A MANUAL

OF

STRUCTURAL BOTANY

AN INTRODUCTORY TEXT-BOOK FOR STUDENTS OF SCIENCE AND PHARMACY

BY

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PREFACE

This volume, which is a condensed but fairly complete introduction to botany, and is suitable as a text-book for academic or collegiate students, has been written with special reference to the needs of the first year student of pharmacy, as a preparation for his second year work in pharmacognosy. It may, therefore, be regarded as an introduction to pharmacognosy, as well as to general botany. It will be followed by a companion volume on Commercial Pharmacognosy.

Pharmacognosy may be defined as the art of identifying, valuing, and selecting drugs of vegetable and animal origin. It is, therefore, not a distinct science, although various sciences may be employed in its practice. In such operations as taking specific gravity, making microscopical measurements and determining the characters of crystals, physics is utilized. In making qualitative tests of identity and purity and determining the percentages of constituents, chemistry is involved. In determining the structural characters of plant and animal bodies, botanical and zoölogical knowledge is necessary. In determining the value of drugs of which the purity and strength cannot be estimated by any of these methods, we may have recourse to physiological tests on animals, or pharmaco-dynamics.

It is thus apparent that the entire field of pharmacognosy is very broad and that its complete working involves varied classes of laboratory operations. The extent and complexity of detail that have become necessary in these operations have required their consideration in separate departments of the pharmaceutical curriculum, so that such branches as physical and chemical testing and pharmaceutical assaying have been established.

The number of drugs of animal origin in general use has become so small that the study of zoölogy is no longer deemed essential, and it is left to botany to contribute by far the greater portion of the instruction now deemed essential as a preparation for the study of pharmacognosy. Manifestly, a knowledge of structural botany is the only scientific basis for the examination of the plant body.

Since a correct knowledge of the structural relations of the plant-parts to one another can scarcely be gained without some knowledge of their uses in the economy of the plant, it follows that at least the elementary facts of plant-physiology must be considered in connection with its anatomy.

The parts of plants which are used as drugs may come to us either in their entire condition or in such large fragments as to be capable of examination with the naked eye, or in the crushed or powdered condition, when their examination requires the aid of the compound microscope. Even in the case of the whole drug, the examination will frequently call for the aid of the microscope in determining difficult questions of identity or quality.

Commercial Pharmacognosy may be defined as the application of pharmacognosy to ordinary commercial operations. It includes the examination of crude drugs by growers, collectors, traders, brokers, importers, and ordinary purchasers for pharmaceutical purposes. All such persons should be qualified to subject their drugs to the most complete and minute examination, or should employ someone who is so qualified; but, as a matter of fact, this is probably not true in more than one case in a hundred, though happily this proportion is steadily increasing. In all others, dependence is wholly upon examinations made with the naked eye, or at most with a pocket lens. The work on Commercial Pharmacognosy will be designed for the use of all such persons in their commercial operations with drugs. It will deal with the commercial aspects of all drugs found in commerce, their identity, varieties, grades, and qualities, their substitutes, adulterants, and imperfections, their trade designations and relative values. Although designed for use as a text-book, it will be especially valuable in its commercial adaptations.

In view of the totally different methods of examination involved, and the apparatus and other facilities required, the subjects of vegetable histology and of microscopical methods and technique are omitted from the present work, its object being to teach the student all that it is possible for him to do in the examination of drugs with the naked eye or with the pocket lens.

H. H. R.

CONTENTS

STRUCTURAL BOTANY

CHAPTER I

FUNDAMENTAL CONSIDERATIONS

Organic Bodies, Organs and Functions.—Living bodies differ from those which are lifeless in their ability to grow by converting into their own substance extraneous and dissimilar substances, as seen in the use of carbonic acid in the production of starch and cellulose. This process is called Assimilation. They consist also of more or less distinct parts, each of which performs special work differing from that performed by the other parts. These parts are called Organs or Members, and the special work which each organ performs is called its Function. Living bodies are, therefore, designated as Organic Bodies and the part of nature composed of them the Organic Kingdom. The term "organic body" is usually preferable to "living body," as it applies equally well to a body in which life has ceased to exist. A third important characteristic of living bodies which may be mentioned is their power to give origin to other independent living bodies, which, separating from their parent, or remaining attached thereto, grow into a resemblance to it. That is, they possess the power of Reproduction.

Organic Matter.—The assimilated matter of organic bodies is called Organic Matter. Organic matter may be living, as cytoplasm, or lifeless as starch. It may, as in the case of the starch, be prepared for future use as food, or be for the construction of tissue, as in the case of cellulose, or it may exist as disassimilated matter resulting from the performance of function, as the poisonous ptomaines of bacteria. The latter may still be of some service in the plant economy, as are volatile oils, or, perhaps, be entirely useless.

Plants and Animals.—Organic bodies are of two kinds—Vegetable and Animal—and are respectively denominated Plants and Animals.

Biology.—The study of the organic kingdom constitutes Biology.

Anatomy.—Biology in attention to the structure of bodies is Anatomy.

Physiology.—Biology in attention to functions is Physiology. We have therefore both animal and plant anatomy, and animal and plant physiology.

Botany.—Biology relating to plants is Botany.

Gross and Minute Anatomy.—Owing to the totally different methods of examination employed in the two cases, it becomes of the greatest convenience to divide anatomy, in practice, into two parts. That part depending upon observations which can be pursued without the aid of the compound microscope is known as Gross Anatomy. That which requires such aid is Minute Anatomy, or Histology.

Microscopical Botony.—Applied to botany, the latter is commonly known as Microscopical Botany, a term which, though incongruous, possesses the excellent merit of being highly convenient and generally expressive.

As the study of botany involves the use of physics and chemistry, it is apparent that when so applied they become parts of botany, just as botany becomes a part of physics or chemistry when applied in the pursuit of those branches. The propriety of such terms as "chemical botany" or "botanical chemistry" is thus explained.

Departments of Botany.—The departments of botany, and the manner in which one may arise from the necessities of another and contribute to it, may be illustrated as follows:

Systematic Botany.—It being understood that no plants are now in existence which existed in the beginning, all having originated through changes effected in some manner in those which formerly existed, one of the great objects of botanical study is to ascertain the genetic relationships which exist between plants and to constitute such a systematic arrangement of them as shall, so far as practicable, indicate the lines and order of their development from others, that is, of their Phylogeny. This department constitutes Systematic Botany.

Structural Botany.—Since such classification is based chiefly upon structure, it is necessary that there should be a department known as Structural Botany.

Physiological Botany.—Before the facts ascertained by the structural botanist can be utilized in classification, it is necessary that the relative ranks of the structural characteristics should be determined. Of any two structural characteristics, that which was first developed, or is the older in creation, should form the basis of the primary division of the group, the other of a subdivision. In ascertaining such relative ranks, a consideration of the uses of the several characters is of great value, so that Physiological Botany or Vegetable Physiology is brought into service.

Organography.—When structural botany has for its object merely the determination of the organs as they exist, it becomes Organography.

Organogeny or Morphology.—When such object is to determine the development of organs through the transformations of others, as of a petal from a leaf, or a tendril from a branch, it becomes Organogeny or Morphology.

Homologies and Analogies.—The ancestral organ and its developed product are called Homologues of each other, and an Homology or Affinity is said to exist between them. For example, the leaf of a plant, and the petal of its flower, which we assume to have developed through the modification of the leaf, are homologues of one another. When they are only similar, without any genetic relationship, they are Analogues of each other, and Analogy exists between them. Morphology might, therefore, be defined as the study of homologies.

Anthology and Carpology.—As classification has been based very largely upon flower structure and fruit structure, the study of these, respectively, has been dignified by the titles Anthology and Carpology.

Phytography.—The description of plants in such manner that they can be recognized therefrom is called Descriptive Botany or Phytography.

Other Departments.—Botany has also numerous departments depending upon the class of plants under study, as Phanerogamic Botany, the botany of flowering plants; Cryptogamic Botany, that of flowerless plants; Mycology, the study of fungi; Agrostology, the study of grasses.

Agricultural Botany.—This is subdivided into a number of different departments, such as Agrostology, or Graminology, the study of grasses and of their culture; Horticulture, the study of garden plants and of their culture; Floriculture, Pomology, and Forestry. Doubtless a very large and important department will yet be established for the study of the culture of medicinal plants.

Medical Botany.—This term is self-explanatory as to its general nature. In use, however, it should be more strictly regarded than is customary. The term originally included all botany relating to medicinal plants; but with the development of Pharmacy the greater portion of what was once comprised in the former term has naturally and permanently established itself in the form of the separate department, Pharmaceutical Botany. Medical Botany properly concerns itself with the medicinal properties and active principles of plants, and the determination of their uses, including the principles (but not the practice) of their preparation as based upon such facts, and their classification in view of medical considerations.

Pharmaceutical Botany.—In its widest scope, Pharmaceutical Botany would include the classification, phytography, histology, distribution and culture of medicinal plants, and the collection, preservation, packing, transport, commerce, identification and selection, composition, and methods and processes of preparation for use of the drugs derived from them. From this it would follow that the pursuit of pharmaceutical botany would demand a thorough knowledge of nearly all departments of scientific botany. This conclusion is to be modified, in view of existing conditions, in important directions. The pursuit of the study to such an extent would almost necessarily involve the average pharmacist, at least in this country, in financial failure, through the inattention to practical affairs which would ensue. It is the peculiar office of the teacher of technical science to place its practical benefits within the reach of his students, while relieving them from attention to the greater portion of the field. It is not to be overlooked, however, that while such a process of extensive exclusion is possible, utility requires that a corresponding degree of elaboration shall be attained in special directions. The faithful teacher, moreover, will not refrain from urging as liberal an indulgence in extra-utilitarian study as individual circumstances will properly permit. The directions in which botanical knowledge is most useful to practising pharmacists will determine the most important requirements for botanical study.

Pharmacognosy.—The identification, valuation, and selection of drugs —that is to say, Pharmacognosy—constitute the principal field for the exercise of botanical knowledge on the part of the pharmacist.

It is convenient to divide botanical pharmacognosy, like vegetable anatomy, into gross and minute, the latter concerning itself with those characters which require the compound microscope for their demonstration.

Subjects Essential to Pharmacognosy.—Remembering that vegetable drugs may consist of the entire plant or of any one or more parts thereof, and that they may reach the pharmacist in any condition, from that of unbroken, or even fresh, to that of a fine powder, the departments of botany necessarily pertaining to pharmacognosy and materia medica will appear as follows: A knowledge of classification or systematic botany, while a prime necessity in medical botany, there being a distinct co-relation between natural classification and medicinal value, is one of the less practical and essential elements of pharmaceutical botany. Still, it aids the student in the application of phytography and especially in understanding distribution, and it serves to crystallize and systematize his knowledge of groups of medicinal agents. A good working knowledge of phytography may be regarded as the leading essential. If the drug is to be sought by the pharmacist in nature, he can recognize it only through phytography, whether that knowledge be acquired through folk-lore or book-lore. If, on the other hand, he seeks the crude drug in commerce, he merely restricts his phytography to the plant-part under inspection, and so far from being by this consideration relieved from phytographical labor, its requirements are the more exacting and its methods the more refined, as the recognition and estimation of a fragmentary representative becomes more difficult than that of the complete individual. As "Phytography" in its ordinary employment is about equivalent to "the study of the manifest organs of plants," or of their gross units of structure, morphology becomes the key to the situation.

When drugs come to hand in a comminuted condition, the compound microscope is the only resource, and the department of plant-histology becomes the foundation of work. As will be shown farther on, the greater portion of this subject can be passed over, but that portion which receives attention, permitting the recognition of detached tissue-elements and the determination by their examination of their source, requires observations quite as careful and knowledge quite as accurate as are called for in any other portion of the field. In the New York College of Pharmacy, for the students of which this work is specially prepared, the use of the compound microscope, and the subject of histology, are separately taught, and the treatment of this important subject is left to the appropriate department.

Finally, we note that only an insignificant portion of the materia medica includes the bodies of flowerless plants, so that the great division of Cryptogamic botany, as regards its detailed treatment, is not essential to Pharmacognosy.

Order of Subjects.—In attempting a comparative view of the series of plants, it is unquestionably well to begin with the lowest form and follow the line, or rather lines, of upward development; but in gaining our first knowledge of the structure of the plant organism, sound and accepted rules of pedagogy require that we begin with the more obvious characters of the higher plants, and pursue the analytic method, so far as the special conditions of the case will permit.

It has been repeatedly remarked that plant life is a circle of germination, growth, and reproduction, passing again into germination. It therefore makes little difference, on general principles, at which point we enter upon our series of observations. Begin where we will, we must labor at the disadvantage of requiring more or less knowledge of facts preceding our point of departure, and therefore not as yet possessed. In special cases, however, there is much more room for choice, and there are many reasons why we would advise pharmaceutical students to commence by observing the organ concerned in reproduction, namely, the flower.

CHAPTER II

ANTHOLOGY: THE GENERAL NATURE OF THE FLOWER

The Phytomer.—In order to accurately understand the structure of the flower, we must first consider the general characters of its structural units, which are the same as those of the stem upon which it is borne and of which it is a part. These are well displayed in a willow twig (Fig. 1), presenting a main stem, with perhaps short branches below and leaves above. These leaves are found, upon examination, to arise at regularly occurring points, thus dividing the stem into parts which are seen to possess definite and uniform characteristics. In common language these parts are called "joints," and technically, Phytomers or Phytons.

Units of Structure.—The upper portion of each phyton is commonly somewhat enlarged and it possesses the power of giving rise to three new structures: (1) the leaf (*a*), or in many plants a circle of two or more leaves; (2) a superimposed phytomer, continuing the growth of the stem in its original direction; (3) a branch extending the growth of the stem in a lateral direction, or, if there be more than one leaf, then a corresponding number of such branches. Upon the upper portion of the stem the branches are seen still undeveloped, and in the form of buds (*b*). The bud originates, with rare exceptions, at the point where the leaf emerges from the stem and upon its upper side. This point is known as the Leaf-axil. The portion of the phytomer which gives origin to these three structures is called its Node (*c*). The portion intervening between two nodes is called the Internode (*d*). The internode does not normally possess the power of giving origin to these new parts.

The branch is found, after development, not to differ essentially from the stem, so that a branch may be regarded as a lateral stem, secondary, tertiary, and so on. In noting hereafter the development of the other parts of the plant out of those here named, we shall frequently find the latter so modified that we shall be unable to recognize them by the ordinary methods of examination, so that the relative positions which they occupy will prove an important guide. A correct understanding of morphology requires, therefore, that we keep in mind the following facts relating to the internode, node, leaf, branch, and superimposed phytomer.

1. Any of them may remain more or less undeveloped.

2. There is a definite and regular arrangement as to position of the leaves upon the stem in most cases.

3. Several leaves and as many branches may develop from one node.

4. The branch normally develops as a bud in the leaf-axil, and conversely a leaf, in some form, is normally at the base of each branch in its rudimentary condition.

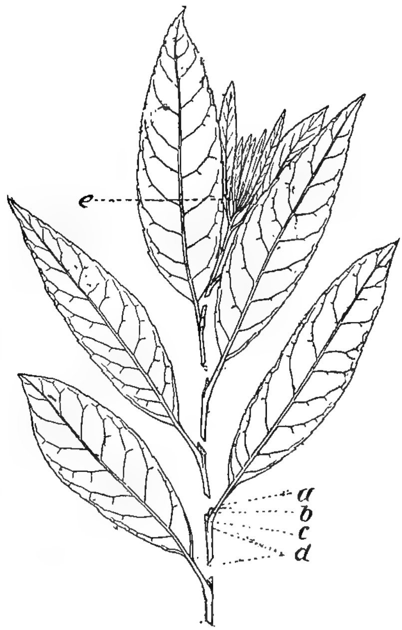


Fig. 1. Leafy twig of willow, its phytomers separated. *a*, leaf; *b*, axillary bud; *c*, node; *d*, internode.

5. All growth developing in the leaf-axil, with the exception of hairs and similar appendages, is a manifestation of the branch.

6. All organs of the plant which we consider, except the root, the hairs, etc., are constructed of the above parts in some modified form.

Certain necessary qualifications of the above statements can be made only when we come to the study of the stem, and these do not involve any failure to understand correctly the principles of anthology.

Propagation by Nodes.—Before proceeding to consider the forms of structural modification of phytomers in the development from them of the flower, certain important properties pertaining to them, in addition to their ability to multiply and grow as above indicated, should receive attention, in order that later a comparison of reproductive methods can be instituted. It is found that if, in the case of many plants, a stem be laid prostrate in the soil, its connection with the parent not destroyed (Fig. 2), its nodes, in addition to producing branches (*a*), may develop roots (*b*) similar in structure and function to those of the parent. If now the phytomers be separated through some portion of the internode, they will heal the wound so produced by the formation of a callus (*c*), continue to grow independently, and become plants similar to the parent. Such a process, here of artificial production, is of frequent natural occurrence and is called Propagation. It is seen to be, in this case, purely vegetative, and may be defined as the production by vegetative processes of a plant-body growing independently and separately from that from which it was derived.

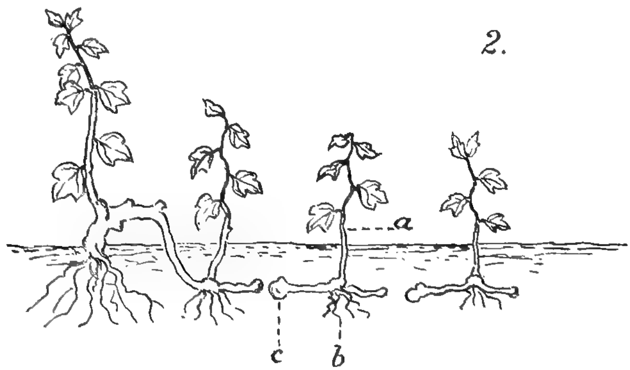


Fig. 2 Propagation by layering. *a*, axillary bud developed into a stem; *b*, adventitious roots; *c*, callus.

Various other modes of stem-propagation may here be referred to, and it may be remarked that the process is not confined to the node, occurring in exceptional cases from fragments of the internode, root, or even leaves. The phytomers, instead of remaining attached during the rooting process (Layering), may be first separated (Propagating by Cuttings). The cutting, in this case called a Scion, may be inserted (Grafting) or a bud may be so inserted (Budding) under the bark of a living stem, or it may be caused to take root in the soil. Propagation by tubers or parts of them, as in the case of the potato, is identical. It may be remarked, in passing, that in the seed itself nature resorts to a similar method, for the contained embryo consists of one or more phytomers. This process is, however, sexual, and is called Reproduction.

Composition of the Stem.—Roughly stated, the stem may be said to consist of three portions: (1) A framework consisting of strands of conducting vessels (54, *g*), associated commonly with fibers; (2) among and around the last a quantity of soft non-fibrous tissue; (3) a covering, membranaceous when young and changing greatly with age.

Composition of the Leaf.—All these parts are extended into the leaf, the first existing in a system of branching ribs or veins, the second as a filling in the meshes of the former, and the third as a highly developed skin-like covering, the epidermis.

Parts of the Leaf.—Morphologically considered, the typical leaf (Fig. 3) consists of three parts which, like those of the stem, will be considered in detail hereafter. The base (*a*) bears the Pulvinus or organ of attachment to the stem, frequently extended into an encircling sheath, and upon either side a membranous expansion (*b*) called the Stipule. The stem of the leaf (*c*) is called the Petiole. The blade (*d*) is called the Lamina. In some plants an additional organ, the Ligule, develops as an appendage upon the face, being a modification of the stipule (Fig. 465, *A*, *b*).

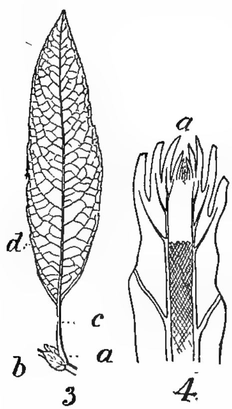


Fig. 3. Leaf of willow. *a*, pulvinus or foot; *b*, stipules; *c*, petiole; *d*, lamina. 4. Diagram of longitudinal section through bud. *a*, the growing point.

Modification of the Structural Units.—If we could observe the phytomers of such a twig during the process of formation in the bud (Fig. 4) we should find them in a more and more rudimentary condition towards its apex or center until we reached an ultimate growing point (*a*), where development had not yet manifested itself. Yet this point would possess the power, under proper conditions, of continuing the process of development and growth of phytomers. It therefore may be said to represent a certain amount of vital energy or potential growth. Now, our fundamental ideas of flower structure rest upon the fact that this vital energy or potential growth may be diverted from the production of phytomers and leaves such as we have been considering and may produce in their stead other structures in which resemblance to and variation from them are mingled in variable proportions. These new structures we then call Modified Phytomers and Modified Leaves. The student should dwell upon this point until the exact meaning of these terms becomes clear. When hereafter he encounters, as he very frequently will, a reference to some organ being modified or transformed, it must never be understood that it was first produced and then changed. The exact meaning is that the change takes place in the direction or exercise of the energy which is to produce the modified structure.

