Introduction

THE PLANT KINGDOM

It is now generally accepted that land-dwelling organisms evolved from unicellular aquatic ancestors such as bacteria and blue-green algae. From these primitive beginnings developed the variety of complex life-forms that are found in the world today. In the course of this period, covering hundreds of millions of years, individual species or groups appeared and disappeared, but the broad categories to which they belonged, once established, have persisted until the present time.

Traditionally all forms of life were considered to be either animals or plants, but more recent research has shown that this simple classification is no longer satisfactory. Indeed there are strong grounds for excluding viruses, bacteria, blue-green algae, and even fungi from the plant kingdom. This new, more restricted concept of the plant kingdom includes the following groups.

1. *Non-vascular plants*
   - (i) algae (unicellular or multicellular freshwater or marine plants, e.g., seaweeds)
   - (ii) bryophytes (mosses, liverworts)
2. *Vascular plants* (plants having a vascular system for conducting water and food solutions)
   - (i) pteridophytes (ferns, horsetails, clubmosses)
   - (ii) gymnosperms (conifers, cycads)
   - (iii) angiosperms (flowering plants)

As may be seen from the geological time-scale (Fig. 1), non-vascular plants were the first to appear, followed at intervals by various kinds of vascular plants. The earliest of these were the pteridophytes, spore-bearing plants with a preference for damp and shady habitats. Then came the gymnosperms, woody plants bearing cones with naked seeds (i.e., not enclosed in an ovary). In this group pollen-grains from the male cones are carried by the wind directly on to the ovules (unfertilised seeds) produced on the scales of the female cones. The most recent group to arise are the angiosperms or flowering plants which have their ovules enclosed in a protective structure, the ovary. This is usually extended upwards to form the style and stigma. Pollen-grains landing on the stigma can only reach the ovules by forming a tube which grows down through the style and into the ovary.

