POPULAR BOTANY

A. E. KNIGHT AND EDWARD STEP

THE LIVING PLANT FROM SEED TO FRUIT

BLOOD-LIPPED ONCID *(Oncidium hæmatochilum).*

The Oncids are a large group of Orchids, natives of tropical America and the West Indies. They all grow upon trees (epiphytes) and exhibit great variety of form and colour. The species figured is a native of New Grenada. The leaves are thick and leathery, and the flowers borne on erect spikes.

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THE LIVING PLANT FROM SEED TO FRUIT

BY

A. E. KNIGHT

AND

EDWARD STEP, F.L.S.

VOLUME II

WITH

721 BEAUTIFUL ILLUSTRATIONS

AND

18 COLORED PLATES

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COLOURED PLATES.

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Illustrations in the Text, Vol. II.

PEACH *(Prunus persica).*

The Peach is believed to have come originally from China, but has been cultivated in Europe from very ancient days, and in this country from the middle of the sixteenth century. It belongs to the same family as the Plums and Sloe. The varieties represented are semi-doubles, cultivated more for the flowers than for fruit.

CHAPTER X

THE LEAF IN RELATION TO ITS ENVIRONMENT—(Continued)

THOSE who have never studied under the microscope the singular forms of the covering hairs of leaves, have pleasures offered to them for many a winter evening. Possibly a glance at the illustrations which accompany this part of our text will help to kindle interest in the subject. Fig. 360 *b* represents some *simple* hairs of a species of *Brassica*; *i* some *forked* hairs of the Whitlow Grass (*Draba verna*); and *h* a *stellate* hair of the pretty Alpine Madwort (*Alyssum spinosum*). In these three specimens the hairs are unicellular, but multicellular hairs are met with in a large number of plants. When the cells grow together in a line, like the beads of a necklace, the hairs are said to be *moniliform*. Of this kind are the epidermal hairs of the Marvel of Peru (*Mirabilis jalapa*, fig. 360 *j*) and of the Virginian Spiderwort (*Tradescantia virginica*, *k*). When the cells spring from a common point, as in the Cretan Horehound (*Marrubium creticum*, *e*), the hairs are said to be *tufted*. *Branched* hairs, which need no describing, are found in several plants. They give the downy (*tomentose*) appearance to the leaves of *Nicandra anomala*, a Peruvian plant of medicinal value (*f*), and to the decurrent leaves of the Great Mullein (*Verbascum thapsus*). In a few plants of succulent habit, like the South African Rocheas, excessive evaporation is prevented by the development of special flinty cells on the epidermis of the thick fleshy leaves (*g*). They are many times larger than the ordinary epidermal cells, and their walls are largely composed of silica. A covering of this kind is simply the salvation of its possessor in time of drought. Not that fleshy leaves are ill-adapted to

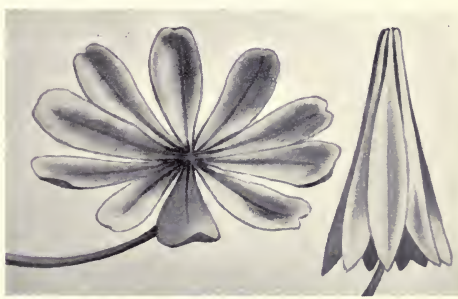

FIG. 352.—LEAVES OF LUPIN.

The first shows the position of the leaflets during the day; at night they fold down close to the stalk.

FIG. 353.—WOOD-SORREL (*Oxalis*).
During the day the leaflets spread out from the leaf-stalk;

FIG. 354.—WOOD-SORREL.
—at night, and during rain, they fold down close to the leaf-stalk.

dry climates; the reverse is the case, the transpiring surface of such leaves being much smaller than if they were flattened out into thin and spreading forms. Yet even the smaller surface needs to be protected, and this it is which gives its value to the flinty armour.

The vertical position which many leaves assume is likewise a means of checking excessive transpiration. One has met with the expression, "the *shadowless* forests of Australia," and the phrase is not inappropriate, for the leaves of many Eucalyptus-trees and Acacias (the chief timber trees in Australian woods) do not assume a horizontal position like the leaves of most European forest-trees, but are placed vertically on edge; and thus the shadows which they cast at midday are reduced to a mere line. This, as we need scarcely add, is due to the fact that the rays of light fall upon the upturned edges of the leaves and not upon the broad surfaces of the blades.* The latter, indeed, escape altogether the meridian sun, though they get the full benefit of his less scorching rays at the beginning and close of the day.

The interesting Compass-plant (*Silphium laciniatum*) should not be forgotten when speaking of the position assumed by leaves in reference to transpiration. Longfellow's *Evangeline* contains a graceful description of the plant (though he confuses flower and leaf), which

* This is also a protection from the injurious effect on the chlorophyll corpuscles of the intense sunlight.

Photo by] [*E. Step.*

FIG. 355.—BLACK MULLEIN (*Verbascum nigrum*).

The leaves are downy with a dense growth of stellate hairs. The yellow flowers are closely packed in long racemes which are a foot and a half long. EUROPE, SIBERIA.

FIG. 356.—SENSITIVE PLANT (*Mimosa pudica*).
Day position of leaf and leaflets.

is widely distributed over the North American prairies:

Look at this delicate plant that lifts its head from the meadow,
See how its leaves all point to the north, as true as the magnet;
It is the Compass-flower, that the finger of God has suspended
Here on its fragile stalk, to direct the traveller's journey
Over the sea-like, pathless, limitless waste of the desert.

The leaves of young specimens of this plant not only assume an almost vertical position, but by a singular twisting of their blades, bring themselves into a position which has earned it the name of Compass-plant. The lobes of each pinnate-parted leaf, extending like fingers on either side of the midrib, are said to point due north and south; but some observers who have watched the plant in its native habitat have thrown considerable doubt upon the statement, as they have found the leaves pointing in all directions.

The leaves of the Marram (*Psamma arenaria*) exhibit a special structure in view of this same purpose—the prevention of excessive loss of water. The plant in question is the Common Matweed of our sandhills, whose spreading fibrous roots are so useful in binding together the shifting sands on the coasts of Norfolk and Holland, and in many other places. It has been noted that "on wet days the leaves open longitudinally, so that their inner surface is freely exposed to the air, and the stomata which are situated there may not have their func-

FIG. 357.—SENSITIVE PLANT.
At night, or when touched, the leaf hangs down, and the leaflets fold closely together.

tions restricted; in dry weather, on the contrary, the leaves are rolled up so that the leaf almost forms a tube, the outer surface of which is hard and quite impervious to water." The mechanism by which this is effected is to be found in certain cells, which form longitudinal rows at the base of the furrows on the under surface of the leaves, and which are very sensitive to moisture. In damp weather the cells increase in turgidity by absorption of water, and the leaf opens.

Fig. 358.—Telegraph-plant (*Desmodium gyrans*).
The small *lateral* leaflets move up and down, twisting at the same time, and describe a kind of ellipse. The movement is not continuous, and is much influenced by temperature.

In concluding these observations on the dangers to plants from excessive heat, and the means provided by Nature to counteract those dangers, one is naturally led to the opposite side of the subject, and the question arises, If too much heat be injurious to a plant, may not, under contrary circumstances, *too great loss of heat* be injurious too? Moreover, if the all-wise Mother has devised means for protecting growing plants from the one evil, may she not also have devised means for protecting them from the other?

To both questions an affirmative answer may be given. Loss of heat has no less to be provided against than excessive transpiration—the damp and chilly nights must be taken into account quite as carefully as the dry and sunny days; for growth goes on in the plant more rapidly in some cases by night than by day, and if it were systematically deprived of heat during the hours of darkness, it would soon languish and die. Now the means which Nature has devised for protecting growing plants from loss of heat are beautifully simple. What is known as the "*sleep*" *of plants*—in other words, the nocturnal drooping and folding of leaves and flowers—comprehends the chief of those means, and we shall here confine our remarks to this well-known phenomenon.

Photo by] [*E. Step.*

FIG. 359.—OAR-WEED (*Laminaria digitata*),

One of the largest of our native seaweeds. The specimens photographed were fifteen feet long.

If you have ever sauntered through a garden by night, and examined, lantern in hand, the dew-drenched vegetation, you will have stumbled upon some curious discoveries. It is easy to imagine the surprise evoked during such an excursion. As you pause before one of the well-ordered beds, and look down at the familiar plants, you involuntarily ask yourself, What has become of the flowers? A few, indeed, are still plainly visible; but there are others that you miss, nor do you realise what has become of them until, on closer examination, you discover that some are closed, and others are hanging down their heads so that only their green collars (the calyces) meet the eye; while others, again, have skilfully concealed themselves behind their own foliage leaves.

The leaves, too, appear to be wonderfully changed. "We are all a-noddin', nid-nid-noddin'," seems to be their drowsy language. The *Tropæolums* no longer confront the vault of heaven with their green shields, which hang listless at their sides; the Lupins have folded up their digitate leaves like umbrellas (fig. 352); and on every hand the foliage seems heavy with slumber.

It may be cruel to unsettle so pleasing a fancy, but the phenomenon described, and which is popularly known as the sleep of plants, is simply a part of Nature's plan for guarding

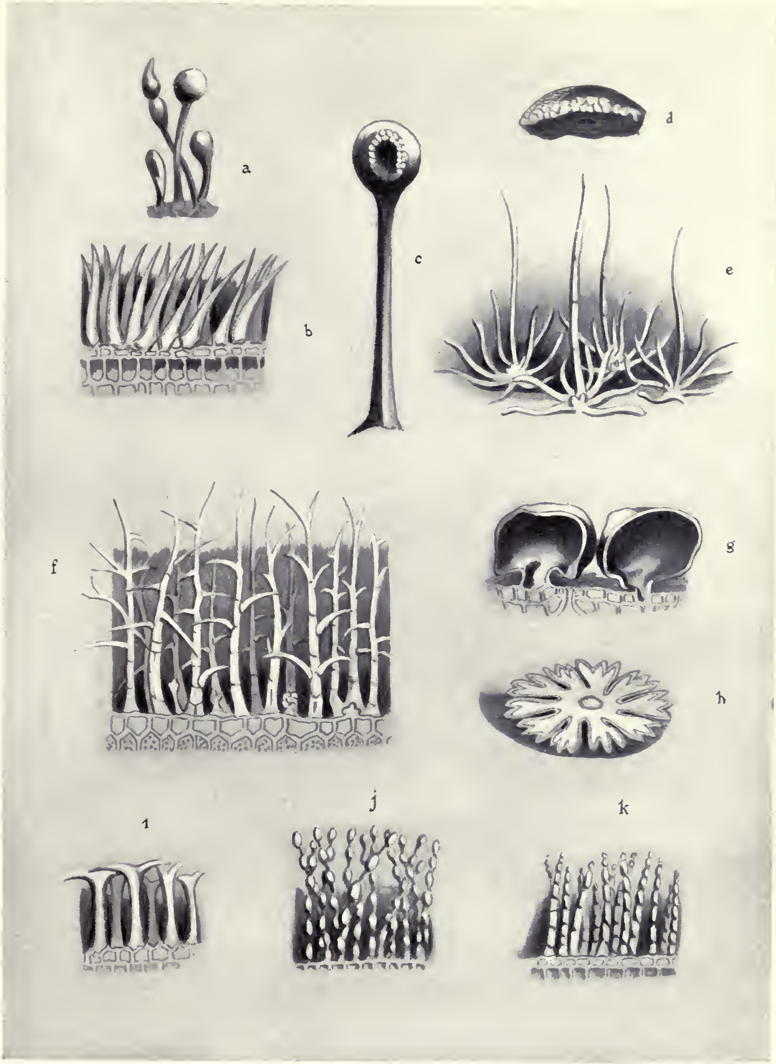

FIG. 360.—HAIRS FROM THE LEAVES OF VARIOUS PLANTS (MAGNIFIED).

(*a*) Glandular hairs of Snapdragon ; (*b*) simple unicellular hairs of a Brassica ; (*c*) glandular tentacle of Sundew ; (*d*) sessile gland of Hop ; (*e*) tufted hairs of Cretan Horehound ; (*f*) branched hairs of Nicandra ; (*g*) flinty covering of Rochea ; (*h*) stellate hair of Alpine Madwort ; (*i*) forked hairs of Whitlow Grass ; (*j*) muriform hairs of Marvel of Peru ; (*k*) muriform hairs of Virginian Spiderwort.

FIG. 361.—STINGING HAIR OF STINGING NETTLE.

her vegetable protégés against excessive loss of heat. The "sleep" position of leaves is, in fact, a protective arrangement. By folding themselves together and assuming, as far as possible, a vertical position, radiation is materially checked, and thus the plants undergo no serious fall of temperature during the night. We must not be misled by this popular term "sleep" into supposing that the nutritive processes of the plant are suspended at this time. "The drooping position assumed by the leaflets of *Oxalis* is simply protective; there is no correlation between the assumption of the drooping position and the temporary loss of the power of assimilation. Preparations made at night from the leaves of *Oxalis* when in the drooping nyctitropic position show a normally active power of assimilation, and the same is the case with leaflets of *Mimosa*. The movements performed in assuming the nocturnal nyctitropic position of certain 'sleep' plants are not accompanied by any corresponding internal changes or alterations in the power of assimilation. In this respect the sleep of plants is more external and apparent than internal and real" (A. J. Ewart, B.Sc., in *Journ. Linn. Soc.* [Botany], vol. xxxi., 1896).

Plants of the great Leguminous order, to which the Acacias, Mimosas, Peas, and Trefoils belong, exhibit the phenomenon of which we are treating in a very striking manner. The Wood-sorrels (*Oxalis acetosella*, *corniculata*, and *stricta*), also, are extremely sensitive to changes of temperature, folding down their leaves even in the daytime if rain threatens (figs. 353, 354), while a blow from a stick will cause them to shrink together with affecting suddenness. Sensitiveness is carried to an extreme in a tropical species of this genus, *Oxalis sensitiva*, concerning which it is affirmed that even the disturbances of the air caused by the approach of man are sufficient to induce the phenomenon, the petioles relaxing and the pinnate leaflets falling together like the leaves of a book. This is also said to be the case with several of the Mimosas; but the two species which are most common in English stove-houses (*M. pudica*, figs. 356, 357, and *M. sensitiva*), though collapsing readily at the slightest touch, certainly do not exhibit such extreme sensibility in this

FIG. 362.—HEDGEHOG VARIETY OF HOLLY.

country. Touch a leaf-point of *Mimosa*, and the small leaflets fold together, and the stalk to which they are attached drops suddenly. The leaflets on other branches of the compound leaf act in the same way; and finally the main leaf-stalk drops suddenly. The Mimosas have received poetic treatment from more than one distinguished writer. Erasmus Darwin says:

Weak with nice sense the chaste Mimosa stands,
From each rude touch withdraws her timid hands;
Oft as light clouds o'erpass the summer glade,
Alarmed she trembles at the moving shade;
And feels, alive through all her tender form,
The whispered murmurs of the gathering storm;
Shuts her sweet eyelids to approaching night,
And hails with freshened charms the rising light.

Photo by] [*E. Step.*

FIG. 363.—TEASEL (*Dipsacus sylvestris*).
Showing the protective spines on the stem, and the spiny bracts interspersed with the flowers in the flower-head.

The movements of so-called sensitive plants are probably in part due to a peculiar modification of certain of their leaf-cells, which—in the Mimosas, at least—are so constructed that delicate threads of protoplasm pass through their walls and maintain a connection with the living matter of adjoining cells. Thus the effects of a touch on one part of a leaf may be transmitted all over it; and if, as is not unlikely, these perforated cells are distributed through the stem and branches as well as the leaves, the effects spoken of may be carried to every part of the plant.

The drooping of the leaf-stalk (which, as in the leaf of *Mimosa pudica*, may alter its angle with the stem from ninety to thirty degrees) is caused by a beautiful piece of mechanism. At the base of the leaf-stalk there is a little cushion-like swelling, called the *pulvinus* (the Latin word for "cushion"), which contains a woody centre surrounded by parenchymatous cells, rich in water. When one of the pinnate leaflets is touched, the effect is transmitted to the pulvinus by the threads of protoplasm, with the result that the water passes from the cells on the lower to those on the upper side, causing the former to pass from a distended into a flabby state. They thus become temporarily unfit to support the leaf-stalk, which in

Photo by] [*E. Step.*

FIG. 364.—HOLLY (*Ilex aquifolium*).

Showing the spiny, dentate leaves and the clusters of red berries.

consequence falls of its own weight. By and by the water gains its original distribution, and then the leaf-stalk resumes its horizontal position.

The celebrated Telegraph-plant (*Desmodium gyrans*) is even more interesting than the Mimosas. It is an East Indian plant with violet flowers and trifoliate leaves, and the latter are in motion night and day. In bright sunshine the two lateral leaflets jerk up and down, and from side to side, in a remarkable manner, while the large terminal leaflet goes through similar though less perceptible movements (fig. 358). Should these movements be artificially checked for a while, the leaf will start again with increased velocity directly the retarding influence is removed. During darkness the

Photo by] [*Henry Irving.*

FIG. 365.—SPEAR PLUME-THISTLE (*Cnicus lanceolatus*).

All parts of the plant above ground are armed with needle-like spines. The florets are specially adapted for the visits of bees with long probosces, particularly humble-bees.

terminal leaflet assumes the perpendicular position which has been already shown to be characteristic of "sleeping" leaves.

The trembling movement of the leaves of the Aspen (*Populus tremula*) has supplied many figurative allusions to prose-writers and poets, and the phenomenon deserves a passing notice. The quivering is due to the elasticity of the long flattened foot-stalks; and Mr. Colbourn, of Hobart, suggests that the rapid movement in the air enables the leaf to throw off the excess of moisture which collects on it in the damp situations of the tree. Some force is given to this view if we look at the Aspen or the Black Poplar immediately after rain, when we shall find great numbers of the leaves held together by moisture. Kerner, however, regards the motion as an arrangement for protecting the flat broad leaves against crushing; but many other broad flat leaves are without this provision. He further remarks that the elasticity is due to the development of bast-strands in the leaf-stalks.

Fig. 366.—A Prickly Pear Cactus (*Opuntia multiflora*), Protected by fine barbed bristles.

We have now considered a few of the dangers to which the green leaves of plants are exposed, but the subject would be very imperfectly treated were no mention made of a danger of another kind. This form of danger belongs to the animate rather than the inanimate world—to "wild beasts and beasts of the field and creeping things" rather than to heat and cold and other such phenomena and forces. Innumerable animals feed upon the green tissues of plants, and find in a vegetarian diet their only sustenance; indeed, if Nature had not provided special contrivances to keep off these devourers, it is next to certain that whole families of plants would long since have vanished from the face of the earth. A few of these contrivances have been incidentally referred to in former chapters. When speaking of the sap of plants, we showed that the milky juice of the Common Lettuce (*Lactuca sativa*) protected the plant from the depredations of ants and other leaf-eating insects; and on a later occasion we saw that the thorns or spines in such plants as the Blackthorn (*Prunus spinosa*), Spiny Restharrow (*Ononis spinosa*), Spurges (*Euphorbia*), etc., render acceptable service by keeping off browsing cattle and herbivorous wild animals. But the subject was only lightly touched, and—from the nature of the connection in which it was introduced—many of these protective contrivances were not alluded to at all.

For example, no mention was made of *prickles*. Prickles are another kind of thorn. They are not, like spines, branches which have degenerated,

Photo by] [J. Holmes.

FIG. 367.—SPANGLE-GALLS ON OAK.

for they spring from the epidermis or cortex of a plant member, and contain no fibro-vascular bundles; while spines, it will be remembered, are traversed by those bundles which connect them with the vascular system of the stem and root. Good examples of prickles are offered by the Dog-rose (*Rosa canina*) and the Holly (*Ilex*), to name no other plants. In the former they occur on the petioles and branches; in the latter they spring from the margins of the leaves.

Plants of a prickly nature seldom develop those structures on leaves and branches which are out of reach of grazing animals. The Common Holly (*Ilex aquifolium*), the bristly dentate leaves of which form a characteristic feature of shrubby specimens of the plant, produces only unarmed leaves, with entire margins, on its upper branches, when it attains to the dignity and dimensions of a tree. Indeed, the gradations from

Photo by] [J. Holmes.

FIG. 368.—CHERRY-GALL ON OAK.

the prickly to the unarmed forms of leaves in the plant named are so numerous and marked, that the species has been separated into varieties to distinguish them. Compare, for example, a leaf of Henderson's Holly (*Ilex a. hendersoni*) with one of the Donington variety (*Ilex a. doningtonensis*), and both with a leaf of the Hedgehog Holly (*Ilex a. ferox*, fig. 362); which latter has prickles not only at the margin, but also on the upper surface. Its popular name is, indeed, exceedingly appropriate; so, too, is its Latin appellative—*ferox*, "savage." Several plants of the large genus *Solanum*, to which the Potato-plant and Woody Nightshade belong (*e.g. S. fontanesianum*, *jacquini*, and *maroniense*), have spiny erections on both sides of the leaf. They are borne upon the midrib and veins, and make the plants extremely awkward things to handle.

Photo by] [*J. Holmes.*

FIG. 369.—BRISTLE-GALL ON OAK.

These galls are caused by the gall-wasp, *Andricus lucidus*.

Many other protective arrangements more or less similar to those described occur readily to the mind; as, for instance, the sharp, strong, needle-shaped (*acicular*) leaves of many Grasses; the formidable thorny terminations of the leaves of the Agaves, and the spine-bordered lobes of leaves like the Thistle (*Carduus*), Teasel (*Dipsacus*), and *Acanthus*. It has been asserted that in the Southern Alps sheep will frequently return from pasture with their nostrils cut and bleeding, and the shepherds know at once that the cause of the mischief is a species of stiff-leaved Grass, *Festuca alpestris*, which they seek to destroy by burning. In some instances, Grasses which cause discomfort to grazing animals will be dealt with by the animals themselves, who seize them low down with their teeth and tear them from the ground. Kerner saw thousands of tufts of the Mat-grass (*Nardus stricta*), which had been rooted up by oxen, lying dried and bleached by the sun on some meadows in the Tyrolese Stubaithal.

Photo by] [*E. Step.*

FIG. 370.—STINGING NETTLE (*Urtica dioica*).

The leaves and stem are covered with hollow stinging hairs through which a poison is introduced to the victim's flesh. The small green flowers are wind-pollinated. NORTH TEMPERATE REGIONS, N. AFRICA, THE ANDES.

More formidable than any of the protective weapons yet mentioned are the *barbed bristles* which surround the buds on many of the *Opuntias*. Each of these is a sort of compound fish-hook in miniature, and woe to the unwary animal who pushes his nose against the smallest bunch of them! The little hooks enter the tender flesh, and cause intolerable itching, which is often succeeded by painful and, it may be, dangerous inflammation. The tormenting bristles are easily driven deeper, but the backward-pointing barbs tear the flesh unmercifully when any attempt is made to withdraw them. One species, *Opuntia ficus-indica*, better known as the Prickly Pear, is abundantly naturalized in the Mediterranean area, where it forms inpenetrable fences. Another species, *Opuntia ferox*, is said by Schleiden to be especially remarkable because of the strength and size of its defensive thorns. "Among the hairs and smaller spines," he says, "arise very long and thick spines, in different form and number, which give the best characters for the determination of the species. In some, these are so hard and strong that they even lame the wild asses which incautiously wound themselves when kicking off the spines to reach the means to still their thirst. In *Opuntia tuna*, which is the kind most frequently used for hedges, they are so large that even the buffaloes are killed by the inflammation following from these spines running into their breasts. It was this species, also, which was planted in a triple row as a boundary line between the English and French in the island of St. Christopher." Fig. 366 represents a flowering branch of *Opuntia multiflora*.

Fig. 371.—Flowering Branch of a Rose surrounded by a Bedeguar Gall.
The gall-fly and grub of same are shown in the corner of drawing.

No account of the protective armature of green leaves would be complete without a reference to *stinging hairs*. The mention of these very remarkable structures brings to mind the Common Nettle (*Urtica dioica*)—a weed that is known to every child. Let us take a peep through the microscope at one of its stinging hairs, and try to realise what takes place when any rash meddler with the plant gets stung. Our picture (fig. 361) represents a hair in section. It consists of a long, tapering single cell, rising from a cushion-like base, and widening at the apex into a little knob, which is bent somewhat out of the perpendicular. At the point where this bend takes place the cell-wall is extremely thin—so thin that a very slight touch suffices to break off the knob. When, therefore, such a touch is given, the mischief is done, and the acrid irritating fluid contained in the cell escapes at the point of rupture and enters the tiny wound which the vitreous apex of the hair has made. The fluid consists of formic acid and a sort of unorganized ferment or enzyme, the latter being thought to be the more poisonous property of the two. It may be added that the break takes place obliquely (a consequence of the bend above described), so that the broken end resembles the poison-fang of a serpent —to which, indeed, it has sometimes been compared.

Photo by] [*E. Step.*

Fig. 372.—Hairy Galls on Beech,
Caused by a two-winged fly (*Hormomyia*).

A brush from the leaf of any of the British Nettles (*Urtica dioica*, *urens*, and *pilulifera*) is doubtless a light matter, but to be stung by some of the Asiatic species is a very different thing. The great Shrubby Nettle (*Urtica crenulata*) of Northern India, for instance, is a nettle to beware of. "This plant," says Sir Joseph Hooker in his *Himalayan Journals*, "called 'mealum-ma,' attains fifteen feet in height; it has broad glossy leaves, and though apparently without stings, is held in so great dread that I had difficulty in getting help to cut it down. I gathered many specimens without allowing any part to touch my skin; still, the scentless effluvium was so powerful that mucous matter poured from my eyes and nose all the rest of the afternoon in such abundance that I had to hold my head over a basin for an hour. The sting is very virulent, producing inflammation; and to punish a child with 'mealum-ma' is the severest Lepcha threat." The writer explains in a footnote that the hairs are microscopically small, and they only sting violently during the autumn. M. Leschenault, a French botanist who had the misfortune to be stung by the "mealum-ma" at this particular season, while gathering one of the leaves for his herbarium, describes the symptoms that followed as anything but pleasant. At first he felt only a slight pricking which he wholly disregarded; but the pain gradually increased, and at the end of an hour it had become excruciating. The parts affected—the first three fingers of his left hand—felt as though they were being rubbed with a hot iron. Before long the pain had spread up the arm to the arm-pit; and within five hours of being stung the torture was increased tenfold by an ominous contraction of the muscles of the jaw, which made him fear an attack of lockjaw. However, the latter symptoms passed away towards evening, and from that time the pain continued to decrease, though upwards of nine days elapsed before it entirely left him.

Fig. 373.—Nail-galls
On leaf of Lime, produced by a mite.

That the inferior animals are sensitive to the stings of plants no less than man, and therefore that stinging hairs may be a real protection from grazing animals, is illustrated by the fact mentioned by Baillon, that the natives of Java rub buffaloes with a species of Nettle (*Urtica stimulans*) in order to excite them to fight with tigers. On the other hand, these vegetable fangs are innocuous to certain leaf-eating insects, which feed upon them with impunity; indeed, it is well known that the leaves of our British Nettles, which are all furnished with stinging hairs, form the only food of the caterpillars of three of our most beautiful butterflies—namely, *Vanessa atalanta*, *V. io*, and *V. urticæ*. But this fact affords us a very striking object-lesson on the way in which an offensive or merely defensive development in one organism may lead to the very considerable adaptation in some other organism that may be seriously affected by it. The three caterpillars named have developed protecting spines which keep the stinging hairs of the Nettle from contact with their tender skins. Their relative, *Pyrameis cardui*, which feeds on Thistles, is similarly protected. It is remarkable that, so far as we have read, botanical writers have failed to note that hairs similar to those of the Nettle, but in a far

Photo by] [*E. Step.*

FIG. 374.—*Primula obconica.*

This beautiful plant is covered with easily detachable hairs. If these, by incautious handling, come in contact with the human skin, they set up an inflammation very similar to eczema, for which it has been often mistaken.

Photo by] [*J. Holmes.*

FIG. 375.—SPIKED PEA-GALL,

On Dog-rose, caused by the gall-wasp, *Rhodites nervosa.*

less highly developed condition, are found on the leaves and young twigs of the Common Elm (*Ulmus campestris*). They are abundant along the midrib on the lower surface, and though they have nothing like the malignity of the Nettle, they cause a considerable amount of irritation to the hands and wrists of those who touch the leaves. The Elm sends up numerous suckers, and all down the bole it throws out new shoots, which would be probably browsed off but for the presence of these hairs. The Elm belongs to the same natural order (Urticaceæ) as the Nettle.

When investigation has been carried farther it will be shown probably that the hair-structures of many other plants have a protective purpose. Many species of Mullein (*Verbascum*), for example, have branched radiating hairs which rub off easily when the plant is handled, and, though not stiff or prickly, "remain hanging to the smallest inequalities on the surface of the disturbing body. If grazing animals bring the mucous membrane of their mouths into contact with the leaves of the Mullein," the flock-like masses of hair adhere to the tongue and palate and produce sensations that can hardly be pleasant (Kerner). The hairs of several species of *Primula*, also (notably *P. obconica*), set up an inflammation very like eczema when handled incautiously.

It may not be generally known that the singular growths called *galls*, so often to be seen on the leaves and branches of Flowering Plants, are due to insects. Formerly they were held to be entirely of a vegetable nature, and the insects found in them were thought to have been spontaneously generated there. Many species of Cynips lay their eggs in the parts named, plunging their exceedingly delicate ovipositors into the soft tissues, and thereby set up local irritation, which induces a responsive action of the protoplasm, and galls are produced. In some cases, however, the development of the gall does not commence until after the egg is hatched. No tree, probably, furnishes so great a variety of these growths as the Oak (*Quercus*), on which upwards of one hundred and fifty species have been observed, the well-known oak-apple being one of them. It is produced by the punctures of *Dryoteras terminalis*. Two species of Oak-gall often to be met with are produced by an insect named *Spathegaster baccarum*. Fig. 373 represents a leaf of a species of Lime (*Tilia platyphyllos*) with little conical excrescences or nail-galls, the work of a microscopic species of Phytoptus (*P. tilæ*), whose portrait you will notice just above the leaf. Similar galls, but of a downy nature, occur on the leaves of Beech (*Fagus sylvatica*), in this case caused by a two-winged fly (*Hormomyia piliger*). The green (ultimately red), mossy-looking growths called *bedeguars*, or Robin Redbreast's Pincushion, so common on branches of the Rose, are also of insect origin (fig. 371). The gall-fly (*Rhodites rosea*) deposits its eggs in the shoot-bud, which presently swells and begins to put out what should be in the natural course three leaves; but embryo leaves have so little parenchyma between their veins that they fall into threads and thus give the mossy appearance to the galls. On cutting open one of the bedeguars the larvæ of the insect will be found in the centre. In all these cases it appears that only the cells of the meristem can give rise to the galls. These growths do not appear to be actually injurious.

The galls that are found on Hedge Bedstraw (*Galium mollugo*) are produced by a minute two-winged fly (*Cecidomyia aparine*); and the many-chambered gall on young shoots of Spruce (*Picea excelsa*), that look like half a pine cone, are the work of a Coccus (*Kermes*). The "Witches Broom" on the Scots Pine (*Pinus sylvestris*) is an excrescence consisting of a multitude of short shoots produced by a fungus (*Peridermium elatinum*).

What is known as *fasciation*, or the fusing together of parts of a plant which are norm-

Photo by] [*E. Step.*

FIG. 376.—"WITCHES BROOM" ON SCOTS PINE,
Caused by the fungus *Peridermium elatinum*.

ally distinct, as in the triple flower of Fuchsia shown in fig. 377, is likewise (at least, in a large number of instances) due to gall-mites. Many of the singular metamorphoses of plant organs, too—floral leaves which are changed into foliage leaves, petals which become stamens, etc., etc.—are probably attributable to the same exciting cause—a subject of which we shall have more to say when speaking of the Flower.

In some instances galls have a positive economic value, though this, of course, is of no advantage to the plant. The galls of commerce are chiefly those which occur on *Quercus infectoria*, and the best of them come from Aleppo and Smyrna. They yield a fine black colour with any of the salts of iron, and are largely used in the manufacture of writing-ink. Perhaps the most dreaded of gall-producing insects is the grape-louse (*Phylloxera vastatrix*), which pierces with its proboscis the young leaves and roots of the European Vine (*Vitis vinifera*), and thereby causes the growths referred to. The galls, by driving away nourishment from the roots (in which they are ably assisted by the insects themselves), starve and weaken those delicate organs, and at last destroy the plant.

Fig. 377.—Fuchsia.
Monster flower caused by fasciation.

We have now touched upon all the more important facts connected with the forms, structure, and functions of foliage leaves, and with the means provided by Nature for their protection and preservation. A few remarks on the *decay and fall of the leaf* may fitly conclude the subject.

One of the first external signs of incipient decay in green leaves is the fading of their freshness. The green becomes dull, and gradually assumes a yellow, brown, or ruddy tinge, due to varying degrees of oxidation of the chlorophyll, contained in the cells.

The *fall of the leaf* is not primarily nor necessarily due to external forces. Wind and frost may, and do, perform their part, but long before the leaf has attained its full growth and vigour the busy protoplasts have been weaving a layer of cells, which shall infallibly ensure the work of disarticulation. These cells, botanically known as the *layer of separation*, are formed in the base of the leaf-stalk, and run at right angles to the older and displaced cells, so that they divide the leaf from its branch or stem.

Photo by] [*Henry Irving.*

FIG. 378.—" OAK-APPLE " (GALLS OF *Dryoteras terminalis*).

About two-thirds of the natural size. They are found in May and June on the twigs of the Oak, and the numerous larvæ are embedded in the soft tissue of the green- and red-skinned " apple."

CHAPTER XI

FLORAL FORMS AND THEIR RELATIONS TO INSECTS

> To me the meanest flower that blows does bring
> Thoughts that do often lie too deep for tears.
>
> WORDSWORTH.

AS there is a good deal of ground to be covered in this chapter, we will not waste time on the threshold. Our subject is the Flower—in many respects the most important, as certainly it is the most interesting, of the subjects of which Botany treats. The Flower contains the organs of reproduction, a fact which accounts for its pre-eminent importance: while the manner in which those organs discharge their appointed functions—assisted often by the most unlikely agencies, as water, wind, and insects—gives to the study of the Flower an attractiveness all its own. Root, stem, and leaf are not without their fascinations, too, as we have sought to show in earlier chapters, but the Flower is the part of the plant which rightfully commands the lion's share of interest.

FIG. 379.—CREEPING LOOSESTRIFE.
An example of solitary and axillary flowers.

As with the leaf, the beginning of the Flower is the bud. Flower-buds originate in much the same way as leaf-buds, and cannot be distinguished from the latter in their earlier stage. Like leaf-buds, too, they are formed either in the axils or at the ends of branches, and in accordance with those conditions are named respectively *axillary* and *terminal*.

The reader will probably recognize the little flower shown in fig. 379. It is the Moneywort or Creeping Loosestrife (*Lysimachia nummularia*), an English wild-flower partial to ruins and damp woods, and a favourite rockery plant under cultivation. It, and its near relation, the Woodland Loosestrife or Yellow Pimpernel, offer familiar examples of a *solitary* and *axillary* flower. The Herb-paris (*P. quadrifolia*, fig. 381) bears solitary flowers, too, but they are *terminal*, not axillary. The Herb-paris is one of the most singular of our wild-flowers, and, like the Loosestrifes, delights in moist and shady woods.

But solitary flowers, whether axillary or terminal, are the exception rather than the rule. In by far the greater number of plants the bud unfoldsinto a branch system, consisting of several flowers, which are known collectively as the *inflorescence*. The Cowslip (*Primula veris*), Cherry (*Prunus cerasus*), and Forget-me-not (*Myosotis palustris*) may serve as examples. What is popularly known as the "flower" of the Daisy (*Bellis perennis*) and Dandelion (*Taraxacum officinale*) is likewise an inflorescence; each of the so-called flowers being really a multitude of minute flowers (*florets*) crowded together on a single stem. We will consider the structure of one of these composite flowers later on.

Photo by] [*E. Step.*

FIG. 380.—CUCKOO-PINT (*Arum maculatum*).

The front part of the spathe has been cut away to show the minute flowers around the base of the spadix.

In describing a flower the presence or absence of a stalk should always be noted. Stalkless or *sessile* flowers are comparatively rare, but the flower-stems of stalked or *pedicellate* flowers may be so short as to be hardly perceptible. No more remarkable instance of a sessile flower could be named than that vegetable wonder, *Rafflesia arnoldi*, of which some account was given in a former chapter; and if we place side by side with *Rafflesia* the stalked inflorescence of the celebrated *Lilium giganteum*, we have a contrast indeed. A flower-stem of one of these Lilies, cut from a living plant in the Sunningdale Nursery in July, 1879, is preserved in No. 1 Museum at Kew. The circumference of the pedicel is eleven and a half inches, its height thirteen feet! Truly a Brobdingnagian flower-stem.

A stalk which supports a solitary flower, or the primary stalk of an inflorescence, is called a *peduncle*; while the branches or secondary stalks are known as *pedicels*. The stalk of Herb-paris, one of the flowers that we were looking at a moment ago, is an example of a peduncle; so is the primary stalk of the Lily of the Valley (*Convallaria majalis*), while its slender branches, curving with the weight of the dainty little bells, are pedicels. The portion of the floral stem (peduncle) which, in this plant, bears the stalked flowers, is the *rachis*. *Rachis* is the Greek word for "spine," and besides being the term used in anatomical science for the vertebral column of animals, is used for many things which suggest a resemblance to the spine, as the shaft of a feather, the stalk of the frond in Ferns, the axis of a compound leaf, and (as we have just seen) the axis of an inflorescence.

Fig. 381.—Herb-paris.
Solitary and terminal flower.

The Lily of the Valley is an extremely useful plant for an object-lesson. Who is not familiar with its pensile beauty? It is a favourite flower under cultivation, and one of the most sought after of wild-flowers. The plant needs some seeking, too, for it loves to hide from sight in shady glens, covering its nodding white bells with its large and glossy leaves.

You perceive that the leafless peduncle springs directly from a subterranean stem or root-stock—a rhizome, to use the botanical term. On this account the inflorescence is called a *scape*, and the plant itself a *scapigerous herb*. The Primrose, Cowslip, and Oxlip (*Primula vulgaris*, *P. veris*, and *P. elatior*) also offer familiar examples of scapigerous herbs.

Notice, further, that the pedicels of the Lily of the Valley spring from the axils of what appear to be minute leaves—a fact of importance, as similar leaf-like forms are found on most branched inflorescences. They are called *bracts*, from the Latin *bractea*, a thin plate of metal. Bracts are usually green, but in certain plants—as the Flowering Dogwood (*Cornus florida*) and the celebrated Edelweiss (*Leontopodium alpinum*)—they are white or coloured like the petals of flowers, and are then called *petaloid*. In *Poinsettia*

Photo by] [*E. Step.*

FIG. 382.—COWSLIP (*Primula veris*).

A familiar plant whose nodding yellow flowers are borne in an umbel on a tall scape, hence it is described as a scapigerous herb. EUROPE, W. ASIA, N. AFRICA.

FIG. 383.—OAT (*Avena sativa*),
With branched inflorescence (panicle). To the right is a single spikelet detached and enlarged, showing the parts more clearly.

they form the most showy portion of the inflorescence, the flowers themselves being small and inconspicuous. The names *bracteate* and *ebracteate* are applied to flowers according as they possess or do not possess these modified leaves.

Here is a flower that will be readily recognized (fig. 380). No lover of green lanes and sunny meadows bordering banks can be a stranger to the Cuckoo-pint or Wake Robin (*Arum maculatum*), with its "ear-like spindling flowers," as Clare calls them, "betinged with yellowish, white, or purplish hue." But let us be clear as to what we are looking at. The figure does not represent a single flower, but an inflorescence, the numerous flowers of which are congregated round the narrow lower part of the club-like column or *spadix*, while the sometimes spotted enveloping case is simply a special kind of bract, known as a *spathe*. Any large spadix-ensheathing bract, indeed, is termed a spathe, and such leaves are quite distinct from the foliage leaves both in form and functions. The spathe of *Amorphallus titanum*, an Aroid of Western Sumatra, measures nearly six feet in diameter, while its purple spadix attains a height of nearly six feet, and a single leaf has been known to cover an area of forty-five feet in circumference (fig. 384).

In a large number of plants the bracts are collected in a whorl around a cluster of flowers, and then we have what is called an *involucre*. Such an arrangement is often of great service to the densely packed florets, particularly during the night, when loss of heat by radiation is largely prevented by the closing of the involucres. The Yellow Goatsbeard (*Tragopogon pratensis*) and Dandelion (*Taraxacum officinale*) may serve for illustration (fig. 386). Could any more perfect arrangement have been devised for protecting their clustering florets from sudden changes of temperature than these circles of stout little bracts? The Wood-anemone (*A. nemorosa*), whose white or delicate crimson petals open in April or May, has a whorl of three leaf-like involucral bracts at some distance below its single flowers. In the Limes (*Tilia*) the long bracts remain on the trees till the fruit is ripe, and fall with it (fig. 341). They serve the purpose of wings, and materially assist the wind in dispersing the seed. Whether the curious accrescent bracts of *Neuropeltis racemosa*, an Indian plant belonging to the Bindweed family (Convolvulaceæ), subserve a similar purpose, we are not in a position to say.

In the Grasses the outer scales of the spikelets are called *glumes*, the inner *pales* or *paleæ*. One of our common cereals may be taken as an example. Here (fig. 383) is a branched inflorescence or *panicle* of the Common Oat (*Avena sativa*), consisting of a peduncle and pedicels, with a flower-containing spikelet at the end of each. To the right of the panicle one of the spikelets is shown separately, on a larger scale, the glumes are the outer scales, while the inner scales are the pales. The long bristle-like appendage with which one of these inner scales is furnished is known as the beard or *awn*.

FIG. 384.—GIANT ARUM (*Amorphallus titanum*).
The enclosing spathe is nearly six feet across, whilst the central spadix is six feet high. Its leaves are sometimes forty-five feet in circumference.

All inflorescences resolve themselves naturally into two great divisions. When, as in the Pink (*Dianthus*), Buttercup (*Ranunculus*), Gentian (*Gentiana*), etc., a single flower ends the primary axis, which is thereby arrested in its growth and does not elongate, fresh flowers being produced from separate axes and expanding after the central flower, then we have what is known as a *definite* inflorescence. When, on the other hand, the flowers are produced laterally on the axis, which elongates and continues to produce flowers in regular succession from below upwards—as is the case, for instance, in the Snapdragon (*Antirrhinum*) and Wallflower (*Cheiranthus cheiri*), then the inflorescence is said to be *indefinite.* Figs. 396 and 401 will illustrate the differences: figs. 385 and 396 represent definite inflorescences, the latter with numerous floral axes; the inflorescence of *Dicentra* (fig. 387) is indefinite.

There is no need to give a detailed account of the various kinds of inflorescence. They are pretty numerous, and have received names which Dominie Sampson would have loved to roll off his tongue. Under the head of definite inflorescences we have the *fascicle*, the *glomerulus*, the *verticillaster*, and five kinds of *cyme*—*spiked*, *panicled*, *corymbose*, *dichotomous*, and *scorpioid*; while the nomenclature of the various forms of indefinite inflorescence is even more extensive. Those with lengthened axes and sessile flowers, which form a sub-group under the common name of *spikes*, comprise the *catkin*, *spadix*, *strobile*, and *cone*; those with lengthened axes and stalked flowers, constituting a second sub-group under the name of *racemes*, comprise the *corymb*, *panicle*, and *thyrsus*. Then there are the forms with shortened axes and sessile flowers, the *anthodium* and *hypanthodium*, which may be bracketed under *capitula* to make a third group; and, lastly, we have the two kinds of *umbel*, *simple* and *compound*, both characterized by shortened axes and stalked flowers.

FIG. 385.—PINK.
An example of definite inflorescence.

They may be tabulated thus, and the illustrations will help the memory:

DEFINITE INFLORESCENCES (page 327).	INDEFINITE INFLORESCENCES (page 331).	
Fascicle (*c*)	*Spikes.* (Sessile flowers on lengthened axes.)	*Racemes.* (Stalked flowers on lengthened axes.)
Glomerulus (*e*)	Catkin (*h*)	Corymb (*i*)
	Spadix	Panicle (*e*)
Verticillaster (*f*)	Strobile (*c*)	Thyrsus (*f*)
Cyme: Spiked	Cone (*a*)	
Cyme: Panicled (*a*)		
Cyme: Corymbose (*b*)	*Capitula.*	*Umbels.*
Cyme: Dichotomous	Anthodium (*g*)	Simple (*b*)
Cyme: Scorpioid (*d*)	Hypanthodium (*d*)	Compound (*k*)

Many useful ends are brought about by the massing together of inflorescences, and not the least of these is the facilitating of insect visits to the

Photo by] [*E. Step.*

FIG. 386.—GOATSBEARD (*Tragopogon pratensis*).

The floral bracts are much longer than the ray florets, and protect the flower-head before the florets open and while they are perfecting their seeds. EUROPE, N. AND W. ASIA, HIMALAYA.

Photo by] [*E. Step.*

FIG. 387.—BLEEDING HEART (*Dicentra spectabilis*).

A beautiful example of the indefinite inflorescence is furnished by its long racemes.

plant. Small surfaces of colour are always rendered more conspicuous if placed close to one another; and there can be little doubt that bees and other winged insects, which are known to play an important part in the cross-fertilization of plants, are attracted more readily to flowers which club together, so to speak, than to those which maintain a solitary existence. We offer this remark in passing, but the subject will be before us again by-and-by, when there will be opportunity for considering the facts more fully.

Thus far we have been considering flowers in clusters (*i.e.* inflorescences), and little has been said of the flower as an individual; though this is really our main subject. What is a flower? Popularly the term is applied to the delicate and gaily coloured leaves or petals on a plant; but as many true flowers have no petals at all, it is easy to see that the popular conception is defective. Nor is it sufficiently exact to say that a flower is "that part of a plant which subserves the purpose of reproduction." Have we not already seen that leaves, roots, and stems may subserve a like purpose, being capable of producing buds which, whether they remain attached to the parent plant or are severed from it, are unquestionably new individuals? A far more satisfactory definition is furnished by Professor George Henslow, who calls the flower "a living machine for making seed in order to reproduce the plant and so keep up a succession of its kind." Let us add that this mechanism is acted upon, *not* from *without*, like a loom, but from *within*, by the vital force which resides in the protoplasm.

ROSY GARLIC *(Allium acuminatum).*

A representative of the Onion section of the Lily family. The plant springs from a cluster of little bulbs, and the very slender leaves are round and hollow. The umbel of flower-buds is at first enclosed in a papery spathe at the summit of the leafless scape. It is a native of N.W. America. The form illustrated is the Californian variety *(rubrum)* with red-purple flowers.

If we take a simple flower—say a Buttercup—and examine it, we find that it consists of four distinct sets of parts, or *organs*. Starting from the outside (fig. 389) we have, first of all, a green *calyx* (*k*) composed in this case of five leaf-like organs or *sepals*; then the showy yellow leaves or *petals* (figs. 388 and 389, *c*), which are also five in number, and are called collectively the *corolla*; next a number of delicate and slender bodies—the *stamens* (*s*), each of which is furnished with a thread-like stalk—the *filament*, surmounted by a sort of double sac—the *anther*, which opens at the sides by two slits and contains in each of its cells or *lobes* a yellow powder—the *pollen*. The small part of the filament which runs up between the anther-cells is appropriately termed the *connective*. Lastly, in the very centre of the flower we come upon the fourth set of organs, consisting of a number of tiny green bodies—the *carpels*, seated upon a small elevated portion of the *receptacle*, and known collectively as the *pistil* (fig. 391). Looked at under a magnifying glass, each of these carpels is found to consist of a roundish part or *ovary*, which is gradually contracted above into a kind of short bent horn—the *style*, of which the tip or *stigma* is somewhat wider and more shiny than the rest. The ovary is hollow and contains the *ovule*, or precursor of the seed (fig. 390).

FIG. 388.—BUTTERCUP.
Corolla (*c*); stamens (*s*).

The only parts of a flower which are absolutely necessary for the production of seeds are the stamen, or male organ, and the pistil, or female organ; and they are called on that account the *essential floral organs*. They stand in the same relation to the seed as parents to a child; in fact, they are the father and mother of the seed. The calyx or corolla are of altogether secondary importance, and are merely spoken of as the *floral envelopes*.

Some writers have seen an analogy between a flowering plant and a beehive, and certainly a community of bees affords an instructive illustration if the search for resemblances be not pushed too far. Normally speaking, a hive contains three kinds of bees: first, the workers, which are of no sex,

FIG. 389.—BUTTERCUP FROM BELOW.
Corolla (*c*); calyx (*k*).

and usually number many thousands. They are the industrious members of the community, who provide the food and collect and give form to the raw material out of which the cells are constructed. Secondly, there are the males or drones, a less numerous company, though often amounting to several hundreds; and lastly there is the solitary female or queen-bee, upon whose fertility the perpetuation of the species depends.

So it is with the plant. The foliage leaves, which convert the raw food materials derived from the root, etc., into organic compounds, are the workers; the stamens, with their little sacs of meal-like pollen, answer to the males or drones; and the pistil, with its ovules, corresponds fairly well with the female or queen. When it is added that the pollen of the male organ is the fertilizing agent of the female organ —the means by which the ovules are converted into matured and perfect seeds—it will be seen how close is the analogy.

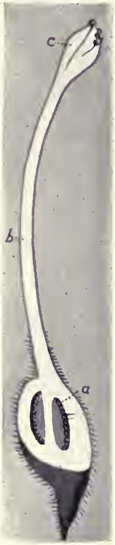

FIG. 390.—SECTION THROUGH PISTIL OF SNAPDRAGON.

Ovary (*a*); style (*b*); stigma (*c*).

It may be asked, In what way does the pollen of the male organ act upon the female organ? The process may be understood by reference to a section of the pistil of a well-known flower, the Snapdragon (*Antirrhinum majus*, fig. 390). Though differing very considerably in form from the pistil of the Buttercup which we were looking at a few moments ago, it resembles, in its main features, the individual carpels of that flower—indeed, like the carpels, it consists of an ovary (*a*), style (*b*), and stigma (*c*). The tiny round bodies shown on the surface of the stigma are grains of pollen, which have been conveyed thither from the anther-cells of the stamens *of another flower* by insect agency, and it is by means of those microscopic grains of yellow dust that the tiny unripe ovules in the swollen base of the pistil are to be fertilized, and thereby made capable of growing into perfect plant-producing seeds. This is effected in the following manner: On reaching the stigma, the pollen-grains, stimulated by a viscid secretion exuded from the stigmatic surface, presently put forth tubes, which force their way down the loose conducting tissue of the style (fig. 396) into the ovary, and so pass on to the ovules, where the definite act of impregnation takes place.

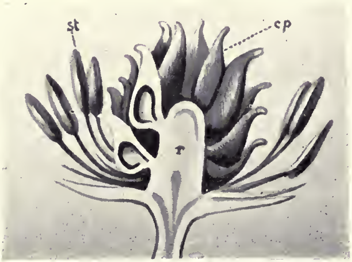

FIG. 391.—BUTTERCUP.

Section showing receptacle (*r*) to which the carpels (*cp*) are attached. They form collectively the pistil, and, when ripe, the fruit.

It is important to get a clear grasp

Photo by] [*Henry Troth.*

FIG. 392.—AMERICAN MEADOWSWEET (*Spiræa salicifolia*).

A favourite plant of pollen-seeking insects, with thyrsoid inflorescence. NORTH AMERICA, ASIA.

FIG. 393.—ABNORMAL FLOWER OF *Wistaria*,
With two petaloid stamens (*ps.*). (The keel, wings, and standard have been removed.)

of what has been before us in this rapid sketch. The process that has been described is the same, in all essential particulars, as that which goes on in the great majority of flowering plants, and it is so simple as to be easily understood. The pollen may be conveyed to the stigma by other than insect agency, and the tubes may pursue a more winding course through the conducting tissue; but these are details, and the above description may be accepted as a fairly representative one. What actually takes place in the ovules when the pollen-tubes have found an entrance will be explained farther on (Chap. XIV.): it is sufficient here to have directed attention to the fact itself. The growth of the tubes may be conveniently demonstrated with the pollen of the cultivated varieties of *Caladium*, all that is needed being to leave a few grains on a damp microscope slide for five or six hours.

We have already seen that the beginning of the flower is, like the beginning of the leaf, the bud: and that a flower-bud and a foliage-bud are indistinguishable in the early stages of growth. The theory of the development of all parts of the flower from leaves was enunciated by the poet Goethe nearly a century ago; and though the announcement of his discovery was accompanied by a good deal of speculation which subsequent research has shown to be erroneous, his main position had much to recommend it, nor does it lack defenders even at the present day. Goethe taught that "the elementary floret expands into a leaf upon the stem, contracts to make the calyx, expands again to make the petal, to contract again into sexual organs, and expand for the last time into fruit."

