We now proceed to consider the form and internal structure of the various organs of plants.

I. ORGANS OF NUTRITION.

1. *Root or Descending Axis.*

Speaking generally, the root is that portion of the plant which descends into the soil. In all plants the root is at first entirely cellular. It may remain permanently so, or vessels may be formed in it. The *Radicle*, or young root (fig. 58, *r*), is the first portion of the embryo protruded from the seed or spore (fig. 54) when germination commences, and resembles very much in structure the young stem. Both are entirely cellular, consisting of a central nucleus of cellular tissue covered by two or more layers of cells. But at the apex of the root a mass of cells is developed, which constitutes what is known as the root-cap or *pileorhiza*. These cells extend for some distance along the sides of the root, forming a sheath, and in some cases, as Lemna, the cap becomes loosened from the root, remaining attached by a few cells at the apex only, and then it is known as the *ampulla*. This root-cap distinguishes structurally the root from the stem, and it serves as a protection to the apical growing-point of the root. The roots of Thallophytes, consisting entirely of cells, do not develop a root-cap.

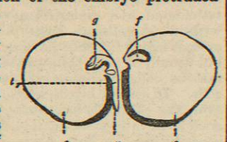


Fig. 58.

The dicotyledonous embryo of the Pea laid open. *c, c*, the two fleshy cotyledons, or seed-lobes, which remain under ground when the plant sprouts; *r*, the radicular extremity of the axis whence the root arises; *t*, the axis bearing the young stalk and leaves *g*, which lie in a depression of the cotyledons *f*.

The root is merely a prolongation downwards of the stem, and the part where they unite is the *collum* or *neck*. Afterwards the root is distinguished from the stem by the absence of a provision for the development of leaf-buds. It is not always easy to distinguish between a stem and a root. Many so-called roots bear at their upper part a portion called their *crown*, whence leaf-buds arise. Underground stems and roots are often confounded. Some plants, as the Moutan Pæony, the Plum-tree, Pyrus japonica, and especially Anemone japonica, have a power of forming buds on what are commonly called their roots. The last-mentioned plant develops these buds on every part of its extensively ramifying root-like prolongations, which may be chopped into numerous pieces, each capable of giving rise to a new plant. Such is also the case with the annulated root of Ipecacuan. Roots are usually subterranean and colourless. Externally, they have a cellular epidermal covering of a delicate texture, sometimes called *epiblema*, in which no stomata exist. In woody plants fibro-vascular bundles are found in the roots, and there is an internal arrangement of tissues similar to that seen in the stem itself, but spiral vessels are rare in the root. The axis of the root gives off branches which divide into radicles or fibrils, the extremities of which, composed of delicate cellular tissue constituting the *punctum vegetationis*, have been erroneously called *spongioles* or *spongelets*; they are not distinct organs. Hairs are often seen on roots, but no true leaves. These hairs consist of simple elongated cells, which occur singly, and appear to serve the purpose of absorption. Roots increase principally by additions to their extremities, which are constantly renewed, so that the minute fibrils serve only a temporary purpose, and represent deciduous leaves; but in large trees which form thick roots an increase in diameter occurs in the root similar to what is seen in the stem itself. In some plants no roots are formed at all; thus in the Orchidaceous plants Epipogium Gmelini and Corallorhiza innata, and also in Lemna arrhiza, no roots occur. Roots may be given off from any portion of a stem, originating as cellular prolongations from the inner portion of the stem, and coming off at any point of the stem, or at small lenticular points to which the name of *lenticels* has been given by some. When the stem is more or less horizontal the roots given off from it pass directly into the soil; but if the stem be erect they pass for a certain distance downwards through the air, and are called *aerial*. The latter are well seen in the Screw-pine (Pandanus), the Banyan (Ficus indica, fig. 59), and

Fig. 59.