Modification Produced by Injury.—Such a diversion of energy may be caused by accident, as seen in the so-called "Willow-cone" (Fig. 5), resulting from an injury inflicted by an insect in depositing its eggs in

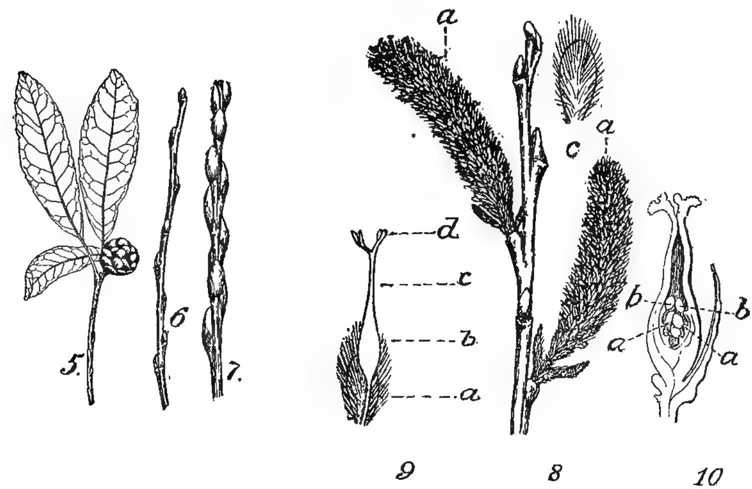


Fig. 5. Willow twig with tip transformed into a gall-cone through insect agency. 6. Willow twig after fall of leaves. 7. The same with axillary buds enlarged, in spring. 8. The same with axillary buds developed into (*a*) female flower-bearing branches. *c*, scale (modified leaf) from one of the nodes of "*a*." 9. Scale with its axillary bud developed into a flower, consisting of a pistil only. *a*, the stipe; *b*, the ovary; *c*, the style; *d*, the stigmas. 10. Longutidinal section through willow pistil. *a*, placenta; *b*, ovule.

the center of a bud. A portion of the structures, having been originated before such injury, will reach a partial development, but further production is checked and a distorted product results.

Bud-scales are Modified Leaves.—In the cases which we shall have to consider the modification dates from an earlier stage and is natural and physiological, instead of pathological, as in the case of the willow-cone. Fig. 6 represents a twig after the fall of its leaves in the autumn. Each bud is seen protected by its lowest leaf, permanently enlarged, and developed into a covering scale. At the base is seen the scar of the leaf in the axil of which the bud was developed. Fig. 7 illustrates the twig in the spring after early growth has enlarged the buds.

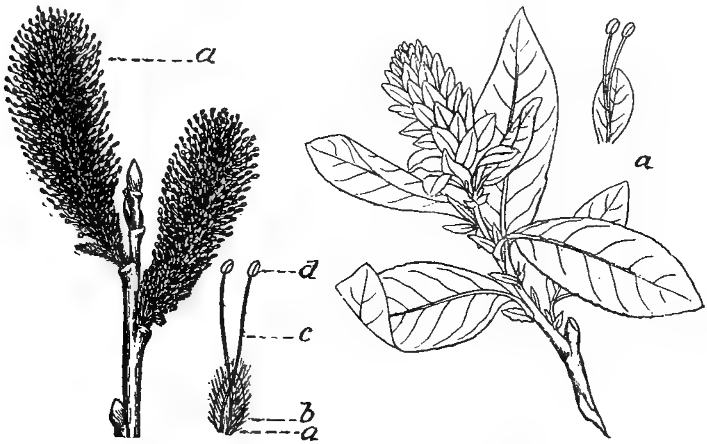
The Flower Cluster is a Modified Branch.—In Fig. 8 (*a*) the covering scale has fallen, the branch has developed to a length of an inch or so, and its structure can be seen to consist of a great number of very short phytomers, each of the crowded nodes bearing a scale (*c*) and in its axis (Fig. 9) a peculiarly shaped body (*a*, *b*, *c*, *d*). These bodies, as we shall soon see, are flowers, and this entire bunch is a flower cluster. That the scales are modified leaves is proved not only by their position, as previously explained, and to be further explained in our study of the leaf, but by the fact that in exceptional cases the branch will produce them in a form intermediate between that of a scale and of an ordinary leaf (Fig. 13, *a*).

Each Flower of the Cluster is a Modified Branch.—Such being the case, anything produced in their axils must, according to the same laws of position, be modified branches. We must therefore regard the flower shown in Fig. 9 in the axil of the leaf, as a modified branch, one of a great many produced upon the parent modified branch shown in Fig. 8. How profound is the modification which has taken place in the latter can be appreciated from a consideration of its reduced size, for it is now approximately full grown. The great number of phytomers upon it, had they reached the form and extent of development reached by those in Fig. 1, would have produced a branch many feet, or even yards, in length, whereas in their present form they will produce a structure only an inch or two long. As we shall soon see, increased complexity of structure has replaced the greater amount of tissue-growth of the leafy branch, a cluster of flowers having been produced in its stead.

The Flower Explained and Defined.—Examining now the little modified branch (Fig. 9) taken from the larger branch (Fig. 8, *a*), we observe that it presents two uniform portions or halves, united into a single body except at the tip, where they are separate. In exceptional cases we find this separation extended downward, perhaps even to the base of the body, and each of the separated portions expanded, formed and veined very much like a small leaf, which, in fact, it is. The little branch, *a*, *b*, *c*, *d*, is thus to be regarded as bearing two leaves which have been developed in a united condition. Upon dissection (Fig. 10) the body thus formed from these two leaves is found to be hollow at one portion, containing two slight projections upon its inner wall (*a*), and upon these a number of minute rounded bodies (*b*). If allowed to develop and mature under the requisite conditions, we should find that these bodies had become seeds. The structure producing them we now see to be *a branch, so modified as to produce seeds, and this constitutes our definition of the flower.*

Some Flowers are Imperfect.—It does not follow that because constructed for the production of seeds, a flower is always capable of performing this office independently, and, indeed, such is not the case with the flower under consideration, which is, therefore, an Imperfect one.

Sex and Sexual Reproduction.—Minute microscopical examination discloses within the bodies which are to become seeds, minute structures called Macrospores, which, after germination and growth in that place, produce cells comparable, in their essential characters, to the ova of animals, and requiring a similar fertilizing process to cause their development.* Flowers, or at least certain of their products, are thus seen to possess sex and to be capable of performing sexual reproduction, or reproduction proper. Commonly, both sexual parts are present in one flower, and of these the female, the 2-leaved branch here considered, and in this case all that there is to the flower, is called the Gynaecium, frequently represented by the symbol G.



11 12. 13.

Fig. 11. Willow twig with axillary buds developed into (*a*) male flower-bearing branches. 12. Scale (modified leaf) from 11, *a*, with its axillary branch developed into a male flower consisting of two stamens. *a*, position of node; *b*, scale; *c*, filament; *d*, anther. 13. Abnormal willow twig, the scales (*a*) of its flower-bearing branch intermediate between the ordinary form and the leaf.

The Gynaecium is Composed of One or More Pistils.—In Fig. 47, the gynaecium consists of five such bodies, and in other flowers it consists of various numbers. One of them is called a Pistil, so the gynaecium may consist of but one, or of any number of pistils.

The Pistillate or Female Flower.—This flower (Fig. 9) possesses only the gynaecium, and is therefore often spoken of as a "Female Flower," technically a Pistillate flower, and indicated by the symbol ♀.

* For an explanation of this subject see Chapter IX.

The Staminate or Male Flower.—Before considering the structure of the pistil we will examine a "Male Flower," borne, in the case of the willow, upon a plant which produces no pistillate flowers. Fig. 11 illustrates branches (*a*) crowded with male flowers each (Fig. 12, *a*), as before, in the axil of a scale (*b*). In this case the two modified leaves forming the flower are entirely separate and the hollow portion of each (*d*) is small, borne at the summit of a stem (*c*) and filled (Fig. 14) with a great number of minute rounded bodies. These correspond, though of the other sex, to the macrospores which we have found the pistillate flower to produce, and they are called Microspores—in flowering plants, Pollen-grains. They possess the power of germinating, growing, and producing Male Cells, comparable to the spermatozoa of animals, and requisite for the fertilization of the corresponding egg-element produced by the macrospores.

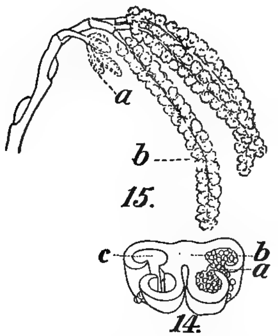


Fig. 14. Diagram representing transverse section through anther. *a*, theca, containing pollen; *b*, connective; *c*, locellus. 15, alder twig. *a*, pistillate-flowered branches; *b*, staminate-flowered branches.

The Androecium is Composed of one or more Stamens.—The male portion of a flower is called the Androecium, frequently indicated by the symbol A, and it consists of one or more Stamens, in this case of two. As this flower consists only of androecium, it is known as a Staminate Flower, indicated by the symbol ♂.

The Sporophyte, Sporophyll, and Sporangium.—We have now seen that both the stamen and the pistil, homologues of leaves, exist for the production of spores. A modified leaf producing spores is called a Sporophyll. Both the stamen and the pistil form hollow bodies for containing one or more spores. Such a spore-case is called a Sporangium or Sporange. A plant producing sporophylls and sporanges is called a Sporophyte. Macrosporophytes, Macrosporophylls and Macrosporanges are those producing only macrospores or female spores. Microsporophytes, Microsporophylls, and Microsporanges are those producing only microspores or male spores.

Dioecious, Monoecious and Polygamous Flowers.—When, as in this case, the macrospores are produced by one plant and the microspores by another, the plant is dioecious. If in addition each plant produced some perfect flowers it would be Dioeciously Polygamous. If, as in the Alder (Fig. 15) pistillate flowers (*a*) and staminate flowers (*b*), or otherwise stated, spores of both sexes, are produced by the same plant, it is Monoecious. If, in addition, the plant bear some perfect flowers it is Monoeciously Polygamous.

Hermaphrodite and Perfect Flowers.—When, as illustrated in Fig. 17, the flower possesses both gynaecium and androecium, it is Hermaphrodite, indicated by the symbol ☿. Hermaphrodite flowers are not always perfect, as one of the organs, while perfect in form, may be functionless; whereas, in order to be perfect, both parts must be present and functionally active.

Degrees of Imperfection.—Imperfect flowers present all intermediate grades between that last mentioned and that in which there remains no trace of the lost part, or in which it has even been transformed into an organ of a different kind.

Parts of the Stamen.—The stem-like portion (Fig. 12, *c*) regarded as corresponding to the petiole of the sporophyll, is the Filament. The portion containing the spores or pollen is the Anther (*d*). The two halves of the anther, each corresponding to a half of the lamina of the sporophyll, are the Thecae (Fig. 14, *a*). At an earlier stage each theca is subdivided into two Locelli (Fig. 14, *c*), and in many plants this condition persists to maturity (Fig. 138). The portion connecting the thecae with one another and with the filament is the Connective (*b*). Our detailed study of the stamen, as of the pistil, may here be anticipated by the statement that any or all of their parts may in different flowers be found modified in an extreme degree by reduction, exaggeration, or special form of growth, and may bear appendages in great variety, their true nature, or even their identity, in many cases being thus masked. Often an appendage apparently consisting of a modified stipule exists.

Parts of the Pistil.—The stem-like base (Fig. 9, *a*), not present on most pistils, is the Stipe or Thecaphore. It represents the united petioles of the sporophylls. The body of the pistil represents either a single sporophyll having its edges brought together and united, with the upper leaf-surfaces inside of the cavity (Figs. 219 and 220), or, as in this case, more than one sporophyll, the edges of one meeting those of the other in the same manner (Fig. 27, *e*) or in many cases in a different manner. The edges, after meeting along the hollow portion, project inward more or less, while along the tip, for a greater or less distance, they may be everted, as seen in Fig. 17, *b*. A sporophyll of a pistil is a Carpel and we see that a pistil may consist of one or more carpels.

The seed-rudiments which produce and contain the macrospores are the Ovules (Fig. 10, *b*). The outgrowth from the inner wall of the ovary upon which the ovules develop is the Placenta (Fig. 10, *a*). The hollow portion of the pistil, containing the placentae and ovules is the Ovary (Fig. 9, *b*). The divisions of the ovarian cavity, which sometimes exist, are called Cells (Fig. 221, etc.), and the partitions which separate them are called Septa or Cell walls. A point upon a pistil (Fig. 9, *d*) which lacks its epidermis and permits entrance into the ovary of the pollen-product is a Stigma. (See also Figs. 191, etc.) A portion connecting the stigma to the ovary, narrower than the latter and usually not hollow, is the Style (Fig. 9, *c*).

The leafy nature of the Carpel and its products is well illustrated by Fig. 19, which represents a reverted state of the pistil.

The Essential Organs.—Since the androecium and gynaecium are capable of producing seeds without the necessity for other floral parts, they are commonly known as the Essential organs, others as the Non-essential organs.

Protection Needed by the Essential Organs.—The danger of accident, as the result of blows, punctures, erosion, or even changes of temperature, to the complex mechanism and delicate structure of the essential organs, and the resulting necessity for their protection, is obvious. In the case under consideration the flowers are so closely crowded upon their supporting branch that their leaf-scales (which are not parts of the flowers, but grow out underneath them, from the nodes) afford the necessary protection. But commonly this is not the case, and each flower must provide and possess its own protecting organs. It must be borne in mind, however, that protection is usually the least important office which such organs fulfil.

The Calyx.—A series, or apparent or real circle, of such modified leaves, underneath or surrounding the androecium, is displayed in the flower of *Pulsatilla* (Fig. 16, *a*) and constitutes its Calyx, frequently indicated by the symbol K, the several leaves being called either Sepals or Calyx-Lobes, in accordance with conditions to be considered hereafter.

The Corolla.—Commonly, there is a second series or circle between the calyx and androecium, as in the buttercup (Fig. 17, *a*), and this is called the Corolla, frequently indicated by the symbol C, its several leaves, Petals or Corolla-lobes, according to their condition. Rare cases occur in which, although but a single circle is present, it is regarded as a corolla.

Sinuses.—The space between two adjacent petals or corolla-lobes—and the same is true of a similar space between any two organs or divisions standing side by side—is called the Sinus.

Petals and Sepals.—Occasionally the petals will be numerous, forming more than one circle. A petal or sepal is normally not composed of distinct parts, unless it be by a narrowed insertion, called the Unguis or Claw, which is frequently present (Fig. 18, *a*), the broad part being called the Lamina, Blade, or Limb. It is then said to be Unguiculate. Usually the form of sepals and petals is more obviously leaf-like than that of the stames and carpels, and frequently in color and texture, particularly of the sepals, they are strongly foliaceous. The calyx and corolla may, however, possess any color or texture and they may be similar or dissimilar, usually the latter, in this feature. The petals, as well as the sepals, may even differ among themselves in color and texture.

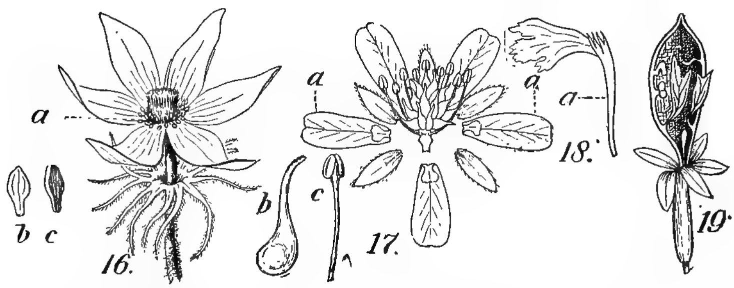


Fig. 16. Flower of *Pulsatilla*, subtended by epicalyx, with calyx of 6 sepals; *a*, torus; *b* and *c*, rudimentary or aborted petals. 17. Flower of *Adonis*. *a*, petal; *b*, pistil; *c*, stamen. 18. Unguiculate petal of *Dianthus*. *a*, unguis or claw. 19. Flower with its carpel partly reverted to the leaf-form.

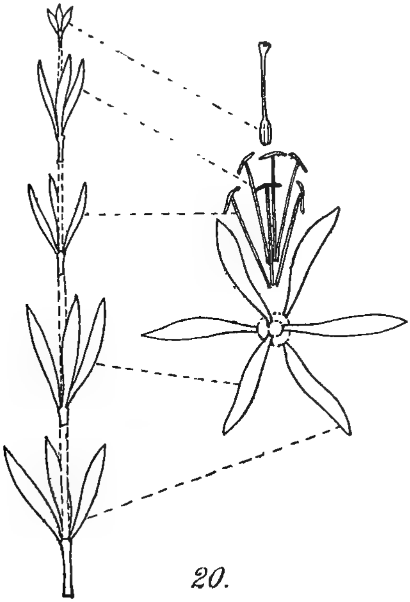
The Perigone.—The calyx, or the calyx and corolla together when both exist, constitute the Perigone, less aptly called the Perianth or Floral Envelopes. A flower possessing both calyx and corolla is called Dichlamydeous; one with calyx only, Monochlamydeous, indicated by Co, and one with neither, Achlamydeous or Naked, indicated by Ko-Co. Those which have no corolla are called Apetalous.

The Complete Flower.—A flower possessing calyx, corolla, androecium, and gynaecium is called Complete.

The Neutral Flower.—Some plants habitually produce a portion of their flowers without essential organs (Fig. 268, *a*). Such flowers are called Neutral.

The Torus.—It must ever be borne in mind that all these parts are constructed of the modified leaves of the floral branch. The latter is called the Torus or Thalamus, or, less desirably, the Receptacle. The torus may, therefore, be defined as *the reduced branch which gives origin to the parts of the flower* (*a*, in Figs. 16, 23, and 24).

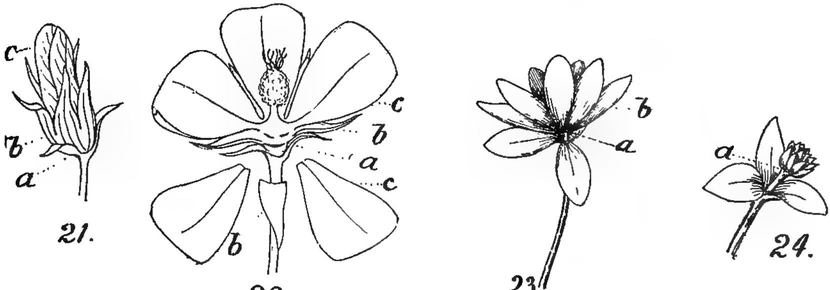
Relation of the Flower and its Parts to the Branch and its Leaves.—The relation of these parts to their branch may be displayed by comparing the leafy stem of a lily with the dissection of a lily flower (Fig. 20).



20.

Fig. 20. Diagram showing homology between leafy stem and flower of lily, the lowest whorl of former corresponding to the calyx of latter, the second to the corolla, the third and fourth to the two sets of stamens, the uppermost to the carpels, the torus to the branch.

The Epicalyx.—What appears to be a double calyx, or one calyx outside of another, is frequently seen. This appearance is sometimes



21. 22. 23. 24.

Fig. 21. Bud of *Callirrhoe*. *a*, epicalyx; *b*, calyx; *c*, corolla. 22. The same expanded. 23. Apetalous flower of *Hepatica*. *a*, torus; *b*, calyx. 24. The same, calyx removed. *a*, the torus showing the epicalyx as distant.

due to the actual manifestation of two circles, as in the mustard; at others to appendaging (see Fig. 36), but usually to a circle of modified foliage leaves standing close to the torus (Figs. 21 and 22, *a*), and known as the Epicalyx. When, as in this case, the flower has in addition a calyx and corolla the real nature of the epicalyx is readily understood. But when (Fig. 23) there is no corolla, the calyx (*b*) being colored like one, the epicalyx may easily be mistaken for a calyx. In this instance, however, it may be seen by turning back the epicalyx or removing the calyx (Fig. 24) that the point of insertion of the former is upon the stem below the torus (*a*), so that it can be no part of the flower proper. The divisions of the epicalyx are called Bracts, though the term is not restricted to this use, as will be seen farther on.