FIG. 394.—ABNORMAL FLOWER OF *Begonia*,
With sepals developed as green foliage leaves.

On the other hand, there are physiologists of the first rank who hold the theory of the German poet in light esteem, and to whom the pronouncement that "every flower is simply a metamorphosed leaf-shoot" is a dangerous expression, implying that the flower has been developed in course of evolution from a leaf-shoot, for which, in their judgment, there is not sufficient evidence. We are disposed to concur in this view, and rather than yield allegiance too readily to Goethe's theory would say

Photo by] [*E. Step.*

FIG. 395.—LARGE-FLOWERED ST. JOHN'S WORT (*Hypericum calycinum*).

Also known as Rose of Sharon. The large flowers offer good examples of spiral æstivation. The profuse stamens form a number of little bundles.

that there are flower-shoots and leaf-shoots, without attempting to derive one from the other.

Yet the tendency of the floral organs to relapse into the foliar form in certain abnormally developed flowers, at least confirms the idea that floral leaves and foliage leaves are homologous structures.

Most of us, doubtless, have met with flowers of the kind referred to—"monstrous" flowers, as they are called. In *Science Gossip* (1890) there is an interesting series of papers on the subject, by Dr. J. E. Taylor, with drawings of some of the more remarkable monstrosities. In one place we find an abnormal Knapweed (*Centaurea nigra*), of which some of the florets have become leaf-like; in another, a Daisy (*Bellis perennis*) has developed a true foliage leaf instead of a bract in the involucre. A third specimen (a flower of the Enchanter's Nightshade—*Circæa lutetiana*) appears with a portion of its stigma transformed into the anther of a stamen, and a stamen assuming the character of a petal, while, in place of another of its petals, two sepals are developed! Not less remarkable is the figure of a Peach-flower, whose organs exhibit a steady gradation from petals to foliage leaves; and farther on in the volume we meet with an abnormal Rose, entirely devoid of petals, and with sepals which seem to have been trying ard to produce a serrated margin. The stamens of this flower are normally developed, but the pistil (if pistil it may be called) is a curiosity, the style being elongated into a green and healthy-looking shoot, bearing some two or three dozen ordinary leaves!

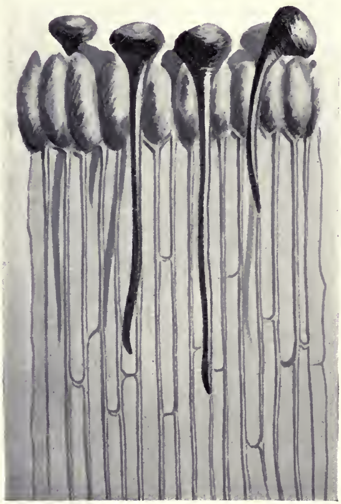

FIG. 396.—SNAPDRAGON.

A portion of the stigma and style, showing pollen-grains on the former putting forth tubes and penetrating the style.

The "monster" flowers which have come under our own notice are not so singular as those figured in Dr. Taylor's remarkable articles, but they serve no less to illustrate Goethe's law. The first figure (fig. 393) represents a flower of *Wistaria*, from which the coloured petals have been removed. In this example the abnormally developed organs are the stamens, one of which has a small leaf-shaped purple petal growing out from the centre of the style; while another has developed a similar petaloid organ in place of the anther-lobes. In the second figure (fig. 394) we have a "monstrous" flower of Begonia (*B. octavia*), whose outer petals—or rather sepals—have been metamorphosed into green leaves, with midrib, veins, etc.

In many species of the genus *Clematis*, the sepals are *petaloid*—that is to say, they are coloured like true petals, while the petals are absent. The former are spoken of collectively as the *perianth*, this being the name applied to the floral envelopes of a flower when calyx and corolla are not easily distinguished. It would be well, perhaps, to keep exclusively to this use of the term, rather than apply it in a loose way to the floral envelopes of any and every flower. In the figure of *Clematis cærulea* (fig. 398), the six petal-like organs (really sepals) constitute the perianth.

Probably no flower better illustrates the truth we are considering than

Fig. 397.—Definite Inflorescences.

(a) Panicled cyme of Chinese Privet (*Ligustrum lucidum*). (b) Corymbose cyme of Dogwood (*Cornus sanguinea*). (c) Fascicle of Sweet-william (*Dianthus barbatus*). (d) Scorpioid cyme of Forget-me-not (*Myosotis palustris*). (e) Glomerulus of Box (*Buxus sempervirens*). (f) Verticillaster of Yellow Archangel (*Lamium galeobdolon*).

the White Water-lily (*Nymphæa alba*), in which the gradual stages of transformation from the green sepals of the calyx to the yellow pollen-producing stamens may be seen to great advantage. We are not speaking now of "monstrous" specimens of the flower (nor were the Begonia and Clematis last alluded to at all abnormal), but of the ordinary White Water-lily; which thus shows, in a permanent fashion, the community which exists between the various members of the flower. For the sepals merge into petals, and the petals into stamens, by such imperceptible gradations that at certain points it is difficult to say to what set of organs particular parts belong. In drawings made to illustrate the fact, it is easy enough to see that one figure with its dark green colouring is a sepal, and that a second, though of a paler green, is probably a sepal too; but what of the next figure? This is neither a decided green nor a pure white, but a cross between the two, and it might be called indifferently a sepal or a petal. In the next row we have petals beyond a doubt; but we are again at a loss when we come to another row. Do these organs represent petals or stamens? They are broad and white like the former row, but the thickening at their apex is of a yellow colour, and has all the appearance of rudimentary anther-lobes. The figure beside it is equally perplexing, and not till we get far in do we find a stamen pure and simple, with normally developed style and anther and abundance of pollen. The transition is far more gradual than the description might lead one to suppose. In the flower itself a large number of petaloid sepals and stameniferous petals have place between the organs named; and each differs in some slight degree from its neighbour. Here, then, you have an abiding witness to the facts of which we have been treating—a constantly accessible illustration of that homology of structure which seems to exist between the members of every flower. We are now in a position to carry our inquiry a step farther.

FIG. 398.—FLOWER OF *Clematis cærulea*,
With petaloid sepals.

A flower being only a modified shoot, it is not surprising that the

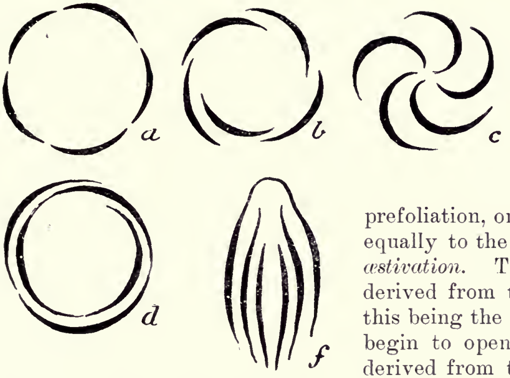

FIG. 399.—ÆSTIVATION OF FLOWERS.
(a) Valvate. (b) Imbricate. (c) Contorted or twisted. (d) Quincuncial. (f) Vexillary.

arrangement of rudimentary floral organs in the bud is analogous to the arrangement of young foliage leaves; and therefore that what has been already said on the subject of prefoliation, or vernation, applies almost equally to the subject of *prefloration*, or *æstivation*. The word "æstivation" is derived from the Latin *æstas*, summer, this being the season when most flowers begin to open, just as "vernation" is derived from the Latin *ver*, the season specially associated with the expanding of leaf-buds. Moreover, the terms which are employed in describing the various modifications in the one, answer almost equally for the other; though flower-buds exhibit certain arrangements which are peculiar, and for which special terms have had to be invented.

It is sufficient here to observe that all the various modifications may be arranged under two heads, the *circular* and the *imbricated* or *spiral*. The former comprehends those varieties in which the component parts of the whorl (the sepals of the calyx, petals of the corolla, and so forth) are arranged in a circle and nearly on the same level; and the latter includes those forms in which the said parts overlap one another, and have a more or less spiral arrangement, the consequence of their being placed at slightly different levels. For interesting varieties of circular æstivation the calyx of the flower-buds of the Lime (*Tilia*) and Hollyhock (*Althæa rosea*) and the folded corolla of the Potato (*Solanum tuberosum*) may be profitably examined; while the Camellia, Rose, Bindweed (*Convolvulus*), Snapdragon (*Antirrhinum*), and St. John's Wort (*Hypericum*) offer examples of the chief varieties of spiral æstivation (figs. 395 and 399).

FIG. 400.—FLORET OF DANDELION.
(a) Cohering anthers. (b) Extremity of style. (c) Ligulate corolla.

We approach more interesting ground when we begin to speak of the *expanded* flower. The question of form and arrangement again meets us on the threshold, but the study of the structural variations of flowers by no means confines one to the acquisition of name-lists or to tedious and meagre definitions. The question is one of scientific importance, involving as a preliminary step the arrangement of multitudes of appearances under primary points of view, and their classification according to rule and exception; by which means alone a discovery of the actual laws of Nature is rendered possible. Now, manifold as are the structural arrangements of flowers, the variations really concern only a few simple subjects, and when these are grasped the investigation of the causes which produce the differences in the whole floral world is by no means a hopeless undertaking (Schleiden).

FIG. 401.—COMMON PEA.
A carpel with seeds removed.

The *subjects of variation* are, in fact, four; and the first to be mentioned is *number*. A Lily, for example, has three sepals, three petals, and six (*i.e.* twice three) stamens; while its pistil, though looking like a single organ, is really made up of three carpels which have grown together. The Lily belongs to the great class of Monocotyledons, and three may be said to be the characteristic number of that class. In the floral whorls of Dicotyledons, on the other hand, threes are a rarity; nor can any number be said to be characteristic, though fours and fives are very common. A Fuchsia has four coloured sepals, four petals, twice four (*i.e.* eight) stamens, and four carpels. A flower of Cherry, on the other hand, has its two outer whorls, the calyx and corolla, in fives, and its stamens form a multiple of five—namely, twenty. The ovary does not follow the rule—it is solitary; nor is this case by any means an exceptional one, the parts of the pistil in the majority of Dicotyledons being fewer than in the other whorls.

It might easily be shown that whorls of flowers correspond to cycles of leaves, but it would be exceeding our present limits to push our inquiries farther in this direction.

The second of the four subjects of variation is *cohesion*. This term is applied by botanists to the union of *like* parts in a flower, as of sepal with sepal, petal with petal, stamen with stamen, and so forth. Both the calyx and corolla of a Primrose are good examples of cohesion. Here the five sepals unite in a tube and form what is called a *gamosepalous* calyx; the five petals are also fused together, and so the corolla is described as *gamopetalous*. A calyx whose sepals are not united is said to be *polysepalous*; a corolla with separate petals is *polypetalous*. In the Laburnum (*L. vulgare*) the fila-

FIG. 402.—INDEFINITE INFLORESCENCES.

(*a*) Cone of Larch (*Larix europea*). (*b*) Umbel of Cowslip (*Primula veris*). (*c*) Strobile of Hop (*Humulus lupulus*). (*d*) Hypanthodium of Fig (*Ficus carica*). (*e*) Panicle of a Yucca. (*f*) Thyrsus of Horse-chestnut (*Æsculus hippocastanum*). (*g*) Capitulum of Corn Blue-bottle (*Centaurea cyanus*). (*h*) Catkin of Hazel (*Corylus avellana*). (*i*) Corymb of Cherry (*Cerasus mahaleb*). (*k*) Compound umbel of Fool's Parsley (*Æthusa cynapium*).

Fig. 403.—Carrot (*Daucus carota*).
Section through epigynous flower.

ments of the stamens cohere so as to form a tube—they are *monadelphous*. In the Dandelion (*Taraxacum officinale*) it is the anthers which unite, and the stamens are said to be *syngenesious* (fig. 400). Lobelia shows both conditions. Stamens which are united into two, three, or more groups are termed *di-*, *tri-*, and *polyadelphous* respectively.

Then as to carpels. These may be united in two ways. "If we take a pea-pod, we shall find that it closely resembles a narrow, long-pointed leaf folded down the middle, with the edges in contact. Such is really Nature's method of making a carpel, of course greatly modifying the leaf for its new purpose (fig. 401). The peas, *i.e.* the ovules, are always produced down the united margins in two rows, *i.e.* one row on each margin. Now suppose we take two or more pea-pods. Place them with their margins in contact, and then compress them so that the *sides* will meet, and imagine them to have thus *grown* in contact. They would then be in a state of cohesion, and a cross section through the ovaries would reveal as many chambers as there are carpels. That is one way. This is well seen in the pistil of the Bluebell (*Scilla nutans*) [and the Purple Spring Crocus (*Crocus officinalis*), fig. 406)]. Another may be illustrated as follows: Take two or more pods, but this time crack them open down the margins where the peas are (but not down the opposite side); half the peas will now be found on one margin and half on the other. Now place the open pods in a circle, edge to edge, and imagine the edges only to become coherent. There will thus be *one* large chamber, with as many double rows of ovules as there are carpels. The Violet (*Viola*) and Mignonette (*Reseda lutea*) will illustrate this condition" (Henslow).

Pistils which are made up of two or more carpels are described as *compound*, to distinguish them from *simple* pistils, which contain only one carpel. Yet it must not be

Fig. 404.—Begonia.
Section across syncarpous ovary, showing axial placentation.

supposed that the carpels of all compound pistils cohere. In the Buttercup, for example, they are free and distinct (fig. 407), whence they are called *apocarpous*. In Begonia, on the other hand (fig. 404), they are united, or *syncarpous*.

We come now to the third subject of variation—namely, *adhesion*, or the union of *un*like parts of a flower. A calyx uniting with a corolla, a corolla with stamens, and stamens with pistil, would all be instances of adhesion; though the first-named manner of union is not common. Very seldom do

Photo by] [*E. Step*.

FIG. 405.—DOG-ROSE AND FIELD-ROSE.

Showing urn-shaped (*urceolate*) receptacles, which later turn red and become the "hips" enclosing the fruits. The calyx is seen above the receptacle.

sepals unite with petals—or, indeed, with members of any other floral whorl. The adhesion of petals and stamens is, however, common enough, and may be looked for as a thing of course *whenever the petals of a flower cohere*.* A well-known example is the Foxglove (*Digitalis*). On opening one of the flowers the four stamens may be seen adhering to the inner side of the bell-shaped gamopetalous corolla. The anther-lobes and a part of each of the filaments are free, but the lower portions are united to the corolla, upon

* Flowers of the Heath family (*Ericaceæ*) are among the few exceptions.

FIG. 406.—CROCUS.
Transverse section of ovary showing three separate chambers.

which they appear as prominent ridges. Adhesion between stamen (or stamens) and pistil is comparatively rare, but when this consolidation of male with female organs takes place they are called *gynandrous*, from the Greek *gunē*, a female, and *andros*, male.

The fourth and last subject of variation is *form*. The old idea that the beautiful and oftentimes singular shapes of flowers were designed by the Creator chiefly—if not exclusively—for the pleasure of man has been long discarded by thoughtful minds; and in the present day one hardly needs to be told that the manifold varieties of floral form are, in the vast majority of cases, so many adaptations for the admission or exclusion of insect visitors, and for facilitating the dispersion of the pollen. In the zest of what is still, in effect, but a new discovery, many facts relating to this subject have doubtless been distorted, and theories built upon them which will have to be modified or withdrawn; yet the great central fact remains, and it is one of wide-reaching importance. In succeeding chapters some account will be given of the peculiar contrivances by means of which insects are lured to certain flowers and are made the unconscious instruments of pollination; but at present it is better to direct our attention to typical rather than to special forms.

It should be further remarked that the subject of Form has particular, though by no means exclusive, reference to the calyx and corolla. Many uses have been enumerated for these floral envelopes. In the earlier stages of the flower they serve as a protection to the delicate cells of the immature stamens and pistil; and at a later period they perform the same kindly offices for the pollen, which might otherwise be blown away prematurely by the wind, or be stolen by unbidden insect guests, or rendered abortive in consequence of injuries from rain and dew. In many plants, again, they assist in bringing about *autogamy*—that is, the fecundation of the flower by its own pollen; while in others, their powerful odours and vivid colours, by attracting pollen-dusted insects, are instrumental in effecting a precisely opposite result—namely, *allogamy* or fecundation by pollen from another flower. Lastly, the floral envelopes may act as a protection to the nectar, which, though oftenest secreted at the base of those organs, is not infrequently found in hollows and warty projections of the stamens and pistil.

FIG. 407.—BUTTERCUP.
Apocarpous fruits.

Beginning with the outermost floral whorl or calyx, let us try to realize, by means of a few examples drawn from familiar flowers, some of the facts to which we have been referring. We can conceive of no easier or more interesting way of acquiring a knowledge of the morphology of floral organs than by considering them in relation to the functions which they fulfil.

Photo by] [*F. C. Taylor*

FIG. 408.—GARDEN CLEMATIS (*Clematis jackmanni*).

A climbing plant of the great Buttercup order, with no distinction between sepals and petals.

In some flowers—as the Carrot (*Daucus carota*, fig. 403)—the calyx is a quite inconsiderable set of organs; while in others, as the Alpine Liane (*Atragene alpina*), *Delphinium consolida*, the Hellebores (*Helleborus*), and the curious *Molucella*, it forms the most attractive part of the flower. This is notably the case with the shallow bell-shaped calyxes of the last-named flower, to which is due the very singular appearance of the densely packed axillary flowers, arranged in whorls on the stems. *Delphinium* has its posterior sepal prolonged as a *spur*, into which the two petals (or, rather, gamopetalous corolla), which are also spurred, fit as neatly as a lady's finger in a glove. Now in this flower the petaloid spur is the nectary, so that the ensheathing sepal of the calyx is simply a beautiful arrangement for the protection of the nectar. The Garden Nasturtium (*Tropæolum majus*) is also furnished with a spurred calyx, but the corolla has no such appendage; nor is one required, for, in this instance, the sepaline spur is itself the nectary (figs. 410 and 411).

FIG. 409.—MONKSHOOD (*Aconitum napellus*).
Humble-bee entering helmet-shaped (*galeate*) flower.

In the Monkshood (*Aconitum*) we have an example of a helmet-shaped or *galeate* calyx (fig. 409). The two posterior sepals unite to form the helmet; and the structure, which reminds one of the head-armour of some Homeric hero, affords excellent protection to the anthers and nectaries. The two lateral sepals are serviceable in another way, as they form a platform for humble-bees, which play an important part in the pollination of the flower.

The urn-shaped or *urceolate* floral receptacle of the Rose (*Rosa*)—that green shiny swelling which afterwards changes to a red colour and forms the outer covering of the berry—is often spoken of as the calyx; but it is more correct to restrict this term to the five segments which spring from the somewhat contracted margin of the urn, and which, in such cases, are simply free sepals (fig. 405). As these sepals remain after the fruit has ripened, the calyx is said to be *persistent*—a feature which the Rose possesses in common with the Henbane (*Hyoscyamus niger*, fig. 412), Mallow (*Malva*), Pear (*Pyrus*

FIG. 410.—NASTURTIUM.
Section through flower, showing interior of calyx spur.

communis), Apple (*Pyrus malus*), Gooseberry (*Ribes grossularia*), Strawberry (*Fragaria vesca*), and Melon (*Cucurbita*). In other flowers, however—the Buttercup (*Ranunculus*) will serve as an example—the calyx is *deciduous*, that is to say, it falls off before the fruit ripens; while in a few cases, as the Poppy (*Papaver*), *Eschscholtzia*, and those interesting Malayan shrubs, the Pternandras (fig. 413), where its chief purpose appears to be to protect the young and insecurely fastened petals of the bud, it drops off as soon as the flower opens. Such a calyx is said to be *caducous*. Some persistent calyxes are *accrescent*—that is, they continue to grow after the flowering time, like that of the Winter Cherry (*Physalis alkekengi*), a solanaceous plant often cultivated in gardens. The highly coloured inflated calyx of this plant is, indeed, its sole attraction, for the cohering sepals so enclose the other organs of the flower as to hide them completely from view (fig. 417).

We mentioned the Strawberry just now, and we may add that the calyx consists (apparently) of a *double* whorl of sepals—in other words, of two calyxes *—and some botanists distinguish them by calling the outer whorl the *epi-calyx*. Whatever may be the general purpose of an epi-calyx, it certainly renders good service in the case of the Strawberry by protecting the young "fruit" from the depredations of insects—not of winged insects, of course, but of those which approach the coveted object by way of the stalk.

FIG. 411.—NASTURTIUM (*Tropæolum majus*),
With spurred calyx.

* Another opinion is that there is only one whorl of sepals, the outer structures being regarded merely as stipular growths thereupon.

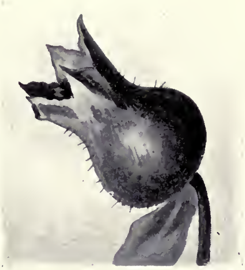

Fig. 412.—Henbane.
Urceolate persistent calyx.

Against winged insects a more or less inflated calyx is often a first-rate protection; for besides putting them to the labour of gnawing through the calyx before the proboscis can be inserted, it serves to hold them at a distance even when that difficulty has been surmounted. Take, for instance, the sack-shaped (*saccate*) base of the calyx of Honesty (*Lunaria*, fig. 415), and conceive how difficult it would be for one of the smaller tissue-gnawing insects to get at the interior of the flower. To bite a hole large enough for the insertion of its proboscis would not be sufficient; the hole would have to be widened till it was large enough to admit the insect itself, otherwise the little plunderer would be too far off to reach the nectar. In flowers where the inflation of the calyx is greater, the difficulties of gaining access to the interior are, of course, proportionately increased. We must not stop to particularize, though the *globose* calyx of the Winter Cherry, to which we referred a moment or two ago, would afford a ready illustration. The whole subject will be before us again in the next chapter, when we shall deal with the contrivances in flowers for the exclusion of unbidden guests, one of the most fascinating of botanical themes.

The other forms of calyx which remain to be spoken of may be treated in connection with the forms of the corolla, to which we now invite attention.

Let us commence with a perfectly symmetrical or *regular* flower—that is to say, one the halves of which, produced by all possible sections, are similar; such, for example, as the Wallflower (*Cheiranthus cheiri*). Here we have a calyx of four sepals, two overlapping the edges of the other two so as to form a sort of false tube (a true *tubular* calyx may be seen in the Primrose—*Primula vulgaris*), and these serve as a support to the four *clawed* petals, which, it will be noted, are arranged in the form of a Maltese cross. Hence, the corolla is described as *cruciform*. It would be going too far from our subject to show how the several correlated points of structure in this flower are connected with its pollination by insect agency; but we may just notice how admirably the cruciate corolla is adapted as a landing-stage for nectar-seeking visitors.

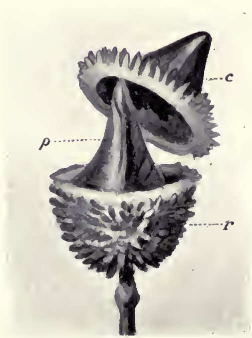

Fig. 413.—*Pternandra cordata*.
Flower-bud showing (*p*) petals, (*c*) calyx, (*r*) receptacle.

Photo by] [*E. Step.*

FIG. 414.—GARDEN LARKSPUR (*Delphinium exaltatum*).

A beautiful North American plant much grown in gardens, where crossing and selection have produced many varieties. The showiness of the flower is due to the sepals, the petals being reduced to two small nectaries, the dark centre of the flower in the photograph.

Fig. 415.—Honesty (*Lunaria*).
Section of flower showing saccate calyx.

In contrast to the Wallflower, take a Pansy (*Viola*). A Pansy is a good example of an *irregular* flower. By cutting through the centre perpendicularly we get two similar halves, but in no other way can the flower be divided symmetrically. Flowers exhibiting this kind of bilateral symmetry are known as *monosymmetrical* or *zygomorphic* (Greek *zeugnumi*, I join, and *morphe*, a shape). Flowers the petals of which are placed like the spokes of a wheel, and which may therefore be divided vertically into similar halves through two or more planes, are termed *actinomorphic* (Greek *aktin*, a spurious form of *aktis*, a ray, and *morphe*). All regular flowers are actinomorphic: most irregular flowers are zygomorphic. Some flowers cannot be symmetrically divided in any plane—they are asymmetric.

There is a curious fact about the Pansy. What appears to be the lowermost petal is really the upper, for the flower has been reversed. It has been thought that the purpose of the curve in the flower-stalk is to strengthen the flower and thus to enable it to sustain the weight of insects. When a honey-bee visits a Pansy, it almost always turns round on alighting, and sucks with its head downwards, and the flower is bent down by the insect's weight—a circumstance which indirectly bears out this idea. Notice the streaks of colour on the petals, all leading towards the centre of the flower. They are *honey-guides* for the insect visitors—*pathfinders*, as some have named them. There will be more to say about these pathfinders on a future occasion, but allusion is made to them here by way of emphasizing the contrast which the petals of this flower present to those of another common flower, the White Campion (*Lychnis vespertina*, fig. 416). The pure white corolla of this species of Campion has no guiding marks; in this case they would be of no service, for the flower expands in the evening, and insects are attracted to it by its whiteness. There are five petals, attached by claws to the base of a tubular calyx, and these are the characteristic features of a *caryophyllaceous* corolla. The Maiden Pink (*Dianthus deltoides*), Carnation (*D. caryophyllus*), and Catchfly (*Silene*) exhibit the same features. The *rosaceous* corolla consists of five petals, too, but they are without claws: the Buttercup (*Ranunculus*, fig. 419) is a good example.

Fig. 416.—White Campion (*Lychnis vespertina*),
With styles exserted.

Notice how the corolla of the White Campion is constricted near its upper end by the toothed or *dentate* calyx. This is another contrivance for shutting out unwelcome visitors. Only a thin proboscis, at least three-fifths of an inch long (such, for instance, as that of the Small Elephant Hawk-moth (*Chœrocampa porcellus*), which often visits and cross-pollinates the flower), could reach to the fleshy part of the ovary where the honey is stored. In fact, both the calyx-tube and the elongated claws of the petals assist in preserving the nectar for those insects whose visits are really serviceable to the plant. In flowers with salver-shaped (*hypocrateriform*) corollas, like the Primrose and Common Lilac (*Syringa vulgaris*), the tubes formed by the cohering petals answer much the same purpose as the clawed bases of caryophyllaceous corollas, and also protect the pollen from drops of rain and dew—the latter an important consideration in the case of plants which dwell amid mountain-mists, like the delicate species of Primulaceæ belonging to the genus *Androsace*, and many species of Phlox (fig. 421). "If flowers of *Aretia glacialis*, a plant growing on the moraines of glaciers, are examined after a shower," says Kerner, "it is found that every one has a drop resting upon it which slightly compresses the air in the narrow tube of the corolla, but cannot reach the pollen upon the anthers lower down the tube. A subsequent shake or puff of wind causes the drops to roll off the limb of the corolla, or else they are got rid of by evaporation; in either case, the flower becomes once more accessible to insects." Salver-shaped corollas must be distinguished from *rotate* or wheel-shaped corollas, such as we get, for instance, in purple-flowered Woody Nightshade (*Solanum dulcamara*). In the former the tubes are long and narrow, in the latter they are short; but in both the limb is placed at right angles to the tube.

FIG. 417.—WINTER CHERRY (*Physalis*), Showing the accrescent calyx.

We come now to the *tubular* corolla. From what has been said about the uses of caryophyllaceous and salver-shaped corollas, the purpose of this third form may be readily divined. It, also, has reference to insect-pollination. The Common Honeysuckle (*Lonicera peryclymenum*) may serve as an example. The sweet-scented flowers

FIG. 418.—GREAT VALERIAN (*Valeriana officinalis*). Showing the gibbous corolla.

are adapted for fertilization *exclusively* by long-tongued crepuscular and nocturnal moths; and why? Because the wax-like tubes are long and narrow—too long for short-tongued insects to reach the honey while standing at the mouth of the flower, and too narrow to enable them to descend bodily to the nectary. As a matter of fact, the flowers bloom at the very season when hawk-moths are most abundant—that is, during May and June—and they exhale their perfume most strongly in the evening, when these moths are on the wing.

Another form of gamopetalous corolla which must not be passed over is that which, from its resemblance to a funnel, has received the name *infundibuliform*. The name is less elegant than the flower to which it is applied. The delicate white chalices of our beautiful Hedge Convolvulus (*C. sepium*) are of this form. Funnel-shaped flowers have not such a reputation for exclusiveness as have those of tubular and salver shape; and it has been observed of the Hedge Convolvulus that all sorts of thrips and little flies frequent the flowers by day, sheltering and feeding there, though they confer no benefit in return. Only on bright, moonlight nights, when the sphinx-moths are about, does the plant reap any advantage from its visitors. A friend of the naturalist Delpino, standing by a hedge overgrown with this Bindweed, was able to capture numbers of one species of sphinx-moth (*S. convolvuli*) simply by closing with finger and thumb the orifices of the flowers as the moths inserted their heads.

Fig. 419.—Rosaceous Corolla of a Buttercup.

A form of corolla closely related to the infundibuliform is the *campanulate*, or bell-shaped. We have examples of a *regular* campanulate flower in the Rampion (*Campanula rapunculus*, fig. 426) and other Bell-flowers, and of an *irregular* or *oblique* campanulate flower in the equally well-known Foxglove (*Digitalis*, fig. 420). The wide bell-shaped corollas of Campanula are specially adapted for humble-bees; but the flowers number other kinds of bees among their visitors, and numberless beetles and small flies use them as shelters from the rain or make the comfortable bells their night quarters. The Foxglove is also specially adapted for humble-bees, for, says Hermann Müller, "no other insects are large enough to touch the stigma and anthers with their backs when creeping into the tube." They are, in fact, the only pollinators of the Foxglove. Possibly the enlargement of the under side of the corolla, which gives the irregularity to the flower, is intended as a landing-stage for the insect (it is certainly so used), and may also be an arrangement

Photo by] [*E. Step.*

FIG. 420.—FOXGLOVE (*Digitalis purpurea*),

With obliquely bell-shaped corollas which can be pollinated only by humble-bees, for which they have become specially adapted. The lip on the lower side forms an alighting platform from which the humble-bee crawls right into the bell. WESTERN EUROPE.

Fig. 421.—Mossy Pink (*Phlox subulata*), With salver-shaped corollas.

to relieve the strain upon that part of the bell where the weight of the humble-bee presses most.

We find ourselves among flowers of more intricate construction when we come to speak of *labiate* or lipped corollas. The White Dead-nettle (*Lamium album*), one of the commonest of our weeds, is the flower chosen for illustration (fig. 425). The corolla is decidedly irregular, and on a cursory examination it is not easy to distinguish from one another the five cohering petals which compose it; though by bearing in mind the simple rule that *petals should alternate with sepals*, the difficulty will vanish. Guided by this rule it will be found that the lower lip or cleft piece in front is one petal, that the pointed and inconspicuous appendages on either side the corolla-tube are the rudiments of two more, and that the remaining pair form the overshadowing hood or upper lip of the flower. "We can estimate by direct observation," says Hermann Müller, "how perfect the adaptation of this flower is to bees' [humble- or other large bees'] visits. The bee alights on the under lip, and in doing so thrusts its head between the broad lateral lobes of the mouth, clings with its fore feet to the base of the under lip, and with its mid- and hind-feet to the two lobes of the under lip; then if its proboscis is not less than ten millimetres [about two-fifths of an inch] long, it can at once reach the base of the flower. While sucking, the thorax, and in the case of small workers the base of the abdomen also, fills up the space between the upper and lower lips, and the vaulted upper lip fits the bee's back, which is pressed against the stigma and the open face of the anther."

Personate or mask-like corollas, of which the Toadflax (*Linaria*) and Snapdragon (*Antirrhinum*) offer convenient examples, are even more elaborate in their construction than the labiate form. They re-

Fig. 422.—Whortleberry (*Vaccinium*). Urceolate corolla.

Fig. 423.—Grapevine (*Vitis*). Mitræform corolla.

semble the latter in possessing a double lip, the essential point of difference being that their lower lips approximate to the upper, so as to close the orifice of the tube or throat. In the Toadflax (fig. 429) this arrangement shuts out flies and beetles, which lack the requisite strength to force an entrance, while the length of the nectar-storing spur excludes short-lipped bees, which are not so incapable of breaking in. Thus the flowers become exclusively adapted for the long-tongued species, by which, indeed, they are diligently visited. The Toadflax, it may be noted in passing, is one of those flowers which, though normally irregular, will sometimes become regular by producing in all their petals or sepals the very feature which is the cause of their irregularity. In the flower in question, the peculiarity is that each of the five petals, by virtue of this excess of irregularity, produces a spur, while the upper part of the flower loses its personate character and becomes regular. The wonder excited in the mind of the great Linnæus by this phenomenon led him to apply to it the name *peloria*, from the Greek word *pelōron*, a monster. Of course, in a normally and regularly spurred corolla, like the Columbine (*Aquilegia vulgaris*, fig. 427), the term "peloria" would not be applicable.

Photo by] [*E. Step.*

FIG. 424.—SEASIDE CONVOLVULUS (*Convolvulus soldanella*),

With funnel-shaped pink flowers. The leaves are small, heart-shaped or kidney-shaped, and the stem rarely twines.

The arrangement in the personate corolla of the Snapdragon is similar to that of Toadflax, though not identical. Here, as there is no spur to keep off smaller bee-intruders, the entrance is more firmly closed, and it is only when the flower is old and beginning to wither that it opens its door to such visitors. The flower is, indeed (to quote Lord Avebury), "a strong box of which the humble-bee only has the key." This guarding of the entrance is a necessary precaution, for if flies and small bees were admitted from the first they would simply pilfer all the honey, and the flower would be less diligently visited by its chief pollinators, the humble-bees. Ants and small flies, however, will often squeeze their way in, their great difficulty being rather how to get out than how to gain an entrance—a circumstance referred to by Mr. Knapp in his charming *Journal of a Naturalist*. "It has not perhaps been generally observed," he writes, "that the flowers of this plant—'bulldogs,' as the boys call them—are perfect insect traps; multitudes of small creatures seek an entrance into the corolla through the closed lips, which upon a slight pressure yield a passage, attracted by the sweet liquor that is found at the base of the germen [ovary]; but when so admitted, there is no return: the lips are closed, and all advance to them is impeded by a dense thicket of woolly matter, which invests the mouth of the lower jaw.

Fig. 425.—White Dead-nettle (*Lamium album*).
The two-lipped calyx is also shown separately (lower figure).

> Smooth lies the road to Pluto's gloomy shade;
> But 'tis a long unconquerable pain
> To climb to these ethereal realms again.

But the Snapdragon is more merciful than most of our insect traps. The creature receives no injury when in confinement; but, having consumed the nectareous liquor, and finding no egress, breaks from its dungeon by gnawing a hole at the base of the tube, and returns to liberty and light."

This last statement is evidently a mistake. Mr. Knapp is probably referring to the neat round hole which is made by certain short-tongued bees *from without*, to enable them to reach the nectar and nullify the flower's precautions for their exclusion.

The wood-ant (*Formica rufa*) is a common plunderer of the flower, but, as already remarked, its chief pollinators are humble-bees, which do no injury to their host, and leave by the door they enter at. "It is most interesting to observe," writes Kerner, "how a humble-bee buzzes about till it alights on the two knobs of the lower lip, and then, having opened the mouth by means of hinges on either side of the corolla, suddenly disappears into the cavity of the flower to fetch honey. In the Calceolarias," continues this writer, "the phenomenon is even more remarkable. The humble-bee sits on the inflated, slipper-like lower lip, and opens the mouth by a light pressure against the upper lip. Then a nectary, hitherto hidden in the slipper-like cavity, comes to light, flap-like, and amply provided with

Photo by] [*E. Step.*

FIG. 426.—RAMPION (*Campanula rapunculus*),

A rare wild-flower that may be mistaken at sight for the Hare-bell, but the *upright* flowers are borne in a panicle, instead of being drooping and solitary or in a few-flowered raceme. EUROPE, NORTH AFRICA, NORTH ASIA, NORTH AMERICA.

Fig. 427.—Columbine (*Aquilegia vulgaris*),
With each of the five petals ending in a spur.

honey. This nectary is presented to the humble-bee just like a spoon as it sits on the lower lip. Directly the bee goes, the lower lip snaps to, and the nectary disappears from view." The Calceolarias, indeed, bring before us a new form of corolla, the *calceolate*, or slipper-shaped. They offer good illustrations of special thickenings in parts of flowers where the strain caused by insects is most felt. *Calceolaria pavonii* is a striking example of this. Along each of the upper edges of the curved basal part of this flower—that part which carries the inflated end upon which the bee stands—there is a thickened ridge, and this gives wonderful strength to the support and prevents injury when the bee alights.

The very cohesion of the petals, in this as in all flowers where cohesion takes place, is also a source of strength; and swellings and hollow projections in particular places may subserve a similar end. The bulge in the tubular part of the Foxglove flower is evidently for this purpose; as in all probability are the curious projections in many kinds of *gibbous* or pouched corollas. The Great Wild Valerian (*Valeriana officinalis*, fig. 418) offers a good example of this form. The small pouch or hump in this particular flower is the nectary, in the green fleshy floor of which the honey is secreted. As the pouch is short and easily accessible, the flower is largely patronized by insects, and cross-pollination regularly takes place.

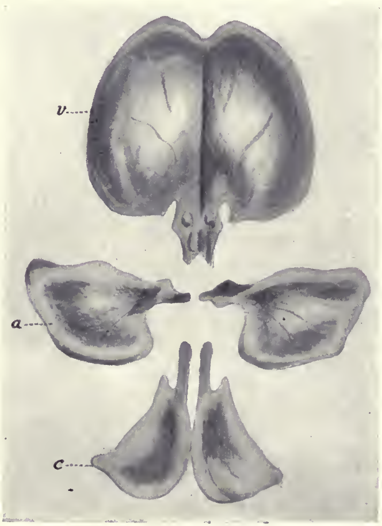

Fig. 428.—Papilionaceous Corolla,
With the parts separated. (*v*) Vexillum or standard. (*a*) Alæ or wings. (*c*) Carina or keel.

Returning for a moment to the simpler kinds of gamopetalous flowers, notice a familiar example of the *globose* corolla (fig. 430). It is the Figwort (*Scrophularia nodosa*), which blooms in moist places from July to September. Perhaps it is not the best instance that might be given of the globular form—some of the Heaths (*Erica*) would better fulfil the requirements of the name—but we have adopted it because the flower is one of those which, unlike the flowers which we have been hitherto considering, lay themselves out for pollination by insects with *short* probosces. Wasps are its chief visitors, and easily reach down to the honey at the base of the corolla: while long-tongued insects, such as humble-bees and butterflies, avoid the flower altogether.

The globular form often merges imperceptibly into the *urceolate*, or urn-shaped—indeed, a single spray of Heath will sometimes show both forms (fig. 431)—but a better example of an urceolate flower than the Heath is the Whortleberry (*Vaccinium myrtillus*), the corolla of which might have furnished designs to the sepulchral-urn-makers of ancient Etruria (fig. 422). As a rule, only insects with a proboscis long enough to reach from the exterior to the base of the corolla, where the honey is lodged, can reach that coveted treasure, as the opening is too narrow to admit the bodies or even the heads of the majority of nectar-sipping insects.

Photo by] [*E. Step.*

FIG. 429.—YELLOW TOADFLAX (*Linaria vulgaris*),

With personate or mask-like corolla. The upper and lower lips close tightly to keep out all insects but bees.

A curious and exceptional form of corolla is the mitræform or mitre-shaped (fig. 423). It occurs in the Grape Vine (*Vitis vinifera*). The five petals, which are coherent at their tips, form a dome-like covering to the stamens and ovary; but they are green and insignificant, and hardly distinguishable from the foliage; on which account they are valueless as insect lures. The plant, therefore, does well in getting rid of them as soon as possible,

FIG. 430.—FIGWORT,

With sub-globose corolla. Adapted for pollination by wasps.

and this is effected in a beautiful manner. The petals become detached at their base, and curl up spirally—that is to say, towards their common point of attachment at the apex of the flower; and in this condition they remain till, by the expanding of the stamens, they are thrown off completely.

A more interesting, because more intricate, form of irregular flower than any which we have yet considered is that which constitutes the characteristic feature of the well-known and extensive sub-order of Leguminosæ, to which the Pea and Bean belong--namely, Papilionaceæ. This name at once suggests the form of the corolla, which Tournefort and Ray, and the early botanists generally, conceived to bear a resemblance to a butterfly with expanded wings. *Papilio* is the Latin word for "butterfly," and hence the corolla came to be called *papilionaceous* and the sub-order Papilionaceæ. But it was reserved for a modern philosopher to advance the startling suggestion that possibly the first butterflies were flowers "which got loose from their stalks and flew away"! Papilionaceous flowers are pollinated almost exclusively by bees, to which the several parts of the corolla bear the most evident relation. The reproductive organs (stamens and pistil) are contained in the two inferior petals (fig. 428), which cohere to form the keel or *carina* (*c c*), the latter an excellent contrivance for protecting the anthers from pollen-feeding insects and from rain. The lateral petals (*a a*)—known as the wings or *alæ*—besides affording a platform for bees, serve as a lever to depress the keel, as well as to bring it back to its place after depression, if repeated insect-visits are necessary for pollination. Lastly, the large posterior petal, which is known as the standard or *vexillum* (*v*), gives conspicuousness to the flower, as well as closes the entrance to the nectary *from behind*, so that insects seeking honey must sit either on the keel or wings.

FIG. 431.—HISPID HEATH.

Complete flower (upper), and the same after removal of calyx and corolla, to show position of stamens and pistil.

We must not conclude these remarks upon the forms of calyxes and corollas without some reference to *composite* flowers A composite flower is really a number of *florets* crowded together on a single base or *receptacle*, such as we find, for instance, in the flower-head (capitulum) of a Daisy (*Bellis perennis*) or Dandelion (*Taraxacum officinale*). We have chosen for illustration the flower-head of a Chrysanthemum (*C. carinatum*), the florets of which are more easily distinguished than are those of the commoner flowers above named. What you see (fig. 433) is a section, the flower-

Photo by] [*Walter Rossiter.*

FIG. 432.—COMMON HYDRANGEA (*H. hortensis*).

A native of China and Japan. The flowers grow in corymbs and only a few are fertile, the outer flowers being enlarged at the expense of the stamens.

Fig. 433.—Annual Chrysanthemum (*Chrysanthemum carinatum*).

Section through a flower-head (*capitulum*) to show how the numerous florets are arranged upon the receptacle.

head having been cut through longitudinally in order to exhibit a perfect row of the disc florets. Each of these florets, which you will observe are tubular in form, is a perfect flower, capable of setting seed. The corolla-tube covers at its base the ovary, and hides from view the greater part of the styles, the only portion visible being the end which bears the branched stigmas. Surrounding the flower-head are some florets of another kind, each of the so-called petals being a female flower, or, in scientific parlance, a *rayed* floret with *ligulate* (*i.e.* strap-shaped) corolla.

One of the great purposes effected by the massing together of the florets in composite flowers is admirably suggested by Kerner in his remarks upon the taking up of pollen by insects. "Great quantities of pollen," he tells us, "adhere to the under parts of insects in the case of composite inflorescences. Shortly after the opening of the corollas the style bearing an external load of pollen is exserted from each of the little tubular and ligulate florets composing the capitulum in this group, and, owing to the fact that large numbers of these florets invariably open simultaneously, numbers of styles laden with pollen project close together from the discoid head. A largish insect settling on a capitulum may therefore be dusted with the pollen of numerous florets at once." Darwin observes that the ray-florets of composite flowers protect the florets of the disc by folding inwards at night and during rainy

CLOSE-HEADED BEFARIA *(Befaria coarctata).*

The Befarias are a genus of plants related to the Rhododendrons. The species illustrated is a native of the Alpine districts of Peru. The apparently crowded, but really alternate leaves are oblong, smooth and leathery, with grey undersides. The purple flowers form a terminal corymb, and their footstalks and sepals are covered with rusty cotton.

weather. Composite flowers constitute the largest order in the Vegetable Kingdom (Compositæ), about one-tenth of the Flowering Plants belonging to it. A characteristic of this order not yet touched upon, yet intimately connected with our present subject, is the production of a *pappus* from the limb of the calyx. Two forms of such hairy crowns are the *sessile* and the *stipitate*. The formation of a pappus is looked upon as a modification of the calyx. It is made subservient, as every child knows, to the scattering of the fruit.

In not a few flowers the corolla is provided with a supplementary organ known as the *corona* or crown, sometimes called the *paracorolla*, which in some cases is small and inconspicuous, and in others large enough to add materially to the beauty or singularity of the plant. A corona is one of the distinguishing marks of the large genus *Narcissus*, to which our own Wild Daffodil (*Narcissus pseudo-narcissus*) belongs. In a less exaggerated form this "corona" will be found also in the Forget-me-not (*Myosotis*) and *Primula*. Henslow (*Journal of the Linnean Society*, vol. xvi., 1877) regards it as a development of a fold in the inner epidermis of the corolla. In the well-known Poet's Narcissus (*N. poeticus*) the white crown is surrounded by a cinnabar-red border, which is probably a means of attracting insects; and in most species of the family this organ is either delicately marked or the whole of the corona is of a

Photo by] [*E. Step.*

FIG. 434.—HENBANE (*Hyoscyamus niger*).

The yellow corolla is veined with purple, and the urn-shaped calyx is persistent. The seed-vessel is a box or *pyxis* with a well-defined lid.

deeper colour than the rest of the perianth. The crown of the Passion-flower (*Passiflora*), which in some species is single, in others double, is split up into narrow threads which Fritz Müller, a naturalist who has given much attention to the mechanism of floral organs, believes to be of service in detaining small insects in the lowest chamber of the flower, and keeping them caged for humming-birds, the chief pollinators of many species of *Passiflora.*

In the White Dead-nettle (*Lamium album*) there is a circle of hairs in the narrow part of the corolla-tube, near the base, which serves the purpose of excluding flies and small bees from the nectar, these being useless to the plant. The corona of our beautiful bog-flower, Grass of Parnassus (*Parnassia palustris*), is very interesting. It consists of five scales (the nectaries) terminating in hairs, each of which is surmounted by a yellow

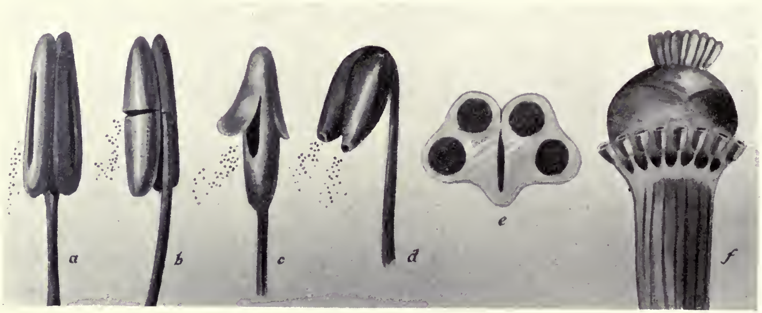

FIG. 435.—ANTHERS AND THEIR DEHISCENCE.

(*a*) Longitudinal, (*b*) transverse, (*c*) valvular, (*d*) porous dehiscence; (*e*) cross-section of stamen of a Lily (*f*) stamens of a Milkwort (*Polygala erioptera*).

glandular body, which has all the appearance of a drop of fluid. Even flies are deceived by these shining knobs, mistaking them for drops of honey.

We come now to the stamens or male organs, which are known collectively as the *andrœcium.* The forms of these, like the forms of the calyx and corolla, vary considerably. Bearing in mind what has been said already about the stamens in connection with cohesion and adhesion. there is really little else to be acquired.

It is instructive, however, to notice the diversities of form and mechanism which the andrœcium presents, and which are usually connected with that most important function, the scattering of the fertilizing meal or pollen. Thus, in the Grasses (Gramineæ) and Plantains (*Plantago*) whose pollen is carried by the wind, the anthers swing loosely on their connectives, and so assist the wind in its useful labour—they are *versatile*; while in certain species of Sage (*Salvia*) the connective forms a curved bar or lever, and

Fig. 436.—Pistils.

(*a*) Canterbury Bell; (*b*) Pansy: transverse section of young ovary; (*c*) Pansy; (*d*) Begonia; (*e*) White Campion (*f*) Calceolaria; (*g*) Clarkia; (*h*) Periwinkle.

runs transversely to the filament, to which it is attached by a movable joint, the purpose of which will be explained hereafter. From some stamens the filament is entirely absent, and the anthers, which are then described as *sessile*, may be attached either to the petal of the flower, as in Vervain (*Verbena*), or to some part of the pistil, as in the Birthwort (*Aristolochia*). In a large number of cases the connective is perfectly continuous with—or, in other words, is a direct prolongation of—the filament, the point of attachment of the anthers being immediately upon the top of the filament; but far more frequently the latter is prolonged up behind the anther-lobes. The terms *basifixed* or *innate* and *dorsifixed* or *adnate* are applied respectively to these two kinds of attachment.

When the *face* of the anther—or, in other words, the surface opposed to that to which the connective is attached—is turned towards the pistil of the flower, the stamens are said to be *introrse*; when, on the other hand, the face is turned towards the petals, the stamens are *extrorse*. The *direction* in which the anthers *dehisce*—that is, discharge their pollen—is thus largely dependent upon the position of the stamens—a fact to be carefully noted. The *mode* of dehiscence is chiefly determined by the nature of the apertures through which the pollen escapes. When, as is most frequently the case, the anther opens by narrow upright slits running from top to bottom of the lobes, the dehiscence is said to be *longitudinal*; when the lobes are slit crosswise, the dehiscence is *transverse*. In not a few flowers the lobal orifices are wide and concealed by delicate valves or flaps, which lift up like a trap-door at the moment of shedding the pollen. This is *valvular* dehiscence. When, as in the case of the Common Whortleberry (*Vaccinium myrtillus*), the dehiscence is effected by minute fissures or pores at the tips of the lobes, we speak of it as *porous*.

FIG. 437.—STAMENS OF (*a*) LITSÆA; (*b*) PYROLA; (*c*) GARCINIA.

The anthers assume the most various shapes—globular and oval, pear-shaped and worm-shaped, curved and undulating (the latter a form which reminds one of the convolutions of the human brain), pitcher-like and box-shaped, etc., etc.; while many of these forms are rendered still more striking by the presence of appendages in the shape of hairs, tubes, fleshy hooks, leaf-like expansions, coloured bladders for attracting insects, feathery growths, and other singular contrivances whose name is Legion. Such appendages are usually prolongations of the connective. The almost naked stamens of *Leitneria floridana*, a shrub with willow-like leaves inhabiting the marshes of the southern United States, are seated upon bracts, furnished with hairy appendages, which give a curious flocculent appearance to the whole inflorescence. The morphology of the *gynœcium*, or pistil, need not detain us long. A pistil also consists of three parts—the ovary, the style, and the stigma. Just as the stamen assumes different forms according as its filament is long or short, its connective with or without appendage, its anther-lobes globular or oval, pear-shaped or linear, etc., etc., so the form of the pistil varies in accordance with analogous diversities in the ovary, style, and stigma. The mode of insertion of the style is also a cause of variation. It may spring either from the top of the ovary, when it is *terminal*; or from the side, when it is *lateral*; or from the base, when it is *basilar*. Sometimes it is entirely absent, and then the stigma rests upon the ovary, and is said to be *sessile*.

The style, indeed, is not an essential part of the pistil; the stigma is. It will be remembered that the latter is the organ which serves for the detention of the pollen-grains. Nature, as might be guessed, has all sorts of devices for facilitating this object, and hence the multitudinous forms of stigma—*peltate, plumose, penicillate, petaloid*, etc.—which the pistils of flowers present.

Fig. 438.—Apple.

Section through perigynous flower after the corolla has fallen.

It should be added that the relative position of the calyx, corolla, and stamens to the pistil is a matter of considerable importance. Observe the flower of a Geranium. Here the ovary is *superior* to the other floral organs, which are attached to or below its base. Such a flower is termed *hypogynous*, from the Greek words *hupo*, under, and *gunē*, a woman. Compare these with the sections of the flowers of Rose and Apple, in which, by the more vigorous growth of the axes, a tube is formed around the carpels, and the stamens and perianth are raised so that they stand on the apex of the rim of the tube. The Rose and Apple are *perigynous* flowers (Greek *peri*, around, and *gunē*).* In the Begonia and Carrot we have a third mode of insertion. In both cases the ovaries are situated below the perianth—they are inferior: whilst the flowers as a whole are described as epigynous (Greek *epi*, upon, and *gunē*).

* In the case of the Rose, each of the carpels has a distinct ovary ; in the Apple the ovary fills the whole cavity of the tube, with the inner wall of which it is fused. The immature "pips" are ovules, not ovaries.

Photo by] [*E. Step.*

FIG. 439.—SWEET VIOLET (*Viola odorata*).

Showing the reversal of the flower by the curving of the flower-stalk. The plant to the left is the white-flowered form.

CHAPTER XII

THE WELCOME OF THE FLOWERS

These have their sexes! and when summer shines.
The bee transports the fertilizing meal
From flower to flower, and e'en the breathing air
Wafts the rich prize to its appointed use.

COWPER.

