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FERNS AND GYMNOSPERMS

Module C



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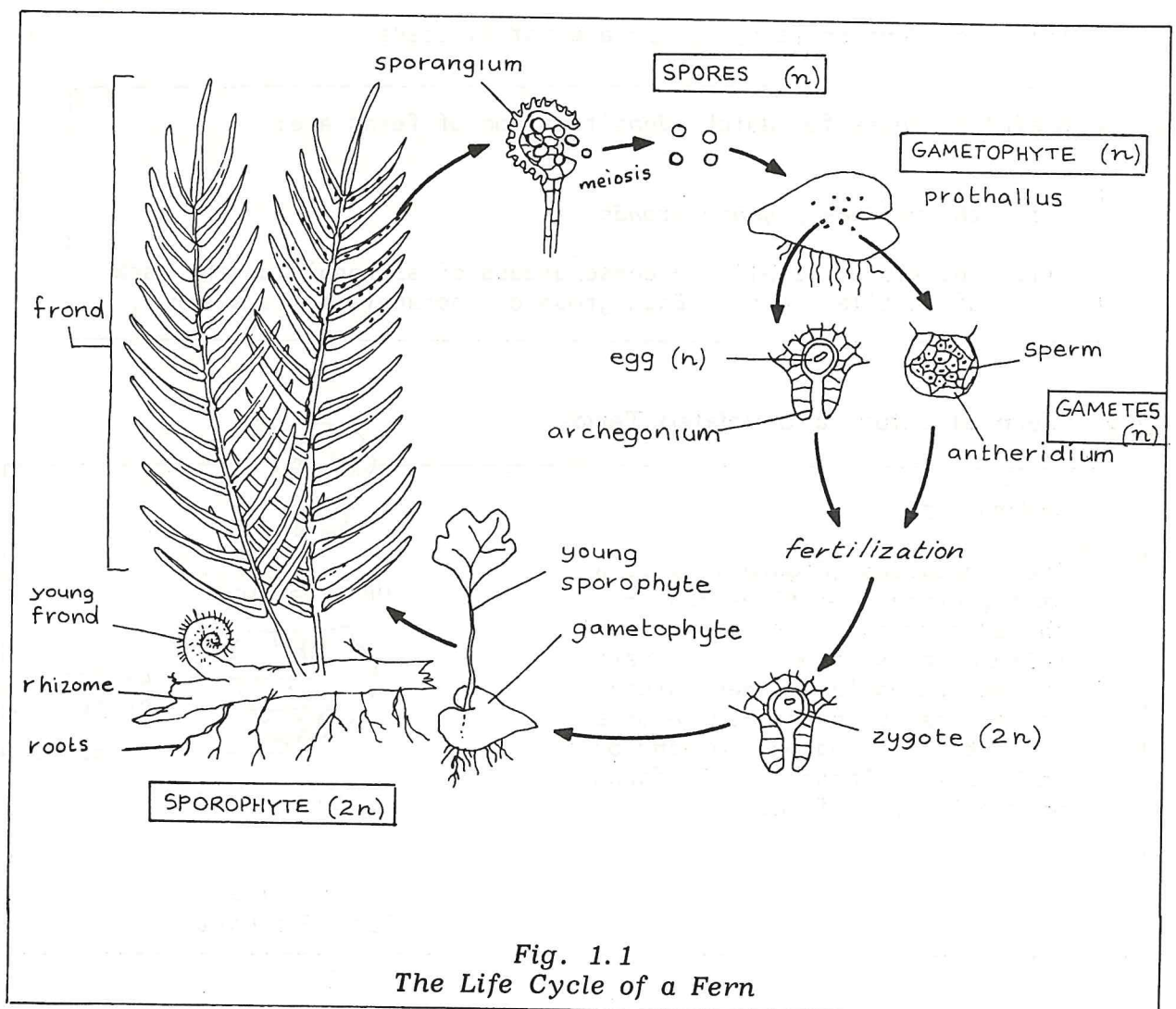
Chapter 1

1.1 General Characteristics and Life Cycle

True ferns belong to the class Filicopsida. This class is made up of about 10,000 species. There are about 107 genera and 350 species in the Australian flora.

The general characteristics of the group are:

- (a) The life cycle is made up of *two distinct stages*: a *sporophyte* and a free-living *gametophyte* stage. The sporophyte produces spores. The gametophyte produces gametes. These alternate regularly in the life cycle. This process is known as an *alternation of generations*. (See Figure 1.1)



- (b) The *sporophyte* stage is the prominent generation. The plant is made up of stems, roots and fronds. The stem in most ferns is underground and is called *rhizome*. Roots arise directly from the rhizome.

On the lower surface of fertile *fronds* are clusters of spore cases (sporangia, singular *sporangium*). Each group of sporangia is called a *sorus* (pl. sori). Spores are produced in the sporangia. The sporophyte is diploid ($2n$). Spores are haploid (n); i.e., they have half the number of chromosomes in the sporophyte. The spore germinates to form the gametophyte.

- (c) *Gametophytes* are small, delicate, green plants called *prothalli* (sing. *prothallus*). These are haploid and produce sex organs. The female sex organ is called *archegonium* (pl. archegonia). It produces an *egg* or *ovum*. The male sex organ is called *antheridium* (pl. antheridia). It produces free swimming *sperms*. The sperms swim across free water to reach the egg in the archegonium. A sperm unites with an egg to form a *zygote*. This is referred to as *fertilization*. The zygote is diploid and grows to form a new sporophyte.

- (d) Reproduction is by *spores* and not by seeds.

Useful features for quick identification of ferns are:

- i. the *rolled-up young fronds*
- ii. the spores usually in dense groups of sporangia on the back of fertile fronds. Each group of sporangia forms a *sorus*.

1.2 Fern Structure and Related Terms

GAMETOPHYTE

The *prothallus* (Figure 1.2) is a small, green, sometimes heart-shaped structure. Fine hair-like *rhizoids* arise from various parts of the prothallus. When mature, the prothallus bears *female organs* or *archegonia* and *male organs* or *antheridia*. These are all found on the lower surface.

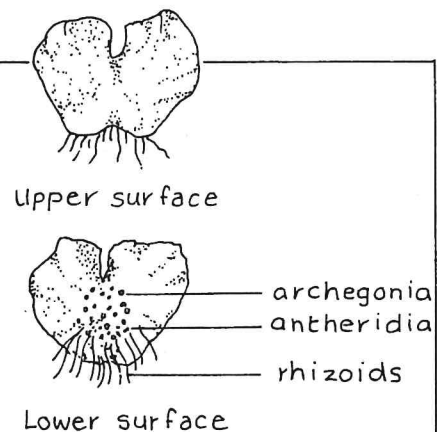


Fig. 1.2
Fern Prothallus

The antheridia burst in the presence of water releasing motile sperm cells. The sperms swim towards the archegonia. These fertilize the eggs within the archegonia. The resultant diploid zygotes develop into sporophyte plants. (Figure 1.3)

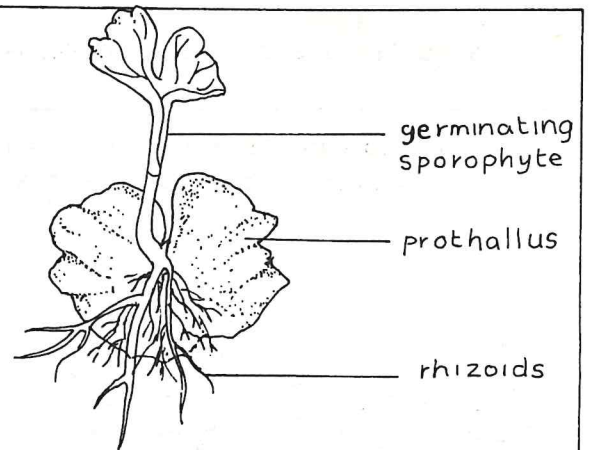


Fig. 1.3
Prothallus with Germinating Sporophyte

SPOROPHYTE

The fern sporophyte is made up of a stem (rhizome) that bears leaves (fronds) and roots (rhizoids). (See Figure 1.4)

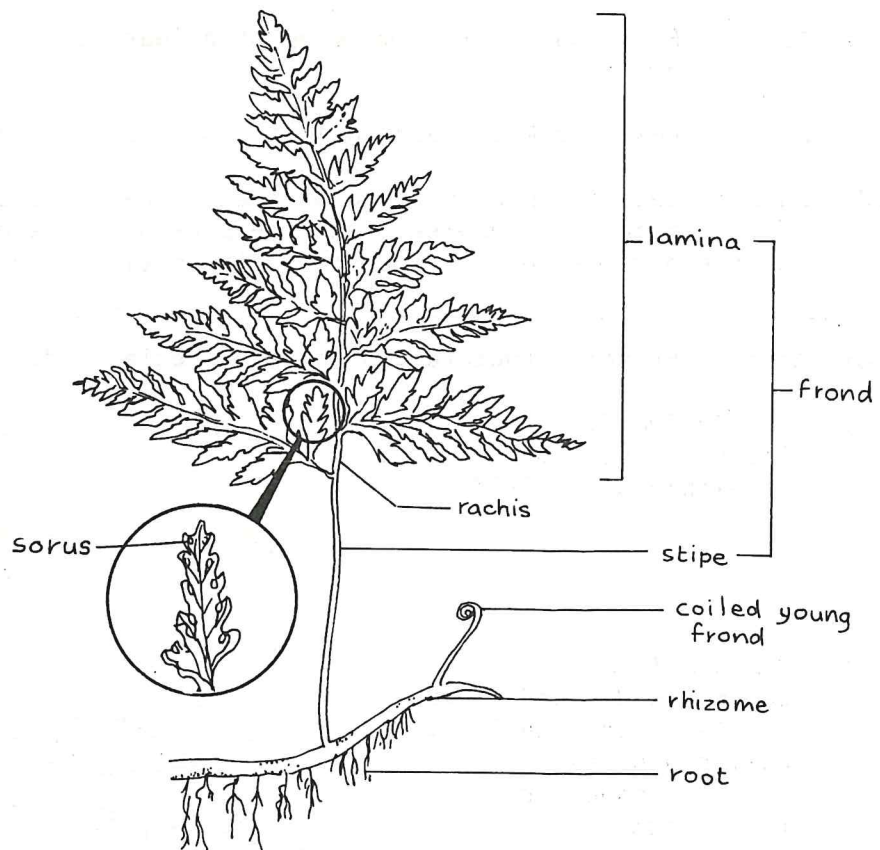
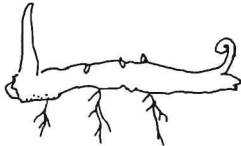


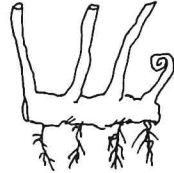
Fig. 1.4
Davallia sp. showing rhizome, frond, young frond and rhizoids.

Some terms are unique to ferns. These are explained below:

- (a) *Rhizome* (Stem). They can be long-creeping, medium-creeping, short-creeping or erect and tufted.



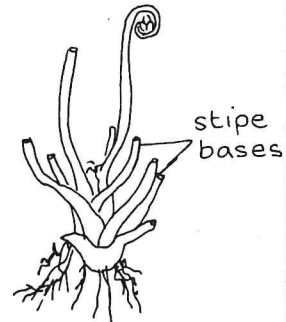
Long-
Creeping



Medium-
Creeping



Short-
Creeping



Tufted

WOODY TRUNK

In tree ferns, the upright woody trunk is hard on the outside and soft on the inside. Part of the outside is made up of masses of tough aerial roots.

- (b) *Frond*. Fern leaf. It is made up of a leaf stalk and a lamina.