CHAPTER III

LAWS OF FLORAL STRUCTURE

Meaning of the Term.—When we speak of a natural law as governing a certain natural object, we refer merely to some observed mode or manner of the existence of that object. Thus it is a law that water flows downward, because that has been observed to be one of the peculiarities of this substance. Similarly, warm air rises, wood burns when fire is applied to it, and the sepals and petals of a flower possess a similar form to that of the leaves of the plant on which they grow and of which leaves they are homologues. Nevertheless, water will sometimes run up hill because it is forced up, warm air sometimes does not rise because it is confined, wood will not burn because it is wet or otherwise fireproof, and the sepals and petals will not conform with the leaves because some plants have no leaves, or because the influence of some other law, known or unknown to us, has interfered with the action of the one stated.

Under the natural and unobstructed influence of the morphological development of the flower from a branch and of its parts from the leaves of that branch, the flower and its parts would possess certain definite and typical characters. In the process of such development, however, there is a constant tendency toward variation from the typical state, the extent and direction of which variation are determined by the external conditions and forces to which the living plant is subject, so that, as a rule, flowers differ greatly from that typical state. A careful study of all flowers will nevertheless show that their general plan of structure is in accordance with these laws, with more or less variation in the details.

Modification of the Typical Flower.—We shall here consider the laws of floral structure in relation to the following characters: The relative number and position of parts of different kinds or of different series, as those of the calyx compared with those of the corolla, or of the androecium compared with those of the gynaecium; the separation of each part from every other, both of the same and of different kinds or series; a similarity in form and size of the parts composing any one series;

the characteristic form and function of all the parts of one kind. For the identification of the parts of a typical flower, the few illustrations and definitions already given will prove ample, but such flowers are very rare. The great majority of them deviate from the type in one or more directions to such a degree and in such a variety as to very frequently create difficulty in identifying or circumscribing the several parts. To fit the student for properly meeting the difficulties which so arise, as well as for understanding botanical terminology, it is necessary to specify and explain the principal forms of variation and to establish such a classification of them as their varied nature will permit.

Law 1: Symmetrical Flowers.—The number of parts of each kind or series is the same as of each other, or they have a common multiple. The term Isomerous is used to indicate that the same number of parts enter into the formation of the two or more circles to which the term is applied. In the case of the gynaecium, it is the carpels which are counted as parts of the circle or series, whether developed each as a separate pistil, or all united into one. The number of stamens is normally equal to that of the sepals and petals combined, that is, they form two circles. If the flower is typical, the number of stamens will thus be just twice as great as that of the parts of any other kind. A flower constructed in accordance with this law is called Symmetrical.

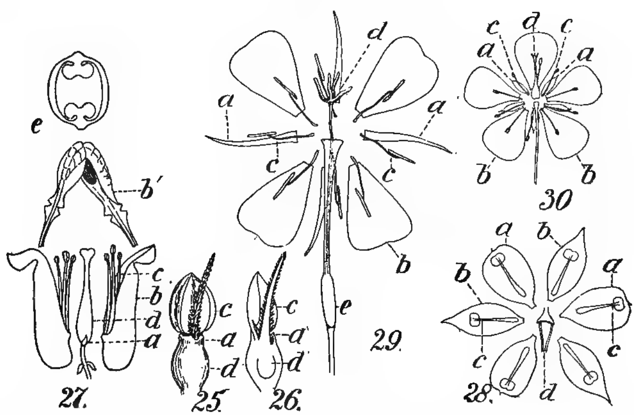


Fig. 25. Apparently monomerous flower of *Hippuris*. *a*, calyx; *c*, stamen; *d*, pistil. 26. Longitudinal section of same. 27. Dimerous flower of *Bicuculla*. *a*, sepals; *b*, original petals; *b′*, petal-like bodies developed from one pair of stamens; *c*, the other pair of stamens, each divided into three; *d*, pistil; *e*, cross-section of ovary, showing two placentae. 28. Trimerous flower of *Veratrum*. 29. Tetramerous flower of *Oenothera*. 30. Pentamerous flower of *Geranium*.

Terms Indicating Numerical Symmetry.—Thus, the flower of *Hippuris* (Figs. 25 and 26) has an entire calyx, apparently of one sepal, no corolla, one stamen, and one carpel, and is, in its present state, Monomerous or One-merous. The symmetrical flower of *Bicuculla* (Fig. 27) possesses two sepals (*a*), four petals (*b* and *b′*), six stamens (*c*), and a two-carpelled pistil (*d* and *e*), and is Dimerous or Two-merous. That of the *Veratrum* (Fig. 28) is similarly based on the plan of three, and is Trimerous or Three-merous. *Oenothera* (Fig. 29) is Tetramerous or Four-merous, and *Geranium* (Fig. 30) is Pentamerous or Five-merous. Fig. 43 displays the plan of such a flower in cross-section and admirably illustrates our second law also.

Suppression and Duplication.—Suppression results in the possession of less parts of one kind than are possessed by the typical flower, while Duplication results in the possession of more. From what follows it will be seen that neither suppression nor duplication necessarily interferes with the numerical plan, although they frequently do so.

In the monochlamydeous flower of *Pulsatilla* (Fig. 16) suppression of the entire circle of petals has occurred, although vestiges of them remain. In the staminate and pistillate flowers of the willow, all organs except a single series are suppressed. In the *Claytonia* (Fig. 45) one complete stamen-circle has been suppressed.

In all these cases the remaining parts accord with the numerical plan and the flowers are still symmetrical. Suppression which thus results is called Regular Suppression.

Irregular Suppression.—This is displayed in the calyx of *Claytonia,* with three of its five sepals wanting, in the androecium of the 4- or 5-merous flower of Horse-chestnut, which usually wants 1 to 3 of the requisite number of stamens, and in the gynaecium of the 4-merous flower of the olive (Figs. 31 and 32), which has but two carpels remaining. In this flower, both forms of suppression appear to have occurred, for but 2 of its 8 original stamens remain. To irregular suppression the term Abortion has been applied, while by others this is restricted to suppression in which a vestige of the lost organ remains, as in case of the petals of *Pulsatilla,* and one set of stamens in Fig. 38, *a*.

Regular Duplication.—Duplication, like suppression, presents a regular and an irregular form. Regular duplication is seen in the 5-merous flower of the strawberry (Fig. 36), with its 10 sepals; the 3-merous flowers of *Magnolia* (Fig. 35), with 6 to 9 petals, and *Menispermum,* with 12 to 24 stamens, and in the 5-merous flower of *Malva,* which frequently has 10 carpels.

Chorisis and Syngenesis.—The development into two or more separate parts of an organ originally entire is called Chorisis. This is exhibited in the androecium of the mustard, where the multiplication of two of the stamens, each into two, has occurred. The development in a united condition of two or more organs originally separate is called Syngenesis. This is exhibited in the two carpels of the mustard, which are united to form a single pistil.

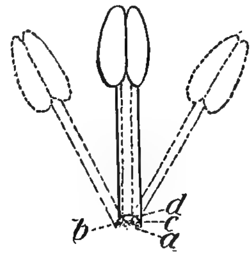
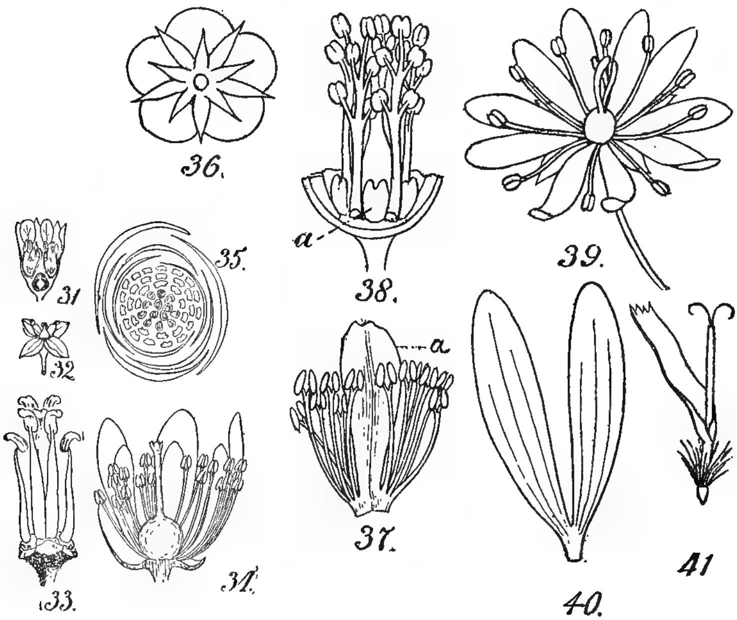


Fig. 30 A. Diagram illustrating the process of chorisis.

The nature of the process is illustrated by the accompanying diagram (Fig. 30 A). Let *a* represent a mass of elementary tissue which is normally to develop into a stamen. If it develop by a uniform growth throughout the mass, it will become a single stamen, *d*. If, upon the other hand, it grow separately at the points *b*, *c*, and *d*, it must result in the production of three separate bodies, each of which



Figs. 31 and 32. Tetramerous flower of olive, 6 of its stamens and 2 of its carpels suppressed. 31. Same in longitudinal section. 33. Androecium of mustard, showing a stamen developed as two, through chorisis. 34. Flower of *Tilia*, showing each stamen developed into a cluster and a petal through chorisis. 37 shows such a cluster detached. 35. Diagram of transverse section of *Magnolia*, showing duplication through metamorphosis. 36. Flower of strawberry, the calyx-appendages simulating an epicalyx. 38. Androecium of *Psorospermum*, the stamens of one set undergoing chorisis, those of the other aborted into gland-like bodies. 39. Flower of *Stellaria*, the corolla apparently double. 40. A petal of the same, bifid by chorisis. 41. Flower of *Taraxacum*, the calyx having undergone chorisis.

may become a perfect stamen, as represented by the dotted lines. The process thus results in branching.

The important point for the student to note is that while we should thus have three stamens as to form and function, we should have but one as to the numerical plan of the flower, for all have developed from the point belonging to one, and from the elementary tissues of one, and all represent but one leaf-homologue. Sometimes the total number of stamens (or other parts) will thus be multiplied, each element undergoing the same change, while at others only one or two in the circle will be thus modified. The latter would result in irregular duplication. In studying the law of position of parts, we must note the great difference between duplication occurring in this way and that from the development of a new circle independently of any process of chorisis. This peculiarity of position in chorisis is well illustrated by the flower of *Tilia* (Fig. 34), where three groups or fascicles of stamens can be seen, each produced from one, and in that of *Psorospermum* (Fig. 38) where there are five, the separation being here confined to the upper portion. In this case, remains of a suppressed circle of stamens are present in the form of gland-like bodies (*a*). Chorisis is well displayed in the calyx of a floret of the Dandelion (Fig. 41), whose sepals have become divided into numerous bristle-like portions, and in the corolla of the *Stellaria* (Fig. 39), each of whose petals (Fig. 40) has become divided into two.

Production by Chorisis of a Part of a Different Kind.—Chorisis sometimes produces an organ of a different kind from the original, as in the case of the original stamens of the *Tilia*, where each, besides dividing into about 7 stamens, has at the same time yielded one or more little petals (Fig. 37, *a*) standing in front of the stamen group.

Median and Lateral Chorisis.—Chorisis is Median in the case of the last-mentioned petals, which stand in front of the organ out of which they were formed, Lateral in the case of the stamens, which stand beside the organ out of which they were formed.

An Indefinite Number of Parts.—When the number of organs of one kind, as of petals, as in the rose (Fig. 59), or of stamens (Fig. 60), exceeds twenty, it is commonly spoken of as Indefinite, indicated by the symbol ∞, although in most cases it falls within certain definite upper and lower limits which are of diagnostic value.

Indication of the Numerical Plan by Diagram.—The numerical plan and deviations therefrom are often indicated pictorially by diagrams like that shown in Fig. 43. When dots are introduced, as in this diagram, they indicate the position of organs which should be present in accordance with the floral type, but which have in that case suffered suppression. A diagram thus marked is called Theoretical, while if the dots are omitted it is called Empirical. Frequently, also, a dot is placed above the diagram to indicate the position of the plant-stem on which the flower is borne, this being the Superior or Posterior side of the flower, while underneath it is often indicated the leaf or bract in the axil of which it is situated, this being the Inferior or Anterior side of the flower.

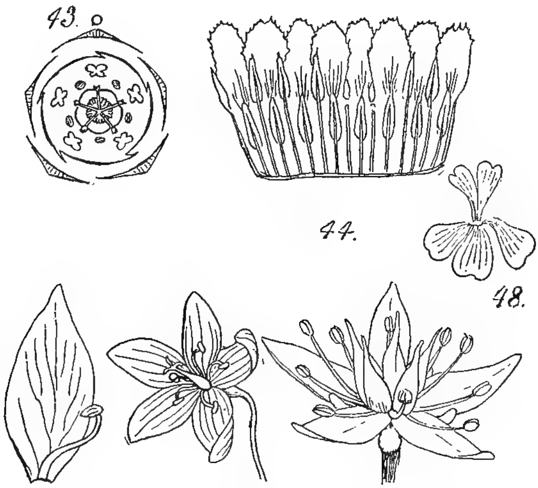


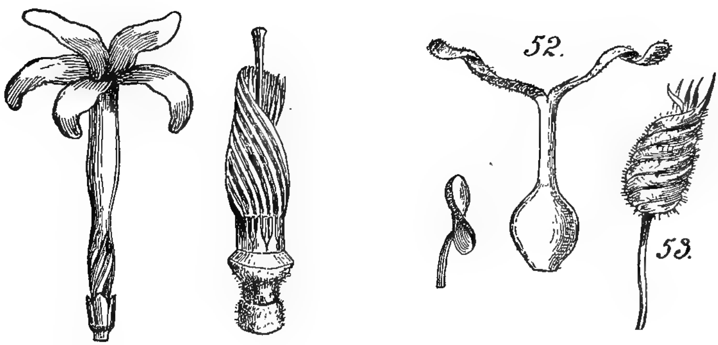
Fig. 43. Diagram of transverse section of *Geranium*, showing the alternation of parts. 44. Vertical view of *Illipe*, one set of stamens alternating with, the other opposite to, the corolla-lobes, and several of the stamens aborted. 45. Flower of *Claytonia* with outer set of stamens suppressed. 46. One of the remaining stamens anteposed to petal. 47. Typical flower of *Sedum*. 48. Slightly irregular corolla of *Pelargonium*.

Indication of the Numerical Plan by Formula.—The manner of indicating by formulae the number of parts in calyx, corolla, androecium, or gynaecium has already been indicated. It will now be seen that by a combination of these expressions, the entire plan of the flower can be indicated by a single formula. K3, C3, A3 + 3, G^2 indicates 3 sepals, 3 petals, 2 circles of 3 stamens each, and 2 carpels. K3, C3, A^3 + 0, G^2, would indicate that the second circle of stamens had suffered suppression, but each of the first circle had divided into three. In a diagram, the positions of the suppressed stamens would be indicated by dots, while the doubled set remaining would be indicated in pairs, thus:

The letter n, in place of a figure, as in the following formula, K5, C5 A5 + n, G^5, indicates that the number of parts of that kind (in this case the stamens of the second circle) is not constant.

Law 2: Alternation of Position.—The parts of each circle alternate in position with those of the adjacent circles. In other words, each part of the flower stands opposite a sinus of the adjacent outer and inner circles. Thus, in Fig. 44, the stamens of the circle nearest the corolla-lobes alternate with the latter, while those of the next circle alternate with the former and are consequently opposite to the corolla-lobes. In Fig. 43 the same relation can be observed between the other circles. It is thus clear that the parts of two alternating circles, as of the first and third, or the second and fourth, must stand opposite each other, or in the same radial line.

Anteposition Resulting from Suppression.—It is also clear that if two circles shall be brought into juxtaposition by the suppression of an intervening circle, their parts will naturally stand opposed and thus appear to invalidate our second law, as in the case of the stamens and



49 50. 51. 52. 53.

Figs. 49 to 53. Figures illustrating torsion.

petals of *Claytonia* (Figs. 45 and 46), where the stamen-circle originally standing between the other one and the corolla has been suppressed. Organs thus placed, the one directly in front of the other, are called anteposed.

Note should also be taken of the fact, already pointed out, that the cluster of organs produced by chorisis corresponds in position with the single part by the modification of which it was produced.

Position Sometimes Obscured.—In examining the position of parts great care should be taken by the student to see the actual point of insertion, as the free portion of an organ frequently deviates from the line of its true position and leads to error.

Torsion.—One such condition which can easily lead to error is Torsion, or twisting. This relates to a permanent condition of the mature organ and not a temporary embryonic state such as the twisting of the corolla in the bud. Torsion of the base of the corolla is shown in Fig. 49, of the stamens in Fig. 50, of the anther in Fig. 51, of the style in Fig. 52, and of the fruit in Fig. 53. Torsion also frequently affects other parts of the plant, especially the stems of flower and leaf.

The treatment of the subject of position here presented is necessarily superficial and incomplete, owing to our failure to have considered already the subject of leaf-arrangement. There is a direct correlation between the arrangement of foliage-leaves and the parts of the flower. As the arrangement of the former is sometimes by circles or whorls and sometimes by spirals, it follows that some flowers may be arranged on the former plan (Fig. 20), some (at least in part) upon the latter, and such we actually find to be the case. There is no one of the floral series but what at times exhibits in its parts (in most cases when they are numerous) a well-marked spiral arrangement. Such are denominated Acyclic, while those having their parts in true whorls or circles are called Cyclic.

Flowers Normally Possessing but One Stamen-circle.—It should be noted that the very frequent occurrence of flowers possessing but one stamen-circle, and this alternating with both carpels and petals, has led to the belief that in some plants but one stamen-circle is the rule, a second calyx-circle existing instead of the second stamen-circle. Care should be taken not to confuse the idea of this second calyx-circle with that of the totally different epicalyx.

Law 3: Regularity.—The parts composing one circle agree in form and size. A flower all of whose circles obey this law is Regular. An illustration is found in the flower of *Veratrum* (Fig. 28).

Irregularity and How it May Result.—Irregularity may result from abortion (Fig. 44), where three of the upper circle of stamens are different from the other five; from appendaging (Fig. 65), where one of the five petals bears a long spur; or from mere variation in form (Fig. 110) or size (Fig. 48). Sometimes, as in the last case, the variation is so slight that the student will be in doubt as to its existence, while at other times an accidental variation in an individual plant may suggest irregularity where it is not a characteristic. Very often an irregularity so slight as to be scarcely perceptible in the open flower may be more conspicuous in the bud. In cases of doubt the relationship of the plant to others whose flowers are regular or irregular may aid to a decision.

A tendency to antero-posterior irregularity in flowers would appear to be generally characteristic of their higher development.

Law 4.—Each part of a circle develops separate and disconnected from all others in that and in other circles. As the mass of tissue forming each of the floral parts becomes isolated and projected from the torus, its margins and faces should develop completely separate from those of all adjacent parts. The law assumes that growth shall continue in the isolated portions, by which process they must continue separate. But this form of growth of the parts does not always occur. Very commonly the point of growth changes or becomes restricted to the basal portion, where they have not yet separated from one another. This projection from the torus of an undivided or unseparated portion, and its subsequent growth, must clearly result in the development of a portion of the flower consisting of more than one floral part in union. The component parts are usually indicated by more or less of a separation of their apical portions. This principle has been already carefully explained in connection with Fig. 42.

Connation.—There is no other direction in which deviation from the type represented in Fig. 47 is so frequent and variable as in that just described, nor in which the results are so far-reaching or call for so extensive a classification and terminology. The deviations are of two classes. When a part is united laterally with another part of the same circle the condition is called Connation, Cohesion, Coalescence, or Syngenesis. When connation does not exist the parts are said to be Distinct or Eleutherous. Connation will be discussed in our detailed consideration of the several floral parts.

Adnation or Adhesion.—In the second form, called Adnation or Adhesion, one circle is more or less united with another. Adhesion may affect any two or more circles of the flower, and it may affect an entire circle or only one or more of its parts. Thus, Fig. 54 illustrates a petal of the vanilla adnate to the ganaecium, while the other petals are free. It is plain that when the calyx and gynaecium are adnate, all the intervening circles must be included in the condition, as in the lower portion of the colocynth (Fig. 56). Since all the parts start from the torus at *a*, they must be adnate to the whole surface of the ovary between the points *a* and *b*.

