verticillate leaves. When the interruption to development takes place at the end of a branch, the leaves become *fasciculate* or clustered, as in the Larch. The primitive or generating spiral may pass either from right to left or from left to right. It sometimes follows a different direction in the branches from that pursued in the stem. When it follows the same course in the stem and branches, they are *homodromous;* when the direction differs, they are *heterodromous.* In different species of the same genus the phyllotaxis frequently varies.

All modifications of leaves follow the same laws of arrangement as true leaves—a fact which is of importance in a morphological point of view. In Dicotyledonous plants the first leaves produced (the cotyledons) are opposite, in some cases verticillate. This arrangement often continues during the life of the plant, but at other times it changes, passing into distichous and spiral forms. Some tribes of plants are distinguished by their opposite or verticillate, others by their alternate, leaves. Labiate plants have decussate leaves, while Boraginaceæ have alternate leaves, and Tiliaceæ usually have distichous leaves; Cinchonaceæ have opposite leaves; Galiaceæ, verticillate. Such arrangements as $\frac{2}{5}$, $\frac{3}{8}$, $\frac{5}{13}$, and $\frac{8}{21}$ are common in Dicotyledons. The first of these, called a *quincunx,* is met with in the Apple, Pear, and Cherry (fig. 130); the second, in the Bay, Holly, Plantago media; the third, in the cones of Pinus (Abies) alba (fig. 133); and the fourth in those of the Pinus (Abies) Picea. In Monocotyledonous plants there is only one seed-leaf or cotyledon produced, and hence the arrangement is at first alternate; and it generally continues so more or less, rarely being verticillate. Such arrangements as $\frac{1}{2}$, $\frac{1}{3}$, and $\frac{2}{3}$ are common in Monocotyledons, as in Grasses, Sedges, and Lilies. In Acotyledons the leaves assume all kinds of arrangement, being opposite, alternate, and verticillate. It has been found in general that, while the number 5 occurs in the phyllotaxis of Dicotyledons, 3 is common in that of Monocotyledons.

In the axil of previously formed leaves leaf-buds arise. These leaf-buds contain the rudiments of a shoot, and consist of leaves covering a growing point. The buds of trees of temperate climates, which lie dormant during the winter, are protected by cataphyllary leaves constituting the *tegmenta* or *perulæ.* These scales or protective appendages of the bud consist either of the altered laminæ, or of the enlarged petiolary sheath, or of stipules, as in the Fig and Magnolia, or of one or two of these parts combined. These are often of a coarse nature, serving a temporary purpose, and then falling off when the leaf is expanded. They are frequently covered with a resinous matter, as in Balsam-poplar and Horse-chestnut, or by a thick downy covering as in the Willow. In plants of warm climates the buds have often no protective appendages, and are then said to be *naked.*

The arrangement of the leaves in the bud has been denominated *vernation, prefoliation,* and *gemmation.* In considering vernation we must take into account both the manner in which each individual leaf is folded and also the arrangement of the leaves in relation to each other. These vary in different plants, but in each species they follow a regular law. The leaves in the bud are either placed simply in apposition, as in the Mistleto, or they are folded or rolled up longitudinally or laterally, giving rise to different kinds of vernation, as delineated in figs. 135 to 144, where the folded or curved lines represent the leaves, the thickened part being the midrib. The leaf taken individually is either folded longitudinally from apex to base, as in the Tulip-tree, and called *reclinate* or *replicate;* or rolled up in a circular manner from apex to base, as in Ferns (fig. 135), and called *circinate;* or folded laterally, *conduplicate* (fig. 136), as in Oak; or it has several folds like a fan, *plicate* or *plaited* (fig. 137), as in Vine and Sycamore, and in leaves with radiating vernation, where the ribs mark the foldings; or it is rolled upon itself, *convolute* (fig. 138), as in Banana and Apricot; or its edges are rolled inwards, *involute* (fig. 139), as in Violet; or outwards, *revolute* (fig. 140), as in Rosemary. The different divisions of a cut

Fig. 135. Fig. 136. Fig. 137.

Fig. 138. Fig. 139. Fig. 140.

FIG. 135.—Circinate vernation.
FIG. 136.—Transverse section of a conduplicate leaf.
FIG. 137.—Transverse section of a plicate or plaited leaf.
FIG. 138.—Transverse section of a convolute leaf.
FIG. 139.—Transverse section of an involute leaf.
FIG. 140.—Transverse section of a revolute leaf.