THE FLOWERING PLANTS

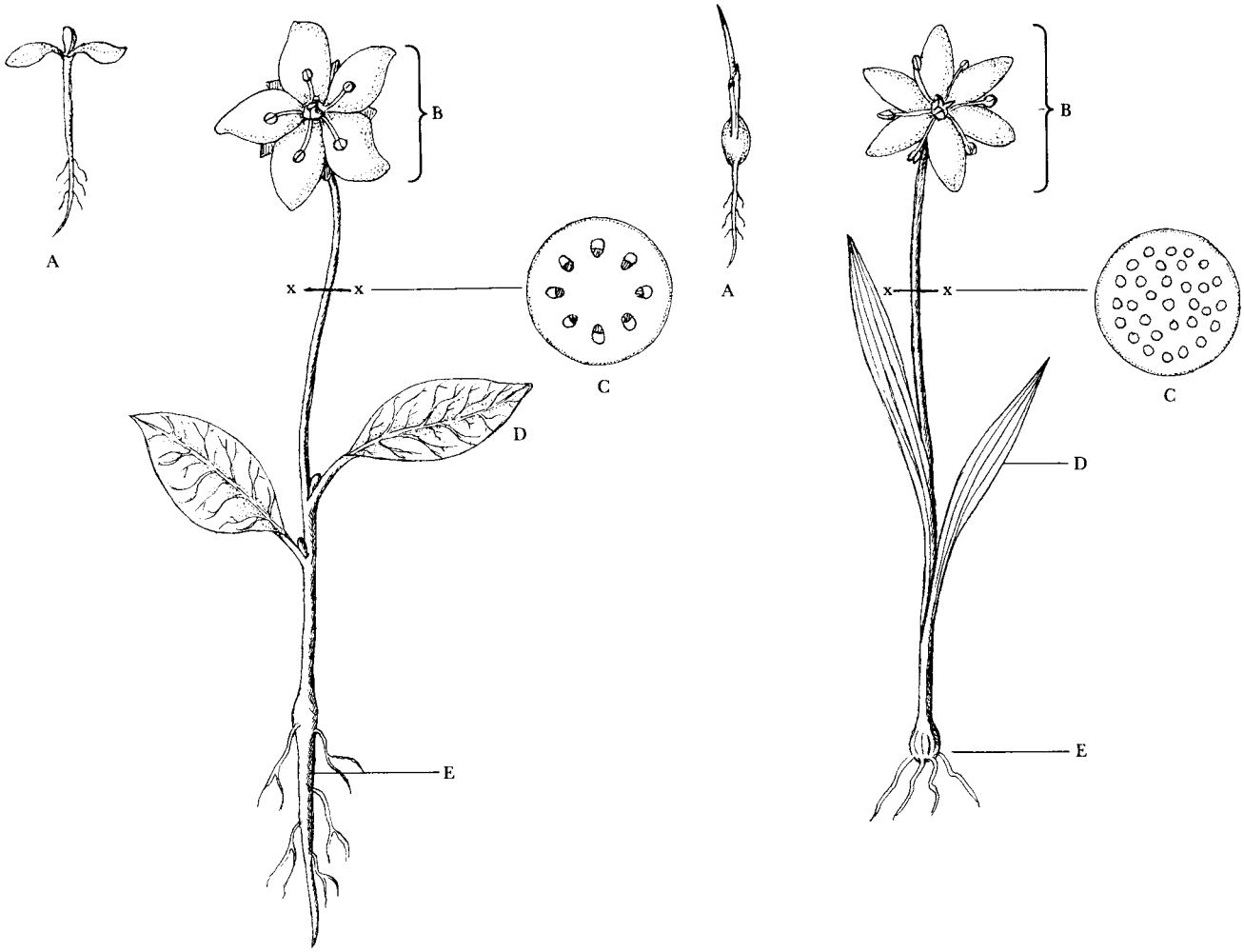
Classification and evolution

The classification of the flowering plants or angiosperms is based upon comparative study of the structure of their flowers and fruits. Thus, one of the most obvious differences between plants, namely whether they are trees, shrubs, or herbs, is not a character used in the main classification into different families, and indeed many important families of flowering plants, such as Rosaceae and Compositae, contain both woody and herbaceous representatives. But it is significant, and also useful in identification, that certain families, such as those comprising the catkin-bearing group or Amentiferae, are wholly or very largely composed of woody plants, whilst others are entirely herbaceous.

It is generally assumed that the change from woody to herbaceous forms, and vice

Fig. 2

		Dicotyledon	Monocotyledon
A	Seedling	2 cotyledons present.	1 cotyledon present.
B	Flower	Flower-parts in 4's or 5's. Perianth usually clearly divisible into calyx and corolla. One to many carpels present.	Flower-parts in 3's or 6's. Perianth often not clearly divisible into calyx and corolla. Usually 3 carpels present.
C	Stem	Herbaceous or woody. Vascular bundles forming a ring.	Usually herbaceous. Vascular bundles distributed throughout the stem.
D	Leaves	Usually broad with reticulate veins.	Usually narrow with parallel veins.
E	Roots	Usually a taproot with secondary roots.	Fibrous, and adventitious, arising from the base of the stem.



versa, has occurred many times within different evolutionary lines of flowering plants. Many botanists also hold the view that the primitive angiosperm was a dicotyledon with woody stems and large, terminal flowers like the modern *Magnolia*, but this theory has not been proved to the satisfaction of all. Neither is it certain how the monocotyledons originated, though it may be that the common ancestor of both monocotyledons and dicotyledons was some shrubby angiosperm with primitive floral structure belonging to a group that is now completely extinct. Although the form of the earliest flowering plants is still unknown, it seems clear from the fossil record that they arose in the early Cretaceous period (120 million years ago) and that before the end of that period (80–90 million years ago) they had ousted the conifers and cycads from their position of dominance and established themselves in their stead as the characteristic form of land plant, a place they have continued to hold to the present day.

Structure of the whole plant

With very few exceptions, growth in the flowering plants is maintained underground by a **root** system and above ground by a **shoot** system (Fig. 2). The shoot system consists of one or more stems bearing leaves which are arranged spirally or in pairs, or more rarely in whorls of three or more, along each stem. The point from which a leaf arises is called a **node**, and the portion of the stem between two nodes is described as an **internode**. The angle formed by a leaf and its parent stem is known as an **axil**, and buds appearing in this position are called **axillary**. A bud may also be found at the apex of the stem, in which case it is described as **terminal**. Each bud is, in fact, a shoot with very short internodes and immature leaves. Some buds do not develop further but, if they do so, the internodes lengthen and the leaves enlarge, forming a typical shoot.