THE important part which insects and other external agents play in the fertilization of flowers was indirectly alluded to in the last chapter, and we propose now to follow out this interesting subject in some detail.

The insects which visit flowers may, for popular purposes, be divided into two classes—*bidden and unbidden guests*; the former being useful to the plant, the latter useless. It may be added that an insect which is a welcome visitor to one kind of flower may be an unwelcome visitor to another; so that the terms "bidden" and "unbidden" have only a relative significance. Incidental allusion has been already made to some of the contrivances in plants for the exclusion of certain visitors; we may now consider a few more of these contrivances, with special reference to the flower.

Of the necessity of excluding various kinds of insects from certain flowers there can be no question. "Guests might come," says Dr. Ogle,

Photo by] [*Henry Irving.*

FIG. 440.—SNOWDROP (*Galanthus nivalis*).

The Snowdrop produces but a single flower throughout the year, but this flower, if unfertilized, persists fresh and open for a long period ; and hence, if deprived of the visits of hive-bees (its chief pollinators) for many days at a time which may often happen in consequence of unfavourable climatic conditions), the ability to hold out is of great advantage to the plant. EUROPE and W. ASIA.

FIG. 441.—CYCLAMEN (*Cyclamen europæum*).

in his amusing preface to Kerner's famous little book, *Flowers and their Unbidden Guests*, "who were not of sufficient importance, and the banquet [whether of nectar or pollen] be wasted on them; for it is only when insects have a certain shape, size, or weight that she requires their visits, and can use them profitably for her purposes. . . . All insignificant and unremunerative visitors, all such, moreover, as would creep in by the back entrance, must be kept out."

Thus the opposite leaves of a plant may form a kind of collar, or series of collars, to the inflorescence, insurmountable to wingless insects from below, as is the case in many Gentians; or even the stipules and alternate leaves may act in the same way, as in the Common Pear and Thorow-wax respectively.

How excellently, again, is a *pendulous* flower adapted for the exclusion of small creeping insects! Take the Snowdrop (*Galanthus nivalis*, fig. 440). Where is the ant that could get inside the hanging flowers of this February maid?—if the ant were in the habit of climbing up plants at that season. The slippery curved walls would defy all its efforts; and, as a matter of fact, only winged insects pollinate the flower. Hive-bees, which are the most useful to the plant, enter the drooping bells without difficulty. When the object of a hive-bee's search is the pollen, "it thrusts its head, fore-legs, and mid-legs into the flower, clinging by means of its hind-legs to the outer surface of an inner perianth-segment. With the tarsal brushes of its fore- and mid-legs it sweeps pollen from the anthers and places it in the baskets on its hind-legs. If it wishes to suck honey, it usually finds it more convenient to use its own fore- and mid-legs for clinging to the perianth." * In either case the bee's head gets well covered with pollen, some of which is sure to be deposited on the stigma of the next flower which it visits, for the style of the Snowdrop projects beyond the anthers, and the bee's head must come in contact with the stigmatic surface on entering.

FIG. 442.—PLUMBAGO (*Plumbago capensis*).

The *curvature* of many perianth leaves also subserves the purpose of excluding wingless insects from the nectar and pollen. "I placed," says Kerner, "some small and by no means timid

* Müller: *Fertilization of Flowers.*

ants, of a kind (*Lasius nigra*) which under ordinary circumstances show themselves to be capital climbers, on the flowers of *Cyclamen europæum* (fig. 441). At first they tried to make their escape downwards by the peduncle; but as I had put the flower-stalk in water, they turned back and managed to recross the calyx and get back to the corolla. After some useless clambering about the reflexed tips of the petals, they at last reached their curved margins, and here all their skill was baffled, and they fell either into the water or to the ground."

Photo by] [*E. Step.*

FIG. 443.—MARSH CALLA (*Calla palustris*).

The white spathe serves as an alighting platform for the flies that are attracted by the unpleasant odour to pollinate the flowers.

The calyx, epi-calyx, and bracts may be further protections to the flower, by preventing insects from eating their way through the corolla to the nectary, a burglarious proceeding of which even bees are sometimes guilty. We have seen how admirably an inflated calyx effects the same results, holding the would-be intruder at a distance from the honey, even when the tissue has been gnawed through; and the fact might be enforced by other examples. Hermann Müller remarks of one of the Louseworts (*Pedicularis verticillata*) that "the calyx is swollen, and the lower part of the corolla-tube is bent at right angles within the calyx; the honey is thus guarded from *Bombus mastrucatus*, which tries in vain to reach it." In the Canterbury Bell (*Campanula medium*) the tough inflated hairy calyx, with its valvate divisions, stands above the ovary, the nectar being sufficiently guarded by the expanded bases of the five stamens which surround it (fig. 436 *a*); while in *Clarkia* (fig. 436 *g*) the curious boat-shaped gamosepalous calyx, like the curved petals of the Cyclamen referred to by Kerner, is an admirable contrivance for keeping out small wingless insects.

We have seen how perfectly the flowers of *Antirrhinum* and Toadflax are adapted for the exclusion of certain intruders, and many equally perfect adaptations of corolla and calyx might be enumerated, where the same end is to be gained. In a number of instances, the corolla "forms a narrow tube, still further protected by the presence of hairs, sometimes scattered, sometimes, as in the White Dead-nettle, forming a row. In others the tube itself is so narrow that even an ant could not force its way down; while in some of the Gentians the opening of the tube is protected by the swollen head of the pistil. . . . In Clover (*Trifolium*), Birdsfoot Trefoil (*Lotus*), and many other Leguminosæ, the ovary and the stamens, which cling round the ovary in a closely fitting tube, fill up almost the whole space between the petals, leaving only a very narrow tube. In still more numerous species the access of ants and other creeping insects is prevented by the presence of spines or hairs, which constitute a veritable *cheval de frise.* Often these hairs are placed on the flowers themselves, as in some Verbenas and Gentians. Occasionally the whole plant is more or less hairy: and it

Photo by] [*E. Step.*

FIG. 444.—MARSH MARIGOLD (*Caltha palustris*).

A splendid Buttercup whose brilliance is due to the golden sepals, the petals being absent.

Photo by] [*E. Step.*

FIG. 445.—PURPLE LOOSESTRIFE (*Lythrum salicaria*).

The flowers, though outwardly all alike, are of three forms, differing in the length of the pistils and the filament of the stamens: a plan that secures cross-pollination. NORTHERN TEMPERATE REGIONS and AUSTRALIA.

will be observed that the hairs of plants have a great tendency to point downwards, which, of course, constitutes them a more efficacious barrier" (Lord Avebury).

Lastly, in not a few cases creeping insects are kept away from the interior of the flower by viscid secretions on the stem or calyx, to which the unfortunate visitors get glued, and from which there is usually no escape. Thus the calyx of *Plumbago* (fig. 442) is furnished with glandular hairs, which stand out horizontally from the epidermis, and are fatal to many a wandering aphis and small fly. The Honeysuckle (*Lonicera*) is another familiar instance of a flower which produces these viscid protective hairs on its calyx, but in the Catchflies (*Silene nutans* and *S. noctiflora*) they are much more effective, as may be judged by the number of small insects usually found glued to the calyx and flower-stalk.

The Tutsan-leaved Dogsbane (*Apocynum androsemifolium*) is a plant which resorts to extreme measures in dealing with uninvited guests. The French call it *Gobe-mouche*, or Fly-gulper, and the name is well bestowed. In fact, the stamens of the flower have an ugly trick of nipping intruding flies by their probosces and detaining them as captives till death puts an end to their miseries. Then the filaments open and the dead insects are released. "Allured by the honey on the nectary of the expanded blossom," says Knapp, in his *Journal of a Naturalist*, "the instant the trunk [of the fly] is protruded to feed on it, the filaments close, and, catching the fly by the extremity of its proboscis, detain the poor victim writhing in protracted struggles till released by death, a death apparently occasioned by exhaustion alone; the filaments then relax, and the body falls to the ground. The plant will at times be dusky from the numbers of imprisoned wretches."

FIG. 446.—GOATSBEARD (*Tragopogon pratensis*).
The involucral bracts are longer than the ray-florets. The flower is supposed to close at noon ("John-go-to-bed-at-noon"), but it is seldom open so late.

More than one plant is known in which the expulsion of unremunerative visitors is effected, not by the plant itself, but by other and remunerative insects. Kerner has enumerated four of such plants—*Centaurea alpina*, *C. ruthenica*, *Jurinea mollis*, and *Serratula lycopifolia*, all of them belonging to the great Composite order. "The young capitula of these Composites," says the eminent naturalist, "are particularly liable to the attacks of devouring beetles, especially of *Oxythyrea funesta*, which bites big holes in the heads, destroying crowded flower-buds and involucral scales without the least difficulty. To meet this danger a garrison of warlike ants is employed. Honey is secreted from big stomata on the imbricating scales of the still-closed capitula in such quantities that one can see a drop of it on every scale in the early morning, while later in the day, as the water evaporates, little masses or even crystals of sugar are to be found. This sugar, either in its liquid or solid form, is very palatable to the ants, which habitually resort to these capitula during the period of its secretion, and to preserve it for themselves they resent any invasion from outside. If one of the afore-mentioned beetles appears, they assume a menacing attitude.

Photo by] [*E. Step*

FIG. 447.—MARSH LOUSEWORT (*Pedicularis palustris*).
Parasitic upon the roots of other plants. It has a dull pink corolla and a reddish-green calyx.

They hold on to the involucral scales with their last pair of legs and present their forelegs, abdomen, and powerful jaws to the enemy. Thus they remain till the beetle withdraws, if necessary hastening its retreat by squirting formic acid in its direction."

It has been remarked that wingless insects are most active when the dew

FIG. 448.—FLOWER OF HORSE CHESTNUT.
Hermaphrodite or complete flower with stamens and pistil.

has evaporated, and that this is the signal for the closing of many flowers; but it may be doubted whether these circumstances stand in the relation of cause and effect. Flowers open and close at almost all times of the day and night; and though in some cases the periods of their opening have *distinct* reference to the visits of bidden guests, it seems extremely doubtful that the periods of their closing have any reference to unbidden ones. Be that as it may, the phenomena of the opening and closing of flowers are full of interest, and as the subject has been named, we will offer a few remarks upon it before passing on.

It is well known that Linnæus devised a *floral clock* at Upsala, by grouping together plants according to the hours at which they open and close, and that for a time the growing of these flower-clocks in public and private gardens became quite a rage. In recent years Kerner has repeated the experiment at Innsbruck (47° N. lat.), and a comparison of his tables with those of the older naturalist has shown that flowers both open and close earlier in the day at Upsala than at the more southerly situated Innsbruck. "The result," he says, "especially the earlier opening, is probably connected with the fact that the sun during the flowering season of the plants in question rises about an hour and a half earlier at Upsala than at Innsbruck."

Of the flowers in Linnæus' clock the earliest to open was the Goatsbeard (*Tragopogon pratensis*, fig. 446), a Composite flower like a large Dandelion, which has received in this country the name of John-go-to-bed-at-noon, from its habit of closing about midday.

Broad o'er its imbricated cup
  The Goatsbeard spreads its saffron rays,
But shuts its cautious florets up,
  Retiring from the noontide blaze.

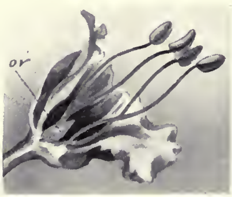

FIG. 449.—SECTION OF HORSE CHESTNUT, MALE FLOWER.
(*ov*) Rudimentary ovary. There is no style or stigma.

Owing to its very early opening it has been pollinated usually long before noon; and as soon as a flower has been pollinated it either begins to close, changes colour, or casts off its now useless non-essential organs. The latest flower to open was the magnificent Queen of the Night, which unfolded its scentless white petals two hours before midnight.

We approach now a new and more important division of the subject—namely, the means by which the pollen of flowers is conveyed to the

Photo by] [*E. Step.*

FIG. 450.—SWEET CHESTNUT (*Castanea sativa*).

The male and female flowers are produced by the same individual, and on the same spray. The small staminate flowers will be seen on the upper parts of the spray; the large female burs on the lower part.

stigma as a preliminary to fertilization. The consideration of these means brings us in touch with those denizens of the insect world which may be reckoned among the *bidden* guests of flowers. The subject has received an extraordinary amount of attention during recent years, and is practically inexhaustible. The phenomena of which it treats are themselves often spoken of as fertilization, but this use of the term—albeit we confess to being frequent offenders in this respect—is hardly correct. Pollination is a better word.

Photo by] [*E. Step.*

Fig. 451.—Ash (*Fraxinus excelsior*).

The flowers are without petals or sepals, and yet are perfect because each one consists of two stamens and a pistil.

Let us begin with flowers which pollinate themselves. Now it will be evident at a glance that such flowers must bear the male and female organs on the same individual; hence we call them *bisexual* or *hermaphrodite.*

The presence or absence of one or both of the essential organs of a flower is a matter of great importance. One of the commonest hermaphrodite flowers is the Buttercup (*Ranunculus*). Here the male and female organs are both present in the shining yellow cup, and hence it is not only bisexual, but *perfect.* Even though the Buttercup had no calyx or corolla, it would still be perfect. As a matter of fact it possesses both those organs; and since, in addition, it possesses both pistil and andrœcium, it is said to be *complete*. The absence of *any* of the four organs—calyx, corolla, andrœcium, or pistil—renders a flower *incomplete*; but only the absence of one of its *essential* organs (*i.e.* the andrœcium or the pistil) renders it *imperfect*. We are speaking, of course, not of that which is accidental and abnormal, but of that which is characteristic of the flower. Thus the Common Ash (*Fraxinus excelsior*), which bears its male and female organs on the same flower (fig. 451), but has no floral envelopes whatever, is a perfect flower; while, on the other hand, the Arrowhead (*Sagittaria*), in the different species of which both calyx and corolla are always present, but which bears the sexes on different flowers, is imperfect. We need hardly add that, in both cases, the flowers are incomplete. It is, then, evident that all imperfect flowers are either male or female; if the former, they are called *staminate*; if the latter, *pistillate*—names which explain themselves; while flowers which have neither male nor female organs are described as *neuter*. Of this latter kind are the outer florets of some of the Composites.

Photo by] [*E. Step.*

FIG. 452.—SALLOW (*Salix caprea*).

The spray on the left consists of the male catkins, the so-called "palm"; that on the right is made up of female catkins.

Now, though the sexes are often separated in the manner described, staminate and pistillate flowers are not always or necessarily borne on

FIG. 453.—HENBIT (*Lamium amplexicaule*).

(*a*) Perfect flower; (*b*) cleistogamic flower; (*c*) section of (*b*).

different plants. We might, indeed, liken the andrœcium and pistil to tenants in a house where the rooms are flowers and the house itself is the plant. When, as in the Oak (*Quercus robur*), Walnut (*Juglans regia*), and Sweet Chestnut (*Castanea sativa*, fig. 450), the male and female flowers occupy the same house, they are said to be *monœcious* (Greek *monos*, one, and *oikos*, house); when, as in the Juniper (*Juniperus*), Poplar (*Populus*), and Willow (*Salix*, fig. 452), the sexes not only occupy different rooms, but different houses, being borne on distinct plants, the flowers are appropriately termed *diœcious* (Greek *di*, two, and *oikos*). Hence, too, the plants themselves are capable of sexual classification, some being male, others female, others bisexual, and a fourth class, in which male, female, and hermaphrodite flowers are found on one and the same individual, *polygamous*.

With this digression, let us revert to the subject which led to it—the pollinating of a flower by its own anthers. The process of self-pollination is the first stage of autogamy, which, as already explained, is the fecundation of a flower by its own pollen; and the whole process may, and sometimes does, take place without the flower opening at all. It has, indeed, been discovered by comparison of several closely allied flowers that the smaller ones are frequently self-pollinated—nay, that in some cases the *same* plants which produce ordinary cross-pollinated flowers produce minute self-pollinated ones which never open. Thus we may say that there are two kinds of autogamous flowers—those which open like ordinary flowers, and those which remain closed. A glance at an example or two will make the fact additionally clear.

To take the last-named first. These, as the whole process is effected in the closed flowers, are called *cleistogamic*, a name derived from the Greek *kleistos*, closed, and *gamos*, marriage. The Henbit Dead-nettle (*Lamium amplexicaule*) offers excellent examples of cleistogamic flowers. The richly tinted reddish-purple corollas of the expanded blossoms of this not uncommon weed are familiar to most persons

FIG. 454.—FLOWERS OF *Myosotis* IN SECTION.

(*a*) Wood Scorpion-grass; (*b, c*) Yellow and Blue Scorpion-grass (*d*) Forget-me-not.

Photo by] [*E. Step.*

FIG. 455.—HARD HEADS (*Centaurea scabiosa*).

A beautiful composite flower, with all the florets rayed, and of a bright purple colour. The overlapping bracts of the involucre have toothed brown margins. EUROPE, SIBERIA, W. ASIA.

(fig. 453, *a*). They are met with in dry and sandy fields during the sultry months of July and August; but few probably have noticed, earlier in the year, the small bud-like unexpanded flowers of this plant (fig. 453, *b*). These are cleistogamic flowers, which *never* open—undeveloped flower-buds, with anthers and stigmas that mature so that perfect fruits are produced. Were you to open one of these buds at the moment of pollination (fig. 453, *c*), you would find that the long and flexible style (*st*) had curled round so as to bring the inner side of its forked stigma in contact with one of the anthers. Perhaps you would even find that the anthers had not opened, but that the pollen-tubes had perforated its delicate walls and were growing in the direction of the stigma.

Fig. 456.—Great Willow-herb (*Epilobium hirsutum*).
(*a*) Flowering branch; (*b*, *c*) stamens and pistil arranged for cross-pollination. In (*d*) the stigma-lobes have curled back to effect contact with the anthers of the shorter stamens.

The Dog-violet (*Viola canina*) is another plant which produces these undeveloped flowers. Professor Ainsworth Davis remarks that "in summer the ripe fruit of the cross-pollinated flowers will be found, and, close to them, minute bud-like structures. These are the cleistogamic flowers; their anthers are so placed that the pollen-grains can send their tubes straight to the stigma. Such a flower produces, perhaps, only two hundred pollen-grains, as opposed to some thousands in an ordinary blossom." As a rule, indeed, cleistogamic flowers are pollen saving. Thus, a single self-pollinating flower of Wood-sorrel (*Oxalis acetosella*) contains about four hundred grains; a flower of Touch-me-not Balsam (*Impatiens noli-me-tangere*) about two hundred and fifty; and of Cut-grass (*Leersia*) not above fifty. Contrast these figures with the number of pollen-grains in the Peony, 3,500,000, or in a single flower-head of Dandelion, 365,000!

There is a species of Bitter-cress (*Cardamine chenopodifolia*) which has cleistogamic flowers that burrow into the earth. They spring from underground runners or stalks, and are produced earlier than the open flowers, which are borne upon aerial shoots. Charles Darwin and others have asserted the same thing of the cleistogamically produced capsules (seed-vessels) of the Violet; but Professor Henslow, in his *Origin of Floral Structures*, appears to doubt the correctness of the observation. He explains that they certainly are "very, if not more, frequently, not buried at all, but only concealed beneath the foliage."

In the cleistogamic flowers of the Common Wood-sorrel (*Oxalis acetosella*) the unopened corolla forms a sort of cap, which may be removed entire, although, in the flowers that open, the petals do not cohere at all.

The production of cleistogamic flowers appears to depend upon

FIG. 457.—MORNING GLORY (*Ipomœa purpurea*).
(*k*) Calyx; (*c*) corolla; (*s*) stamens; (*st*) stigma.

FIG. 458.—CLIMBING COBÆA (*Cobæa scandens*).
Section of flower in first stage of development; and fruit.

FIG. 459.—CLIMBING COBÆA.
Section of flower in third stage of development.

Fig. 460.—Meadow Cranesbill (*Geranium pratense*).

A protandrous flower.

Fig. 461.—Birthwort (*Aristolochia clematitis*).

Section of flower showing palisade hairs and essential organs.

various causes, the chief of which are the *time of blossoming* and the *influence of climate.* Of these causes the latter is the most important. In Southern Italy, for example, the climate can develop normally expanding flowers, and render them fertile, so that cleistogamy is suppressed; whilst here in England the climate is seemingly not sufficiently warm to do this, and cleistogamic buds appear as compensation. The vegetative energy comes to the fore during the summer, but expanding flowers are not produced simultaneously with it; indeed, as Henslow observes, "it is not until the vegetative period has ceased, and the materials are remade for their development, that larger flowers are again borne"—that is to say, "later in the year, as in November, and also in the following spring."

We come now to the second class of autogamous flowers—namely, those which develop in the normal way, and expand (or, at least, are capable of expansion) at the period of maturity. This class, as has already been explained, comprises all self-pollinating flowers which are not cleistogamic. It must not be supposed, however, that self-pollinating flowers are never cross-pollinated. As a matter of fact, the former process is often only adopted as a last resource. The various species of *Myosotis* offer interesting illustrations of this truth. Thus the Wood Scorpion-grass (*M. sylvatica*) is usually cross-pollinated by flies; but if no insects appear, the anthers shed their pollen directly upon the stigma, which lies conveniently below it (fig. 454, *a*). The Yellow and Blue Scorpion-grass (*M. versicolor*) protrudes its stigma from the flower when ready for pollination (fig. 454, *b*); but if the usual agents in this process—bees and flies—do not appear,

Photo by] [*E. Step.*

FIG. 462.—SHEPHERD'S PURSE (*Capsella bursa-pastoris*).

A common and ubiquitous weed whose inconspicuous flowers are self-pollinated. They have no nectar and no scent. Found in all TEMPERATE CLIMATES.

FIG. 463.—ASPIDISTRA.
Section of flower, showing sessile anthers and mushroom-like stigma.

the corolla-tube elongates, and by that means its sessile anthers, which form a circle on the interior surface of the tube, are rubbed against the knotted stigma (fig. 454, *c*). In the Forget-me-not (*M. palustris*) anthers and stigma are on a level, so that self-pollination is sure to take place in the absence of insects (fig. 454, *d*).

Take the Common Groundsel (*Senecio vulgaris*), again. It is one of the Composites, and each of its capitula bears from sixty to eighty inconspicuous tubular florets, which vary in length from one-tenth to one-eighth of an inch. Marginal or rayed florets, which might serve to attract insects, it has none, and hence, though the honey is easily accessible, the plant seldom gets visited. In this case, therefore, self-pollination takes place almost as a matter of necessity. The styles are furnished at their tips with tiny brushes, which sweep out the pollen-grains in a most effectual manner, holding them fast to the edges of the stigmas, into which the delicate tubes push their way.

Perhaps such diminutive flowers as those of *Myosotis* and Groundsel are not the best examples that might be chosen to illustrate the facts before us, and it will be helpful to name a familar flower of larger growth, which, though normally cross-fertilized, occasionally pollinates itself. Such a flower is the well-known Garden Convolvulus (*Ipomœa purpurea*, fig. 457). "Whilst the flowers are young," says Darwin, "the stigma projects beyond the anthers, and it might have been thought that it could not have been fertilized without the aid of humble-bees, which often visit the flowers; but as the flower grows older the stamens increase in length, and their anthers brush against the stigma, which thus receives some pollen." Its action, indeed, resembles that of *Myosotis versicolor*, save that the bringing of the anthers to a level with the stigma is effected by the lengthening of the stamens—not of the corolla-tube. Kerner asserts that the process of autogamy or self-pollination in *Ipomœa* is further facilitated by the involution of the corolla, which occurs at the close of flowering, whereby the anthers coated with pollen are pressed against the stigma.

FIG. 464.—OXLIP (*Primula elatior*).
(*a*) Pin-eyed and (*b*) Thrum-eyed flowers.

Self-pollination by means of the

style, which we have described as taking place in the Groundsel, may be seen to more advantage in the larger florets of most species of the Knapweed family (*Centaurea*, fig. 455), as well as in most of the Willow-herbs (*Epilobium*, fig. 456). Take, for instance, the beautiful Mountain Centaury (*Centaurea montana*). This plant has a very long list of insect visitors, and yet, when need so requires, the florets are quite competent to pollinate themselves. The anthers are united into a tube which conceals the greater part of the style and is itself almost concealed by the corolla-tube. The anthers open towards the style, upon which in consequence they shed their pollen (introrse dehiscence), and, as might be expected, a good deal of the precious dust gets scattered on the hairs. Here, unless removed by insect agency, it remains until the florets enter upon their last stage; when the style-branches roll back, and in so doing bring their stigmatic surface in contact with the pollen on the circlet of hairs. Thus autogamy is effected.

To describe even a tithe of the means by which the same important end is brought about in other flowers would require more space than the scope of this work allows. In the case of pendent flowers like *Soldanella*, where the style projects beyond the stamens, the pollen may get sprinkled on the stigma; and this may also be the case in upright flowers when the anthers are placed above the stigmatic surface, as in the Lilac (*Syringa*). We have seen how the lengthening of stamens may bring about autogamy, and instances are not uncommon in which the curving or erecting of those organs fulfils the same purpose. The pistil, too, may shorten or elongate, curve or straighten, when self-pollination is the object; or (as in the case of the Mountain Centaury above described) the stigma itself may be adapted to this end.

Photo by] [*E. Step*.

FIG. 465.—PURPLE LOOSESTRIFE (*Lythrum salicaria*).

See also fig. 466.

The important part which the petals sometimes play in this process was clearly indicated in what was said concerning the elongation of the corolla-tube in *Myosotis versicolor*; nor is this the only means by which autogamy is effected by the corolla. In gamopetalous flowers, like the Foxglove (*Digitalis*), the end may be gained by the loosening and falling of the corolla, the adherent stamens brushing against the stigma as the corolla slips along the style, while in flowers with free petals the very closing of the corolla may ensure self-pollination. An excellent illustration of this last method is afforded by the Devil's Fig (*Argemone mexicana*), whose handsome yellow flowers bloom only for a single day. Kerner remarks that "in the morning, as soon as the petals are wide open and the tension of the sheath of stamens surrounding the pistil is somewhat relaxed, there is an immediate fall of pollen on the concave surfaces of the petals. . . . When the evening comes the petals close up over the pistil, and one of them brings its inner surface, which is covered with pollen, into direct contact with the stigma." *Apropos* of this subject, it has been observed of the Water-crowfoot (*Ranunculus aquatilis*) that when the stream in which it is found is much swollen after rain, the flowers remain submerged and fertilize themselves without opening.

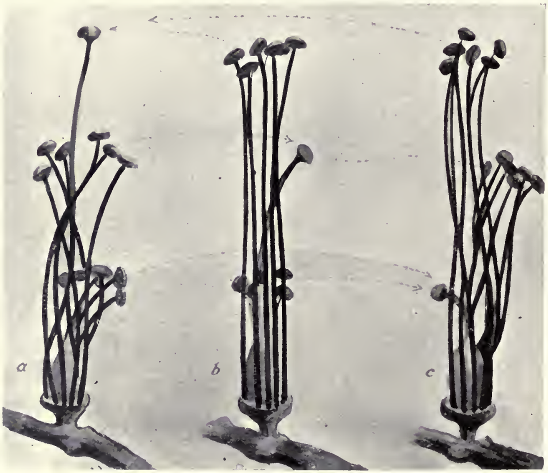

FIG. 466.—PURPLE LOOSESTRIFE (*Lythrum salicaria*).
Illustrating the trimorphism of these flowers. The calyx and corolla have been removed.

In the beautiful Climbing Cobæa (*Cobœa scandens*) we see how autogamy may be effected by a co-operation of movements. On the expansion of the bud, insect-pollination is the first object provided for, and while the campanulate corolla nods invitingly on its stem, the anthers, which are borne on long filaments with hairy bases, lie right in the mouth of the bell, just where the first humble-bee visitor will be sure to knock against them (fig. 458). During this stage the style remains out of sight, with its three-forked stigma tightly closed. In the second stage, anthers and stigma change places, and the filaments of the former, lengthening considerably, twist themselves up

Photo by] [Henry Troth.

Fig. 467.—Magnolia (*Magnolia glauca*).

Showing the flowers in successive stages of expansion. They are protogynous—that is, the pistil matures before the stamens.

like corkscrews. This is the insect's last chance, and now, should no fertilization have taken place, the flower enters upon its third and final stage. For this, it assumes a completely pendent position (fig. 459). While anthers and stigma draw together, the branches of the latter open and present their stigmatic surfaces, and, finally, the pollen falls upon them. On the whole, it is a wonderful instance of the parts of a flower co-operating to a given end.

From what has been said it will be abundantly clear that though the pollen of a bisexual flower may effect the pollination of that flower, such a result is by no means inevitable; indeed, as a matter of fact, a very large number of bisexual flowers are almost always cross-pollinated; and Darwin has shown pretty conclusively that in many plants cross-fertilization has a distinct advantage over self-fertilization—*at least, for some generations*—inasmuch as the flowers thus crossed produce more numerous seeds and healthier seedlings.

This is not the place to discuss the much-debated question whether, *in the long run*, plants are gainers by cross-fertilization. It is a point upon which botanists are still divided. One eminent observer, Professor George Henslow, says emphatically that *habitually* self-fertilized plants are the most prolific, and that our previous ideas, based upon Darwin's experiments and theories, are all wrong, and must be reversed. "The most conspicuous flowers and regularly (if at all) fertilized by insects are not," he asserts in his *The Making of Flowers*, "the best off; *but they cannot help themselves.* The responsive power within them is *automatic*, so to say, and not *volitional.* Whatever an insect does to them, they must yield to it, and grow in adaptation to it, but while they are thus being stimulated to become what *we* may choose to call finer flowers and handsomer plants with larger leaves and so on, yet all this is secured at a sacrifice of fertility." He contends that though Darwin proved that intercrossing is a *stimulating process*—at least, for a time—

FIG. 468.—INDIAN CROCUS (*Cœlogyne lagenaria*).

A beautiful Orchid whose lip is veined and striped to provide honey-guides for insects. See also fig. 470.

his experiments also went to show that "when the two processes were continued for a few years the plants derived by successive self-fertilization in a few generations not only recover themselves, so to say, but sooner or later surpassed in fertility the descendants of plants successfully intercrossed for the same number of years."

Photo by] [*E. Step.*

FIG. 469.—LAMB'S-EAR PLANTAIN (*Plantago media*).
With wind-pollinated (anemophilous) flowers.

However, the fact remains. Cross-fertilization occurs much more frequently in Nature than self-fertilization; and this truth may be readily accepted without committing oneself to the dictum of Darwin—which, indeed, is no longer taken seriously by competent botanists—that Nature abhors self-fertilization.

A *via media* between Darwin and Henslow is offered in Step's *Romance of Wild-flowers*: "The small but ubiquitous Shepherd's Purse (*Capsella bursa-pastoris*) may be taken as a type of the inconspicuous-flowered weeds of this family [*Cruciferæ*], which fertilize themselves, and produce such abundance of seed that they take possession of all cultivated ground so soon as the husbandman's back is turned. Their flowers range in diameter from one-fourth to one-twelfth of an inch, and in some cases the petals have been converted into stamens as being more useful to plants once dependent upon the visits of insects, but which have now learned to do without them. The presence of these minute white petals, and in some cases honey-glands that no longer secrete honey, testifies to the fact that these plants have come down in the world. Yet, in spite of their lack of show or 'presence,' they are a standing rebuke to those writers who have

FIG. 470.—INDIAN CROCUS.
Lip of flower showing fringes and streaks of colour—honey-guides.

so strongly asserted that cross-fertilization produces a more vigorous and successful race. What cross-fertilization by insect agency does is to produce more brilliant individuals, and to keep up large flowers of bright hue. In fact, it produces a kind of floral aristocracy; whilst the principal work of the vegetable kingdom—the abstraction of carbon from the atmosphere, the setting free of oxygen, the production of food for the entire animal races—is done mainly by the less brilliant weeds and grasses and trees—the working classes."

We have seen how certain bisexual flowers adapt themselves to self-pollination; we may next consider how another class of flowers, also bisexual, provide against it. This brings us to the phenomena of dichogamy, upon which we must say a few words. The term is derived from the Greek *dicha*, in two parts, and *gamos*, marriage; and whenever the reproductive organs (stamens and pistil) of a bisexual flower mature at different times we have an instance of dichogamy, and the flower is said to be a dichogamous flower. When the stamens mature first, so that the pollen in their anther-lobes escapes before the stigma in the same flower is ready for pollination, the flower is said to be *protandrous* (Greek *proteros*, before, and *andros*, male); and this is the case in most species of *Geranium*, *Pelargonium*, *Malva*, Umbelliferæ, Compositæ, and Campanulaceæ. When, on the other hand, the stigma matures and loses its capacity for pollination before the anthers of the same flower have shed their pollen, the flower is said to be *protogynous* (Greek *proteros*, before, and *gunē*, a female). Some species of *Magnolia*, *Aristolochia*, *Scrophularia*, and *Plantago* have protogynous flowers, but they are much less common than are the other kind.

The Meadow Cranesbill (*Geranium pratense*, fig. 460)—the largest of our British Cranesbills—is a good example of a protandrous flower. It might at first sight be thought to be a self-pollinating flower, for at the time when the anthers dehisce they are bent right over the pistil: but at this stage in the flowering the pistil is immature, and the stigmatic tissue is protected from pollen falling upon it. At a later period, however, when the anthers have diverged from the pistil, the latter matures, its five branches ex-

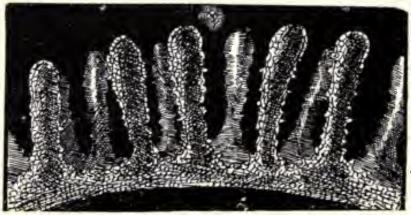

FIG. 471.—INDIAN CROCUS.
Hairs of a portion of two of the fringes of the lip highly magnified.

Photo by] [*E. Step.*

FIG. 472.—MOSSY SAXIFRAGE (*Saxifraga hypnoides*).

A beautiful sub-alpine plant, forming huge moss-like cushions from which rise the white bell-shaped flowers in profusion. The stamens mature before the pistils (*protandrous*).

WESTERN EUROPE, SCANDINAVIA, NORTH AMERICA.

pand, exposing the stigmatic surface, and the flower is cross-pollinated by insect agency.

The Common Birthwort (*Aristolochia clematitis*) is a remarkable instance of a protogynous flower. Fig. 461 shows a section through the swollen base of the dull yellow perianth, in the interior of which we see the six-lobed stigma and a few of the anther-lobes, which are sessile on the short style. Now the stigma of this Birthwort matures two or three days before the anthers are ripe, and at the time of its maturity the flower is entered by small black midges of the genera *Ceratopogon* and *Chironomus*. It will be noticed that the dull yellow corolla of the flower is swollen at the base, but contracts above into a tube which is lined, in the first stage of the flower, with stiff downward-pointing hairs. Along this tube the midges crawl in quest of refreshment, which they find in the succulent tissue that forms the smooth walls of the roomier chamber below. From the centre of the floor of this chamber uprise the six short stamens, the anther-lobes of which are adnate to the stigmatic column. Their meal finished, the midges rest awhile, soothed by the warmth of the apartment. Then they turn to depart. But egress is a different thing from ingress, and on crawling to the tube they find that escape is cut off. The hairs which they had passed over so easily are now a stockade of bristling points. The little guests are prisoners!

FIG. 473.—TIGER-STRIPED ONCID (*Oncidium tigrinum*). An Orchid

What is to be done? At first the midges take the calamity with calmness, and explore their prison with evident care. In the course of their explorations they crawl over the stigmatic surface and—supposing them to have come from another flower—fertilize the ripe stigma with the pollen which they have brought thither. Hours pass away: the stigma withers: but the midges are still held captive. A whole day goes by—two days—and release seems as far off as ever. They become anxious and restless. On the third day the anthers open and discharge their pollen, and the midges, worked up by this time into a fine bustle of alarm, get repowdered with the yellow meal. Their term of imprisonment is now at an end, for lo! the prison bars have collapsed—the stockade of hairs has completely withered, and the midges pass easily out of the flower, laden with an abundant freight!

VARIEGATED ONCID *(Oncidium variegatum)*.

The Oncidiums are a genus of Orchids of which about two hundred and fifty species are known. The Variegated Oncid bears panicled flowers an inch across, of a pretty pink stained with cinnamon at the base of the petals. It is a native of the West Indies.

In the well-known window-plant, *Aspidistra elatior*, the flowers are sometimes protandrous and sometimes protogynous, and self-fertilization is still further guarded against by the curious mushroom-like stigma, which covers the anthers umbrella-fashion, so that the stigmatic surface is quite out of reach of pollen from the same flower (fig. 463). "The capitate stigma closes the flower, leaving only four small openings through which Delpino supposes small flies to enter; the pollen falls out of the anthers and lies in the cavity of the flower. The flies emerge all dusted with pollen, and alighting on the stigma of another flower place pollen there before they

Photo by] [*E. Step.*

FIG. 474.—FORGET-ME-NOT (*Myosotis palústris*).

A well-known streamside flower with yellow-centred sky-blue corolla of salver shape.

find the small entrance" (Müller). These remarks apply equally to the other species of Aspidistra—*A. lurida*, *punctata*, etc. The flowers referred to are also visited by numbers of *Podura*, probably for the sake of the pollen, some of which they may carry from flower to flower.

An even more curious way in which bisexual flowers lay themselves out for cross-fertilization without irregularity is known as *heterostylism*. The law is well illustrated in many plants of the Primula family, to which the Primrose, Cowslip, and Oxlip (fig. 464) belong. "Most children are aware," says Grant Allen, "that we have in our woods two kinds of

Primroses, which they know respectively as pin-eyed and thrum-eyed. In the pin-eyed form, only the little round stigma is visible at the top of the pipe, while the stamens, here joined with the corolla-tube, hang like little bags half-way down the neck of it. In the thrum-eyed form, on the other hand, only the stamens are visible at the top of the tube, while the stigma, erected on a much shorter style, occupies just the same place in the tube that the stamens occupied in the sister blossom. Now each Primrose-plant bears only one form of flower. Therefore, if a bee begins visiting a thrum-eyed form, he will collect pollen on his proboscis at the very base only; and as long as he goes on visiting thrum-eyed flowers, he can only collect, without getting rid of any grains on the deep-set stigmas. But when he flies away to a pin-eyed blossom, the part of his proboscis which collected pollen before will now be opposite the stigma, and will fertilize it; while at the same time he will be gathering fresh pollen below, to be rubbed off on the sensitive surface of a short-styled flower in due season. Thus every pin-eyed blossom must always be fertilized by a thrum-eyed, and every thrum-eyed by a pin-eyed neighbour."

Fig. 475.—Flower-buds of *Aralia nudicaulis*.

(*a*) Umbel of unopened flowers; (*b*) abnormal growth of a single flower; (*c*) umbel at an earlier stage of growth.

Heterostylism is carried to an extreme in *trimorphic* flowers, where, besides a long- and a short-styled form, we get a third condition, to which Darwin has applied the name "mid-styled." The flowers of Purple Loosestrife (*Lythrum salicaria*, figs. 445, 465) offer, perhaps, the best examples of trimorphism. The three forms are shown with diagrammatic stiffness in fig. 466, the floral envelopes (calyx and corolla) having previously been stripped off. Comparing the different forms: in the left-hand figure there are six short stamens, six mid-length stamens, and a long style; in the central figure there are six short stamens, six long ones,

Photo by] [*Henry Troth.*

FIG. 476.—SKUNK CABBAGE (*Symplocarpus fœtidus*).

A North American bog-plant ; interesting as showing an intermediate stage between the open spathe of *Calla palustris* and the closed prison of *Arum maculatum*, Its spathe is streaked with purple and yellow, and it gives out an odour like that of the Skunk, and a mid-length style; and in the right-hand figure, six mid-length stamens, six long ones, and a short style. Now the singular fact about these flowers is this: the long-styled forms are almost invariably fertilized by pollen from long stamens; the mid-styled forms by pollen from mid-length stamens; and the short-styled forms by pollen from short stamens; and hence, of course, the flowers are usually cross-pollinated. Darwin, indeed, has shown that when fertilization takes place under other conditions — when, for instance, a long-styled flower is pollinated by short or mid-length stamens—the seeds produced are smaller and less healthy.

FIG. 477.—FIG (*Ficus carica*).
Longitudinal section through hypanthodium, showing the flowers in the interior.

Hermann Müller tells us that when the flower of Purple Loosestrife is fully expanded—which, however, owing to the crowded nature of the spike, is not often—"the upper petals stand vertically while the lower project obliquely forward; and the latter form, therefore, a rudimentary platform for insects. The irregularity in position of the stamens and pistil is of more importance; they all occupy the inferior (outer) part of the tube, so that insects cannot reach the base of the flower between them, but only above them; and their ends are bent upwards, so that the under surface of the insect must come in contact both with anthers and stigma. Honey is secreted by the fleshy base of the flower, and surrounds the short stalk of the ovary, and fills the space between it and the sides of the tube. Insects are attracted from a distance by the crimson spikes of flowers, and are guided on their way to the honey by the dark red colour of the inner surface of the calyx and by the dark lines in the middle of each petal. These insects are caused to perform regular cross-pollination by the trimorphism of the flowers, which forms the most remarkable feature of the plant."

The arrangements in Nature for securing the cross-fertilization of plants are by no means exhausted with the phenomena of dichogamy and heterostyly. These provisions are doubtless the rule among insect-pollinated flowers, but there are innumerable exceptions to the rule; and, moreover, all cross-fertilized plants do not owe their pollination to insect agency. Other animals, such as snails and birds, sometimes perform this office; and in a large number of cases wind and water are the pollen-carriers. For the present, however, we may confine ourselves to flowers that are pollinated by insects.

Photo by] [*E. Step.*

FIG. 478.—BIRD'S-EYE PRIMROSE (*Primula farinosa*).

A beautiful plant of northern moors and meadows with lilac-coloured flowers. Dimorphic like the Common Primrose.

We have already shown that many flowers are specially adapted, either by their form or mechanism, for the visit of certain insects; and further, that the colours, scents, and nectareous sweets of such flowers act as lures to the guests that are wanted. The flower, indeed, as a talented

FIG. 479.—NECTARIES.
The first figure is a petal of Buttercup showing pocket-like nectary at its base; the second a petal of Barberry with its two nectaries.

writer remarks, "is no longer a simple passive victim in the busy bee's sweet pillage, but rather a conscious being, with hopes, aspirations, and companionships. The insect is its counterpart. Its fragrance is but the whisper of welcome, its colour is as the wooing blush and rosy lip, its portals are decked for his coming, and its sweet hospitalities humoured to his tarrying; and as it finally speeds its parting affinity rests content that its life's consummation has been fulfilled."

In considering the means by which insects are attracted to flowers, six important features may be specially noted. These are Conspicuousness, Odour, Irregularity, Honey-guides, Nectar, and Pollen. Let us take them in their order.

Size, colour, and the massing of flowers are the three chief causes of *Conspicuousness.* Of these the first and last need not be dwelt upon. It is obvious that the larger a flower is, the greater are its chances of attracting attention; equally obvious is it that small flowers which cluster together (say as umbels or flower-heads) have a decided advantage over flowers of the same size which are solitary. Then there is colour. The bright colours of flowers, and in some cases the bright tints of the adjoining parts, such as the flower-stalks, bracts, etc., have evident reference to the visits of insects; indeed, it was the opinion of Sprengel, a German botanist of the eighteenth century, that "flowers differ in colour in accordance with the kinds of insects which frequent them." That bees readily distinguish colour has been proved by Lord Avebury, and the experiments of Darwin point to the same conclusion. "It is a curious question," Darwin writes, "how bees recognize the flowers of the same species. That the coloured corolla is the chief guide cannot be doubted. On a fine day, when hive-bees were incessantly visiting the little blue flowers of *Lobelia erinus*, I cut off all the petals of some, and only the lower striped petals of others, and

FIG. 480.—LARKSPUR.
A flower of *Delphinium grandiflorum* with spurred calyx and corolla.

Photo by] [*Walter Rossiter.*

FIG. 481.—MOUNTAIN DRAGON'S-MOUTH (*Horminum pyrenaicum*).

An interesting genus, containing only one species, of the order Labiatæ; the purple flowers bear in the lower part of the corolla-tube palisades of elastic hairs to protect the honey from unbidden guests. MOUNTAINOUS PARTS OF TEMPERATE EUROPE.

Fig. 482.—Section of Pansy Flower (*Viola tricolor*),
Showing spurred stamens projecting into the spur of the petal. The lateral petal will be seen to have at its base a tuft of hairs which aid the bee in clinging to the flower.

these flowers were not once again sucked by the bees, although one actually crawled over them. The removal of the two little upper petals alone made no difference in their visits. Mr. J. Anderson states that when he removed the corollas of the Calceolaria, bees never visited the flowers."

That this is not a rule without exception, however, Darwin has himself pointed out. He shows clearly enough that colour is not the only insect guide, and offers the common-sense suggestion that insects may be able "to recognize plants even from a distance by their general aspect, in the same manner as we should do." We may add that the entire removal of the corollas of several flowers of the Garden Convolvulus (*Ipomœa purpurea*)—an experiment which we tried not long since—did not hinder bees from visiting those flowers; indeed, they seemed to resort to them more freely than to the unmutilated flowers, although the latter were fully expanded at the time.

Sprengel's opinion has been quoted that "flowers differ in colour in accordance with the kinds of insects which frequent them," and it would be easy to bring forward an array of arguments in support of this view. It has been noticed, for example, that the favourite colours of the honey-bee are blue, violet, crimson, purple, and deep violet-blue, particularly the last-named; but that scarlet, orange, and yellow attract them but little—if at all. Possibly, as Kerner suggests, the nerve-bundles which correspond to those colours are wanting in their eyes. Butterflies and humble-bees, on the other hand, are very partial to scarlet. Scarlet appears also to be the favourite colour of humming-birds; and the fact is to be noted that scarlet flowers abound in those countries where humming-birds are found. Crepuscular and night-flying insects are most affected by white and pale yellow, a circumstance easily accounted for, since the deeper-coloured flowers become invisible when twilight falls.

Flies and beetles which frequent dung-heaps and offal are drawn to greenish yellow or brownish yellow flowers, like the Parsley and Ivy, the Aralia and Sumach; and "this phenomenon has been explained by the similarity of the colours named with those of the dung-heap and offal generally" (Kerner). Wasps, which are so partial to decaying fruit, seem to have a predilection for dark brown; whilst carrion-flies are most susceptible to pale fawn-red and dirty violet, the prevailing tints in decaying flesh. Hermann Mülier says of the gigantic *Amorphallus titanum*, whose spathe is thirty-three inches in diameter, and the bare part of whose floral axis attains a length of six feet, that it "is adapted by its dirty

Photo by] [*E. Step*

FIG. 483.—CUCKOO-FLOWER (*Cardamine pratensis*).

Two of the sepals are enlarged at the base to accommodate the nectaries.

yellow and dark purple colours for dung- and carrion-flies." A more familiar example is our own little Cuckoo-pint (*Arum maculatum*). All such flowers give out an offensive odour which serves as an additional attraction to carrion-loving flies.

Physiologically speaking, the cause of the colours of flowers (as, indeed, of fruits also) is the existence of pigments in their cells, either dissolved or in solid particles. The colouring principles are the same as in autumn leaves—namely, anthocyanin and phylloxanthin. Thus the yellow hue of the florets of the Dandelion is due to microscopic bodies of protoplasm tinged with a yellow pigment, which are contained in the epidermal cells; while the colour of the Pheasant's-eye (*Adonis autumnalis*) is due to a red pigment. In the last-named flower the particles are less than $\frac{1}{6000}$ of an inch in diameter. In blue, violet, and (so-called) black flowers (which are probably in most cases a deep shade of violet), the colouring matter is usually dissolved in the cell-sap. White flowers do not derive their whiteness from any pigment, but from the fact that their epidermal cells are filled with air. Professor Thomé has shown in the case of *Zinnia elegans* how peculiarly the separate pigments of a flower may be distributed in different superimposed layers of cells. "The marginal florets of the capitulum are scarlet on the upper and light yellow on the under side, while the layers of cells nearest the surface contain a purple sap with orange granules. The rest of the cells are filled with a colourless sap in which float a smaller number of light yellow granules."

FIG. 484.—SAXIFRAGE (*Saxifraga officinalis*).

The white corolla has two violet spots at the base of each petal. Pollinated by short-lipped insects, especially flies.

The changes in the colours of flowers, like the changes in the colours of leaves, are due to oxidation. The Common Borage (*Borago officinalis*) changes from pink to blue; and the pale pink bells of the young flowers of the Garden Convolvulus (*Ipomœa purpurea*) frequently change to a deep purple as they mature. These are familiar instances of oxidation

Photo by] [*Walter Rossiter*

FIG. 485.—AFRICAN LILY (*Agapanthus umbellatus*).

A Cape plant with large umbellate heads of bright blue flowers, and long strap-shaped leathery leaves, springing from a large bulb. The flower-head offers a good example of the umbel form of inflorescence.

FIG. 486.—SECTION OF PASQUE-FLOWER.
(*a*) Stamens; (*n*) nectaries.

in cells containing the blue colouring principle (anthocyanin). Yellow flowers, on the other hand, if they change at all, keep to their own series of colours—oranges and pure reds—so that there is fitness in De Candolle's division of flowers into *xanthic* and *cyanic*—a yellow series and a blue.

Here, as elsewhere in Nature, the rule is not without exceptions. Thus, the Yellow and Blue Scorpion-grass (*Myosotis versicolor*) changes from yellow in the bud to blue in the open corolla; and the Garden Hyacinth (*Hyacinthus orientalis*), whose generic name denotes a deep purply blue colour, is not infrequently pale yellow. Other exceptions might be pointed out.

Kerner draws attention to a third colouring principle, a scarlet-red pigment, as yet little known; but notably present in the blood-coloured inflated calyx of the Winter Cherry (*Physalis alkekengi*). It may serve, he thinks, to frighten animals. If this be so, the brilliant hues of flowers must in some instances be looked upon as means of repulsion rather than of attraction.

FIG. 487.—INFLORESCENCE OF PETTY SPURGE (*Euphorbia peplus*), showing the horned nectaries.

From Conspicuousness we come to *Odour*. Odour and Conspicuousness are the two means by which insects are attracted to a plant *from a distance*, just as honey-guides facilitate their search for the nectary when the flower is reached. That odours really do attract insects has been attested by Darwin, who found that they visited flowers which he had covered with muslin nets. The same naturalist tells us that "Nägeli affixed artificial flowers to branches, scenting some with essential oils and leaving others unscented; and insects were attracted to the former in an unmistakable manner. . . . Of all flowers," he further remarks, "white is the prevailing one; and of white flowers a considerably larger proportion smell sweetly than of any other colour—namely, 14·6 per cent.; of red, only 8·2 per cent. are odoriferous. The fact of a larger proportion of white flowers smelling sweetly may depend in part on those which are fertilized by moths requiring the double aid of conspicuousness in the dark and of odour. So great is the economy of Nature, that most flowers which are fertilized by crepuscular or nocturnal insects emit their odour chiefly or exclusively in the evening. Some flowers, however, which are highly odoriferous, depend solely on this quality for their fertilization, such as the night-flowering Stock (*Hesperis*) and some species of Daphne; and these present the rare example of flowers which are fertilized by insects being obscurely coloured."

Photo by] [*E. Step.*

FIG. 488.—WOOD SPURGE (*Euphorbia amygdaloides*).

A larger species than the Petty Spurge, and a perennial. The horns of the nectar glands converge in this species.

Conspicuousness and Odour usually go together, but this is not always the case. The flowers of the Willow, Lime, and Mignonette are notable exceptions. The hypanthodium of the Fig is another. What attracts the wasp to the Fig? Not the brightness of its densely packed unisexual flowers, for they are hidden quite out of sight. It is the odour. Were it not for the odour the

FIG. 489.—NECTAR GLANDS.

The first figure shows a gland at the base of the ovary in *Veronica*; the second is part of a cherry leaf with two nectaries (*n*) at its base.

flower might remain unvisited and would probably never get fertilized, for the Fig is protogynous. In fact, the two kinds of Fig-tree—*caprificus* and *ficus*, as the Italians call them—stand to each other in the relation of male and female, being, broadly speaking, the different sexes of the one species, *Ficus carica*; and each appeals to the olfactory sense of insects with a distinct purpose. *Caprificus* may be popularly regarded as the "male tree"—*i.e.* its hypanthodia produce male flowers near the opening (*ostiole*) and abortive female flowers, known as gall-flowers, lower down. *Ficus* is the "female tree"; its inflorescences, which form the edible Fig, contain only female flowers.