Epigyny.—In the last case, as in all cases where one or more circles are adnate to the gynaecium, the free or ununited ends of the parts must lose the appearance of emanating from the torus and must appear to emanate from the gynaecium. They are, therfore, said to be Epigynous. At this point the student should not fail to impress himself with an understanding of the fact that in all such cases the epigynous organs really originate at the torus, and that in a cross-section through the adherent portions the microscope will often demonstrate the tissues of such a part adnate to those of the part from which it appears to emanate. In descriptive phraseology, the term "Calyx adherent" always means "adherent to the ovary," or epigynous, even though the

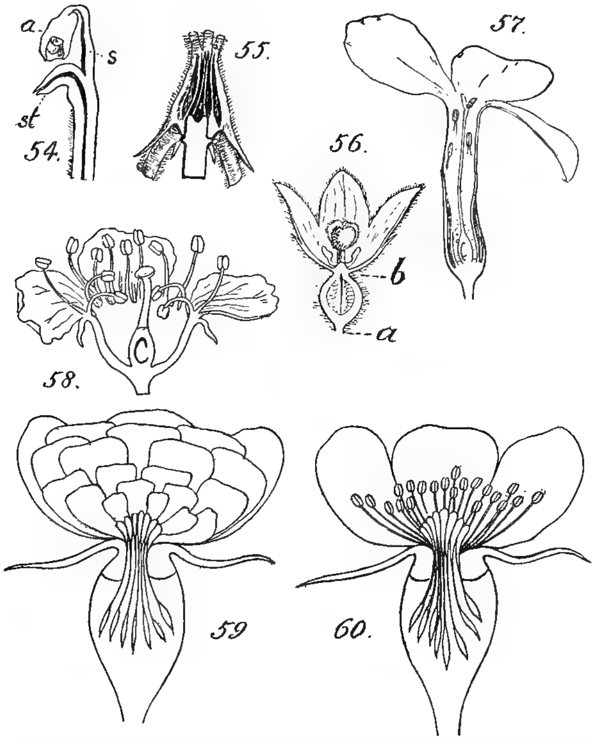


Fig. 54. Adnate petal of *Vanilla*. 55. Gynandrous stamens of *Adenium*, as prevalent in the Apocynaceae. 56. Flower of colocynth, with inferior ovary and superior (adherent) calyx. 57. Longitudinal section through flower of *Phlox*, showing stamens adherent to corolla. 58. The same through flower of cherry, showing adhesion of all parts except the pistil. 59. "Double" flower of rose, showing the stamens of the "single" flower (60) transformed into petals.

words "to the ovary" are omitted. Another mode of stating the same condition is to say "Ovary inferior" or "Calyx superior." It frequently happens that the condition is only partial, when the terms "Half inferior" and "Partly inferior" are employed. There are cases where proper application of any of these terms is doubtful and some perplexity is created.

The Hypanthium.—In many cases the torus, which is to be remembered as the end of a branch, is hollow and has the lower portion of the flower inside of it and adherent to the inner surface of its cup (Figs.

59 and 60). In this case the outer surface of its cup may be mistaken for that of an adherent calyx. The enclosed portion of the calyx really is adherent, but it is not visible, since it is enclosed and concealed by the hollow torus, which is known as a Hypanthium. It is often extremely difficult to distinguish between a simple adherent calyx and a hypanthium, and good botanists frequently disagree in particular cases.

Perigyny.—The insertion of a corolla or an androecium which is adherent to a free calyx, as in the cherry (Fig. 58), or of an androecium adherent to a free corolla, as in the *Phlox* (Fig. 57), is denominated Perigynous.

Hypogyny.—Organs which are not in any way adherent are denominated Free, and because their insertion is manifestly upon the torus underneath the gynaecium, they are said to be Hypogynous (Fig. 47).

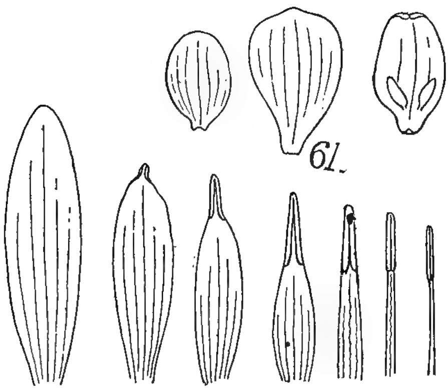
Gynandry.—With the stamens adnate to the pistil the flower is said to be Gynandrous (Fig. 54). The body thus formed of the united androecium and gynaecium is technically known as the Column. (See also "Stamen-column.") A peculiar form of gynandry is common among the relatives of the *Apocynum* (Fig. 55).

Law 5.—Each part preserves its own function and a characteristic form. The forms agreeing with this law correspond in general with those which have been indicated in our account of the flower. Deviations from it are caused by Metamorphosis, Enation, resulting in the true appendaging of an organ, the very similar process of exaggeration in the growth of a part, retardation in its growth, or its suppression or abortion. With the exception of the first, the results of these processes will be discussed under the details of the respective parts.

Metamorphosis is the simulation in form or function, or both, of one organ by another. The rose, which normally has but five petals (Fig. 60), is seen under cultivation to consist of a dense mass of them, in many circles, becoming a so-called "double" flower. An examination of the inner petals of such a flower (Fig. 59) discloses that they are successively smaller and more stamen-like as they stand nearer the stamens, indicating their origin through the metamorphosis of the latter, which are fewer in proportion as the petals are more numerous. In another form of the rose, the "Green Rose," the petals in turn appear transformed into leaves or leaf-like bodies. Such accidental or artificial deviations from the normal type are called Monstrosities. The sepals also frequently present a leafy appearance, sometimes as an abnormality but in most species habitually. Even the stamens and carpels frequently display the latter abnormality.

Retrograde Metamorphosis.—In all of these cases the change is from a more complex organ, or one of higher rank, to one of a lower, and is called Retrograde Metamorphosis, or Reversion of Type.

Progressive Metamorphosis also occurs. It is seen in the gradual transformation of bracts, themselves transformed leaves, into sepals in the Barberry (Fig. 61), and of sepals into petals and petals into stamens. Even stamens may become metamorphosed into carpels or carpels into stamens, one instance being the flowers of the willow, where organs have been seen intermediate in appearance between the two.



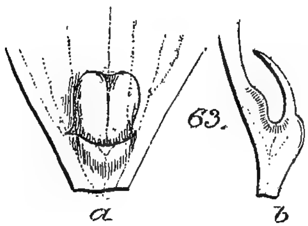
62.

Fig. 61. Structures from flower of *Berberis*, intermediate between petal and stamen. 62. Same from flower of *Castalia*.

Teratology.—Cases of abnormal retrograde metamorphosis are very common, and have given rise to a separate department of study known as Teratology.

Enation or Outgrowth.—Enation and the effects produced by it are well illustrated in one of their forms by the petals of certain genera of the *Ranunculaceae.* The retention of a drop of nectar at the base of the petal of some species of buttercup is effected by the presence there of a minute scale (Fig. 63), covering over a slight depression. The nectar is partly lodged in this pit, partly held between the petal and the scale. In the *Coptis* (Fig. 64), a closely related plant, the depression is deepened into a more obvious cavity and the scale is dispensed with, while in the *Delphinium* (Fig. 65) the cavity becomes a long tube.

Glands.—Although the detailed consideration of appendages will be taken up in connection with the several organs to which they appertain, we shall here consider a special class of them, called Glands, not only of great importance in diagnosis and classification, but of such physiological importance that from that point of view they constitute a distinct organ of the flower. For the peculiarities of structure and secretory function of glandular tissue, works on histology must be consulted. Here we note that although glands are sometimes distributed through the other tissues in such a way as to be imperceptible on superficial examination, their tissue is at other times collected into more or less conspicuous bodies of definite form and position. The term "Gland" is frequently applied also to bodies which resemble glands in location and form, but which do not appear to be glandular in function. Glands may be stalked (Fig. 66, *a*), sessile (Fig. 67, *a*), or depressed (Fig. 68, *a*, see Nectary), and they may develop upon various parts



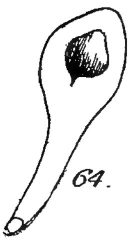
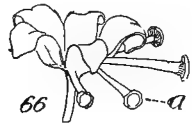
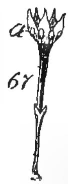


Fig. 63. (*a*) frontal; (*b*) lateral, views of base of petal of buttercup, showing a scale which retain nectar in nectary. 64. Petal of *Coptis*, hollowed to form a nectary. 65. Long hollow spur forming nectary in flower of *Delphinium*.





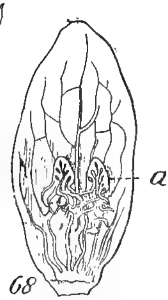


Fig. 66. Stalked glands (*a*) on calyx of *Dinemandra*. 67. Sessile glands (*a*). 68. (*a*) Depressed glands (nectary) on petal of *Frasera*. 69. (*a*) Basal gland prevalent in the Apocynaceae. 70. (*a*) Glands at base of stamen of *Sassafras*.

of the flower or plant. Those upon the outside of the calyx are extensively utilized in classification in the family Malpighiaceae, while those upon the inside are so used in the families Apocynaceae (Fig. 69, *a*) and Gesneriaceae.

Fig. 68 is an illustration of glands located upon the corolla, while Fig. 70, *a*, illustrates them connected with the stamens, as seen in *Sassafras*.

Glands upon filament-like stalks, suitably located, may easily be mistaken for stamens. Glands may be themselves appendaged.

As to their origin, it may be stated that glands frequently result from metamorphosis of the remains of an aborted organ. Thus, in the staminate willow-flower (Fig. 12) a small gland between the bases of the stamens is supposed to represent the aborted pistil, while similar ones at the base of the pistil, in the pistillate flower (Fig. 9), are supposed to represent the aborted stamens.

The misleading effects of suppression have been observed in *Hepatica* (Figs. 23 and 24) in the absence of the corolla, the metamorphosis of the calyx toward corolla and of the epicalyx toward calyx. Those of abortion are seen in the *Pulsatilla* (Fig. 16), where the petals *b* and *c* are reduced to simulate filaments.

Exaggeration of Growth is well displayed in the torus of the strawberry and the placentae of the watermelon (Fig. 312), which respectively contribute the massive edible portions of those fruits.

The principles of anthology as applied to the higher types of plants, having thus been followed into and through the typical flower, and the general nature of the deviations therefrom having been outlined, we shall proceed to a detailed consideration of the several parts of the flower, with the object of preparing us to interpret the multiform appearances which those organs present in the extensive flora from which our drugs are derived.

That division will not, however, close our consideration of flower structure, as some important modifications will remain to be discussed in our chapter on pollination and fertilization.

CHAPTER IV

THE PERIGONE

Study of the Perigone.—The perigone is to be studied as to the number of its circles, their color, texture, and surface, the number of parts forming each, their adhesion or cohesion, if existing, the form and divisions, if any, of each and of its parts, appendages, secretions, metamorphosis or other variations, arrangement of the parts in the bud, movements or other noteworthy habits, and duration.

Number of Parts.—The normal condition of two circles, the modification of these through abortion, suppression, duplication and metamorphosis, and their agreement with the numerical plan of the flower and its modification through the same influences, need no further discussion. The number of parts entering into either perigone circle, whether these exist in a distinct or coherent state, is indicated by the appropriate numeral preceding the suffix "phyllous;" thus Monophyllous, Diphyllous, Triphyllous, and so on.

Color and Texture.—The typical idea of a calyx more or less herbaceous and a corolla thin, delicate, and brightly colored, is not always realized. In the *Crocus* and most related flowers the parts of both circles are similarly petaloid. The petals of *Garcinia* are thick and fleshy, in *Caopia* they are leathery, and in *Alzatea* hard and almost woody, at least when dry. The surfaces of the sepals, particularly the outer, are not commonly glabrous, while those of the petals are; but even the latter are often glandular, pubescent, densely woolly, or even prickly. No shade of color is denied to either circle of the perigone, nor is the color necessarily uniform among its parts or even over the surface of any one part. The shade and markings are very liable to vary in different individuals of the same species, so that color is not always a good character on which to base a determination. In general, the color deepens as the altitude of the habitat increases.

Form of Parts.—The strictly typical state calls for a general resemblance between the form of the perigone parts and that of the foliage leaves of the plant which bears them. They sometimes display a keel corresponding to the mid-rib of the leaf, and as in the leaf, this may be continued into a terminal point. They may be concave, as in *Theobroma* (Fig. 71); the margin may be toothed and the apex toothed or fimbriated, as in *Silene* (Fig. 72); the toothing of the margin may extend into a pinnatifid condition, as in the calyx lobe of *Rosa canina* (Fig. 73), and that of a toothed or fimbriate apex into the cleft or divided state of chorisis.

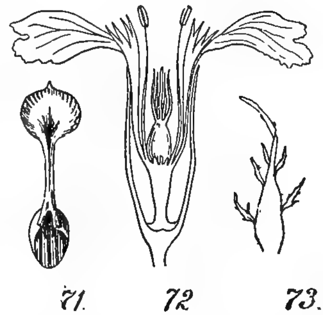
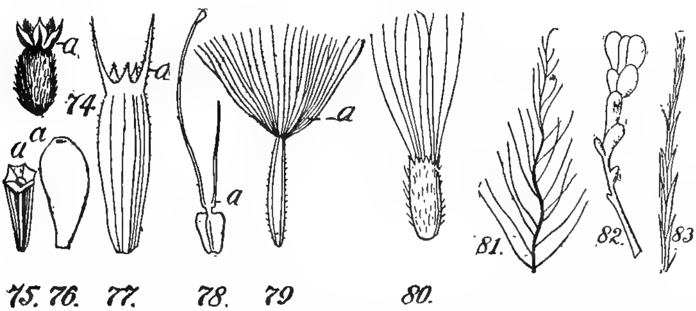


Fig. 71. Concave petal of *Theobroma*. 72. Flower of *Silene*, the petals toothed at apex and bearing a crown at junction of limb with claw; also a conspicuous anthophore in base of calyx. 73. Pinnatifid sepal of *Rosa*.

The Pappus.—The peculiarly divided calyx illustrated in Fig. 79, *a*, is denominated a Pappus, and this term has been extended to all forms of the calyx (Figs. 74 to 83) existing in that family (the *Compositae*) and in some others. Fig. 80 illustrates the action of median, as well as of lateral chorisis, in the development of a double pappus, the outer circle being much shorter and different in kind.

The several forms of perigone parts corresponding to those of leaves (see leaf-forms) and numerous intermediate ones not illustrated, should be carefully considered by the student, as they have a most important bearing upon the forms of the corolla produced by cohesion, which we shall shortly consider.



Figures illustrating forms of the pappus: Fig. 74 Pappus little changed from ordinary superior calyx-limb. 75. That of *Tanacetum*, reduced to a short cup. 76. That of *Absinthium*, practically obsolete. 77. That of *Wyethia*, 2 of the calyx-teeth awned. 78. That of *Grindelia*, the two remaining calyx-teeth aristiform. 79. That of *Arnica*, the ordinary setose form. 80. The double pappus of *Erigeron*, the outer series very short. 81. Plumose bristle from pappus of *Lasiopogon*. 82. Scaly bristle from pappus of *Eriosphaera*. 83. Serrate bristle from pappus of *Cineraria*.

Adhesion.—Both adhesion and cohesion are exceedingly common in the case of the perigone. The former has already been pretty fully considered. Very rarely is it so complete that there is not at least a portion of the parts remaining free. Since the adherent parts are alternating, adhesion necessarily involves the ultimate effect of cohesion. In the case of cohesion extended very high, peculiar effects, often puzzling to the beginner, are produced, as in the case of *Oenothera* (Fig. 29).

Here the calyx, after adhering to the entire surface of the ovary (*e*), is continued upward in the form of a long, slender tube resembling a flower-stem. Inside of this tube the petals and stamens are adnate, and do not become free until they reach its summit.

Cohesion.—Cohesion, like adhesion, may be partial or complete. In its slightest forms, with a mere band of union at the base, it may escape observation, as in the case of the corolla of *Lysimachia* (Fig. 84). In such cases a decision is best reached by carefully pulling away the

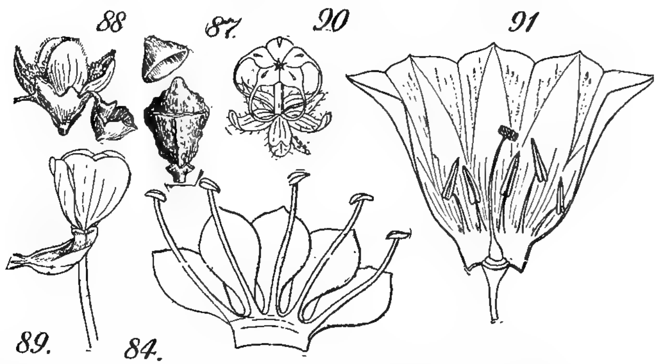


Fig. 84. Adnate corolla and androecium of *Lysimachia*, the parts of each coherent at the base only. 87. Completely separating calyptra of *Eucalyptus*. 88. Partly attached calyptra of *Mitranthes*. 89. Corolla of *Oenothera* escaping through a fissure in side of calyx. 90. Corolla of *Ayenia*, its petals coherent at summit only. 91. Completely coherent petals of *Ipomoea*, leaving the margin merely sinuate.

corolla. If there is a union, however slight, the corolla may thus be removed as one body. Agglutination will occasionally cause an appearance of cohesion, but upon applying the test here specified, the parts will be found to separate readily, without the tearing of any tissue.

The Calyptra.—A peculiar and extreme form of cohesion is that in which the sepals refuse to separate even at the apex when the flower expands, and the calyx is torn loose from its basal attachment, falling entire as a Calyptra, as in the corolla of *Eucalyptus* (Fig. 87), or remaining attached at one side as in *Mitranthes* (Fig. 88). A modification of it permits the remainder of the flower to escape through a rent in the side, as sometimes in the case of *Oenothera* (Fig. 89). Very rarely cohesion exists at the apex only, a remarkable instance being the corolla of *Ayenia* (Fig. 90).

Terms Indicating Cohesion or its Absence.—When the petals are distinct the corolla is said to be Eleutheropetalous or Choripetalous. The older but less desirable term is Polypetalous. When they are coherent, the corolla is said to be Gamopetalous or Synpetalous, the older and less desirable term being Monopetalous. Corresponding terms for the calyx are Eleutherosepalous, Chorisepalous, or Polysepalous, and Gamosepalous, Synsepalous, or Monosepalous. In the gamopetalous and gamosepalous state the parts cease to be designated petals and sepals, and are known respectively as Corolla-lobes and Calyx-lobes.

The relative altitude to which the cohesion is carried is indicated by special terms. When existing at the base only, the circle is said to be parted (Fig. 84); when extending about half-way up, as in *Solanum,* Cleft (Fig. 92); when still farther, but yet leaving a considerable portion ununited, as in *Spigelia,* Lobed (Fig. 97), and when having only traces of the parts ununited, Toothed (Fig. 102). A peculiar form is that in which the position of the parts is indicated by a mere waving irregularity of the margin, as in the flower of *Ipomoea* (Fig. 91), which is then said to be Sinuate or Undulate. The student must not fail to discriminate between the entirely different senses in which these terms are here used, in reference to the entire calyx and corolla, and as used previously in reference to the margin of a single part thereof.

Special Forms of Calyx and Corolla.—We must next consider certain specific forms of the calyx and corolla as wholes, which are of very great diagnostic value. That the form of a gamopetalous corolla is determined by the form of the petals of which it is composed is readily seen by comparing Figs. 18 and 98. In Fig. 18 we have a petal with a long, slender claw and a broad limb. Several such petals united by their edges must yield a corolla with a broad border supported upon a long tube; just such a form is that represented by Fig. 98. Similar results are shown in Figs. 97 and 99, and it is not difficult, on examining these figures, to imagine the exact form of the component parts. In Fig. 93 we have a union of somewhat broader petals, while those of Fig. 103 were so very short and broad as to have resulted in a saucer-shaped corolla.

Although such characteristic forms are most numerous among the coherent class, they are not wanting among those in which cohesion does not exist. Sometimes a non-coherent corolla will necessarily assume such a form through the restraint exercised by coherent sepals. At other times the form is entirely independent of such restraint.

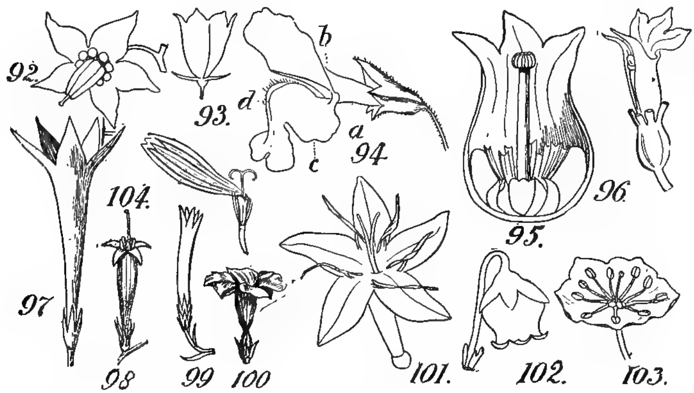
The Tube, Throat, and Limb.—In such corollas and calyces as are represented by Figs. 97 to 99, the narrow portion is denominated the Tube and the broad portion the Limb. When the change from tube to limb is not abrupt, there will be an intermediate portion, as displayed at *b* in Fig. 94, called the Throat. Less frequently this term is applied also to the delimiting circle between the limb and the tube when these do meet abruptly. Occasionally distinct contraction instead of a dilatation will be found at the throat, as very frequently occurs in other parts of the tube (Fig. 100).