leaf may be folded or rolled up separately, as in Ferns, while the entire leaf may have either the same or a different kind of vernation. The leaves have a definite relation to each other in the bud, being either opposite, alternate, or verticillate; and thus different kinds of vernation are produced. Sometimes they are nearly in a circle at the same level, remaining flat, or only slightly convex externally, and placed so as to touch each other by their edges, thus giving rise to *valvate* vernation. At other times they are at different levels, and are applied over each other, so as to be *imbricated,* as in Lilac, and in the outer scales of Sycamore (fig. 63); and occasionally the margin of one leaf overlaps that of another, while it in its turn is overlapped by a third, so as to be *twisted, spiral,* or *contortive.* When leaves are applied to each other face to face, without being folded or rolled together, they are *appressed.* When the leaves are more completely folded they either touch at their extremities and are *accumbent* or *opposite* (fig. 141), or are folded inwards by their margin, and become *induplicate;* or a conduplicate leaf covers another similarly folded, which in turn covers a third, and thus the vernation is *equitant* (fig. 142), as in Privet; or conduplicate leaves are placed so that the half of the one covers the half

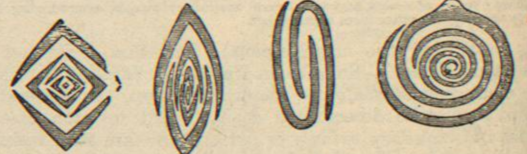

Fig. 141. Fig. 142. Fig. 143. Fig. 144.

FIG. 141.—Transverse section of a bud, in which the leaves are arranged in an accumbent manner.
FIG. 142.—Transverse section of a bud, in which the leaves are arranged in an equitant manner.
FIG. 143.—Transverse section of a bud, showing two leaves folded in an obvolute manner. Each is conduplicate, and one embraces the edge of the other.
FIG. 144.—Transverse section of a bud, showing two leaves arranged in a supervolute manner.

of another, and thus they become *half-equitant* or *obvolute* (fig. 143), as in Sage. When in the case of convolute leaves one leaf is rolled up within the other, it is *supervolute* (fig. 144). The scales of a bud sometimes exhibit one kind of vernation, and the leaves another. The same modes of arrangement occur in the flower-buds, as will be afterwards shown.

Leaves expose the fluids of plants to the influence of air and light. The fluids so exposed are elaborated. and thus fitted for the formation of the various vegetable tissues and secretions. For the proper performance of this function the structure of the leaves, and their arrangement on the stem and branches, render them well adapted. The cells in the lower side of a leaf where stomata exist are chiefly concerned in the aeration of the sap, whilst other assimilative processes go on in the upper cells. The elaboration of fluids in the leaves necessarily implies interchange of their constituents with those of the surrounding atmosphere; hence two processes are inevitable—a passing inwards into the leaf of the atmospheric elements by a *process of absorption,* and an outward current of the components of the plant-juices by a *process of exhalation.* The absorption of carbonic acid, water, and other fluids is carried on by the leaves, chiefly through their stomata, and most rapidly by the under surface of ordinary leaves in which the cuticle is thinnest, the cellular tissue least condensed, and stomata most abundant; the upper surface of the leaf, which usually presents a polished and dense epidermis with few stomata, taking little part in such a process. An exhalation of both liquids and gases also takes place from the leaves, regulated by the number and the size of stomata as well as by the nature of the epidermis. The process of *transpiration* of fluids imparts moisture to the atmosphere, and hence the difference between the air of a wooded country and that of a country deprived of forests. Thus leaves have an important influence upon the climate of a country. In darkness little or no transpiration takes place, and in diffuse daylight it is less than in the sun's rays. The exhalation of gases constitutes the process of *respiration.* The nature and amount of the gases respired depends both on the circumstances in which the leaves are placed and on the condition of the plant. But normally at all times there seems to be a respiration of carbonic acid, which, under the influence of light, is at once decomposed by the green parts of the plant, the carbon being fixed and the oxygen set free; consequently, in darkness no oxygen is eliminated. Leaves, after performing their functions for a certain time, wither and die. In doing so they frequently change colour, and hence arise the beautiful and varied tints of the autumnal foliage. This change of colour is chiefly occasioned by the diminished circulation in the leaves, and the higher degree of oxidation to which their chlorophyll has been submitted.

Leaves which are articulated with the stem, as in the Walnut and Horse-chestnut, fall and leave a scar, while those which are continuous with it remain attached for some time after they have lost their vitality, as in the Beech. Most of the trees of Great Britain have deciduous leaves, their duration not extending over more than a few months, while in trees of warm climates the leaves often remain for two or more years. In tropical countries, however, many trees lose their leaves in the dry season. The period of defoliation varies in different countries according to the nature of their climate. Trees which are called evergreen, as Pines and Evergreen-oak, are always deprived of a certain number of leaves at intervals, sufficient being left, however, to preserve their green appearance. The cause of the fall of the leaf in cold climates seems to be deficiency of light and heat in winter, which causes a cessation in the functions of the cells of the leaf; its fluids disappear by evaporation; its cells and vessels become contracted and diminished in their calibre; various inorganic matters accumulate in the textures; the whole leaf becomes dry; its parts lose their adherence; a process of disjunction takes place by a folding inwards of the tissue at the point where the leaf joins the stem or branch which gradually extends until complete separation takes place, and the leaf either falls by its own weight or is

detached by the wind. In warm climates the dry season gives rise to similar phenomena.