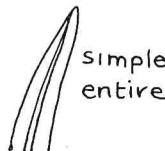
- (c) *Stipe*. Leaf stalk between rhizome and base of lamina.

- (d) *Rachis*. Leaf stalk above base of the lamina. The colour of the stipes and rachises, and the presence of scales, hairs and tubercles are important diagnostic features.

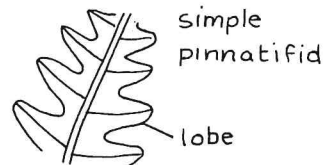
- (e) *Lamina* (Frond) structure can be very specialised.

- i. *Simple frond*:

These can be simple entire or simple pinnatifid.



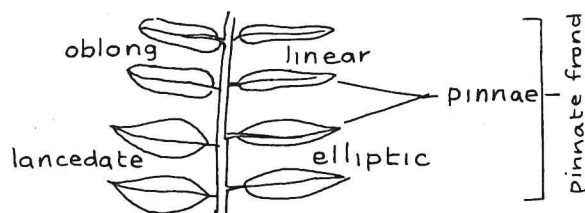
Simple
entire



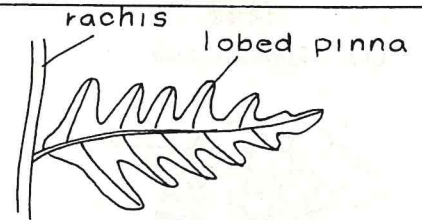
Simple
pinnatifid

- ii. *Pinnate frond*:

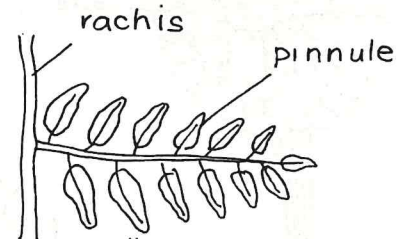
Lamina is divided to the rachis. Each leaflet is called a pinna. Leaflet shapes are illustrated.



- iii. *Bipinnatifid frond*:
Pinnae are lobed.



- iv. *Bipinnate frond*:
Pinnae further subdivided
to form pinnules.



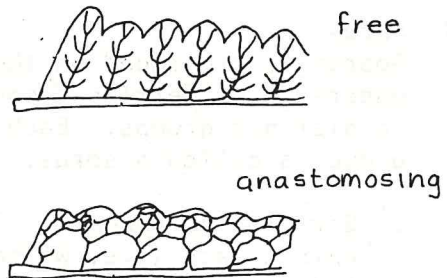
- v. *Trippinnatifid frond*:
Pinnules are lobed.



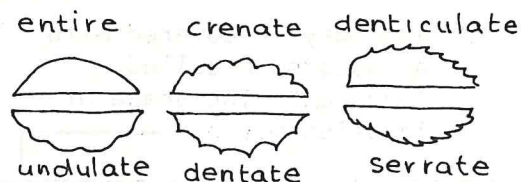
- vi. *Trippinnate frond*:
Pinnules are further
subdivided.



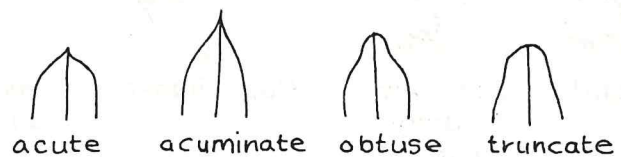
- (f) *Leaf venation*:
where veins branch and
do not join, the venation
is free. Where veins
rejoin to form a network,
the venation is
anastomosing.



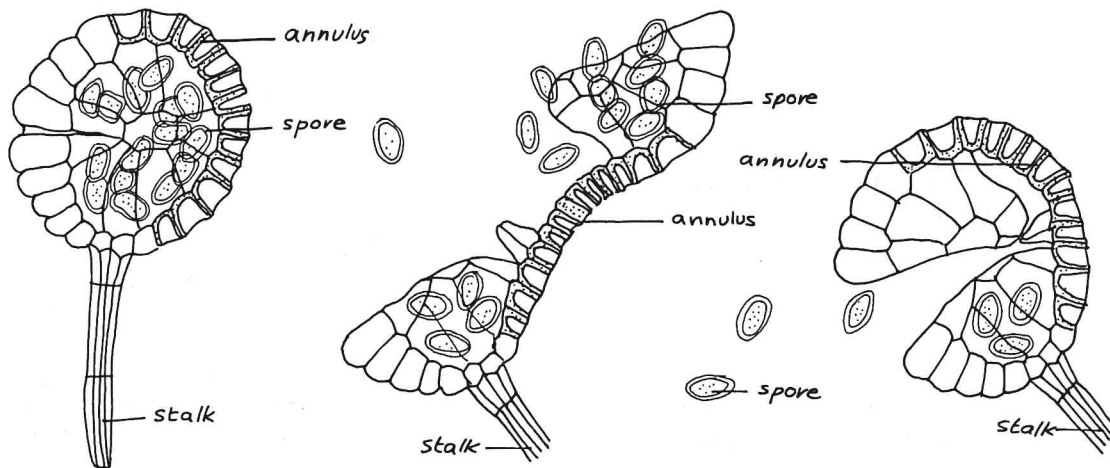
- (g) *Leaf margin*
can be entire, undulate,
crenate, dentate,
denticulate or serrate.



- (h) *Leaf apices*
can be acute, acuminate,
obtuse or truncate.



(i) Sporangium



A sporangium is a spore-containing sac on a stalk.

When the sporangium is ripe and the air is dry, the row of special cells called annulus springs back, ruptures the sac and releases some spores.

The annulus then snaps back into position and releases more spores.

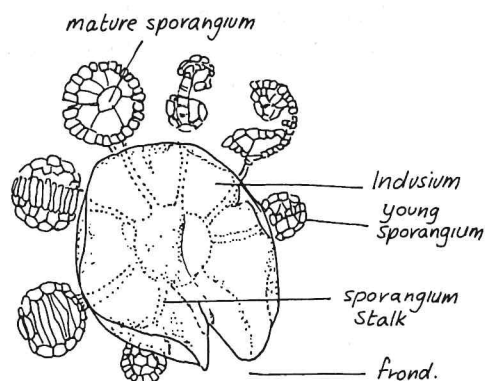
(j) Sorus

Sporangia are found on the underside of fertile fronds in distinct groups. Each group is called a sorus.

- Sori may be *naked* or *exindusiate* (i.e. without indusium)

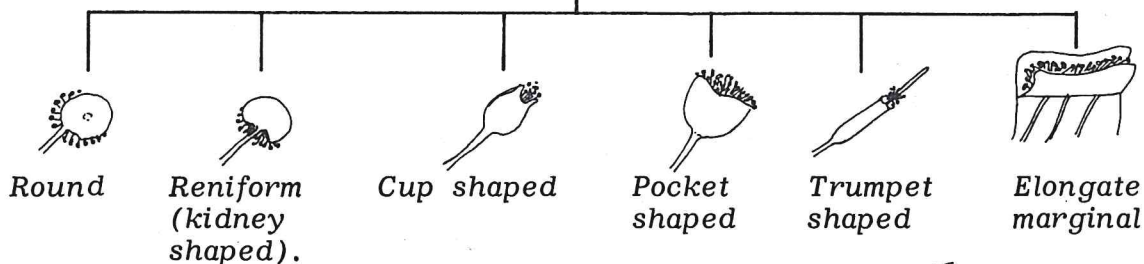


Sorus without indusium



Sorus with indusium

- Sori may be covered with an outgrowth called *indusium*. The shape of indusium may be:



- Sori may be covered with a *false indusium*. A false indusium is formed by the reflexed leaf margins.



1.3 Four Common Genera of Ferns

(The classification of these ferns is as set out in Clifford & Constantine, 1980*)

Adiantum Maidenhair ferns (Adiantaceae)

This genus is widely cultivated throughout the world. There are nine Australian species. Small to large ferns. Rhizomes creeping covered with dark scales. Stipes slender, wiry, dark brown to black. Lamina 1 to 4 times pinnate. Pinnule often thin, delicate, unequally sided. Sori occur along margins on the underside of the pinnules, protected by kidney-shaped false indusia.

There are many beautiful species that make attractive pot plants. Some examples are:

A. aethiopicum. Common Maidenhair Fern, Figure 1.5. Widespread, Stipe reddish brown, slender, arising from a tufted rhizome. Pinnules delicate and wedge-shaped.

A. hispidulum. Rough Maidenhair Fern or Five-finger Jack. Fronds branched in a finger-like manner. Pinnules numerous and rough.

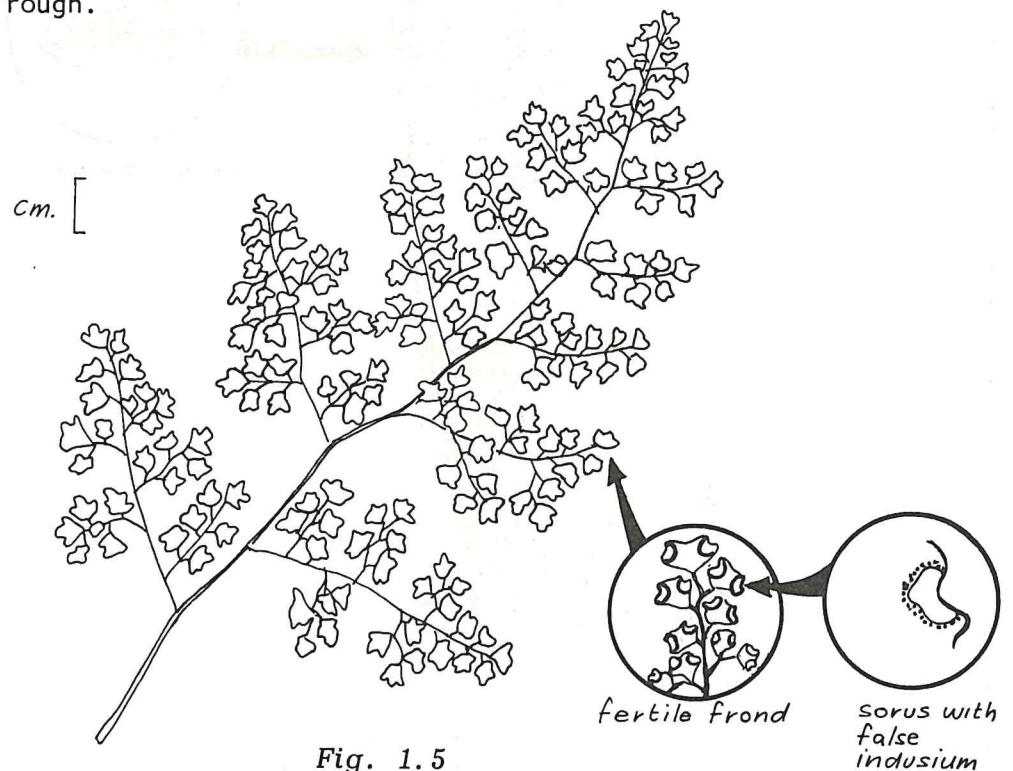


Fig. 1.5
Adiantum aethiopicum (common maidenhair fern). Fertile frond.

*Clifford, H.T & Constantine, J. *Ferns, Fern Allies & Conifers of Australia* (1980). University of Queensland Press.

Nephrolepis Fishbone Fern (Oleandraceae)

Widely cultivated. Commonly grown as garden and indoor plants.

Rhizomes tufted, bearing clumps of fronds and slender runners. Rhizomes and runners scaly. Fronds erect or arching, narrow, pinnate. Pinnae sessile, falcate, margins crenate. Sori round, located near edges of pinnae. Indusium reniform.