The Margin.—The terminal boundary line, including all its extensions and intrusions, is called the Margin. The margin may intrude partly or quite to the tube, so that the cohesion may include none or the whole, or any part of the throat, or of the limb.

Special Terms Indicating Form.—The terms regular and irregular apply to lobes precisely as though they were distinct sepals or petals and to the united portions as well as to the lobes. Some of the terms applicable to the forms of the gamopetalous corolla (and, of course, to the gamosepalous calyx) refer to its entire body, while others refer to its several parts. The former class, and among them those which are regular, will be first considered.

The term Cylindrical is self-explanatory. If nearly cylindrical, it is called Cylindraceous. Such shapes are shown in Figs. 29 and 99. If such a one is manifestly angled, as in the calyx of *Mimulus* (Fig. 94), it is Prismatic, and the same is true of other tubular forms. If the entire body flares regularly (Fig. 97), or if there is such a flaring portion upon a cylindrical tube, it is called Infundibular or Funnel-shaped. The less broadened infundibular forms are called Trumpet-shaped, as in the honeysuckle. If the flaring portion or limb is flat, or nearly so upon a cylindrical or cylindraceous tube, it is called Hypocraterimorphous, Hypocrateriform, or Salverform, as in the flower of the coffee (Fig. 101). A corolla which is bell-shaped is called Campanulate (Fig. 93). Of this there are two sub-forms, the Open (Fig. 91) and the Contracted (Fig. 95). The term Globular or Globose is self-explanatory. It may be specified, however, that the mouth must be small and with no conspicuous limb, or with the limb turned back flat against the body. Approaches to the globular form are called Sub-globular or Globoidal. Other related forms are the Ovoid or egg-shaped and oblong. A somewhat globoidal form, with conspicuous recurved margins, is Urceolate or Urn-shaped (Fig. 102). Of the broader or more widely expanded forms, the campanulate develops outward into the Hemispherical and the Crateriform or Saucer-shaped, as in the Kalmia (Fig. 103). When still more flattened out it becomes Rotate or Wheel shaped, as in the *Solanum* (Fig. 92).

A gamopetalous corolla sometimes has a fissure on one side extending nearly or entirely to the base as in the *Lobelia* (Fig. 96). When in addition the corolla or the split portion of it loses its tubular form, becoming flattened out, it is called Ligulate or Strap-shaped, as in the Dandelion (Fig. 104).



Special Forms of Perigone.—Fig. 92. Rotate corolla of *Solanum*, with connivent anthers. 93. Campanulate corolla of *Campanula*. 94. Prismatic calyx and bilabiate, personate corolla of *Mimulus: a*, the tube; *b*, the throat; *c*, the lower lip; *d*, the palate. 95. Contracted campanulate corolla of *Leucothoë*. 96. Fissured corolla of *Lobelia*. 97. Infundibular corolla of *Spigelia*. 98. Hypocrateriform corolla. 99. Cylindrical corolla. 100. Hypocrateriform corolla of *Echites* with portion of tube constricted. 101. Hypocrateriform corolla of coffee flower. 102. Urceolate corolla of *Pernettya*. 103. Crateriform corolla of *Kalmia*. 104. Ligulate corolla of *Taraxacum*.

Accuracy Required in the Use of Terms.—The applicability to the tube and limb separately of many of the terms here applied to the entire corolla is apparent. It should be noted, however, that very detailed descriptions of these respective parts, as well as of the throat, with specification of any irregularities and marks, are often imperatively demanded. This is especially true of the florets of the Compositae, where such characters, although very slight, frequently serve for specific distinction.

Special terms for forms resulting from the possession of appendages will be considered later.

Terms Indicating Irregularity.—Terms indicating irregularity will next be considered, commencing with those applicable to the entire body.

Either the base or the mouth is Oblique when a plane transecting it is not at right angles to the floral axis. The body is declined (Fig.

107) when, either with or without any manifest curve, its axis is turned from the perpendicular, so that it rests more or less against one side of the calyx. It may be Straight or Curved, and the curvature may be Simple (Fig. 99) or Compound as in the Sigmoid calyx of *Aristolochia* (Fig. 106). When dilated upon one side only it is Ventricose, as in some species of *Salvia* (Fig. 111), or, if the swelling is small and prominent, Gibbous (Fig. 107, *a*). When the swelling is carried downward, so as to form a sac, as in *Cypripedium* (Fig. 112, *a*) it is called Saccate. When the dilation is directed upward, so as to form a hood, as in *Aconite* (Fig. 108, *a*), it is called Cucullate or Galeate, and when the hood is

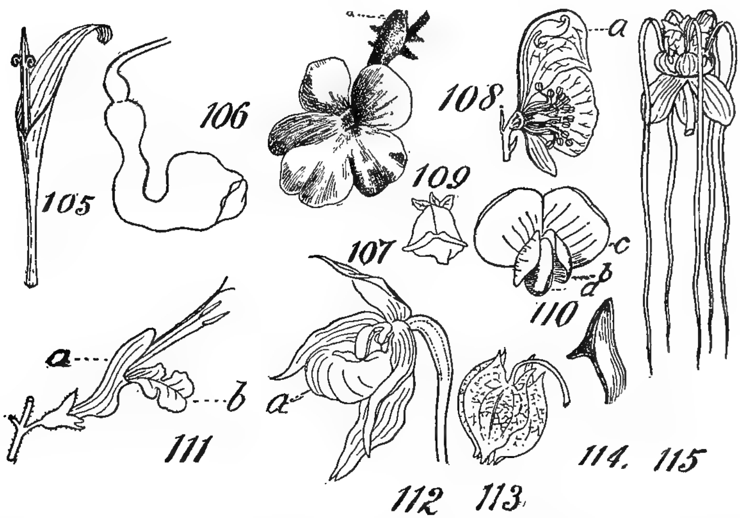


Fig. 105. One-lipped corolla of *Dinoseris*. 106. Sigmoid-curved calyx of *Aristolochia*. 107. Corolla of *Achimenes*, the mouth oblique, the base declined and gibbous. 108. Galeate upper petal of *Aconite*. 109. Personate corolla of *Chelone*. 110. Papilionaceous corolla of *Lathyrus*. 111. Ringent and gibbous corolla of *Salvia*. 112. A saccate lower petal of *Cypripedium*. 113. Auricled calyx of *Nicandra*. 114. Dorsal spur on petal of *Myrmephytum*. 115. Long-caudate petals of *Theobroma*.

compressed laterally and much enlarged proportionately to the size of the body it is called Cristate. Most of these terms are also applicable to a single lip of the form next to be considered or to a petal. When one or more of the lobes of a corolla are separated by a deeper sinus than those of the others it is called Labiate or Lipped. If the fissure proceeds entirely across the corolla, cutting off the lower portion, it becomes One-lipped (Fig. 105). Otherwise it is Bilabiate or Two-lipped (Fig. 111). The two lips are denominated respectively the Upper or Inner (*a*), being that which is nearer the stem of the plant when the flower and its stem are standing erect and without any twisting, and the Lower or Outer (*b*). It is always of importance to note the number of lobes included in each lip, in doing which the student may be misled either by chorisis, one or more extra lobes making their appearance, or, far more frequently, by cohesion, two lobes coalescing into one so as to simulate suppression. Two forms of the bilabiate corolla are commonly recognized—the Ringent in which the lips stand widely apart (Fig. 111), and the Personate, in which the mouth is occluded (Fig. 109).

Several distinctive titles are applied to flower-forms which are characteristic of large and important families or sub-families, the Labiate being one. Another is the Papilionaceous, in reference to its simulation of the form of a butterfly (*Papilio*), as in the common Pea (Fig. 110). The five petals are as follows: Two (*a*) are more or less coherent by their lower edges to form the Body or Keel; two others (*b*) are denominated the Wings; the fifth (*c*) is large, broad, and commonly reflexed so as to appear erect, and is called the Vexillum or Standard.

Caryophyllaceous and Cruciferous Corollas.—Special names have also been applied to the choripetalous corollas characteristic of the pink and mustard families. The former, the Carophyllaceous corolla (Fig. 72), consists of five petals, each with a long, slender claw extending to the summit of an elongated calyx, and there expanding abruptly into a broad limb. The other, the Cruciferous corolla, has four petals, of similar structure and form, so placed as to present the form of a cross.

Appendages.—Appendages to the perigone, while less numerous and varied than in the case of the other organs, call for our careful attention, as they sometimes occasion false interpretations. In the sense in which the term is here employed, we do not refer to hairs and similar outgrowths which modify the surface of the parts, and which pertain equally to other parts of the plant, but to developments which pertain distinctly to the flower, modifying its structure or functions, or commonly both, in some important way.

The Auricle.—In *Nicandra* (Fig. 113) we observe a slight appendage at the base of the calyx-lobe on either side and directed downward. Such an appendage, because of its resemblance to the lobe of the ear, is called an Auricle. Its appearance is somewhat exaggerated in this case, owing to the fact that the calyx is inflated. Smaller auricles are seen at the base of the calyx of *Lobelia* (Fig. 153). A similar appendage is sometimes directed upward, and by its union with the contiguous one forms an organ exactly resembling an intermediate or false sepal, as in the Strawberry (Fig. 36). Such appendages, which undergo considerable variation in form and consistency, may or may not be stipular in their nature. Marginal teeth extended into conspicuous appendages have already been referred to.

The Cauda or Tail.—Sometimes the apex is similarly prolonged into a Cauda or Tail, an extremely exaggerated form of which is sometimes seen (Fig. 115).

The Awn.—An apex extended into an acute, stiff, slender point is an Arista or Awn (Fig. 78, *a*). An awn sometimes emanates from the producing organ at the back, instead of at the apex, and is then called a Dorsal Awn.

The Horn.—An awn-like body which is hollow is a Cornu or Horn (Fig. 150, *a*).

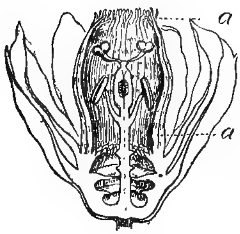
The Spur.—A horn-like appendage extending downward is called a Calcar or Spur (Fig. 65). The spur may also be dorsal (Fig. 114). All of the appendages noticed above may be found upon either calyx or corolla.

The Fornicate Corolla.—Sacs to the corolla are sometimes intruded, as in *Mertensia* (Figs. 118 and 119), instead of extruded. The corolla is then said to be Fornicate. Instead of sacs there may be longitudinal folds, as in some species of Gentian.

The Palate.—When a single large sac occludes the mouth of a bilabiate corolla it is called a Palate (Fig. 94, *d*).

Many appendages such as we have noticed are secretory in function and they may even be glandular in form. Doubtless the various secretions are characteristic, and might, in pharmacy, in exceptional cases, be utilized for diagnostic purposes, but the attempt has never yet been made.

The Corona or Crown.—Lastly, we note what is perhaps the most important, as it certainly is the most striking and interesting, of the corolla or calyx appendages—namely, the Crown. The crown is an outgrowth, more or less membranaceous, from the face of the perigone. Its morphological nature is not understood or agreed upon, and is probably not the same in all cases. It may be a mere abnormal product of median chorisis, or it may be the homologue of the ligule of certain leaves, hereafter to be considered (see *b* in Fig. 465, *A*), the latter being regarded as a normal and morphologically distinct part. When the crown develops from a petal with a distinct narrowed basal portion, which may be assumed to correspond to the petiole of the formative leaf, it usually develops from or near the point where this is joined to the broader portion (Fig. 18). The crown becomes very important in classification in such families as *Passifloraceae* (Fig. 116, *a*), *Asclepiadaceae*, and *Amaryllidaceae* (Fig. 117, *a*). A ring of intruded folds at the throat (Fig. 119) is often, perhaps incorrectly, called a crown. It is sometimes very difficult to determine whether the crown is an appendage of the corolla or of the androecium. Its adhesion is sometimes to the androecium and not to the corolla, and sometimes to both. In some species of *Passiflora* which have no corolla, the attachment is to the calyx only.



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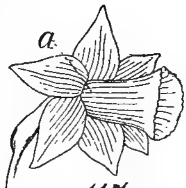

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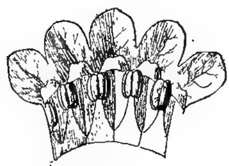

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Fig. 116. Longitudinal section, through flower of *Passiflora* exhibiting crown at *a*. 117. Flower of *Narcissus* exhibiting a large crown at *a*. 118. Flower of *Myosotis*. 119. The same opened to show folds in throat.

Praefloration.—The arrangement of the parts of the perigone in the bud yields some of our most important diagnostic characters as distinguishing families, sub-families and genera, and has been the subject of elaborate classification. The demands of pharmacognosy, however, call for attention to only the principal types of Praefloration or Aestivation. The three principal types depend upon the fact that the combined breadth of all the parts of a perigone circle must (1) be insufficient to enclose the bud, in which case open spaces must be left between their margins (*Reseda*) or the summit must be left uncovered (the calyx in Fig. 120), the form in either case being called Open; (2) it must be exactly sufficient to enclose it, the edges then meeting exactly, with nothing to spare and the form being called Valvate (Fig. 123, the calyx); or (3) it must be excessive, in which case the excess may be disposed of in one of several ways. In one, the parts, after meeting squarely, are uniformly turned straight outward (Fig. 121), the form being called Valvate Reduplicate. In another, they are turned straight inward, the Valvate Induplicate form (Fig. 122). They may even be rolled inward, the Involute form. When lapping the one over the other they are Imbricate (Fig. 123, the corolla). Here it is important to note whether the overlapping is from right to left, Dextrorse (Fig. 125), or the reverse, Sinistrorse (Fig. 124). In determining this point, the relations can best be understood by imagining the flower as a man, his feet in the direction of the torus and his hands representing the petals. To be dextrorse, his right hand must be covered by his left. In other words, the terms "right" and "left," in this position, signify right-covered and left-covered, not right-covering and left-covering.

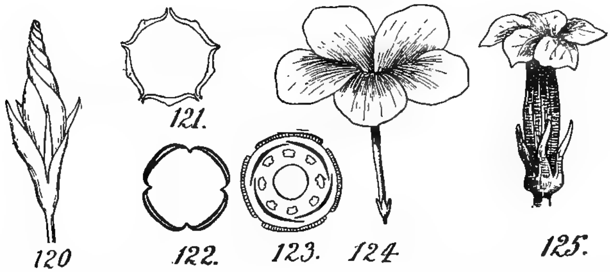

Fig. 120. Bud of *Ipomoea* with open calyx and convolute corolla. 121. Transverse section through valvate reduplicate calyx of *Hibiscus*. Fig. 122. The same, valvate-induplicate calyx of *Clematis*. 124. Sinistrorse imbrication of corolla-lobes of *Lochnera*. 125. Dextrorse imbrication of corolla-lobes of *Echites*.

Petals, sepals, or stamens are occasionally rolled vertically downward from the apex, this form being called Circinate. Occasionally we find the petals folded and doubled in an irregular manner, the Crumpled or Corrugated form of praefloration. A number of terms are called for by the peculiar conditions of the gamopetalous form. Economy of space is here commonly secured by longitudinal folding, the Plaited form. Vertical shortening is often secured by twisting, the Convolute form (Fig. 120, the corolla). In this case it is important to determine the direction of the contortion as dextrorse or sinistrorse, in the same way as that of imbrication.

Other details as to the precise mode of overlapping are frequently worthy of note.

In determining the form of praefloration, care must be taken to select a well-formed bud.

The Mixed Form.—The praefloration may be mixed, as in *Oenothera*, where the parts are valvate at the base and slightly imbricate or reduplicate at the immature apex. At the best, intermediate and perplexing forms will be encountered.

Duration.—The duration of the perigone, especially of the calyx, is frequently of considerable importance from the standpoint of pharmacognosy, although in general not so. When a part falls away at, or very shortly after, expansion it is Caducous. When lasting about a day, and then either falling or perishing upon the flower, as in the poppy, it is Fugacious. When lasting longer than a day, but falling soon after fertilization, it is Deciduous. When remaining and retaining more or less of its normal appearance for some time after fertilization, it is Persistent. When so remaining, but in a withered condition, it is Marcescent. These definitions assume that fertilization takes place normally. If this be artificially prevented or deferred, the freshness of a corolla is often very greatly prolonged. (See Fertilization.) Important facts relating to the Accrescent calyx of the fruit will be presented when the latter is discussed.

Some very interesting facts concerning characteristic movements of the corolla, its sleeping and awakening and other habits, should be sought in general works on botany.

CHAPTER V

THE ANDROECIUM

Review.—It has already been shown, in considering the general nature of the flower, that in at least a large part of the flowering class, the androecium typically consists of two stamen-circles, the stamens of each isomerous with the parts of the other circles, one standing in front of each petal and sepal, that each stamen is entirely free and distinct, and of characteristic form and structure (Figs. 12 and 14). We have also pointed out some of the forms of deviation due to duplication, suppression, adhesion, and metamorphosis. To these the following general remarks may be added.

Sterile Filaments and Anthers.—When an anther, still present, has lost its function, it is called a Sterile or Imperfect Anther. When the anther has become suppressed, but the filament remains, the latter is called a Sterile Filament. Either of these is called a Staminodium. One or more complete circles of sterile filaments, changed or not by metamorphosis, may be mistaken for a crown or a disk (Fig. 38). Adhesion of the stamens to the corolla, or even to the ovary, may include only one circle, the other circle being entirely free, or they may be adnate in different degrees (Fig. 44).

Terms Indicating the Number of Stamens.—Before discussing other and specific points of variation, we shall consider the typical organ more in detail. The number of stamens in the androecium is indicated by joining the appropriate numeral to the suffix "androus;" thus, Monandrous, Diandrous, Triandrous, Tetrandrous, Pentandrous, etc. These terms do not necessarily indicate the numerical plan of the flower. When the number is 20 or more, the term Polyandrous or Stamens Indefinite is commonly employed.

Color.—In color, the filament is commonly white or whitish, and the anther yellow; but this is not an absolute rule, as the latter is often blue, brown, black, or otherwise colored.

Construction of the Anther.—There are several distinct forms of attachment of the anther to its filament which are characteristic of larger or smaller groups. Its origin from the leaf assumes that each theca corresponds to a vertical half of the leaf from which it has developed, and the production of a secondary or "false" partition separating each theca longitudinally into two locelli. This implies a four-locellate condition of all anthers (Fig. 138). Ordinarily this condition is not permanent, the false septa more or less completely disappearing after the formation of the pollen, leaving the mature anther two-celled, or this condition is brought about in other ways.

Attachment of the Anther.—*The Adnate Form.*—It is furthermore assumed that the filament is normally continued along the back of the anther in the relation of the midrib of the formative leaf. This form of attachment is called Adnate (Fig. 126).

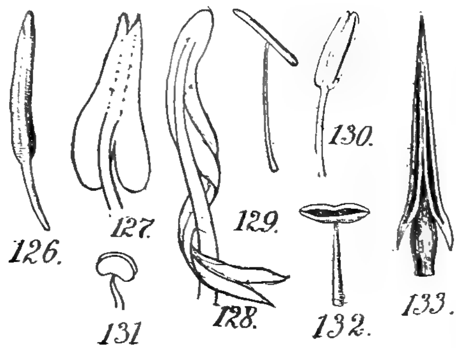

Fig. 126. Adnate anther of *Magnolia*. 127. An incumbent anther. 128. Twisted anther of *Ceiba*. 129. Versatile anther of *Oenothera*. 130. Innate anther of *Sanguinaria*. 131. Reniform confluent anther of *Malva*. 132. Horizontal confluent anther of *Pentstemon*. 133. Sagittate anther of *Tabernaemontana*.

Incumbent Form.—It may be attached only at some point upon the back (Dorsifixed). Of this there are two forms. In one (Fig. 127) the anther is rigidly fixed, its lower portion close to and parallel with but free from the upper portion of the filament, the Incumbent form.

Versatile Form.—In the other, it moves freely upon the pivotal point of attachment (Fig. 129), the Versatile form. Rarely the anther is wrapped or twisted about its filament (Fig. 128).

Innate Form.—The continuation of the filament, instead of being along the back, may be centrally up through the base and between the thecae (Fig. 130), the Innate form.

Sagittate Form.—The lower portions of the thecae may be separated from one another and from the connective (Fig. 133), the Sagittate form.