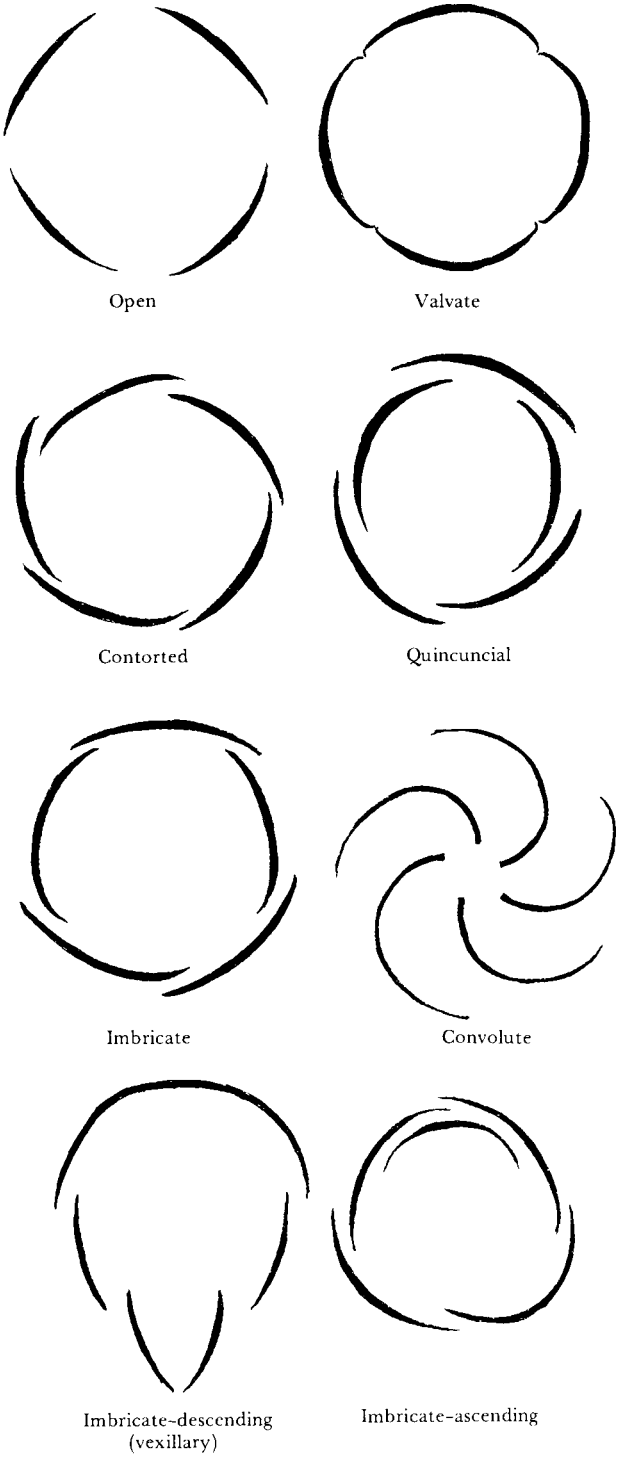
A flower may be regarded as a bud which is modified for the purpose of reproduction of the parent plant. The outermost leaves have changed little, retaining their leaf-like appearance and protective function. The inner leaves, on the other hand, have in many cases undergone considerable modification in shape and colour, and have become highly specialised in order to perform a variety of functions necessary for the successful propagation of the plant concerned. These modified leaves are now referred to as floral parts.

In the more primitive families such as Magnoliaceae, the floral parts are many or **indefinite** in number and are arranged on an elongated axis. In more advanced families there is a reduction in the number of parts which then arise from a much shortened axis. In either case, the production of a flower means that growth of the stem concerned is now limited, although it may continue to elongate sufficiently in order to allow the flower-cluster or **inflorescence** to develop fully.

Growth of a stem by apical extension is termed **monopodial** and results in an inflorescence known as a **raceme**. In contrast to this, the main stem may cease to lengthen owing to a flower being formed at its apex. If this occurs, side or **lateral** branches may arise from buds below this flower. This is called **sympodial** growth and results in an inflorescence known as a **cyme**. Determining whether an inflorescence is racemose or cymose may sometimes be difficult but they are usually distinguishable by the order of flower development. In a raceme the youngest flower is situated at the apex of the stem, while in a cyme the oldest flower occupies this position. Grouping the flowers together into an inflorescence, of whatever kind, renders them more conspicuous and is an important aid to pollination.

The term inflorescence is often used solely for a cluster of individual flowers, but, correctly employed, it includes the stem from which the flowers arise which is termed the **peduncle**. Sometimes, however, the flowers are solitary on a stem as in *Galanthus* (Snowdrop). If an individual flower is unstalked it is said to be sessile, but if stalked this stalk is known as a **pedicel**. There may often be scale- or leaf-like structures arising from the peduncle or pedicel. These are termed **bracts**

Fig. 3. Aestivation.



or **bracteoles**, and are usually simple in shape compared with the foliage leaves. Where bracteoles are present in dicotyledons, there are usually two situated opposite each other on the pedicel, but only a single bracteole may be present in monocotyledons. In many inflorescences each pedicel arises from the axil of a bract on the peduncle. In the Compositae and Dipsacaceae the inflorescence is condensed to a head of sessile flowers known as a **capitulum** which is borne on the thickened and flattened apex of the peduncle. The bracts of these flowers are crowded into one or more whorls round the capitulum, and together form an **involucre**.