Concerning these gall-flowers, some very remarkable facts are known. "As the name indicates," says Kerner, "not fruits but galls are produced from these modified female flowers, and this happens in the following manner. There is a small wasp . . . *Blastophaga grossorum*, which lives upon the Fig cultivated in the South of Europe. This insect passes into the cavity of the inflorescence through the orifice, and there sinks its ovipositor right down the style-canal of a flower and deposits an egg close to the nucellus of the ovule. The white larva developed from the egg increases rapidly in size and soon fills the entire ovary, whilst the ovule perishes. The ovary has now become a gall. When the wasps are mature they forsake the galls. The wingless males are the first to emerge, and they effect their escape through a hole which they bite in the gall. The females remain a little longer in the galls and are there fertilized by the males. Afterwards they come out also, but only stay a short time within the cavity of the inflorescence, issuing from it as soon as possible into the open air. They crawl up to the mouth of the inflorescence, and in doing so come into contact with the pollen of the male flowers and get dusted all over the body, head, thorax, abdomen, legs, and wings. After squeezing through between the scaly leaves at the mouth of the inflorescence, and having at last reached the outside, they let their wings dry and then run off to

FIG. 490.—NECTAR GLANDS.

The dark spot (*n*) on each of the stipules of the Broad Bean is a nectar gland.

Photo by] [*James E. Tyler.*

FIG. 491.—FLAMINGO-PLANT (*Anthurium scherzerianum*).

The spathes of this plant, which is a native of Central America, are of an intense and brilliant scarlet, but the flowers yield no honey. It is thought that flies and beetles are attracted to them, as in the case of their relatives the Arums.

Fig. 492.—Pollen of Evening Primrose (*Œnothera biennis*).

Fig. 493.—Pollen of Pumpkin (*Cucurbito pepo*).

Fig. 494.—Pollen of Passion-flower (*Passiflora*).

other inflorescences on the same or on a neighbouring Fig-tree." If the latter, and the tree happens to be a "female tree" in an early stage of development, the result may be anticipated. The little visitors gain an entrance, perhaps tearing or even losing their wings on the sharp scales near the aperture, and, as they bustle about the hollow inflorescence, the pollen which they have brought with them gets dusted on the stigmas, and fertilization ensues.

Odorous flowers are of two kinds, fragant and fœtid. The former, which are by far the most numerous, are chiefly visited by bees, butterflies, and moths; the latter, by carrion-flies and dung-beetles. *Arum crinitum*, says Hermann Müller, "attracts carrion-flies by means of its strong odour of putrid flesh. The smaller visitors are held fast by sticky hairs in the floral chamber and digested." He elsewhere affirms that the disgusting smell of the Marsh Calla (*C. palustris*, fig. 443), serves the double purpose of attracting carrion-flies and repelling injurious animals. This remark would be equally true of the gigantic *Rafflesia arnoldi*, many Irises, and the remarkable Dragon Arum (*A. dracunculus*).

Fig. 495.—Pollen of Scots Pine (*Pinus sylvestris*).

Kerner, with characteristic thoroughness, has proposed to divide the floral scents into five groups, which he names the indoloid, aminoid, benzoloid, paraffinoid, and terpenoid scents—a distinct improvement on Dr. Robert Brown's threefold and somewhat empirical division into superodorants, subodorants, and inodorants. To the *indoloid* group belong those volatile substances which arise from the decomposition of albuminous compounds, and diffuse into the atmosphere; and in which one or several benzole nuclei are retained, as well as nitrogen. These compose the greater number of the fœtid scents; and the flowers in which they are developed "resemble animal corpses in their colouring, having usually livid spots, violet streaks, and red-brown veins on a greenish or fawn-coloured background." To the *aminoid* group belong those volatile substances which diffuse into the air and have an amine as their foundation, like the scents of Hawthorn, Ivy, and Mountain Ash. The *benzoloid* group comprises those scents which are formed from the so-called aromatic bodies, like oil of cloves and vanilla, and are found in the Honeysuckle, Wallflower, Pink, Violet, Lilac, and a host of other flowers. The *paraffinoid* scents include the vegetable acids and alcohol of those hydrocarbons which are known as paraffins, such as valerianic acid and oil of rue. They are found in the Rose, Valerian, Rue, Elder, etc. The last or *terpenoid* group consists of scents produced from ethereal oils destitute of oxygen, called terpenes; the well-known oil of lavender is one of them. They are usually developed in the tissues of the stems and foliage, but the Citron, Lavender, Thyme, Magnolia, and some other plants produce them in their flowers.

Many flowers which are not cross-pollinated by insects, and some few that are, are quite odourless to man; though it does not follow of necessity that they are scentless to insects. To take an example: The flowers of the Virginia Creeper (*Ampelopsis quinquefolia*), in which we can detect no scent, evidently appeal to the olfactory sense of bees; otherwise it would be impossible to account for the readiness with which they find out the flowers, which have green corollas and are undistinguishable among the leaves at a little distance. As an instance

Photo by] [*E. Step.*

FIG. 496.—TWAYBLADE (*Listera ovata*).
An Orchid with very small flowers, but each flower with remarkable arrangements to ensure cross-pollination.

FIG. 497.—FLOWER OF PEA (*Pisum sativum*).

FIG. 498.—SECTION OF PEA FLOWER

after removal of calyx, wings, and standard, and one of the petals of keel. In the remaining petal are the stamens and pistil, and, in the conical cavity above the anthers, the pollen.

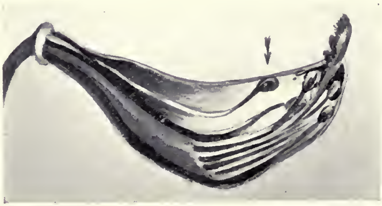

FIG. 499.—SECTION OF PEA FLOWER

depressed in the direction of the arrow. When such depression is caused by the weight of a bee, the pollen-covered style-brush is forced out and strikes against the underside of the bee.

of the power of smell in insects, Kerner relates that when, some years ago, the Aroid *Dracunculus creticus* from Cyprus was planted in the Vienna Botanic Gardens, though there were no carrion-flies in the vicinity, nor refuse matter of any kind to attract them, the large fœtid-smelling flower-sheath no sooner opened than it was freely visited by those insects, who came flying thither from every quarter. A captive Hawk-moth which the same distinguished naturalist let loose in the gardens at a distance of two hundred yards from a plant of Honeysuckle, flew directly, straight as an arrow, to the plant, and was found by Kerner, who had placed a cinnabar-red mark on the moth, hovering about over the flowers. Here again scent alone can have guided the insect.

Perhaps it will now be said, If scent and colour are the two chief means by which insects are attracted to flowers from a distance, what is to detain and reward them when the flowers are reached? In other words, What provision is made for their reception? This question is answered by completing the list of floral attractions which we have named. Two out of the six have been already dealt with. The remaining four are: Irregularity, Honey-guides, Nectar, and Pollen.

Irregularity is specially connected with the comfort of the insect. Labiate flowers, for example, provide a *landing-stage* for their visitors, as was pointed out in the case of the White Dead-nettle. The Calceolarias, which

Photo by] [*Henry Troth.*

FIG. 500.—WILD GINGER (*Asarum canadense*).

The brown bell-shaped flowers of this plant are produced close to the ground, much like those of *Aspidistra*. At first the three lobes are folded over the mouth of the flower, leaving only narrow slits through which small flies, attracted by the camphor-like odour and the livid colour, enter, and are imprisoned until they have been dusted with pollen, much as in the case of Cuckoo-pint. This species is a native of North America, but there is a European species which has been naturalized in parts of England.

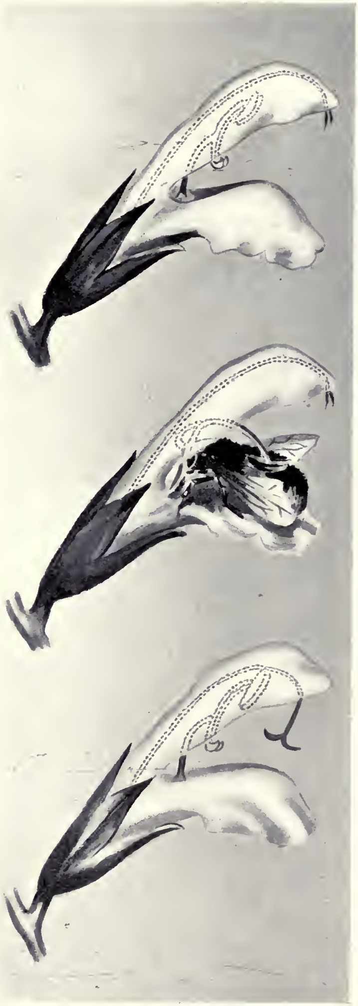

FIG. 501.—FLOWER OF SAGE (*Salvia officinalis*),
Showing the mechanism as set in motion by the visit of a bee.

offer another typical form of irregular flower, not only provide a platform, but present their nectary to the humble-bee directly he has taken his seat; the Aristolochias, which are chiefly pollinated by flies, are furnished with conveniences in the way of perches and expansions for alighting, which clearly save the little guests a world of trouble. The Orchids (figs. 468 and 473) are provided with "all sorts of lobings and sinuses, fringes, pegs, and knobs on the lower lip, which serve as landing-stages and as fulcrums for further explorations to numerous flies, wasps, bees, humble-bees, and butterflies." So one might go on furnishing examples indefinitely. The subject is inexhaustible, though whether the irregularity should be regarded as one of the causes of insect visits, or whether it is merely an effect, as Professor Henslow would persuade us, are questions which need not be discussed in this place.

The second provision in flowers for the reception of insects comprehends all those markings and accessory growths on the sepals and petals which are known as *Honey-guides* or *Path-finders*. The beautiful pencillings of flowers (spots, stripes, etc.), no less than their bright colours, serve, it is thought, to attract insects. Sprengel maintained nearly a century ago that the purpose of the marks is to guide to the nectary, a notion which Darwin for a long time scouted; but when the latter published his book on the *Effects of Cross and Self-fertilization in the Vegetable Kingdom*, he had come round to Sprengel's view, and, indeed, defended it therein. In Darwin's opinion the case of the Pelargonium affords the best evidence that these marks have really been developed in correlation with the nectary. "The two upper petals," he writes, "are thus marked near their bases; and I have repeatedly observed that when the flowers vary so as to become peloric or regular, they lose their nectaries and at the same time the dark marks; when the nectary is only partially aborted, only one of the upper petals loses its mark. . . . It is, however, evident that insects could discover the nectar without the aid of guiding-marks. They are of service to the plant only by aiding insects to visit and search a greater number of flowers within a given time than would otherwise be possible; and thus there will be a

Photo by] [*E. Step.*

FIG. 502.—BARBERRY (*Berberis vulgaris*).

The yellow flowers have irritable stamens which spring up and dust insect visitors with pollen.

better chance of fertilization by pollen brought from a distant plant, and this we know is of paramount importance."

Hairs, prickles, the grooves of petals, and warty protuberances may also serve as path-finders; and one or more of these features may be present in a flower in addition to the guiding-marks. This is the case in the beautiful Orchid known as the Indian Crocus (*Cœlogyne lagenaria*, fig. 468), where the yellow fringes (figs. 470, 471) borne on the lilac veins of the lip of the flower, and the striped and barred markings on either side, act as path-finders. At the same time, it must not be supposed that all the stripes, spots, etc., of flowers are guides to the nectary. Probably in not a few

FIG. 503.—FLOWER OF *Kalmia latifolia.*
In the first condition the stamens are bent back and the anthers held fast in pouches of the corolla.

cases their purpose is purely an æsthetic one. The Opium and Common Red Poppies, for example (*Papaver somniferum* and *P. rhœas*), have no honey, and yet they are strikingly marked; and in many labiate flowers and Saxifrages (*e.g. Saxifraga officinalis*, fig. 484) the marks are so small as to be hardly visible at a few paces—at least, to the human eye. But, of course, if their presence is related to insect visitors they are only intended to be seen at short range—when the insect is actually on the flower.

We come now to *Nectar*. Of all the attractions which flowers hold out to insect visitors, this is undoubtedly the chief. Nectaries are usually, though not always, situated deep down in the flower; and they present a variety of forms. In some flowers they have the appearance of small fleshy warts and pegs; in others they are grooved; in others ring-shaped; and in the fourth case, hollowed out like spoons or shallow cups. These are the most common forms. The nectar itself "is not," says Professor Trail, "identical with honey, although, as furnished by many plants, it is the material from which bees make the latter. Analysis has shown the sugar of nectar to be, very generally, cane-sugar, while that of honey is grape-sugar, consisting of dextrose and levulose in equal proportions. The conversion of the cane-sugar is brought about by an admixture of salivary secretion at the time the nectar is sucked up. This conversion has been well made out in the case of bees; and since larger animals and man are known to convert cane-sugar into grape-sugar as an initial process in digestion, it is probable that butterflies and moths effect the same changes as the bee."

FIG. 504.—FLOWER OF *Kalmia latifolia.*
A bee in search of nectar causes the anthers to spring from the pouches and dust the visitor with pollen.

Photo by] [*E. Step.*

Fig. 505.—Comfrey (*Symphytum officinale*).

A coarse, bristly plant that grows chiefly by watersides. The pale yellow or blue purple flowers are in scorpioid cymes. The anthers shed their pollen before the stigma is mature. Nectar is secreted by the fleshy base of the ovary, which induces the visits of humble-bees. EUROPE and WESTERN SIBERIA.

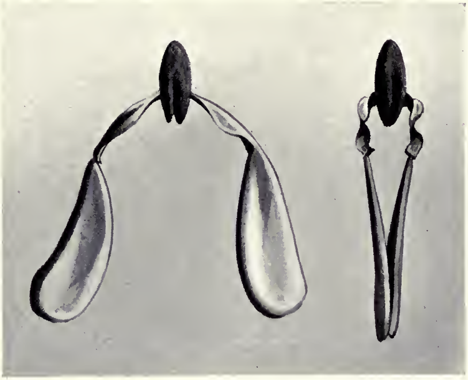

Fig. 506.—Pollinia of *Asclepias cornuti*.

The first shows the pollinia immediately after removal from the flower. The second shows them a little later, when by the twisting of the strap-like connections they have been brought close together.

Fig. 507.—*Catasetum tridentatum*.

One of the most remarkable of the Orchids.

At a meeting of the Linnean Society a few years ago some interesting specimens of honey were exhibited. Among these were the Eucalyptus honey from South Australia, which, like the plant from which it derives its properties, is valued as a febrifuge; and a quantity of the Arbutus honey from Turkey, which is said to produce drowsiness and sleep. The reddish honey of the Brazilian wasp, which is known to be actually poisonous, was also represented in the collection; as were the spring honey of Eastern Nepaul, which is noxious owing to the bees feeding on the nectar of Rhododendrons; the honey of Trebizond, which is an irritant and intoxicant narcotic because of the poison of the Pontic Azalea and Rhododendron infused through it; a poisonous African honey obtained from a bee which feeds on Euphorbia flowers; and, lastly, a pale-looking honey from Coorg, in Southern India, of which a very small quantity is said to produce severe headache, nausea, and prostration. Needless to add, the honey of our English bees is perfectly innocuous and wholesome.

The position of the

nectary varies in different plants, and bears, as a rule, the most evident relation to the pollinating of the flower. In the Japan Lily (*Lilium speciosum*) the narrow grooves at the bases of the perianth form the nectary; and this is also the case in the Martagon Lily (*L. martagon*), though here the nectary is more complicated in structure. The grooves (which are deeper than the grooves in the Japan Lily) are bordered by stiff hairs which rise up and arch over to form a tube, through which the nectar must be sucked, so that only long-tongued insects can get at it. In the Garden Nasturtium (*Tropæolum majus*) the sepaline spur of the calyx is the nectary; while in the Larkspur (*Delphinium*, fig. 480) and some closely allied species, the hollow petaline spur secretes the nectar. The two upper petals of *Delphinium elatum*, for example, lie close together so as to form a hollow cone, at the end of which is the nectar; whilst the spur, beside serving as a guide to the sucking-tubes of bees (the flower's chief pollinators) prohibits by its length the access of insects with shorter tongues.

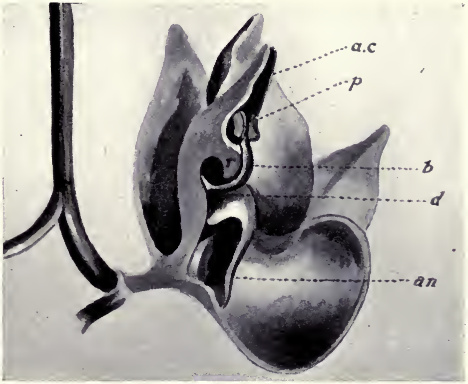

FIG. 508.—*Catasetum tridentatum.*
A section of the flower: (*ac*) anther case; (*p*) pollen masses; (*d*) viscid disc; (*b*) band connecting pollen-masses with disc; (*an*) one of the antennæ; (*r*) rostellum.

In the Crowfoot family (*Ranunculus*) the nectar is protected by small scales at the base of the petals—one scale to each petal—as may be seen in the Buttercup (*R. acris*, fig. 479, and *R. bulbosus*); while in the Common Barberry (*Berberis vulgaris*, figs. 479 and 502)—of which more hereafter—each of the petaline nectaries is double. They differ

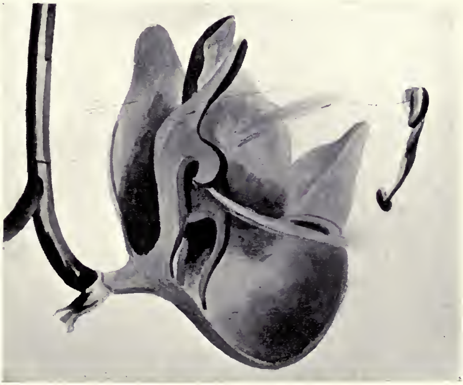

FIG. 509.—*Catasetum tridentatum.*
The flower in the act of expelling the pollinium.

FIG. 510.—FLOWER OF YUCCA (*Yucca recurva*).

also from the nectaries of *Ranunculus* in being thick and fleshy. In the Hellebores the petals are converted into little green vases, which are filled with nectar.

In the Violet and Pansy (*Viola*) the correlation between the nectaries and the other organs of the flower is extremely interesting. The intricate arrangement of the several parts is a little baffling at first, but the drawing (fig. 482) will help to an understanding of the mechanism of the flower. The sketch represents a flower laid open to show the two nectar-excreting appendages of the lower stamens, which, it will be noticed, are inserted in the spurred petal. Into this spur the liquid honey drops. The curious globular head of the stigma, with its hollow mouth-like chamber and tongue-shaped flap, is seen peeping above the triangular anthers, which surround the style collar-fashion; while the pear-shaped ovary is completely hidden by the broadened and cohering filaments of the stamens. The drawing also shows one of the two lateral petals, with its tuft of hairs. Both of the lateral petals are furnished with these hairs, which aid the bee in clinging to the flower. In some species of *Viola* the grooved part of the inferior spurred petal is also fringed with hairs, but they are for collecting pollen.

FIG. 512.—YUCCA-MOTH GATHERING POLLEN.

FIG. 511.—YUCCA-MOTH (*Pronuba yuccasella*).
With ball of pollen (*p*) held by tentacle (*a*).

Photo by] [*H. Irving.*

FIG. 513.—YUCCA-PLANT (*Yucca gloriosa*).

This plant is cross-fertilized by insect agency in a manner which makes it one of the wonders of the vegetable world. The process is fully described in a later chapter.

Now, when a bee wants to reach the honey in a flower—say, of *Viola tricolor*—it must insert its proboscis close under the capitate stigma, and this, as shown in the sketch, lies in the groove of the inferior petal. Into this groove the anthers shed their pollen, either of themselves or when the pistil is shaken by the bee, and hence the insect's proboscis, in passing down the groove to the spurred nectary, gets plentifully dusted with the yellow meal. As the proboscis is withdrawn, it shuts to the flap-like door of the stigmatic chamber, so that, for the nonce, no pollen can enter that cavity; but when the bee thrusts its head into the next flower, it leaves some of the precious dust on the upper surface of the flap.

In the Alpine Liane (*Atragene alpina*) the grooved inner surface of the basal half of the stamens forms the nectary. "The pendulous violet flowers," says Hermann Müller, "only give up their honey to insects which can force asunder the numerous stamens, which are set closely in several whorls," and which, we may add, are held together on the outside by a whorl of stiff, erect, spoon-shaped staminodes.* Bees and humble-bees are

FIG. 514.—*Odontoglossum alexandræ.*
(*a*) A spray of flowers; (*b*) A single flower; (*c*) Pseudo-bulbs and leaves.

* A *staminode* is a barren stamen, more or less filiform in shape, placed either within or without the perfect stamens, but not furnished, like them, with anthers at the apex. H. Müller calls the staminodes of *Atragene alpina* "petals"; Kerner, "leaves"; Baillon, "staminodes."

among the few insects powerful enough for this work; and, in point of fact, they alone have been observed to pollinate the plant.

Fig. 515.—*Vallisneria spiralis.*
Female plant on the left; male plant on the right.

The nectaries of cruciform flowers (Cruciferæ) are usually glandular swellings at the base of stamens, the honey when secreted either remaining in drops upon the glands, or accumulating in the spaces between the stamens and pistil and in the sepaline pouches. The Cuckoo-flower (*Cardamine pratensis*, fig. 483) — of which Gerarde quaintly says, "it doth bloome in April and Maie, when the cuckoo doth begin to sing her pleasant notes without stammering"—is a good example. The nectar glands are the green fleshy cushions at the bases of the two shorter and the two aborted stamens, and the honey secreted by these glands accumulates in the pouched bases of the sepals. "In the young bud all the six anthers are turned towards the pistil, which projects above them. Before the flower opens the four inner stamens elongate and overtop the stigma, and make a quarter of a revolution outwards, each one towards the small stamen nearest to it; so that now an insect, in trying to reach the honey of one of the larger glands [those surrounding the bases of the shorter stamens], must rub its head or proboscis against the pollen-bearing surface of one of the taller anthers" (Müller).

FIG. 516.—FLOWER OF NETTLE (*Urtica dioica*).
The male or staminate flower.

In the Pasque-flower (*Anemone pulsatilla*) we have an instance of stamens metamorphosed into nectaries—or rather of rudimentary stamens, with shortened filaments, and glands instead of anthers (fig. 486). In Papilionaceous flowers, like the Pea and Bean, the cohering fertile stamens secrete and store the nectar (figs. 497–499). They form a tube around the ovary, and the honey is poured into the base of the tube.

Very curious are the nectaries of the well-known Petty Spurge (*Euphorbia peplus*), so common as a garden weed throughout the kingdom (fig. 487). The border of the cup-like involucre is studded with shining, crescent-shaped glands, which are much resorted to by flies, beetles, and other short-lipped insects, on account of the nectar with which the glands are coated. They are, in fact, the nectaries; and by their prominence and accessibility they compensate for the inconspicuousness of the flowers. There is a nearly allied plant to the Spurges, a species of *Dalechampia*, which, according to Fritz Müller, attracts the insects which cross-pollinate it by means of a colourless resin secreted in special glands. This resin is collected by the insects (bees), and used in nest-building. In the Carrot (*Daucus*), Elder (*Sambucus*), and Ivy (*Hedera*) the nectary is also conspicuous, lying almost on the surface of the flower.

Ovarian nectaries are found in *Antirrhinum*, Speedwell (*Veronica*), the Common Comfrey (*Symphytum officinale*), and other plants. In the Spiked Speedwell (*V. spicata*, fig. 489) the fleshy base of the ovary secretes the nectar, and the tube of the corolla holds it like a cup. A ring of long stiff hairs at the mouth of the tube shelters the nectar from rain. This is also the case with the Brooklime (*V. beccabunga*), which is freely visited by insects, particularly flies. The ovarian nectary of Comfrey (fig. 505) is a white annular ridge, and in order to get at it the insect (usually a humble-bee) has to force apart the anthers, which form an inverted cone near the mouth of the tubular corolla. This releases the pollen, which falls upon the insect, and in due course is transferred to another flower.

FIG. 517.—FLOWERS OF VALLISNERIA.
(*a*) Female flower; (*b*) bud of male flower; (*c*) male flower open.

Other nectaries are sometimes found on the foliar parts of plants, at a considerable distance from the flowers. "It is always pleasant," says a writer in *Nature*, 1893, "to

Photo by] [*Henry Irving.*

Fig. 518.—Alder (*Alnus glutinosa*).

The upper branch supports male flowers in catkins: the lower, female flowers in spikes, whose scales become woody in fruit and much like the cones of some Conifers. EUROPE, NORTH AFRICA, and ASIA.

hear the contented hum of the bees amongst the young Laurel leaves [of *Cerasus lusitanica*]; for with no ulterior ends of their own the prosaic green bushes regale their friends with the sweets secreted by the yellow glands at the bases of their leaves, and, whatever may be said to the contrary, afford a triumphant proof that plants are not exclusively selfish and utilitarian, as we in our half-knowledge are sometimes apt to imagine." Certain species of *Prunus* (*e.g.* the Cherry, *P. cerasus*) produce nectaries in the form of small red glandular swellings on their leaf-stalks (fig. 489), though the receptacular tubes of the flowers also secrete honey. The Broad Bean, again (*Vicia faba*), has nectaries on its stipules (fig. 490); so have the Vetch (*V. sativa*) and the Scabrous Balsam (*Impatiens tricornis*). These secretory glands appear to be an ingenious device for enlisting the services of ants.

Photo by] [*E. Step.*

FIG. 519.—HAZEL FLOWERS (*Corylus avellana*).

The long, swinging catkins consist of male flowers only. The female flowers are bud-like, with crimson threads (stigmas) protruding from the top. These later develop into the familiar Hazel-nuts.

It is probable that the writer in *Nature* just quoted would have modified his statement had he inquired a little further. The truth is that the provision of these nectar-glands on the foliage of plants, so far from being evidence of the plants' philanthropy, is like much that passes for the same virtue in our species—dictated by strict business considerations. Instead of causing a net drain upon the capital, it yields

BLUE VANDA (*Vanda cærulea*).

A representative of a genus of Indian and Malayan Orchids. The pale blue flowers are here represented little more than half the natural size, which is about five inches across. Ten or twelve of them are produced in a raceme on a stem two or three feet high. It is a native of Northern India and Burmah.

Photo by] [*E. Step.*

FIG. 520.—WOOD ANEMONE (*Anemone nemorosa*).

A beautiful woodland spring flower. Flowers and leaves arise separately from a woody underground creeping stem. It has no petals, but the sepals are coloured to take their place. Although providing no nectar, the flowers are visited by insects who assist in cross-pollination.

a handsome percentage of profit. In some strange way the plants have learned that much of the food of ants consists of other insects, and that it is good to be rooted within reasonable distance of a nest of ants; for the industrious and usually pugnacious little creatures climb trees and other plants in search of insects that are fretting the leaves, and if at the same time they can get a little of the sugar they so greatly desire, they will make a point of patrolling the plant that supplies it, and for their own ends keep it clear of insects other than their own domestic Aphides. We have mentioned several plants that produce these nectar-glands on the leaf-stalks or stipules; but it is stated that more than three thousand species are known to make this provision for their ant friends. Some of the Acacias not only make it worth the while of this patrol to remain on duty, but they provide sentry-boxes for their convenience. Instead of stipules, they produce a pair of large hollow spines in which a number of ants can be, *and are*, housed. They take care also to produce nectar, which is poured out by glands on the leaf-stalks, and some of them in addition bear queer little bodies, formed of albuminous matter, at the tips of the leaflets. These bodies are produced as food for the ants, and their removal does not injure the plant. In other lands cultivators, who are perhaps more observant than the same class in this country, have taken advantage of these facts for the protection of their fruit crops. The orange growers in the province of Canton, instead of depending on natural arrangements, collect ants' nests and connect them with their trees; and a similar practice is adopted by the fruit-growers in parts of Italy. (See Step's *Messmates: a Book of Strange Partnerships.*)

Photo by] [*E. Step.*

FIG. 521.—FIELD WOOD-RUSH (*Luzula campestris*).

A wind-fertilized plant, with grass-like leaves fringed with soft white hairs. The flowers in are cymes, mostly on slender, swaying branches.

That the quantity of nectar secreted by the flower varies greatly in different plants goes without the saying. While in some species the amount is so small as to be hardly discoverable, in others the blossoms literally flow with it. In the interesting Honey-flowers (*Melianthus*), a genus of strongly scented South African shrubs, the secretion is enormous. In *Melianthus major* an actual "rain of honey" pours from the cowl-shaped petals when the inflorescence is shaken. In the wonderful *Coryanthes*, a genus of tropical orchids, the nectareous fluid is secreted near the base of the stalk, and drips continuously into the helmet-shaped lip at the time of flowering. Upwards

Photo by] [*E. Step.*

FIG. 522.—LADY'S TRESSES (*Spiranthes autumnalis*).

A native Orchid of dry pastures and hillsides. The small fragrant white flowers are arranged in spiral rows upon the stem. The leaves appear in little rosettes after and apart from the flowering stem. EUROPE, NORTH AFRICA.

FIG. 523.—TWAYBLADE (*Listera ovata*).
(*a*) Labellum; (*n*) grooved nectary; (*s*) stigma; (*r*) rostellum; (*p*) pollinia.

of an ounce of the fluid has been found in one of these receptacles.

So much for Nectaries. We have now considered five of the means by which insects are attracted to flowers with a view to the transference of pollen, and only one remains to be spoken of. The five already treated are Conspicuousness, Odour, Irregularity, Honey-guides, and Nectar; the sixth is the fecundating dust itself.

In the majority of insect-pollinated flowers the pollen-grains are either rough or sticky, and thus are distinguished from the pollen-grains in wind-pollinated flowers, which are usually smooth. The reason of this is obvious. The rough and sticky kinds—"clinging pollen," as Kerner calls them—are adapted for clinging to insects visiting the flowers; the smooth kind—dusty pollen—is not less adapted for dispersion by the wind; for being easily taken up by the slightest breeze, and having no inequalities of surface, its resistance in passing through the air is of the slightest.

Few objects are so beautiful under the microscope as the pollen-grains of flowers. Not only do they vary greatly in their general forms, but their walls in many instances show the most exquisite sculpturing and patterns, which—if animals of the lower creation are as susceptible to beauty of form as man—must delight the eyes of the insects engaged in transporting the pollen from flower to flower. We may draw attention to an example here and there. Each spherical grain of the Passion-flower (*Passiflora*, fig. 494) looks under a strong magnifying power like a beautifully chased Indian bowl. In *Lapageria*, *Cucurbita* (the Gourd family, fig. 493), and not a few other plants, the spherical grains are covered with spines. In the Scots Pine (*Pinus sylvestris*, fig. 495) each grain is provided with a pair of bladder-like wings, which stand out from the grain like goggle-eyes. As the pollinating agent in this plant is the wind, the bladder-like structure is a most useful contrivance.

In a good many plants, as the Evening Primrose (*Œnothera biennis*, fig. 492), *Clarkia*, *Fuchsia*, etc., clinging pollen is strengthened by the presence of a sticky, structureless substance called *viscin*, which causes the grains to hang together in strings. The same substance appears to be the cementing vehicle in the majority of Orchids, where every pollen-sac (corresponding to an anther-lobe in ordinary flowers) contains an agglutinated club-shaped pollen-mass, known as a *pollinium*. The two pollinia commonly slope down to a little viscid gland or knob—the *rostellum*, which readily adheres to any object coming in contact with it, and which serves to mark the frontier between the solitary stamen * and the stigmatic surface below it.

In the Common Twayblade (*Listera ovata*, fig. 523) this organ is flat and scale-like, and arches over the stigmatic surface. "Sprengel has correctly described," says Hermann Müller, "how small insects regularly alight on the lower end of the labellum (*a*), and slowly creep upwards, licking the honey in the groove (*n*); when they have finished and raise their heads, they come in contact without fail with the slightly prominent edge of the rostellum (*r*). On the slightest touch, this exudes a small white drop of fluid, which reaches the apex of the pollinia (*p*), and hardening instantly, cements them to the object whose touch caused the exudation; and so in every flower which has not previously been visited, the insect visitor receives a new pair of pollinia. The insect flies away startled, and soon afterwards alights on the labellum of another flower, usually on another plant."

* Most species of Orchideæ are monandrous—*i.e.* have only one stamen in each flower; but a few species are diandrous.

Photo by] [*E. Step.*

FIG. 524.—BROAD-LEAVED HELLEBORINE (*Epipactis latifolia*).

A portion of the long raceme of this native Orchid. In this photograph the parts of the flower may be seen clearly. It is visited by wasps principally.

CHAPTER XIII

SOME PLANT MARRIAGES AND THE GUESTS THAT ASSIST AT THE FUNCTION

Rest, silver butterflies, your quivering wings;
Alight, ye beetles, from your airy rings;
Ye painted moths, your gold-eyed plumage furl,
Bow your wide horns, your spiral trunks uncurl;
Slide here, ye hornèd snails with varnished shells;
Ye bee-nymphs issue from your waxen cells!

ERASMUS DARWIN.

WE propose to speak in this chapter of a few of the contrivances by which the cross-fertilization of flowers is brought about; a subject to which a considerable portion of Chapters X, XI, and XII may be regarded as an introduction. A good deal was there said about the means by which insects are attracted to flowers—those baits provided by the flowers in the way of bright or dull colours, nectar, pollen, etc., which bees and moths, flies, butterflies, and beetles find so irresistible; but as to what takes place in the flower during and after visitation comparatively little has been said. In returning to the subject it is not our purpose to confine our remarks as heretofore to the part which *insects* play in this important work. We propose to consider also the labours of other pollinating agents in the animal world, as snails and birds; and after that to say something of the transference of pollen by those two inanimate carriers, wind and water.

FIG. 525.—BLUE PASSION-FLOWER (*Passiflora cœrulea*).

The crown is split up into narrow threads which are believed to be of service in detaining small insects in the lowest chamber of the flower to encourage the visits of humming-birds, the chief pollinators of Passion-flowers.

It has been observed

Photo by] [*E. Step.*

FIG. 526.—HEMLOCK STORK'S-BILL (*Erodium cicutarium*).

The flowers are self-fertile. They open about 7 a.m., and by noon have shed their petals, so that as a rule the flowers can only be seen in the morning. The seeds are attached to long spirally twisted awns, which constitute a most efficient mechanism for sowing them. EUROPE, N. AFRICA, W. ASIA to N.W. INDIA.

Fig. 527.—Hemlock Stork's-bill (*Erodium cicutarium*).

With seven-spotted lady-bird clinging to a petal which its weight has dislodged.

by Dr. Ogle that in flowers which are cross-fertilized by insects, Nature does not hold out her baits one minute sooner than necessary. "The brilliancy, the scent, and the nectar are only furnished when the flower is ready for its guests and requires their presence; just as a thrifty housewife lights her candles when the first guest is at the door. The mature bud is furnished with no such attractions."

We have seen that Darwin's pronouncement that "Nature abhors self-fertilization," though not yet recognized (like Newton's law of gravitation or Boyle's law of the pressure of gases) as an established law of natural science, has yet some striking facts to support it; and more of these facts will come before us in the present chapter. We have seen, too, that the curious and often minute correlations in certain flowers are in view of their cross-pollination by insects; and that the parts of the flower which sustain the weights, strains, thrusts, etc., are admirably modified and strengthened, as though to facilitate and encourage the guests by whose visits the crossing is to be effected. Of this subject also the present chapter will furnish additional illustrations.

Yet it must not be thought that *all* cross-pollinated flowers are so careful of their guests. In some instances it is really surprising that the visitors remain at all, so little are they encouraged. Watching one day some seven-spotted ladybirds (*Coccinella septempunctata*) licking honey from the pretty rose-pink flowers of the Hemlock Stork's-bill (*Erodium cicutarium*), Hermann Müller met with an amusing illustration of this fact. While seated on a petal the insect would apply its mouth to one of the nectaries at the base; and then all at once the petal would break off, and either precipitate the beetle to the ground or leave it clinging to the next petal. "In the former case it would keep on its way round the flower, and perhaps pull off all five petals, one after another; but when it fell it was always at once on its legs again, running to another stalk of the same plant to climb up anew. I saw," adds this careful observer, "one beetle fall four times to the ground without growing wiser by experience" (fig. 527).

How irritating, again, must be the treatment offered to the gnat-pollinators of the Aristolochias, who (as we were seeing in another chapter) are held prisoners in the blossoms for a period not far short of sixty hours! Much the same sort of thing goes on in the flowers of the Indian stoveplant *Ceropegia elegans*, though in this case the insects (small flies) are not imprisoned for so long a time, and instead of getting dusted with pollen they leave the flower with the pollinia on their proboscides. In the Dutchman's Pipe (*Aristolochia sipho*), a native of North America, escape is prevented by the smoothness of the perianth-tube and its curvature at both ends, but when the midges have fulfilled their allotted task, the perianth withers and they are thus enabled to crawl out. Analogous devices are not unknown even among our commoner British plants. The Cuckoo-pint (*Arum maculatum*) is certainly guilty in this respect. The construction of the flower-clusters—whose prisoner guests are those tiny moth-like flies, the Psychodæ—has been briefly explained in Chapter X. The flies pass in by the wide entrance formed by the upper part of the spathe and descend to the lower chamber, which becomes their prison. A number of reflexed hairs (rudimentary flowers) encircle the spadix in the upper part of the chamber, forming a palisade, which, though not preventing ingress, cannot be repassed by insects within the chamber, who are bewildered by the sloping rigid bars when they try to fly towards the light. Below the hairs is a closely packed ring of male flowers, and lower still, at the very base of the spadix, a surrounding cluster of female flowers. These mature first, and announce the fact to the Psychodæ by emitting a foul ammoniacal odour,

Photo by] [*E. Step.*

FIG. 528.—NETTLE-LEAVED BELLFLOWER (*Campanula trachelium*).

The flowers are specially adapted for the visits of bees. Nectar is provided at the base of the pistil, and covered by the expanded bases of the stamens.

which is very attractive to those insects. They flock to the banqueting-house in great numbers, and if they have brought pollen from other arums, pollinate the stigmas, which thereupon wither. The little visitors at the same time receive payment for their services in nectar, of which each stigma yields a single drop. Afterwards the anthers shed their pollen, which falls upon the chamber floor, and the flies get well dusted. Their services being now required by the plant no longer, the palisade of hairs shrivels up, and the prisoners are set free.

Photo by] [*E. Step.*

FIG. 529.—BUTTERFLY ORCHIS (*Habenaria bifolia*).

The greenish-white flowers are specially adapted for pollination by moths, and are very fragrant at night, when they show up conspicuously.

The imprisonment of *bidden* guests is not however a frequent occurrence among plants. It is by no means a usual thing for the front door to be locked on a visitor when he enters a flower. Nevertheless, the treatment which these unconscious benefactors receive is often sufficiently rough and unhandsome; and perhaps no plants are greater offenders in this respect than those rajahs of the Vegetable World, the Orchids, to which we shall refer again shortly. For the present let us examine one or two of our common flowers, in which the contrivances for securing cross-fertilization, though exceedingly curious, are simpler than those of the flowers named.

We may start with what has been aptly called the *brush and piston mechanism* of the cultivated Pea (*Pisum sativum*), which supplies a type rather common, though with varying modifications, among papilionaceous

Photo by] [*E. Step.*

FIG. 530.—SPOTTED ORCHIS (*Orchis maculata*).

The pale purple or white flowers are spotted and streaked with purple as guides to insects, though no nectar is provided. It is believed that the insects suck sweet moisture from the tissues of the hollow spur. The plant to the left of the photo is the Twayblade. The Spotted Orchis is native in EUROPE, N. ASIA, and the HIMALAYA.

Photo by] [*E. Step.*

FIG. 531.—NEEDLE WHIN (*Genista anglica*).

One of the Pea-flower tribe. The flowers do not open unless visited by insects, when the insect's weight causes the flower to explode, as it were, and cover it with a shower of pollen.

flowers. In Chapter X we described the several parts of a flower of the Pea, and showed the adaptation of those parts to its chief pollinators—bees. We saw that the stamens and pistil are contained in the keel or carina of the blossom, those two cohering petals which protect the anthers from pollen-feeding insects, and that the alæ or wings—*i.e.* the two lateral petals—afford a platform for the bee guest, as well as serve as a lever to depress the keel. The last fact is of much importance owing to the effect attending such depression—an effect which will be explained in a moment.

We will suppose that fig. 497 represents a pea-blossom which is about to be visited by a bee. The flower is giving forth its seductive odour; the bright standard is fully spread; a supply of nectar has flowed into the staminal tube; and the anthers have discharged their moist, sticky pollen into the conical part of the keel, thereby covering the tiny brush with which the end of the unripe style is provided. All is ready. Presently the bee alights; and as its weight falls upon the wings of the flower the keel is depressed. At once the piston mechanism comes into play, for the style, being a fixture, does not yield to the depression, and so the pollen-laden style-brush is thrust through the apical hole of the keel. Here it comes in contact with the breast of the bee, which gets plentifully smeared with the pollen. When the insect has sipped its fill of nectar, it flies off to another and perhaps older flower, the stigma of which is mature and pretty sure to receive some of the pollen from the last flower. Thus cross-pollination is effected.

What is known as *percussive mechanism* is admirably illustrated in the Salvias, that genus of labiate flowers to which belongs the Common Sage (*Salvia officinalis*) of our gardens. The remarkable feature in this form of mechanism is the *rocking part of the stamens*, which, as we saw when speaking of the male organs of plants, is a specialized form of the connective. The connective is, in fact, a curved bar attached to the filament of the stamen by a movable joint, and running transversely to it. The upper part of this curved bar is the longer and bears the anther (fig. 501); while the stubby lower part has no anther and is finished off with a knob. The flowers are diandrous and the stamens are so close together that the knobs, which stand just in the open jaws of the corolla, almost touch. Tucked away in the upper hooded portion of the corolla is the style; but its forked stigma is closed during the first stage of the flower, its services not being required till later. The nectaries are situated deep down in the tube of the corolla, near the ovary, so that when a bee alights on the landing-stage it must push its head right into the jaws of the flower before it can get at the nectar. Here the knobs of the two connectives block the way, and both of these knobs get struck by the bee's head. This is the act of percussion which puts the machinery in motion. Instantly the connectives swing round on their hinges, and the pollen-bearing anther-lobes are brought down upon the bee's back, besprinkling it with the yellow dust. Should the next flower visited be in the female stage, the pistil will present a different appearance from that described

Photo by] [*E. Step.*

FIG. 532.—SPOTTED ORCHIS.

The flower-spike is here shown of the natural size. See also fig. 530, page 427.

above. No longer tucked away out of sight under the hood, the style will have elongated and curved over, and the two forks of the stigma will have opened wide, and be hanging just at the suitable height for picking off the pollen from the bee's back. Clearly the old game of quintain, so great a favourite with our forefathers, is not yet obsolete!

Irritability in the organs of flowers, particularly in the essential organs (stamens and pistil), is almost always due to mechanical contrivances and connected with cross-fertilization. Witness the irritable stamens of the Common Barberry (*Berberis vulgaris*, fig. 502), which spring up and scatter their pollen on the head of the bee as it thrusts its proboscis into the nectar. Witness, too, the yet more remarkable stamens of the American Laurel (*Kalmia latifolia*), a flower the pollination of which has been very fully described by Professor Beal, of Michigan. In this case the anthers are forcibly held down in the saucer-shaped corolla by means of little pockets, the filaments being thus bent back and transformed into so many springs. "It is interesting to watch the operations of a humble-bee upon the flowers," says another American observer, Professor Asa Gray. "The bee, remaining on the wing, circles for a moment over each flower, thrusting its proboscis all round the ovary at the bottom; in doing this it jostles and lets off the springs, and receives upon the under side of its body and its legs successive charges of pollen. Flying to another blossom, it brings its pollen-dusted body against the stigma, and commonly revolving on it as if on a pivot while it sucks the nectar in the bottom of the flower-cap, liberates the ten bowed stamens, and receives fresh charges of pollen from that flower while fertilizing it with the preceding one." If flowers of Kalmia are protected from insects (the experiment was tried by Mr. Beal with coverings of fine gauze), they wither, drop off, and set no seed; the reason being that no stamen gets liberated of itself while fit for action (figs. 503, 504).

FIG. 533.—SPOTTED ORCHIS.

A flower, partly in section, visited by bee. In pushing its tongue down the spur, its head comes in contact with the pollen-masses and brings them away, as shown below.

A curious method of clamping the pollen-masses (pollinia) of flowers to the feet of insects is to be noticed in the Asclepiads, and has been distinguished as *clip mechanism*. In *Asclepias cornuti*, for example, the connective of each pair of pollinia is a hard substance "capable of holding

Photo by]] [*E. Step*.

FIG. 534.—GOODYER'S ORCHIS (*Goodyera repens*).

A rare plant of northern Pinewoods, superficially resembling Lady's-tresses, though actually very different. EUROPE, SIBERIA, HIMALAYA, NORTH AMERICA.

Photo by] [*E. Step.*

FIG. 535.—DWARF ORCHIS (*Orchis ustulata*).

A diminute species of dry pastures and downs. The flowers are only a third of an inch in their longest measurement. The arrangements of the flower are similar to those of the Spotted Orchis.

any small delicate object by gripping it like a clip" (fig. 506); and these clips are so disposed in the flower that when an insect visits it for nectar a foot is pretty sure to get caught by one of them. On trying to free itself the insect brings away the pollinia, which then, by a remarkable twisting of the ligulate strands which connect them with the clip, are brought close together. This facilitates their insertion by the insect in the stigmatic chamber of a new flower, where, by a breaking of the strands, the leg and its burden part company. The clips, however, remain attached to the insect; and wasps and flies have been caught with as many as eight of these vegetable pincers fastened to a single foot.

The Brazilian Asclepiad, *Araujia albens* (*Physianthus albens* of gardeners) has acquired an evil reputation outside its own country and been nicknamed the "cruel plant," for causes connected with its floral mechanism. In Brazil the cross-pollination of its tubular flowers is effected chiefly by humble-bees, which find no difficulty in pulling themselves free when their feet get caught in the slit-like notches that guard the way to the pollinia; and thus the pollen-masses get carried off to new flowers. In other parts, however, as Michigan, Italy, and the Orange Free State, the plant is visited in large numbers by moths, whose complete ignorance of the mechanism of the flowers becomes their ruin. Thrusting their probosces in the slits to get at the nectar, they are held fast, and all their struggles to liberate themselves only fix them tighter. With their heads in the tubes of the corollas, and their bodies and wings projecting, they die a lingering death.

We come now to the Orchids. The parts of an Orchid flower have been described in the previous chapter, where also the pollination of a British orchid, the Common Twayblade (*Listera ovata*), is briefly described. Perhaps it will not be taken amiss if, before going farther afield, we direct attention to another British species—the Spotted Orchis (*Orchis maculata*)—the pollination of which differs from that of the Twayblade in some important particulars.

Photo by] [*E. Step.*

FIG. 536.—GREEN-MAN ORCHIS (*Aceras anthropophora*).

The divisions of the long lip are supposed to represent the human figure, the arched sepals forming the head. The arrangements are much like those of the Purple Orchis.

It will be seen (fig. 533) that the sepals and two upper petals of this flower arch over the pollinia and rostellum, and that the inferior petal or lip affords an excellent landing-stage for visitors. This petal is prolonged backwards into a hollow spur, which takes the place of a nectary; for though it secretes no free honey, its delicate and succulent tissue is much prized by flies and bees. The pouched rostellum, which contains a brownish and viscid matter, projects into the mouth of the spur and also overhangs the two stigmatic surfaces; while the only perfect anther (the others are mere rudiments) stands immediately above it. Now, an insect visiting the flower and dipping its head into the spur, necessarily strikes against the rostellum. In so doing the pouch gets ruptured, and as the ruptured membrane curls back, it brings into view two viscid discs or balls in close connection with the caudicles (stalks) of the pollinia. These instantly adhere to the intruding object, and when the insect withdraws its head, the two pollinia are seen to be sticking up upon it like a pair of clubbed horns. Moreover, the cement, which has remained viscid under its membranous covering perhaps for many hours, now hardens with great rapidity—a wonderful and indispensable provision, for were the pollinia to fall sideways or backwards, their usefulness for purposes of cross-fertilization would be at an end. Nevertheless, at their present angle they are equally useless, for, on visiting another flower, what can happen but that the insect will push them back into their old position? This danger is obviated by a beautiful contrivance, which Darwin thus explains: "Though the viscid surface remains immovably affixed, the apparently insignificant and minute disc of membrane to which the caudicle adheres is endowed with a remarkable power of contraction . . . which causes the pollinium to sweep through about ninety degrees, always in one direction—viz., towards the apex of the proboscis—in the course on an average of thirty seconds. . . . Now, after this movement and interval of time (which would allow the insect to fly to another flower) . . . the thick end of the pollinium is exactly in position to strike the stigmatic surface." Surely if evidence were wanted for the argument of Design in Nature, you have it here! We may add that Darwin is speaking of the Purple Orchis (*O. mascula*); but his remarks apply equally to the Spotted Orchis.* The plants are closely related, and the manner of their pollination is the same in all essentials; indeed, throughout the genus *Orchis*, but little variation of the organs will be found.

Photo by] [*E. Step.*

FIG. 537.—PURPLE ORCHIS (*Orchis mascula*).

An early spring Orchis with red-purple flowers whose arrangements for pollination are very similar to those of the Spotted Orchis.

The genus *Orchis* is not the only group of orchideous plants containing species which are unprovided with true nectaries. The wonderful *Catasetum*

* Indeed, to two other British Orchids—viz., the Green-winged Orchis (*O. morio*) and the Marsh Orchis (*O. latifolia*).

FIG. 538.—FRAGRANT ORCHIS (*Habenaria conopsea*).

A plant of the downs and dry pastures, with a spike of very fragrant bright rose-red or purple flowers, which have a long and slender spur. The spur is half filled with nectar and specially adapted to the long tongues of butterflies and moths. The latter appear to be attracted chiefly to the form with white flowers. EUROPE, N. and W. ASIA.

tridentatum and its female, the *Monachanthus*,* are further examples (fig. 507). The cup or *labellum*—which in other species is usually the nectar receptacle—is singularly inverted in the varieties specified, and thus is altogether precluded from fulfilling that purpose. Yet, since the sexes stand on separate plants, insects must be attracted to the flowers in order to secure pollination; and insects, like beings of a higher order, will not work except for reward. Darwin was the first to point out that the labellum itself, which in these varieties is thick and fleshy and of "a pleasant nutritious taste," probably affords food to its insect visitors, and thus answers the purpose of nectar, just as do the tubes in *Orchis maculata* and *O. mascula*. His surmises have been abundantly verified.

Photo by] [*E. Step.*

FIG. 539.—GREEN-WINGED ORCHIS (*Orchis morio*).

A plant frequently mistaken for the Purple Orchis, but distinguished at a glance by the parallel green lines along the sepals, and absence of purple spots from the leaves.

Darwin regarded the genus *Catasetum* as "the most remarkable of all Orchids." They possess the extraordinary power of forcibly expelling their pollinia when a certain part of the flower—the horns or *antennæ* of the column (fig. 508, *an*)—is touched; and therein lies their extraordinary interest. Observe how the band or pedicel of the pollinium (*b*), which connects the disc (*d*) with the pollen-masses (*p*), is curved about the projecting rostellum. This pedicel is in a high state of tension. When either of the taper-

* So dissimilar is the female flower of *Catasetum tridentatum* from the male that it was long regarded as belonging to a distinct genus, *Monachanthus*, and styled *M. viridis*. Singularly enough, *C. tridentatum* also bears hermaphrodite flowers, which differ no less in appearance from the male and female forms than do those from one another. Hence the plants producing them were classed with a third genus, *Myanthus*, under the specific name *barbatus*. But a plant was discovered bearing flowers of the three supposed genera on one spike, and so the true state of things was recognised, and revision of names made accordingly.

ing sensitive projections or antennæ is touched (and bees visiting the flower to gnaw at the labellum inevitably come in contact with it), "the edges of the upper membrane of the disc," says Darwin, "which are continuously united to the surrounding surface, instantaneously rupture, and the disc is set free. The highly elastic pedicel then instantly flirts the heavy disc out of the stigmatic chamber with such force that the whole pollinium is ejected, bringing away with it the two balls of pollen, and tearing the loosely attached spike-like anther from the top of the column (fig. 509). The pollinium is always ejected with its viscid disc foremost."

Photo by] [*E. Step.*

FIG. 540.—BIRD'S-NEST ORCHIS (*Neottia nidus-avis*).

An Orchis without leaves and with yellow-brown flowers. The roots take the form of a mass of thick fibres whose interlacing is supposed to look like a bird's nest.

The force of the discharge will sometimes send the pollinium a distance of two or three feet. One of the attendants at Kew Gardens told the writer that he was once severely rated by a lady who had been struck in the face by the pollinium of *Catasetum saccatum*, and had come to him with the disc yet sticking to her cheek! Such experiences are not uncommon. Lord Avebury saw a flower of *Catasetum callosum* precipitate its pollinium a distance of three feet, when it hit a pane of glass and adhered to it. "From the large size of the flower, more especially of the viscid disc, and from its wonderful power of adhesion," says Darwin, "we may safely infer that the flowers are visited by large insects. The viscid matter sticks so firmly when it sets hard, and the pedicel is so strong (though very thin and only one-twentieth of an inch in breadth at the hinge) that to my surprise it supported for a few seconds a weight of 1,262 grains—that is, nearly three ounces; and it supported for a considerable time a slightly less weight." Needless to say, no effort which an insect thus encumbered could exert would remove the disc and pedicel; "but the caudicles are ruptured without much difficulty, and thus the balls of pollen would be left on the viscid stigmatic surface of a female flower."