II. ORGANS OF REPRODUCTION.

We now proceed to pass in review the reproductive organs of plants. In Phanerogamous plants, as already mentioned, these organs are conspicuous, and constitute what is known as the flower; in Cryptogamous plants they are inconspicuous. All Dicotyledonous and Monocotyledonous plants are included in the former; Acotyledonous and Thallogenous plants compose the latter. The structures which go to form these organs are not, however, formations of a new type, but are merely modifications of those structures which we have already considered under the nutritive organs. For example, the various parts of the flower in Phanerogams are really phyllomes, the supporting structures of the flower are caulomes, the spore-bearing sac of many Cryptogams is a trichome; and in this way a morphological equivalency may be traced betwixt the two series of organs. Further, the difference betwixt the reproductive organs of Phanerogams and those of Cryptogams is one more of degree of differentiation than of actual morphological difference. In Phanerogams the flowers or floral axes are produced from flower-buds, just as leaf-shoots arise from leaf-buds. These two kinds of buds have a resemblance to each other as regards the arrangement and the development of their parts; and it sometimes happens, from injury and other causes, that the part of the axis which, in ordinary cases, would produce a leaf-bud, gives origin to a flower-bud. A flower-bud has not in ordinary circumstances any power of extension by the development of its central cellular portion. In this respect it differs from a leaf-bud. In some cases, however, of monstrosity, especially seen in the Rose (fig. 145) and Geum, the central part is prolonged, and bears leaves or flowers. In such cases the flowers, so far as their functional capabilities are concerned, are usually abortive.

Flower-buds, like leaf-buds, are produced in the axil of leaves, which are called *floral* leaves, *bracts,* or *hypsophyllary* leaves.

The term *bract* is properly applied to the leaf from which the primary floral axis, whether simple or branched, arises, while the leaves which arise on the axis between the bract and the outer envelope of the flower are *bracteoles* or *bractlets.* Bracts sometimes do not differ from the ordinary leaves, and are then called *leafy,* as in Veronica hederifolia, Vinca, Anagallis, and Ajuga. Like leaves they are entire or divided. In general as regards their form and appearance, they differ from ordinary leaves, the difference being greater in the upper than in the lower branches of an inflorescence. They are distinguished by their position at the base of the flower or flower-stalk. Their phyllotaxis is similar to that of the leaf. When the flower is sessile the bracts are often

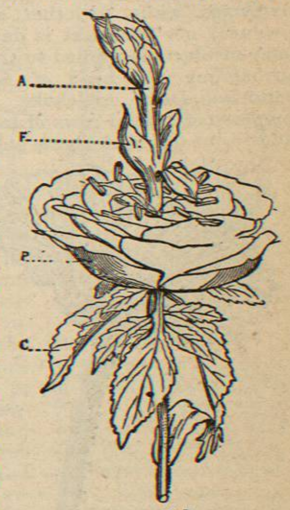

Fig. 145.

Proliferous or monstrous Rose, showing the prolongation of the axis beyond the flower. C, calyx transformed into leaves; P, petals multiplied at the expense of the stamens, which are reduced in number; F, coloured leaves representing abortive carpels; A, axis prolonged, bearing an imperfect flower at its apex.

applied closely to the calyx, and may thus be confounded with it, as in Malvaceæ and species of Dianthus and Eranthis, where they have received the name of *epicalyx* or *calyculus.* In some Rosaceous plants an epicalyx is present, due to the formation of stipulary structures by the sepals. In many cases bracts seem to perform the function of protective organs, within or beneath which the young flowers are concealed in their earliest stage of growth.

When bracts become coloured, as in Amherstia nobilis, Euphorbia splendens, Erica elegans, and Salvia splendens, they may be mistaken for parts of the corolla. They are sometimes mere scales or threads, and at other times they are abortive, and remain undeveloped, giving rise to the *ebracteated* inflorescence of Cruciferæ and some Boraginaceæ. Sometimes no flower-buds are produced in their axil, and then they are *empty.* A series of empty coloured bracts terminates the inflorescence of Salvia Horminum. The smaller bracts or bracteoles, which occur among the subdivisions of a branching inflorescence, often produce no flower-buds, and thus anomalies occur in the floral arrangements. Bracts are occasionally persistent, remaining long attached to the base of the peduncles, but more usually they are deciduous, falling off early by an articulation. In some instances they form part of the fruit, becoming incorporated with other organs. Thus, the cones of Firs and the strobili of the Hop are composed of a series of bracts arranged in a spiral manner, and covering fertile flowers; and the scales on the fruit of the Pine-apple are of the same nature. In amenta or catkins the bracts are called *squamæ* or scales. At the base of the general umbel in Umbelliferous plants, a whorl of bracts often exists, called a *general involucre,* and at the base of the smaller umbels or umbellules there is a similar leafy whorl called *involucel* or *partial involucre.* In some instances, as in Fool's-parsley, there is no general involucre, but simply an involucel; while, in other cases, as in Fennel, neither involucre nor involucel is developed. In Compositæ the name involucre is applied to the leaves, scales, or *phyllaries,* surrounding the head of flowers (fig. 146, *i*), as in Dandelion, Daisy, Artichoke. This involucre is frequently composed of several rows of leaflets, which are either of the same or of different forms and lengths, and often lie over each other in an imbricated manner. When the bracts are arranged in two rows, and the outer row is perceptibly smaller than the inner, the involucre is sometimes said to be *caliculate,* as in Senecio. The leaves of the involucre are spiny in Thistles and in Dipsacus, and hooked in Burdock. Such whorled or verticillate bracts may either remain separate (*polyphyllous*), or may be united by cohesion (*gamophyllous*), as in many species of Bupleurum, and in Lavatera. In Compositæ besides the general envelope called the involucre, there are frequently *chaffy* and *setose* bracts at the base of each flower, and in Dipsacaceæ a membranous tube surrounds each flower. These structures are of the nature of an epicalyx. In the acorn the *cupula* or cup (fig. 147, *a*) is formed by a growing upwards of the flower-stalk immediately beneath the flower, upon which scaly or spiny protuberances appear. It is of the nature of bracts. Bracts also compose the husky covering of the Hazel-nut. In the Yew the succulent covering of the seed is by some considered to be formed by the bracts.