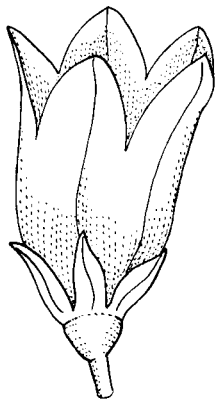
Structure of the flower and fruit

The flower is a specialised structure evolved for the process of seed formation, which is normally the result of a sexual union. Some plants, however, have the ability to form seeds without the aid of fertilisation. This form of reproduction, which is found in several common genera of Rosaceae (e.g., *Alchemilla*, *Rosa*, and *Rubus*) and Compositae (e.g., *Hieracium* and *Taraxacum*) is known as **apomixis** (more strictly **agamospermy**).

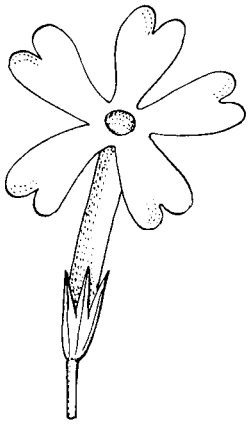
The floral axis on which the flower-parts are arranged is termed the **receptacle** or **torus**. Where a single flower is borne on a pedicel, the receptacle is the upper end of the flower-stalk. In the Dipsacaceae and Compositae the flowers have no individual stalks but are arranged in a head at the top of the peduncle. Here it is the upper end of the peduncle which is called the receptacle. In either case, the receptacle is often enlarged and may be flat, concave, or convex in shape.

As a rule, the individual flower consists of male and female reproductive organs surrounded by a **perianth**, usually divisible into **calyx** and **corolla** (Figs. 3 and 4). If only the male reproductive organs are present the flower is described as **staminate**, and if only the female organs are present it is termed **pistillate**. In some flowers the calyx or the corolla may be absent. But in the majority of species all four kinds of floral parts are present. Working from the outside towards the centre of the flower, the floral parts are as follows.

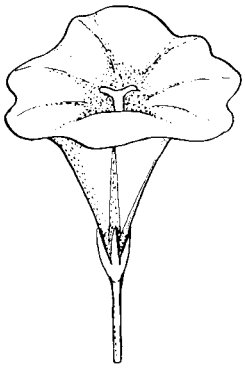
Fig. 4. Corolla forms and special structures.



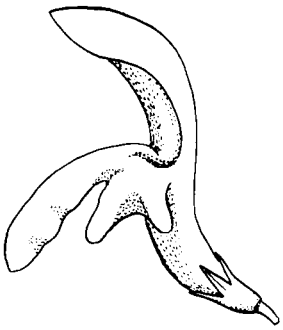
Campanulate
(78. Campanulaceae)



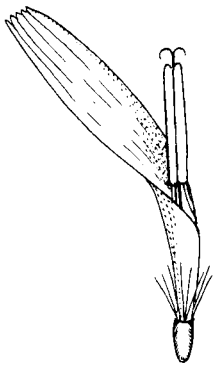
Salver-shaped
(69. Polemoniaceae)



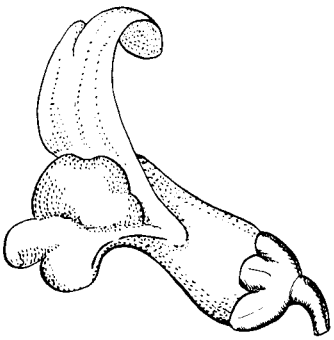
Funnel-shaped
(68. Convolvulaceae)



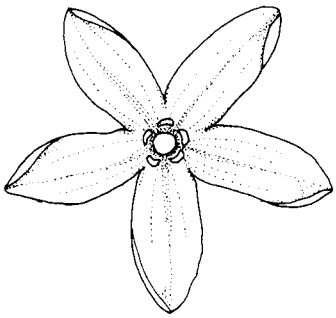
Labiate
(72. Labiatae)



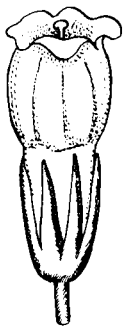
Ligulate
(83. Compositae)



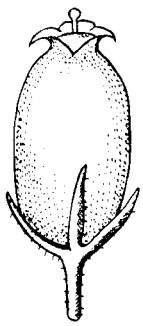
Personate
(74. Scrophulariaceae)



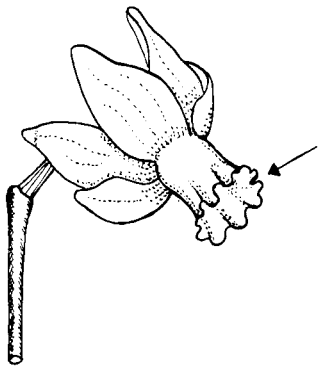
Rotate
(67. Solanaceae—*Solanum*)



