point and run down the stem)

Decussate: in pairs, alternately, at right angles

Definite: (1) of a precise and constant number such as stamens in a flower. (2) inflorescences that terminate in a flower, growth being resumed by lateral buds, eg. cymes

Dehiscence: the manner in which the wall of a mature organ ruptures to allow the contents to escape

Dehiscent: opening or bursting at maturity

Dentate: toothed

Determinate growth: growth that ceases when an organ has reached a certain size and shape; eg. of a leaf.

Dichotomous: divided into two approximately equal branches; a form of branching common in algae and primitive land plants where there is no main axis.

Diffuse: spreading and much branched form of growth

*Dioecism (*hence *dioecious):* a species having unisexual flowers where the male and female flowers are borne on different plants

Disc: glandular tissue found in some flowers between the ovary and stamens or immediately outside stamens (.g. Rutaceae)

Disc floret or *flower:* small flower (usually with tubular corolla) borne on the central portion of the heads of some Asteraceae

Dissected: divided into segments

Distal: remote from; at the end

Distichous: leaves or bracts arranged in two vertical ranks: eg. leaves in Irises and Travellers' Palms; the florets in many grasses

Divaricate: a growth form with extremely divergent branching; straggling

Domatia: small glandular pits or swellings, often bearing a patch of hairs, found in some species on the abaxial leaf surface in the angles between the major lateral veins and the midrib.

Dorsiventral: having structurally different upper and lower surfaces

Drupaceous: applied to fruit with a structure of a drupe

Drupe: a succulent, indehiscent fruit having the pericarp differentiated into 3 distinct layers: outer epicarp (skin), soft mesocarp (pulp) and inner stony endocarp

Endarch: describes vascular bundles in a stem or root where primary xylem develops from the centre outwards: ie. protoxylem inside metaxylem

Endocarp: the hard stony innermost layer of a pericarp

Endosperm: nutritive tissue developed in seeds; in Angiosperms it develops from the triple fusion nucleus and is triploid, in gymnosperms it is the female gametophyte and is haploid

Entire: without division, incision, or separation

Ephemeral: short-lived; annual

Epicalyx: extra bracts below the sepals of a flower, often forming an involucre or resembling a second calyx. (eg. Ericaceae)

Epicarp: the outermost layer of the pericarp; skin

Epigynous: referring to perianth parts (petals and sepals) that are attached to the floral receptacle (stem tissue) above the level of the ovary, sometimes borne on an extended receptacular cup that is free from the ovary (see fig. 2.5 right).

Epipetalous: stamens borne on the petals

Epiphyte: a plant perched, but not parasitic on, another plant or other object. (eg. ferns, orchids)

Exarch: describes vascular bundles in a stem or root where primary xylem develops from the outside towards the centre ie. protoxylem outside metaxylem

Exstipulate: without stipules.

Extrorse: stamens opening towards the circumference of the flower

Falcate: sickle-shaped

Fimbriate: fringed with fine hairs

Flaccid: limp, flabby

Floral tube: a tubular structure present in some flowers and interpreted either as the fused basal portions of the androecium and perianth, or as an up-growth of the receptacle. It may be free or fused to the ovary

Floret: the greatly reduced flower in a compound inflorescence; eg. grasses or Asteraceae

Follicle: a dry dehiscent fruit formed from one carpel and having one longitudinal line of dehiscence e.g. Proteaceae (cf. *Legume*)

Free: not united with any other part; of petals, stamens, etc.

Glabrous: without hairs

Glaucous: dull green with a whitish-blue lustre

Glumaceous: small boat-shaped bract found in the inflorescences of some monocots; may enclose a flower or flower cluster.

Gynandrous: stamens adnate to the pistil (ovary and/or style)

Gynobasic: applied to a style which arises from the base rather than the apex of the ovary; either arising in a central pit or from the side of the ovary

Gynoecium: the carpels (female parts - stigma, style and ovary) of one flower

Gynophore: a stalk on which a superior ovary is sometimes borne above the floral receptacle

Hair: an unflattened (radially symmetrical) epidermal appendage consisting of one or several cells

Halophyte: a plant which grows in and tolerates salty places

Hastate: shaped like a spear-head

Head: an inflorescence of sessile flowers crowded together on a receptacle and usually surrounded by an involucre

Heath: a plant community dominated by small shrubs (usually less than 2 metres high) which usually have small hard leaves

Herb: a plant which does not produce a woody stem

Herbaceous: referring to non-woody plants or herbs. When applied to the texture of a leaf or frond, green and soft, midway between membranous and leathery (not succulent)

Hermaphrodite: bearing both male and female sex organs in the same flower; bisexual.