There are about 30 widely spread species; 6 are found in Australia. These include *N. cordifolia*, (Figure 1.6), *N. hirsutula* and *N. oblitterata*.

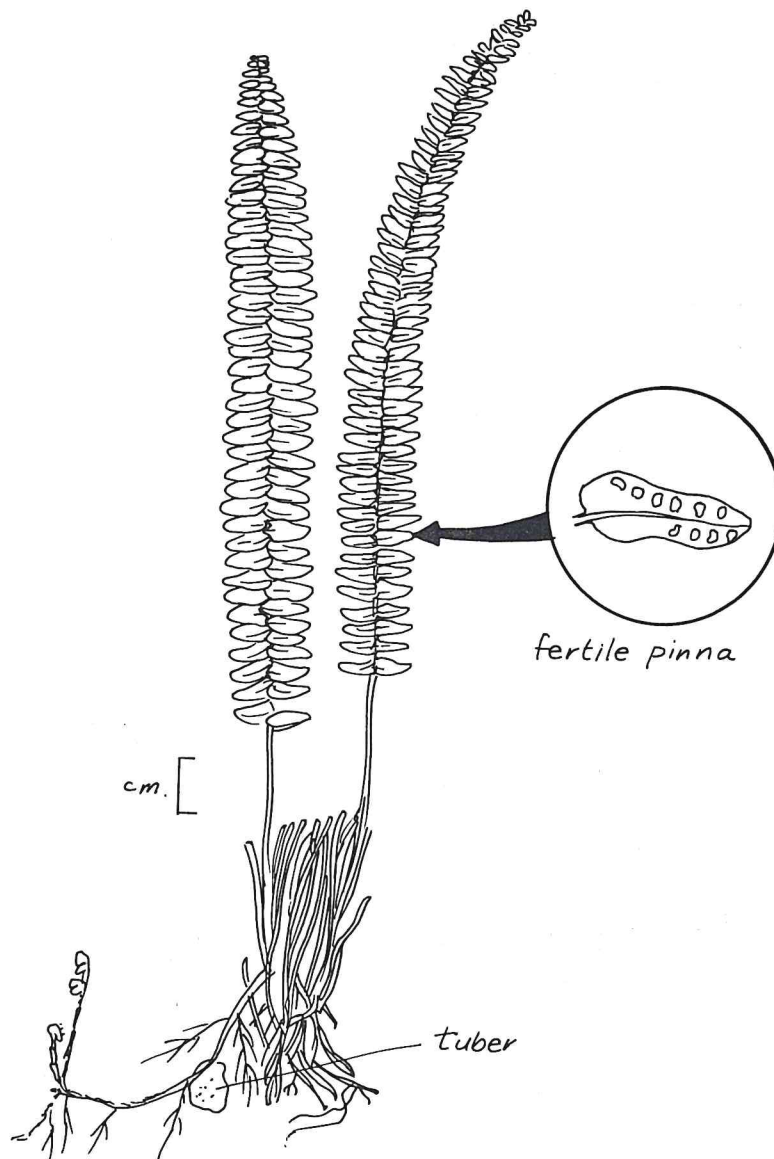


Fig. 1.6
Nephrolepis cordifolia
(fishbone fern). Showing fertile frond.

Pteridium Brackens (Dennstaedtiaceae)

Terrestrial ferns with extensively creeping, woody rhizomes covered with reddish-brown hairs. Stipes stiff, erect, glabrous, shallowly grooved. Fronds large, stiff, leathery, triangular, dark green above and lighter beneath, 3 or 4 times pinnate. Sori in a thin continuous line on the edges of the pinnules. Indusium two-lipped, the inner one a true papery indusium, the outer one a false indusium formed by the leaf margins turned downwards.

Brackens are widespread around the world and in Australia. Their classification is still controversial. There are three local species in Australia that are sometimes regarded as one species with three geographic sub-species.

Brackens are found in a wide variety of habitats, but always on well drained soil. Brackens can become a nuisance because they spread quickly and can cover large areas. When eaten in large quantities, they can induce poisoning in animals. Brackens are difficult to transplant.

The most widespread Australian species is *P. esculentum*.

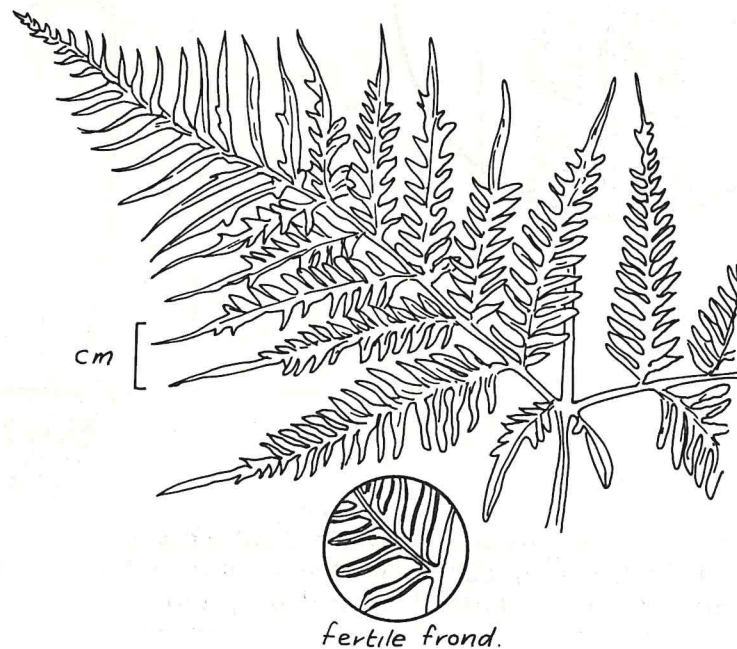


Fig. 1.7
Fertile frond of *Pteridium esculentum*
(Australian bracken)

Asplenium, Spleenworts (Aspleniaceae)

Epiphytes, lithophytes or terrestrial.

Rhizomes tufted or creeping, covered with greyish-brown to purple small scales. Rachis grooved. Fronds erect, arching or weeping; simple, pinnate or bipinnate. Sori elongated, mainly in lines on the edges of small veins, and covered by an indusium that opens towards the midrib. There are about 650 species in the genus. About 20 are found in Australia. Some species are very variable and some forms are popular as horticulture plants.

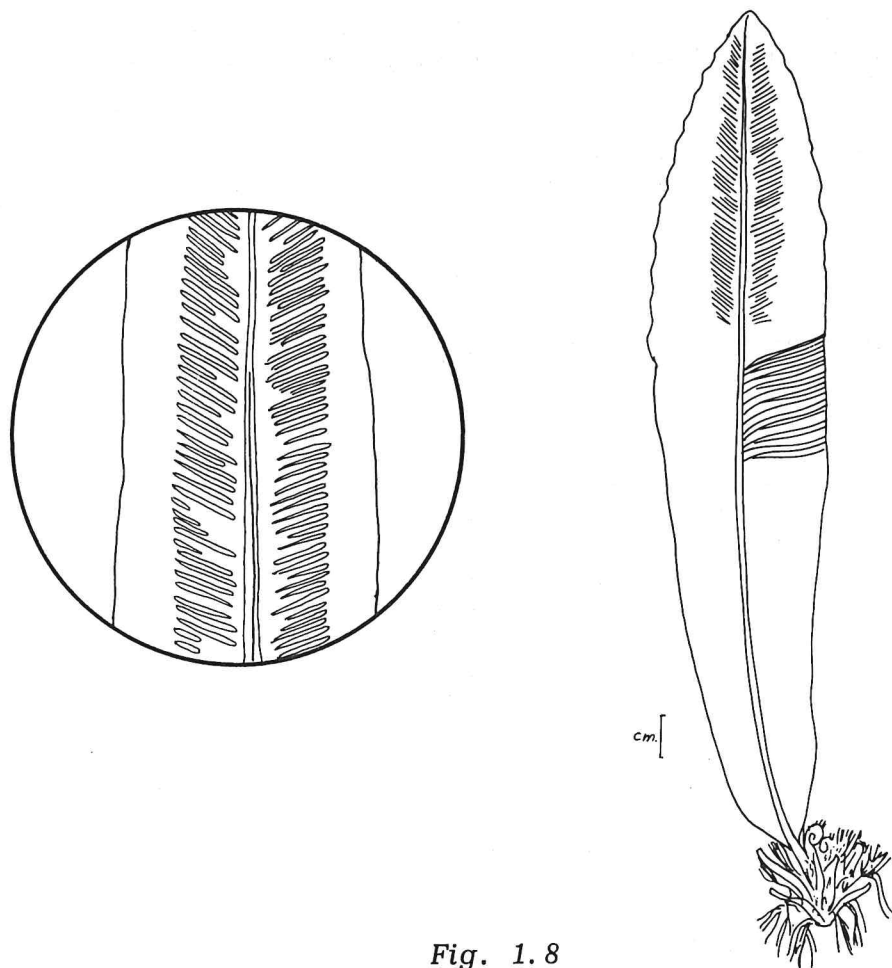


Fig. 1.8

A. nidus (Bird's Nest Fern)

A large fern with long simple entire fronds arising in a rosette from a central base. Potted as indoor plant.

NOTE: The more commonly grown "Bird's Nest Fern" is actually *A. australasicum*. It can be distinguished from *A. nidus* by:

- i. Its midrib being more acutely keeled on under-surface of frond, &
- ii. Its sori occupying more than half the length of vein (half or less than half in *A. nidus*).

1.5 A Key to Selected Genera of Ferns

- a. Sorus without indusium.
 - b. Sori linear, more or less blended into one ... *Angogramma* (Rue fern).
 - bb. Sori rounded.
 - c. Fronds 1 - pinnatifid.
 - d. Veins free *Polypodium* (polypody ferns)
 - dd. Veins reticulated .. *Phledodium*
 - cc. Fronds 2-3 pinnate *Dryopteris* (Male ferns)
- aa. Sorus with indusium.
 - b. Sori under edge of reflexed leaf margin which forms the indusium.
 - c. Fertile segments with sori separate and distinct, not confluent in a marginal line *Adiantum* (Maidenhair fern)
 - cc. Fertile segments with sori forming a continuous marginal line..... *Pteridium* (Bracken)
 - bb. Sori on the back of pinnae.
 - c. Shape of sori linear or oblong ... *Asplenium* (Spleenwort)
 - cc. Shape of sori round or reniform.
 - d. indusium peltate or umbrella shaped attached to middle of sorus ... *Cyrtomium* (Holly Fern)
 - dd. indusium reniform attached to one side of the sorus ... *Nephrolepis* (Fishbone fern).

(Reproduced with permission from the Botany Department, University of Western Australia)

Chapter 2

2.1 Distinctive Characteristics of Gymnosperms

Gymnosperms, like angiosperms, are *seed bearing plants*. Seeds of angiosperms are enclosed within fruits, e.g. tomato. In other words, seeds are completely surrounded by a continuous covering of fruit tissue (see Figure 2.1A). The distinctive feature of gymnosperms is that *seeds are borne exposed on the surface of cone scales*.

The scales of most young cones are usually arranged close together in a tight fit, so that seeds appear completely surrounded and hidden from view. These scales, however, are never actually united. Seeds in gymnosperms are typically said to be *naked*. *Naked-seed plants* are collectively called gymnosperms.