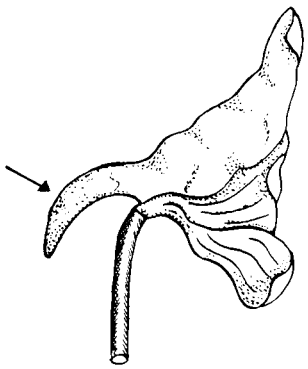
Tubular
(70. Boraginaceae—*Symphytum*



Urceolate
(32. Ericaceae – *Erica*)

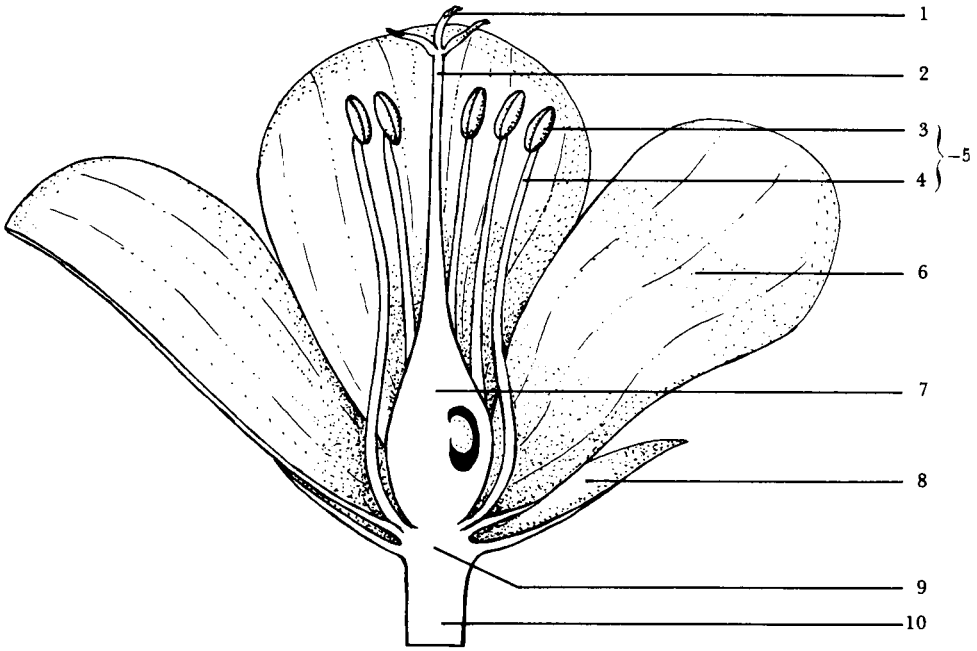


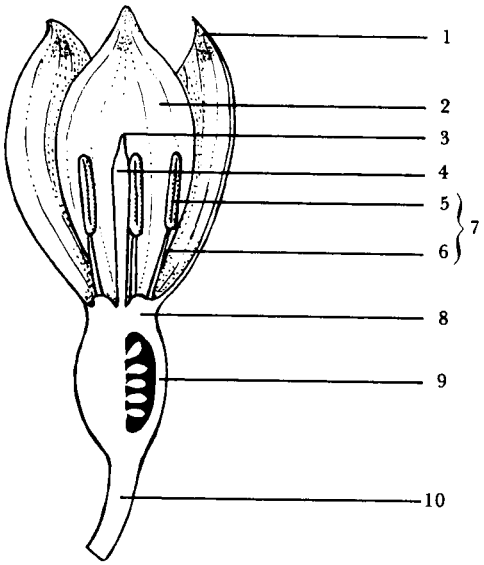
Corona
(98. Amaryllidaceae—*Narcissus*)



Spur
(5. Ranunculaceae—*Delphinium*)

Fig. 5. Top – half-flower of dicotyledon, e.g., *Geranium*: 1, stigma; 2, style; 3, anther; 4, filament; 5, free stamen; 6, free petal of 5-petalous corolla; 7, superior ovary of 5 united carpels (1 ovule per carpel); 8, free sepal of 5-sepalous calyx; 9, receptacle; 10, pedicel. Bottom – half-flower of monocotyledon, e.g., *Leucojum*: 1, outer perianth-segment; 2, inner perianth-segment; 3, stigma; 4, style; 5, anther; 6, filament; 7, stamen; 8, receptacle; 9, inferior ovary containing ovules; 10, pedicel.