Fig. 146.

Fig. 147.

FIG. 146.—Head (capitulum) of Marigold (*Calendula*), showing a congeries of flowers, enclosed by rows of bracts or phyllaries, *i*, at the base, which are collectively called an involucre.
FIG. 147.—Fruit of the Oak (*Quercus pedunculata*), showing a collection of bracts, *a*, forming the cup (cupula) of the acorn *b*.

When bracts become united together, and overlie each other in several rows, it often happens that the outer ones do not produce flowers, that is, are empty or sterile. In the Artichoke the outer imbricated scales or bracts are in this condition, and it is from the membranous white scales or bracts (*paleæ*) forming the choke attached to the edible receptacle that the flowers are produced. The sterile bracts of the Daisy occasionally produce *capitula,* and give rise to the Hen-and-Chickens Daisy. In place of developing flower-buds, bracts may, in certain circumstances, as in proliferous or *viviparous* plants, produce leaf-buds, and the flower-buds, like the leaf-buds, may be *terminal* or they may be *lateral.*

A sheathing bract enclosing one or several flowers is called a *spatha* or *spathe.* It is common among Monocotyledons, as Narcissus (figure 148), Snow-flake, Arum, and Palms. In some Palms it is 20 feet long, and encloses 200,000 flowers. It is often associated with that form of inflorescence termed the *spadix,* and may be coloured, as in Richardia æthiopica, sometimes called the Æthiopian or Trumpet Lily. When the spadix is compound or branching, as in Palms, there are smaller spathes, surrounding separate parts of the inflorescence, to which the name *spathellæ* has sometimes been given. The spathe protects the flowers in their young state, and often falls off after they are developed, or hangs down in a withered form, as in some Palms, Typha, and Pothos. In Grasses the outer scales of the spikelets have been considered as sterile bracts, and have received the name of *glumes* (fig. 149, *gl*), and in Cyperaceæ bracts enclose the organs of reproduction. Bracts are frequently changed into complete leaves. This change is called phyllody of bracts. It is seen in species of Plantago, especially in the variety of Plantago media, called the Rose-plantain in gardens. In this plant the bracts become leafy, and form a rosette round the flowering axis. Similar changes occur in Plantago major, P. lanceolata, Ajuga reptans, the Dandelion, the Daisy, the Dahlia, and in Umbelliferous plants. The conversion of bracts into stamens has been observed in the case of Abies excelsa. This has been called staminody of bracts. A lengthening of the axis of the female strobilus of Coniferæ is not of infrequent occurrence in Cryptomeria japonica, Larix europæa, &c., and this is usually associated with a leaf-like condition of the bracts, and sometimes even with the development of leaf-bearing shoots in place of the scales.

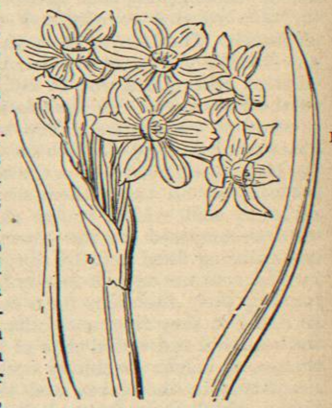

Fig. 148.

Flowers of Polyanthus Narcissus (*Narcissus Tazetta*) bursting from a sheathing bract *b*.

Plate XV.