Ficus indica, the Banyan tree, sending out numerous aerial roots, which reach the soil, and prop the branches.

many other species of Ficus, where they assist in supporting the stem and branches. In the Mangrove they often form the entire support of the stem, which has decayed at its lower part. In Tree-ferns they form a dense coating around, and completely concealing, the stem; such is also the case in some Dracænas and Palms. In *Epiphytes*, or plants growing in the air, attached to the trunks of trees, such as Orchids of warm climates, the aerial roots produced do not reach the soil; they continue always aerial and greenish, and they possess stomata. Delicate hairs are often seen on these epiphytal roots, as well as a peculiar investment formed by the cells of the epidermis which have lost their succulent contents and are now filled with air. This layer is called *velamen radicum*, or covering of the roots. The aerial roots of the Ivy are not the nutritive roots of the plant, but are only intended for mechanical support.

Parasitic plants, as the Mistleto (Viscum), Broom-rape (Orobanche), and Rafflesia, send root-like processes into the substance of the plants whence they derive nourishment. In the Dodder (Cuscuta), the tissue around the roots swells into a kind of sucker (*haustorium*), which is applied flat upon the other plant, and ultimately becomes concave, so as to attach the plant by a vacuum. From the bottom of the sucker the root protrudes, which penetrates the supporting body. In the case of parasitic Fungi, such as Mould, there are cellular filaments which spread among the tissues of plants, and which may be looked upon as equivalent to roots and stems united. They form the *spawn* or *mycelium* of these plants, and in some cases cause rapid destruction of the tissues of plants, as in the disease called Dry-rot.

The forms of roots depend upon the mode in which the axis descends and branches. The mode of branching of roots is almost universally monopodial, only in Lycopodiaceæ is it dichotomous. When the central axis goes deep into the ground in a tapering manner, without dividing, a *tap-root* is produced. This kind of root is sometimes shortened, and becomes succulent, forming the *conical* root of Carrot, or the *fusiform* or spindle-shaped root of Radish, or the *napiform* root of Turnip. In ordinary forest trees the first root protruded continues to elongate and forms a long primary root-axis, whence secondary axes come off. In other plants, especially Monocotyledons, the primary axis soon dies and the secondary axes take its place. When the descending axis is very short, and at once divides into thin, nearly equal, fibrils, the root is called *fibrous*, as in many Grasses (fig. 60); when the fibrils are thick and succulent the root is *fasciculated*, as in Ranunculus Ficaria, Asphodelus luteus, and Œnanthe crocata; when some of the fibrils are developed in the form of tubercules,

Fig. 60.

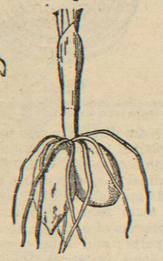


Fig. 61.

Fig. 62.

Fig. 60.—Fibrous root of a Grass. Numerous fibrils coming off from one point.
Fig. 61.—Orchis, showing tubercules or tuberous roots, which contain a gummy matter called bassorin.
Fig. 62.—An epiphytic Orchid with pseudo-bulbs.

the root is *tubercular*, as in Orchis (fig. 61); when the fibrils enlarge in certain parts only, the root is *nodulose*, as in Spiræa Filipendula, or *moniliform*, as in Pelargonium triste, or *annulated*, as in Ipecacuan. Some of these so-called roots are formed of a stem and root combined, and when cut in pieces they give rise to buds and new plants. In some cultivated plants, as Turnip, the central root is sometimes injured, so as to end abruptly, and it then divides into numerous branches, resembling a fasciculated root. This gives rise to the disease called Fingers and Toes, which is very injurious to the crop. Anbury is a disease where a clubbing of the root takes place. The mode in which the fibres of roots are produced and developed gives origin to different forms of rhizotaxis, or root-arrangement.