THE PERIANTH

1. *CALYX*. The calyx forms the outer whorl of the perianth and the separate parts are called **sepals** (see Fig. 5). These are usually green and leaf-like and they enclose and protect the inner floral parts in the bud stage. If the sepals are joined together, the united portion is called the **calyx-tube** and the free portions the **calyx-lobes**. Sometimes the sepals are coloured and may then, like the petals, attract insects. Such sepals are described as **petaloid**. In some families, e.g., Compositae, the calyx has been modified into a group of hairs and is called a **pappus**.
2. *COROLLA*. The corolla forms the inner whorl of the perianth and the separate parts are called **petals**. These are usually coloured and serve to attract insects or, in some exotic species, birds, for the purpose of pollination. If the petals are joined together, the united portion is called the **corolla-tube** and the free portions the **corolla-lobes**. Sometimes the petals are green and they are then described as **sepaloid**. In some cases both sepals and petals are similar in shape and colour. These perianth-segments are often known as **tepals**.

THE REPRODUCTIVE ORGANS

1. *ANDROECIUM*

Structure. The androecium is the collective term for the male organs of the flower, and the individual parts are called **stamens** if functional and **staminodes** if non-functional (see Fig. 6). Each stamen has two main parts: the **anther**, and its supporting stalk, the **filament**. The anther is usually composed of two lobes or **thecae**, each comprising a pair of pollen-sacs or **loculi** which contain the pollen. The lobes are joined together by a continuation of the filament known as the **connective**. Sometimes, as in the family Malvaceae, the anther has only one lobe. It is then termed **monothecous**, in contrast to the normal, **dithecous** condition.

Stamen attachment. The stamens may be attached to the receptacle or to the petals. In the latter case they are called **epipetalous**. Where the stamens are in two whorls, the inner whorl opposite the petals and the outer whorl opposite the sepals, the flower is termed **diplostemonous**. In some families, e.g., Geraniaceae, the position of the whorls is reversed, this arrangement being described as **obdiplostemonous**.

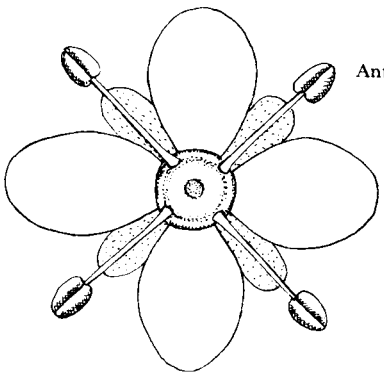
Anther attachment. (i) Fixed anthers. The base of the anther may be fixed to the apex of the filament, i.e., **basifixed**, or the filament may be attached to the back of the anther, i.e., **dorsifixed** (Fig. 7). Sometimes a considerable portion of the anther is united with the filament and it is then incapable of separate movement.

(ii) Moveable anthers. If a dorsifixed anther is attached only to the apex of the filament, it is able to move independently and is termed **versatile**. In certain flowers the filaments are so slender that they bend over at the apex and the anthers are then described as **pendulous**. Versatile and pendulous anthers are frequently found in wind-pollinated flowers.

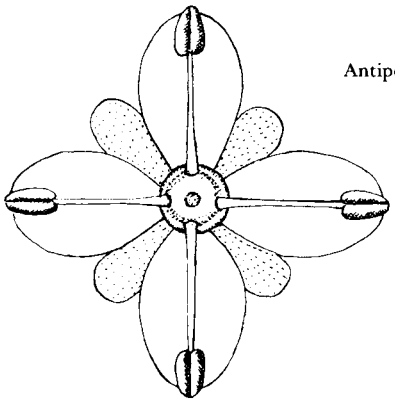
Dehiscence. The opening or dehiscence of the anthers (Fig. 7) is usually lengthwise or **longitudinal**. In this case the opening occurs between each pair of pollen-sacs, and pollen from both sacs of an anther-lobe is released from the same split. Another form of dehiscence (**poricidal**) is exhibited by some members of the Ericaceae, pollen being shed through terminal pores. Yet another kind of pollen-shedding, **valvate** dehiscence, is shown by the Lauraceae. In this family a flap-like valve opens upwards to liberate the pollen. Dehiscence of an anther is described as **introrse** if it is towards the centre of the flower, and **extrorse** if it is away from the centre (Fig. 8). In some families the anther opens at the side, and this is known as **lateral** dehiscence.

Fusion. The stamens may be free from each other or they may be joined together in some way. In the Malvaceae and some of the Leguminosae all the filaments are united for most of their length, forming a tube round the gynoecium. The stamens are then termed **monadelphous**. In other members of the Leguminosae the stamens are united by their

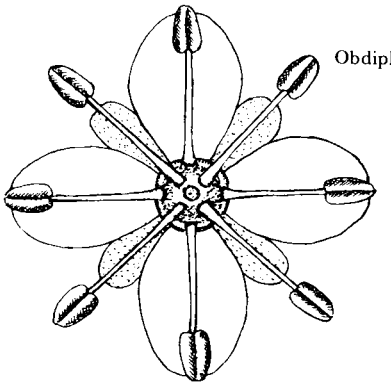
Fig. 6. Stamen arrangement.