In striking contrast to the Catasetums are those Orchids which secrete great quantities of nectar, like *Coryanthes*. The sweet fluid secreted by the strange-looking horns of *Coryanthes macrantha*, for example, drips so plenteously into the bucket-shaped portion of the labellum at the period of flowering that it half fills the bucket—indeed, would *quite* fill it, were it not that the receptacle is provided with an overflow spout! Above the bucket is a hollow chamber, walled and ceiled with fleshy ridges and provided with two side entrances. "The most ingenious man," says Darwin, "if he had not witnessed what takes place, would never have imagined what purpose all these parts serve. But Dr. Crüger saw crowds of large humble-bees visiting the gigantic flowers of this orchid—not in order to suck nectar, but to gnaw off the ridges within the chamber above the bucket; in doing this they frequently pushed each other into the bucket, and their wings being thus wetted, they could not fly away, but were compelled to crawl out through a passage formed by the spout or overflow. Dr. Crüger saw a continual procession of bees thus crawling out of their involuntary bath. The passage is narrow, and is roofed over by a column, so that a bee, in forcing its way out, first rubs its back against the viscid stigma, and then against the viscid glands of the pollen-masses. The pollen-masses are thus glued to the back of the bee which first happens to crawl out through the passage of a lately expanded flower, and are thus carried away. When the bee, thus provided, flies to another flower, or to the same flower a second time, and

Photo by] [*E. Step.*

FIG. 541.—PYRAMIDAL ORCHIS (*Orchis pyramidalis*).

Somewhat like the Fragrant Orchis, but with larger flowers. The flower-spike is at first pyramidal. The long spur contains no nectar, and visiting insects have to suck at the lining membrane.

Photo by] [*J. G. Tulett.*

FIG. 542.—YUCCA PLANT (*Yucca gloriosa*).

The fertilization of the Yucca—fully described in the following pages—is one of the wonders of plant life.

is pushed by its comrades into the bucket, and then crawls out by the passage, the pollen-mass necessarily first comes into contact with the viscid stigma, and adheres to it, and the flower is fertilized. Now at last we see the full use of every part of the flower—of the water-secreting horns, of the bucket half full of water, which prevents the bees from flying away, and forces them to fall out through the spout, and rub against the properly placed viscid pollen-masses and the viscid stigma."

Photo by] [*E. Step.*

FIG. 543.—MUSK ORCHIS (*Herminium monorchis*).

A little-known Orchid with green flowers, which secrete no nectar—it has no spur—but gives off the odour of musk in the evening for the attraction of small beetles.

A gardener of long experience in Orchid culture informs us that *Stanhopea haseloffi*, which belongs to an allied genus, is cross-pollinated in the same way as *Coryanthes*, save that the half-drowned bees *fall out* of the bucket, and strike against the pollinium in falling.

The subject of insect-pollination is inexhaustible, yet even the slightest sketch would be inadequate that failed to contain some reference to the fertilization of the Yucca-plant. It is nearly forty years since Professor C. V. Riley, of Missouri, first announced the method of pollination of the Yuccas by a little white moth, which he christened *Pronuba yuccasella*. Since that time much has been written on the subject, and in 1892 Dr. Riley published a valuable monograph on Yucca pollination, from which we have gleaned most of the particulars given below. The monograph, which extends to sixty large octavo pages, and is fully illustrated, is included in the third annual report of the Missouri Botanical Garden.

The Yuccas are a very interesting genus of plants of the lily family, comprising numerous species and even sub-genera, all characterized by anthers not reaching anywhere near the stigma; so that fertilization unaided can take place only by the merest accident. These plants, in fact, depend for their very existence on certain little white moths, belonging to the important group Tinæina, and to the genus *Pronuba.* Thus the Yuccas affords an instance—apparently the only known instance—of plants which are dependent on a single species for pollination.

FIG. 544.—MARSH-CALLA (*Calla palustris*).

A marsh snail is seen to be climbing the stem. Snails have been observed to pollinate the flowers.

The common Yuccas of the United States are forms of *Yucca filamentosa*, and their white-winged pollinator is the commoner Yucca moth, *Pronuba yuccasella* (fig. 512). During the daytime this moth, either singly or in pairs, may be found resting with folded wings within the half-closed flowers. After sundown it is to be seen flitting swiftly from plant to plant and flower to flower; the dusky nature of the hind wings and of the under surface of the front wings almost completely off-setting and neutralizing, when in motion, the upper silvery whiteness of the latter. This is the male insect. The female is busily at work most of the time in the flowers; for on her devolves a double duty, which leaves no leisure for these nocturnal flittings. As a part of the maternal task of continuing her race, she must act as foster-mother to the plant in order to ensure a proper supply of food to her larvæ, which, as we shall presently see, feed on its seeds. Her activity begins soon after dark, and consists at first in assiduously collecting a load of pollen. She may be seen running to the top of one of the stamens, and bending her head down over the anther, stretching her maxillary tentacles, which are wonderfully modified for the purpose, to the fullest extent; and using her palpi to scrape the pollen from the anthers towards the tentacles.

After gathering a sufficient supply, and shaping it into a pellet twice or thrice the size of her head, she sets off for another flower, leaving the despoiled blossom to be pollinated by some other individual of her race. On entering the new flower, she takes up a favourable position, and after resting motionless for a short time, plunges her lance-like ovipositor into the soft tissue of the pistil, and conducts her first egg to its destination. Mark what follows. No sooner is the ovipositor withdrawn than the moth runs up to the top of the pistil, thrusts the pollen into the stigmatic funnel, and

FIG. 545.—MARSH-CALLA (*Calla palustris*).

A single flower removed from the spadix and enlarged.

rams it down effectually with a to-and-fro motion of her head. If, as is commonly the case, another egg is deposited in the same pistil, and after that a third, each act of oviposition is succeeded by a fresh act of pollination; but on each occasion a different notch of the style is selected, and thus a supply is ensured for the ovules in each carpel. How perfectly the insect does its work may be gathered from the fact that artificial attempts to cross-fertilize the Yuccas by means of brush-pollination are rarely, if ever, successful.

The larva hatches in about a week, and at first appears to live on the degenerate and swollen ovules: but finally it enters one that is developing. In this state it undergoes three different moults, its colour meanwhile changing from a translucent white to a rosy hue; and with the ripening of the seeds, the larva attains its maturity. Just about the time the fruits are hardening and ready to dehisce, and the seeds are already coloured, the maggot bores a passage through the pod, makes its way to earth, and, tunnelling several inches below the surface, spins in its underground fastness a tough silken cocoon intermixed with the soil. In this condition it remains during the autumn, winter, and spring months, and only assumes the chrysalis state a few days before the blooming of the Yuccas. The chrysalis is armed with spines on the head and back, by means of which it works its way to the surface, and in due time issues forth a perfect insect; henceforth to live its little life above ground, and, in conjunction with some chosen companion of the other sex, to carry on the useful work which its parents have carried on before it.

FIG. 546.—BALSAM (*Impatiens*).

The flowers are adapted to the visits of humble-bees. At first the stamens mask the pistil and stand in the entrance to the flower. Later the pistil occupies this position and receives pollen brought from a younger flower.

Of animals outside the great class Insecta which aid in bringing the reproductive elements of plants together, the chief are snails and birds. Delpino, indeed, divides the plants fertilized by animals into three groups: I. *Ornithophilæ*, or bird-lovers; II. *Entomophilæ*, or insect-lovers; and III. *Malacophilæ*, or snail-lovers. Groups I. and III. remain to be spoken of.

The plants fertilized by the agency of snails are comparatively few in number. The Marsh-calla or Snake-root (*Calla palustris*, figs. 544, 545) may serve as an example; though its chief pollinators are carrion-loving flies, which are attracted to the flowers by their offensive smell. Pond-snails, however, crawl up the partially submerged stem to the spadix, receive pollen from the anthers of the lower ring of flowers, and, continuing their journey, pollinate the female flowers higher up.

Photo by] .[*F. C. Taylor.*

Fig. 547.—*Alocasia spectabilis.*

An herbaceous plant belonging to the extensive order Aroideæ. The large radical leaves of this plant are beautifully variegated. In one species the flowers have been observed to be pollinated by snails.

FIG. 548.—SECTION OF LAPAGERIA.
The nectary is at the base of the flower, that is, the upper part as it hangs.

In *Alocasia odora*, a plant belonging to the same order (*Aroideæ*), snails enter the spathe by a narrow opening, lose their way when inside, and in their purblind efforts to regain the entrance, dust themselves with pollen, which they convey to the stigmas of younger plants. Delpino was of opinion that the snails "are poisoned by an irritant secretion within the chamber of the spathe, and are so prevented from devouring the flowers" after cross-pollination has been effected. The same naturalist has recorded observations on the snail-pollination of *Rhodea japonica* and of *Cypripedium caudatum*, and states of the former that the flowers which proved fertile were always those over which snails had crawled.

Then as to birds. In tropical, and even in temperate America, sun-birds and humming-birds are the welcome guests of many flowers. "Chiefly in the months of July and August," says Waterton, "the tree called Bois Immortel, very common in Demerara, bears abundance of red blossom, which stays on the tree for some weeks; then it is that most of the species of humming-birds are very plentiful. The wild red Sage [? *Salvia coccinea*] is also their favourite shrub, and they buzz like bees round the blossoms of the Wallaba-tree [*Eperua falcata*]. Indeed, there is scarce a flower in the interior, or on the sea coast, but what receives frequent visits from one or other of the species."

It will be noticed that the plants named by Waterton in the above passage all bear *red* flowers; and many naturalists have pointed out that humming-birds appear to have a penchant for scarlet. Fortunately—both for visitors and visited, for bird guests and plant hosts—scarlet blossoms are plentiful in the primeval forests of Central America, where humming-birds chiefly have their home. In those densely vegetated regions may be seen the flaunting reds of the lianes and epiphytes of many widely differing genera, with the dazzling scarlets of Begonias and Fuchsias, of Sages and Lobelias, of Browneas and Erythrinas, the very construction of whose blossoms in not a few instances forbids their being rifled by insects. Numbers of such flowers take a lateral direction, and are unprovided with landing-stages; for humming-birds never alight when feeding, but sip the nectar as they hover with widespread wings at the mouths of the flowers. The absence of ridges, knobs, and fringes, which serve so useful a purpose in insect-pollinated flowers, is also to be remarked.

Darwin, in his *Cross and Self-fertilization of Plants*, gives an interesting summary of the cases of bird-pollination known to himself, which it will be useful to quote. "In South Brazil," he says, "humming-birds fertilize the various species of *Abutilon*, which are sterile without their aid. Long-beaked humming-birds visit the flowers of *Brugmansia*, whilst some of the short-beaked species often penetrate its large corolla in order to obtain the nectar in an illegitimate manner, in the same way as do bees in all parts of the world. It appears, indeed, that the beaks of humming-birds are specially adapted to the various kinds of flowers which they visit; on the Cordillera they suck the *Salviæ*, and lacerate the flowers of the *Tacsoniæ*; and in Nicaragua Mr. Belt saw them sucking the flowers of *Marcgravia* and *Erythrina*, and thus they carried pollen from flower to flower. In North America they are said to frequent the flowers of *Impatiens*. I may add that I often saw in Chili a Mimus with its head yellow with pollen from,

Photo by] [*E. Step.*

FIG. 549.—YARROW (*Achillea ptarmica*).

A small Composite that is specially attractive to the little bees of the genus Prosopis.

as I believe, a *Cassia*. I have been assured that at the Cape of Good Hope, *Strelitzia* is fertilized by the Nectarinidæ [the Sun-birds]. There can hardly be a doubt that many Australian flowers are fertilized by the many honey-sucking birds of that country. Mr. Wallace remarks that he has 'often observed the beaks and faces of the brush-tongued lories of the Moluccas covered with pollen.' In New Zealand, many specimens of the *Anthornis melanura* had their heads covered with pollen from the flowers of an endemic species of Fuchsia."

Photo by] [*E. Step.*

Fig. 550.—White Campion (*Lychnis vespertina*).

Its white flowers open in the evening, when it becomes sweet-scented for the attraction of night-flying moths. Nectar is secreted by the base of the ovary. In the daytime the flowers look faded or dead.

A later observer, Professor W. Trelease, of the Missouri Botanical Garden, gives a yet longer list, and states that an Alabama planter once laughingly said to him: "You'll have to note every conspicuous flower if you want a full list of those visited by the humming-birds." On several occasions the professor watched the ruby-throated humming-bird extracting nectar from the glands at the base of the involucre in cotton-flowers (*Gossypium*); and he found that humming-birds were largely—if not exclusively—used in the crossing of *Malvaviscus*, a scarlet-flowering genus of tropical shrubs.

The observations of a still younger botanist, Mr. William Sugden, of Michigan, are equally worthy of attention. Mr. Sugden tied bags over the flower-buds of *Impatiens fulva*, and also over flowers which had opened, but before the stamens (whose anthers in the first stage form a covering over the pistil) had disappeared. In neither case were good seeds produced, though artificial crossing under similar conditions was successful. Flowers of the same species, unconfined in this manner, but divested of their petals, set no seed whatever; and this was also the result

Photo by] [*E. Step.*

FIG. 551.—HEATHER OR LING (*Calluna vulgaris*).

The most conspicuous part of the flower is the rosy calyx, the corolla being quite small. The leaves are very minute and like overlapping scales. They are specially adapted to resist cold. EUROPE, W. SIBERIA, AZORES, GREENLAND, N. AMERICA.

even when the nectar-gland only was removed. Mr. Sugden noticed also that black bees, which visited the free and unmutilated flowers in large numbers, hardly ever touched an anther or pistil, so that they were of no use as pollinating agents. The visits of wild bees and the common honey-bee were equally profitless to the flowers; and even when a humble-bee hit pollen in its plunges to get at the nectar, it left the plant after trying a single flower. With humming-birds the case was quite different. Every time one of these little creatures thrust his arrowy beak into a flower of the first stage, his head would strike the anthers and become dusted with pollen. On visiting a flower in the second stage —*i.e.* after the withering of the crown of anthers—the bird's head would come in contact with the exposed stigma, with the inevitable result that some of the pollen would be left upon it.

Photo by] [*E. Step.*

FIG. 552.—ASPEN (*Populus tremula*).

The simple flowers are borne in long catkins, which appear before the leaves to allow pollination by the leaves. Those shown in the photo are the male catkins.

Of the plants which lay themselves out for cross-fertilization, but which do not invite the co-operation of small animals, some employ water as their agent, and others the wind. External aid for the purpose in question may therefore be of three kinds, and the plants which require those agencies to bring their reproductive elements together may be grouped under one or another of the following heads: *Zoöphilæ*, or animal-lovers; *Hydrophilæ*, or water-lovers; and *Anemophilæ*, or wind-lovers.

Wind- and water-pollinated plants are rigid economists, except in the matter of pollen. They have no attractive odours, no bright petals, no nectar. Birds and insects may be allured by these things, but not so wind

CERVANTES' ODONTOGLOT *(Odontoglossum cervantesii)*.

The Odontoglots are a beautiful genus of epiphytal Orchids inhabiting the tropical regions of America. Over a hundred species are known. Cervantes' Odontoglot is a native of Mexico. Each pseudo-bulb produces a single leaf and a spike of from three to five rosy-lilac flowers. Natural size.

and water, which, having no senses to be appealed to, would be unaffected by colour, sweets, or scent. Yet being wasteful carriers, these agents require abundance of pollen; and, if water is to be the vehicle of transmission, the pollen must be either lighter than the water or of like specific gravity; if wind be the agent, the pollen must be smooth, light, and incoherent. In the vast majority of cases these conditions are found to be wonderfully fulfilled.

Of hydrophilous plants some are adapted for fertilization under the water: and these are provided with a pollen of like specific gravity to the surrounding fluid; others are adapted for fertilization at the surface, and the pollen of these—unless borne upon a floating raft—is specifically lighter than the water. The Grass-wracks (*Zostera*) are remarkable for producing a pollen the grains of which do not, like the generality of pollen-grains, burst in water. Moreover, the grains assume the form of elongated cylindrical tubes on quitting the anthers, which greatly facilitates their conveyance through the water to the threadlike stigma of the flowers. Something almost analogous takes place in certain cryptogamic plants—notably the *Florideæ* or Red Seaweeds—where the male cells are neither motile nor provided with hairs, but are borne about passively by currents of water till they attach themselves to the slender projecting terminal cells of the female organs.

Photo by] [*E. Step.*

FIG. 553.—SCOTS PINE (*Pinus sylvestris*).

The male flowers are here shown spirally arranged in spikes and a large number of spikes forming a cluster. The female flowers are borne on the same tree, but on separate branches.

The Sea Ruppia or Tassel-grass (*R. maritima*), closely allied to *Zostera*, is a widely distributed plant adapted for pollination *on the surface* of water. At the period of maturity the submerged flower-stalk lengthens, and the plant lifts its head above the marsh or salt-pool which it inhabits. Lengthening continues until the object is attained, but thereupon ceases, no matter what the depth or shallowness of the water. The Rev. Gerard E. Smith, a botanist well acquainted with the plant, has thus sketched the process: "The anthers are vesicular and buoyant: as they swell and become mature, the membranous sheath enclosing them is distended, and the whole is brought to the surface of the water. The flower-stalks are rapidly lengthened, the flowers quit the sheath, which then becomes a bladder, and aids the elevation of the spike an inch above the water. Presently the anthers burst, the vesicle loses its buoyancy, and the flower-stalks, bearing the fertilized stigma, sinks within the bosom of the parent plant." It will be noticed that the flowers both of Tassel-grass and *Zostera* are small and inconspicuous, and possess neither calyx nor corolla. Large blossoms and bright colours would be useless to plants which depend on water for the distribution of their pollen, just as they are to the wind-pollinated forest trees.

Photo by] [*E. Step.*

FIG. 554.—SCOTS PINE (*Pinus sylvestris*).

The female flowers are seen at the tips of the shoots. The cones are soon formed, but the seeds do not ripen until the second year.

Doubtless the most curious of hydrophilous plants is the Italian Eel-grass (*Vallisneria spiralis*), which is also one of the greatest marvels of the vegetable world. It is distributed throughout Southern Europe, and grows in still water. Our illustration (fig. 515) shows both the male and female plants, with their strap-shaped leaves and flowers in various stages; the male plant is on the right, the female on the left. The pistillate (*i.e.* female)

Photo by] [*E. Step.*

FIG. 555.—AUSTRIAN PINE (*Pinus laricio*).

The male flowers are here seen arranged after the same manner as in the Scots Pine, but they are much larger. Both species produce an enormous quantity of pollen, most of which is blown away on the wind without coming into contact with the female flowers.

flowers are borne on long stalks (fig. 517, *a*), each of which, whilst the stigmas are maturing, is enveloped in a kind of bladder. The staminal flowers are similarly invested, but they grow in thick clusters, and one sheaf suffices for all the individuals of a cluster. Each of these male inflorescences is borne on a short rachis (fig. 517, *b*, *c*), which remains short to the end of the chapter; but at a certain stage the pedicels of the female flowers lengthen to an extraordinary extent, and presently reach the surface of the water. The floral sheaths in the plants of both sexes meanwhile fall apart, and everything betokens readiness for nuptial celebrations.

But now an interesting problem arises. While the female flowers, held by their thread-like pedicels, are floating restfully on the bosom of the water, the male flowers are anchored far down below by their diminutive stalks to the short axes. How are the sexes to be brought together? The problem is solved in a very wonderful, and, at the same time, a very simple manner. The submerged male flower-buds detach themselves spontaneously from their axes, and, being lighter than the water, ascend to the surface. Here they drift about for a while; then open, and, twisting back their three sepals in an ingenious manner, so as to make a float, bring into view the two perfect stamens, which now stand well out of the water like a pair of snail's horns. These miniature floats, as Kerner beautifully remarks, "are blown hither and thither by the wind, and accumulate in the neighbourhood of fixed

Photo by] [*E. Step.*

FIG. 556.—OAK (*Quercus robur*).

These are the male flowers in long, loose catkins. The female flowers—borne by the same tree—are like little buds, and not so noticeable.

bodies, especially in their recesses, where they rest like ships in harbour. When the little craft happens to get stranded in the recesses of a female Vallisneria flower, they adhere to the trilobed stigma, and some of the pollen-cells are sure to be left sticking to the fringes on the margins of the stigmatic surfaces." Pollination having been thus effected, the pedicel of the fertilized flower contracts spirally and the ovary descends to the bottom of the water to perfect its seeds.

Photo by] [*E. Step.*

FIG. 557.—COTTON-GRASS (*Eriophorum polystachion*).

The Cotton-grasses are Sedge-like plants that cover vast areas of boggy moorland. The "cotton" really consists of delicate bristles which represent the petals of other flowers.

We come now to the anemophilous or wind-pollinated plants. Most of our forest trees, and the grasses, are examples of this group. Wind is far more extensively employed as a pollen-carrier than water, but is not so busy an agent as insects. Flowers which lay themselves out for wind-pollination are characterized by abundance of smooth and dusty pollen; by stigmas specially adapted for catching and retaining it; and, as we have seen, by an absence of bright-coloured floral envelopes, perfumes, and honey. "The amount of pollen produced by anemophilous plants," says Darwin, "and the distance to which it is often transported by the wind are both surprisingly great. Mr. Hassal found that the weight of pollen produced by a single plant of the Bulrush (*Typha*) was 144 grains. Bucketfuls of pollen, chiefly of *Coniferæ* and *Gramineæ*, have been swept off the decks of vessels near

FIG. 558.—POLLEN-GRAINS OF GREAT PANICLED SEDGE (*Carex paniculata*).

the North American shore; and Mr. Riley has seen the ground near St. Louis, in Missouri, covered with pollen, as if sprinkled with sulphur; and there was good reason to believe that this had been transported from the pine-forests at least 400 miles to the south. Kerner has seen the snow-fields on the higher Alps similarly dusted; and Mr. Blackley found numerous pollen-grains, in one instance 1,200, adhering to sticky slides, which were sent up to a height of from 500 to 1,000 feet by means of a kite, and then uncovered by a special mechanism." A shower of pollen which fell in Inverness-shire in the year 1858 (our authority is Professor Ainsworth Davis) covered the ground to a depth of half an inch.

Of the three great classes into which the Flowering Plants are divided—namely, Monocotyledons, Dicotyledons, and Gymnosperms—one class, the last named, is entirely composed of wind-pollinated plants. The Gymnosperms derive their names from the fact that their ovules are not contained in an ovary—they are naked. The flowers, which are unisexual and without calyx or corolla, would stand but a poor chance of perfecting their seeds were it not for the kindly offices of the wind.

The Scots Pine (*Pinus sylvestris*) offers a good example of the wind-pollinated gymnosperm. Its inflorescences are cones, the male cones, which grow in clusters, being much smaller than the female. In the month of June the anthers open, and discharge their *winged* pollen, which is furnished with microscopic air-bladders (fig. 495), into the grooved backs of the membranous anther-scales, where it lies ready for the breeze to scatter it. Meanwhile the female cones get ready for the "sulphur shower," and being unprovided with any stigma or subsidiary stigmatic appendage, the naked ovules exude a viscid substance which holds fast the pollen that falls in their way, and which, as it dries up, draws the pollen through the micropyle into the interior of the ovule. The fertilized ovules do not arrive at maturity—that is, become ripe seeds—for two years; and hence every female cone may be said to have three periods, which correspond with three distinct stages in the development of the inflorescence. In the first period the cone is green and small, and is seated on one of the very young shoots; in the second period (*i.e.* at the beginning of the second year) the cone is larger, but still green, and of course the shoot has become older; in the third period—the cone being now two years older—the scales have become brown and woody, and the seeds are ripe.

FIG. 559.—POLLEN-GRAIN MAGNIFIED,

Showing the intine bursting through the extine as the pollen-tube.

Among the Angiosperms (Dicotyledons and Monocotyledons) the contrivances for

Photo by] [*E. Step.*

Fig. 560.—Great Water Dock (*Rumex hydrola-pathum*).

The largest of our species of Docks, growing by river-sides and attaining a height of five or six feet. The wind-pollinated flowers are minute, but conspicuous by being combined in large panicles, which give it a very handsome and striking appearance. Its distribution is restricted to Europe.

wind-pollination are more elaborate than among the Gymnosperms. "The anemophilous angiosperms," says Hermann Müller, "have for the most part enormously developed stigmas, which project in the form of long tails, brushes, laminæ, or discs; their male flowers are very seldom immovable, but are generally easily shaken by the wind, either the axis of the male inflorescence or the peduncle of the male flowers, or the filaments themselves, being long and pendulous; in some cases the stamens are explosive, and project all the pollen into the air."

We may take as our first example the flowers of the Hazel (*Corylus avellana*). Most people are familiar with the long pendulous "lambs' tails," as the children call them, which make their appearance on the Hazel in the autumn, and which, in the South of England, open in January or February. These are the male inflorescences or catkins* (fig. 519). The female inflorescences are the small cone-like growths (*strobiles*), sometimes rather loosely described as "female catkins," which appear in the axils of the new shoots. The tiny groups of crimson threads projecting from the tops of the strobiles are bunches of forked stigmas. The anthers open while the hazels are still bare of leaf, and roll out their pollen into the trough-like depressions of the flower's scaly bracts, which retain it "until the tassels are set swinging by a gust of wind." Then the yellow dust, with no foliage to impede it, is blown hither and thither, and the stigmas of a great number of female flowers are sure to get pollinated.

Photo by] [*E. Step.*

FIG. 561.—HAZEL (*Corylus avellana*).

Abnormal male flowers. A single catkin has branched at half an inch from its origin and ends in a bunch of twenty-five short catkins. Natural size.

That *pendulous flowers*, no less than pendulous inflorescences, should facilitate the scattering of pollen by the wind goes without the saying. Many species of *Rumex*, the genus to which our Broad-leaved Dock and Sheep's-

* The more technical name for a catkin is an *amentum*.

sorrel (*R. obtusifolius* and *acetosa*) belong, are of this kind, and are anemophilous. In the Alpine Dock (*R. alpinus*) and the Garden Sorrel (*R. scutatus*), the anthers are pendulous at the ends of the delicate filaments, and the pollen-dust is shaken out of them in the lightest breeze.

Most of the Sorrels, however, and with them the Grasses, Sedges, Rushes, and Wild Plantains, are embraced under a far more common variety of anemophilous flowers—namely, *the forms with long stamens*. In the Rye-plant (*Secale cereale*), for instance, the essential organs protrude freely from the widely expanded flowers, and cross-pollination is effected on a large scale by the wind. Delpino has some interesting observations on the Ribwort Plantain (*Plantago lanceolata*) which seem to show that the flowers of this species are in process of development from an anemophilous to an entomophilous form. He says: "One form, with a strong and very tall scape, and very broad white anthers which quiver in the wind, grows in meadows and is exclusively anemo-

Photo by] [*E. Step.*

FIG. 562.—LARGE PLANTAIN (*Plantago major*).

An abnormal form with the flower-spikes bearing numerous large bracts with purple edges. The form is constant, being reproduced true from seeds.

philous, for I have never seen it visited by insects. The second form grows on the hills, and has a much shorter scape; it also is essentially anemophilous. I once saw a species of *Halictus* on a spike, trying to get pollen; but the structure of the flower is so unfitted for pollen-collecting, that great part of the pollen fell to the ground without benefiting either the plant or the insect. Finally, the third form is dwarfish and confined to the mountains; it has the shortest spike and filaments; on meadows in the Apennines at Chiavari I have seen bees in numbers flying from one flower to another of this variety, collecting the pollen and performing cross-fertilization.

Photo by] [*E. Step.*

FIG. 563.—COMMON SORREL (*Rumex acetosa*).

A common plant formerly used as a salad and pot-herb: its juices abounding in oxalate of potash. The sexes are on separate plants, and the pollen is carried by the wind.

"This, therefore, is a form of *Plantago* which hangs between the anemophilous and entomophilous conditions, and is capable of being fertilized equally well by the wind and by the bees. If the filaments became stiff and coloured, and the pollen-grains adhesive, while the anthers lost their peculiar quivering, we should have before us the passage from anemophilous characters, the evolution of an entomophilous from an anemophilous species.

"This hypothetical transition has actually occurred. *Plantago media* is a form that has become entomophilous; the filaments have become pink, the anthers are motionless, the pollen-grains have become more

Photo by] [*E. Step.*

Fig. 564.—False Cyperus (*Carex pseudocyperus*).

One of the finest of our Sedges, growing to a height of about three feet. The stems are three-sided, with rough edges. The spikelets take the form of long drooping catkins, two to three inches long. The male spikelets are solitary; the females in clusters of four or five. Wind-pollinated. TEMPERATE REGIONS GENERALLY.

Photo by] [*E. Step.*

FIG. 565.—WOOD SAGE (*Teucrium scorodonia*).

The pale ochreous flowers are much visited by bees. The purplish stamens after shedding their pollen bend back to allow the pistil to occupy their former position.

aggregated, and it is visited regularly by *Bombus terrestris*, as I have observed at the same spot (Chiavari) in the Apennines."

Explosive forms of anemophilous flowers are met with in the Nettle family (Urticaceæ) and a few other species. The Great Nettle (*U. dioica*, fig. 516) is an excellent example. Here the sexes are on different plants, and the flowers are small, green, and inconspicuous. While the male flower is unopened, the stamens, which are furnished with an elastic tissue, curve inwards; but as the flower matures, they gradually become dry, and, a result of this dryness, spring outwards, spurting the pollen into the air. In this way they assist the wind in disseminating the fecundating dust.

The Wall-pellitory (*Parietaria officinalis*), a common weed on old walls and in dry waste places, scatters its pollen in a similar manner. The coiled-up stamens are highly irritable, and at the proper time force asunder the segments of the calyx which hold them down and flirt out their pollen. It is a remarkable fact that, in the hermaphrodite flowers of this plant, the brush-shaped stigma of the pistil falls off before the anthers dehisce, and thus self-pollination is prevented.

Closely related to the Nettles and Wall-pellitory is the equally remarkable Artillery-plant (*Pilea microphylla*). This is a small plant, with leaves resembling those of Wild Thyme, and minute diœcious flowers, common enough in indoor ferneries. The English name refers to the copious discharge of pollen when the stamens straighten themselves—a phenomenon which may be artificially induced by sprinkling the plant with water. The anthers empty themselves instantaneously, the contents flying out like the puff of smoke from a distant gun.

The only other group of wind-pollinated plants which need be noticed here is that which comprises the *forms with immovable flowers.* In these it is usual to find that provision is made for temporary storage of the pollen *should no wind be stirring when the anthers dehisce.* For instance, in the Arrow-grass (*Triglochin palustre*) the pollen is rolled into the deep concavities of the perianth leaves; while in the Sea-buckthorn (*Hippophaë rhamnoides*) it is discharged into little bladders formed by the uniting concave scales in which the stamens lie. Let a warm dry wind spring up, and the bladders open by narrow chinks, and set free the pollen—which, however, can only escape a little at a time. The Broad-leaved Pond-weed (*Potamogeton natans*) is a good example of a wind-pollinated plant with immovable flowers.

Here our chapter must close, though not for lack of matter to carry us farther. The subject of the Pollination of Plants is inexhaustible, and must ever remain so; for, in pursuit of the study, we are brought again and again—as in the study of the *Life* of Plants—to the borders of the Unknown Land. Here it is that questions press upon us which, as Schleiden

Photo by] [*E. Step.*

Fig. 566.—Hornbeam (*Carpinus betulus*).

The male flowers are in pendulous catkins two inches in length. The female flowers form a large spike, which lengthens after fertilization to three or four inches, and becomes pendulous. Those shown are the male catkins.

finely remarks, we can neither repel nor answer. "What has the wind to do with the date-harvest of Bileduljerid, and with the sustenance of millions of men? What cares the gall-fly that on its activity depends the fig trade of Smyrna, and the food or support of thousands of human beings? Or does the beetle, whose theft facilitates the increase of the Kamschatkan Lily, imagine that their bulbs shall be the means to save the whole population of Greenland from starvation in the following hard winter? If

FIG. 567.—SWEET CHESTNUT (*Castanea sativa*).
The long catkin marked (*a*) consists of male flowers; those marked (*b*) are females.

all this is the result of unsubstantial natural laws, whence this wonderful interdependence and connection of subordinate forces, to bring to pass events which have so deep an influence on the history of humanity? We do, indeed, see into the mechanism of the puppet; but who holds the strings, and directs all its motions to *one purpose*? Here closes the office of the naturalist, and, instead of answering, he turns from the world of space and lifeless matter upward to where, in holy anticipation, we seek the Ruler of Worlds."

Photo by] [*Henry Irving.*

FIG. 568.—GRAPE VINE (*Vitis vinifera*).

A familiar cultivated plant that climbs by means of tendrils, and has inconspicuous flowers of peculiar form. The fruits are berries. Native of the Mediterranean region.

CHAPTER XIV

THE PROMISE OF THE PLANT THAT IS TO BE

. . . Fruit and seed,
New loosed from thorn-bush, tree, and flaunting weed,
And now by wing, or scale, or plume up-borne,
Fare forth on pilgrimage.

WHEN water, wind, or animal (or, it may be, the unaided plant) has fulfilled its function as an agent of pollination, the true process of *fertilization* begins. The outcome of fertilization is the *fruit.*

In popular language the term "fruit" may mean many things, but botanists usually confine it to the ripened pistil or ovary of a flower. Possibly this use of the term is rather too exclusive. Kerner would extend the definition to "everything which undergoes alteration after fertilization either in the flowers or flowering axis," and urges that as the changes in question are "for the purpose of promoting the interests of the embryo," whatever participates in this object is the fruit. However, not to appear singular, we will abide by the definitions of the text-books, and take it that a fruit is a ripened and developed ovary.

How does this ripening and development take place? The accompanying figures will help us to understand the process. Fig. 570 represents an ideal section through a uniovular ovary just after pollination. *a* is the stigma, upon which are six pollen-grains. The style (*b*) widens into the ovary (*c c*), which contains a single *inverted* ovule (*d*)—the latter not shown in section. We speak of the ovule as inverted because the micropyle (*g*) is not at the apex of the ovule, but, by a twisting round of the whole ovule, is brought close to the *funicle* or point of attachment (*f*).*

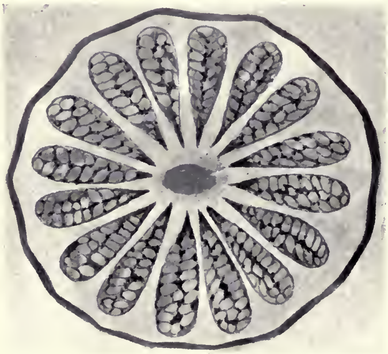

FIG. 569.—WHITE WATER-LILY (*Castalia alba*).

A transverse section of the ovary, showing the ovules in the carpels.

* This is the commonest form of ovule, and is described as *anatropous.* It must be carefully distinguished from the bent

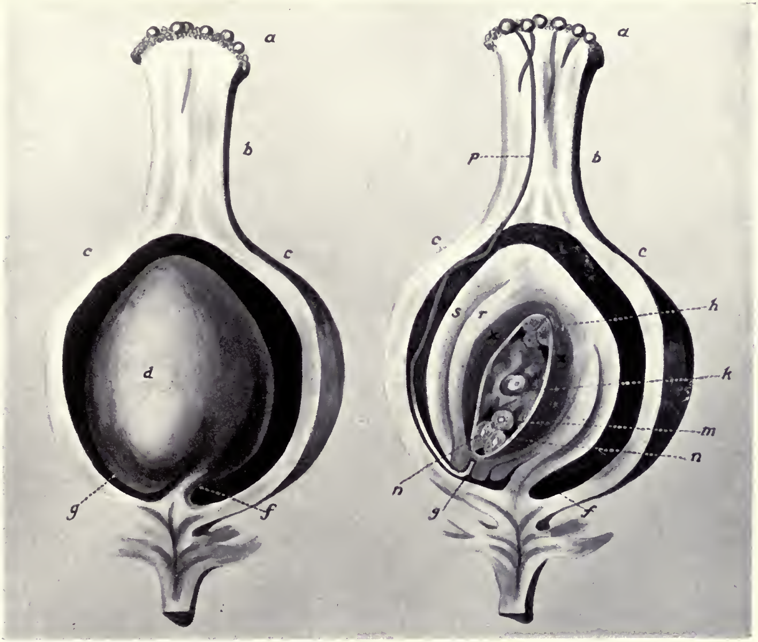

FIG. 570.—UNIOVULAR OVARIES.

The first diagram shows the ovary in section before fertilization (the ovule not in section). (*a*) Stigma, upon which are six pollen grains; (*b*) style; (*c c*) ovary containing a single inverted ovule (*d*); (*f*) stalk (funicle) of ovule; (*g*) aperture (micropyle) of ovule through which the pollen-tube enters. In the second diagram the letters *a* to *g* are as above. (*h*) Antipodal cells; (*k*) central nucleus; (*m*) egg-cell (oosphere) from which, after fertilization, the embryo plant is developed; (*n n*) co-operating cells (synergidæ); (*p*) pollen-tube entering the micropyle; (*r*) inner envelope of ovule; (*s*) outer envelope of ovule. The space containing *h*, *k*, *m*, *n* is the embryo-sac; the part surrounding it (*x*) is the nucellus.

The second diagram shows the same pistil, but with the ovule also in section. Observe the structure of the ovule, here represented at the stage immediately preceding fertilization. Commencing from the outside, we have first a coat or envelope (*s*)—the *outer integument*; secondly, an inner coat (*r*)—the *inner integument*; and within that a mass of tissue (*x*), represented by the dark shading—the *nucellus*. Embedded in the nucellus is the *embryo sac*, which contains an abundance of protoplasm, with large vacuoles

or *campylotropous* form, in which the ovule curves upon itself like a horseshoe, and so brings the micropyle near the base. This is well seen in the Pea (fig. 571) and in the seeds of Shepherd's Purse (*Capsella bursa-pastoris*). Straight or *orthotropous* ovules, which have the funicle and nucellus in the same straight line, are common among the Gymnosperms, and occur also in the Dock family. The Yew (*Taxus baccata*) offers an excellent example of this form.

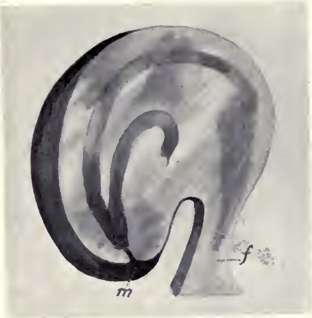

FIG. 571.—CAMPYLOTROPOUS OVULE OF PEA.
(*m*) Micropyle ; (*f*) funicle.

and a central nucleus (*k*); and in addition to the protoplasm, a number of small cells (*m*, *n*, etc.). First and chief is the egg-cell or *oosphere* * (*m*), from which, after fertilization, the embryo plant is developed. Its two sister-cells (*n n*), which co-operate in this work, are known as the *synergidæ*. They are situated somewhat nearer the micropyle (*g*) than the oosphere, and constitute with it the "egg apparatus." The three cells at the opposite end of the embryo sac are the *antipodal* cells. Soon after their formation each of the antipodal cells becomes invested with a cell-wall, but they appear to play no part in any of the subsequent phenomena, and their use we are not at present able to estimate.

Watch the process of fertilization. On putting forth its tube the pollen-grain shapes a course down the loose conducting tissue of the style until it reaches the micropyle of the ovule. The tube, it should be explained, is an outgrowth of the inner coat or *intine* of the pollen-grain through the *extine* or outer coat (fig. 559), and it bears at the end a reproductive nucleus, which is in fact the male sexual cell or *male gamete*. Forcing its way down the micropyle, the pollen-tube perforates the embryo sac, and then, opening at the tip, allows the reproductive element—which has meanwhile divided to form two male cells—to pass out. Thus released, the generative nuclei traverse the synergidæ—which thereupon shrivel and collapse—and, with that, one of these male cells enters the egg-cell and fuses with the female nucleus. *This is the act of fertilization.*

FIG. 572.—SPINY FRUIT OF MEGARRHIZA CALIFORNICA.

The cell formed by the fusion of the male and female nuclei is called the *oosperm* or embryonic cell; and from this cell (as the latter name suggests) is eventually formed the embryo or baby plant—the essential part of the *seed*.

Immediately after fertilization *endosperm* begins to form in the embryo sac, either by cell division—as in some Dicotyledons—or by free cell formation—as in all Monocotyledons and many Dicotyledons. The embryo sac meanwhile increases greatly in size and gradually

* Called also the *germsphere* and *ovum*.

Photo by] [*E. Step.*

FIG. 573.—DANDELION (*Taraxacum officinale*).

The plumed fruits form a globe of down, which is broken by the wind and the separate fruits sail like parachutes to a distance.

absorbs the tissue of the nucellus. In plants of the Water-lily and Pepper orders (Nymphæaceæ and Piperaceæ) and a few others, a portion of the nucellus remains, and forms what is known as *perisperm.* When both the endosperm and perisperm are completely used up by the embryo in the course of its development, the ripe seed consists simply of a seed-coat (formed from the integuments of the ovule) and the embryo, and is described as *ex-albuminous.* In cases where the ripe seed contains endosperm as well as the embryo, it is called an *albuminous* seed. As we have already dealt with the subject in Chapter VI, we need not retrace the ground here.

From what has been said, however, the distinction between a fruit and a seed must be at once evident. The former is a ripened and developed *ovary*: the latter, an impregnated and matured *ovule.* The fruit, in fact, *contains* the seed or seeds, just as the ovary contains the ovule or ovules. In the Gymnosperms, which have naked ovules, the seeds are of necessity naked also; hence they are not true fruits. True fruits are, indeed, confined to the Monocotyledons and Dicotyledons.

Fig. 574.—Wood-sorrel (*Oxalis*) expelling its Seeds.

In dealing with the diversities of form and external structure of fruits and seeds, it is interesting to consider them in the light of Adaptation. By this means the inquiry is immensely simplified; for it is evident that those diversities are mainly directed to one end—*the dispersion of the seed.* The seed, in fact, must be adapted to travel.

Now seeds and fruits were great travellers centuries before Vasco da Gama and Columbus were heard of, and had crossed seas and continents, and planted colonies all over the world long before the earliest caravan set out from Bactria, or the first Phœnician merchantmen spread sail on the blue waters of the Mediterranean. The necessity for becoming travellers was imposed upon the vegetable community from the outset. Had those old-world fruits just fallen from their parents' arms, so to speak, and lain where they dropped, the consequences must have been disastrous. In a few years vegetation would have been almost choked; the strongest plants would have killed out the weaker, whole families of plants would have thus become extinct, and the distribution of the remainder would have been much retarded.

Fig. 575.—Seed of Wood-sorrel.

The elastic outer integument is bursting open to expel the seed.

It is therefore a matter for thankfulness that provision has been made in nature for the dispersal of the fruits and seeds of plants. This great end is effected in many ways. Sometimes the plant ejects its own offspring in a more or less forcible manner by means of special tissues which act as slings, catapults, etc.; sometimes the fruits themselves are capable of creeping or hopping along the ground; sometimes they are provided with plumes, aeroplanes, or with envelopes filled with air, which render them so buoyant that they are able to perform long aerial journeys, the least breeze being sufficient to carry them along; sometimes the wind lays hold of them when on the ground and drives them forward with rapidity; sometimes the water is their friend, and stream and torrent, lake and ocean, become instrumental in transporting them to new and distant homes; sometimes the fruits are furnished with hooks or sticky secretions which facilitate their dispersion by birds and other animals.

The Wood-sorrel (*Oxalis acetosella*), whose delicate white blossoms may be often seen peeping among the mossy uncovered roots of forest-trees, is one of our commonest wild-flowers. It offers a familiar example of plants with sling fruits. When the seeds are ready for dispersion, the capsules containing them burst open, and the strong tense tissue which covers each of the seeds being ruptured at the same time, the seed is jerked out to a considerable distance (figs. 574, 575). In the Squirting Cucumber (*Ecballium elaterium*, fig. 576) the arrangement is even more curious. The seeds are contained in a juicy pulp, which fills the fleshy and bristly "cucumber," and which is kept from bursting out by the hooked and stopper-like stalk. When the seeds are ripe,

Fig. 576.—Squirting Cucumber (*Ecballium elaterium*).

When the fruit is ripe it breaks off from the stalk, and from this point the seeds and pulp are squirted out with force.

the fruit severs itself from the stalk, and instantly the seeds are squirted out in a fountain of pulp through the unprotected hole. In the Touch-me-not Balsam (*Impatiens noli-me-tangere*, fig. 577) the five divisions of the capsule leap from the stalk when the seeds are ripe, and, twisting suddenly up, get rid of their offspring in a very summary manner.

The Common Dandelion (*Taraxacum officinale*, fig. 573) offers the most familiar example of the dispersal of plumed fruits by means of the wind. Each of its white downy balls, "the schoolboy's clock in every town," is an aggregation of such fruits, waiting for the first breeze to scatter them. The beauty of these tiny parachutes, and the gracefulness of their motion as they float through the summer air, cannot be too greatly admired. The Tillandsias, many of which are epiphytes, have plumed fruits which are specially adapted for anchoring them to the bark of old trees, where they are able to germinate immediately. In *Cirsium nemorale*, one of the Plume Thistles, the fruits just break away from their sessile plumes and fall to the ground, whenever an obstacle is encountered in the course of flight. Doubtless the obstacle gives sufficient promise of *terra firma* below to encourage them thus to slip their parachutes and risk a descent.

FIG. 577.—TOUCH-ME-NOT BALSAM (*Impatiens noli-me-tangere*) EXPELLING ITS SEEDS.

Creeping fruits are characterized by their stiff bristles, which are peculiarly sensitive to moisture. As a result of this sensitiveness, the fruits continually change their position, and are able to propel themselves along in a definite direction, a hygroscopic arrangement which enables them to be carried long distances.

Even jumping fruits are not unknown. Insect activity within the fruit is the cause of the phenomenon, and one of its effects is undoubtedly the dispersion of the seeds. Two plants are known which have so-called "jumping beans"—viz., *Sebastiania palmeri* and *S. bilocularis*; and the insects which cause the motion are *Carpocapsa saltitans* in the former, and *Grapholitha sebastiania* in the latter. *Sebastiania palmeri* is a very peculiar tree. It was discovered not many years since in a morass, half

Photo by] [*E. Step.*

FIG. 578.—DEWBERRY (*Rubus cæsius*).

Closely related to the Blackberry, but with trailing stems, the strong spines reduced to bristles, and the fruit consisting of a few very large drupes which are covered with a thick coat of grey " bloom." There are usually only three leaflets, which are green on both surfaces.

a mile square, in the neighbourhood of Alamos, Mexico. The fruit is of triangular shape, divided into three equal portions by strongly defined lines. Two of these parts contain a small spherical black seed; the third, a "jumper" or small maggot. On falling to the ground the fruit splits, and that portion which contains the maggot immediately starts off, hopping in an extraordinary manner *away from the tree on which it grew.*

The object of these movements has not yet been discovered, but the theory is that the maggot instinctively knows that if it remains near the parent tree it will be destroyed by an enemy. The insect lives upon the contained seed, and has no desire to escape—indeed, seems to be extremely comfortable in its dark quarters. If a small hole is carefully bored in the shell, the maggot instantly sets to work to repair the damage, and in a very short time will have closed the hole with a fine silky web. After this is done the insect resumes its tireless and saltatory travels. As

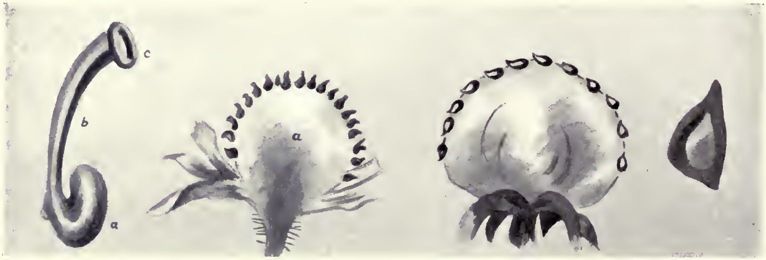

FIG. 579.—STRAWBERRY (*Fragaria vesca*).

The first figure shows (*a*) ovary, (*b*) style, and (*c*) lobed stigma. The second figure is a section through the receptacle (*a*) of an unripe "berry," with membranous pistils seated on the surface. The third figure shows the same in a ripe condition with carpels on the exterior; and the remaining figure is a section through one of the carpels, showing the contained seed.

there is no hole or other indication of a way by which the shell could be entered, it is supposed that the egg is laid in the flower before the fruit is formed; probably also, the moth which lays the egg cross-pollinates the flower at the same time. The perfect insect is a grey-brown moth, with speckled upper wings which measure three-quarters of an inch from tip to tip. The moth releases itself from its prison by chiselling out a piece of the hard shell, like a circular pavement-trap in miniature. The most delicate fret-saw, even in skilled hands, could not do the work better. It must be understood that these "jumping beans" never produce seedlings, for the contained larva destroys the seed.

Instances are even known of *whole plants* which migrate from place to place when their fruits are ripe. Of this sort are the wonderful "wind-witches" of the Russian steppes, which have so appealed to the imagination of the peasants of those regions. At the fruiting stage the stiff erect flowering stems of this plant, which spring from a common axis almost level with the root, curve outwards to the circumference of the plants, and by that means give a strong pull to the radish-shaped root, sufficient to force it from the ground. The environment of the plant favours this singular and apparently suicidal proceeding, for the earth during the summer season is full of cracks. Then, when the wind comes howling over the steppes, the plant is caught up and driven along with others of its kind, and together they fly bounding over the plain. One by one their wild careers are checked, and each settles down to shed its seeds in its new resting-place.

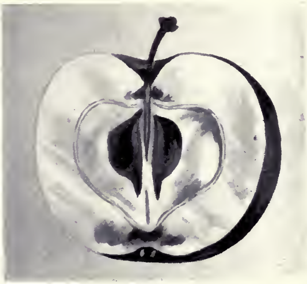

Fig. 580.—Apple.
Longitudinal section of pome.

Having offered these general remarks, we will now consider the subject of the Phanerogamic Fruit in more detail.

A fruit or ripened ovary consists, normally speaking, of two parts—the protective enveloping case, known as the *pericarp*, and the seed or seeds (ripened ovules). The pericarp consists of three layers, each of which has a distinguishing name. The outermost layer—*i.e.* the integument or skin of the fruit—is the *epicarp*; the middle layer is the *mesocarp*; and the inner coat the *endocarp*. When, as frequently happens, the middle layer is of a fleshy or succulent nature, it is called the *sarcocarp*.

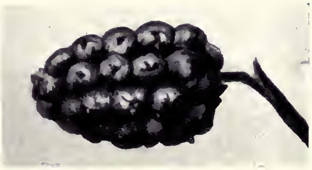

Fig. 581.—Mulberry.
A pseudo-syncarp.

It was noticed a few pages back that parts of plants are sometimes described as fruits which are not true fruits at all. We call these spurious fruits *pseudocarps*. The strawberry, apple, fig, and mulberry are familiar examples. The red, succulent, fleshy part of the Strawberry is not a ripened ovary, but the greatly swollen receptacle or *thalamus* of the flower; and the real fruits are the small, dry, seed-like carpels scattered over its surface. In an Apple the edible part is not the ovary alone, but embraces the succulent and enlarged floral receptacle, which also, as in the Strawberry, forms the bulk of the

Fig. 582.—Medlar.
A pome.

"fruit." The ovary occupies the cavity of this much-distended tube, and is fused with the inner wall of it. The "pips" are the seeds. This form of spurious fruit is termed a *pome* (fig. 580). The chief substance of a fig, again, is its fleshy receptacle or axis, the true fruits being the hard yellow grains borne on the inside of the cavity of the receptacle. In the Mulberry (*Morus*) the bracts of the clustering flowers coalesce with the perianth, and form a succulent matrix for the individual fruits. A mulberry is, in fact, a collection of spurious fruits fused together—in botanical language, a *pseudo-syncarp* (fig. 581).

Other well-known examples of pseudo-syncarps are afforded by the Bread-fruit-tree (*Artocarpus incisa*) and the Pineapple (*Ananassa sativa*). These *collective fruits*, as they are called, must be carefully distinguished from *aggregate fruits*, in which the clustered carpels are derived from a single flower, as in the Raspberry and Blackberry (*Rubus idæus* and *R. fruticosus*). The raspberry and blackberry, moreover, are *syncarps*, not pseudo-syncarps.

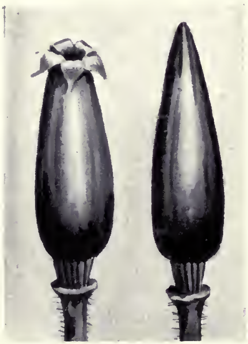

FIG. 583.—CORN-COCKLE.
Toothed capsule—open and closed.

Thus we come to true fruits. These may be conveniently divided into three classes. To the first class belong those fruits which break and shed their seeds, or are *dehiscent*; to the second class, those which do not break, or are *indehiscent*; and to the third class, those splitting fruits which in some cases shed their seeds, and in others—the majority of cases—do not. We call these splitting fruits *schizocarps*.