Roots either fix the plant in the soil or attach it to other bodies. They absorb nourishment by a process of imbibition or endosmose through their cellular extremities. The elongation of the roots by their extremities enables them to accommodate themselves to the soil, and allows the extremities of the rootlets to extend deeply without being injured. Roots, in their lateral extension, bear usually a relation to the horizontal spreading of the branches, so as to fix the plant firmly, and to allow fluid nutritive substances to reach the absorbing extremities. As has been already stated, the structure of perennial roots is identical with that of the stem. Thus in Dicotyledons we find a pith, medullary rays, zones of wood, cambium layers, and bark, although no medullary sheath is present. In Monocotyledons we have fibro-vascular bundles distributed in a matrix of cellular tissue. The young primary root in Monocotyledons differs from that in Dicotyledons in that it rises deeply within the embryonal tissue, and on germination this tissue is ruptured and forms a sheath, around the base of the roots, called *coleorhiza*. Amongst Monocotyledons the primary roots usually soon die, and secondary roots are formed in abundance. In vascular Dicotyledonous plants the structure of the root is similar to that of the stem. In Thallogens the roots consist merely of simple or branching filamentous hair-like structures. In some large tropical Seaweeds the root-like bodies develop to a large extent, but serve only as fixing organs, and take no share in nourishing the plant.

2. *Stem or Ascending Axis.*

A stem may be defined as an axis bearing leaves. Structurally it differs from a root in having no development of cells forming a cap over the growing point. Under the term *caulome* (stem structure) are included all those parts of a plant morphologically equivalent in bearing leaves. The stem generally ascends, seeking air and light, and has therefore been termed the *ascending axis*. Stems have usually considerable firmness and solidity, but sometimes they are weak, and either lie prostrate on the ground, thus becoming *procumbent*, or climb on plants and rocks by means of rootlets, like the Ivy, being then called *scandent*, or twist round other plants in a spiral manner like Woodbine, when they are *volubile*. Twining plants turn either from right to left, as the French Bean, Convolvulus, Passion-flower, Dodder, Periploca, and Gourd; or from left to right as Honeysuckle, Twining Polygonum, Hop, and Tamus. Bryony tendrils twine from right to left, and left to right, alternately. In warm climates twining plants (*lianæ*) often form thick woody stems; while in temperate regions they are generally herbaceous. Exceptions, however, occur in the case of the Clematis, Honeysuckle, and Vine; the twining stem of the vine has been called *sarmentum*. Some stems are developed more in diameter than in height, and present a peculiar shortened and thickened aspect, as Testudinaria or Tortoise-plant, Cyclamen, Melocactus, Echinocactus, and other Cactaceæ; while in many Orchids (fig. 62) the stem assumes an oval or rounded form, and is called a *pseudo-bulb*.

Names are given to plants, according to the nature and duration of their stems. *Herbs*, or *herbaceous* plants, have stems which die down annually. In some of them the whole plant perishes after flowering; in others, the lower part of the stem forming the *crown of the root* remains, bearing buds from which the stem arises next season. In what are called *biennial* herbs, the whole plant perishes after two years, while in *perennial* herbs the crown is capable of producing stems for many years, or new annual products are repeatedly added many times, if not indefinitely, to the old stems. The short permanent stem of herbaceous plants is covered partially or completely by the soil, so as to protect the buds. Plants producing permanent woody stems are called *trees* and *shrubs*. The latter are less than five times the height of a man, and produce branches from or near the ground; while the former have conspicuous trunks, which attain at least five times the height of a man. Shrubby plants of small stature are called *under-shrubs* or *bushes*. The limits between these different kinds of stem are not always well defined; and there are some plants occupying an intermediate position between shrubs and trees, to which the name of *arborescent* shrubs is occasionally given. The stem receives the name of *caulis* in ordinary herbaceous plants which do not form a woody stem, *culm* in grasses, *truncus* in trees, *caudex* or *stock* in Palms and in some Cacti, and *stipe* in Ferns. The term *haulm* is probably a corruption of culm; it is used by farmers to designate the stem of grasses and the herbaceous stems of plants. The stem is not always conspicuous. Plants with a distinct stem are called *caulescent*; those in which it is inconspicuous are *acaulescent*, as the Primrose, Cowslip, Gentian, and Dandelion. A similar term is given in ordinary language to plants whose stems are buried in the soil, such as Cyclamen or Sowbread. Some plants are truly stemless, and consist only of expansions of cellular tissue representing stem and leaf, called a *thallus*, and hence are denominated *Thallogens*, or *Thallophytes*.