Heterophylly: species having two different forms of leaves.

Heterophyllous: having leaves of different forms eg. distinctive juvenile and adult leaves of many eucalypts; submerged and aerial leaves of some water plants.

Hilum: a scar left on the seed coat at the spot where it was attached to the placenta

Hirsute: covered with long spreading hairs

Hispid: densely covered with short stiff hairs or bristles

Homologous: Of structures showing homology; *v.i.*

Homology: A similarity in plan and detailed structure of organs in different species resulting from their descent from a common ancestor; often a similarity despite different functions [cf. *analogy*]

Homonyms: the same name (binomial) applied to two different taxa (species) by different authors; that which was first validly published is accepted, the later one being rejected as invalid. Homonyms can only be distinguished by their different *authorities*

Homoplasy: similar features in different species having independent evolutionary origins, similarity not resulting from common ancestry

Hyaline: translucent and usually colourless

Hypogynous: referring to perianth parts (petals and sepals) that are attached to the receptacle (floral axis or stem) below the level of the gynoecium of a flower; ie. with a superior ovary (see fig. 2.5)

Imbricate: with the edges overlapping

Imparipinnate: a pinnate leaf with a terminal leaflet

Incurved: bending or curved inwards or upwards

Indefinite: (1) floral parts too many to be counted easily (2) inflorescences capable of constant extension via apical growth of the main axis.

Indehiscent: not opening at maturity

Indeterminate growth: growth from an axis bearing an apical meristem which forms an unrestricted number of lateral organs

Indumentum: a general term for the hairy covering of plants

Induplicate: of perianth segments arranged with the edges bent inward and the external face of these edges touching without twisting

Indusium: (1) any covering of a sorus whether a modified organ or merely the incurved margin of the pinna; (2) a cup or ring of hairs below the stigma forming a pollen collecting structure (e.g., Goodeniaceae)

Inferior ovary: one which lies below the point of attachment of the calyx; ovary submerged within the floral receptacle

Inflexed: bent inwards; incurved

Inflorescence: a group or cluster of flowers

Interjugary glands: additional glands occurring along the leaf-rachis between the insertions of successive pairs of pinna. Occurs below the single and often slightly larger gland which is found at or just below the insertions of these pinnae. (eg. *Acacia*)

Internode: the portion of the stem between two successive nodes or leaf attachments

Interpetiolar: stipules positioned between the petioles of opposite leaves

Involucre: a whorl or several whorls of bracts surrounding an inflorescence (e.g. Asteraceae)

Involucral bracts: bracts around the base of the capitulum, often resembling sepals or petals

Involute: rolled inwards or upwards

Irregular flower: a flower which has one or more of its segments dissimilar in shape from the others of the whorl; not radially symmetrical (eg. Fabaceae)

Isobilateral: having the same structure on both sides; a leaf having identical surfaces

Isomerous: a flower having segments of successive whorls equal in number (i.e. sepals, petals, stamens, etc.)

Keel (hence *keeled*): (1) a ridge like the keel of a boat; (2) the two anterior petals of the corolla joined (eg Papilionaceae)

Lamina: the expanded portion of a leaf or fern frond; leaf-blade

Lanceolate: narrow and tapering at each end and about 4 times as long as broad

Lateral: fixed on or near the sides of an organ; arising from a leaf-axil

Latex: thick milky or clear juice found in some plants (eg. rubber tree, lettuce)

Lax: loose, not compact

Leaflet: a separate portion of a compound leaf

Legume: (1) a dry dehiscent fruit formed from one carpel and having two longitudinal lines of dehiscence (eg. pea pod) (2) a member of one of the Family Fabaceae (colloquial)

Liana (liane): a climbing or twining plant

Lignotuber: a woody swelling partly or completely underground and bearing at the base of a stem many cortical buds that may produce separate stems (often after fire)