Of the various forms of dehiscent fruits one of the commonest is the *capsule*. Strictly speaking, capsules are fruits with two or more carpels whose pericarp liberates the seeds by toothed or valvular openings, by pores, or by the falling off of a lid; but the term is frequently applied, with more latitude than correctness, to all dry dehiscent fruits. However, as the other forms of capsule have special distinguishing names, we shall here employ the term in its more exclusive sense.

Good examples of *porous* capsules are found in the Poppy (*Papaver*). The pores are provided with little flaps on the sides, beneath the eaves of a roof-like top, and these flaps move up and close the pores in time of rain, or when the atmosphere is exceptionally moist. In dry weather they open outwards, and as the poppy-heads sway in the breeze the light small seeds get shaken out and scattered over a wide area.

Protective arrangements somewhat similar to the above seem to be a special feature in what are known as *toothed* capsules. The Corn-cockle (*Lychnis githago*, fig. 583) is a case in point. In wet weather its five teeth meet in a point and prevent the entrance of a drop of rain, but on dry

Photo by] [*E. Step.*

FIG. 584.—MEDLAR (*Mespilus germanica*).

The fruit is a pome like that of the Apple, consisting of the ovary and swollen receptacle, crowned by the persistent calyx-lobes which surround a depressed area. The tree, which is a native of Greece, Asia Minor, and Persia, has become naturalized in the hedgerows of the Midlands and South of England, also in the Channel Islands.

days, and when the seeds are ripe, the teeth are curved back. The seeds escape by this opening.

Compare carefully the capsules depicted in figs. 586, 587, which are shown in transverse section, and represent respectively the fruit of the *Iris* and Meadow-saffron (*Colchicum autumnale*): fig. 585 is a fruit of the Common Thorn-apple (*Datura stramonium*). In fig. 588 the three forms are shown diagrammatically. Now, in each of these examples it will be noticed that the capsule dehisces in a different manner. In the Iris the capsule splits through the back of its three seed-containing cavities (by its dorsal suture, as we should say), and thus the cavities or *loculi* are broken open. This is known as *loculicidal* dehiscence. *Septicidal* dehiscence is illustrated in the Meadow-saffron. Here the carpel separates into its component ovaries, each of the walls of separation or dissepiments dividing into two, and thus the loculi remain intact. In the Thorn-apple there is no splitting of the dissepiments, which remain attached to the axis, but the carpellary wall which surrounds them, and to which they are attached, breaks away at the three points of attachment, and so the seeds escape. This is *septifragal* dehiscence.

FIG. 585.—THORN-APPLE (*Datura*).
The carpellary wall alone splits and separates from the dissepiments. Septifragal dehiscence.

From the circumstance that, in each of the three examples here given, the pericarp comes away in pieces or valves, the dehiscence is also said to be *valvular*. Allusion has been made already to two very remarkable instances of valvular dehiscence. The sling-fruits both of *Impatiens* and of *Oxalis* come under this category. In the former, the mesocarp consists of large and highly turgid cells, which keep the whole of the capsule in a state of great tension; so that when the fruit is touched the valves fly open, and eject the seeds with considerable force; in the latter, as we have seen, the bursting of the elastic fleshy outer integuments of the seeds is the cause of their expulsion.

"On the heights of the Kahlenberg, at Vienna, at the edge of the wood," says Kermer, grows an under-shrub which bears the name of *Dorycnium herbaceum*. It is one of the Papilionaceæ, and develops spherical one-seeded fruits, which ripen in October. I once collected from this plant several twigs laden with fruit, for the purpose of a comparative investigation on which I was engaged, and brought them home and laid them on my writing-table. Next day as I sat reading near the table, one of the seeds of the *Dorycnium* was suddenly jerked with great violence into my face. Shortly afterwards I saw a second, third, fourth, and ultimately about fifty seeds let fly from the small clusters of fruit, and each time I heard a peculiar sound which accompanied the bursting open of the fruits and ejection of the seeds. The rays of sunshine from the window had evidently heated and dried the fruits, and occasioned this surprising phenomenon." The poet Goethe gives a somewhat similar account of the seed dispersion of *Acanthus mollis*; and methods closely resembling these have been observed in many other plants. Plants with sling-fruits form, in fact, a large group.

FIG. 586.—IRIS.

Transverse section of capsule, illustrating loculicidal dehiscence.

A very curious form of capsule is the *pyxis*, in which the splitting takes place transversely, and the top of the capsule falls completely off. The fruits of *Anagallis*, the Pimpernel family (fig. 589), all have this mode of dehiscence; but more striking examples are furnished by the less known tropical genus, *Lecythis*, about which many a quaint story is told. *Lecythos* means an oil-jar, and the popular name for these fruits is "monkey-pots." "The great urn-shaped fruits," writes Charles Kingsley, "big enough to serve for drinking-vessels, each kindly provided with a round wooden cover, which becomes loose, and lets out the savoury sapucaia nuts inside, to the comfort of all our 'poor relations.' The pots are used for catching monkeys." "Filled with sugar," says a writer in the *Gardener's Chronicle* (1861), "they are placed on the ground which such animals frequent. The sugar attracts the latter, who pick it out leisurely till they are disturbed, when they insert the paw, grasp as much sugar as it will hold, and endeavour to escape with the prize. But their doubled fist, being larger than the mouth of the pot, cannot be withdrawn, and the monkeys, tenaciously holding the sugar, run off with a pot firmly enclosing one paw. This renders it impossible for them to escape from their pursuers by climbing, and they are easily run down."

FIG. 587.—MEADOW-SAFFRON.

Transverse section, illustrating septicidal dehiscence.

The remaining dry dehiscent fruits which

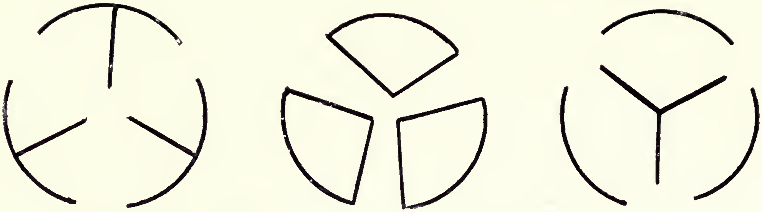

FIG. 588.—DIAGRAMMATIC REPRESENTATION OF FIGS. 586, 587, AND 585.

are sometimes described as capsules are the follicle, the legume, the siliqua, and the silicula. We will take them in that order.

The *follicle* is a superior, one-celled fruit, containing one or more seeds. which are liberated in most instances by a ventral suture only. *Magnolia glauca* and some other species of *Magnolia* are exceptions. As a rule, several follicles are collected in a cluster at the end of a flower-stalk, but solitary follicles are common in Proteaceæ; and there are a few plants (*e.g.* the Pæony, normally developing two or more follicles with each flower, which occasionally produce but one. The Columbine (*Aquilegia*) and Larkspur (*Delphinium*) offer good examples of the follicle.

The *legume* or *pod* resembles the follicle in that it arises from a single carpel; but, unlike the follicle, it dehisces at *both* sutures. This is the characteristic fruit of the great order *Leguminoseæ*, to which the Pea and Bean belong. The legumes assume a curious twisted form in the small genus *Scorpiurus*, which includes the interesting Caterpillar-plant (*S. vermiculata*, fig. 594), and a spiral form in the Purple Lucerne (*Medicago sativa*, fig. 597). When the pod is contracted in a bead-like (*moniliform* manner, as in the Gum Arabic plant (*Acacia arabica*, fig. 601), it is termed a *lomentum*.

FIG. 589.—PIMPERNEL.
The fruit is a pyxidium, which splits transversely and the upper part falls away completely, like a lid.

The legumes of the Earth-nut (*Arachis hypogæa*, fig. 599) deserve notice on account of peculiarities other than those of form. The specific name *hypogæa* (Greek *upo ge*, under ground) is an allusion to the curious circumstance that the young pods, as they begin to mature, are forced into the earth by a lengthening of the flower-stalks, and ripen their seeds below the ground. This phenomenon is not confined to the Earth-nut, but has been observed in a few other plants—*Trifolium subterraneum*, for example, and the Sweet Violet (*Viola odorata*). The fruits of the latter are not leguminous. Plants with burying fruits,

Photo by] [*E. Step.*

FIG. 590.—HORSE-CHESTNUT (*Æsculus hippocastanum*).

The prickly fruit is a succulent capsule, and when ripe it splits into two or three valves to set free the large seeds known as Conkers. Mountain regions of GREECE, PERSIA, and NORTHERN INDIA.

says Kerner, "have always been a source of wonder to botanists, and their number is not large. The best known examples are *Arachis hypogœa*, *Cardamine chenopodiifolia*, *Linaria cymbalaria*, *Phrynium micans*, *Trifolium subterraneum*, and *Vicia amphicarpa*. If these plants were only to bring fruit to maturity underground, or were to draw all their fruits below the ground as soon as the seeds were mature, in order that germination and the development of new plants might ensue at that spot, their behaviour would imply a renunciation of dispersion to any distance, and the phenomenon would be highly enigmatic. The puzzle is satisfactorily solved, however, when we take into account the fact that all these plants invariably have the chance of being dispersed to great distances either before the fruits become concealed in the earth, or by means of a second form of fruit which ripens aboveground, and is evidently adapted to being scattered abroad through the agency of animals, or by means of aerial or

Photo by] [*E. Step.*

FIG. 591.—BRAZIL NUT (*Bertholletia excelsa*).

The hard-shelled triangular nuts to the number of fifteen or twenty are enclosed in a thick-walled, woody fruit which can only be broken by great force. The seeds (" nuts ") are released naturally by the rotting of this strong-box.

SPECKLED ODONTOGLOT *(Odontoglossum nævium).*

An epiphytal Orchid, native of Colombia, with slender leaves, and beautiful white flowers speckled with purplish-crimson. The flower-spikes are about fifteen inches long and bear from ten to sixteen flowers. They are here figured one-third less than the natural size.

FIG. 592.—FOLLICLES OF PÆONY (*Pæonia*).

aqueous currents." *Linaria cymbalaria* grows down the face of old walls, and its capsule-stalks twist until the capsule is brought to a chink, into which it is thrust. Here, when the seeds are ripe, the capsule opens and discharges them under conditions favourable for their germination.

The *siliqua* consists of two carpels, the exposed walls of which break away, leaving the seeds attached to an upright central framework, the *replum*; on which is stretched a delicate membrane which forms the false septum of the fruit. Siliquas are characteristic of the Crucifers, and usually take a long, narrow form, as in the Wallflower (*Cheiranthus cheiri*) and Stock (*Matthiola*, fig. 596). In the genus *Lunaria*, which includes the well-known garden plant Honesty, the form is broadly elliptical (fig. 602). The force and suddenness with which the siliquas in some species of Crucifers fly open, owing to the drying and contraction of the walls, greatly facilitate the dispersion of the seeds.

FIG. 593.—LARKSPUR (*Delphinium grandiflorum*).

A cluster of follicles (usually five) is produced by each flower.

The siliquas of the so-called "Rose of Jericho" (*Anastatica hierochuntica*, fig. 600) are of unusual form, and the whole plant at the time of fruiting exhibits phenomena which are exceedingly curious. Its branches, which are ordinarily of a spreading character, curve inwards when the fruits are ripe, and form a kind of cage or trellis about the siliquas. This position is maintained, and the siliquas remain closed in a dry atmosphere, but directly the air becomes moist, the branches straighten out again, and the siliquas open. The seeds are thus fully exposed, and with the first rainfall are washed out of the fruit-valves and dispersed over the land.

FIG. 594.—CATERPILLAR-PLANT (*Scorpiurus vermiculata*).

The fruit is a twisted legume.

The *silicula* differs in no essential particulars from the siliqua. The former

Fig. 595.—Lupin (*Lupinus*). The fruit is a legume.

term is simply a diminutive of the latter—a fact which gives the key to a definition. Briefly, indeed, a silicula is a broad and very short siliqua. The ubiquitous Shepherd's Purse (*Capsella bursa-pastoris*) offers the readiest example of this form of fruit; but, for variety's sake, we have chosen for illustration a silicula of the Evergreen Candytuft (*Iberis sempervirens*, fig. 603).

It will be noticed that the capsule, follicle, legume, siliqua, and silicula are all forms of *dry* dehiscent fruits. Fleshy or succulent pericarps have no place in this fivefold group. Nevertheless there are two forms of dehiscent fruits in which the characteristic alluded to is met with—namely, the succulent capsule and the dehiscent drupe.

Fig. 596.—Stock (*Matthiola annua*). A siliqua, and the same dehiscing.

The green prickly husk of the Horse-chestnut (*Æsculus hippocastanum*, fig. 590) is a pericarp, which, when ripe, splits into valves and sets free the large red-brown seeds—the so-called "nuts." It is a *succulent capsule.* So, too, is the unarmed fruit of the nearly related Sweet Buckeye (*Pavia flava*), whose native habitat is the mountainous districts of Tennessee and North Carolina.

The Walnut (*Juglans regia*) is a *dehiscent drupe.* Its green fleshy covering consists of epicarp and mesocarp. The hard shell enclosing the seed is endocarp. The fleshy covering, which is rich in tannin, protects the unripe seed from nut-cracking animals; but when the seed is ripe, the envelope splits and curls away, and the so-called "nut" (whose development is really analogous with that of a plum-stone) drops to earth. It is still protected by the thin but stony shell, and even when that is broken there is the bitterness of the skin to give the seed a final chance.

Fig. 597.—Lucerne (*Medicago sativa*). The fruit is a spiral legume.

The curious hooked fruits of the Martynias are *subdrupaceous capsules.* Frank Buckland used to say of *Martynia proboscidea* that its fruits must have been created "for the express purpose of sticking to the tails of the

Photo by] [*E. Step.*

FIG. 598.—IVY-LEAVED TOADFLAX (*Linaria cymbalaria*).

A Continental plant that has become well-established on our old walls. The fruit-stalk bends down and moves about until it finds a chink into which the capsule is thrust, and there on ripening it discharges its seeds.

wild horses that roam the plains of South America"; and certainly one of the objects of the hooked spines and bristles of fruits of whatever kind is their dispersion by animals. Kerner estimates that the fruits and seeds of about 10 per cent. of all Flowering Plants are provided with processes of this description, some of which take the form of hooks and others of barbs. In this case the *Martynia* fruit splits to release the contained seeds which are gradually shaken out by the effort of the animal to get rid of its encumbrance. The Goose-grass (*Galium aparine*), a long, weak, straggling plant very common in our hedges and thickets, has small fruits (dry, indehiscent pericarps, in this case) which are literally covered with hooked bristles. Country people call the plant "cleavers," from its habit of cleaving to objects with which it is brought in contact, and children like to throw the hispid fruits at one another for the fun of seeing them "stick." In the Burweed (*Xanthium*, fig. 604) the hooks are borne upon the bardened involucre, which grows about and covers the one-seeded fruit. Very similar in effect are the top-shaped fruits of Agrimony (*Agrimonia eupatoria*), which become detached from the plant by every fur-clad creature that touches it in passing. A walk through the pastures in early autumn will result in our nether garments being thickly coated with these fruits.

FIG. 599.—EARTH-NUT (*Arachis hypogœa*).
The young pods are thrust into the earth by the lengthening of their stalks, and there they ripen their seeds.

The capsules of the African Grapnel-plant (*Harpagophytum procumbens*) are provided with claw-like spines of a particularly powerful kind, which grasp the hoofs of unwary animals in the Orange River region where the plant abounds, causing them the greatest pain; nor is there relief from the torment till the capsule splits up to release the seeds.

FIG. 600.—ROSE OF JERICHO (*Anastatica*).
Fruiting branch.

Thus far our attention has been mainly confined to dehiscent fruits; we will now speak a little of those which never open spontaneously, or, in other words, are *indehiscent*. It will be seen as we proceed that the provisions for dispersion, in the way of hairs, curved bristles, and hooked spines on the one hand, and of wings, plumes, etc., on the other, are far more common in indehiscent than in dehiscent fruits; and the reason is obvious. The pericarp, which releases its seeds spontaneously at the time of ripening, has done its work when dehiscence has taken place, and the seeds are left, so to speak, to their own resources. The broken, empty seed-case has no further use. But in the case of an indehiscent fruit, where pericarp and seed do not part company on the ripening of the latter, a contrivance of some kind to assist dispersion is clearly a valuable provision.

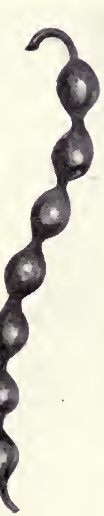

FIG. 601.—GUM ARABIC-TREE (*Acacia arabica*).
A lomentum.

Take a stone-fruit, such as the plum, by way of illustration (fig. 608). A plum is a fleshy, indehiscent fruit called a *drupe*, with a stony endocarp, which invests the "kernel" or seed (fig. 607). (This may be accepted as a definition of a drupe.) Now,

FIG. 602.—HONESTY (*Lunaria annua*).
Siliquas of elliptical shape.

Fig. 603.—Evergreen Candytuft (*Iberis sempervirens*). A silicula.

as the seed of the plum matures, the fleshy mesocarp, or sarcocarp, becomes more succulent and loses its acidity, while the green epicarp, hitherto only to be distinguished with difficulty from the surrounding leaves, assumes a yellow, red, or purple colour, and so becomes very conspicuous. By reason of these changes, animals—particularly birds—are attracted to the fruits, which they devour greedily. The seeds, thanks to their environment of stony endocarp, resist digestion, and in many cases are transported to great distances. The cherry, apricot, peach, and a host of other drupaceous fruits undergo very similar transformations and are distributed by similar means.

The fruit of the Coco-nut Palm (*Cocos nucifera*), with its fibrous mesocarp, is also a drupe, though some botanists speak of it as a *nut.* This is one of the fruits disseminated by water—a fact which accounts for the prevalence of palm-groves on the coral islands of the Pacific. In the vicinity of Key West, an island of the Florida reefs, and as far north as Jupiter Inlet, two hundred miles from Key West, the sandy beach is lined with Coco-nut Palms, which owe their presence there to the wrecking of a vessel which had a cargo of the nuts on board. The Double or Sea Coco-nut (*Lodoicea seychellarum*, fig. 606) is distributed by similar means. "The Seychelles," says Miss Gordon Cumming in her *Two Happy Years in Ceylon*, "contribute a fine specimen of their own particular Palm, the *Coco-de-mer* [Sea Coco-nut], which was so long known only by the great double nuts (shaped like a kidney when cut open) which tidal currents floated far out on the Indian Ocean and to the shores of the Maldive Islands, where they were occasionally picked up by sailors and brought home to puzzle botanists. It was not till last [*i.e.*, the eighteenth] century that the parent Palm was discovered in the Seychelles, and it was found that the Palm, with a fruit like twin coco-nuts, bears a crown of huge fan-shaped leaves, akin to those of the Palmyra Palm, crowning a stem a hundred feet high."

Fig. 604.—Burweed (*Xanthium strumarium*). With hook-clad involucre.

Another common form of indehiscent fruit is the *berry.* In a berry the whole of the seed-case or pericarp becomes fleshy or succulent—there is no stony endocarp as in the drupe. The grape, currant, gooseberry, and mistletoe are well-known examples. The gourd is really a huge berry

Photo by W. Reid] [*Wishaw.*

FIG. 605.—YELLOW PLUMS, FRUIT OF THE AMERICAN PLUM-TREE (*Prunus americana*).

The fleshy fruits are drupes. The seed is contained in a stony endocarp—the "plum-stone."

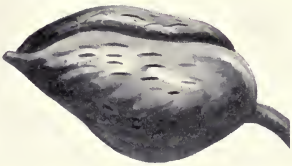

FIG. 606.—DOUBLE COCO-NUT (*Lodoicea seychellarum*). A drupe.

with a hard outer layer, but it is more often called a *pepo* (fig. 611). Dispersion of the seeds of berries is effected largely by animals, under circumstances very similar to those attending the seed dispersal of drupaceous fruits. The seed-coats resist the action of digestive juices as effectually as does the stony endocarp of the plum or cherry.

Few indehiscent fruits are more puzzling on a first examination than the orange. The development of the three layers of the pericarp is very remarkable, and forms one of the characteristics of a remarkable kind of fruit—the *hesperidium* (fig. 612). The peel of the orange consists of epicarp and mesocarp; while the membranous partitions which project internally towards the centre of the fruit, and divide off the juicy pulp into separate groups of cells (the misnamed "quarters" of the orange) consist of endocarp. The pulp itself, in which the "pips" or seeds are embedded, is a development of succulent cells (internal hairs) from the inner lining of the ovary—*i.e.*, from the endocarp. The lemon, shaddock, etc., have the same distinguishing feature, and are equally good examples of the hesperidium.

FIG. 607.—SECTION THROUGH THE "STONE" OF A PLUM.

The three sorts of indehiscent fruits which we have been considering—drupe, berry, and hesperidium—are all succulent; the others are dry. They are the achene, nut, caryopsis, and cypsela.

FIG. 608.—SECTION THROUGH A PLUM.

Showing the "stone" invested by the fleshy mesocarp.

A dry indehiscent fruit developed from a pistil with single carpel is an *achene;* if the pericarp is thin and leathery, and not adherent to the seed-coat, it is an achene; if hard and woody, a *nut.* Any dry one-seeded indehiscent fruit with a hard endocarp is called a nut. As a rule, a nut has but one chamber, the partition-walls disappearing by atrophy as the fruit develops. The fruits of the Buttercups (fig. 613) are achenes; the fruits of the Hazel (*Corylus*, fig. 614) are nuts. The husk which partly envelops the hazel-nut is formed by greatly enlarged bracts.

In the Oak (*Quercus*, fig. 624) the nuts, usually called acorns, are seated in cups or *cupules* of bracts, which, curiously enough, are only formed after fertilization. In the British Oak (*Quercus robur*) these cups are rough on the exterior; but in those of the Turkey Oak (*Quercus cerris*) they are coated with moss-like outgrowths. The order *Cupuliferæ* derives its name from these vegetable cups. Beech-nuts, the fruits of *Fagus sylvatica*, are contained in a spiky husk—the enlarged four-partite involucre of bracts—which, on a superficial view, might be mistaken for the pericarp. Each involucre usually contains one or two nuts, which are sharp-cornered and triangular, and which, on the splitting of the husk in the autumn, fall to the ground.

Fig. 609.—Cone of Chinese Arbor-vitæ (*Thuja orientalis*).

Fruit dispersion in cupuliferous plants is largely assisted by animals. "Many noble oaks," says a writer in the *Zoologist*, quoted by Dr. Cooke, "have been planted by the squirrel, who unconsciously yields no inconsiderable boon to the domain he infests. Towards autumn this provident little animal mounts the branches of Oak-trees, strips off the acorns and buries them in the earth, as a supply of food against the severities of winter. He is most probably not gifted with a memory of sufficient retention to enable him to find every one he secretes, which are thus left in the ground, and springing up the following year, finally grow into magnificent trees. Pheasants devour numbers of acorns in the autumn, some of which, having passed through the stomach, probably germinate."

Fig. 610.—Milk-thistle (*Silybum marianum*). Cypsela with sessile pappus.

A dry fruit whose leathery pericarp closely adheres to the seed-coat is termed a *caryopsis*. This is the characteristic fruit of the family of Grasses. The Wheat-plant (*Triticum*) presents a good type of the caryopsis. A full-grown and perfect grain of wheat will, on examination, be found to resemble the accompanying figure

Fig. 611.—Gourd (*Cucurbita pepo*). A berry with hard exterior; also called a pepo.

FIG. 612.—MYRTLE-LEAVED ORANGE (*Citrus aurantium,* var.).
A hesperidium.

(fig. 615). In form it is a compressed oval, and is enclosed, firstly, in certain chaffy scales, which are easily separated from it; then the membranous pericarp or ovary; and within that, the *testa*, which is the outer integument of the seed, and to which the pericarp closely adheres. Thus a grain of wheat is not merely a seed. It consists of a pericarp as well as seed, and consequently is a true fruit. Fig. 617 shows one of the caryopses of a curious Indian Grass (*Coix lachryma*), popularly known as Job's Tears. The peculiar heavy grey pearly fruits, hanging in clusters out of their sheaths, give this plant a unique appearance.

It is to be noticed that the caryopsis only differs from the achene in one particular. In the former, the pericarp is closely adherent to the testa of the seed; in the latter there is no adhesion whatever. Both are superior fruits (the ovaries being free from and rising above the perianth); and in this respect, and this only, they differ from the *cypsela*, which is inferior.

The *cypsela* is the characteristic fruit of the great order of Composites; and its usual addition of a stipitate or sessile pappus admirably adapts it for dispersion by the wind (figs. 610, 616). Johnston's *Botany of the Eastern Borders* contains some apposite remarks on the wind dispersion of plumed cypselas, and usefully supplements what has been already said on this subject in our preliminary remarks. "Elevated on the apex of a long beak," says this writer, "the parachute of the seed of the Goatsbeard (*Tragopogon pratensis*) consists of a number of slender spokes, which diffuse themselves circularly, and are 'telarly

FIG. 613.—URCHIN CROWFOOT (*Ranunculus arvensis*).
An achene. The second figure shows the fruit and seed in section.

Photo by] [*E. Step.*

FIG. 614.—HAZEL (*Corylus avellana*).

The fruits (nuts) are invested by a leathery husk or "shuck" formed of greatly enlarged bracts. The shrub or small tree is a native of EUROPE, NORTH AFRICA, and TEMPERATE ASIA.

Fig. 615.—Wheat (*Triticum*).
A section through the grain or caryopsis.

interwoven,' somewhat after the fashion of the spider's web. This comparatively intricate structure is given as a countervail to the great size and weight of the seed. The down of Dandelion is supported on a long and slender pedicel, and is an object of vulgar admiration; but it scarcely equals in beauty the similarly patterned fruit of the *Helminthia*. The Thistle's down is, on the contrary, sessile—the threads being sometimes only spinous, at other times plumed like a feather—and the down of the latter is peculiarly light. The coronet of the Carline-thistle (*Carlina*) is remarkable for its elegance and circular spread and plumage, and buoys easily its silky coated seed [*i.e.*, fruit]. In the Sow-thistles (*Sonchus*) what we most admire is the ribbed and striated seeds [fruits], but the down that diffuses them is abundant and of pure whiteness. The seeds [fruits] of the Coltsfoot (*Tussilago*) afford an example of a structure, common in the order, where the seed [fruit] is surmounted by a tuft of silken hairs, armed at regular intervals with a series of denticles or spines, only visible with a good magnifier. We have a contrast to this in the curious fruit of the Blue-bottle (*Centaurea cyanus*), which has a small tuft of asbestine spines at the base, and a large but short tuft of rigid stout lanceolate spines on the top, the edges of each of them indented with close and sharp serratures like a saw. This tuft cannot float the seed in the air, but it will obviously direct and hasten its descent into the soil, and it will be remarked that the forward direction of the spines must be opposed to every influence to cast them up again, after having been buried under the surface."

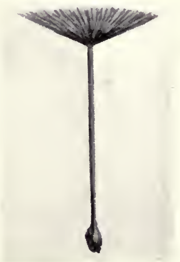

Fig. 616.—Dandelion (*Taraxacum*).
A cypsela with stipitate pappus.

We have now dealt with two of the three great classes into which all true Phanerogamic fruits may be divided; it remains only to speak of the third class—viz., the splitting fruits, or *schizocarps*.

Schizocarps are multiple, usually indehiscent, fruits, which split into one-seeded portions called *mericarps*, resembling nuts or achenes. Each of these portions is itself a true fruit. The splitting

Fig. 617.—Job's Tears (*Coix lachryma*).
A caryopsis.

may be either longitudinal or transverse; and, of course, the number of parts into which a given schizocarp will divide is determined by the number of its seeds. One with two seeds will split into two parts; another with five seeds, into five parts; and so forth: and this fact has led to the classification of schizocarps into bipartite, tripartite, quadripartite, quinquepartite, and multipartite.

FIG. 618.—SAMPHIRE (*Crithmum maritimum*).
A cremocarp.

The well-known fruit of the Maples (*Acer*, fig. 628) is a bipartite schizocarp. Its two brown-winged mericarps are known as *samaras*—a name applied to all winged mericarps. These wings carry the two heavy seeds to a considerable distance from the parent tree. It has been ascertained by experiment that, when deprived of the wings, the seeds drop to the ground in one-fourth of the time taken by the winged fruit to accomplish the same distance. In the double fruits of many Umbelliferous plants, the mericarps separate at their lower parts, but remain attached at their apex to a fork-like filiform process, the *carpophore*, as is well shown in the Samphire (*Crithmum maritimum*, fig. 618). Bipartite schizocarps which follow this type are known as *cremocarps* or hanging fruits. In some Umbelliferæ the cremocarps are winged.

FIG. 619.—WYCH ELM (*Ulmus montana*).
A samara. The fruit proper (in the centre) is shown in section.

Winged fruits and seeds (for we may speak of them together) are adapted for dispersion by the wind. They reach their highest development in the Trumpet-flowers (*Bignoniaceæ*), where the large wings extend three or four inches, "and the seeds float like a large butterfly, wafted from place to place, until a secure home is reached." In many—perhaps most—cases, the wings are not able to sustain the fruits in the air unless a pretty strong wind is blowing; but it must not be forgotten that the wind is the great agent for detaching the fruits from the parent tree, and the same gust which loosens a cluster of samaras from the bough may

FIG. 620.—BLACK HOREHOUND (*Ballota nigra*).
A quadripartite schizocarp.

sweep them many yards through the air before its force is spent.

The other kinds of splitting fruits named above require but little description, and the accompanying illustrations will help to fix their distinctive features in the memory. Fig. 622 shows a tripartite, and fig. 620 a quadripartite schizocarp—the former of the Garden Nasturtium (*Tropæolum majus*), the latter of the Black Horehound (*Ballota nigra*). Two quinquepartite schizocarps are depicted in fig. 623—one of them in the act of splitting. They are fruits of the Bloody Cranesbill (*Geranium sanguineum*). Fig. 621 is a multipartite schizocarp of the Common Mallow (*Malva sylvestris*).

FIG. 621.—COMMON MALLOW (*Malva sylvestris*).
A multipartite schizocarp.

Like the Touch-me-not Balsam (*Impatiens noli-me-tangere*), of which we have already given some account (p. 476), the fruits of the Bloody Cranesbill are sling-fruits. "If you would wish to catch the *Geranium* in the act of sowing its seeds," says Dr. Lindley, "gather a little branch of the ripe fruit on a fine summer's morning before the dew is off it, and put it in the sun. By degrees the fruits will dry, and if you watch them, you will be surprised by some of them, on a sudden, emitting a snapping sound, and you may see first one and then another of the carpels quickly curving upwards towards the top of the style, opening at the same time by their face, so as to let this seed drop out." All this commotion is caused by the elongation of

FIG. 622.—NASTURTIUM (*Tropæolum majus*).
A tripartite schizocarp.

FIG. 623.—BLOOD-RED CRANESBILL (*Geranium sanguineum*).
A quinquepartite schizocarp, or sling-fruit.

Photo by] [*E. Step.*

FIG. 624.—TURKEY OAK (*Quercus cerris*).

The leaves are longer and more sharply lobed than in our native Oak. The acorn-cups are covered with moss-like scales. The acorns do not ripen until their second year. A native of SOUTHERN EUROPE and the LEVANT.

FIG. 625.—POPLAR (*Populus*).

Part of fruiting catkin discharging its seeds, which support a tuft of fine silky hairs which assist dispersion.

the axis of the style *after* its five-partite outer layer (to the base of which the carpels are attached) has ceased to grow. A state of great tension is thus produced, and when the splitting takes place the carpels are actually pulled out by the roots, whereupon they roll up upon themselves as though frightened at what they have done. In the Marsh-cranesbill (*G. palustre*) the contraction is so violent that the seeds are hurled to a considerable distance.

A minute description of the external forms and subsidiary appendages of the *seeds* of plants hardly falls within the scope of the present work. The testa, or outer integument, may be smooth, as in the Bitter Cucumber (*Citrullus colocynthis*); reticulated, as in Larkspur (*Delphinium*, fig. 593); papillose, as in the Corn-cockle (*Lychnis githago*, fig. 626); ridged, as in the Rangoon Creeper (*Quisqualis indica*, fig. 629); or woolly, as in the Brazilian climbing shrub, *Trigonia villosa* (fig. 633). The seed of *Leptodermis lanceolata* (fig. 632), a Bengalese evergreen shrub, is enclosed in a reticulated sac of endocarp; while others are more or less enveloped in a remarkable appendage known as the *arillus*, which springs from their point of attachment to the placenta. The arillus is split into long silky hairs in the Willow (*Salix*); in the Nutmeg-tree (*Myristica moschata*) it consists of a dry flocculent coat (from which the mace of commerce is obtained); and in the Common Yew (*Taxus baccata*) it is succulent. The manner in which the aril of the Yew grows up around the seed is shown in fig. 631. Winged seeds are common in the Gymnosperms, and are borne on scales, which are hence called *ovuliferous scales*. The Scots Pine (*Pinus sylvestris*) furnishes a ready example. On a dry breezy day the cones open with a crackling sound and set free the seeds, which fly twirling

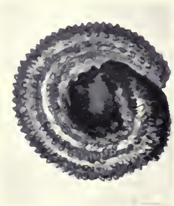

FIG. 626.—CORN-COCKLE (*Lychnis githago*).

Papillose seed.

FIG. 627.—LARKSPUR (*Delphinium*).

A reticulated seed.

FIG. 628.—SYCAMORE (*Acer pseudo-platenus*).

Samaras or bipartite schizocarp.

Fig. 629.—Rangoon Creeper (*Quisqualis indica*).

Ridged seed.

Fig. 630.—Hop Hornbeam (*Ostrya carpinifolia*).

Female catkin, and one involucre opened to show the seed.

through the air. It is impossible to open a pine-cone before its time without hacking it to pieces, and yet the mechanism by which the opening is effected naturally is very simple. The central column or stalk to which the scales are attached begins to grow, and this has the effect of separating all the scales. The wing of the seed is an upper layer of the scale, from which it becomes detached when the seed is ripe. In a breeze sufficiently strong to pick them from between the scales of the cone, the seeds go spinning through the air to a distance of eighty or a hundred yards. In the Hop Hornbeam (*Ostrya carpinifolia*) the seeds are contained in inflated involucres, which hang in catkin-like clusters from the branch, and are readily borne about by the wind (fig. 630). In the Hornbeam (*Carpinus betulus*) the involucre is very large and three-lobed. In the Birch (*Betula alba*) the seeds, to a great number, are borne in cylindrical cones, the scales of which loosen in dry weather to set them free. They are quite small, but each is provided with a pair of thin wings, upon which they flutter away from the tree like a swarm of tiny flies—which indeed they closely resemble. So abundant is this seed-fall that where birch trees are plentiful the ground around them appears to be covered with a thick coating of bran.

The seeds of the Willow-herb (*Epilobium*) and some other plants are

Fig. 631.—Yew (*Taxus baccata*).

Fruiting shoot showing development of the arillus. (*a*) Female flower surrounded by scale-like bracts. (*b*) A later stage: the arillus (*r*) growing up around the seed. (*c*) A ripe seed surrounded by the fleshy red arillus.

furnished with hairy coronets which assist dispersion; while those of the Poplar and Willow (*Populus*, fig. 625, and *Salix*) are provided with a silky fluff, which subserves the same purpose. Myriads of such seeds get stuck in the soft muddy banks of rivers, where they are sucked into the soil and quickly germinate. Much the same happens in the case of the Cotton-grasses (*Eriophorum*), where the long silky hairs that represented the perianth at flowering time (see fig. 557) remain attached to the fruit and entirely surround it. When they have been carried off by the wind and sink among the sphagnum and other marsh-plants, the delicate filaments get clogged with moisture which at once fixes the seed in a suitable situation for the future plant and sets up the right conditions for germination.

FIG. 633.—*Trigonia villosa.*

Seed covered with long woolly hairs.

FIG. 632.—*Leptodermis lanceolata*

An evergreen of Bengal. A seed enclosed in reticulated sac of endocarp.

Some seeds appear to be designed specially to impose upon animals and induce them to help in the work of dispersion. Among our smaller herbs some, like Cow-wheat (*Melampyrum*), produce seeds that closely resemble the cocoons of ants—the so-called "ants'-eggs"—and these have been seen to be picked up by ants and carried away to their nests, where, of course, they germinate. But even birds are similarly imposed upon. In the case of a grain-eating bird a seed eaten and passed through the grinding apparatus known as the gizzard would have little chance of ever escaping and germinating; but with insectivorous birds the conditions are different. A seed that resembled a beetle or a small caterpillar would form an attraction to such a bird, and when swallowed would have every chance of passing uninjured through the digestive tract and being voided at some distance from the shrub upon which it was eaten. *Biserrula pelecinus* produces a seed-pod that closely resembles a centipede; *Martynia diandra* has a seed which looks like a beetle with long antennæ; the seeds of the Castor-oil plants (*Ricinus*) are like swollen ticks, and those of *Jatropha* are exactly like the upper side of a beetle.

FIG. 634.—YEW.

Section through ripe seed and arillus.

Photo by] [E. Step.

Fig. 635.—Austrian Pine (*Pinus laricio*, var. *austriaca*).

In general similar to the Scots Pine, but with much longer leaves and larger cones, which are almost horizontal on the shoot. CENTRAL AND SOUTHERN EUROPE, and WESTERN ASIA.

CHAPTER XIV

HIDDEN MARRIAGES

"'Twas a most secret marriage."
"I pray you tell me of it."

Old Play.

WE have already glanced briefly at the phenomenon of reproduction by spores, and cited examples from the principal groups of the Cryptogamia—the so-called Flowerless Plants—but these plants are so numerous, and they are divided into so many classes and orders, each with its own particular variation of the reproductive process, that a rather fuller treatment of this phase of their economy seems called for. Though none of them produces the petals and sepals which to the public eye constitute the sole claim to the title of flower, and though in some there is not the

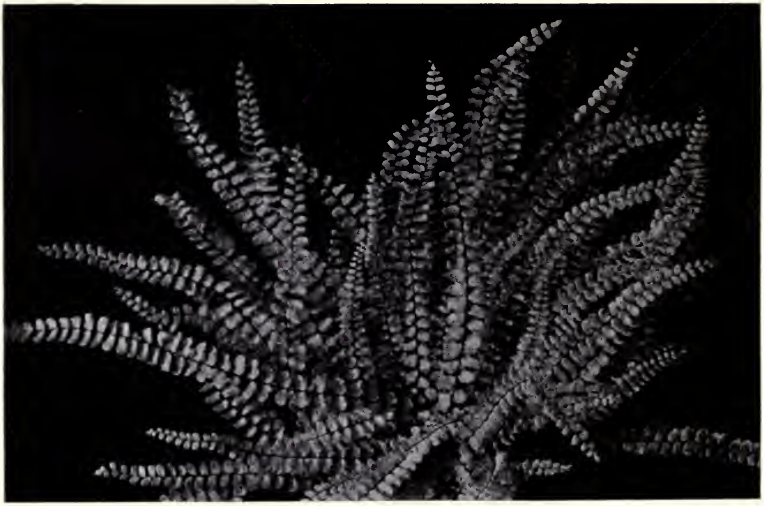

Photo by] [*E. Step.*

FIG. 636.—MAIDENHAIR SPLEENWORT (*Asplenium trichomanes*).
One of the prettiest of our ferns. Common on rocks and old walls in some districts.

faintest approach to a sexual union, the term "flowerless" as applied to the entire division of these plants is somewhat inappropriate and misleading. In many of the groups the essential organs of Phanerogams are represented by *antherids* and *archegones*, and the female element has to be fertilized by the male before a true embryo can be formed.

Until recent years the term *spore* was made to do duty in this division as the name for bodies of widely differing values, and the result has been that much confusion is caused in the minds of students. To-day botanists proceed upon the more sensible plan of giving distinctive names to the body resulting from special methods of fertilization, in harmony with those used for Phanerogams, restricting the use of *spore* to those propagative bodies that are produced without fertilization. We shall adopt this terminology in the main here.

The vast majority of the Cryptogamic Plants are composed entirely of cellular tissue. Scalariform tracheides are the most frequent form of thickening in the *xylem*, and sieve-tubes occur commonly in the *phloem*, but true vessels formed by the union of cells are rare.

Fig. 637.—Hard Fern (*Lomaria spicant*).
(*a*) Barren fronds. (*b*) Fertile frond.

Respecting the diversity in the foliar organs of the Vascular Cryptogams, Messrs. Bennett and Murray have given in a paragraph a clear view of the principal types: "The size and form of the leaves are extremely various. In *Lycopodium*, *Selaginella*, and some other genera, they are very small, unsegmented, and lanceolate, not unlike those of mosses, and form a dense imbricated clothing to the stem; in *Psilotum* they are altogether rudimentary; in the Equisetaceæ they are reduced to

FIG. 638.—MALE FERN.
A pinnule, or lobe of a pinna. The roundish scales are indusia covering the sori.

divisions or teeth of a membranous sheath; in *Isoëtes* (Selaginellaceæ), *Pilularia* (Rhizocarpeæ), and *Phylloglossum* (Lycopodiaceæ) they are long, narrow, and awl-shaped. In some ferns the barren and fertile leaves differ from one another in appearance and especially in the degree of division of the lamina. In *Salvinia* they are of two kinds, one floating on the surface of the water and entire; the other submerged, very finely divided, and performing the functions of a root; in *Azolla* (Rhizocarpeæ) they are floating and bilobed. In some genera of Filices and their allies the leaves are quite entire; in the Hymenophylleæ they are very delicate, consisting of only a single layer of cells, and in the smaller species closely resemble those of the foliose Hepaticæ; while in most ferns they are of considerable (in the tree-ferns of gigantic) size, with well-marked petiole, rachis, and lamina, and distinguished by the great extent to which the lamina is divided. In most cases (except the Hymenophyllaceæ) they are abundantly provided with *stomates.* The tissue beneath the epiderm consists of a parenchymatous mesophyll containing abundance of chlorophyll, the portion of which adjacent to the upper epiderm is frequently developed as palisade-parenchyme. This mesophyll is permeated by 'vascular' bundles or veins, which branch off from the cauline bundles, and are distinguished in the majority of ferns by their dichotomous mode of branching, in contrast to the reticulate anastomosing in Dicotyledons, and the parallel arrangement in most Monocotyledons. Among Gymnosperms a similar arrangement is presented by *Salisburia* and *Stangeria.* The floral metamorphosis of the leaves of Flowering Plants does not occur in Vascular Cryptogams, nor their special agglomeration round the organs of reproduction as in Mosses."

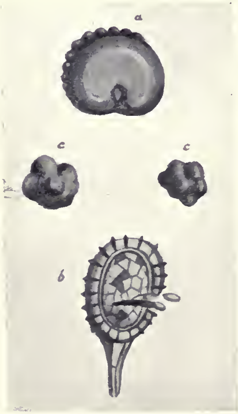

FIG. 639.—MALE FERN.
(*a*) A sorus covered by its indusium. (*b*) A sporange splitting to set free the spores (*cc*).

The spore-case (*sporange*) varies greatly in the different families, and is variously grouped, but there is more uniformity in the origin of the spore itself, which is produced much in the same way as the pollen-grain of Flowering Plants. A single cell, or group of cells, shows by the nature of its contents at an early period that it differs from the surrounding cellular tissue. It is known as

Photo by] [*E. Step.*

FIG. 640.—MALE FERN (*Nephrodium filix-mas*).

So called from its robust habit of growth. One of the most familiar of our woodland and hedgerow ferns.

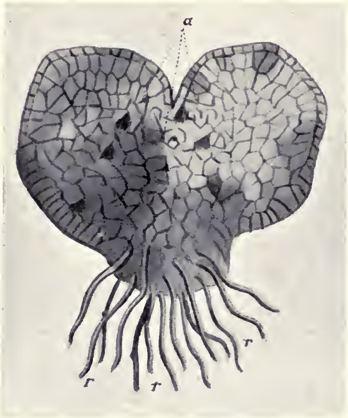

Fig. 641.—A Prothallium.

The scale-like body that results from the germination of a fern-spore. (*a*) Archegonia. (*r*) Rootlets.

the *archespore*, and from it is developed the *sporogenous tissue*, which divides and subdivides into the mother-cells from which the spores originate.

The Vascular Cryptogams (Pteridophyta) are divided into the following Classes and Orders :—

Pteridophyta.

Class	Order
I. Filicinæ	1. Filices, or Ferns.
	2. Hydropterideæ, or Water-ferns.
II. Equisetinæ	3. Equisetaceæ, or Horse-tails
III. Lycopodinæ	4. Lycopodiaceæ, or Club Mosses.
	5. Selaginellaceæ, or Selaginellas and Quill-worts.

The Order Filices or Ferns is the best-known of all the Cryptogams and most of its families have been well worked out. They are chiefly perennial herbs (very few annual), though some have shrubby stems or root-stocks, and the tree-ferns are arborescent. Their leaves, or fronds, may be simple, as in the case of the Common Hartstongue (*Scolopendrium vulgare*, finely subdivided like those of the Bracken (*Pteris aquilina*), or divided to any intermediate extent. The sporanges are borne in clusters (*sori*) of various kinds on the back or the margins of the frond, and are usually placed above a vascular bundle. The sorus is often protected by an *indusium*, which is an outgrowth from the epiderm and may be two-valved, cup-shaped, linear, hood-like, buckler-shaped, kidney-shaped, or a continuation of the frond margin. In some species the sori are produced on special fronds, which may differ in appearance from the barren fronds, as is the case with our Hard Fern (*Lomaria spicant*, fig. 637) and Parsley Fern (*Cryptogramme crispa*).

Fig. 642.—Fern-spores Germinating.

The first figure shows the shoot with rootlet bursting through the exospore. The second shows a more advanced stage, and the division of cells to form the prothallium.

In germination the exospore bursts and

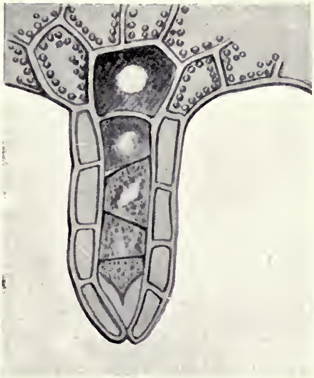

FIG. 643.—AN ARCHEGONIUM.

An organ on the under side of the prothallium in which, after fertilization, the young fern-bud is produced.

the contents by growth and division rapidly develop into a minute green heart-shaped scale (*prothallium*), with a depression of the anterior margin, in which the growing point is seated. The prothallium as a whole consists of a single layer of cells, but behind the growing point a cushion of several layers is formed, from one part of which root-hairs are produced. On a portion of the cushion clear of root-hairs the archegones will be found, and among the root-hairs or on the margins are the antherids. *Cystopteris fragilis* produces prothallia of two kinds, a smaller bearing antherids only, and a larger bearing both antherids and archegones. The prothallia of *Gymnogramme* bear antherids at first and archegones appear later (fig. 641). Each antherid contains comparatively few antherozoids, each being ribbon-shaped, coiled three or four times, with a number of fine cilia at the fore end. The archegones have a curved neck with a canal leading to the oosphere. The canal is formed by the breaking up of a central row of cells whose walls and contents dissolve into mucilage, which is expelled and serves to retain the antherozoids, which then make their way into the canal, some of them reaching the oosphere and fertilizing it. Only one archegone on a prothallium is fertilized; and on many prothallia no fertilization takes place. In some varieties of *Athyrium filix-fœmina* and *Aspidium angulare* prothallia bearing normal antherids and archegones are produced on the fronds. The phenomenon is known as *apospory* or suppression of the asexual generation. Certain species of *Asplenium* and *Cystopteris* produce buds on the fronds, which grow into little plants without any fertilization.

FIG. 644.—AN ANTHERIDIUM.

Antherozoids escaping.

In Polypodiaceæ, which comprises most of our native genera, the sporanges have foot-stalks; in all or nearly all the other orders they are sessile. Each sporange has originated in a single cell of the epiderm. It is a round, oval, or pear-shaped capsule, and when mature the walls

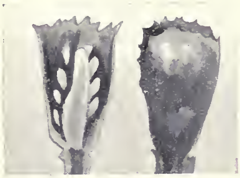

FIG. 645.—CUP-SHAPED INDUSIUM OF FILMY FERN (*Hymenophyllum*), and the same in section.

consist of a single layer of cells. A longitudinal row of these cells, known collectively as the *annulus*, have thickened borders. From two to four others, known as *lip-cells*, have lignified walls; it is between these lip-cells that the dehiscence or rupture of the sporange begins. This is brought about by the drying and consequent unequal contraction of the cells of the annulus, which pulls the lip-cells apart; following their separation the sporange splits across and scatters the spores. The annulus does not form a complete ring in this order. Frequently from the foot-stalk of the sporange in Polypodiaceæ there is a hair-like outgrowth —a *paraphyse.* There are normally sixty-four spores in each sporange of this order, produced in the usual way by division of the archespore into mother-cells and subdivision of each of these into four spores.

In the Family Hymenophylleæ (Filmy Ferns) there is usually a creeping stem, and the fronds are very thin and translucent, the mesophyll consisting of one layer of cells only. The indusium is cup-shaped (fig. 645). The fertile vein projects beyond the edge of the frond, and a prolongation of it called the *columel* extends into the centre of the indusium, where the sporanges are borne spirally upon it. Instead of being seated on a footstalk as in Polypodiaceæ, they are attached to the columel by one of the two convex faces. The annulus is complete. The spore undergoes division into three cells before the rupture of the exospore, two of which soon cease to develop, but the third increases greatly in length, divides transversely, and puts out thread-like lateral shoots, from which flat prothallia are produced. As will be seen later, this form of prothallium approximates to the *protoneme* of Mosses, and as the order contains the simplest of the ferns it may be that it marks a stage in their evolution from the Mosses. The antherids will be found about the middle of these filaments, the archegones at the extremity. The phenomenon of *apogamy*—the substitution of a vegetative for a sexual mode of reproduction—occurs frequently in this order, and it is thought may be quite usual in certain species. Little foot-stalks (*sterigmas*) produced from the prothallium bear bulbils of a few cells which slowly germinate and grow into sporophytes without any process of fertilization. All the species in this order are of exceedingly delicate texture, and can only endure a moist warm atmosphere. The fronds are without stomata.

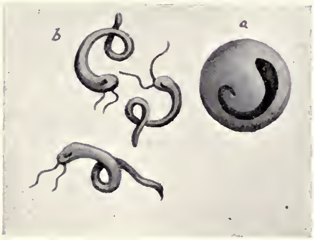

FIG. 646.—ANTHEROZOIDS.

(*a*) Antherozoid in mother-cell. (*b*) Antherozoids escaped from cells.

Photo by] [*E. Step.*

FIG. 647.—PRICKLY BUCKLER FERN (*Nephrodium spinulosum*).

A common fern of graceful habit in old woods where the leaf-mould is deep.

The Order Osmundaceæ is deficient in the indusium, and the annulus is very greatly modified. The sporanges are borne on certain of the pinnules of the fertile frond of which the mesophyll is partly or entirely undeveloped, so that only the sporanges thickly clustered round the midrib are visible. The sporange is not symmetrical; in some species it is shortly stalked, in others sessile. The incomplete contracted annulus is near the apex on one side, and at a little distance from this the sporange splits vertically. The prothallium exhibits a tendency to become diœcious; sometimes all the spores from one sporange produce prothallia that bear antherids only, or archegones only. Some prothallia bear antherids first and archegones later. Often the prothallium throws out adventitious shoots, and so propagates itself vegetatively.

FIG. 648.—MOONWORT (*Botrychium lunaria*).

One branch of the frond bears the sporangia. (*a*) Closed sporanges enlarged.

In all these orders of Ferns the vernation is *circinate*, the frond and its divisions being rolled up from the apex. The genera *Ophioglossum* and *Botrychium*, often included in the Class Filices, differ from them in this respect among other differences, their fronds in the incipient stage being folded from the sides. These genera are, therefore, elevated into a separate class, the Ophioglossaceæ. The upright stem produces only a few leathery fronds, often only one frond. The rachis of the frond is furnished at the base with scaly outgrowths, like the so-called stipules found in a tropical order of ferns, the Marattiaceæ. When the rachis has attained half its final length, it forks, one branch developing into a smooth leafy expansion, furnished with stomates on both surfaces, the other becoming the sporophyll bearing the closed sporanges. These fronds are of very slow growth; in our Moonwort (*Botrychium lunaria*, fig. 648), for example, they do not appear above ground until four years after the formation of the bud, their expansion marking their fifth year. The root-stocks are poorly developed, bearing thick fleshy root-

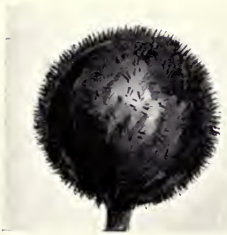

Fig. 649.—Pillwort.
One of the sporocarps enlarged.

fibres without root-hairs; those of Adders-tongue (*Ophioglossum vulgatum*) put forth adventitious buds.