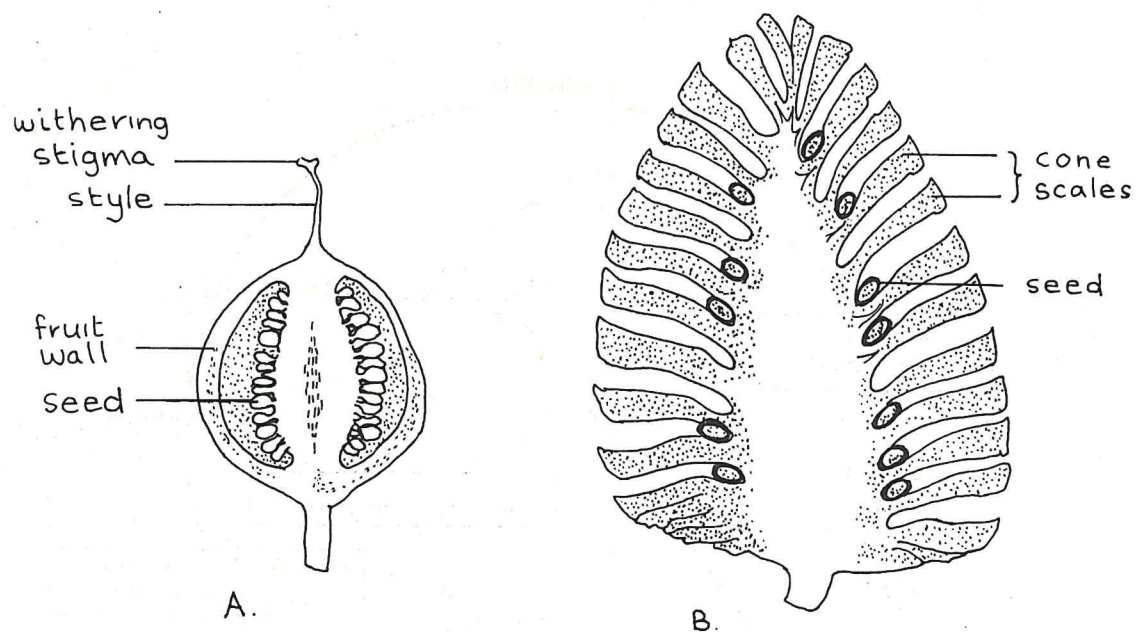


Fig. 2.1

- A. An angiosperm fruit showing seeds enclosed in a fruit (LS)
- B. A mature gymnosperm cone showing seeds borne on cone-scales (LS)

2.2 Life Cycle of Gymnosperms

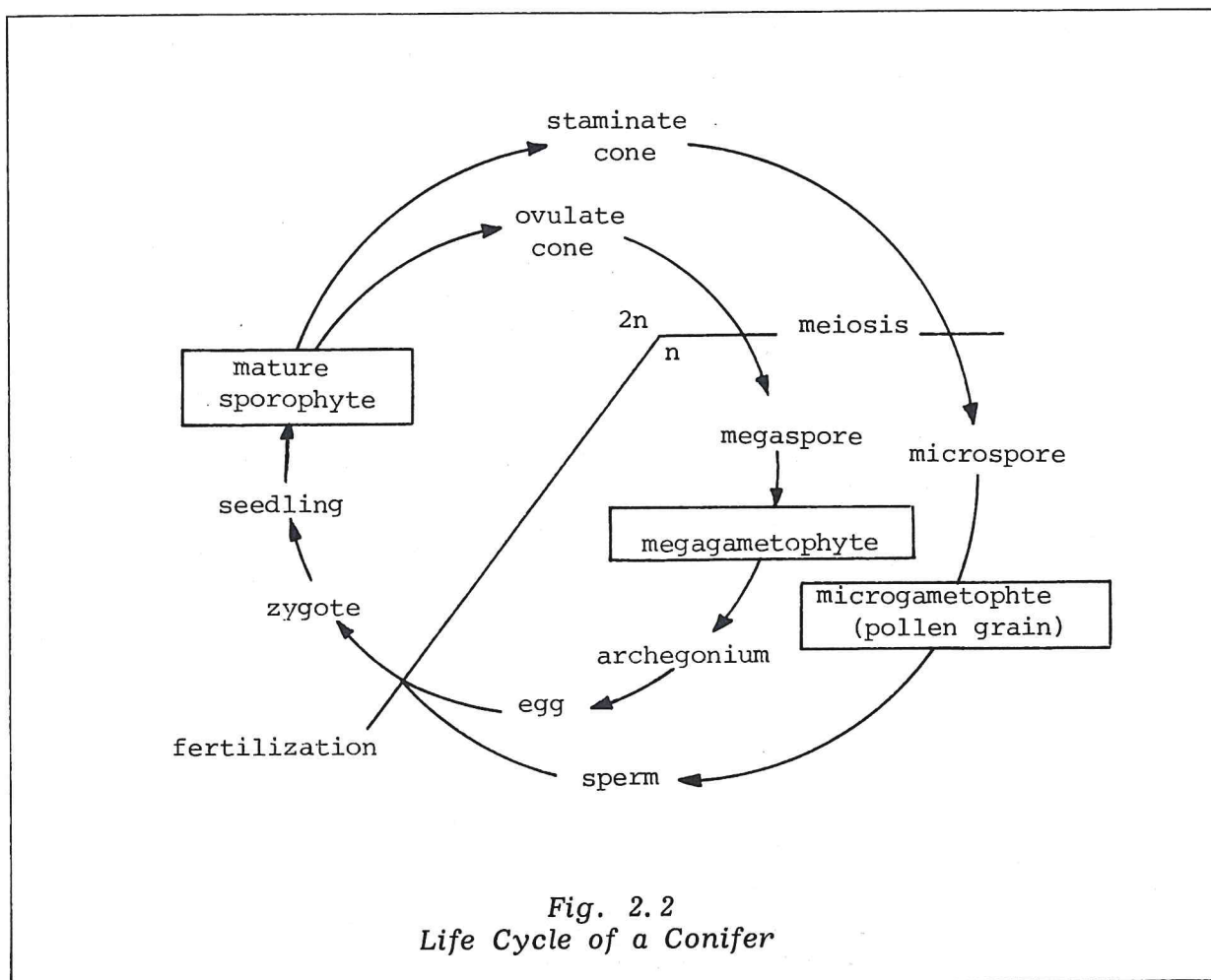
The life cycle of gymnosperms (Figure 2.2) is made up of two stages as in ferns. These are:

- (a) the sporophyte stage and
- (b) the gametophyte stage.

The sporophyte is green and independent. In general, the sporophytes of gymnosperms are larger than those of ferns. They vary from the palm-like Cycads to the giant Redwood trees (*Sequoia sempervirens*) which attain heights exceeding 100 m in California. Two kinds of spores are produced, namely

- i. microspores (σ spores)
- ii. megaspores ($\wp$ spores)

Microspores are produced on staminate (σ) cones. Megaspores are produced on ovulate ($\wp$) cones.

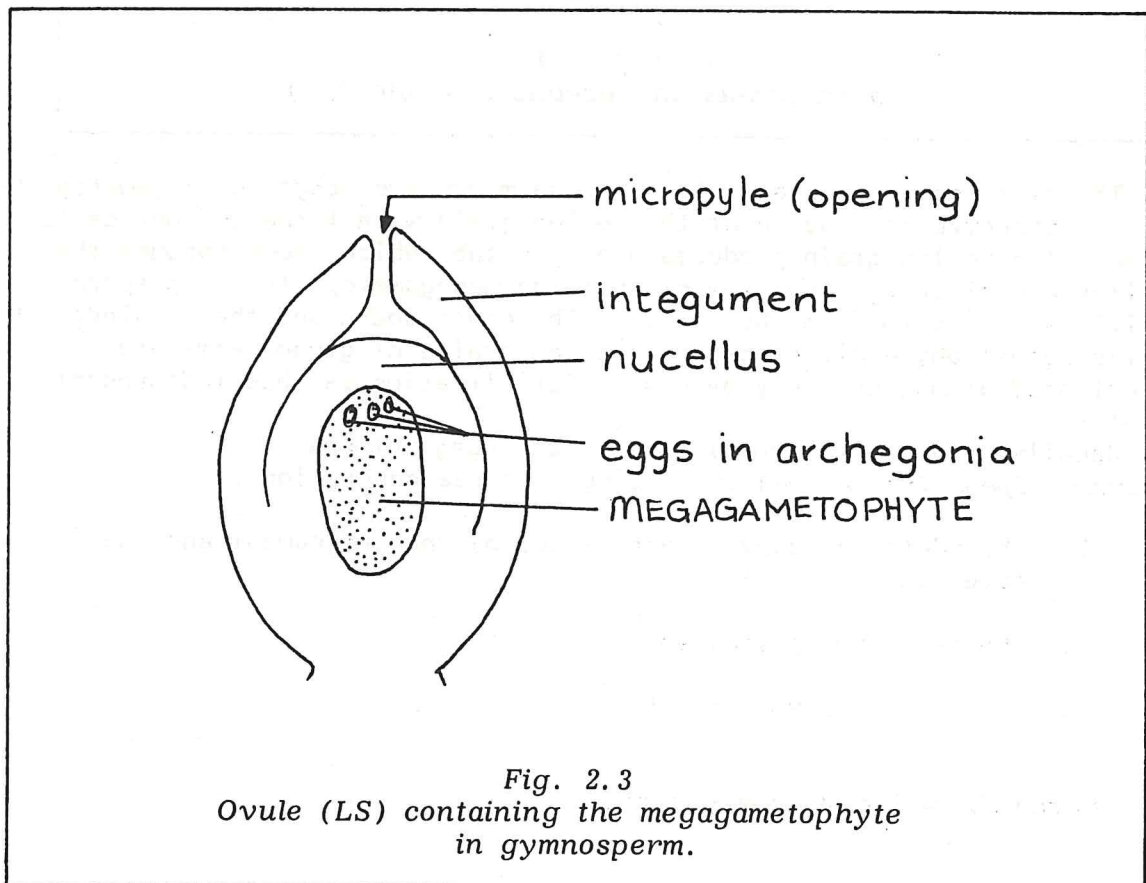


Gametophytes are much smaller and simpler than those of ferns. They lack chlorophyll and are completely dependent on the sporophytes. There are two types of gametophyte in gymnosperms:

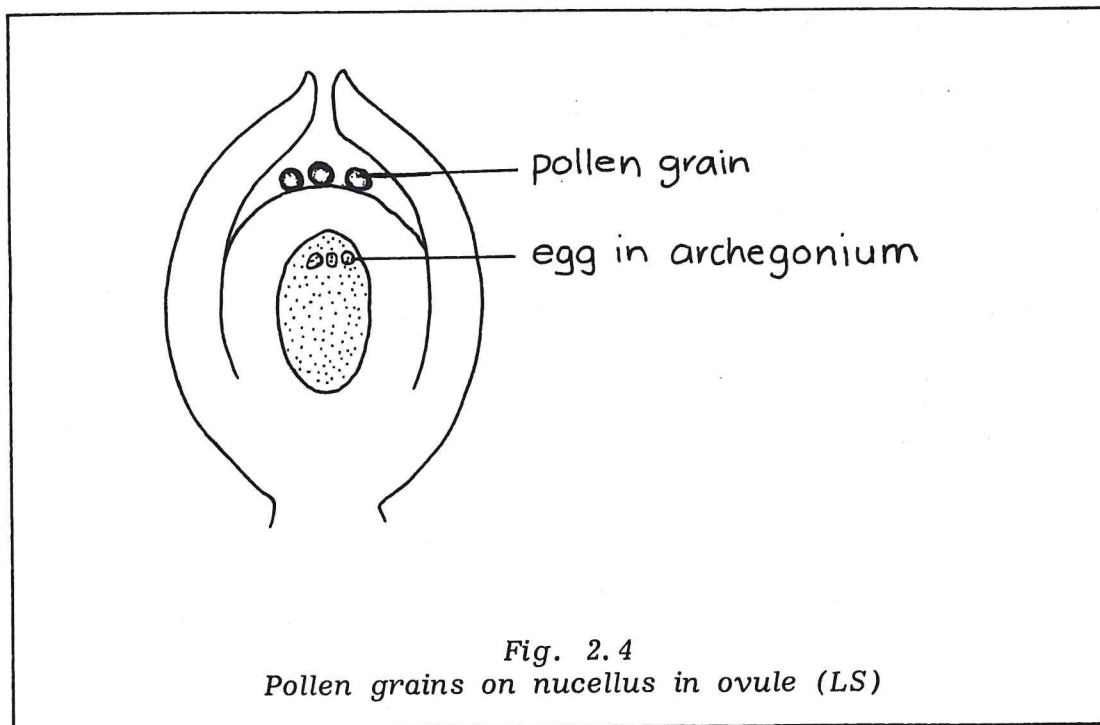
- i. megagametophyte and
- ii. microgametophyte.