Ligulate: (1) with a ligule; (2) strap-shaped, as in zygomorphic ray florets of Asteraceae

Ligulate: (1) a variously shaped appendage facing toward the base of a leaf (especially in grasses, but also some sedges, see Fig. B, p 110), petiole, or perianth segment; (2) the strap-shaped corolla lobe or limb in ray florets of ASTERACEAE

Limb: the upper free and usually spreading portion of a petal within a fused corolla

Linear: long and narrow, with parallel sides

Locule: ovule or seed-containing chamber within a fruit or ovary; also *Loculus*

Macerated: a process by which tissue is softened or digested chemically so that the cells are separated, and can be examined individually

Mallee: a woody plant with many stems arising from an underground woody tuber (lignotuber); usually applied to eucalypts only

Megaphyll: leaf evolved from a lateral branch of a stem; found in ferns and seed plants

Membranous: thin and translucent

-merous : a suffix referring to number of parts in a flower, e.g. 5-merous, each floral whorl contains 5 parts.

Mesocarp: the middle layer, usually fleshy, of a 3-layered pericarp or mature fruit wall

Microphyll: leaf evolved from an outgrowth from the surface of a stem; found in Lycopods

Monoecious: having unisexual flowers with both male and female flowers being borne on the same plant

Monopodial: referring to a stem with a single main axis which produces lateral organs of which the youngest is always at the tip

Mucro: a sharp terminal point

Mucronate: having a short terminal point

Multiple fruit: a fruit derived from the carpels of many individual flowers crowded together on the same axis

Nectary: a specialised gland which secretes nectar

Node: that part of the stem from which a leaf or leaves and/or bracts arise; the knot in a grass stem

Nut: a dry, indehiscent, one-seeded fruit formed from 2 or more carpels

Ob: a prefix signifying that the meaning of the simple word is reversed e.g. obcordate - the reverse of cordate

Obsolete: parts that are absent or very reduced

Obtuse: blunt or rounded at the apex

Ochrea: a sheath, formed from 2 stipules, encircling the stem in most Polygonaceae

Operculum: the cap-like structure covering the stamens and style of a flower bud (eg. *Eucalyptus*) formed from fused perianth-segments

Opposite: leaves arising at the same level, but on opposite sides, of a stem

Ovary: the basal portion of a carpel or group of fused carpels in which one or more ovules are enclosed, and which develops into the fruit after fertilisation

Ovule: the egg-containing structure (within the ovary of an angiosperm) consisting of a megasporangium (nucellus) surrounded by integuments,. Develops into the seed after fertilisation

Ovum: female gamete

Palmate: divided into leaflets that diverge

from the same point (the end of the petiole)

*Panicle (*hence *paniculate)*: a much branched, racemose inflorescence, of stalked flowers

Pappus: a circle or tuft of bristles, hairs or feathery processes in place of the calyx on florets in the Asteraceae, which persists on the seed (cypsella) and aids in dispersal by wind

Parietal placentation: the ovules attached to placentas arranged around the outer wall of an ovary which has a single cavity on the outside

Paripinnate: a pinnate leaf without a terminal leaflet (cf. *imparipinnate*)

Pedicel: the stalk of each single flower within an inflorescence or flower cluster

Pedicellate: on a pedicel; being stalked

Peduncle: the stalk of an inflorescence or of a solitary flower or of a sporocarp

Pedunculate: on a peduncle

Pellucid: transparent

Peltate: having the stalk (petiole) attached at the back and more or less in the centre (of the leaf lamina)

Perennial: living for more than two years

Perfect flower: a bisexual flower, possessing all parts i.e. fertile stamens, ovary, petals and sepals)

Perianth: the calyx and corolla, especially when they are morphologically similar

Pericarp: the wall of a fruit derived from the ovary wall after fertilisation

Pericycle: the region of a stem or root immediately outside the phloem (and inside the endodermis when present); often includes bundles of fibres.

Perigynous: referring to perianth (sepals and petals) which are attached to the floral receptacle (ie. stem tissue) at the same level as the ovary (ie. neither above nor below the ovary). See Fig. 2.5 centre

Persistent: remaining until the part that bears it is fully matured

Petal: one of the (usually) conspicuous segments forming the inner whorl of the perianth (corolla)

Petaloid: assuming the characters of petals

*Petiole (*hence *petiolate):* the stalk of a leaf

Petiolule: the small stalk of a pinna, pinnule etc.