As we have seen, in the Polypodiaceæ each sporange is formed from a single cell of the epiderm; but in the Ophioglossaceæ a single sporange is the product of a group of specialized cells beneath the epiderm, and is therefore more homologous to an entire sorus in the true ferns. Its walls, several cells thick, are products of the epiderm, and are still furnished with stomates. Their full development occupies a year, and they are then globose in shape, have no annulus, and split transversely to liberate the minute squarish spores. Instead of germinating on the surface as do the spores of ferns, these appear to need burial before developing into prothallia; at least, so far as it has been observed, the prothallium is a subterranean tuberous body, devoid of chlorophyll, and bearing archegones and antherids seated in pits or projections of the upper surface—the former in *Botrychium*, the latter in *Ophioglossum*. These organs and their contents are very similar to those of ferns.

Fig. 650.—Pillwort (*Pilularia globulifera*).
Portion of plant showing sporocarps at base of the fronds.

The Order Hydropterideæ, or Water-ferns, is a small group consisting of few genera and species, with a solitary British representative, the Pillwort (*Pilularia globulifera*, fig. 650). They are aquatic or semi-aquatic plants, and the spore-cases (*sporocarps*) are borne at the base of the leaves. The Pillwort, which grows on the margins of lakes and ponds where it is submerged in winter and exposed in summer, consists of a creeping stem from the under side of which are produced at intervals small tufts of fibrous roots, and from the upper surface erect, cylindrical, bristle-like bright green leaves, in whose axils are the short-stalked, globular sporocarps. These sporocarps, which have a hard shell of sclerenchyma, are divided into four compartments, and in each of these, springing from the broadest face of the wall, is a cushion analogous to the placenta in the ovary of

Phanerogams, to which are attached megasporanges containing one large spore, and microsporanges containing a large number of small spores. The sporanges attached to each placenta constitute a *sorus*. The megasporanges are chiefly the lower bodies of the sorus, and although at an early stage of development the contents of each becomes broken up into sixty-four cells, only one of these becomes mature and develops into a megaspore. Each microsporange, however, produces sixty-four microspores. The megaspore becomes invested, first, in a hard brown coat, but later this receives an outer gelatinous coat—the *epispore*—consisting of three layers, except at the apex of the spore where the two outer layers are wanting, and the apex in consequence lies in a cavity whose walls are the two outer layers of the epispore. At the apex the protoplasm breaks up into several cells, which are not at first invested by cellulose, but finally form a tissue containing a little chlorophyll and developing into a *prothallium*. The growth of the latter causes it to break through the apical layers of the megaspore and project as a spherical body into the cavity previously referred to. In the centre of the prothallium there is a large cell (afterwards the *archegone*) covered by four other cells, from which arise the neck and stigmatic cells of the *archegone*. The greater portion of the protoplasm of the archegone contracts into an *oosphere* (fig. 643).

FIG. 651.—PILLWORT (*Pilularia globulifera*).
A diagrammatic section of one of the sporocarps, showing clusters of megasporanges and microsporanges in each of the four compartments.

Each microspore divides into three cells, of which one becomes a sterile prothallium, but each of the other two divides into sixteen cells, and the nucleus of each of these becomes an *antherozoid*—a rod-like body coiled four or five times, to which are attached a few cilia, by whose vibration the body is impelled. The antherozoids find their way to the funnel above the apex of the megaspore, and getting entrance by the neck of the archegone, reach the *oosphere* and fertilize it. The result of this fertilization is the development of the oosphere into an *oosperm*, which becomes invested with cellulose and undergoes segmentation to form the embryo with its root, stem, first leaf, and an attachment (foot) to the prothallium. Thus arises the *sporophyte* like that by which the sporocarps were produced. The "leaves" of Pilularia consist only of the petiole, no lamina being developed. In the early stages these leaves are coiled up from the apex to the base,

Photo by] [*E. Step.*

FIG. 652.—SEA FERN (*Asplenium marinum*).

A fern with thick, leathery fronds, that grows only on maritime rocks, and chiefly over the entrances to caves and recesses.

and gradually unroll as they grow to their full size.

Marsilea, which grows in similar situations to *Pilularia*, but does not occur in this country, has a quatrefoil leaf, the segments of which fold together towards night and expand again in the morning, thus agreeing in its sensitiveness to light with the leaves of *Oxalis* and other trefoils among Phanerogams.

FIG. 653.—PILLWORT.

One of the microspores.

The Class Equisetinæ, or Horsetails, consists of the order Equisetaceæ and a single genus, *Equisetum*, of erect, hollow-stemmed, jointed, and leafless plants. The leaves are represented by the teeth of the sheath in which each node terminates. The branches, where present, are jointed, but, unlike the stem, are solid, and spring from the base of the sheath. The stems are ridged and grooved longitudinally, each species having a characteristic number and form of ridges, and the sheath-teeth correspond with them. In some species there are barren and fertile stems, the latter being without branches and almost or entirely devoid of chlorophyll. Silica is deposited abundantly in the cell-walls of the cuticle, and in consequence several species have long been used under the name of Dutch Rushes for scouring and polishing metal. So abundant is this mineral that all the vegetable matter may be burnt out without affecting the form of the structure. Stems and branches alike are provided with stomates and chlorophyll, and can carry on the functions of the absent leaves.

The fertile stems bear at their extremity a cone-like spike of sporange-bearing discs. These discs or scales are the sporophylls; they are many-sided (usually hexagonal), supported on a central foot-stalk, and bear on the under side from five to ten sporanges. The sporophylls are arranged in whorls corresponding with the sheaths, and probably, like them, are modified leaves. Between the uppermost developed sheath and the lowest whorl of sporophylls there is an undeveloped sheath forming an involucre to the fruit-spike. The sporange has no annulus, and opens by a longitudinal fissure to set free the spherical spores, which differ from those of ferns in having four coats, the outer of which splits up spirally into four strips with broader ends, known as *elaters* (fig. 654). These elaters are highly hygroscopic, and

FIG. 654.—HORSETAIL (*Equisetum*).

(*a*) Spore with elaters coiled around it. (*b*) The same with the elaters extended.

TOOTHED CEANOTHUS (*Ceanothus dentatus*).

A representative of a large genus of American shrubs, of which several have found favour in our gardens as wall plants. The minute flowers are borne in globular clusters and are either some shade of blue or white. The present species has small, nearly smooth leaves with toothed edges. It is a native of California and Oregon.

as they dry they stretch out from the spore; but on the air becoming moist, they contract, and twist around the spore. If a slide of these spores be breathed upon and then viewed through the microscope, they will be seen to leap about as they dry. Another difference between these and fern-spores is found in their possession of chlorophyll. Fern-spores with few exceptions are devoid of this important substance, and if kept dry will retain their vitality, in some species, for several years; but chlorophyll will not keep, and unless the spores of Equisetaceæ are placed under such conditions as to induce germination, they perish within a few days of their dispersion. If the proper conditions are present, germination is very rapid—a matter of a few hours only.

The prothallia are commonly diœcious—that is, the archegones are borne on a different prothallium from that which bears the antherids, but a few organs of the opposite sex are often produced at a later date. They are very much longer than broad, and the newest portion is much broader than the old. The less vigorous prothallia are male, the more vigorous female; both are lobed at their anterior margin, but the lobes of the females are long strap-shaped extensions. Both forms are found in

Photo by] [*E. Step.*

FIG. 655.—PILLWORT (*Pilularia globulifera*).

In favourable situations this plant grows in such quantities that it might be mistaken for a kind of grass. portion of such a colony is here shown.

close proximity, so that the antherozoids can easily pass to the archegones by the aid of the moisture that condenses upon the prothallium. The sexual organs and their contents are very similar to those of the ferns. After fertilization of the oosperm and formation of the embryo, minute stems are produced, differing in little except stature from the mature stems, and an underground perennial rhizome is also developed. In some species

Photo by] [*E. Step.*

FIG. 656.—FIELD HORSETAIL (*Equisetum arvense*).

Fertile stems bearing the cones, which appear in advance of the much taller and branched barren stems. The latter are shown in Fig. 657 on the opposite page.

there is a vegetative propagation by the formation of tubers on the rhizome and the bases of the stems, in which starch, etc., is stored.

The Class Lycopodinæ consists of the Orders Lycopodiaceæ and Selaginellaceæ. In the former the typical genus *Lycopodium* is represented in Britain by five species of Club Mosses, so-called because in some species the sporophylls are crowded together on special erect branches which, from being stouter than the stem immediately below them, have a club-like

Photo by] [*E. Step.*

FIG. 657.—FIELD HORSETAIL (*Equisetum arvense*).

The barren fronds which grow to a height of two or three feet present a strong contrast to the fertile spikes shown on the previous page. Here there are whorls of long, jointed branches from base to summit. NORTH EUROPE, NORTH ASIA, NORTH AFRICA, the HIMALAYA, and NORTH AMERICA.

appearance. There is usually a rigid wiry stem which forks repeatedly, and is covered with overlapping small undivided leaves, which either invest the stem all round or are arranged in from two to six rows. Some exotic species have erect stems, and of these certain tropical ones are stout and shrubby. Several have even become climbers, and a few have given up their connection with the earth and grow only upon trees (*epiphytic*). The kidney-shaped sporange is attached by a short stout foot-stalk to the base of the upper side of the sporophyll or leaf. It is one-celled, and

Photo by] [*E. Step.*

FIG. 658.—MARSH CLUB MOSS (*Lycopodium inundatum*).

This species is less noticeable than the others, from its habit of keeping close to the soil in marshy places, and from the shortness of its stems which die back in winter. The fertile branches are erect and end in slightly thickened cones, which are evident in summer.

splits when ripe into two valves. The numerous spores are more or less rounded, marked with three radiating lines on the upper side, and on germinating, the exospore splits along these lines into three valves, from which the endospore projects and grows into the germinating filament. A transverse wall (*septum*) develops across the filament and divides it into a small basal cell and a larger apical cell. No further change occurs in the basal cell, but the apical one divides into two series of cells, and each of these cells afterwards divides into two. Each cell is provided with a few grains of chlorophyll, except in *Lycopodium annotinum*, whose prothallium, being buried, is destitute of chlorophyll, and yellowish white in colour. Archegones and antherids are produced in close proximity upon the upper side of the prothallium. The antherozoids are minute, consisting of only a few coils and, so far as at present observed, a couple of cilia. Apparently only one archegone is fertilized on each prothallium. Very little is known of the early stages of growth in the sporophyte, but there is reason for believing that it follows a similar course to that of the Ferns.

FIG. 659.—LESSER ALPINE CLUB MOSS (*Selaginella selaginoides*).

Microsporange to the right, and megasporange to the left of stem.

Under the name of Lycopodium powder the spores have been used in mass for coating pills, being damp proof; and in pyrotechny they are known as Vegetable Brimstone. They also have their use in dyeing. The Club Mosses, with the exception of the Marsh Club Moss (*Lycopodium inundatum*), are found on elevated moorlands, chiefly in the north; the Marsh species comes farther south, and is found on swampy heaths and around bogs. It forms creeping branched shoots of only a few inches in length, and some of the branches take a vertical direction of growth. These are quite stout and bear sporophylls. The Common Club Moss (*Lycopodium clavatum*) extends for several feet, and throws up numerous erect branches with the clubbed extremity which gives the popular and expressive name to the group. But the club appearance is not so much due to any real greater stoutness of the upper part as to the fact that the leaves for a short distance below are less spreading, and have their upper faces more closely pressed to the stem. This gives a more slender appearance to this part, and enhances the slight advantage the club has in circumference. The Fir Club Moss (*Lycopodium selago*) is a conspicuous object on northern mountains, though it also occurs sparingly upon high

FIG. 660.—COMMON CLUB MOSS (*Lycopodium clavatum*).

(*s*) Spikes or cones, (*a*) Fertile leaf or sporophyll with sporange, (*sp*) Spore.

ground as far south as Cornwall and Sussex. It has been likened to a fir-tree in miniature, but it might easily be mistaken for an early condition of a coniferous seedling. It has little of the clubbed character, and it does not creep. All its shoots take an upward direction, and it therefore forms bushy clumps. In common with those of several other species, some of the lower leaves of the cone produce buds instead of sporanges, and these separate and fall to the ground, where they develop directly into plants without the intervention of the prothallium stage.

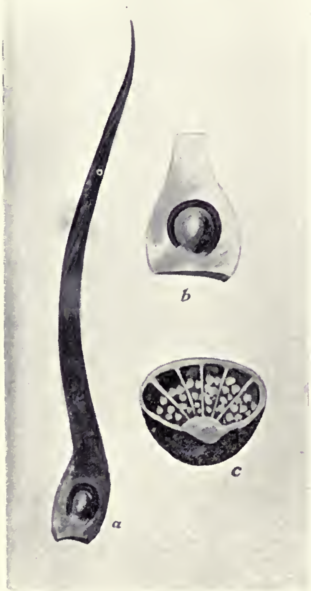

Fig. 661.—Quillwort (*Isoëtes lacustris*).

(*a*) Leaf with sporange in base. (*b*) Base of leaf on larger scale. (*c*) Transverse section through ripe sporange, showing spores.

The Order Selaginellaceæ consists of the two genera *Selaginella* and *Isoëtes*, both of which are represented by British species. Both megaspores and microspores are produced, but in a manner different from those of the Water-ferns, and the prothallium is quite devoid of chlorophyll. Our only native species of *Selaginella* is the Lesser Alpine Club Moss (*Selaginella selaginoides*), a small moss-like plant inhabiting bogs and marshes. Several of the numerous exotic species are well known in our conservatories and greenhouses. *S. selaginoides* has creeping stems only a few inches long and completely clothed all round with overlapping lance-shaped leaves. A few branches are of more erect growth, and the leaves of these are longer, more closely pressed to the stem, which ends in a stouter scaly cone about an inch long. This cone is the part of the plant that bears the sporangia, and the leaf-like scales containing them are known as *sporophylls*. The sporange, on a short stalk, springs from the stem just above the base of the sporophyll. Those in the lower sporophylls are spherical and megasporanges; in the upper sporophylls, there are flattened microsporanges (fig. 659). Each megasporange contains only three or four megaspores, which are set free by the splitting of the sporange into three or four valves; the microsporanges are only two-valved, and their contents are minute and numerous. Both kinds of spores are invested by three coats—*endospore*, *exospore*, and *epispore*. The growth of the prothallium within the apical portion of the megaspore proceeds *pari passu* with the development of the larger body, whilst the protoplasm which

Photo by] [*E. Step.*

FIG. 662.—GREAT HORSETAIL (*Equisetum maximum*).

This is a much stouter and taller plant than the other native species, attaining to a height of six feet or more, the white stem with a diameter of half an inch. The fertile stem is even stouter, but seldom more than a foot in length.
EUROPE, NORTH AND WEST ASIA, NORTH AFRICA, and NORTH AMERICA.

fills the greater portion of the spore is being converted into a cellular tissue variously designated the *secondary prothallium* and *endosperm*. The archegones are produced on the surface of the prothallium, some of them being already present when the latter is extruded from the megaspore. There is a neck with its canal leading to the interior with its oosphere. The microspores are coloured red or orange, and although development begins in the sporangia throughout the winter, they appear to make no advance upon their condition when set free. In spring, however, fresh activity is manifested, and one portion of the protoplasm becomes an antherid, some of whose numerous cells contain coiled antherozoids with two long cilia attached to the tapering forepart. For half an hour or so after the rupture of the mother-cells the antherozoids are endowed with motion, and find their way by the neck canal to the oosphere. Thus fertilized, the oosphere develops into an embryo with a pair of primary leaves, a root, and a foot or organ of absorption.

FIG. 663.—HAIR MOSS (*Polytrichum commune*).
(*aa*) Antheridia. (*bb*) Hairs and sterile filaments (*paraphyses*).

The Prickly Club Moss (*Selaginella selaginoides*) is found in swampy situations, chiefly on mountain-sides, not farther south than Wales. Its slender stem is not more than six inches in length. It creeps along the ground, but the fertile branches which bear the sporanges rise erectly, and end in a cone with larger leaves (sporophylls).

The genus *Isoëtes* is represented in this country by a single species, the Quillwort (*Isoëtes lacustris*). Though the plants of Quillwort and Selaginella are as unlike as possible, the developmental history of the embryo is very similar to what we have just described. The Quillwort grows at the bottom of lakes among the mountains of the northern half of Britain, and its stem takes the form of a corm whose increase is not so much in length as in diameter. The leaves are awl-shaped, with broad overlapping bases which entirely hide the corm and in which the sporanges are produced. The outer leaves bear megasporanges, the inner ones microsporanges (fig. 661). A second species, *I. hystrix*, found in Guernsey, is of terrestrial habit, growing on sandy soil which is only occasionally inundated. In this Order the prothallium is not nearly so precocious as in *Selaginella*. The megasporange decays and sets free the megaspore, and it is not until several weeks later that the contents become converted into cellular tissue. Then the epispore breaks up by a three-rayed fissure at its apex, and the rupture of the endospore follows, exposing part of the prothallium, which is in this case spherical.

Photo by] [*E. Step.*

FIG. 664.—SCREW MOSS (*Tortula subulata*).

A moss common on wall tops and woodland banks. The curved cylindrical capsules are borne on long, bristle-like stalks, and the peristome is spirally twisted so as to resemble a screw.

An archegone appears at its apex, very similar to that of Selaginella, and if this becomes fertilized no other is produced; but in the event of failure, others appear until fertilization of one is effected. The microspores are three-sided and ultimately contain long, slender, and spirally coiled antherozoids, which taper to a fine point at each end, where numerous cilia of great length are produced. The swarming period is only a matter of a few minutes, the antherozoids finding their way to the oosphere by the neck canal as in Selaginella.

Fig 665.—Liverwort (*Marchantia polymorpha*).
With antheridial receptacles.

We now come to those Cryptogams in which the structure is entirely cellular, the first division of which is the

Bryophyta.

Class I. Musci. Mosses.
„ II. Hepaticæ. Liverworts and Scale Mosses.

In these classes we find an alternation of generations, as in the Pteridophyta, but there is a difference to be explained. Beginning with the spore, we find it to consist of a central mass of protoplasm, in which are chlorophyll-grains, etc., invested by an inner coat or endospore, and an outer coat, or exospore. On germinating, the endospore and its contents burst through the exospore and develop into a hair-like body—the *protoneme.* Side shoots from the protoneme develop into chlorophyllous scales in the Liverworts, and into leafy stems in the Mosses. These in turn bear sexual organs—archegones and antherids (figs. 665, 666).

In the protoneme of the Mosses cell-division takes place in one direction only—transversely; but as this may go on indefinitely, we have the filamentous form. Some of the cells thus formed send out lateral shoots which in turn divide transversely, so that the protoneme may be ultimately many-branched. Distinct buds are also produced which develop into wiry stems, which are clothed with two, three, or four rows of leaves. The protoneme and this leafy plant produced by it must be considered as together constituting the oophyte or sexual generation. The leaves of Mosses are never stalked, and with the exception of a line down the centre (midrib), and in most cases along the margins, consist of a single layer of cells; stomates being therefore unnecessary, the leaves have none; but the stem is often liberally provided with stomates. The midrib is not always continued to the tip of the leaf; on the other hand, in many species it extends beyond the tip as a fine hair-like point of variable length. Around the three-sided apex of the stem the leaves are more densely crowded, and these are more or less modified. They constitute the peri-

Fig. 666.—Liverwort.
With archegonial receptacle. (*a*) Cup-shaped receptacle containing gemmæ.

Photo by] [*E. Step.*

FIG. 667.—HAIR MOSS (*Polytrichum commune*).

The largest of native Mosses. It grows in large patches on heaths and moors. The rather angular capsule is covered before ripening by a thatch-like cap (*calypter*) of long silky scales. This is thrown off by the growth of the capsule.

chæte, popularly but incorrectly known as the "flower" of the Moss. These "flowers" are of three kinds: first, containing antherids only; second, containing archegones only; and third, containing both antherids and archegones. Sometimes these occur on the same plant, in some species on different plants. Where the sexes are thus separated the plant is said to be *diœcious*, where the two sexes are on the same plant the latter is *monœcious*; and when one "flower" contains both antherids and archegones it is hermaphrodite. The male flower (*perigone*) may be distinguished by its broader and thicker leaves. Among the sexual organs are a number of thread-like or club-shaped bodies known as paraphyses. The antherid when mature consists of a foot-stalk bearing a club-shaped (sometimes spherical) head, which opens at the apex or splits down the sides, freeing a large number of minute cells, in each of which is coiled a long antherozoid, tapering forwards, at which extremity it is provided with two long cilia (fig. 663). The antherozoids swim about in the mucilaginous fluid which accompanies their expulsion and make their way to the archegones. The latter consist of a swollen basal portion, in which is the oosphere, and a long, slender neck, pierced by a canal, the mouth of which is guarded until maturity by a couple of lid-cells (the *stigma*). At maturity, a quantity of mucilage being ejected from the canal, the lid-cells are forced apart, and the way is open for the entrance of the antherozoids. As a rule, only one oosphere in a "flower" is fertilized and becomes an oosperm. This develops into the sporogone or asexual generation, which, until it perishes, always remains attached to the sexual generation and is nourished by it. The growth of the sporogone ruptures the archegone transversely and stands revealed as the stalked capsule of the Moss containing the spores. The remains of the ruptured archegone become the *vagine* or sheath below the capsule, and the *calypter* or cap above it. This calypter is, as a rule, of very thin, chaffy material, and is thrown off by the expansion of the capsule, much as the similar bud-scales are thrown off by the expansion of the buds of trees and shrubs in spring. In the Common Hair Moss (*Polytrichum*) the calypter is thick and shaggy, consisting of long hair-like scales of a pale golden hue, which makes the

FIG. 668.—*Plagiochila asplenioides*, A SCALE MOSS.
The general character of these plants is here shown—the creeping stem with its delicate leaves arranged in one plane, and the terminal fruits, one intact and the other after it has burst to discharge its spores.

patches of this moss a very noticeable feature of the heaths where it grows in abundance, and often to a considerable height—for a moss, that is.

When the sporange is freed from the vagine and the calypter, we can see that it has a distinct lid or *opercule*, which is thrown off to allow the escape of the spores. When this is lifted off, the sporange will be found to have either a smooth rim around its mouth (*gymnostomous*), or it bears a *peristome*—a single or double series of slender appendages, the inner row being cilia, the outer row teeth, whose number is always some multiple of four. The peristome is hygroscopic. When the atmosphere is dry, the teeth or cilia stand away from the mouth and allow the dispersion of the spores; in damp weather they close the orifice and keep the spores dry. A very common species that exhibits this hygro-

Photo by] [*E. Step.*

FIG. 669.—TWO MOSSES.

That to the left is the very common Cord Moss (*Funaria hygrometrica*) which comes up wherever vegetable matter has been burnt on the ground. The clump to the right is the Convolute Screw Moss (*Tortula convoluta*).

metrism well under a low power of the microscope is the Cord Moss (*Funaria hygrometrica*) that forms a continuous carpet over the charred earth wherever there has been a heath fire. A better example for those who work with the pocket-lens rather than the compound microscope will be found among the Screw Mosses (*Tortula*) that cover the tops of old walls. One such is shown in fig. 664, where the comparatively long and cylindrical capsules will be seen supported on long bristle-like stalks. The teeth of the peristome are in this genus very long, and when closed they are coiled spirally. The entire peristome then presents the appearance of a reddish screw, which fact has suggested the name of Screw Moss. In *Polytrichum*, in which the teeth are short, there is another piece of mechanism to the same end. Beneath the opercule the mouth of the sporange is closed by an *epiphragm* supported on a central pillar, the *columel*, which rises from the base of the sporange. The wall of the sporange contracting in dry weather brings the epiphragm half-way up the peristome, thus allowing the spores to sift out between the teeth. In damp weather, with the elongation of the sporange, the epiphragm again comes to the base of the peristome and the orifices are closed. In the Order Phascaceæ the sporange does not dehisce at all, and the spores are only liberated by the decay of the walls. In Andreaceæ, again, there is no opercule, but four or eight slits appear in the sporange wall, from below the summit to near the base. In addition to this sexual process, Mosses may be produced vegetatively by throwing off little buds, which root and develop into perfect plants. In some of our native species this is the only method of reproduction, the sporangia never being produced.

Fig. 670.—Liverwort (*Marchantia polymorpha*).
An archegonium.

In the Liverworts and Scale Mosses we find two distinct types—a more or less flat green scale like a large fern prothallium, and a delicate plant with a well-marked differentiation into stem and leaves. Species that conform to the first type are known as Thalloid Hepatics; such as answer the second description are Foliose Hepatics. Both forms are entirely cellular, and are attached to the soil by root-hairs. The process of reproduction is similar to what we have seen in the Mosses, in that the spore gives rise to a protoneme from which the sexual generation is developed. The mode of bearing the sexual organs differs in various orders and genera. They may be produced from the growing point of the main stem or branches of the Foliose forms; in the substance or on the upper surface of the Thalloid forms, and in Marchantiaceæ on a special stalked outgrowth of the thallus, and known as the antheridiophore or the archegoniophore, according to sex (figs. 665, 666). Both organs may be produced by one plant (*monœcious*), or they may be on separate plants (*diœcious*). These sexual organs originate in little swellings, which afterwards are seated each on its own little foot-stalk. The antherid splits irregularly and sets free a number of cells, each containing a spirally coiled, ciliated antherozoid.

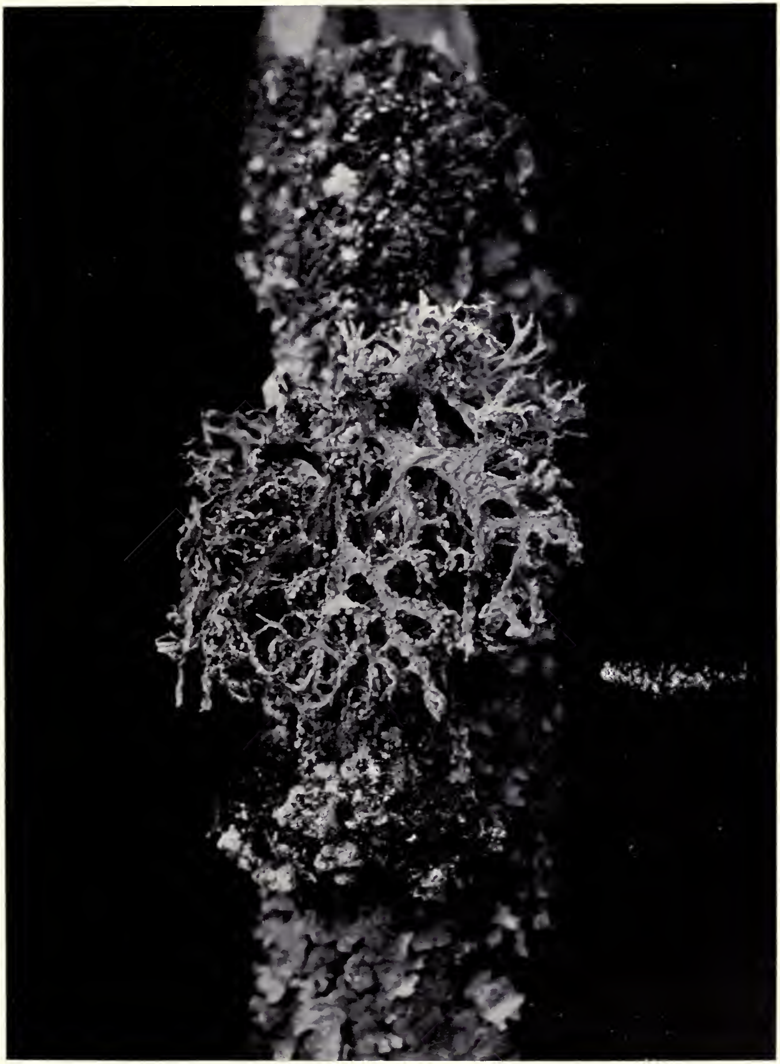

Photo by] [*E. Step.*

FIG. 671.—A LICHEN (*Evernia prunastri*).

Common on the bark and branches of trees, particularly on blackthorn and firs. Its pale greenish-grey branches are always more or less drooping.

The archegone has an enlarged lower portion containing the oosphere, and an upper neck with its canal, through which the antherozoids gain access to the oosphere. After fertilization the oosphere develops into the sporogone, usually elevated on its stalk, which carries it up through the calypter; this is the entire non-sexual generation. In *Riccia* the sporogone is immersed in the thallus. Among the spores are long attenuated cellular bodies, the *elaters*, whose walls are furnished with spirally twisted threads, which are hygrometric and cause the twisting of the elaters as they absorb or part with moisture. Their movements under this influence assist in the dispersal of the spores. The spores may be invested in one, two, or three coats, but usually two.

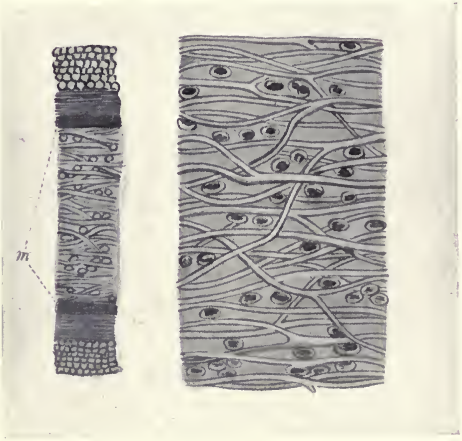

FIG. 672.—SECTIONS THROUGH LICHEN.

In the left-hand figure the loose *hyphæ* marked *m* is the gonidial layer, which is shown more highly magnified in the second figure. The round and oval forms between the *hyphæ* represent the algal elements.

The popular name Liverwort, applied to the larger and more conspicuous members of this class, is, as its Saxon termination shows, an old folk-name. The appearance of the epidermal cells and the shape of the fronds were supposed to be in little a picture of the human liver, and to indicate under the Doctrine of Signatures that it was to be used as a medicine in liver troubles. As late as the middle of the seventeenth century we find Nicholas Culpeper, who was great on Signatures, describing the Liverwort as "a singular good herb for all the diseases of the liver, both to cool and to cleanse it, and helpeth the inflammations in any part, and the yellow jaundice likewise," and "an excellent remedy for such whose livers are corrupted by surfeits, which cause their bodies to break out, for it fortifieth the liver exceedingly, and makes it impregnable." It had to be "bruised and boiled in small beer and drank," but with the happy-go-lucky methods of prescribing in his day, he omits to say whether a dose consisted of a tablespoonful or a quart. The open-air exercise involved in a search for the numerous species would probably do far more to keep the liver normal than a barrel of Culpeper's small beer in which *Marchantia polymorpha* had been boiled. More than two hundred and sixty species of the Hepaticæ are known to inhabit the British Islands, and though they are all comparatively small plants, they are in most cases characterized by great beauty and delicacy of form. The leafy Scale-mosses are of a more delicate structure than most Mosses, their leaves being filmy and almost transparent, which is due to the cells being larger and the cell-walls thinner. The stems are more addicted to creeping, and the leaves are mostly all in the same plane. They are shade and moisture-loving plants, and must be sought in the damp shade of woods, on the rocks and margins of mountain streams, the banks of ditches, the swampy borders of pools. As an example of these foliose Crystalworts we give a figure of *Plagiochila asplenioides* (fig. 668), a species that may be found growing at the base of tree trunks in moist woods. The toothed leaves are arranged pinnately along the two sides of the stem, and the fruit is borne at the extremity of the branches. As drawn, the leaves show a central division or fold, and this must not be taken for a nerve, for in all the Crystalworts the nerve, so conspicuous a feature in the leaves of Mosses and higher plants, is entirely wanting. Of the two fruits shown, that to the right has the sporange intact; that to the left has split into its four valves which spread out to release the spores.

Photo by] [*E. Step.*

FIG. 673.—BEARD MOSS (*Usnea dasypoga*).

A delicate grey Lichen that hangs in lengths of a foot or more from old forest trees.

The remaining classes of Cellular Cryptogams are grouped under the divisional name of

THALLOPHYTA.

Class I. Fungi.
„ II. Characeæ. Stoneworts.
„ III. Rhodophyceæ. Red Algæ.
„ IV. Phæophyceæ. Brown Algæ.
„ V. Chlorophyceæ. Green Algæ.
Class VI. Conjugatæ. Conjugates.
„ VII. Peridineæ. Dinoflagellates.
„ VIII. Diatomeæ. Diatoms.
„ IX. Schizophyta. Fission Plants.
„ X. Myxomycetes. Slime Fungi.

Photo by] [*E. Step.*

FIG. 674.—CUP MOSS (*Cladonia pyxidata*).

A familiar Lichen common on mossy banks. The trumpet-shaped cups spring from a small flat thallus and bear apothecia around their mouths.

The plants of the first class, the Fungi, are characterized by a total absence of chlorophyll and starch. Two distinct portions of a fungus are recognized, the vegetative or *mycele*, and the reproductive or *sporophore*. That to which we apply the term "mushroom" or "toadstool" is the sporophore; the mycele consists of a network of white threads ramifying in the vegetable humus below. Fungi have no roots, properly speaking, though the mycele fulfils their office, both as absorbers of nutriment and for purposes of attachment. As they possess no chlorophyll, they are unable to decompose carbon dioxide, and therefore have to obtain their carbon in an already organized condition. This they get from dead or decaying plants and animals or from organic products, or by attacking living organisms.

Photo by] [*E. Step.*

FIG. 675.—*Ramalina scopulorum.*

A Lichen that grows—among other places—on maritime rocks only a few inches above high-water mark. The photograph shows it growing in such a situation with a narrow channel of sea-water flowing between.

Species that perform the latter operation are classed as *parasites*; those that content themselves with organic remains are *saprophytes*. Members of either class that have the power during the whole or part of their life of performing the functions of the other class are qualified as *facultative* saprophytes or parasites, as the case may be. Another group live symbiotically with algæ, and are known as *lichen-forming fungi*—Lichens, formerly considered as a distinct subdivision of Cryptogams, being now known as compounds of fungal and algal elements (figs. 671-675).

As the Fungus is obviously the dominant partner in this joint-stock company, it is usual to treat of Lichens under the head of Fungi, but from the field naturalist's point of view it is still convenient to consider them as though they were simple organisms, and to retain their distinctive names. Many of them are among the most beautiful of our cryptogamic plants, and adorn what they grow upon, whether it be an old wall, an alpine rock, the trunk or branch of a tree, or the bare earth of moor or woodland. These differences of situation adopted by the various so-called species produce great variety of form and habit, some sitting so closely that they might be regarded as mere stains or dabs of paint. Others spread out flat branching lobes or hang as grey beards from trees, and some spread over the ground or grow up from it like miniature shrubs. Among the latter are the Reindeer Moss (*Cladonia rangiferina*, fig. 104), and the pretty Cup Mosses of the same genus (fig. 674). The Dog Lichen (*Peltigera canina*, fig. 677) spreads along the ground, forming patches five or six inches in diameter, much like a large Liverwort, but of a more leathery texture. Its names are accounted for by the fact that in former days it was considered a specific for hydrophobia. This belief may have been due, under the "Doctrine of Signatures," to the dog-tooth-like appearance of the fruits along the margin of the lobes. The herbalists called it Ground Liverwort, under the impression that it was a kind of *Marchantia*. A similar "signature" caused the prescription of the Lichen known as Lungs of Oak (*Sticta pulmonaria*) in pulmonary troubles, the pitted underside being supposed to resemble the structure of the lungs and so to indicate its suitability for mending them

FIG. 676.—POTATO-BLIGHT (*Phytophthora infestans*).

One of the Phycomyceteæ. At (*a*) the hypha is seen growing out through a stomate of Potato leaf and bearing sporanges. (*b*) Zoospores. (*c*) A germinating zoospore.

when diseased. Many of the Lichens have long been extensively used in the art of dyeing. The Reindeer Moss already referred to is of the utmost value to the wandering Laplander, who feeds his domestic herds upon it during the winter. The Reindeer are said to know where it is growing under the snow, which they scrape away with their antlers. The Icelander makes similar use, not only for his cattle, but for himself also, of another Lichen, the Iceland Moss (*Cetraria islandica*), which at one time had a great

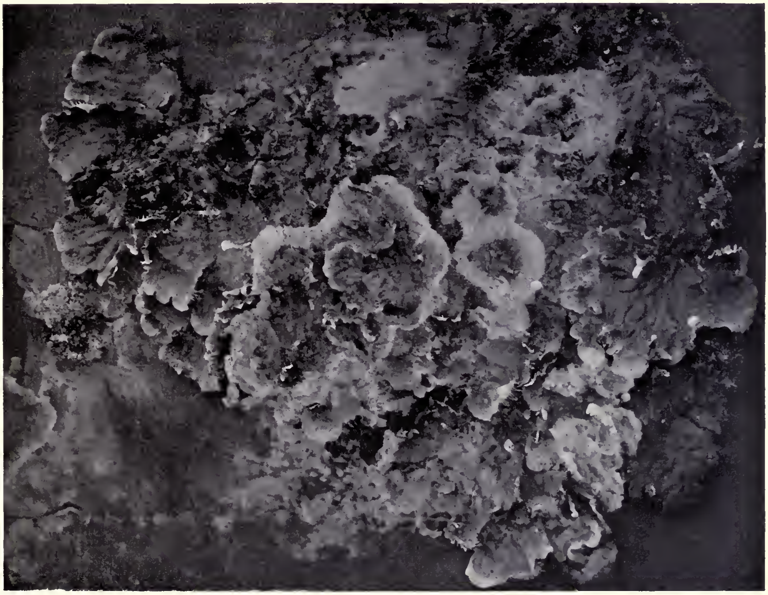

Photo by] [*E. Step.*

FIG. 677.—DOG LICHEN (*Peltigera canina*).

One of the largest of the Lichens. It grows upon the ground and resembles a Liverwort on a large scale. The fruits of a pale-brown colour, with incurved margins, spring from the edge of the thallus.

vogue in this country as a food for invalids, and still retains a place in the British Pharmacopœia.

The compound body of the Lichen is known as a *thallus*. Although subject to great variation of form all the kinds may be separated into two groups—those that lie flat and spread upon the surface they grow upon, and those that branch and grow in a vertical direction. The first kind are known as foliaceous Lichens, the second kind as fruticulose Lichens. The Dog Lichen is an example of the foliaceous class, the Reindeer Moss may stand as representative of the fruticulose class. There is a subdivision of each of these groups, for some of the foliaceous Lichens are of very hard texture, and to these the term crustaceous is applied. So, too, some fruticulose Lichens have their lobes or branches reduced to fine threads and are therefore denominated filamentous. The Beard Moss (*Usnea dasypoga*, fig. 673) is of this kind.

Neither Algæ nor Fungi are long-lived plants, although the woody *Fomes* among the Fungi may subsist for twenty years or so; but no such limit can be set to the life of some of the foliose Lichens. Any one who over a long period of years has made observations in any particular district must have noticed how certain patches of Lichens on old walls or rocks maintain their position with little apparent increase of size. The combination of the two elements in their structure appears to give them the power of almost perpetual renewal. Berkeley expressed his belief that "Patches of such Lichens as *Lecidea geographica* probably date from almost fabulous periods, and even small patches are often of considerable age. I have myself watched individuals for twenty-five years, which are now much in the same condition as they were when they first attracted my notice." The same belief must have been in Ruskin's mind when he penned a much-quoted passage in "Modern Painters," for one of its sentences runs: "The orange stain upon the edge of yonder western peak reflects the sunsets of a thousand years." This durability of the living Lichen remains when specimens have been collected for reference by the student. This fact should make the group a favourite one with collectors, though it has not done so to any extent. Lichens require none of the troublesome preparation demanded by most natural history specimens. Exposure to the indoor atmosphere without pressing in porous paper will secure their satisfactory drying with little (in many cases no) loss of the living form, and even in those cases where there is shrinkage a few minutes' soaking in tepid water will restore the plumpness and pliability that may be necessary for purposes of study.

FIG. 678.—BROWN MOULD (*Mucor mucedo*).

(*a-c*) Gonidia from which the plant develops. (*d*) Sporange. (*e*) The same bursting to release the spores.

It was formerly held that Lichens obtained their nourishment entirely from the atmosphere, but the modern view is that the rhizoid filaments of the Fungus partner draw water and mineral substances from the stratum upon which it grows, and this material, useless to the Fungus, the Alga can work up in the sunlit upper tissues into proteids upon which the Fungus

Photo by] [*E. Step.*

FIG. 679.—A CLUSTER OF PUFF-BALLS (*Lycoperdon perlatum*).

The stout stem is sterile, but the globose head is filled with a dense mass of minute spores. When these are ripe the apex of the Puff-ball opens to set them free.

can feed. In return the waste products of the Fungus can be again utilized by the Alga. It will be seen that the partnership is not absolutely equitable, for whilst the Alga can live without assistance from the Fungus, the latter is entirely dependent upon the Alga. Where the Lichen grows upon the bark of trees or upon the soil, the Fungus partner may get most of what it requires from the humus, but in the case of species growing upon the vertical face of a rock there can be no question that the Fungus is

Photo by] [E. Step.

FIG. 680.—THE SOLITARY TOADSTOOL (*Amanita solitaria*).

A representative example of the Agarics, in which the spore-bearing surface is spread over radiating plates (gills) on the underside of the cap (*pileus*). The hanging frill or ring around the stem was, before the expansion of the Toadstool, spread over the gills and attached to the edge of the cap.

entirely dependent upon the activity of its algal partner. Reproduction is of two kinds: both Fungus and Alga produce spores which set up new partnerships, and brood-buds or *soredes* separate from the thallus. These consist of one or more algal cells invested by a few wisps of the fungal hyphæ.

The methods of spore-bearing in the Fungi differ greatly, but the spores are mostly formed non-sexually by a cell dividing transversely, the dividing portion rounding and dropping off as a spore. In the moulds (Oomycetes, Zygomycetes, etc.) they are formed singly or in chains, terminating branches. They may be formed by a division of the protoplasmic contents within a mother-cell, which thus becomes a sporange, the spores being liberated by the rupture or disappearance of the sporange-wall. These spores may be motile (zoospores) by the activity of cilia, as in *Saprolegnia* and *Peronospora* (fig. 676), or non-motile, as in *Mucor* (fig. 678) and the great majority of the Ascomycetes.

FIG. 681.—EARTH STAR (*Geaster hygrometricus*).
The outer layers of the peridium have split and curled back, and the spores are escaping from the apical opening.

These spores germinate under favourable conditions by pushing out *germ-tubes* which lengthen and branch until they form a new mycele. Moist and thin-walled spores that do not soon find the conditions favourable to germination perish; but many dry spores, if kept dry, retain their vitality for very long periods, and some of these (resting-spores) will not germinate until after some definite period from the time they were formed.

In some groups there is no sexual generation, or at least such has not yet been discovered. This is the case, among others, of the larger Fungi, the Basidiomycetes, which includes the Mushrooms. Where it occurs it chiefly follows one of two methods. In Peronospora, Achlya, and possibly some Uredineæ, an oosphere is fertilized by the intrusion of an antheridial tube from an antherid formed on the same or a neighbouring branch. In Zygomycetes two special cells come together by their apices and become firmly united. The apical portion of each (*gamete*) is then cut off by a transverse wall, and the division between the gametes gradually disappears, and the contents of both conjugate, the united mass growing into a *zygosperm*.

Photo by] [*E. Step.*

FIG. 682.—EARTH STAR (*Geaster hygrometricus*).
The two outer coats (combined) are shown in the act of splitting into eight segments.

As indicated above, it is a common error to regard a mushroom or toadstool as the Fungus. We might as correctly regard an apple as the apple-tree by which the apple was produced. The apple is the fruit, which could not be formed without the preliminary activity of the vegetative system—the roots, stem, and leaves. So with the toadstool, it appears only after a considerable amount of activity on the part of the vegetative body, in this case the mycele. If a toadstool be carefully taken up with the surrounding earth, dead leaves, or rotting wood from which it springs, it will be seen to be attached to the matrix by a large number of white or colourless threads of great fineness. This is the mycele or fungus proper, of which the toadstool is the carpophore or fruit-bearer. Usually these threads are septate—that is, they are broken up into compartments by transverse walls; or, to put it in another way, they consist of slender cylindrical cells placed end to end. The tip of one of these threads farthest away from the base of the toadstool is the growing point, and it appears to have special powers beyond that of increasing in length. When a tree breaks out into large brackets of *Fomes* or *Polyporus*, the owner sometimes thinks he will cure the disease by taking away the brackets, but these are rather symptoms than the disease itself, though they hold within their tubes the germs by which the disease may be spread. The tree is already doomed, for the deadly mycele has ramified through the trunk and branches, demoralizing the sound timber and con-

Photo by] [*E. Step.*

Fig. 683.—Crested Clavaria (*Clavaria cristata*).

An example of the branching species of Clavarieæ. A pure white or cream-coloured species found in damp woods.

Photo by] [E. Step.

FIG. 684.—THE SPARASSIS (*Sparassis crispa*).

This fine fungus (here shown one-half the natural size) is covered with twisted, thin, brittle lobes of a creamy white tint. It is found only in pine-woods and is considered one of the most desirable of the esculent species.

verting it into touchwood. The growing point of the mycele comes in contact with a wood-cell, and pours out a ferment which has the power to break down the hard wood into cellulose, which further dissolves into a fluid which the mycele can then absorb.

The mycele of a toadstool that springs from a bed of dead leaves acts upon the cells of the leaves in the same manner. They crumble into humus, in which condition their material is again available for nourishing the roots of the green plants. Some forms of Fungi appear to exist only in the mycele stage, and are known as *Mycorhiza*. This *Mycorhiza* has been found to be a pretty constant attendant on cupuliferous trees—oak, beech, alder, hazel, etc.—investing the rootlets as with a spider's web, and by breaking up the humus with its ferment reducing it to a condition which enables the rootlets to absorb it. It is the mycele again that is the destructive agent in "Dry Rot" (*Merulius lachrymans*), that in this country chiefly affects worked timber in houses, and spreads even through mortar so long as it has its base in the wood-work. The huge fan-shaped sporophores may be cleared away, and the house-owner fondly imagine that he has got rid of the pest, but the stout beams will continue to give way and the flooring to crumble like pasteboard. Nothing short of clearing out all the affected wood and the ramifying mycele and the pickling of new material in some known fungicide will put an end to the trouble.

Photo by] [*E. Step.*

FIG. 685.—JEW'S-EAR FUNGUS (*Hirneola auricula-judæ*).

Growing upon old Elder branches. It is an example of the Tremellineæ. Several stages in the development of the sporophore are shown. Some specimens bear a remarkable likeness to a human ear.

In some of the species that attack trees this mycele runs up between the bark and the wood, and ultimately attains to a flat, horny network, known as a Rhizomorph, such as we have already illustrated (fig. 181). Another form taken by the mycele of certain species of Fungus is known as a *sclerotium*. The best-known example of these sclerotia is afforded by Ergot (*Claviceps*), which grows upon Rye and other grasses, and is used as a medicine in special cases. The Ergot spores floating in the air, or carried by an insect, alight on the flowers of grasses, and there germinating, the mycele enters the ovary and feeds upon its contents. Instead of the ovule developing into a "grain" or seed, there emerges from the ovary a long, black, curved body, the sclerotium, which consists of hardened mycelium, and bears upon its surface conidia, or chains of spores. These sclerotia are shown in fig. 686 on the grass *Molinia cœrulea*. When fully developed they fall to the ground, and remain quiescent through the winter; but in spring slender little mushroom-like bodies grow out of them. Within the globose heads the spores are produced, which, escaping into the air, get into the flowers of grasses and renew the cycle. Other species of Fungi also produce sclerotia, but the example given must suffice.

Photo by] [*E. Step.*

FIG. 686.—ERGOT (*Claviceps microcephala*).

On the grass *Molinia cœrulea*. The large curved bodies are the sclerotia which fall to the earth, and in spring give rise to the sporophores.

The illustrations to this chapter will serve to give some idea of the striking differences of form in the sporophores of the various groups into which the Fungi have been divided. These are too numerous to be examined in detail here; we can only glance at a few of the different types of sporophores. Such examples as we are able to mention and illustrate are sufficiently striking to those who imagine that Fungi are either toadstools or moulds. Between these two types there is a long line of forms differing widely from both extremes.

The order Hymenomycetes is so called because the spore-bearing surface consists of a membrane (*hymenium*), which is fully exposed when the sporophore is properly mature. It is divided into six families.

The Solitary Toadstool (*Amanita solitaria*, fig. 680) may be taken as

Photo by] [*E. Step.*

FIG. 687.—DRY ROT (*Merulius lachrymans*).

Portions of the huge sporophore (several feet across) developed on oak panelling. The most destructive pest of worked timber.

an example of the family Agaricineæ, which is divided into several sections according to the colour of the spores—white-spored, pink-spored, yellow-spored, and black or purple-spored. In this family, consisting of the mushrooms and toadstools, the sporophore consists typically of a stem (mostly central) supporting a *pileus* or cap, whose lower surface bears a large number of plates (gills) set on edge and radiating from the stem. The object of this plan of structure appears to be to increase the spore-bearing surface, for the hymenium is spread over both sides of the

Photo by] [*J. T. Newman.*

FIG. 688.—MOREL (*Morchella esculenta*).

Representing the Discomycetes. The spores are contained in small bladders (*asci*) in the external parts of the head, which, as seen in the specimens illustrated, are irregularly folded and much wrinkled. These Fungi are edible.

plates, and so has an area enormously greater than that of the pileus. This surface is closely packed with club-shaped processes, some of which are sterile and rounded at the summit. Others (*basidia*) end in four sharp points, each surmounted by a spore. When the sporophore first makes its appearance, owing to the elongation of the stem pushing it through the soil, it is more or less spherical and comparatively small. In the case of the genus *Amanita* the entire sphorophore is invested by a general wrapper (*volva*), which is ruptured by the lengthening of the stem and the expansion of the cap, the latter breaking the upper portion of the volva into scaly fragments, which may be seen on the cap in the photograph. In some genera no remains of the volva are left on the cap. In *Amanita* the gills are further protected in the unexpanded toadstool by a delicate membrane (the veil) which spreads from the stem to the margin of the pileus, from which it separates and hangs as a beautiful frill around the upper part of the stem.

Photo by] [*E. Step.*

FIG. 689.—*Tremella mesenterica.*

This representative of the Tremellineæ grows on dead branches, and is of a rich golden-yellow colour and the consistency of jelly.

In the Family Polyporeæ the place of the gills is taken by a sponge-like mass consisting of tubes packed closely together, and the spores on their basidia are contained in the tubes. The tube-mass may be soft (*Boletus*), corky (*Polyporus*), leathery (*Polystictus*), woody (*Fomes*), etc. The characteristic of the Hydneæ is the substitution of spines for tubes or plates. In Thelephoreæ there are neither gills, tubes, nor spines, the basidia being borne upon a smooth and fully exposed hymenial surface. A similar arrangement is found in Clavarieæ and Tremellineæ, but in these there are considerable differences in the forms of the sporophore. Two photographic examples are given of the Clavarieæ—the Crested Clavaria (*Clavaria cristata*, fig. 683), and the Sparassis (*Sparassis crispa*, fig. 684), the latter a choice edible fungus found in pine-woods. Some of the genera of Hydneæ and Thelephoreæ are represented by encrusting species that lie with the under or sterile surface

Photo by] [*E. Step.*

FIG. 690.—*Mitrula phalloides.*

A wax-like Fungus of marshy ground, representative of the Discomycetes.

closely attached to dead branches and twigs much after the manner of Lichens. One of the best known of Fungi—*Stereum hirsutum*, which forms small leathery brackets on old posts and stumps—belongs to the Thelephoreæ; as also does one of our few luminous Fungi—*Corticium cæruleum*, which is bright deep-blue in colour, and gives out a pale greenish light in the dark.

The sixth Family—*Tremellineæ*—consists of more or less gelatinous Fungi of which two characteristic photographs are presented—the Jew's-ear (*Hirneola auricula-judæ*, fig. 685) and *Tremella mesenterica*, fig. 689). The latter is so jelly-like in consistence that it is impossible to handle it in a fresh condition. It is frequent on dead branches, and is a beautiful rich golden yellow in tint. It has no stem and no definite shape, but is variously folded and twisted, often like a miniature turban of yellow silk. The Jew's-ear is a remarkable form that grows upon the stems and branches of dead and dying elders and, occasionally, on elm-stumps. Some specimens are remarkably like the human ear with its folds and lobes. It is of a gristly consistence with minutely velvety exterior, of a greyish-brown tint; the interior polished and of a paler hue, and it is on this surface that the spores are produced.

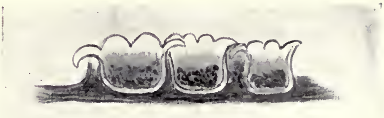

FIG. 691.—CLUSTER-CUPS.

A small portion of a cluster seen in section, showing the spores within.