The arrangement of the flowers on the axis, or the ramification of the floral axis, is called *inflorescence* or *anthotaxis.* The primary axis of inflorescence is sometimes called *rachis;* its branches, whether terminal or lateral, which form the stalks supporting flowers or clusters of flowers, are *peduncles,* and if small branches are given off by it, they are called *pedicels.* A flower having a stalk is called *pedunculate* or *pedicellate;* one having no stalk is *sessile.* In describing a branching inflorescence, it is common to speak of the rachis as the *primary* floral axis, its branches as the *secondary* floral axes, their divisions as the *tertiary* floral axes, and so on; thus avoiding any confusion that might arise from the use of the terms *rachis, peduncle,* and *pedicel.*

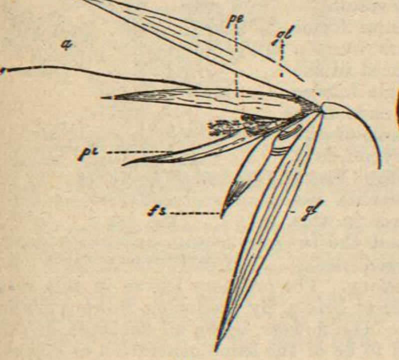

Fig. 149.

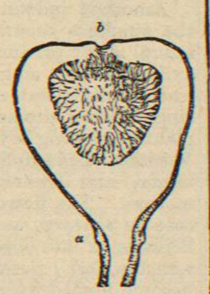

Fig. 150.

FIG. 149.—Spikelet of Oat (*Avena sativa*) laid open, showing the bracts *gl, gl,* which are denominated empty glumes; *pe,* the outer pale or glumellule (floral glume), with a dorsal awn *a*, *pi,* the inner pale; *fs,* an abortive flower.
FIG. 150.—Peduncle, *a,* of Fig (*Ficus Carica*), ending in a hollow receptacle *b,* enclosing numerous male and female flowers.

The *peduncle* may be cylindrical, compressed, or grooved; simple, bearing a single flower, as in Primrose; or branched, as in London-pride. It is sometimes succulent, as in the Cashew, in which it forms the large coloured expansion supporting the nut; spiral, as in Cyclamen and Vallisneria; or spiny, as in Alyssum spinosum. In some Rushes there is a green terete, and sometimes spiral, floral axis. Sometimes the peduncle proceeds from radical leaves, that is, from an axis which is so shortened as to bring the leaves close together in the form of a cluster, as in the Primrose, Auricula, Hyacinth, &c. In such cases it is termed a *scape.* The floral axis may be shortened, assuming a flattened, convex, or concave form, and bearing numerous flowers, as in the Artichoke, Daisy, and Fig (fig. 150). In these cases it is called a *receptacle* or *phoranthium* or *clinanthium.* The floral axis sometimes assumes a leaf-like or *phylloid* appearance, bearing numerous flowers at its margin, as in Xylophylla longifolia and in Ruscus; or it appears as if formed by several peduncles united together, constituting a fasciated axis, as in the Cockscomb, in which the flowers form a peculiar crest at the apex of the flattened peduncles. Adhesions occasionally take place between the peduncle and the bracts or leaves of the plant, as in the Lime-tree (fig. 151), Helwingia, Chailletia, several species of Hibiscus, and Zostera. The adhesion of the peduncles to the stem accounts for the extra-axillary position of flowers, as in many Solanaceæ. When this union extends for a considerable length along the stem, several leaves may be interposed between the part where the peduncle becomes free and the leaf whence it originated, and it may be difficult to trace the connection. The peduncle occasionally becomes abortive, and in place of bearing a flower, is transformed into a tendril; at other times it is hollowed at the apex, so as apparently to form the lower part of the outer whorl of floral leaves as in Eschscholtzia. The termination of the peduncle, or the part on which the whorls of the flower are arranged, is called the *thalamus* or *torus.* The term *receptacle* is also sometimes applied to this, whether expanded and bearing several flowers, or narrowed so as to bear one. It may be considered as the growing point of the axis, which usually is arrested by the production of the flowers, but which sometimes becomes enlarged and expanded. Thus, in the Geranium (fig. 152) it is prolonged beyond the flower in the form of a beak (*rostrate*); in the Arum (fig. 153) it is a club-shaped fleshy column; in the Strawberry (fig. 154) it becomes a conical succulent mass, on which the seed-vessels are placed; while in Nelumbium it forms a truncated tabular top-like expansion (*turbinate*), enveloping the seed-vessels. The margins of the receptacle may grow up whilst the centre remains depressed, and thus a concave torus is formed, as in the Rose (fig. 155). In some monstrous flowers of the Rose and Geum it is prolonged as a branch bearing leaves. Peduncles and pedicels sometimes become remarkably elongated, and this elongation of the flower-stalks sometimes alters the general character of the inflorescence. We occasionally observe the heads of flowers of the common White Clover becoming racemose by the lengthening of the flower-stalks.

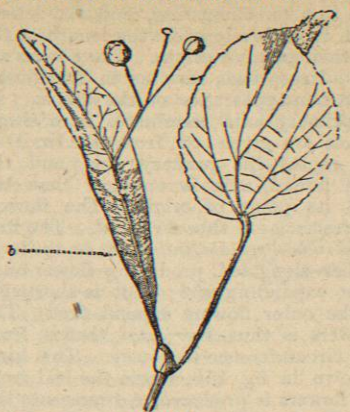

Fig. 151.