Phyllode: a flat petiole of leaf-like appearance, that takes on the function of a leaf

Phyllotaxis: pattern of attachment of leaves on the stem: eg. alternate (one leaf at each node), opposite (two leaves at each node), whorled three or more leaves at each node). See Fig. 1.2

Pinna: the primary segment of a divided leaf-lamina

Pinnate leaf: a compound leaf whose leaflets are arranged in 2 rows on opposite sides of a common axis or rachis

Pinnatifid: a leaf blade that is divided into lobes on both sides, about half-way to the midrib

Pinnatisect: a leaf blade that is cut into lobes on both sides down to or almost to the midrib; the lobes or segments not stalked

Pinnule: the ultimate segment of a divided leaflet

Pistil: a free carpel or group of fused carpels

Placenta: the part of the ovary to which the ovules are attached

Placentation: the arrangement of the placentas and the attachment of the ovules to them.

Plesiomorphy: the original or ancestral state of a character from which the other state(s) has/have been derived more recently. cf *apomorphy*

Plumose: feathery, as in the branched pappus hairs of some Asteraceae

Plumule: the shoot (stem and leaf) of an embryo.

Pollinium: a mass of pollen grains cohering by means of their wavy texture or fine threads

Polygamous: having hermaphrodite and unisexual flowers mixed together

Prickle: sharp pointed structure without a vascular supply developed as an outgrowth of the surface of a plant stem or petiole eg. rose prickle

Procumbent: trailing or spreading along the ground, without putting forth roots

Protandrous : having the male parts maturing before the female (eg. the anthers shedding pollen before the stigmas in the same flower are receptive).

Protogynous : having the female organs maturing before the male (eg. stigmas receptive before the anthers of the same flower liberate pollen).

*Pubescent (*hence *pubescence):* covered with short soft hairs

Pulvinus: a swollen base of a leaf or leaflet which brings about movements of the leaf

Pungent ending in a sharp and rigid point, as in holly leaves

Punctate: marked with dots, depressions or translucent glands

Pyriform: pear-shaped

Quincuncial: a type of aestivation (see Fig. A)

Raceme (hence *racemose*): an inflorescence of stalked flowers in which the growing point continues to add to the inflorescence so that the youngest flowers are nearest the apex

Rachis: the axis of a compound leaf bearing pinnae or pinnules. See Fig. 1.1

Radial symmetry: having a plane of symmetry about more than one diameter or axis

Radicle: root of an embryo

Ray: (1) the strap-like part of the corolla of a ray flower of the Asteraceae; (2) the branch of an umbel

Receptacle: the part of the axis which bears the floral parts

Recurved: curved backwards or downwards

Reflexed: bent backwards or downwards at a sharp angle

Regular: flowers having a radially symmetrical perianth

Reticulate: forming a network

Revolute: rolled backwards from the extremity or edge onto the under surface

Rhizome: an underground stem

Rosette: of herbs, a cluster of leaves radiating from a stem at ground level

Rupestral: living or growing on or among rocks

Sagittal: a plane of symmetry; a plane of sectioning that divides an organ into two mirror-image halves

Sagittal Section of a flower: a section drawn from a flower that has been cut vertically into two mirror-image halves.

Scabrous: rough to the touch

Scale: any thin membranous body, usually a degenerate or rudimentary leaf

Scarious: dry and membranous

Scrambler: Plants with weak stems that trail across the ground and over rocks and other plants, often with some erect branches

Scrambling: a weak stemmed plant without special means of securing a hold to support it as a climber; often semi-climbing

Scurfy: scaly, the scales being bran-like

Sepal: one of the segments (usually green) forming the outer of the two whorls of a flower, and collectively known as the calyx

Sepaloid: sepal-like

Septum: a partition

Serrate: notched on the edge with asymmetrical teeth which point forward

Sessile: without a stalk or petiole

Simple: undivided leaves

Spicate: resembling a spike; in the form of a spike

Spike: an inflorescence of sessile flowers (or spikelets in the case of grasses) borne on a simple elongated axis, the youngest flower being at the apex of the axis