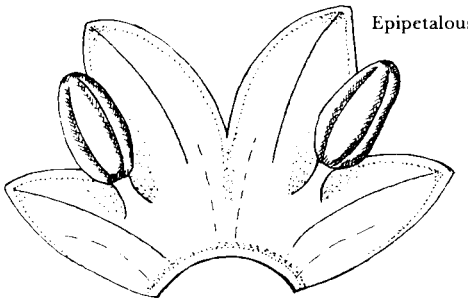
Antisepalous



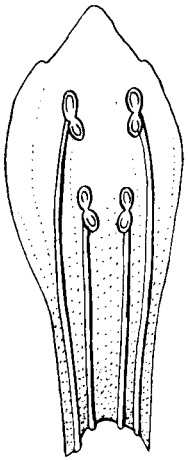
Antipetalous



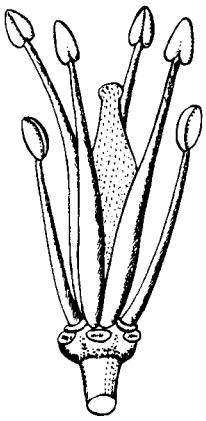
Obdiplostemonous



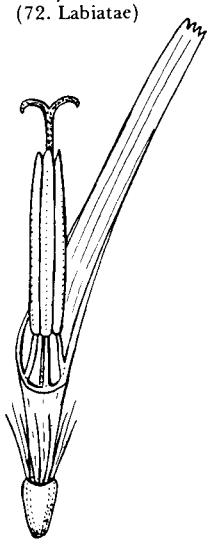
Epipetalous



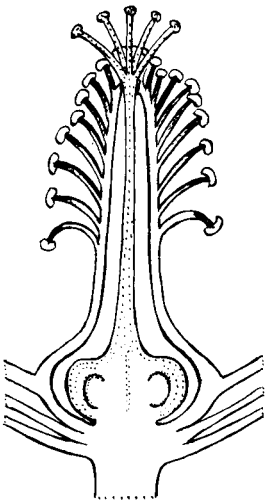
Didynamous
(72. Labiatae)



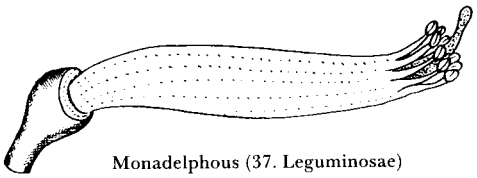
Tetradynamous
(30. Cruciferae)



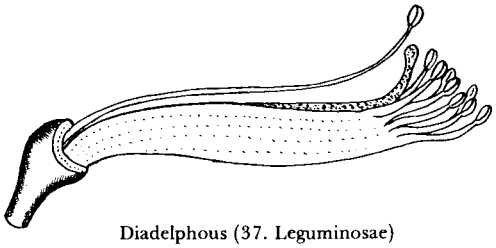
Syngenesious
(83. Compositae)



Monadelphous (21. Malvaceae)

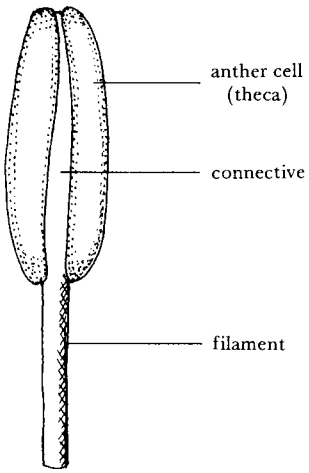


Monadelphous (37. Leguminosae)

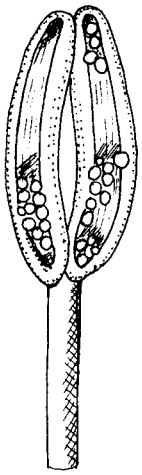


Diadelphous (37. Leguminosae)

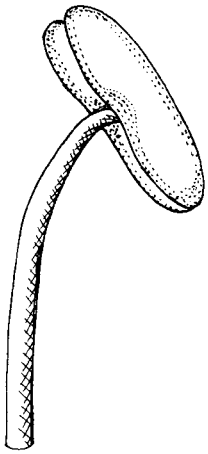
Fig. 7. Anther forms.