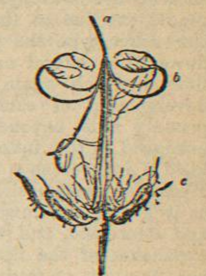

Fig. 152.

FIG. 151.—Leaf and flowering branch of the Lime-tree (*Tilia*). The bract *b* is adherent to the peduncle or flower-stalk. The flowers are arranged in a corymbose cyme.
FIG. 152.—The calyx and beak-like process of Geranium, with the parts of the pistil (the carpels) curled upwards, so as to scatter the seed. *a,* the extremity of the rostrum or beak, whence the name crane's bill is derived; *b,* the carpels curled up by means of the styles which are attached to the beak; *c,* the calyx.

Fig. 153.

Fig. 154.

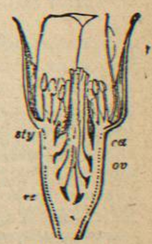

Fig. 155.

FIG. 153.—Spadix of Cuckow-pint (*Arum maculatum*), consisting of numerous male flowers *b,* female *a,* and abortive flowers *c,* sessile on a succulent rachis, and enclosed in a spathe, which in the figure has been removed. The rachis ends in a succulent club-shaped mass of cellular tissue, *d.*
FIG. 154.—Fruit of the Strawberry (*Fragaria vesca*), consisting of an enlarged succulent prolongation of the receptacle, bearing on its surface numerous carpels, which are often erroneously called seeds. The calyx is seen at the lower part.
FIG. 155.—The fruit of the Rose cut vertically. The receptacle *re* lines the interior of the calyx *ca,* and the carpels with their ovaries *ov* and styles *sty* are attached to it. The stamens and petals are seen at the upper part attached to the calyx.

Before proceeding to an examination of the parts of the flower-bud, we will consider the various modes of arrangement of the flowers upon the axis, or the *inflorescence.*

We may recognize two distinct types of inflorescence—one in which the flowers always arise as lateral shoots from a primary axis, which goes on elongating, and the lateral shoots never exceed in their development the length of the primary axis beyond their point of origin. The flowers are thus always *axillary*. Exceptions, such as in Cruciferous plants, are due to the non-appearance of the bracts. In the other type the primary axis terminates in a single flower, but lateral axes are given off from the axil of bracts, which again repeat the primary axis, and the development of each lateral axis is stronger than the primary axis beyond its point of origin. The flowers produced in this inflorescence are thus *terminal*. The first kind of inflorescence is *indeterminate, indefinite*, or *axillary*. Here the axis is either elongated, producing flower-buds as it grows, the lower expanding first; or it is shortened and depressed, and the outer flowers expand first. The expansion of the flowers is thus *centripetal*, that is, from base to apex, or from circumference to centre. This kind of inflorescence is shown in fig. 156, where the leaf from which the cluster of flowers is produced, *f*, represents the bract or floral leaf. The *rachis*, or primary axis of the flower is a'; this produces small leaflets *b*, which bear smaller flower-leaves or bractlets, from which peduncles or secondary axes spring, each bearing single flowers. In fig. 157 the same kind of inflorescence is shown on a shortened axis, the outer flowers expanding first, and those in the centre last.

Fig. 156.

Fig. 157.

Fig. 156.—Raceme of Barberry (*Berberis vulgaris*) produced in the axil of a leaf or bract *f*, which has been transformed into a spine, with two stipules *s* at its base; a', primary floral axis, bearing small alternate bracts *b*, in the axil of which the secondary axes a'', a'' are produced, each terminated by a flower. The expansion of the flowers is centripetal, or from base to apex; the lower flowers have passed into the state of fruit, the middle are fully expanded, and those at the top are still in bud. Indeterminate simple inflorescence.

Fig. 157.—Head of flowers (capitulum) of Scabiosa atro-purpurea. The inflorescence is simple and indeterminate, and the expansion of the flowers centripetal, those at the circumference opening first.

The second kind of inflorescence is *determinate, definite*, or *terminal*. In this the axis is either elongated and ends in a solitary flower, which thus terminates the axis, and if other flowers are produced, they belong to secondary axes farther from the centre; or the axis is shortened and flattened, producing a number of separate floral axes, the central one expanding first, while the others are developed in succession farther from the centre. The expansion of the flowers is in this case *centrifugal*, that is, from apex to base, or from centre to circumference. It is illustrated in fig. 158, where a representation is given of a plant of Ranunculus bulbosus; a' is the primary axis swollen at the base in a bulb-like manner *b*, and with roots proceeding from it. From the leaves which are radical proceeds the axis ending in a solitary terminal flower f'. About the middle of this axis there is a leaf or bract, from which a secondary floral axis a'' is produced, ending in a single flower f'', less advanced than the flower f'. This secondary axis bears a leaf also, from which a tertiary floral axis a''' is produced, bearing an unexpanded solitary flower f'''. From this tertiary axis a fourth is in progress of formation. Here f' is the termination of the primary axis, and this flower expands first, while the other flowers are developed centrifugally on separate axes.