Stems have a provision for a symmetrical arrangement

of leaves and branches,—*nodes*, or points whence leaf-buds are produced, being placed at regular intervals. No such provision occurs in roots. The intervals between nodes are called *internodes*. The stem, although it has a tendency to rise upwards when first developed, in many instances becomes prostrate, and either lies along the ground partially covered by the soil, or runs completely underneath its surface, giving off roots from one side and buds from the other. Some stems are therefore subterranean, and are distinguished from roots by the provision made for regular leaf-buds. The first rudiment of the young stem in the embryo appears outside the seed or spore after the radicle has been protruded. It is termed the *plumule* (fig. 58), and differs from the radicle in the absence of a root-cap and in its tendency to ascend. The apical growing portion of the young stem constitutes the terminal bud of the plant, and by its development the stem increases in height; but in addition there is a provision for the production of lateral buds, which develop into lateral shoots more or less resembling the parent stem, and by these the branching of the plant is determined. These buds are found in the *axil* of previously-formed leaves; or, in other words, in the angle formed between the stem and leaf. They are hence called *axillary*. They are produced always from the outer portion of the stem except in the case of Equisetaceæ (Horsetails), where they have a deep-seated origin. At first they consist entirely of cellular tissue, but in the progress of growth vascular bundles are formed in them continuous with those of the stem, and ultimately branches are produced, which in every respect resemble the axis whence the buds first sprang. As the axis of the bud increases in length, cellular projections appear at regular intervals upon the primary meristem, which are the rudimentary leaves.

Buds, as has been stated, are either terminal or lateral. By the production of the former, stems increase in length, while the latter give rise to *branches* (*rami*), from which others, called *branchlets* or *twigs* (*ramuli*), arise, and add to the diameter of the stem. The terminal bud, after producing leaves, sometimes dies at the end of one season, and the whole plant, as in annuals, perishes; or part of the axis is persistent, and remains for two or more years, each of the leaves before its decay producing a bud in its axil. This bud continues the growth in spring. In ordinary trees, in which there is provision made for the formation of numerous lateral buds, any injury done to a few branches is easily repaired; but in Palms, which only form terminal buds, and have no provision for a lateral formation of them, an injury inflicted on the terminal bud is more likely to have a prejudicial effect on the future life of the plant. In the trees of temperate and cold climates the buds which are developed during one season lie dormant during the winter, ready to burst out under the genial warmth of spring. They are generally protected by external modified leaves in the form of *scales* (*tegmenta* or *perulæ*), which frequently exhibit a firmer and coarser texture than the leaves themselves. They serve a temporary purpose, and usually fall off sooner or later, after the leaves are expanded. The bud is often protected by a coating of resinous matter, as in the Horse-chestnut and Balsam Poplar, or by a thick downy covering, as in the Willow. Linnæus called leaf-buds *hibernacula*, or the *winter quarters* of the young branch. In some plants, as in Platanus, the buds destined to live through the winter are so completely surrounded by the base of the petiole as not to be visible until the leaf has fallen off. These are said to be *intrapetiolar*.

In the bud of a common tree, as the Sycamore (fig. 63), there is seen the cicatrix left by the leaf of the previous year *c*, with the pulvinus or swelling *p*, then the scales *e*, *e*, arranged alternately in a spiral, and overlying each other in what is called an *imbricated* manner. On making a transverse section of the bud (fig. 64), the

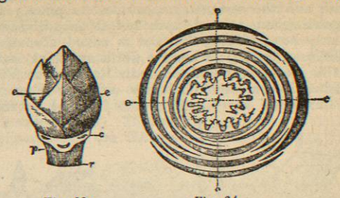


Fig. 63. Fig. 64.

Fig. 63.—Leaf-bud of Sycamore (*Acer Pseudo-platanus*) covered with scales.
Fig. 64.—Transverse section of the same leaf-bud.