Reniform and Horizontal Forms.—The sagittate condition is sometimes extreme, the anthers becoming more or less reniform (Fig. 131) or semicircular, or they may even become horizontal (Fig. 132). This is to be distinguished from the form which is horizontal by versatility (Fig. 129), by the presence in the latter of the two cells side by side, in the former, end to end.

Extrorse and Introrse Attachments.—Rarely the adnate form will possess the connective upon the inner side (next the pistil), when it is Extrorse by Attachment, in the normal form being Introrse.

Forms of the Filament.—Besides these variations in the relation of filament and anther, each is in itself subject to certain modifications, some of which will be discussed in connection with appendages and exaggerated growth. The general form of the filament is subject to much variation which, being characteristic in a given species or genus, requires specification. When cylindrical, either of uniform thickness throughout or regularly tapering, it is Terete. When considerably thickened toward and at the summit, so as to be club-shaped, it is called Clavate. When flattened it is Complanate. Laterally Complanate is so flattened that the edges point toward and from the gynaecium, the broad sides to right and left. Dorsally complanate has the edges pointing to right and left, the broad sides facing toward and from the gynaecium. A dorsally complanate filament may have a sharp ridge or keel running along its back, when it is called Carinate or Keeled. If the ridge is less sharp and prominent it is Costate or Ribbed. It may, upon the other hand, bear a groove, when it is called Channelled. Rarely a filament is Triangulate in cross-section, or otherwise prismatic. When tapering from a broad base to a rather acute apex, and rather short, it is Subulate or awl-shaped. When very slender or thread-shaped, it is filiform. When even more slender so as to be hair-like, it is Capillary.

Forms of the Anther.—The principal forms of anther are oblong, oval, globular, reniform, quadrangular, or linear, and the base or apex may be truncate, rounded, obtuse, acute, or pointed. An anther is occasionally doubled upon itself, when it is styled Sinuous (Fig. 139). It may even take the form of a horizontal ring (Fig. 134). This condition is sometimes preceded by the loss of one theca. In any case of curvature, even slight, of the anther, the same is characteristic and of value in classification, as exemplified in the vast genus *Solanum*, where attention to this character is well nigh indispensable. The filament is also sometimes variously curved or reduplicate, and this condition may be permanent or only temporary during the early stage of the flower, as in *Arctostaphylos* (Fig. 145), where the powerful elasticity of the filament assists in expanding the corolla.

Development of the Spores.—Inside of the theca, develop certain large cells, in rows, the Spore Mother Cells, each of which, by twice dividing, produces a Tetrad of four pollen-grains. Ordinarily the wall of the mother-cell mostly disappears and leaves the grains separate and mobile, while in other cases they cohere in the tetrad or in a cluster of tetrads.

Pollinia and Pollinaria.—Large clusters are called Pollinia or Pollen-masses. The entire contents of a theca may form one pollinium (Fig. 135), or they may be divided into several (Fig. 140). A cluster of pollinia, like the last, is called a Pollinarium. The number of pollinia

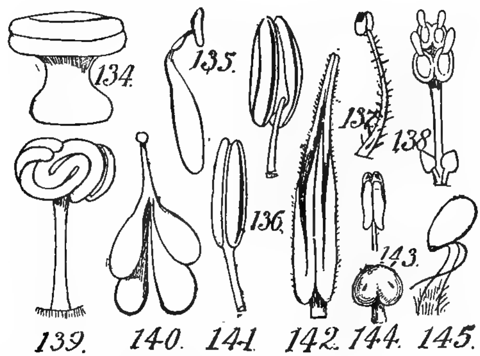

Fig. 134. Ring-formed anther of *Cyclanthera*. 135. Pollinium of *Asclepias*. 136. Dorsal dehiscence in anther of *Hyoscyamus*. 137. Dehiscence by apical pores in *Menziesia*. 138. Dehiscence by valves in anther of *Sassafras*. 139. Sinuous anther of *Sicyos*. 140. Pollinarium of 4 pollinia in *Ponthiera*. 141. Marginal dehiscence in anther of *Convallaria*. 142. Ventral dehiscence in anther of tomato. 143. Dehiscence by apical pores in anther of *Cassia*. 144. Peculiar ventral pores. 145. Apical pores becoming basal by inversion of the anther in *Arctostaphylos*.

in a theca is of much diagnostic importance in the Orchidaceae. The characteristics of the individual pollen-grains are of the utmost value in pharmacognosy, as well as in classification (as, for instance, in the *Acanthaceae*), and are discussed in works on histology.

Dehiscence of the Anther.—We must next consider the structural provisions for permitting the escape of the pollen from the thecae or locellae. This is commonly by splitting, called Dehiscence, along a longitudinal line upon each theca, called the Suture. If the suture is at the back of the anther, as in *Hyoscyamus* (Fig. 136), the dehiscence is called Dorsal. If upon the face, as in the tomato (Fig. 142), Ventral; if upon the edge, as in *Convallaria* (Fig. 141), Marginal.

Introrse and Extrorse Dehiscence.—This suture may face the gynaecium, when the anther is Introrse by Dehiscence, or away from it, Extrorse by Dehiscence. It does not follow that an anther introrse or extrorse by dehiscence is the same by attachment.

Confluent Sutures.—In the sagittate-horizontal anther the sutures of the two thecae often become continuous, the Confluent form (Figs. 131 and 132).

Dehiscence by Pores.—Small orifices, called Pores, frequently exist at the apex, as in *Cassia* (Fig. 143), more rarely at the base. The most scrupulous care must be taken to determine the exact direction in which apical pores look. In some cases, as in *Solanum*, a slight difference will possess specific importance.

Dehiscence by Valves.—A less common form of discharge is by Valves (Fig. 138), the common form for the four-locellate anther. Special mechanical contrivances for aiding in the discharge of the pollen are of great interest and will be mentioned under Cross-pollination.

Cohesion.—Cohesion is responsible for quite as great and important modifications of the androecium as of the perigone. Here, as there, it may be complete, or, beginning at either apex or base, it may stop at any point. Fig. 84 displays the dilated bases of the filaments of *Lysimachia* lightly coherent, the detection of the condition calling for the same keen inspection as in the case of the corolla. In *Guarea* (Fig. 147) the union is seen carried to the anthers, but these left distinct.

Adelphism.—Coherent filaments are styled Monadelphous when all united (Fig. 147), Diadelphous, when there are two groups, even though one of them contains but one stamen, as in *Glycerrhiza* (Fig. 146), Triadelphous when three, and so on. It must not be lost sight of that the terms are applied similarly, whether the union is progressive, the result of cohesion as in this case, or that of incomplete chorisis, as in the *Tilia* (Figs. 34 and 37) and *Psorospermum* (Fig. 38), though its classificatory value is very different in the two cases.

The Stamen-column.—The term column, previously explained, is changed to Stamen-column for monadelphous stamens.

The Synandrium.—The stamen-column is ordinarily hollow, containing the Gynaecium; but when the flower is staminate, the column is solid, and called a Synandrium.

When, as seen in Fig. 92, the anthers come together but do not actually cohere, they are called connivent. The cohesion is carried only partly down the filaments in the squash (Fig. 148), and partly upward in the *Sidalcea* (Fig. 149), but in the *Asclepias* (Fig. 154) it is complete for the entire organs.

Asymmetry and Irregularity.—A lack of symmetry and regularity, acting separately or together, is responsible for a number of characteristic and important states of the androecium requiring distinctive terms.

The Didynamous Androecium.—In the 5-merous flower of *Scutellaria* (Fig. 151) six stamens are suppressed and the remaining four are irregular, there being a pair of each form. This form of androecium has received the title of Didynamous. In this case the anthers of a pair are connivent also.

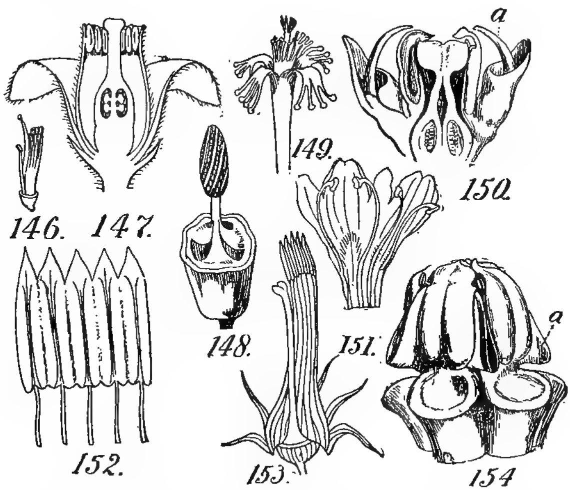

Fig. 146. Diadelphous androecium of *Glycyrrhiza*. 147. Vertical section through flower of *Guarea*, showing monadelphous filaments with distinct anthers. 148. Cohesion of filaments, incomplete at base, in flower of squash. 149. The same, incomplete at summit, in flower of *Sidalcea*. 150. Vertical section through flower of *Asclepias* showing coherent filaments and anthers, with appendages to crown in form of horns. 154. Winged androecium of same. 151. Didynamous androecium of Labiatae. 152. Androecium of *Eupatorium*, the anthers coherent, the filaments distinct. 153. Monadelphous filaments and anthers of *Lobelia*.

The Tetradynamous Androecium.—In that of the Mustard (Fig. 33), two of the stamens have each by chorisis become converted into two, these differing in length from the undivided pair. This form is styled Tetradynamous.

Appendaging.—No other subject connected with the androecium calls for such close and discriminating attention in connection with pharmacognosy as the products of exaggerated growth and enation. No portion of the androecium is free from their effects, which apply equally to it when adherent or coherent, free or distinct. The simplest form of appendage to the filament is that of stipuloid appendages to the base, called Petaloid when assuming the form of a petal, as in Fig. 155 A similar appendage may stand in front of a stamen. One standing in front of a stamen group has been shown in Fig. 37. Appendages may be developed at a higher point in other cases. Appendages in the form of teeth or hairs are very common.

Modifications of the Connective.—Modifications of the connective are numerous and remarkable. The thickening of its entire body, equally or unequally, produces such appearances as are seen in Figs. 156, 157, and 159. Or the extension may result in elongation either above or below the thecae, instead of in broadening.

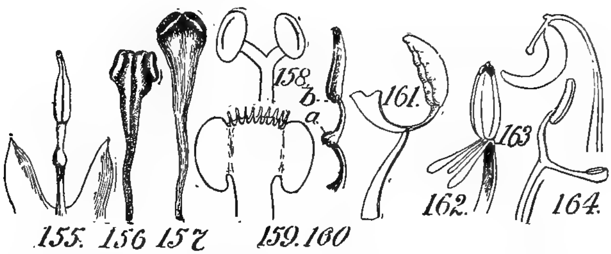

Fig. 155. Petaloid appendage to filament of *Chaetostoma*. 156, 157, and 159. Anthers with the connective broadened so as to separate the thecae. 158. The same with the broadened connective forked. 160. Stamen with connective extended between the apex of the filament (*a*) and the base of the anther (*b*). 161. The same, with an appendage at base of connective. 162 and 163. The appendage with scarcely any elongation of connective. 164. Forked connective of *Salvia*, each branch bearing one of the thecae.

Basal Appendages.—If the extension is downward, it will lead to an apparent jointing of the filament (Fig. 160), the space between *a* and *b* being such a downwardly produced extension of the connective. A slight bulbous enlargement at the base may be modified into the most grotesque forms, as shown in Figs. 161 to 163. Such appendages, in every detail of number, form, position, and direction, are characteristic, and in a family like the *Melastomaceae*, from which most of the above illustrations are taken, possess generic value. Instead of elongating as a single body, the base may apparently divide longitudinally, through extreme broadening, resembling a forked filament, one theca borne on each branch (Figs. 158 and 164.)

One-celled Anthers.—When one of the thecae then becomes suppressed, its connective branch remaining (Fig. 165) or even disappearing (Fig. 166), one of the forms of the one-celled anther results. Another form is produced by simple abortion, without any such modification of the connective, or it may result from the disappearance of the connective.

Dorsal Appendages.—Instead of the base, the back of the connective may be appendaged. It may become expanded into a disk-like form over the backs of the thecae, as in *Gratiola* (Fig. 167). The backs of the anthers may be excavated to receive it, as in *Aloe* (Fig. 168), or it may be appendaged in any other direction.

Apical Appendages.—Appendages of any form may develop at its apex. In the *Compositae* these are frequently triangular, as in *Eupatorium* (Fig. 169, *a*), or lance-shaped. In the *Asarum* (Fig. 170) it is an awn, while in the Violet (Fig. 171) it is sail-shaped. Sometimes it is formed like a feather (Plumose).

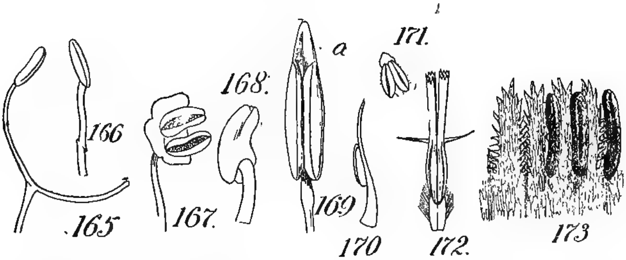

Fig. 165. Forked connective, one of the thecae aborted. 166. The same as in *Audibertia*, with one of the branches aborted. 167. Anther of *Gratiola*, the connective expanded into a saucer-shaped disk. 168. Anther of *Aloe*, the connective hollowed to receive the filament. 169. Anther of *Eupatorium*, the connective bearing a terminal appendage. 170. The same, as in *Asarum*. 171. The same, as in *Viola*. 172. Anther of *Vaccinium*, the thecae extended into awns and bearing also dorsal awns. 173. Monadelphous filaments of *Alternanthera* bearing fimbriate appendages in the sinuses.

Appendages to the Thecae.—It remains to be pointed out that the thecae themselves may be similarly appendaged at any part. Fig. 133 displays caudae, or tails, which are found in a great variety of forms. In Fig. 154, *a*, Alae, or wings, are illustrated. Dorsal spurs or claws (Calcaria) frequently occur and are also often borne at the top. Apical awns to the thecae, forked and pore-bearing at the summit, as well as dorsal awns, are also shown in Fig. 172.

Appendages to the Stamen-column.—The stamen-column itself is subject to remarkable and characteristic appendaging, with or without connection with an adnate disk. Ordinarily, the summit of the stamen-tube terminates at the beginning of the distinct portion of the stamens, but sometimes, as very generally in the *Amaranthaceae* (Fig. 173), it is continued upward in the sinuses of the anthers, and this portion may be lobed and appendaged in the most beautiful manner.

Stamens which extend beyond the margin of the corolla are called Exserted or Exsert. This term is also applicable to any organ which projects beyond the perigone.

CHAPTER VI

THE GYNAECIUM

Gymnospermous and Angiospermous Gynaecia.—Two distinct types of the gynaecium respectively characterize the Gymnosperms and the Angiosperms, both of which classes contribute important medicinal plants. What has been said of the gynaecium in our consideration of the general nature of the flower, pertains wholly to the latter class. A few words concerning the former may be written before taking up our detailed study of the latter.

The Gymnospermous Pistil.—The essential character of the gymnospermous pistil is illustrated in Fig. 174. This consists in its not being shaped into an enclosure for containing the ovules. In the form here figured there is no progress toward such a condition, the carpel remaining more or less flat and bearing the ovules upon its surface; but in the progressive forms there is a cavity, which, however, is never completely enclosed. A high development of it is found in the *Taxus* or Yew (Fig. 175), in which the cavity is deep and open only at the very apex. The pseudo-cavity of the gymnospermous carpel is never divided. It is evident that no true style or stigma can exist in this class of plants, although it must be understood that there is an organ performing the same function of providing for the germination and growth of the microspore, the possession of such an organ being the one distinction between the flowering and flowerless plants.

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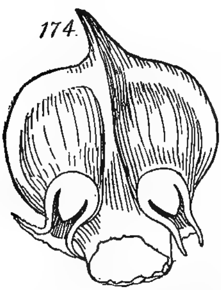

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Fig. 174. Entirely plane gymnospermous carpel of *Pinus*. 175. Cup-shaped gymnospermous carpel of *Taxus*.

Review.—It has been shown that the gynaecium of Angiosperms, except in those rare cases in which a central appendage of the torus is projected upward, occupies the center or summit of the flower; that it consists of one or more carpels or carpophylls which may be all coherent into a single pistil, the Syncarpous, Gamocarpous or Compound Pistil (Fig. 218, etc.), or may each form a separate pistil, the Apocarpous, Monocarpellary, or Simple Pistil (Figs. 219 and 220), and that ordinarily the carpels alternate with the stamens of the adjacent circle. The parts of the pistil have been defined, and it has been shown that of these the stipe or thecaphore is rarely present, and that the style is very frequently absent, resulting in the Sessile Stigma. The different forms of adhesion and its effects, as well as those of suppression and metamorphosis, have also been explained. Some additional facts of a general nature must be considered before taking up the details of this subject.

Method of Examination.—The student should from the outset resist the temptation to seek the characters of the gynaecium in the mature or immature fruit, because of its more convenient size. While many of the characters of the gynaecium are permanent, there are others which disappear after the fertilization of the ovules, and still others which only then make their appearance. The other parts of the flower should be completely stripped off, this operation being performed under close and continuous scrutiny, with the idea of detecting any characteristics of relationship between them and the gynaecium. The latter should then be carefully examined *in situ.* An implement should be passed down between the carpels to determine what degree of cohesion, if any, exists between them, for this will occasionally be found at the very base only, and also to determine if there be any adhesion to a central prolongation of the torus. The details of attachment to the torus must also be determined and their arrangement considered. When numerous, the pistils are apt to assume the spiral arrangement, which has already been noticed in referring to the position of floral parts in general. When solitary, the carpel assumes a position to one side of the axis, thus demonstrating its isolation through the suppression of the complementary parts of the circle. A lack of uniformity, as indicating abortion of one or more carpels, must be looked for. When all are uniformly aborted, in the case of flowers which are hermaphrodite but imperfect, this fact will sometimes escape detection unless both forms of flower are examined. The color, texture, and surface of the carpels call for minute examination in all cases, though there are no peculiarities of a general nature differing from those of the other organs. As in the case of the petals, so in that of the carpels, the general form is determined by that of the foliage leaves; but the form is less closely preserved and the homology is far less apparent here than there, owing to the far more profound modifications which are rendered necessary by the peculiar functions of the carpels, a consideration which will further on be seen to apply with special force to the fruiting stage.

Position of the Style.—The position of the style often calls for scrutiny. It does not always rise, as would be expected, from the summit of the ovary. One process by which deviation in this particular results is illustrated by Fig. 176, which represents the deeply lobed ovary of borage, the single style rising from the depression in the center. If, now, all but one of the parts of such an ovary were to become aborted, the style would be seen rising more or less laterally (Figs. 177 and 178), or even basally (Fig. 179) from the remaining monocarpellary ovary. Even though the styles remain separate in such a divided ovary, yet their insertion is necessarily carried toward the base (Fig. 180).

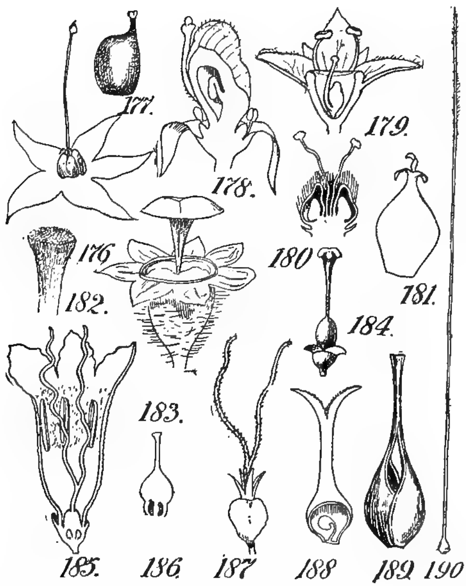
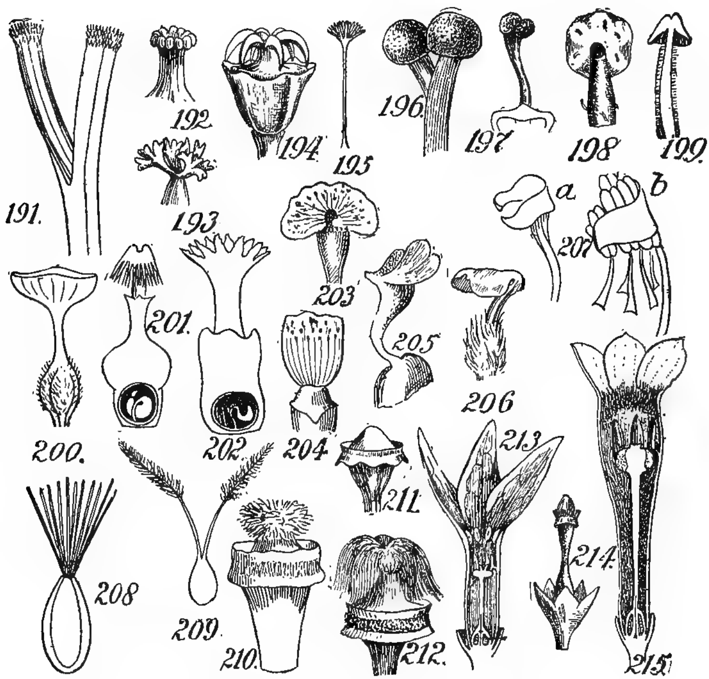


Fig. 176. Deeply 4-lobed ovary of *Borago*. 177. Lateral style on carpel of *Villarsia*. 178. The same in *Astronium*, the style almost basal. 179. The same in *Alchemilla*, the style completely basal. 180. The same, with none of the carpels aborted. 181. Conical style of *Piper*. 182. Clavate style of *Helianthemum*. 183. Obconical and prismatic style of *Bombax*, with umbrella-shaped stigma. 184. Obconical style of *Chimaphila*. 185. Filiform styles of *Poederia*. 186. Style of *Potalia*, with large bulb-like base. 187. Filiform and pilose style of *Galopina*. 188. Style of *Heliocharis*, with subulate branches. 189. Styles showing a tendency to early separation below, while remaining coherent above. 190. Capillary style of maize.