The literal meaning of megagametophyte is "large gametophyte"; "mega" in this context can be considered synonymous with female (♀) gametophyte. Similarly, the microgametophyte means "small gametophyte"; the prefix "micro" can be considered synonymous with male (♂).

The megaspore located within the ovulate (♀) cone grows to form the megagametophyte or ♀ gametophyte. The ♀ gametophyte consists of a single large cell with a few archegonia. Each archegonium contains an egg. The megagametophyte is located within an ovule (see Figure 2.3)



When the ovule is mature, a few cells of the nucellus distintegrate to form a sticky fluid. This exudes from the micropyle. When pollen grains are blown by wind to the surface of the ovule, many of them stick to the fluid. When the fluid evaporates, the pollen grains are pulled down the micropyle to rest on the nucellus (see Figure 2.4).



The microspore germinates to form the *microgametophyte* or σ *gametophyte*. The σ gametophyte is made up of the pollen grain with three to four cells inside. The pollen grain produces a pollen tube which grows through the nucellus and discharges *two sperms* into the megagametophyte. One sperm fertilizes an egg to form the *zygote*. The other sperm and the remainder of the microgametophyte disintegrate. Pollen grains of gymnosperms are disseminated almost entirely by wind. Fertilization is thus independent of water.

Usually only one embryo lives in each megagametophyte.
The ovule ripens into a seed consisting of three generations:

- i. the adult sporophyte represented by the integument and the nucellus.
- ii. the megagametophyte, and
- iii. the young embryo sporophyte

2.3 Three Examples of Gymnosperms

The structure and life history of the *Zamia* palm, the Maidenhair tree and the Pine tree are considered in this course. The classification of these are tabulated below:

	1	2	3
Class	Cycadopsida	Coniferopsida	Coniferopsida
Order	Cycadales	Ginkgoales	Coniferales
Family	Cycadaceae	Ginkgoaceae	Pinaceae
Scientific name	<i>Macrozamia riedlei</i>	<i>Ginkgo biloba</i>	<i>Pinus radiata</i>
Common name	Zamia palm	Maidenhair tree	Pine tree

2.4 Cycadaceae (the Cycad Family)

A family of 9 genera and about 100 species confined to a few restricted areas, mainly in the tropical and subtropical regions of the world.

The four genera found in Australia are *Macrozamia*, *Cycas*, *Lepidozamia* and *Bowenia*.

The family is different from all other gymnosperms in the following features:

- i. the compound leaves
- ii. the palmlike habit, and
- iii. the abundant scattered microsporangia on the male cone scales.

Macrozamia

(a) *Habit*

Woody, palmlike shrubs, to 3 m high.

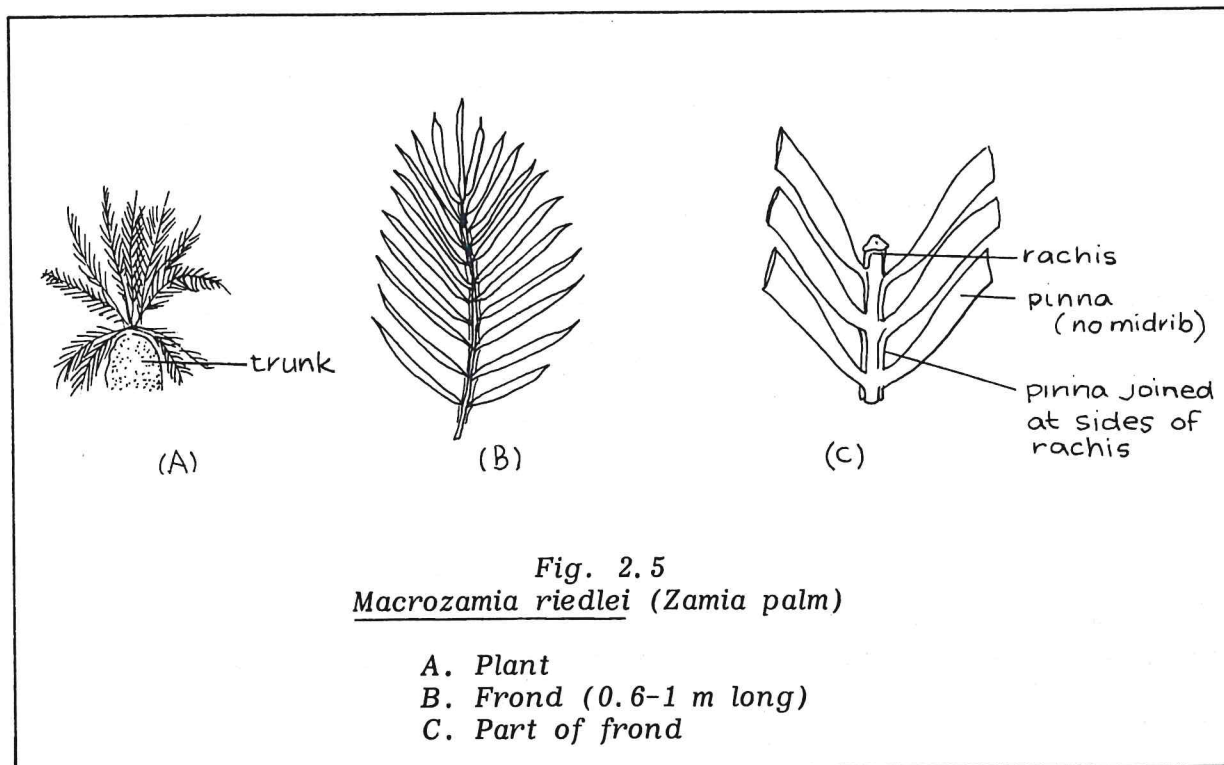
Trunk thick, tuberous and mostly underground.

(b) *Leaves*

Pinnately compound leaves or frond.

Arranged at the top of the trunk in close spirals to form crowns of leaves.

The leaflets or pinnae are tough, leathery and sharply pointed. They are attached to the edges of the rachis and have no midrib. See Figure 2.5.