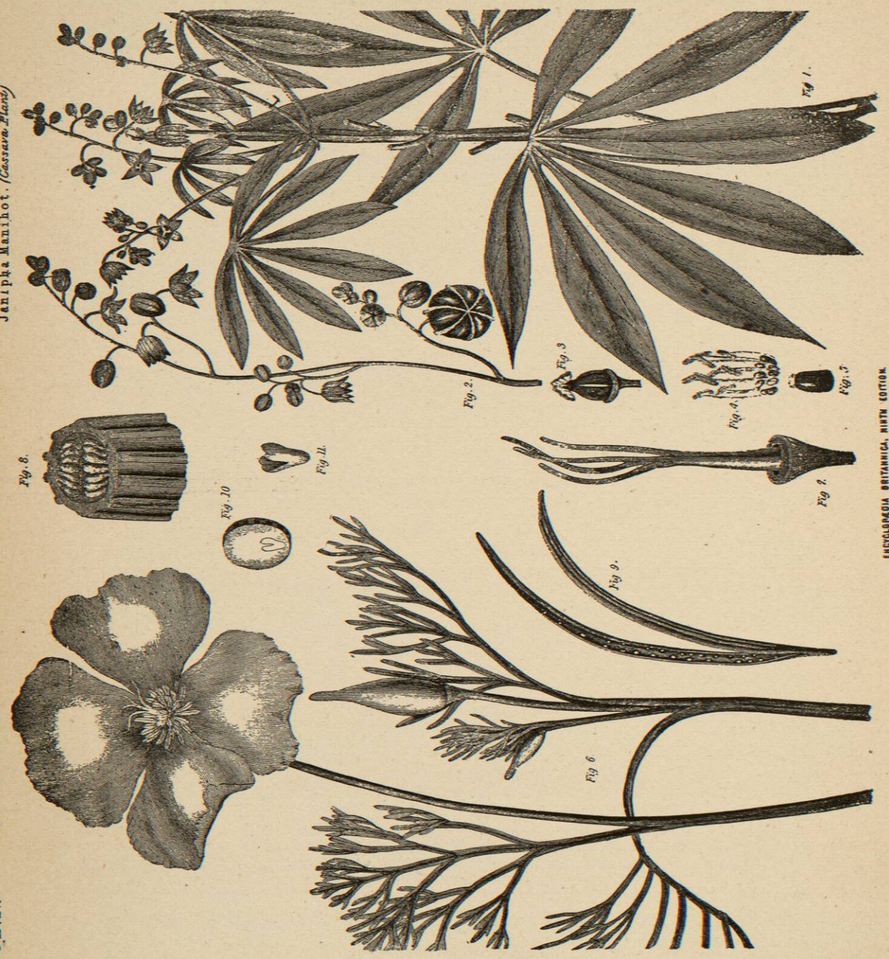
overlying scales *e*, *e*, *e*, *e*, are distinctly seen surrounding the leaves *f*, which are plaited or folded round the axis or growing-point. In plants of warm climates the buds are often formed by the ordinary leaves without any protecting appendages; such buds are called *naked*. A bud may be removed in a young state from one plant and grafted upon another by the process of *budding*, so as to continue to form its different parts; and it may even be made to grow in the soil, in some instances, immediately after removal. In some trees of warm climates, as Cycas, Papaw-tree, Palms, and Tree-ferns, growth by terminal buds is well seen. In these plants the elongation of the stem is generally regular and uniform, so that the age of the plant may be estimated by its height; owing to this mode of growth they do not attain a great diameter. Although provision is made for the regular formation of buds, there are often great irregularities in consequence of many being abortive, or remaining in a dormant state. Such buds are called *latent*, and are capable of being developed in cases where the terminal bud, or any of the branches, have been injured or destroyed. In some instances, as in Firs, the latent buds follow a regular system of alternation; and in plants with opposite leaves, it frequently happens that the bud in the axil of one of the leaves only is developed, and the different buds so produced are situated alternately on opposite sides of the stem. Occasionally, after a partial development as branches, buds are arrested and form knots or nodules. The embryo-buds or nodules of the Beech, Cedar, and Olive are apparently of this nature.