Forms of the Style.—The same descriptive terms as to form already applied to the filament apply equally to the style and its branches. Owing to the frequency with which styles are coherent, ribbed, channelled, or angled forms are common. Fig. 181 illustrates the conical style of *Piper*, Fig. 182, an obconical one; Fig. 183, one obconicoprismatic; Fig. 184, a clavate form; Fig. 186, one with a bulbous base. The style branches in Fig. 185 are filiform; in Fig. 187 they are filiform and plumose; in Fig. 190, capillary, and in Fig. 188, subulate. Rarely, styles will be connate above, distinct below (Fig. 189).

Position and Form of Stigma.—The position and form of the stigma are of very great importance in classification. Its size, as compared with that in other related plants, is apt to be greater or less according as the number of ovules to be fertilized varies.



Figures illustrating forms of the stigma.

The Linear Stigma.—It has already been shown that while the stigma is commonly located at or near the apex, it may extend either entire or divided into two lines for a greater or less distance down the ventral margin of the style, becoming Linear (Fig. 191).

Stigmas Introrsely Located.—If several united styles are separate at the summit, or upper portions, their stigmas are commonly borne upon their inner faces, as in this case, and are frequently, by the cohesion of the former in the young condition, secluded from the access of pollen until a certain time (Figs. 191 and 271). Between the condition of complete separation and complete cohesion of several stigmas there are all degrees of division and of lobing of the divisions (Figs. 192 to 195).

The Capitate Stigma.—A stigma which is strictly terminal and more or less spherical, thus resembling a head, is Capitate (Fig. 196).

The Truncate Stigma.—The Capitate stigma is Truncate when it terminates abruptly in a flat upper surface, as though cut across (Fig. 197).

The Peltate Stigma.—If flattened and attached at the center it is Peltate (Figs. 183 and 198), and this may be horizontal or oblique, as in the latter. The peltate stigma may have its margin reflexed, making it umbrella-shaped (Fig. 199), or upturned, making it cup-shaped, or Cupulate (Fig. 200), and either of these forms may be lobed (Figs. 201 and 202).

The Laminar Stigma.—A stigma flattened out into a blade-like form is called Laminar. Several oblique laminar forms are shown in Figs. 203 to 205. Fig. 207 displays the manner in which the stigma sometimes enfolds the stamen.

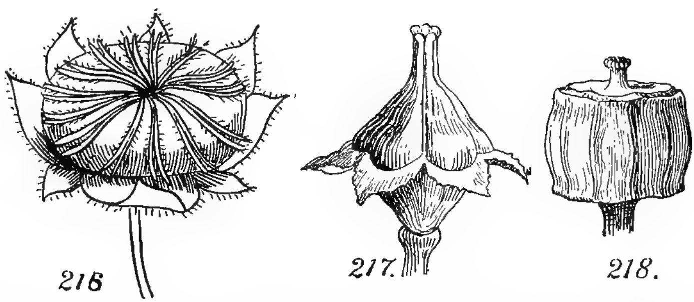
The Annular Stigma.—Stigmas sometimes possess a ring at or below the apex, the Annular form, various modifications of which, unlobed and lobed, are shown in Figs. 210 to 215. Such forms prevail in the family *Apocynaceae* and are of great value in classification.

Appendages to the Stigma.—The Appendages of the stigma are quite as numerous and varied as those of the anther. A Plumose appendage is shown in Fig. 209. Such are common among the grasses. A stigma (or other organ) is called Penicillate when its plumose appendage resembles a little brush (Fig. 208). In *Stigmatophyllon*, the appendage is a little green leaf (Fig. 206).

Terms Indicating the Number of Carpels.—The number of carpels in a compound pistil is indicated by the use of the appropriate numeral followed by the suffix "carpellary," thus Dicarpellary, Tricarpellary.

Determination of the Number of Carpels.—The determination of the number of carpels is of the utmost necessity, but is usually a difficult task for the beginner, especially if he is not previously trained in the art of plant-dissection. The indications may be divided into external and internal. The latter must be apprehended from the study of internal structure explained below.

External Indications.—Whenever there is more than one pistil in a gynaecium, each consists of but one carpel. Complete chorisis of a carpel, producing more than one pistil, never exists, although it frequently appears so, in the fruit. If cohesion is partial, even though so nearly complete as to leave a separation represented by a mere lobing at apex (Fig. 216) or dorsum (Figs. 217 and 218), the determination of the number of its carpels is not difficult. It is true that the latter condition is often complicated by grooving or pseudo-lobing pertaining to the backs of the individual carpels, but such grooves are usually characteristically different from those separating the carpels. While the above remarks have been applied especially to the ovary, they may be applied with equal force to the styles and stigmas. If the exterior of the ovary bear no indications of the number of carpels, we may count the styles, or the divisions or apical or dorsal lobes of a style column, and if those be wanting, then the stigmas or the corresponding characters of the stigma. It must be noted, however, that complete



216 217. 218.

Fig. 216. Ovary of *Modiola*, the lobes of the summit indicating the carpels. 217. The same shown by lateral lobing in *Pentapanax*. 218. The same in *Tetraplasandra*.

or partial chorisis of style or stigma is not at all rare, and care must be taken to avoid falling into error, by counting mere parts as styles or stigmas. In such case the number of lobes of each is apt to equal the number of styles or stigmas.

Internal Indications.—In the case of failure of all these indications to appear, the internal structure must be studied. For this purpose both longitudinal and transverse sections must be made. The former should be so directed as to lay open the inside of a carpel, and of the latter there should be three, through the lower, middle, and upper portions respectively. In most cases a good lens will be sufficient to disclose the characters, but when insufficient, recourse must be had to the stage and low power of a compound microscope. Further details regarding this process will be found in our chapter devoted especially to the methods of floral dissection.

First Plan of Ovarian Structure.—Two distinct plans for the enclosure of the cavity of the angiospermous ovary are recognized. In the first (Fig. 219) the margins of one carpel meet each other, and then, by more or less of an involution, form the placenta with its two rows of ovules within a single cell. If two or more of such carpels then unite in one compound ovary (Figs. 221 and 222), each necessarily forms its own cavity, and there are as many cells as such a pistil has carpels, unless some modification of structure shall take place, as illustrated below.

Axillary, Axile, or Central Placentae.—In all cases where closed carpels of this sort unite in a compound ovary, their ventral sides come into contact, and the placentae are brought together at the center and are known as Axillary, Axile, or Central.

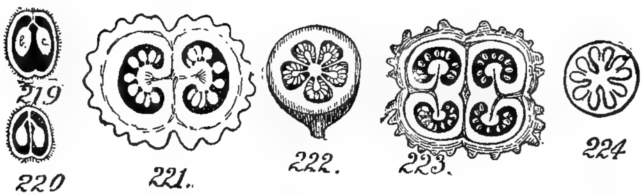


Fig. 219. Transverse section through 1-celled monocarpellary ovary of bean. 220. The same, through 2-celled monocarpellary ovary of *Astragalus*. 221. The same, through upper 2-celled portion of dicarpellary ovary of *Datura*. 223. Through lower, 4-chambered portion. 222. The same, through the 5-carpelled and 5-celled ovary of *Vaccinium*. 224. Through the 5-carpelled, but 10-celled ovary of the flax.

Abortion of the Septa.—If the septa between the cells now become aborted (Fig. 230), the placentae are left free in the center and are collectively called the Free Placenta.

True and False Septa and Cells.—The walls separating the cells of ovaries constructed upon this first plan, because they consist of the original carpellary walls, are called "True," as are the cells. When, as sometimes happens (Fig. 220), a new septum develops from the carpellary midrib, extending across to the placenta and separating its two rows of ovules into two cells, the term "False" is applied both to the septum and to the cells so resulting. If there be several carpels to the pistil, and each undergoes this change, it is clear that there must result twice as many cells as there are carpels (Figs. 223 and 224).

Chambers.—When septa are incomplete, the imperfectly separated cells which result are called Chambers, and the ovary is said to be Chambered. Thus the ovary of *Datura* is completely 2-celled (Fig. 221), but each cell is 2-chambered by partial walls which exist at the basal portion only (Fig. 223).

Second Plan of Structure.—Quite a different group of appearances will result from the higher or more complex form of carpel union, by which the proximate margins of two adjacent carpels meet and unite (Fig. 225) instead of two belonging to the same carpel. The result of this form must be a single cavity or a 1-celled ovary, without regard to the number of carpels, unless, as in the mustard (Fig. 226), one or more false septa may divide it.

Axillary Placentae.—It has been observed that in all cases of the first plan of ovarian structure, the placentae will be central. It is equally clear that in all cases of the second, the placentae must be formed upon the sides, where the edges of the carpels meet. Such placentae are called Parietal (Figs. 225 to 229). Such placentae may, by an extensive involution of the margins, be carried very nearly, or quite, to the axis (Figs. 227 and 228), but unless cohesion actually occurs at that point they are parietal and the ovary is 1-celled.

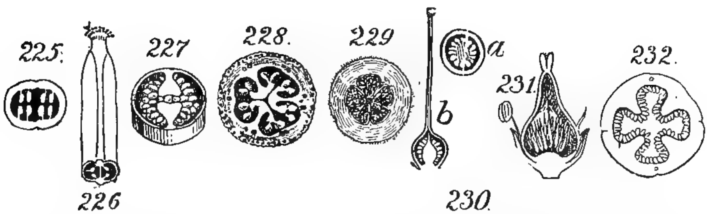


Fig. 225. The 2-carpelled, 1-celled ovary of the gentian. 226. 2-carpelled and falsely 2-celled ovary of mustard. 227. A 2-carpelled, 1-celled ovary, its placentae nearly meeting in the axis. 228 and 229. The same, 3-carpelled. 230. The free central placenta of *Primula*. 231. A 1-celled ovary with basal placenta. 232. 2-carpelled, 1-celled ovary of *Obolaria*, the placentae extended to completely line the wall.

Modifications of the Placenta.—Some further modifications of the placenta require our consideration. The free central placenta has been considered. Such a placenta frequently becomes partly aborted by the gradual disappearance of its upper portion.

Basal and Apical Placentae.—This process may continue until the placenta is reduced to a trace at the base (Fig. 231). In other cases it will be reduced to a trace at the apex (Figs. 235 and 237). Basal or apical placentae may be Centric or Eccentric. Modifications of these processes may result in restricting the placenta to any intermediate point. Upon the other hand, such a placenta may become enlarged and fleshy. Similar changes may occur in the parietal placenta. It may become reduced to a mere point preserved at the apex, base, or intermediate portion. In the watermelon it becomes enormously enlarged, filling the entire cavity with a fleshy, edible mass. In the *Obolaria* (Fig. 232) it is laterally expanded to form a more or less complete false lining to the ovarian cavity. In this position it may remain free or become coherent, so that, as in this case, the entire face of the ovary may appear to be ovuliferous. By a subsequent obliteration of a portion of such an expanded placenta, the remaining portion may be seen to assume an abnormal position, being occasionally confined to the midrib itself.

Ovules.—*Number of Ovules.*—As has already been pointed out, the number of ovules is extremely variable and the proportion of them which become fertilized is little less so.

Position of Ovules.—The position of the ovules is to a great extent determined by the nature of the placenta, as has already been explained. It calls for a number of distinctive terms. The two rows of ovules produced by the two carpellary margins do not always appear distinct, but may be reduced, before or after fertilization, to one.

Series of Ovules.—A vertical row of ovules is called a series, and ovules are thus defined as being One-serialled, Two-serialled (Fig. 219), etc. When there are many series, so that the number is not readily made out, we simply say that they are Many-serialled (Fig. 227).

Collateral Ovules.—Ovules placed side by side (Fig. 219) are called Collateral.

Crowded Ovules.—Sometimes no definite series can be made out, owing to the crowding of many ovules into a small space, as in *Obolaria* (Fig. 232). They are then said to be Crowded.

Divergence of Ovules.—Collateral ovules, and, indeed, any ovules standing together and deviating from a straight line, have a tendency to turn their foramina away from one another.

Direction of Ovules.—As to the directions, in relation to the ovary, which ovules assume, they are Erect (Fig. 233) when standing erect from the base; Suspended (Figs. 235 and 237) when occupying an exactly opposite position; Horizontal (Fig. 234) when taking a direction at right angles to the axis of the ovary; Ascending (Fig. 238) when directed obliquely upward from some point intermediate between base and apex; and Pendulous (Fig. 239) when directed obliquely downward from such a point. When starting as an ascending ovule and afterward drooping (Fig. 236) an ovule is Resupinate, or when as in Fig. 240, Recurved-pendulous.

Obscuring of the Position.—An ovule may have its direction obscured by peculiarities of attachment. Thus, in *Loxopterygium* (Fig. 178), the real base becomes, by extreme obliquity, apparently lateral and causes an erect ovule to be apparently ascending. That of *Anemone* is suspended, but owing to the same condition apparently only pendulous. The terms erect and suspended are after all only relative, as we can never be sure that an ovule which appears in such position is really the uppermost or lowermost of its series. Very often others which would have been in reality the basal or apical have become aborted, as in the last case illustrated.

A merely recurved ovule is not to be mistaken for an anatropous ovule. The latter, as will now be explained, has the contiguous portion of the funicle adherent as a raphe, which comes away with the seed at maturity.

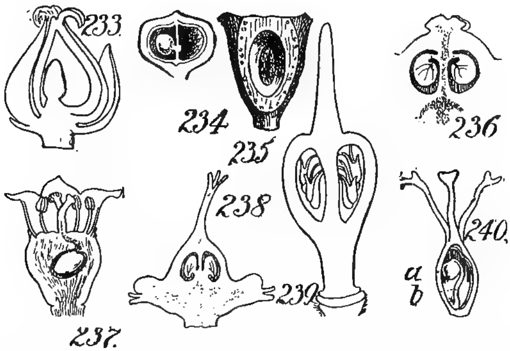


Fig. 233. Erect ovule of *Symmeria*. 234. Horizontal ovule of *Paullinia*. 235. Pendulous ovule of *Guaiacum*. 236. Resupinate ovule of *Euonymus*. 237. Suspended ovule of *Drymicarpus*. 238. Ascending ovule of *Euonymus*. 239. Pendulous ovules. 240. Recurved pendulous ovule of *Brunnichia*.

Structure and Parts of the Ovule.—The recognized varieties of ovules are based upon external structure, which will here be briefly considered. The details of their inner structure will be considered in our chapter on Fertilization.

Body and Funiculus.—The ovule consists of a Body (Fig. 240, *a*) and a Funiculus or Stem (*b*). Named in the order of time in which they are developed, the parts of the body are as follows:

Nucellus and Coats.—The Nucellus, or central portion (Figs. 241 to 244, *n*), containing the parts essential to reproduction, and two coats, the *Primine* or inner (*k*) and *Secundine* or outer (*s*). Certain parts of these, or points upon them, also have distinctive names.

The Micropyle.—The more or less circular opening (*m*) left at the apex by the failure of the coats to completely inclose the nucellus is the Foramen.

The Chalaza.—The structurally opposite end of the body, or the point where nucellus, coats, and apex of funiculus separate from one another (*c*), is the Chalaza.

The Raphe.—If the body become inverted upon its funiculus, either partly (Fig. 243) or wholly (Fig. 242), the portion of the funiculus against which it lies (*r*) will become adnate to it, and is known as the Raphe. The portion of the funiculus remaining free (*f*) is then specifically known as the funiculus. When hereafter in this work the last term is used it will be understood as applying to this free portion. It is thus seen that the raphe is limited at its distal end by the chalaza; but separation of this seed at maturity cannot take place at this point, owing to the adnation of the raphe, as it would do if no such adnation existed.

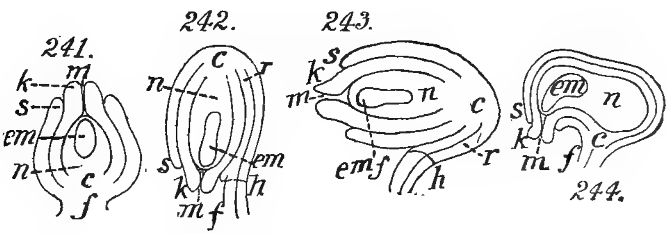


Fig. 241. Atropous or orthotropous ovule; *f*, funiculus; *c*, chalaza; *n*, nucellus; *k*, primine; *s*, secundine; *m*, micropyle; *em*, embryo-sac. 242. Anatropous ovule; *h*, hilum; *r*, raphe; other lettering the same. 243. Amphitropous ovule. 244. Campylotropous ovule.

The Hilum.—Separation in such case must take place at the point where raphe and funiculus join; hence the Hilum, as such point of separation is called, may be variously situated, and need not coincide with the chalaza. In Fig. 241 it is at the chalaza, in Fig. 242 at the opposite end (*h*), while in Fig. 243 (*h*) it is about half-way between. The parts here enumerated are not always conspicuous and may be easily overlooked by the beginner.

Forms of Ovules.—The nucellus is the essential part of the ovule, which in some cases consists of nothing else, and even this may be reduced to its lowest essential elements. An ovule without either coat is Naked or Achlamydeous; with only primine it is Monochlamydeous, and with both it is Dichlamydeous. An ovule without funiculus, and the same is true of any organ not borne upon a stem, is Sessile. The form of the funiculus, as well as its direction, always calls for inspection. It may be very short and broad (Fig. 241), or elongated and slender (Fig. 240), and the latter form may be either straight or variously curved.

The Anatropous Ovule.—An anatropous ovule (Fig. 242) is one the body of which is completely inverted. The raphe runs its entire length and the micropyle is brought close to the hilum, while the chalaza is at the opposite end.

The Amphitropous Ovule.—An amphitropous ovule (Fig. 243) is one which is partly inverted, occupying a position more or less at right angles with its funiculus. Its raphe runs only part of its length, and the hilum is at some point intermediate between the chalaza and micropyle, which are at opposite ends.

The Campylotropous Ovule.—A campylotropous ovule (Fig. 244) is one which need not be at all inverted, but the body of which is doubled over so as to bring the micropyle down near the chalaza. It has, of course, no raphe, and the hilum and chalaza are one. It is very difficult to distinguish this form from an anatropous ovule with a very broad raphe.

The Atropous or Orthotropous Ovule.—This (Fig. 241) is an ovule which is neither doubled nor turned, the body being straight and erect upon the funiculus, and having no raphe, the hilum and chalaza at one, and the micropyle at the opposite end.

Before proceeding to the subject of pollination and fertilization and the changes in the several parts of the flower consequent thereon, we must consider in detail the torus and its modifications.

CHAPTER VII

THE TORUS

Review.—The fundamental principles of anthology are based upon the nature of the torus as a modified branch. We have already considered the evidences of this fact depending upon its position and the relative positions of the parts developing upon it. We shall now consider some which depend upon its modifications. These are in part permanent and typical and in part exceptional and abnormal.

Elongation of the Internodes.—Among the latter we note that in those frequent cases in which the parts of flowers revert to the leaf condition, the torus often elongates, separating the floral series exactly as whorls or spirals of leaves are separated by the internodes upon a branch. At other times, the torus will be continued beyond the apex or center of the flower in the form of a leafy branch. Occasionally one of the sepals will be found at its proper radial point, but vertically distant from the rest of the calyx, a portion of the flower stem intervening.