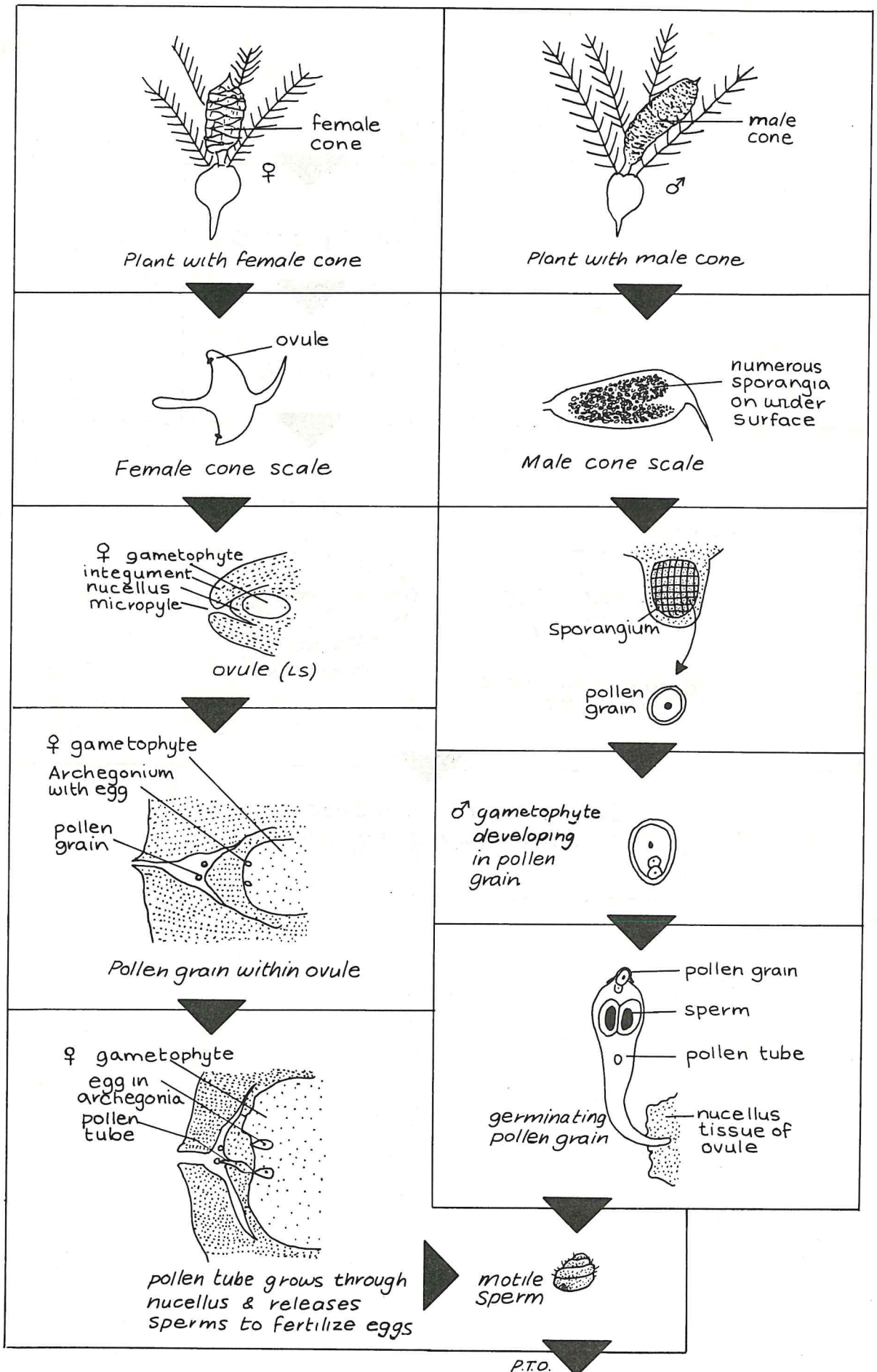
(c) Cones

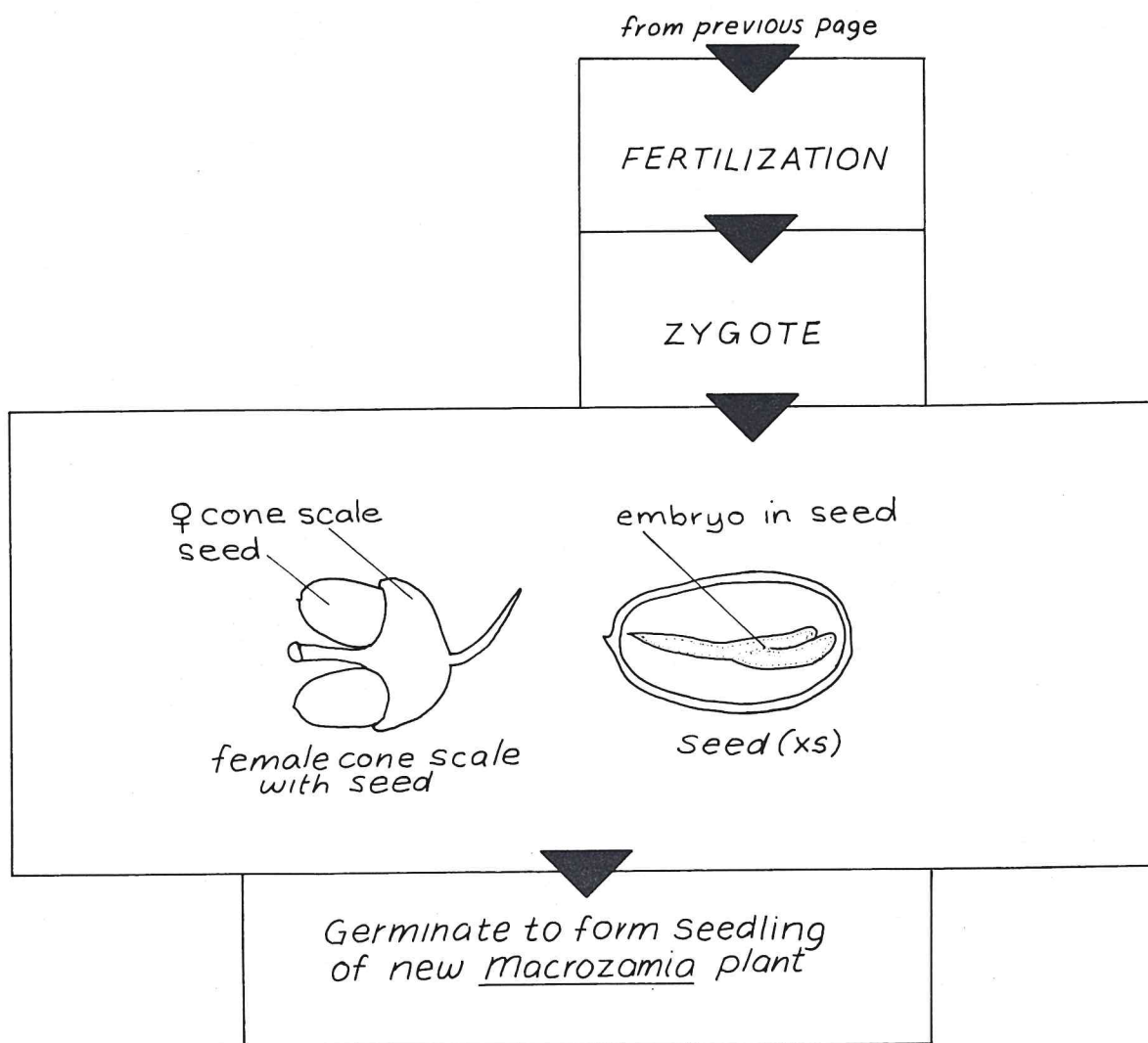
Male and female cones on separate plants.

Cones are located at the tip of trunk on short peduncles. Male (pollen-producing) cone scales bear numerous sporangia. Female (ovule-bearing) cone scales bear marginal ovules. Seed cones (i.e. female cones with seeds) are large and look like pineapples. Seeds are smooth, large and nut-like. They drop off when almost ripe. They germinate easily, but the seedlings grow very slowly.

(d) Life cycle

The life cycle of *Macrozamia* is pictorially represented on the following pages.





(e) *Chronology of Reproductive Stages in Macrozamia riedlei*

The times given for any one stage are only approximate as different stages of development may vary by several weeks for different plants in the same locality.

Month	Female cone	Male cone
	The time of initiation of male and female cones is not known.	
March	Cones still hidden in crown of the plant	
	Ovules approx. 1 mm long;	cones about 2 mm long; sporangia not developed
April May	Cone exposed in crown of plant.	sporangia developing
June July August	Ovule and ♀ gametophyte developing.	sporophylls tightly packed; pollen grains developing
Sept. Oct.	pollination	rapid elongation of axis with separation of cone scales; pollen shed
Dec. Jan.	Fertilization	pollen tube grows through nucellus. Sperm shed
Feb. March June	seed shed.	
July Sept.	embryo enlarging	
Oct.	cotyledons forming	
April May	germination of seed	

2.5 Ginkgoaceae (the Ginkgo Family)

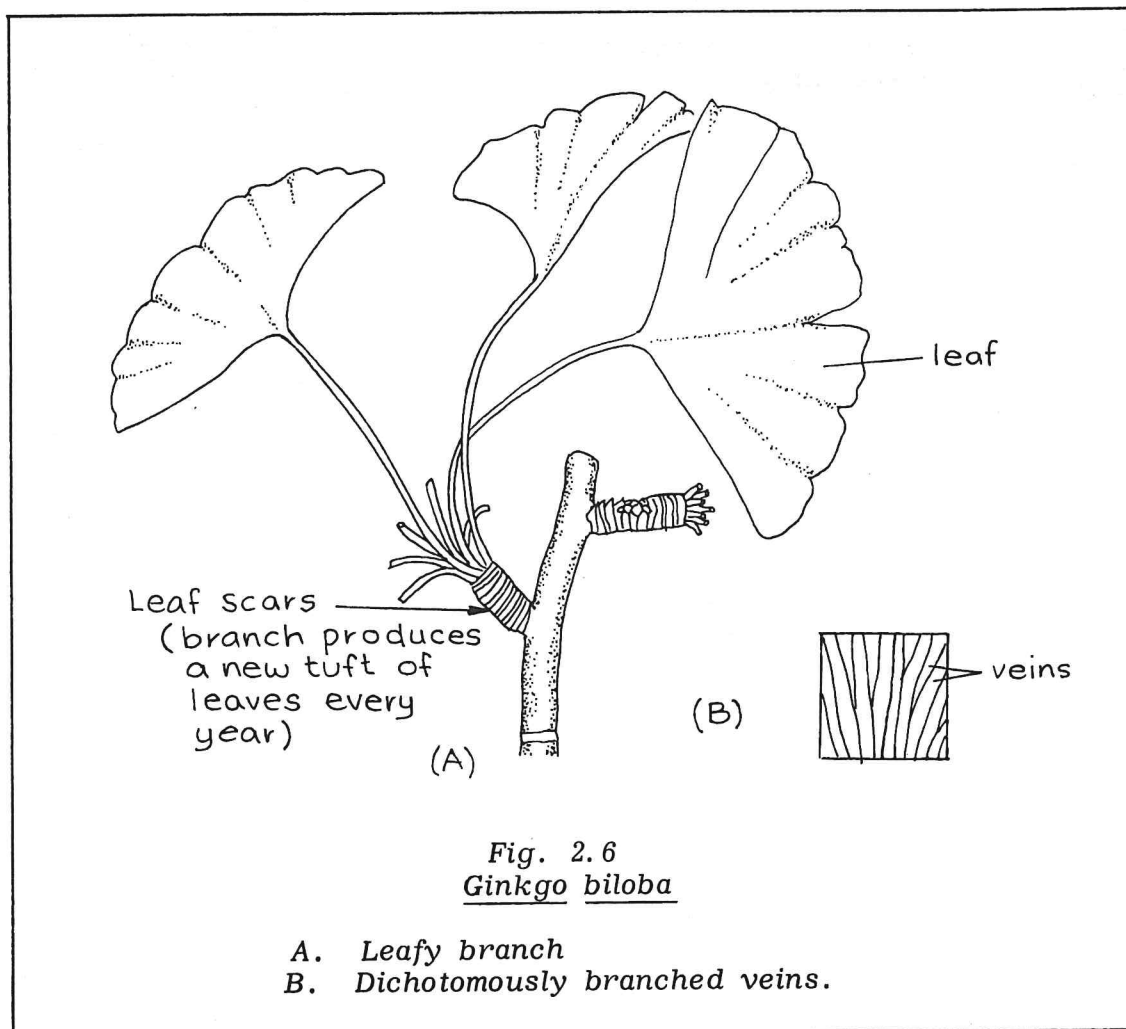
The Ginkgo, or Maidenhair tree (*Ginkgo biloba*) is the only species of the single genus in the family. It originates in Western China and is now widely cultivated as an ornamental tree in temperate countries.

(a) *Habit*

Much branched, dioecious, deciduous tree which grows to about 30 m high.

(b) *Leaves*

Fan-shaped, often two lobed (see Figure 2.6).
Veins are parallel and branch dichotomously.
The leaves look very much like those of Maidenhair fern except for being larger and coarser. Because of this resemblance, *Ginkgo* gets its name of Maidenhair tree.



(c) *Reproductive structures*

Ginkgo is dioecious: the stamens are found on one tree and the ovules are found on another tree.

The *stamens* are formed in groups at the ends of short branches. Each stamen is made up of two or more pollen sacs.

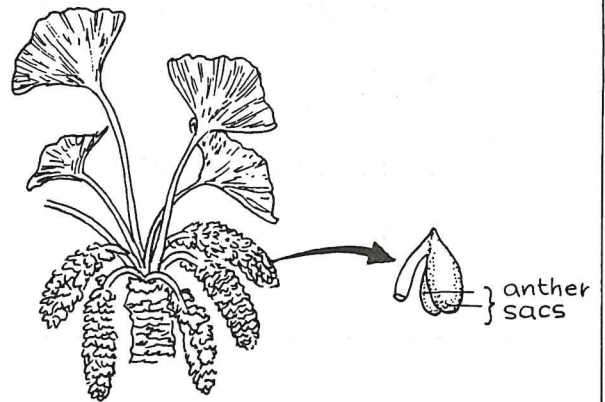


Fig. 2.7
Male reproductive structures
in *Ginkgo*

♀ The *ovules* are borne in pairs at the ends of slender stalks. These are found in groups at the ends of short branches.

The ovule is very similar to that of *Macrozamia*.

It is made up of the female gametophyte surrounded by the nucellus and a single integument.

There are two archegonia in the gametophyte.

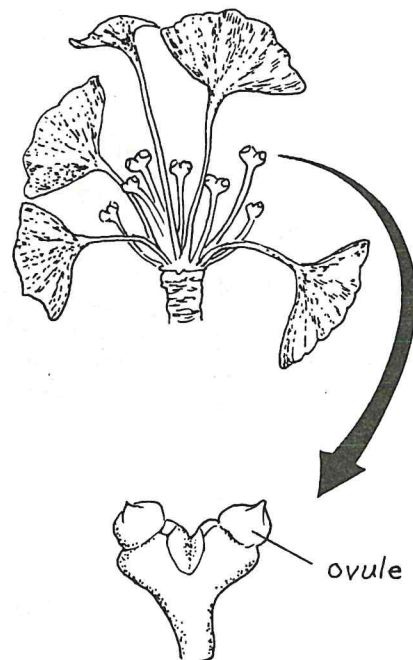


Fig. 2.8
Female reproductive structures
in *Ginkgo*

(d) *Reproduction and life cycle*

The reproduction and life cycle of *Ginkgo* resembles that of *Macrozamia*.