When the terminal bud is injured or arrested in its growth the elongation of the main axis stops, and the lateral branches often acquire increased activity. By continually cutting off the terminal buds, a woody plant is made to assume a bushy appearance, and thus *pollard* trees are produced. Pruning has the effect of checking the growth of terminal buds, and of causing lateral ones to push forth. The peculiar bird-nest appearance, often presented by the branches of the common Birch, depends on an arrestment in the terminal buds, a shortening of the internodes, and a consequent clustering or fasciculation of the twigs. In some plants there is a natural arrestment of the main axis after a certain time, giving rise to peculiar shortened stems. Thus the crown of the root is a stem of this nature, forming buds and roots. Such is also the case in the stem of Cyclamen, Testudinaria Elephantipes, and in the tuber of the Potato. The production of lateral in place of terminal buds sometimes gives the stem a remarkable zigzag aspect. Branches are sometimes arrested in their progress at an early stage of their development, and do not appear beyond the surface of the stem; at other times, after having grown to a considerable size, they undergo decay. In both instances the lower part of the

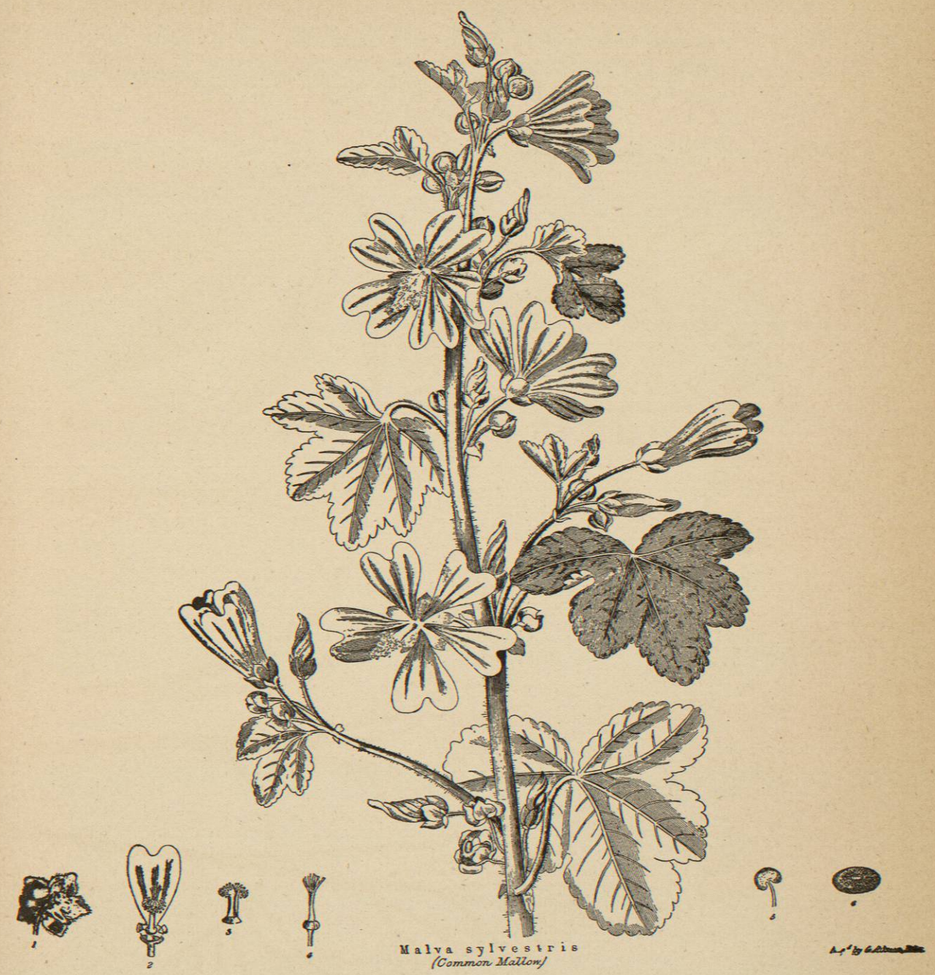
Papaver Rhœas
(Common Red Poppy)

Eschscholtzia californica.