Spikelet: a secondary spike; one or more small flowers subtended by one or two bracts within an inflorescence; eg. grasses, sedges

Spinescent: terminating in a spine or a needle-like point, eg. leaves of thistles

Sporophyll: a leaf-like structure which bears one or more sporangia

Spur: a conical or cylindrical projection from the base or side of one of the perianth whorls

Staminode: a sterile stamen, usually modified morphologically

Standard: the large upper petal of a papilionaceous flower (family Fabaceae)

Stellate: star-shaped

Sterile: without reproductive organs

Stigma: that part of the style adapted for reception and germination of pollen

Stipulate: having stipules

Stipule: an appendage, pairs of which occur at the base of the leaf stalk, sometimes fused into a cap protecting the apical bud

Stoloniferous: producing stolons (lateral stems or runners); in the form of a stolon

Style: that part of the pistil situated above the ovary and bearing the stigma

Subtend: to stand below or close to

Succulent: (1) juicy; fleshy - applied either to fruits, leaves or stem; (2) a plant with a fleshy habit

Superior ovary: one which is not embedded in the floral receptacle (stem tissue); ie. the ovary is sitting on the floral axis, although sometimes within a cup-shaped extension of the receptacle; see Fig. 4.5

Sympetalous (synpetalous): with the petals fused together

Symplesiomorph: a shared ancestral trait; a trait that has been inherited by members of a taxon but which was present in a distant ancestor; ie. arose in the lineage leading to the common ancestor of the taxon, and hence may have been inherited by members of related taxa. A common trait that is not unique to the taxon [cf. *synapomorph*]. Note that, since ancestral and derived are relative terms, the taxon must always be defined when this term is used. Eg. cuticle and lignin are symplesiomorphs in seed plants; double fertilisation in Ericaceae.

Sympodial : type of growth where the main axis actually consists of several successive side branches. Growth of the apical bud is repeatedly terminated (often by flowering or formation of a tendril) and initiated from an axillary bud below the apex

Synapomorph: a shared derived trait; a trait that arose within the common ancestor of a taxon but did not predate the taxon, and hence could have been inherited by all members of the taxon, but not by members of other taxa. [cf. *symplesiomorph, autapomorph*]. Note that, since ancestral and derived are relative terms, the taxon must always be defined when this term is used. eg. double fertilisation in angiosperms.

Syncarpous: having the carpels fused into a unit

Taxon: a term used to describe any taxonomic category, eg. subspecies, species, family etc.

Taxonomy: classification; the study of relationships between plants and animals

Tendril: part of a plant modified into a slender elongate organ used in climbing

Tepals: a division of the perianth, either sepal or petal, when these look alike.

Terete: cylindrical, or almost so

Testa: the seed coat

Thorn : a reduced branch with a hard sharp point; it has a vascular supply and is subtended by a leaf or bract eg. *Bouganvillea*

Tomentose: covered with closely matted short hairs

Tomentum: the hairy covering as described in tomentose

Trifoliate (or *Trifoliolate*): describes leaves having three leaflets; trifoliate is sometimes used to mean having three separate leaves

Truncate: terminating abruptly as if cut off transversely

Tubercule: a small wart-like outgrowth, e.g. forming the base of a hair.

Umbel: an inflorescence of stalked flowers in which all the flower stalks or pedicels arise at the tip of the axis (peduncle) and the flowers lie at the same level

Umbellate: in the form of an umbel

Valvate: (1) parts (eg. petals) arranged with the edges touching; (2) fruit etc. opening by valves

Valve: a distinct portion into which some organs break

Versatile: anthers joined to the filament by the midpoint and swinging freely

v.i.: vide infra, see below

Villous: covered with long weak hairs

v.s.: vide supra, see above

Whorl: a group of three or more leaves or appendages arising from the axis at one level

Xeromorphic: possessing structural features that appear likely to confer resistance to aridity e.g. leaves much reduced in size, rolled, covered by a thick cuticle and/or hairs.

Xeromorphosis: changes induced by the action of increased temperature eg. the thickening of the epidermis.

Xerophyte: a plant which can subsist with a small amount of moisture eg. a desert plant.

Zygomorphic: a bilaterally symmetric flower