A third series of inflorescences, termed *mixed*, may be recognized. In them the primary axis has an arrangement belonging to the opposite type from that on the branches, or *vice versa*. According to the mode and degree of development of the lateral shoots and also of the bracts, various forms of both inflorescences result.

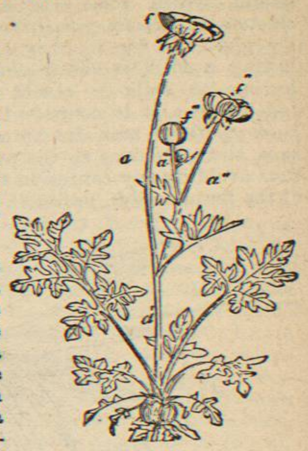

Fig. 158.

Plant of *Ranunculus bulbosus*, showing determinate inflorescence.

Amongst indefinite forms the simplest occurs when a lateral shoot produced in the axil of a large single foliage leaf of the plant ends in a single flower, the axis of the plant elongating beyond, as in Veronica hederifolia, Vinca minor, and Lysimachia nemorum. The flower in this case is *solitary*, and the Inflorescence has been designated *solitary axillary*. The ordinary leaves in this case become floral leaves or bracts, by producing flower-buds in place of leaf-buds. The flowers, being all offshoots of the same axis, are said to be of the same generation or degree, and their number, like that of the leaves of this main axis, is indefinite, varying with the vigour of the plant. Usually, however, the floral axis, arising from a more or less altered leaf or bract, instead of ending in a solitary flower, is prolonged, and bears numerous leaflets, called *bracteoles* or *bractlets*, from which smaller peduncles are produced, and those again in their turn may be branched in a similar way. Thus the flowers are arranged in groups, and frequently very complicated forms of inflorescence result. When the primary peduncle or floral axis, as in fig. 156, a', is elongated, and gives off pedicels a'', of nearly equal length ending in single flowers, a *raceme* or *cluster* is produced, as in Currant, Hyacinth, and Barberry. If the secondary floral axes give rise to tertiary ones, the raceme is branching, and forms what is by some called a *panicle*, as in Yucca gloriosa; but it is better to restrict this term to the lax inflorescence of some Grasses and Rushes. If in a raceme the lower flower-stalks are developed more strongly than the upper, and thus all the flowers are nearly on a level, a *corymb* is formed, which may be simple, as in fig. 159, where the primary axis a' divides into secondary axes a'', a'', which end in single flowers; or branching, where the secondary axes again subdivide. If the peduncles or secondary axes are very short or awanting, so that the flowers are sessile, a *spike* is produced, as in Plantago and Verbena officinalis (fig. 160). The spike sometimes bears unisexual flowers, usually staminiferous, the whole falling off by an articulation, as in Willow or Hazel (fig. 161), and then it is called an *amentum* or *catkin*, hence such trees are called *amentiferous*; at other times it becomes succulent, bearing numerous flowers, surrounded by a sheathing bract or spathe, and then it constitutes a *spadix*, which may be simple, as in Arum maculatum (fig. 153), or branching, as in Palms. A spike bearing female flowers only, and covered with scales, is either a *strobilus*, as in the Hop; or a *cone*, as in the Fir (fig. 133). It may be mentioned here that many do not consider the cone of Firs an axis of inflorescence,

but regard it as a single flower with the floral leaves placed at different heights. In Grasses there are usually numerous sessile flowers arranged in small spikes, called *locustæ* or *spikelets*, which are either set closely along a central axis, or produced on secondary axes formed by the branching of the central one; to the latter form the term *panicle* is applied.

Fig. 159.

Fig. 160.

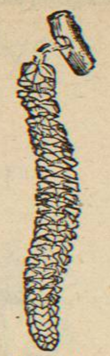

Fig. 161.

Fig. 159.—Corymb of *Cerasus Mahaleb*, produced in the axil of a leaf which has fallen, and terminating an abortive branch, at the base of which are modified leaves in the form of scales, *e*.

Fig. 160.—Spike of *Verbena officinalis*, showing sessile flowers on a common rachis. The flowers at the lower part of the spike have passed into fruit, those towards the middle are in full bloom, and those at the top are only in bud.

Fig. 161.—Amentum or catkin of Hazel (*Corylus Avellana*), consisting of an axis or rachis covered with bracts in the form of scales (*squamæ*), each of which covers a male flower, the stamens of which are seen projecting beyond the scale. The catkin falls off in a mass, separating from the branch by an articulation.