Janipha Manihot. (Cassava Plant.)



ENCYCLOPÆDIA BRITANNICA, NINTH EDITION.



Malva sylvestris
(Common Mallow)

ENCYCLOPÆDIA BRITANNICA. NINTH EDITION.

Fig. 1.

Fig. 2.

Fig. 3.

Fig. 4.

Fig. 5.

Fig. 6.

Fig. 7.

Fig. 8.

Fig. 9.

Anacardium occidentale.
(Cashew Nut Tree.)

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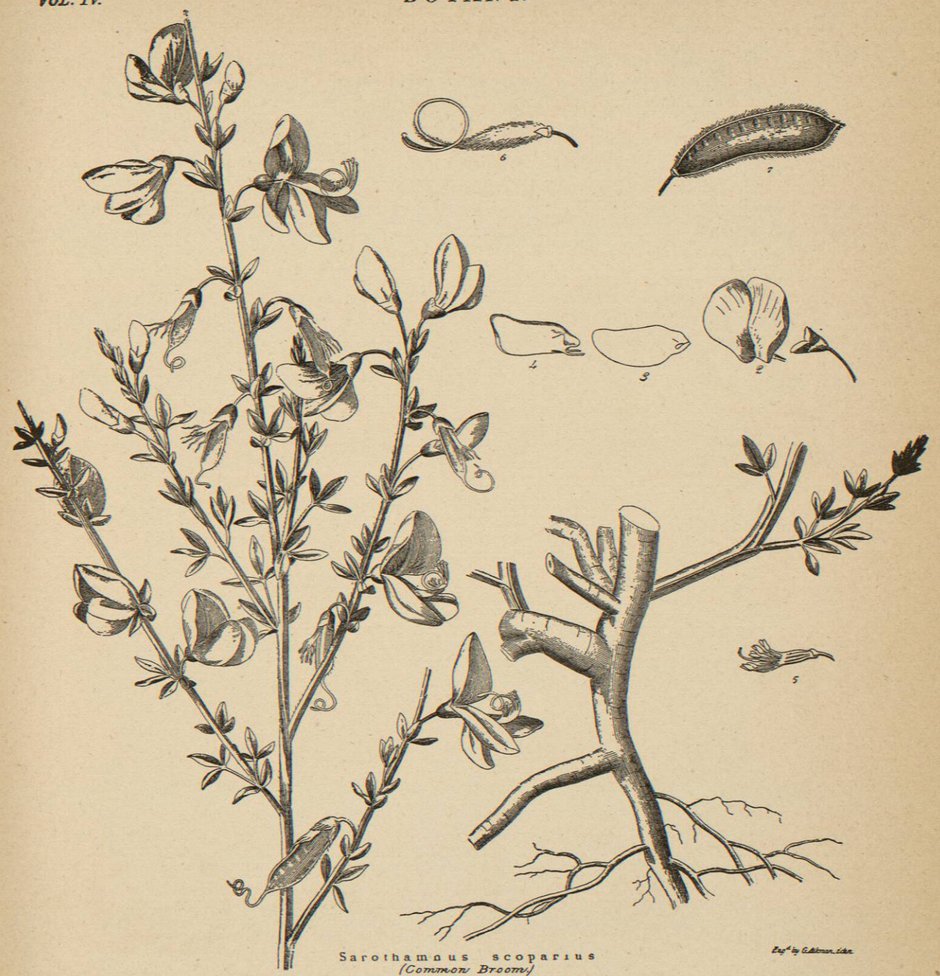

Sarothamnus scoparius
(Common Broom.)

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