- . The pollen grain germinates to form a pollen tube.
- . The pollen tube grows through the nucellus and releases two motile sperms into the female gametophyte.
- . Fertilization takes place; i.e. a sperm fuses with an egg to form a zygote.
- . The zygote develops to form an embryo.
- . The ovule develops to form a seed (Figure 2.9)

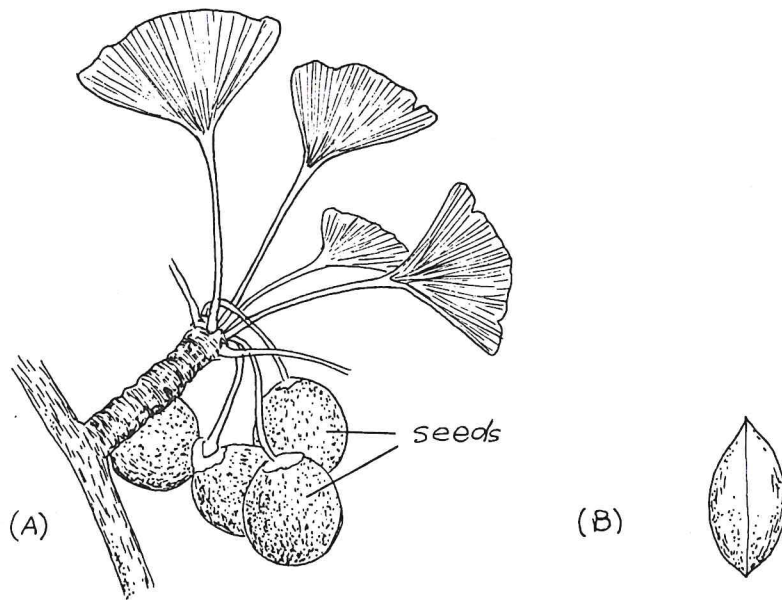


Fig. 2.9
Ginkgo biloba

- A. Branch with seeds which have developed from ovules.
- B. Seed with soft outer coat removed.

2.6 Conifers

Most conifers are evergreens of temperate and subarctic regions of the world. The well known and economically important gymnosperms especially of the north temperate zones belong to this group. In Australia, they include the *Araucaria* (Hoop pine), *Agathis* (Kauri Pine), *Podocarpus* (Plum Pine) and *Callistris* (Cypress Pine.)

This group is different from all other gymnosperms in the following features:

- i. Leaves are simple, scale-like, needle-shaped, linear to lanceolate (much longer than broad).
- ii. Leaves are not dichotomously veined.
- iii. Sperms are nonmotile.
- iv. Ovules are usually in woody cones.

The cones are a conspicuous feature of most conifers so that the group is referred to as cone-bearers.

The genus *Pinus* (pines) is described below to illustrate the group.

Pinus

(a) *Habit*

Usually large trees with straight tall trunks.

There are two kinds of branches:

- i. *Long branches* with only scale leaves.
- ii. *Short branches* with limited growth.
These arise in the axils of scale leaves and bear clusters of needlelike foliage leaves. These short branches are shed at intervals.

(b) *Leaves*

There are four kinds of leaves in a pine tree.

- i. *Cotyledons* (or seed leaves) (Figure 2.11).
There are 6-10 cotyledons per seed.
When the seed germinates, the cotyledons become green and form a leaf whorl on the stem of the seedling.
- ii. *Juvenile leaves*
As the seedling grows, it gives rise to single needlelike leaves that are arranged spirally above the cotyledons.
- iii. *Scale leaves* (Figures 2.10, 2.11)
In the adult pine, small, more or less triangular scale leaves occur singly at the nodes of the small branches.

iv. *Foliage leaves* (Figures 2.10, 2.11)

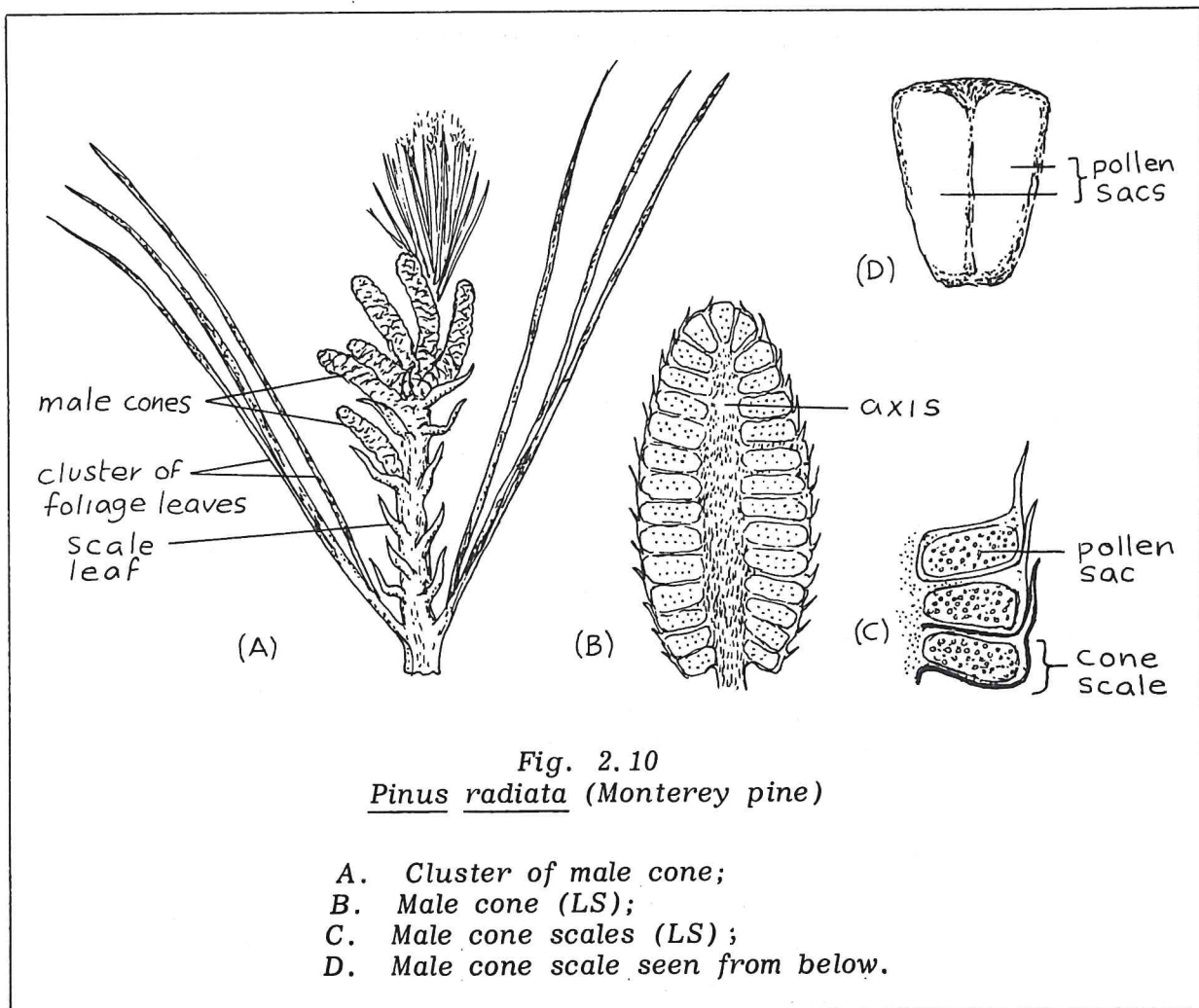
In the adult pine, compact clusters of needlelike foliage leaves are found in the axils of scale leaves. The number of leaves in each cluster is constant and characteristic of the species - the most common numbers are 2, 3 or 5.

(c) *Cones*

The pine is monoecious; i.e., both the male (pollen-producing) cones and the female (ovule-bearing or seed-bearing) cones are found on the same tree.

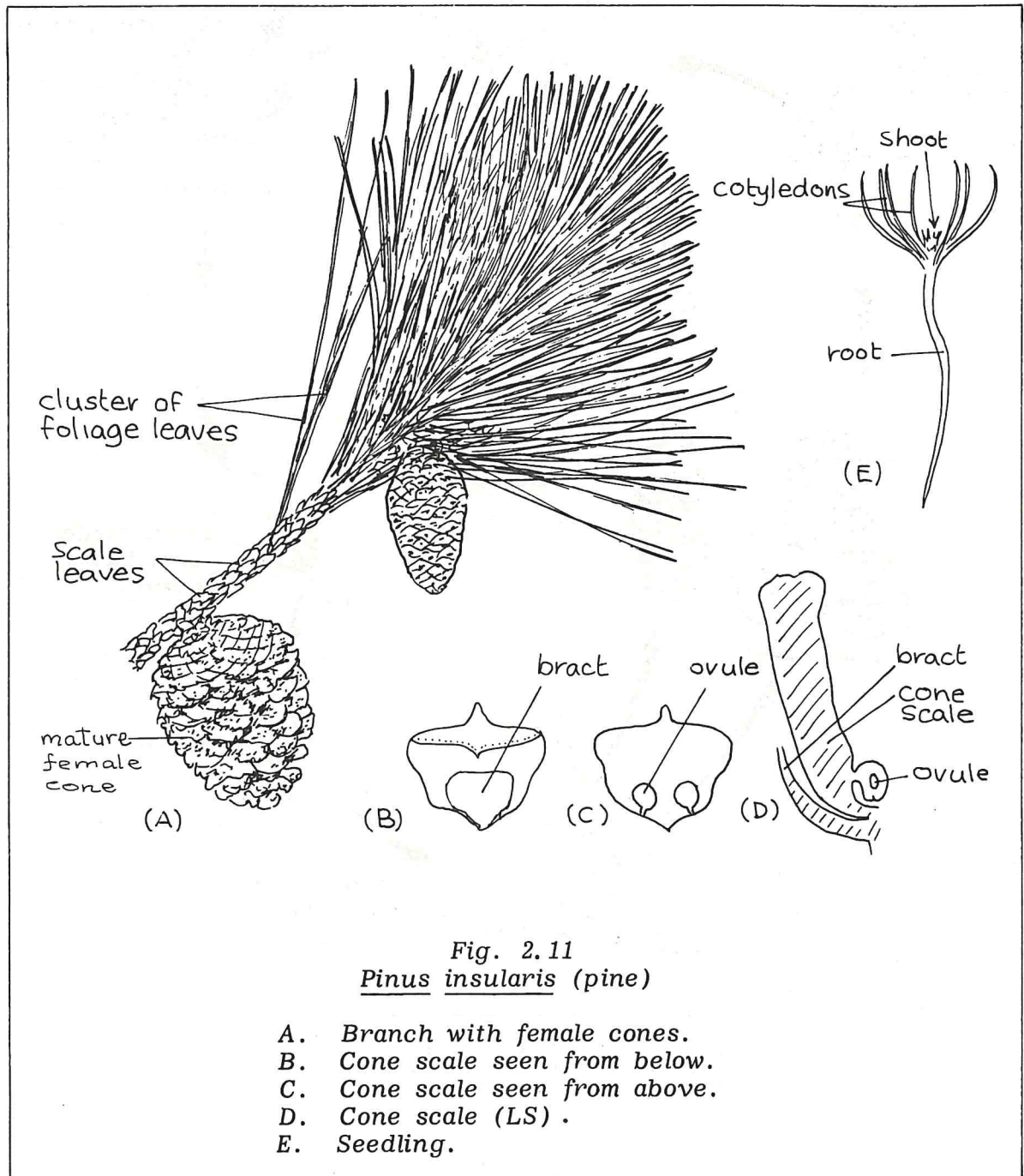
Male cone

Male cones occur in clusters near the end of long branches. (Fig. 2.10). These small cones are produced in the axils of scale leaves. Each cone consists of an axis bearing spirally arranged cone scales. Each cone scale corresponds to a stamen in flowering plants. It has two pollen-sacs on the under surface. Pollen grains are produced in the pollen sacs.