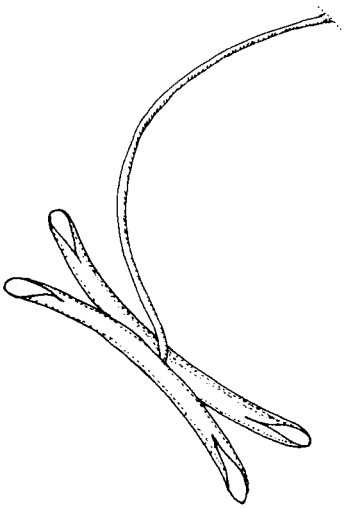
Basifixed anther,
dorsal view



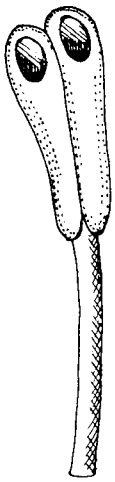
Basifixed anther
with longitudinal dehiscence,
ventral view



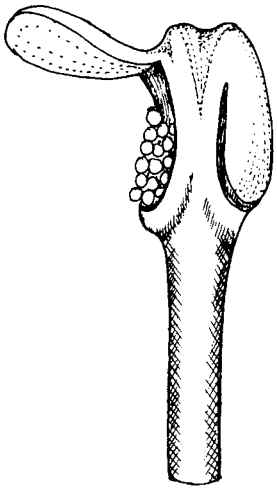
Dorsifixed anther
(non-versatile)



Dorsifixed anther
(versatile)



Anther with poricidal
dehiscence

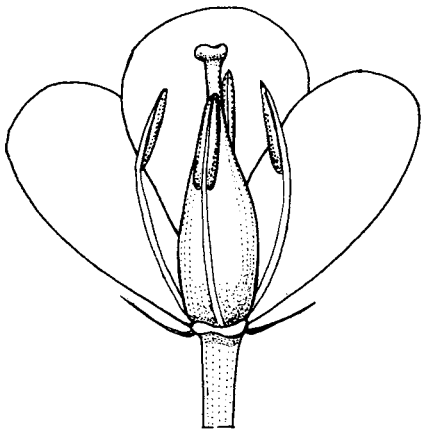


Anther with valvate
dehiscence

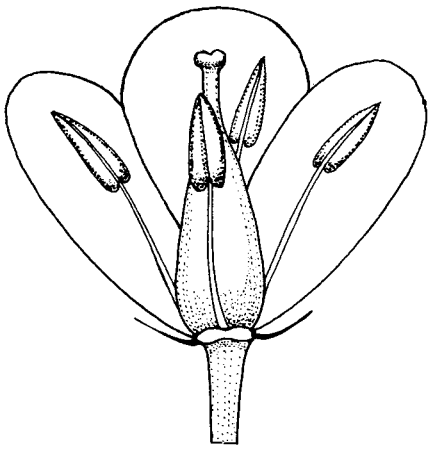
filaments into 2 groups and are called **diadelphous**. In the genus *Hypericum* (Guttiferae) the stamens are grouped into 3 or 5 **fascicles** or bundles, the filaments in each group being joined together only at their base. By contrast, members of the Compositae have the filaments free but the 5 anthers are united. This condition is described as **syngenesious**.

Relative length of stamens. In most families the stamens of a particular flower are all about the same length, but in the Labiatae **didynamous** stamens (two long and two short) occur frequently, and in the Cruciferae **tetradynamous** stamens (four long and two short) are the typical condition.

Fig. 8. Dehiscence.



Introrse



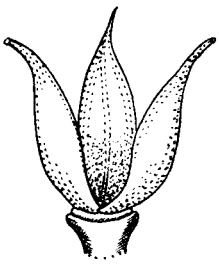
Extrorse

2. *GYNOECIUM*

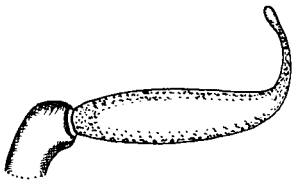
Structure. The gynoecium is the collective term for the female organs of the flower, and the individual parts are called **carpels** (Fig. 9). In some species, e.g., *Vicia faba* (Broad Bean), the gynoecium consists only of a single carpel. In most plants, however, the

Fig. 9. Carpel forms.

Carpels free (apocarpous)

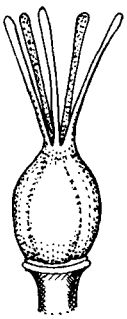


Several free carpels
(5. Ranunculaceae)

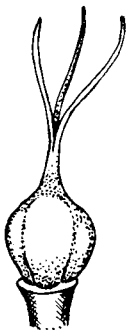


One free carpel
(37. Leguminosae)

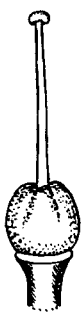
Carpels united (syncarpous)



Styles free
(55. Linaceae)



Single style with branches
(88. Cyperaceae)



Single style with capitate stigma
(33. Primulaceae)

Style absent and stigma sessile
(30. Cruciferae)