The Order Gasteromyceteæ includes the Puff-balls and Earth-stars. The characteristic of this order is the complete seclusion of the hymenium or spore-bearing surface in an enclosed sac until the spores are ripe and ready for dispersion. The Puff-balls (*Lycoperdon*) are familiar objects in summer and autumn. The "ball" is technically a *peridium* whose walls are composed of two layers, of which the outer breaks up into spines or warts which are clearly shown in fig. 679. In some species these fall away as the fungus becomes mature. The spores are produced in the interior and are liberated by the peridium opening at the summit. The Earth-stars (*Geaster*, figs. 681, 682) have the peridium composed of three layers which are at first entire, and constituting a depressed sphere; but as the spores ripen the two outer layers split into a variable number of segments and turn down. In the common species represented (*Geaster hygrometricus*) the segments of the exoperidium

Photo by] [*E. Step.*

FIG. 692.—BIRD'S-NEST FUNGUS (*Cyathus vernicosus*).

Quaint little cups (*peridia*) containing spore-cases (*peridiola*) attached to the cups by long elastic threads. Representative of the Gasteromycetes.

Photo by] [*E. Step.*

FIG. 693.—CANDLE-SNUFF FUNGUS (*Xylaria hypoxylon*).

One of the Pyrenomycetes, that grows upon old stumps. The black, flattened, and branching conidiophores present much the appearance of wicks that have smouldered out. The whiteness is due to the tips being coated with the conidia.

when dry curve up over the endoperidium, but in moist weather bend back and lever the Fungus free from the soil. The remarkable Stinkhorns are included in this order. The common species, *Ithyphallus impudicus*, issues from the earth as a white ball. A little later the volva or wrapper is ruptured and a tall cylindrical column of white spongy substance issues from it. It is terminated above by the conical *gleba*, which consists of honeycomb-like cells at first filled with an olive jelly in which the spores are immersed, and which gives off an abominable and penatrating odour of corruption. This odour attracts innumerable blow-flies, and as the jelly is sweet they imbibe it greedily. The spores pass uninjured through their digestive tract, and are thus widely dispersed.

The Order Ascomyceteæ is broken up into two large sub-orders—the Discomyceteæ and the Pyrenomyceteæ. The Discomycetes produce their spores in *asci* or bladders immersed in the naked hymenium and opening on the surface when ripe. Many of them are disc-shaped (*Pezizæ*, etc.), others have club-shaped or globose heads. Of these latter the Morel (*Morchella esculenta*, fig. 688) is a familiar example. The hymenium lines deep polygonal pits and is exposed

Photo by] [*E. Step.*

FIG. 694.—HORN OF PLENTY (*Craterellus cornucopioides*).
A large black funnel-shaped fungus bearing spores on its ribbed outer surface. A representative of the Thelephoreæ.

Photo by] [*E. Step.*

FIG. 695.—FAIRY CLUBS (*Clavaria argillacea*).

A wax-like greenish-yellow fungus, found rarely upon heaths. An example of the unbranched (simple) species of Clavarieæ.

from the first (see also fig. 201 for a photograph of an example in a younger condition than those shown in fig. 688). The Pyrenomycetes include the Truffle (*Tuber æstivum*), which is wholly subterranean in habit, the Hart-truffles (*Elaphomyces*, fig. 196), *Cordyceps* (figs. 195, 196), the familiar Candle-snuff Fungus (*Xylaria hypoxylon*, fig. 693), and Ergot (*Claviceps*, fig. 686) already described.

Little more than mere mention can be made of the remaining Orders. The Hysteriaceæ consists of Fungi which vegetate under the epidermis of plants and whose ascophores burst through and present the appearance of a black elongated low excrescence with a longitudinal slit. Some take a stellate form, and others rise vertically in the shape of a miniature mussel-shell. They are all minute species.

The Phycomyceteæ is a small Order of Mould-like Fungi whose mycele consists of unicellular threads, that is to say there are no transverse partitions breaking the thread up into cells or compartments. A familiar example may be found in the white mould (*Mucor mucedo*) which appears upon jam, fruit, saccharine fluids and drugs. From the mycele rise *hyphæ* of similar structure upon whose summit is formed a comparatively large spherical sporange whose thin membrane bursts to release the spores. The Potato Blight (*Phytophthora infestans*) and the Salmon Fungus (*Saprolegnia ferox*), an aquatic Fungus, also belong to this Order.

Photo by] [*E. Step.*

FIG. 696.—HAWTHORN CLUSTER-CUPS (*Ræstelia lacerata*).

A spindle-shaped mass of æcidia which distorts branches of hawthorn, etc. A stage in the history of the Fungus shown on the opposite page.

The Uredineæ is an Order of plant parasites, and the fructification in some species takes the form of the well-known "cluster-cups" which burst through the tissues of living plants. In addition to cluster-cups (*æcidia*) there are *spermogonia*, *uredospores*, and *teleutospores*.

In some species of *Puccinia* all these grades are passed on the same host. Such species are known as *Auto-Pucciniæ*; but in others, known as *Hetero-Pucciniæ*, some stages are passed on one plant and the remainder upon a plant belonging to a different genus. A familiar example of this *Heteræcism*, as it is termed, is afforded by the Mildew of wheat. The spermogonia and æcidia are found on the Barberry, and known as *Æcidium berberidis*; the uredospores and teleutospores develop on Wheat, and are known as *Puccinia graminis*. The æcidiospores from the Barberry will germinate on the Wheat and produce uredospores and teleutospores which germinate on Barberry. A similar case is illustrated by our photos (figs. 696, 697). The shoots of

Photo by] [E. Step.

FIG. 697.—*Gymnosporangium clavariæforme.*

The spore of *Ræstelia* germinating on Juniper produces this distortion of the stem, from which proceed the jelly-like, tongue-shaped fructifications, bearing spores which germinate on hawthorn and produce the mass of Cluster-cups shown in fig. 696.

Hawthorn, Pear, and Whitebeam may often be found swollen and scurfy. The leaves and fruit are subject to the same diseased condition. Examination with a lens will show that this spindle-shaped orange swelling consists of a crowd of cluster-cups. Formerly it was considered as a distinct species under the name of *Ræstelia lacerata.* Under the bark of Juniper in autumn there develop teleutospores of *Gymnosporangium clavariæforme*, and in the following April or May these burst through the bark as cylindrical or tongue-shaped masses of pale orange jelly. This stage is perennial on the Juniper, and the spores are carried by the wind to the Hawthorn, etc., where they develop and give rise in the autumn to the cluster-cups of *Ræstelia lacerata*, which is not perennial but only temporary.

FIG. 698.—STONEWORT (*Chara fragilis*).

(*a*) Portion of the plant in fruit; (*b*) fertile leaf with spherical antheridia and spirally walled archegonia; (*c*) antheridium; (*d*) archegonium; (*e*) spore; (*f*) antherozoid.

One other example of this heterœcism may be mentioned. The Silver Fir suffers from a fungoid disease known as Pine-shoot-twist (*Ceoma pinitorquum*), and the Larch from Larch-leaf-rust (*Ceoma laricis*). On the leaves of Aspen may be found minute brownish-yellow cushions known as *Melampsora tremula*. Now these three plant diseases are all caused by one Fungus, whose teleutospores are produced on the Aspen-leaves and carried by the wind to both Silver Fir and Larch, where they produce other stages in the cycle.

The Ustilagineæ are similar to Uredineæ in the fact that they are parasites—entirely on herbaceous plants. The mycele is deep-seated in the tissues of their victims, running along the intercellular spaces and often thrusting suckers through the cell-walls. This mycele is perennial—that is to say, where the host is a perennial plant. In each species there is some particular part of the plant where hyphæ break through to produce their spores on the surface. These spore-masses, usually black or some dark colour that looks black to the unassisted eye, have caused the pests to be known as "Smuts." Most people have seen a field of corn with the ears all "smutted," or covered with the spores of *Ustilago segetum*. *Tilletia caries* produces its spores within the grains of Wheat, and causes the condition known to farmers as "bunt." *Urocystis violæ* disfigures the leaves of Violets, and lives perennially in the rootstock.

FIG. 699.—*Corallina officinalis.*

A common Seaweed whose stems and branches are thickly coated with lime. (*b*) Tetraspores.

The Sphæropsideæ are also minute Fungi. They produce perithecia like the Pyrenomycetes, but these have no asci, the sporules or stylospores being produced within the apex of hyphæ. The Hyphomyceteæ include the well-known Mould *Penicillium glaucum*, and a large number of plant-pests; but many of them are suspected of being not real species, but temporary stages in the development of some of the larger Fungi.

The Class CHARACEÆ, or Stoneworts, consists of only two Orders, Characeæ and Nitelleæ. They are delicate fresh-water plants which have a superficial similarity of form to the Horsetails; that is, there is a main stem with whorls of leaves, and branches of similar structure to the main stems. The leaves spring from distinct nodes, as in the Equisetaceæ, and the branches from the axils of some of the leaves, where also are found the sexual organs. The entire internode—*i.e.* the space between two nodes—consists of one very large cell, in

FIG. 700.—A RED SEAWEED (*Polysiphonia subulata*).

(*a*) Tetragonidium in two stages of growth.

Chara invested by a *cortex* consisting of long slender cells arranged spirally, but in *Nitella* there is no such cortex, and the internodal cell stands absolutely naked. *Chara* also extracts calcium carbonate from the water, and deposits it on its exterior to such an extent that it is often difficult to make out the structure through it. *Nitella* has no such deposit. Long tubular cells grow downwards and serve as roots to fix the plant in the soil. In the clear internodal cells of these plants may be observed the phenomenon known as *cyclosis*, or rotation of the protoplasm along well-defined routes up one side of the cell and down the other, the two currents being separated by clear bands devoid of chlorophyll. In the axils of the leaves will be seen two kinds of bodies, some round and orange-red, the others elliptical and apparently green. The red bodies are antherids, the green are oogones. These oogones under the microscope are really orange, but the colour being masked by surrounding green bracteoles, they appear green to the naked eye. Some plants produce organs of one kind only; in others the two kinds are found close together. Each of these organs is supported on a short stalk consisting of the pedicel-cell (fig. 698).

FIG. 701.—SUGAR TANGLE (*Laminaria saccharina*), With root-like suckers holding to a piece of rock.

The walls of the antherid are composed of eight flat cells, and from the centre of each on the inner surface a cylindrical cell—the *manubrium*—is attached, and extends towards the centre of the antherid, where it supports a rounded cell, the *capitulum*. Each capitulum in turn supports six *secondary capitula* of smaller size, and each of these bears four coiled filaments, which are divided into a large number of flat cells, and in each of these is a spirally coiled antherozoid, like those of the Mosses, with a couple of long cilia at the anterior extremity. When these are ripe, the antherid falls apart and the antherozoids move through the water by lashing their cilia. The red colour is due to the inner face of the wall-cells being lined with chlorophyll-grains, which turn red as the antherid develops.

Photo by] [*E. Step.*

FIG. 702.—SAW-EDGED WRACK (*Fucus serratus*).

One of the commonest of the larger olive seaweeds or wracks, found covering nearly all rocks between tide-marks. A valuable breakwater.

The walls of the oogone consist of long twisted cells, the whole surmounted by a crown of five or ten smaller cells, which ultimately separate and form a neck with a central cavity leading to the interior. Here there is a large central germ-cell (*oosphere*) with a receptive spot at its apex, which becomes liquefied and so allows entrance to the antherozoids when they have passed the narrow passage of the neck. After fertilization the outer coats of the oosperm harden into a black pericarp, and later the entire fruit falls off the plant to the bottom of the pond, where it remains inactive till the following spring, when germination takes place. At this period the oosperm has divided into one large and two small cells, the first apparently serving as a reserve of nutriment, whilst from one of the smaller cells a primary root is developed, and from the other the proembryo—a long filament composed of a single row of cells. Across this a primary node is formed, from which arises a whorl of rhizoids, and beyond the node a very long internode; then another node, from which arises a cluster of leaves, amid which a bud is formed, and from this the new plant takes its origin. The proembryo is continued to a great length beyond the second node. It will be seen that in the entire life-cycle of the Characeæ there is no sporophyte, so there is no true alternation of generations.

Photo by] [*E. Step*

FIG. 703.—LIME-SECRETING PLANTS.

The base of this group is a limpet whose shell has been thickly encrusted by the strong seaweed *Lithothamnium*, from which grows a plant of *Corallina*.

We now reach the huge assemblage of forms that were until recently grouped together under the general name of Algæ, but are now separated into a number of distinct Classes. Many of the species are familiar, as common Seaweeds and plants of fresh-water ponds and streams. As in the case of the Fungi, we can here only give a very brief indication of the characters of each class.

The RHODOPHYCEÆ, or Red Seaweeds, sometimes termed Florideæ, get their name from the fact that in most of the species the chlorophyll in the cells is masked by a red pigment known as phyco-erythrin. They are attached by suckers to rocks, shells, or other weeds, but have no true roots, absorption being performed by the surface-cells of the entire thallus. This assumes a great variety of forms, from the mere threads of *Batrachospermum* and *Callithamnium*, consisting of a single row of cells, to the broad leaf-like ribbons of *Delesseria* with midrib and nervures mimicking the leaves of Phanerogams. In *Corallina* (figs. 699, 703) the thallus is so completely invested with a layer of calcium carbonate that its vegetable nature is disguised, and the plants were long regarded as true corals. There is no alternation of generations, but there are two modes of reproduction —sexual and asexual. The asexual mode is by the division of a mother-cell or sporange, usually into four (hence distinguishable by the name of tetraspores), which are set free by the rupture of the sporange walls. These tetraspores are not ciliated, and have no power of motion, but float with the sea currents until they come to rest and vegetate on some suitable surface. The sexual organs are antherids and carpogones. The contents of the antherid, instead of being broken up into antherozoids, go to form a more or less spherical spermatium. The carpogone has a basal flask-shaped portion surmounted by a filamentous extension, the

Photo by] [*E. Step.*

FIG. 704.—*Jania rubens.*

The fine thread-like stems grow in clusters from the stems of other Seaweeds, as here shown. The threads are all coated with lime.

trichogyne. The basal portion contains the oosperm, and the trichogyne serves as a receptive organ for the spermatium. As the spermatia drift helplessly through the water, one or more become attached to the trichogyne, their contents pass through the walls of both organs and reach the oosperm. By a complicated process, varying in different species, there arise a number of carpospores, which are enclosed in a general envelope, the whole body being known as a cystocarp. Ultimately the walls of this are ruptured, and the carpospores thus set free give rise each to a protoneme, from which a thallus is developed. Several other species in allied genera develop similar coatings of calcium carbonate, and like *Corallina* were formerly regarded as of animal nature. One of these, *Jania rubens*, is shown in fig. 704 growing in tufts on the stems of another Seaweed. *Lithothamnium* encrusts the walls of rock-pools, and forms strong masses on limpet-shells, often whilst the limpet is still occupying the shell. Such an example is shown in fig. 703 with a small plant of *Corallina* growing upon it. When this specimen fell into our hands it presented no resemblance to a limpet, though it was gliding over the rock. *Halimeda tuna*, a large green species, presents much the appearance on a small scale of the Prickly Pear Cactus (*Opuntia*), its points being broad at the top and narrowed to the base. Like *Corallina* and *Lithothamnium*, it secretes calcium carbonate to such an extent that its dead remains form beds of limestone of considerable thickness in which the forms of the joints are well preserved. The well-known Carrageen (*Chondrus crispus*) is a member of the Rhodophyceæ. At one time it was a fashionable food for invalids under the name of Irish Moss, the prevailing fad of the medical profession of that day being that anything glutinous was nourishing. Laver (*Porphyra laciniata*) has also had—and still has—its advocates as a food, or at least as a sauce, when pounded and stewed, or pickled in salt. Murlins (*Alaria esculenta*) and

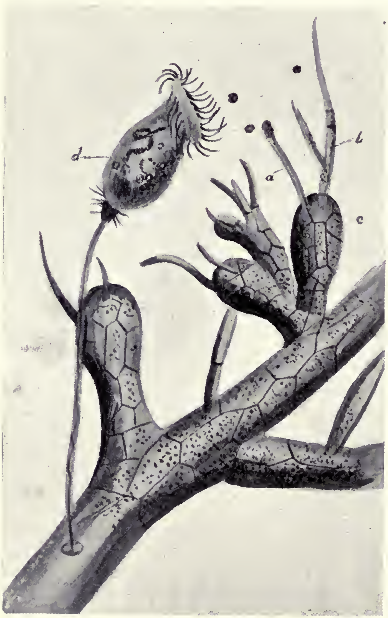

FIG. 705.—*Polysiphonia.*
Portion of female plant with vorticella (*d*); (*a*) trichogyne; (*b*) forked hair; (*c*) sporogone.

FIG. 706.—ASH-LEAVED SEAWEED (*Delesseria sanguinea*).

One of the most beautiful of the Seaweeds, mainly by reason of its colour. Its fronds are clear rosy-red, and so thin as to be almost transparent. The figure is a little less than natural size.

other seaweeds have also been used as food, chiefly by the maritime peasantry and fisher-folk.

Speaking of the fertilization of *Polysiphonia subulata*, which belongs to this class, Professor McAlpine says: "It is evident that the element of chance enters largely into the meeting of the passive male and female elements, and it is not to be wondered at that in many cases fertilization never takes place at all. Professor Dodel-Port has, however, recently observed that Infusoria create currents in the water and thus set the passive sperm-cells [spermatia] in motion. Numerous Vorticellæ, or Bell-animalcules, attach themselves to this seaweed, and create currents which send the sperm-cells spinning about, while the forked hairs beside the trichogyne help to break the force of the current and cause the sperm-cells to settle there. Just as insects obtain pollen or honey from a flower while unconscious agents in its fertilization, so do these water-animals swallow some of the sperm-cells for their pains. Contrivances in Flowerless Plants for ensuring fertilization may not be less wonderful, when better known, than those brought to light in Flowering Plants" (fig. 705).

Photo by] [*E. Step.*

FIG. 707.—PEACOCK'S-TAIL (*Padina pavonia*).

A much-prized Seaweed of sandy shores. The light zones bear lime crystals.

The PHÆOPHYCEÆ, or Brown and Olive Seaweeds, include the Wracks and Tangs, which are abundant and conspicuous on the rocky coasts of the colder seas (figs. 701, 702, 714). Here, again, there is great diversity of form, size, and structure, which may be well exemplified by a comparison of the thread-like rows of simple cells in *Ectocarpus* with the broad leathery fronds of *Laminaria* and *Alaria* on our own coasts, the Antarctic *Macrocystis*, with floating ribbons two or three hundred yards long, and the tree-like *Lessonia* of the same regions. Reproduction of the Brown Algæ varies in the several orders. There are asexual swarm-spores produced in large numbers and discharged

Photo by] [*E. Step.*

FIG. 708.—*Halymenia ligulata.*

A handsome Red Seaweed. The lobes of the variously divided fronds bear many shoots or branches.

from lateral sporangia. There are bodies known as gametes formed in gametangia, which resemble the asexual swarm-spores, but which join in pairs, and, as a result of their fusion, give rise to zygotes, from which new plants develop. There are flask-shaped depressions (conceptacles) in the surface of the thallus, within which are produced antherids and oogones, the former discharging motile spermatozoids, and the latter oospheres. In most species the conceptacle is male *or* female; in *Fucus platycarpus* both antherids and oogones are produced in the same conceptacle. Several species of *Fucus* are the most abundant seaweeds on our coasts, particularly where there are rocks. *Fucus serratus* (fig. 702), and *Fucus vesiculosus* drape all the reefs and afford valuable cover for innumerable marine animals.

The CHLOROPHYCEÆ, or Green Algæ, are of much simpler structure than the foregoing; many of them consist of a single cell, and some of these, owing to their active motile powers, were formerly considered as low forms of animal life. The methods of reproduction are varied, and sexual union is not general. In the Order Protococcoideæ all the species are unicellular, though in some there is a loose union of a few or many individuals into a colony that may give them the appearance of being multicellular. Some of these are found in all stagnant water and on wet walls and tree-trunks, multiplying by simple division of the cell, or by the breaking up of the protoplasm into a number of swarm-spores, each provided with a couple of cilia. These are set free by the rupture of the cell-wall. The Algæ already

Fig. 709.—Bladder Wrack.
Antheridia. Antherozoids are seen escaping from a separate antheridium.

referred to as forming one of the elements in the composition of Lichens belong to this order. More strangely still, some of them (*Zoochlorella*) are found living in the cells of low forms of animal life, such as the Hydra, the Fresh-water Sponge, certain Planarian worms, and *Infusoria*, for whom they manufacture starch, which animals are incapable of doing. Another method of reproduction found in this order is by the union of two naked motile masses of protoplasm, known as planogametes, which become fused together and form a zygote, which develops into a cell-family enclosed in a common envelope. The well-known *Volvox*, so long bandied about from zoologist to botanist and *vice versa*, is by some considered to be a hollow colony of single-celled Protococcids, each with its pair of cilia projecting through the common envelope, whose movements give that revolving motion to the colony that has delighted all who have viewed it through the microscope. Within the colony smaller daughter-colonies may be seen revolving; also aggregations of ciliated spermatozoids. Large colonies may contain as many as twenty-two thousand individuals, each connected to five or six neighbouring cells by delicate threads of protoplasm. Certain of these cells develop into large egg-cells, which are fertilized by the spermatozoids. These egg-cells may be distinguished from the daughter-colonies by the lack of motion. When the egg-cells are mature, the old colony breaks up into its constituent cells, and the egg-cell (now an oospore) sinks to the bottom, and in a resting condition develops into a new colony. In the Order Confervoideæ the individuals are multicellular, but in most cases the cells are in a single row, placed end to end, and form long fine threads. Some are fresh-water species, some marine, whilst one —*Trentepohlia*—is aerial. They are reproduced asexually by the protoplasm of certain cells breaking up into swarm-spores. There are two forms of sexual reproduction.

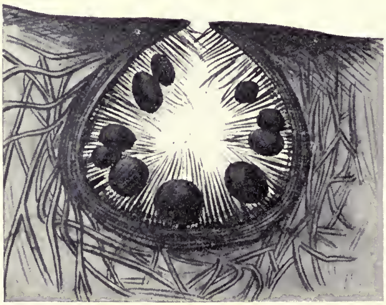

Fig. 710.—Bladder Wrack.
Section of a conceptacle, showing several oogonia among antheridial hairs.

FIG 711.—FORKED SEAWEED (*Furcellaria fastigiata*).

A very common Red Seaweed. The frond is reduced to round forking threads. The spores are produced in pod-like receptacles at the tips of the forks.

One is by the fusion of two planogametes, as in Protococcoideæ; the other is by the enlargement of one cell into an oogonium containing a single cell, which is fertilized by a spermatozoid formed in another cell of the same or another filament.

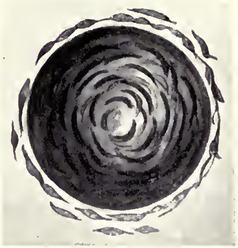

FIG. 712.—BLADDER WRACK.
Oosphere being fertilized by antherozoids.

The Class CONJUGATÆ consists of fresh-water Algæ very similar in appearance to the single-celled and filamentous forms of CHLOROPHYCEÆ, but reproduction is effected asexually by simple cell-division, and sexually by the conjugation of two apparently similar cells resulting in the formation of a zygosperm.

The most familiar representatives of the class are the Yoke-threads (*Zygnema*, *Spirogyra*) and the Desmids, the former consisting of long green hair-like filaments growing in fresh-water, and the Desmids single-celled microscopic water-plants. *Zygnema* consists of a single row of transparent cylindrical cells, joined end to end, and ornamented within by spiral bands of endochrome which gives it a beautiful appearance under the microscope. They float loosely in or on the water and have no attachment suckers. Single cells broken off the thread have the power by cell-division to grow into long filaments, that is, complete plants. When two filaments come together so that their cell-walls are nearly in contact, conjugation takes place. A protuberance grows out from each of the opposite cells, and these shoots meet halfway between the threads, the cell-walls of the tips open to form a connecting tube between the two plants, and the contents of one cell pass into its neighbour, where they coalesce with the contents of that cell. There is complete union of this mass of protoplasm, which then rounds off into a sphere or an ellipse. It has become a *zygosperm*. In some species the union of protoplasm takes place in the connecting tube; in others no tube is formed, but the two plants come in contact by a knee-like bend in each which brings two cells in touch with each other, then the cell-walls between them disappear and a zygosperm is formed in one cell by the union of the contents of both. Occasionally two cells on the same plant will form a zygosperm by each sending out a tube which meets with the other and effects a combination of the two protoplasm masses. However formed, these zygosperms germinate and give rise directly to a fila-

FIG. 713.—BLADDER WRACK.
Oogonium distended by its eight oospheres, and ready to split and release them.

ment like those by which they were produced. Zygnema is common in both running and stagnant water, and forms the green slimy masses frequently seen floating on the surface of ponds and ditches.

The Desmids are almost exclusively inhabitants of fresh water, and are unicellular. They are quite unattached—except temporarily resting, as it were—and float freely, having the power of spontaneous motion. Certain species may combine to form threads, but the segments of such threads are separate organisms. They are all very minute, only the very largest of them—such as *Cosmarium* and *Micrasterias*—being just visible to the unassisted eye. They vary greatly in form, but all the members of a genus conform roughly to one type. They are all symmetrical, and each individual is usually divided into two symmetrical portions by a constriction extending from the margin nearly halfway to the centre. Even the cell contents—chlorophyll bodies and starch-grains—are symmetrically grouped in bands and star-patterns. The transparency of the cell-wall enables these patterns and the rotation of the protoplasm to be seen clearly and distinctly. Some of the long slender species like *Closterium* and *Docidium* have clear spaces at their extremities in which "brownian movements" of the particles suspended in the cell-sap may be seen.

FIG. 714.—BLADDER WRACK (*Fucus vesiculosus*).
Fertile branches bearing conceptacles (*con.*).

In the large Family DIATOMACEÆ all the species are microscopic and abound in water, both fresh and salt. They are all single-celled plants whose cell-wall with few exceptions is highly silicified and takes the form of a slightly unequal pair of valves, each with a rim (girdle), the larger valve overlapping the smaller. The valves are transparent, and enveloped in an outer layer of thin gelatine. These valves are favourite objects with microscopists, who, however, rarely take interest in them as living plants, but take care to clean out all the protoplasm that they may quarrel about the perforations and sculpturing of the valves, which appear to vary according to the lens used for their definition. They are isolated and free-swimming, or variously attached to each other or to higher plants by gelatinous stalks. "Tripoli" and "Kieselguhr" are deposits of the fossil Diatoms of past epochs, which occur in beds of considerable thickness in various parts of the world. The number of species of Diatoms known is enormous—certainly more than ten thousand! In certain species of Diatoms conjugation is effected by two individuals coming together, and after throwing off their siliceous valves the protoplasts become fused to form a new individual, which afterwards multiplies by division. But in the majority of Diatoms there is nothing approaching a sexual union, and the purely vegetative multiplication by division appears to be the rule in the Classes PERIDINEÆ and SCHIZOPHYTA.

FIG. 715.—YOKE-THREAD (*Zygnema*).

Two threads in proximity have united by tubes through which the cell-contents mingle to form zygosperms.

A few words should be said respecting the Class Schizomycetes or Splitting Fungi, better known as Bacteria, though they are so minute that they cannot be studied, or even seen, except by the aid of very high powers of the microscope. In consequence there has been much confusion as to form, structure, and development. They are single cells of spherical, spiral, or cylindrical form, or combined to form chains and filaments. The cell-contents is homogenous protoplasm, in a few cases tinged with chlorophyll. Some have the power of free movement and of rotation round the longitudinal axis; certain of these are possessed of cilia or flagella, but whether these are their organs of motion has not been made out satisfactorily. The spherical forms are known as *Coccus* or *Micrococcus*, the cylindrical as *Bacillus* and *Bacterium* according to whether they are relatively long or short, and the spiral forms as *Spirillum*. Coiled forms other than spirals are known as *Vibrio*, and the compound filaments as *Leptothrix* and *Beggiatoa*. They are reproduced by the cell-contents developing into spores, which are set free by the rupture of the cell-wall, or in the filamentous species by the breaking off of cells

Fig. 716.—The Crimson Plume (*Ptilota plumosa*).

Another beautiful example of the Red Seaweeds. Its usual place of growth is on the long stem of the great Oarweed (*Laminaria digitata*).

which develop into filaments again by cell-division. The hardiness of most species is astonishing: they stand extremes of heat and cold, may be desiccated and remain alive for years, and some even retain their vitality in alcohol. Like the Fungi, they include both saprophytes and parasites. The saprophytes work chiefly by causing decomposition and fermentation; the parasites affect living animals, rarely living plants. As they are at least the accompaniment of many diseases in the human body, attempts have been made in some quarters to regard them as the specific cause of most diseases. Whilst there is no doubt that their malignant agency has been established in some of these (*e.g. Bacillus anthracis* in splenic fever, and the Comma Bacillus in Asiatic cholera), it must not be supposed that all Bacteria are to be looked upon with dread as human enemies. Many of them are known to be beneficent towards humanity, and others science has learned to educate, as it were, to service in the arts and manufactures.

Respecting the Myxomycetes, or Mycetozoa as they are variously called, there is still an amount of disputation as to their true position. By some they are regarded as a group of fungi, and known as Slime Fungi, therefore proper to be included in a work on Botany; but others contend for their animal nature. Produced from microscopic spores, they emerge as a kind of Amœba (swarm-cells) that glide with a streaming movement, thrusting

Photo by] [*E. Step.*

Fig. 717.—*Mucilago spongiosa.*

One of the Myxomycetes that may be found in pastures climbing up the stems of grasses and weeds to form its æthalia.

Photo by] [*E. Step.*

Fig. 718.—*Trichia varia.*

Common on decaying wood. The densely packed sporangia of ochreous tint are shown slightly enlarged.

out a whip-like process on the advancing side, surrounding Bacteria and other minute organisms and feeding upon them, chiefly in decaying wood and other vegetable matter. At a certain period of their life many of these come together and unite into a *plasmodium*, a creamy mass of naked protoplasm, which afterwards divides and forms sporangia, enclosing numerous dust-like spores like those by which the swarm-cells were originally produced. These sporangia differ greatly in form and size, each genus having its characteristic form and the species differing from each other in minor points, some becoming combined in cake-like or cushion-like masses of relatively large size, others forming small spherical or cylindrical bodies, stalked or sessile.

Each swarm-cell possesses a single *nucleus* and a contractile *vacuole.* From the rear end it puts out finger-like processes (*pseudopodia*) with which it catches its food. The pseudopodia draw it into the body, where it is digested in the vacuoles. The swarm-cells increase in numbers by each dividing into two, and these dividing in the same manner again and again. When they unite into the creamy mass known as the plasmodium, they alternately advance and recede as a whole, but the movement is always more in one direction than the other. After a few hours the plasmodium

Photo by] [*E. Step.*

FIG. 719.—*Brefeldia maxima.*

Two encrusted æthalia are shown of the natural size, one on each side of the stump. The black area between them is a coating of the soot-like spores left by the rupture of an old æthalium. The plasmodium stage is shown in fig. 186, page 149.

breaks up into few or many (according to species) smaller masses which form into sporangia. A crust forms around the sporangium and the enclosed portion breaks up into spores; but prior to this a system of delicate threads is constructed, forming a network in which the spores are held. This is known as the capillitium. There are also in some species free threads called *elaters*, spirally twisted and hygroscopic. As the sporangium ripens and dries, the investing membrane breaks up by shrinking and the spores are only held together by the capillitium network. The elaters expand and contract, their movements throwing the spores out through the meshes of the capillitium. Many of them have granules of calcium carbonate in the walls of the sporangia and as knots on the capillitium threads. The same substance appears in the plasmodium.

The period of nutrition corresponds with the amœboid state—that is, the swarm-cell and the plasmodium. As swarm-cells they are negatively heliotropic—they avoid the light and retire into the darkness of rotten wood and decaying leaves; but in the plasmodium stage their heliotropism becomes positive—they stream out towards the light in order to form their sporangia on the exterior of their habitat. The swarm-cells are also positively hydrotropic—they move from dry to moist places; and both swarm-cells and plasmodium are trophotropic—they move towards nutrient substances.

FIG. 720.—DEVELOPMENT OF A MYXOMYCETE.

The upper row shows: 1, a spore; 2, the contents of the same emerging as a swarm-cell with a nucleus; 3, the same with nucleus, vacuole, and flagellum; 4, the swarm-cell has assumed the amœba form. Below is a portion of plasmodium, and to the right a sporange. All diagrammatic.

De Bary, to whose researches much of our knowledge of the Class is due, decided in favour of their animal nature on account of the formation of a plasmodium by the aggregation of the swarm-cells. But although he said their place was "outside the limits of the vegetable kingdom," he continued to include them in his botanical works. What has always appeared to us a strong argument against their being driven out of the vegetable kingdom is that their exhibition of animal traits is restricted to their earlier stages of development. The test of their real nature should be applied to their ultimate condition and their mode of reproduction, both of which are essentially vegetable. The catching and digesting of Bacteria is indicative of animal nature, it is true, but what about the trapping and digesting of animal food by the Sundews, the Butterworts, Bladderworts, and Pitcher-plants? The power of movement in the swarm-cells is paralleled by similar movements in the antherozoids of many cryptogams; and the development of cellulose is by no means a common feature among animals.

But however one may regard these Mycetozoa or Myxogastres, they remain an exceedingly interesting group, such as may be studied easily by all who walk in the woods and country lanes, and we shall try by a few examples of different types to give some elementary idea of their beauty and diversity of form and colour, such as may be acquired by a pocket lens—though for their serious and exact study the microscope is required to be brought into use, as the determination is largely based upon the character of the capillitium, the size and colour of the spores, and so forth.

One of the largest of known species is *Brefeldia maxima*, of which we have already (fig. 186) given a photograph showing it in the plasmodium stage. The appearance of this plasmodium to one who only knows the "Myxies" as almost microscopic forms is astonishing. We have seen it issuing from a large pine stump, flowing out over the bark and climbing up the stems of plants at a short distance in sheets that would cover several square feet. There were no visible cavities in the stump—to all appearance the wood was sound. But they issued as microscopic swarm-spores from microscopic cavities, and multiplied by division on the exterior. A small portion of such an outflow is shown in the photograph of the natural size (see p. 149). After a time the creamy whiteness gets a pinkish tinge, then brown, and a crust forms over detached oval portions two or three inches long. The crust is somewhat shiny, of a dark brown colour, and with an indistinct tesselated appearance. This is an æthalium or compound sporangium, and the tesselated appearance is due to the fact that there are a large number of sporangia packed closely side by side. The semi-fluid creamy mass inside becomes a dry, fine powder like soot. The crust contracts, splits and flakes off, leaving the spores (for such is the powder) free to be blown out by the air-currents (fig. 719).

Mucilago spongiosa, shown in fig. 717, also forms an æthalium, but it is quite different in appearance from that of *Brefeldia*, the sporangia composing it being more loosely compacted. Its creamy plasmodium may be seen in autumn creeping up the stems of grasses and weeds in pastures. At some distance up the stalks it consolidates into masses such as are shown in the photograph, which are thickly covered on the exterior with crystals of lime. Its spiny spores are dull purple in colour. *Leocarpus fragilis* may frequently be found on pine stumps, with large, polished, brown sporangia, clustered owing to the weakness and shortness of their stalks. Our photo (fig. 721) represents it in the plasmodium stage creeping among moss and pine-needles on a pine stump.

The capillitium of some species expands to a remarkable size when the sporangia dehisces. This is particularly the case with several species of *Arcyria*. In *Arcyria nutans*, for an extreme example, the capillitium extends to about ten times the length of the sporangia from which it escaped. *Trichia botrytis* in the swarm-cell stage lives in wood that is thoroughly rotten and sodden, coming to the exterior to form a purple-brown plasmodium, and finally the massive-stalked pear-shaped sporangia. These are at first of a beautiful red colour; but as they dry and harden

Photo by] [*E. Step.*

FIG. 721.—*Leocarpus fragilis.*

The plasmodium of this Myxomycete creeping over mosses and pine-needles on a pine stump.

there is some reduction in the thickness of the stalks and the sporangia turn to yellowish-olive, red-brown, or purple-black. In some cases each sporangium stands apart on its own stalk, but in others from three to eight stalks will unite and support a cluster of as many sporangia.

GLOSSARY OF TERMS

[*Note*—As the application of these terms has been fully explained in the text, the repetition of the same here has been considered unnecessary.]

Achene ; Gr. *a*, not, and *chaino*, I open
Acicular ; Lat. *acicula*, a small needle
Actinomorphic ; Gr. *aktis*, a ray, and *morphe*, a shape
Æstivation ; Lat. *æstas*, summer
Æthalium ; Gr. *aithalos*, soot
Aleurone ; Gr. *aleuron*, ground wheat
Allogamy ; Gr. *allos*, other, and *gamos*, marriage
Amentum ; Lat. a thong
Amplexicaul ; Lat. *amplexus*, embracing, and *caulis*, stem
Anatropous ; Gr. *anatrepō*, to turn in or over
Androecium ; Gr. *andros*, a male, and *oikos*, a house
Anemophilæ ; Gr. *anemos*, the wind, and *phileo*, to love
Angiosperm ; Gr. *aggeion*, a vessel, and *sperma*, seed
Annular ; Lat. *annulus*, a ring
Annulated ; Lat. *annulatus*, ringed
Annulus ; Lat. a ring
Antherid ; Gr. *antheros*, flowery, and *idion*, a diminutive suffix
Antherozoid ; Gr. *antheros*, and *zoon*, an animal
Anthers ; Gr. *antheros*.
Anthocyanin ; Gr. *anthos*, flower, and *kuaneos*, dark blue
Antipodal ; Gr. *anti*, opposite, and *pous*, foot
Apocarpous ; Gr. *apo*, separate, and *karpos*, fruit
Apogamy ; Gr. *apo*, and *gamos*, marriage
Archegone ; Gr. *archē*, a beginning, and *gonē*, birth, production
Archespore ; Gr. *archē*, and *sporos*, seed
Ascidiform ; Gr. *askidion*, a little bottle
Auriculate ; Lat. *auricula*, an ear
Autogamy ; Gr. *autos*, self, and *gamos*, marriage

Bract, Bracteate ; Lat. *bractea*, a thin plate of metal

Caducous ; Lat. *cado*, I fall
Calceolate ; Lat. *calceolus*, a slipper
Calypter ; Gr. *calyptra*, a covering or veil
Calyx ; Lat. *calix*, a cup
Cambium ; Lat. *cambio*, I exchange
Campanulate ; Ital. *campana*, a bell
Campylotropous ; Gr. *campulus*, curved
Capillitium ; Lat. *capillus*, a bush of hair, or beard
Capitulum ; Lat. a little head
Carpel ; Gr. *karpos*, fruit
Carposperm ; Gr. *karpos*, and *sperma*, seed
Caryophyllaceous ; Gr. *karuophullon*, the clove-tree
Caryopsis ; Gr. *karuon*, a nut, and *opsis*, appearance
Cauline ; Lat. *caulis*, a stem
Chlorophyll ; Gr. *chloros*, green, and *phullon*, a leaf

Circinate ; Lat. *circinatus*, rounded
Cladode ; Gr. *klados*, a branch
Cleistogamic ; Gr. *kleistos*, closed, and *gamos*, marriage
Coleorhiza ; Gr. *koleos*, a sheath, and *rhiza*, root
Collenchyma ; Gr. *kolla*, glue, and *enchuma*, something poured in
Columel ; Lat. *columella*, a little column
Conduplicate ; Lat. *conduplicatus*, doubled
Connate ; Lat. *con*, together, and *natus*, born
Convolute ; Lat. *convolutus*, rolled up
Cordate ; Lat. *cor*, the heart
Corm ; Gr. *kormos*, a stem or trunk
Cormophyte ; Gr. *kormos*, and *phuton*, a plant
Corolla ; Lat. diminutive of *corona*, a crown
Cotyledon ; Gr. *kotuledon*, a cup-shaped cavity
Cremocarp ; Gr. *kremannumi*, to hang, and *karpos*, fruit
Crenate ; Lat. *crena*, a notch
Cruciform ; Lat. *crux*, a cross, and *forma*, form
Cryptogam ; Gr. *kruptos*, hidden, and *gamos*, marriage
Cucullate ; Lat. *cucullus*, a hood or cowl
Cuneate ; Lat. *cuneus*, a wedge
Cyanic ; Gr. *kuaneos*, dark blue
Cyanophyll ; Gr. *kuaneos*, and *phullon*, leaf
Cystoliths ; Gr. *kustis*, a bag or bladder, and *lithos*, a stone

Deciduous ; *decidere*, to fall
Decurrent ; Lat. *de*, down, and *curro*, to run
Decussate ; Lat. *decusso*, to divide crosswise
Dehisce ; Lat. *dehiscere*, to gape
Dentate ; Lat. *dens*, a tooth
Dichogamy ; Gr. *dicha*, in two parts, and *gamos*, marriage
Dichotomous ; Gr. *dicha*, and *tome*, to cut
Digitate ; Lat. *digitus*, a finger
Diœcious ; Gr. *di*, two, and *oikos*, a house
Distichous ; Gr *di*, and *stichos*, a row

Elater ; Gr. an impeller
Emarginate ; Lat. *e*, privative, and *margo*, a margin
Endocarp ; Gr. *endon*, within, and *karpos*, fruit
Endosmose ; Gr. *endon*, and *ōsmos*, impulsion
Endosperm ; Gr. *endon*, and *sperma*, seed
Endospore ; Gr. *endon*, and *sporos*, seed
Entomophilæ ; Gr. *entoma*, insects, and *phileo*, to love
Epicarp ; Gr. *epi*, upon, and *karpos*, fruit
Epidermis ; Gr. *epi*, and *derma*, skin
Epiphyllous ; Gr. *epi*, and *phullon*, a leaf
Epispore ; Gr. *epi*, and *sporos*, seed
Exosmose ; Gr. *exo*, outside, and *ōsmos*, impulsion

Exospore ; Gr. *exo*, and *sporos*, seed
Extrorse ; Lat. *extrorsum*, outwards

Fascicular ; Lat. *fasciculus*, a small bundle
Filament ; Lat. *filum*, a thread
Filiform ; Lat. *filum*, and *forma*, form
Fistular ; Lat. *fistula*, a pipe
Flagellum ; Lat *flagella*, a little whip
Fusiform ; Lat. *fusus*, a spindle, and *forma*, form

Galeate ; Lat. *galea*, a helmet
Gamete ; Gr. wife or husband
Gamopetalous ; Gr. *gamos*, marriage, and petal. Applied to corolla.
Gamosepalous ; Gr. *gamos*, and sepal. Applied to calyx
Gibbous ; Lat. *gibbosus*, humped
Glume ; Lat. *gluma*, a husk
Gluten ; Lat. paste
Gymnosperm ; Gr. *gumnos*, naked, and *sperma*, seed
Gymnostomous ; Gr. *gumnos*, and *stoma*, a mouth
Gynœcium ; Gr, *gunē*, a female, and *oikos*, a house
Gynandrous ; Gr. *gunē*, and *andros*, a male

Hastate ; Lat. *hasta*, a spear
Heterophyllous ; Gr. *heteros*, different, and *phullon*, a leaf
Heterostylism ; Gr. *heteros*, and style
Hilum ; Lat. a very small thing
Hydrophilæ ; Gr. *udor*, water, and *phileo*, to love
Hypocrateriform ; Gr. *hypo*, under, and *krater*, a goblet

Indusium ; Lat. an under-garment
Inflorescence ; a collective name for all the flowers produced on one floral shoot
Infundibuliform ; Lat. *infundibulum*, a funnel
Introrse ; Lat. *introrsum*, inwards
Involucre ; Lat. *involucrum*, a wrapper
Involute ; Lat. *involutus*, wrapped up

Labiate ; Lat. *labium*, a lip
Laciniated ; Lat. *lacinia*, a fringe or border
Latex ; Lat. juice
Legumin ; Lat. pulse
Leukoplasts ; Gr. *leukos*, white, and *plasma*, that which has been formed
Loculicidal ; Lat. *loculus*, a little place, and *cædo*, to cut.

Malacophilæ ; Gr. *malakos*, soft [mollusc], and *phileo*, to love
Manubrium ; Lat. a handle
Medullary ; Lat. *medulla*, the marrow
Megaspore ; Gr. *mega*, great, and *sporos*, seed
Meristem ; Gr. *meristos*, divided
Mesocarp ; Gr. *mesos*, middle, and *karpos*, fruit
Metabolism ; Gr. *metabolē*, a changing
Micropyle ; Gr. *mikros*, little, and *pulē*, a gate
Microspore ; Gr. *mikros*, and *sporos*, seed
Monadelphous ; Gr. *monos*, sole, and *adelphos*, brother
Moniliform ; Lat. *monila*, a necklace
Monœcious ; Gr. *monos*, one, and *oikos*, a house
Mucronate ; Lat. *mucro*, a sharp point
Multicellular ; made up of many cells
Mycele ; Gr. *mukos*, mushroom, and *kele*, a tumour

Napiform ; Lat. *napus*, a turnip, and *forma*, form
Nodulose ; Lat. *nodus*, a knot
Nucellus ; Lat. *nucula*, a small nut
Nucleus ; Lat. *nux*, a nut or kernel

Obcordate ; Lat. *ob*, inversely, and *cor*, the heart
Obovate ; Lat. *ob*, and *ovatus*, egg-shaped
Oophyte ; Gr. *oon*, an egg, and *phuton*, a plant
Oosperm ; Gr. *oon*, and *sperma*, seed
Oosphere ; Gr. *oon*, and *sphaira*, a sphere
Orbicular ; Lat. *orbiculus*, a small disc
Ornithophilæ ; Gr. *ornithos*, a bird, and *phileo*, to love
Orthotropous ; Gr. *orthos*, straight
Ostiolum ; Lat. diminutive of *ostium*, a door
Ovary, Ovule ; Lat. *ovum*, an egg

Pales ; Lat. *palea*, chaff
Palmate ; Lat. *palma*, the palm of the hand
Panicle ; Lat. *panicula*, cat's-tail
Papilionaceous ; Lat. *papilio*, a butterfly
Pappus ; Gr. *pappos*, the down of plants
Paraphyse ; Gr. *paraphus*, growing beside
Parenchyma ; Gr. *parenchuma*, the spongy substance of the lungs
Paripinnate ; Lat. *par*, equal, and *pinnatus*, feathered
Pedate ; Lat. *pedatus*, from *pes*, foot
Pedicel, pedicillate, peduncle ; Lat. diminutives of *pes, pedis*, the foot
Peloria ; Gr. *pelōron*, a monster
Peltate ; Lat. *pelta*, a shield
Perfoliate ; Lat. *per*, through, and *folium*, a leaf
Perianth ; Gr. *peri*, about, and *anthos*, a flower
Pericarp ; Gr. *peri*, and *karpos*, fruit
Perichæte ; Gr. *peri*, and *chaite*, flowing hair
Peridium ; Gr. *peri*, and *idea*, form
Perigone ; Gr. *peri*, and *gonē*, womb
Perisperm ; Gr. *peri*, and *sperma*, seed
Peristome ; Gr. *peri*, and *stoma*, a mouth
Personate ; Lat. *personatus*, masked
Petal ; Fr. *pétale*, a leaf, used in reference to floral leaves only
Phanerogam ; Gr. *phaneros*, evident, and *gamos*, marriage
Phloem ; Gr. *phloios*, inner bark
Phyco-erythrin ; Gr. *phukos*, sea-weed, and *erythros*, red
Phylloclades ; Gr. *phullon*, a leaf, and *klados*, a branch
Phyllode ; Gr. *phullon*, and *eidos*, likeness
Phyllotaxy ; Gr. *phullon*, and *taxis*, order
Phylloxanthin ; Gr. *phullon*, and *xanthos*, yellow
Pileorhiza ; Gr. *pileus*, a cap, and *rhiza*, root
Pileus ; Gr. a cap or helmet
Pinnatifid ; Lat. *pinnatus*, feathered, and *findo*, I split
Pinnatisect ; Lat. *pinnatus*, and *seco*, I cut
Pistil ; Lat. *pistillum*, a pestle
Plasmodium ; Gr. *plasma*, anything moulded
Plicate ; Lat. *plica*, a fold
Plumule ; Lat. *pluma*, a feather
Pollen ; Lat. fine flour or dust
Polyadelphous ; Gr. *polus*, many, and *adelphos*, brothers
Primine ; Lat. *primus*, first
Procarp ; Gr. *protos*, first, and *karpos*, fruit
Prosenchyma ; Gr. *pros*, beside, and *enchuma*, something poured in
Proteus ; a fabulous person who could change his form at will
Protandrous ; Gr. *proteros*, before, and *andros*, male
Protogynous ; Gr. *proteros*, and *gunē*, female
Prothallium ; Gr. *proteros*, and *thallos*, a shoot

Protoneme; Gr. *prōtos*, first, and *nema*, a thing spun, a thread
Protophyte; Gr. *prōtos*, and *phuton*, a plant
Protoplasm; Gr. *prōtos*, and *plasma*, that which has been formed
Pseudocarp; Gr. *pseudōs*, false, and *karpos*, fruit
Pseudopodia; Gr. *pseudōs*, and *podos*, foot
Pulvinus; Lat. a cushion
Pyxis; Gr. *puxidion*, a little box

Rachis; Gr. the spine
Radicle; Lat. *radix*, a root
Raphides; Gr. *raphis*, a needle
Reniform; Lat. *ren*, a kidney, and *forma*, form
Replum; Lat. *replum*, the leaf of a door
Reticulated; Lat. *reticulum*, a small net
Retuse; Lat. *re*, back, and *tundo*, I hammer
Revolute; Lat. *revolutus*, rolled back
Rostellum; Lat. diminutive of *rostrum*, a beak
Runcinate; Lat. *runcina*, a saw

Saccate; Lat. *saccus*, a bag
Sagittate; Lat. *sagitta*, an arrow
Saprophyte; Gr. *sapros*, rotten, and *phuton*, a plant
Sarcocarp; Gr *sarkos*, flesh, and *karpos*, fruit
Scalariform; Lat. *scala*, a ladder
Scape; Lat. *scapus*, a stalk
Schizocarp; Gr. *schizo*, to split, and *karpos*, fruit
Sclerenchyma; Gr. *skleros*, hard, and *enchuma*, anything poured or put in
Secundine; Lat. *secundæ*, second
Sepal; Fr. *sépale*, invented term to correspond with *pétale*
Septicidal; Lat. *septum*, an enclosure, and *cædo*, to cut
Septifragal; Lat. *septum*, and *frango*, to break
Sessile; Lat. *sessilis*, sitting
Sorus; Gr. *sōros*, a heap
Spadix; Lat. a palm-branch
Spathe; Gr. *spathē*, a broad blade
Spathulate; Lat. *spathula*, a broad slice
Spermocarp; Gr. *sperma*, seed, and *karpos*, fruit
Sporange; Gr. *sporos*, seed, and *aggeion*, a vessel
Spore; Gr. *spora*, seed
Sporocarp; Gr. *sporos*, and *karpos*, fruit
Sporogenous; Gr. *sporos*, and *genao*, to produce
Sporophyll; Gr. *sporos*, and *phullon*, a leaf
Sporophyte; Gr. *sporos*, and *phuton*, a plant
Stamen; Lat. a fibre
Stigma; Gr. *stigmē*, a point
Stomate; Gr. *stoma*, a mouth
Style; Lat. *stylus*, a stake
Subulate; Lat. *subula*, an awl
Synantherous; Gr. *sun*, together, and anther
Syncarpous; Gr. *sun*, and *karpos*, fruit
Synergidæ; Gr. *sun*, and *ergon*, work

Testicular; Lat. *testis*, a testicle
Tetraspore; Gr. *tetra*, four, and *sporos*, seed
Thallophyte; Gr. *thallos*, a shoot, and *phuton*, a plant
Tomentose; Lat. *tomentum*, down
Trichogyne; Gr. *trichos*, hair, and *gunē*, female
Truncate; Lat. *trunco* to maim or cut off

Urceolate; Lat. *urceus*, a pitcher
Utricular; Lat. *utriculus*, a little bottle

Vernation; Lat. *ver*, the spring
Versatile; Lat. *versatilis*, revolving
Verticillate; Lat. *verticillis*, a little whorl

Xanthic; Gr. *xanthos*, yellow
Xylem; Gr. *xulon*, wood or timber

Zoophilæ; Gr. *zoon*, animal, and *phileo*, to love
Zoospore; Gr. *zoon*, an animal, and *sporos*, seed
Zygote, Zygomorphic; Gr. *zeugnumi*, I join, and *morphe*, a shape

ERRATA

Page 49—By the turning of a numeral in printing, the chemical formula for Glucose is made to read $C_6H_{12}O_9$; it should be $C_6H_{12}O_6$, as correctly given on page 44.

Plate III—Glory Pea (*Clianthus dampieri*). The popular name belongs to the New Zealand species (*C. puniceus*); we are informed that it is not used in connection with the Australian species.

Page 445—Fig. 549 should, strictly speaking, be named *Sneezewort* Yarrow, to distinguish it from *Achillea millefolium*, the Milfoil Yarrow.

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(Scientific names of plants printed in *italics*.)

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