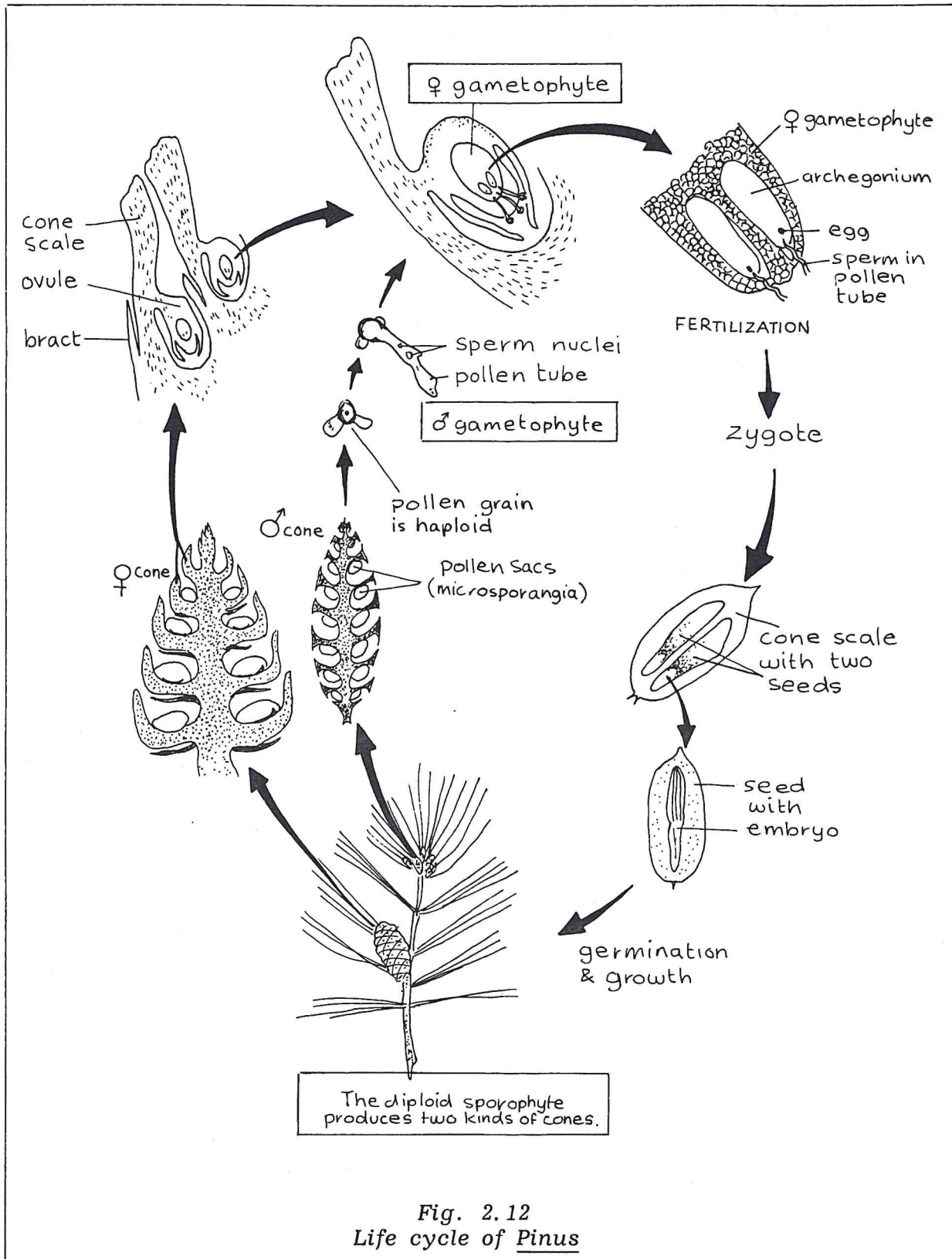


Female cone

Female cones are produced at the end of special short branches. There are two ovules at the base of each cone scale. Below each cone scale is a bract (Figure 2.11). The structure of the ovule resembles the ovule in *Macrozamia*.



(d) Life cycle



The life cycle of *Pinus* is depicted in Fig. 2.12. The most important events are described below.

i. *Pollination*

Pollen grains are carried by the wind and deposited in the micropyles of the ovules. This process is called pollination. The female cones are upright and the cone scales spread apart at the time of pollination. After pollination, the cone hangs downwards.

ii. *Fertilization*

On reaching the micropyle, the pollen grain sends out a pollen tube which grows through the nucellus. It enters the archegonium and releases two sperm nuclei into it. The sperm nuclei are different from those of *Macrozamia* and *Ginkgo* in that they are nonmotile. A sperm nucleus fuses with an egg nucleus to form a zygote. This process is called fertilization.

iii. *Seed formation*

The zygote develops to form an embryo.
The ovule develops to form a seed.
There are 6-10 cotyledons to each seed.
The zygote is the first cell of the sporophyte generation.

iv. *Seed Germination*

The seed germinates (Figure 2.11E) and grows into a pine tree.

v. *Cone formation on pine tree*

The mature tree produces male and female cones. Within the female cone, a spore in the ovule gives rise to the female gametophyte. Pollen grains are produced in the male cone. They germinate to form a simple male gametophyte.

2.7 Comparison of Alternation of Generation in ferns, gymnosperms and angiosperms

In the life cycles of ferns, gymnosperms and angiosperms, there is an alternation of:

- i. A large plant which produces spores (the *sporophyte* generation), and
- ii. A minute plant which produces gametes (the *gametophyte* generation).

The gametophyte is much smaller than the sporophyte in all the three groups of plants.

- In the ferns, the gametophyte is a small prothallus with rhizoids, a green thallus, archegonia and antheridia.
- In the gymnosperms and angiosperms, the megagametophyte (♀) is basically one large cell with a small number of cells or nuclei within. It is located within the ovule in the gymnosperm cone and the angiosperm flower. The microgametophyte (♂) consists of the pollen grain with its pollen tube and a few nuclei.

The fern gametophyte is green, able to synthesise its own food and is *independent* of the sporophyte. The gametophytes in gymnosperms and angiosperms are nongreen cannot synthesise their own food and are *dependent* on the sporophyte.

The fern gametophyte is dependent on *free water* for the sperms to swim from the antheridia to the eggs in the archegonia to fertilize them. (This is why ferns need to live in a moist environment). The gametophyte of most gymnosperms and angiosperms do not need free water for fertilization to take place. Pollen tubes grow through tissues of the ovule to discharge sperms into the megagametophyte.

The fertilized egg (zygote) in the fern gametophyte divides to form an embryo. The embryo grows into a young sporophyte while still attached to the gametophyte. (See Fig. 1.3.) The small gametophyte is unable to offer the embryo much food or protection against drought and extremes in temperature. Not surprisingly, few embryos develop into mature sporophytes. In gymnosperms and angiosperms, the ovule develops into a *seed* with its enclosed embryo. A seed increases the embryo's chance for survival in the following ways:

- (a) it provides an adequate supply of stored food to nourish the young sporophyte until it is large enough to produce its own food;
- (b) it forms a protective coat around the embryo to prevent dessication and damage by extremes of temperature;
- (c) it may remain dormant through an extended period that is unfavourable for germination

A greater number of embryos of seed plants survive than do those of ferns. The result is that in all natural plant populations, seed-bearing plants greatly outnumber all other plants.

2.8 Keys to Native Gymnosperms of Western Australia

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University of Western Australia)

CYCADALES - Cycadaceae & Zamiaceae

Plants of palm-like habit, trunk subterranean or to 2 m with a crown of pinnate leaves.

- a. Leaf pinna with thick midrib and no lateral veins;

Female sporophylls in a $\pm$ spreading group; sporophyll finely woolly with a pectinate edge distally. Ovules 2-several;

Male sporophylls in a determinate cone; sporophyll finely woolly, scale-like, with erect terminal spine *Cycas media*
(Northern Province - Kimberley)

- aa. Leaf pinna without a midrib, and with several fine longitudinal veins;

Female sporophylls in a determinate cone; sporophyll glabrous, broad, greatly thickened distally, with an erect terminal spine. Ovules 2 only;

Male sporophylls in a determinate cone; sporophyll glabrous, broadly scale-like with an erect terminal spine... .. *Macrozamia riedlei*
(South-Western Province)

CONIFERALES - Cupressaceae & Podocarpaceae

- a. Leaves scale-like, in whorls of 3, 3-6 mm long, appressed to stem except for spreading tips; ♀ cones with 6 fertile cone-scales.

- b. ♀ cone-scales of equal length, partially covered proximally by barren cone-scales... .. *Actinostrobus*

- bb. ♀ cone-scales, 3 of them longer than the alternating 3, not covered proximally by barren cone-scales... .. *Callitris*

- aa. Leaves linear, flat, to 9 cm x 4 mm;
 ♀ strobilus (= cone) of 4-6 bract
 scales, usually only 2 of them
 fertile. Fruit a drupe on a fleshy
 receptacle formed by fusion of the
 bract scales and cone axis *Podocarpus*
 (P. drouyniana)

Actinotrobus

- a. Mature ♀ cones ± 1 cm long x 1 cm
 broad, cone-scales incurved at
 their apices. Narrow pyramidal
 shrub to 4 m, foliage green, never
 glaucous *A. pyramidalis*
- aa. Mature ♀ cones ± 1.5 cm long
 x 1.6 cm broad; cone-scales not
 incurved, apices acute.
 Glaucous shrub to 5 m *A. arenarius*
- aaa. Mature ♀ cones ± 2 cm long x 2 cm
 broad; cone-scales contracted near
 their apices into a neck, each
 ending in spreading point. Diffuse
 shrub to 60 cm from subterranean
 stems *A. acuminatus*

Callitris

- a. Mature ♀ cones smooth when fresh,
 slightly wrinkled when dry.
- b. Leaves dorsally keeled.
 Ovules (seeds) few, usually
 6 perfect.
- c. Leaves ± 3 mm long. Cones
 1.2-2.0 cm diam. Cone
 scales with alternate 3
 much shorter and more
 triangular than the
 others, each with a large
 conical dorsal point *C. roei*
- cc. Leaves ± 5 mm long. Cones
 ± 1.5 cm diam. Cone
 scales with alternate
 3 only slightly shorter than
 the others, each with a
 minute conical dorsal point *C. drummondii*
- bb. Leaves not dorsally keeled, but
 rounded, usually glaucous.
 Ovules (seeds) numerous. Cones
 ± 1.5 cm - 2.0 cm diam.

- c. Cones slenderly pedunculate.
Cone scales thin (± 2.5 mm thick) brown; alternate 3 half to three-quarters length of others, often varying in size in the same cone *C. columellaris*
- cc. Cones thickly pedunculate.
Cone scales thick (± 5 mm), greyish; alternate 3 $\pm$ half as long as, and more regularly triangular than the others *C. canescens*
- aa. Mature ♀ cones tuberculate with numerous resin tubercles when fresh or dry.
 - b. Cones ± 1.7 cm diam., tubercles of even size (2 mm diam.) and distribution *C. verrucosa*
 - bb. Cones ± 2.5 cm., tubercles of unequal size (up to 3 mm diam.) and distribution *C. preisii*

KEYS TO TERMS

- acute:  -shaped
- determinate: growth of limited duration, culminating in a fully differentiated structure with no further growth.
- drupe: simple fleshy fruit derived from one carpel, usually one-seeded
- glabrous: without hairs
- glaucous: pale bluish-grey colour
- keeled:  -shaped
- pectinate: comb-like, lobes very narrow and close
- tubercle: (tuberculate) small wart-like protuberance