If the primary axis, in place of being elongated, is contracted, it gives rise to other forms of indefinite inflorescence. When the axis is so shortened that the secondary axes arise from a common point, and spread out as *radii* of nearly equal length, each ending in a single flower, or dividing again in a similar radiating manner, an *umbel* is produced, as in fig. 162. From the primary floral axis *a* the secondary axes come off in a radiating or umbrella-like manner, and end in small umbels *b*, which are called *partial umbels* or *umbellules*, to distinguish them from the *general umbel* formed by the branching of the primary axis. This inflorescence is seen in Hemlock, and other allied plants, which are hence called Umbelliferous. If there are numerous flowers on a flattened, convex, or slightly concave receptacle, having either very short pedicels or none, a *capitulum* (head), *anthodium*, or *calathium*, is formed, as in Dandelion, Daisy, and other Composite plants (fig. 146), also in Scabiosa (fig. 157) and Dipsacus. In the American Button-bush the heads are globular, in some species of Teazel, elliptical, while in Scabious, and in Composite plants, as Sunflower, Dandelion, Thistle, Centaury, and Marigold, they are somewhat hemispherical, with a flattened, slightly hollowed, or convex disk. If the margins of such a receptacle be developed upwards, the centre not developing, a concave receptacle is formed, which may partially or completely enclose a number of flowers that are generally unisexual. This gives rise to the peculiar inflorescence of Dorstenia (fig. 163), or to that of the Fig (fig. 150), where the flowers are placed on the inner surface of the hollow receptacle, and are provided with bracteoles. This inflorescence has been called *hypanthodium*.

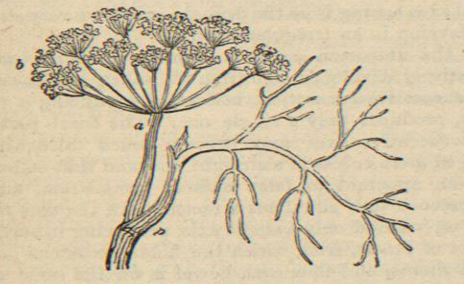

Fig. 162.

Compound umbel of Common Dill (*Anethum graveolens*), having a primary umbel *a*, and secondary umbels *b*, without either involucre or involucel. The petiole *p* of the leaf is sheathing, and has been denominated pericladium.

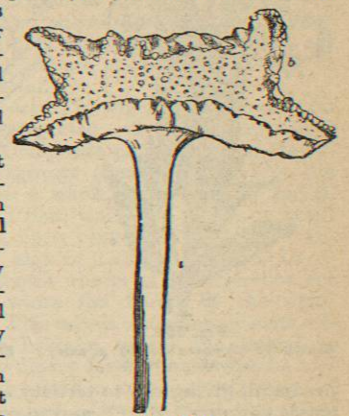

Fig. 163.

Peduncle *a* of *Dorstenia*, with concave receptacle *b*.

Lastly, we have what are called *compound indefinite* inflorescences. In these forms the lateral shoots, developed centripetally upon the primary axis, bear numerous bracteoles, from which floral shoots arise which may have a centripetal arrangement similar to that on the mother shoot, or it may be different. Thus we may have a group of racemes, arranged in a racemose manner on a common axis, forming a raceme of racemes or compound raceme, as in Astilbe. In the same way we may have compound umbels, as in Hemlock and most Umbelliferæ (fig. 162), a compound spike, as in Rye-grass, a compound spadix, as in some Palms, and a compound capitulum, as in the Hen-and-Chickens Daisy. Again, there may be a raceme of capitula, that is, a group of capitula disposed in a racemose manner, as in Petasites, a raceme of umbels, as in Ivy, and so on, all the forms of inflorescence being indefinite in disposition.

The elongation of secondary flower-stalks sometimes alters the general character of the inflorescence, changing a spike into a raceme, a raceme into a corymb, a capitulum into an umbel, and so forth. The capitulum of flowers in some Compositæ, such as Hypochæris radicata and Senecio vulgaris, by a similar change in the pedicels assumes the form of an umbel. Among Umbelliferæ the umbels are sometimes supported on very long stalks, while the pedicels of the individual flowers are not lengthened. In Eryngium the shortening of the pedicels changes an umbel into a capitulum. The umbellate inflorescence of Pelargonium has been seen changed into a raceme.

The simplest form of the definite type of inflorescence is seen in Anemone nemorosa and in Gentianella (Gentiana acaulis, fig. 164), where the axis terminates in a single flower, no other flowers being produced upon the plant. This is *solitary terminal* inflorescence. If other flowers were produced, they would arise as lateral shoots from the bracts below the first-formed flower. The general name of *cyme* is applied to the arrangement of a group of flowers in a definite inflorescence. A *cymose* inflorescence is an inflorescence where the primary floral axis before terminating in a flower gives off one or more lateral unifloral axes which repeat the process,—the development being only limited by the vigour of the plant. The floral axes are thus centrifugally developed. The cyme, according to its development, has been characterized as *biparous* or *uniparous*. In fig. 165 the biparous cyme is represented in the flowering branch of Erythræa Centaurium. Here the primary axis a' ends in a flower f', which has passed