The Anthophore.—A similar condition, but affecting an entire series, normally characterizes certain species, or groups of species. The elongation may affect any internode or internodes. When (Fig. 246, *a*) it is between calyx and corolla it is called an Anthophore. Sometimes, as in *Viscaria* (Fig. 248), the anthophore may be very slight, so as to escape detection until a longitudinal section reveals its presence.

The Gonophore.—A similar elongated portion between corolla and androecium is a Gonophore (Fig. 249, *a*).

The Gynophore.—One between androecium and gynoecium (Fig. 249, *b*, and Fig. 252, *a*) is a Gynophore. A thecaphore (Fig. 9) often resembles a gynophore and may be mistaken for it. The point of articulation and separation at maturity will determine whether the stalk is a portion of the ovary (thecaphore) or of the torus (gynophore).

The Carpophore.—A slender extension of the torus upward among the carpels, which are attached to it, constitutes the Carpophore, as in *Erodium* (Fig. 245). The presence of a carpophore is characteristic of plants in the Umbelliferae (Fig. 247).

The Gynobase.—In the Boraginaceae the carpophore is frequently reduced to a pyramidal or conical form, or is shortened or laterally expanded until it is merely convex or even plane. To all such modifications the term Gynobase is applied. In this condition it may become hollowed out at the insertion of the carpels, as in borage (Fig. 250). In all forms of the gynobase it is important to note the point of attachment of the divisions of the ovary and the scars which the latter leave upon removal.

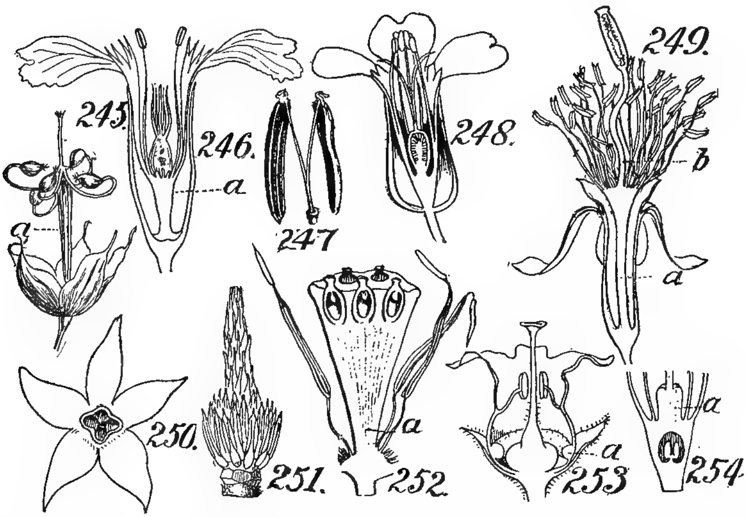


Fig. 245. Pistils of *Erodium* springing away from the carpophore (*a*). 246. Flower of *Lychnis*, showing anthophore at *a*. 247. Carpels of parsnip attached at summit of carpophore. 248. Flower of *Viscaria* with obscure anthophore. 249. Flower of *Maerna*, a gonophore at *a*, a gynophore at *b*. 250. Gynobase of *Borago*. 251. Numerous pistils of *Magnolia*, imbricated upon a carpophore. 252. Greatly enlarged gynophore of *Nelumbium*. 253. Ring-shaped disk (*a*) of *Salpichroa* adnate to calyx. 254. Epigynous disk (*a*) of *Coussarea*.

Abbreviation of the Internodes.—The above considerations refer to elongations of internodes of the torus. The condition of adnation of floral parts may, upon the other hand, be usually looked upon as one in which the normally very short internodes of the torus are still further shortened, so as to bring the parts into most intimate connection.

Lateral Expansion of the Internodes.—Instead of undergoing a mere elongation of its internodes, the torus may be laterally expanded at any or all points, with or without elongation, and in innumerable forms.

The Disk.—An expansion or appendage of this kind, although the term may be properly regarded as including all forms of enlargement or extension of the torus, is called a Disk.

Forms of the Disk.—The simplest form is, perhaps, that seen in the blackberry, a hemisphere, with the pistils arranged upon its surface

(Fig. 305), although most of the enlargement here seen, as in the next, is the accrescence of fructification. The disk of the strawberry (Fig. 304) is similar, but its pistils are partly immersed. In the rose, a related plant (Figs. 59 and 60), the form is modified by the elevation of the margins, instead of the center, so that a cup-shaped disk is formed, the pistils attached over its inner surface. In the cherry (Fig. 58) the disk is thin and lines the calyx-tube, the pistil being free. In the apple there is a similar disk lining the calyx-tube, and it, at maturity, is thick, fleshy, and edible, and encloses the five pistils. In the *Magnolia* (Fig. 251) the torus is vertically much elongated and at the same time

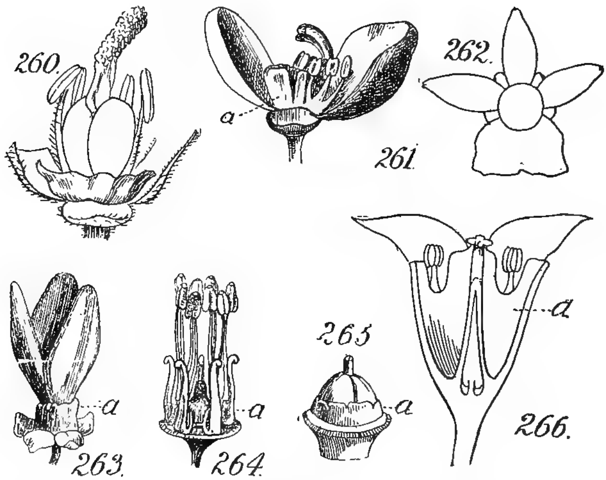


Fig. 260. Saucer-shaped disk of *Pseudima*. 261. Similar disk of *Allophylus*, but irregular and unilateral. 262. Disk with two lobes coherent. 263. Cupulate, sinuate-margined disk of *Hippocratea*. 264. Disk of *Xanthoceras*, of five distinct horns. 265. Cupulate disk with lobed margin. 266. Campanulate disk of *Santalum*, adnate to calyx-tube.

much thickened, the pistils adnate along its surface. In the *Nelumbo*, the torus (Fig. 252) is enlarged into a top-shaped or Turbinate body, with the pistils embedded in the flat upper surface. Instead of thus occupying a hypogynous position, the disk may be projected between any two of the circles, and it may be wholly or partly adnate to either (Fig. 266, *a*), or to both of them, or it may be entirely free. When adnate to both circles it is plain that it becomes responsible for the existing adnation between the latter. It may then exist only at the base, or it may entirely fill up the interspace between the parts and even become epigynous, so that the ovary is immersed in it or buried underneath it (Fig. 254, *a*). The adnate disk may be shorter or longer than the circle to which it is adnate. The simplest manifestation of the disk is that of a mere swelling or ring (Fig. 253) at the summit of the torus; its greatest that in which it becomes an elongated cup or tube. Either form may be entire or more or less divided, from that with a mere sinuately lobed margin (Fig. 263) through the toothed and lobed (Fig. 265) to that consisting of entirely separate divisions (Fig. 264). It may be regular, as in the above illustrations, or very irregular (Fig. 261), and cohesion may exist between some of its divisions while the others are distinct (Fig. 262). The lower portion may be adherent while the upper, lobed or entire, is free (Fig. 266). It may be itself appendaged, and it may or may not be glandular in nature. Finally, we note that the disk may be double, its two circles occupying different internodes of the torus. The texture of the disk is commonly thicker than that of the other parts, but it may be laminar. It is, therefore, sometimes easy to mistake a disk for a corolla, aborted stamen-circle, or crown. In all its peculiarities above described, and in the number, size, and form of its divisions and appendages, the disk is characteristic and of the greatest value in classification, either generic, as in the *Gesneriaceae*, or specific, as in *Eschscholtzia*.

CHAPTER VIII

DISSECTION AND ANALYSIS OF THE FLOWER

Apparatus Required; Microscopes.—For the thorough and convenient examination of floral structure, it is desirable to employ both the compound and the simple microscope, and it is better to use two forms of the latter. The compound microscope for ordinary use should have a focus of about $1\frac{1}{4}$ inches, and it should be provided with a strong illumination for viewing opaque objects. The simple microscopes used should be a dissecting microscope, having a magnifying power of some 20 to 30 diameters and an ordinary jeweller's loup. It must not be assumed, however, that all of these instruments, useful as they are, are essential to the work. Excellent work in all directions can be performed by the use of a strong loup alone, especially if it be held in the eye or attached by means of a flat steel wire passing around the head or inserted into a spectacle frame, so that both hands may be free for the work of dissection.

Other Apparatus.—The other apparatus required is a pair of pointed forceps, a pair of stout needles inserted into thick wooden handles, and a dissecting knife.

Regular Order of Procedure.—It is well for the student in the examination of flowers to accustom himself to a definite order of procedure, as the numerous points to be noted are thus far less likely to be forgotten or overlooked than when considered in a disorderly manner. It is furthermore highly desirable that the characters observed should be written down in systematic sequence before the book is referred to. The order of procedure is from without inward, or in other words, from below upward. The anthotaxy should first be carefully examined and the position of the flower with reference to others in the cluster noted, as well as its position upon the stem and the direction in which it faces. The position when in bud should be compared with that when in flower. When flowers are aggregated in close clusters surrounded by involucres, all the characters of the latter as a whole and of the bracts of which they are composed, must be noted precisely the same as though we were studying the calyx of a single flower. The receptacle upon which the flowers are borne within the involucre must also be thoroughly examined as to its size, form, and surface and the presence of bracts or scales interposed among the flowers.

Coming next to the study of a single flower, it must first be examined in the bud condition and its praefloration determined. In making this observation, it is necessary that the parts, first of the calyx and afterward of the corolla, should one by one be carefully separated with needle or forceps, beginning at the apex and drawing backward and downward, the lines of separation being closely scrutinized while the separation is taking place. The fully expanded flower is next examined. The presence of both calyx and corolla, or of one or neither, is first in order. The regularity or irregularity of the several circles can be determined at a glance, as well as their numerical symmetry. The same rapid glance will determine the relative sizes of the different circles, the exsertion or inclusion of the essential organs, the general form of the flower, and color, surface, and positions of the parts. All the above observations may be regarded as superficial. It then becomes necessary to examine into those details which require dissection.

The sepals should first be turned back and examined as to their cohesion at the base, when this is so slight as to be inappreciable upon superficial examination. At the same time their adhesion to the inner series, especially to the ovary, can usually be determined. The corolla should then be carefully pulled off to ascertain whether any degree of cohesion exists among its petals and also to determine the relation of the stamens to it. The stamens are next to be removed, and this is preferably done by pushing against them at the base from a lateral direction with a blunt instrument, so as to ascertain whether they exhibit a tendency to cohere in groups. The superficial characters of the gynaecium also can now be readily ascertained. The presence of a disk interposed between gynaecium and calyx must then be searched for and its characters determined, as in the case of the other circles. It has already been explained that the disk may be easily overlooked through its adhesion to calyx or corolla or both. Occasionally it will be overlooked because it exists in the form of a granular or powdery mass.

The general observations thus determined should next be verified and more accurately made by making a vertical incision through one side of the calyx and disk, if the latter be present, and carefully removing them. The body thus removed may then be flattened out and the relations of all its parts be fully seen. If, after the initial incision has been made, it be ascertained that adhesion exists between the calyx and gynaecium, so that the former is not readily removed, the incision must then be carried entirely through the flower and the latter separated into two approximately equal portions. In either case search for nectaries or other appendages must next be made. This subject has been so thoroughly considered, that it need not be again taken up except to say that glands, which are frequently metamorphosed stamens or appendages to the several parts, must not be mistaken for a disk. With the flower in this position it may also easily be seen whether the parts are cyclical, and if so the number of circles may be determined. If duplication has occurred, its origin in chorisis or metamorphosis is readily determined, while if suppression has occurred it can readily be referred to the respective circle.

The relation of the parts to one another having been thus determined, each of them must next be studied individually. The shape and texture, and the division into parts, with the details of any existing appendages, will be sought separately in sepal, petal, and stamen and in filament and anther separately. In the examination of the stamen, it is essential that it be examined separately in direct lateral, ventral, and dorsal views, as only thus can the true relations of its parts become known. The form of attachment of anther to filament and the point of junction between filament and connective are next in order, as well as the form of dehiscence of the thecae and especially the position and direction assumed by the sutures, pores, or valves of the latter. The chief difficulty in the examination of the stamens will be in determining the part upon which any existing appendages originate. The position which such an appendage occupies is frequently quite misleading as to the nature of its origin, and it must be carefully moved about with the points of the needles, great care being taken that no delicate attachment is severed, before it can be definitely ascertained whether an appendage originates from filament, connective, or theca.

It is, moreover, not rarely the case that the characters of appendage and anther are so concealed or even substituted that the one may be mistaken for the other. The examination of the stamen is not complete until the characters of the pollen, as to its being granular or collected into pollinia, the nature and characters of the latter, and even the characteristics of the individual pollen-grain, have been determined by the aid, chiefly, of the compound microscope.

The gynaecium, still in position upon the torus, must next be studied as to its relations to the latter and its composition of united carpels or separate pistils. If of separate pistils, they must be separately removed from the torus, great care being taken not to mutilate the latter, and their number and regularity must be determined. If regular, the detailed examination of one of them is sufficient, but if irregular, one of each form must be separately studied.

The external characters of the pistil present no difficulty for examination, but the examination of their structure and contents constitutes perhaps the most difficult part of floral dissection. It is very desirable that the stigmas be subjected to examination with the compound microscope, as the character of its surface and the form and distribution of the stigmatic surface proper upon the style and upon the body, which may at first sight be regarded as the stigma, is frequently a matter of the utmost importance. The dissecting knife must now be used for dividing the ovary into a number of transverse sections, which must then be separately viewed by transmitted light. This examination will determine the number of cells and their completion by the continuation of the septa from top to bottom. It will also in most cases be sufficient to enable us to determine the number of ovules and the position and character of the placentae. All these points should, however, be verified by the subsequent examination of vertical or longitudinal sections. Finally the ovules must be removed and their form and structure determined by the aid of a compound microscope.

It may be pointed out in conclusion that the examination of a single flower is not always sufficient to determine the structural characters. Dimorphism or dichogamy, unrecognized by the student, may lead to the most false conclusions.

The student should also be cautioned against the temptation to examine the partially or wholly matured fruit with the idea that he can thus more easily determine the characters of the gynaecium. As will be shown later, great changes frequently occur in the structure of the pistil during fructification.

Preparation of Dried Specimens for Examination.—The order of examination is the same whether a fresh or a dried flower be under consideration. In the case of the latter, however, it is necessary that it be first thoroughly softened by immersion in water. For this purpose it may be left in warm water all night or for a longer period, or as is usually more convenient, it may be boiled for from one to five minutes, according to its texture, in a spoon or porcelain dish held in the flame of an alcohol lamp. Considerable experience is required to know just how long to subject it to the action of the hot water. If too quickly removed, the tissues will be found stiff and resistant, while if it be boiled too long, they will become so thoroughly limp as to lose all trace of their natural position. If the process is perfectly performed, the flower may be thrown upon a blotter and after the excess of moisture has been thus removed, will be found very much in the original growing condition and yielding easily to manipulation.

CHAPTER IX

POLLINATION AND FERTILIZATION

Review.—It has been stated that the essential female element of reproduction in the flower is produced in the nucellus of the ovule, the male by the germination of the pollen-grain. It has also been shown that these two elements are produced separately, and in most cases remotely, from one another, and that some means must exist for bringing them together in order that fertilization may be effected.

POLLINATION

In those plants (Gymnosperms, Figs. 174 and 175) in which no stigma exists, this is accomplished by immediate contact of the pollen with the ovule, which is exposed for the purpose. In those in which a stigma exists, it is accomplished by the deposit and fixation of the pollen thereupon. To either of these processes the term Pollination is applied.

Close-pollination and Cross-pollination.—The two elements may proceed from the same flower, in which case the term Self-pollination or Close-pollination is applied, or they may proceed from different flowers, in which case the term Cross-pollination is applied. It will be noted further that there are degrees of cross-pollination, according to whether the elements proceed from flowers upon the same or upon different plants. When the flowers are perfect, it is at least possible in most cases for them to be either close- or cross-pollinated.

Cross-pollination Beneficial.—In nearly all cases, the reproductive function is strengthened through cross-pollination, which explains the fact that nearly all flowers are constructed so as to facilitate the process, while most of them are so constructed as to incommode, and very many to prevent, close-pollination. In a few cases the flower is constructed so as to prevent cross-pollination.

Methods of Securing Cross-pollination.—The methods of effecting cross-pollination may be divided into the ordinary and the exceptional.

The latter must be considered individually. The former are two—namely, through the agency of the wind and through that of insects (or occasionally other animals).

Anemophilous and Entomophilous Flowers.—Flowers adapted to the former methods are called Anemophilous; those adapted to the latter are called Entomophilous. Occasionally the flower is so formed that the movement of the water during rains, or in streams, effects pollination.

Provisions in Anemophilous Flowers.—The activity of the wind being beyond the control of the flower, the adaptation of the structure of an anemophilous flower is limited to securing the benefits of such action when it comes into play. This consists chiefly in (1) a gregarious habit—the growing together in great numbers of individuals of one kind, as in the case of grasses and of most of the forest trees of temperate latitudes; (2) a very abundant pollen (3), which is loosely fixed, one method being illustrated by Fig. 267, light and easily removed and transported; and (4) the disposition of the ovule of gymnosperms, and the form and disposition of the stigma and connected parts of angiosperms, so as to catch the pollen. All these provisions may be readily seen to affect the process in the case of *Pinus palustris*, for example. In this plant the pollen-grains contain several cells, all but one of them empty, thus decreasing their specific gravity. They are produced in such great abundance that the crop, carried by strong winds, has been known to fall at a great distance as a thick deposit, the so-called "sulphur-showers" of history. The trees are densely massed, to the exclusion of almost all others, and bear innumerable cones (Fig. 360), each consisting of numerous scales, outwardly flaring, and so disposed as to catch many of the pollen grains and guide them downward to the little pockets at their bases.

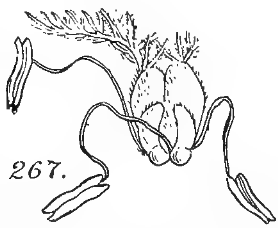


Fig. 267. Anemophilous flower of a grass.

Provisions in Entomophilous Flowers.—In entomophilous flowers, such provisions as above described for the utilization of the pollen-carrying forces, must be preceded by others of a different nature, calculated to first set in motion and attract these forces.

Provisions for Attracting Insects.—Provisions for attracting external agents are found chiefly in the form, coloration, and size of the flower or of one or more of its parts, the production of fragrant and nutritive secretions and the exercise of these influences at the most opportune times.

Form.—The form of the flower is efficient when it resembles a form attractive to an insect the visit of which is desirable, or when it is one well calculated to display effectively the coloration; and it is not impossible that certain forms, like certain colors, are attractive *per se.* The forms of nectar-bearing flowers are, moreover, in most cases, such as to facilitate the collection of the food by the visiting insect, or, when otherwise, to effect special objects to be considered farther on. For example, it is usually a peripheral or central position of the nectaries which respectively determine the extrorse or introrse dehiscence of the anthers.

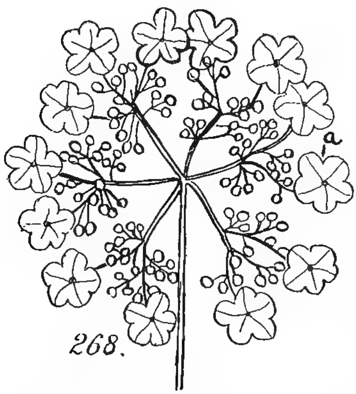


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Fig. 268. Inflorescence of *Viburnum* with neutral marginal flowers.

Color.—Coloration also may be attractive, through its simulation of an insect or merely by its serving to make known to the insect the presence or position of the flower concerned—as a white, light-colored, or lustrous flower, in attracting insects which fly only when there is little light.

Function of Neutral Flowers.—Flowers are frequently modified in size so as to effect these results, and this modification is often secured at the expense of their own sexual functions. Fig. 268 illustrates a cluster of *Viburnum* flowers, the marginal being large and light-colored and admirably adapted to attract insects, but destitute of perfect reproductive parts. This tendency to produce upon the same plant flowers of two kinds, the one for display, the other for reproduction, is widely manifested. In the *Epiphegus,* the flowers produced respectively upon the lower and upper portions of the stem exhibit this difference. In such heads of flowers as the Daisy, the showy marginal flowers are very frequently sterile, even though pistillate, and attract insects which then pollinate the inconspicuous central flowers.

Odor.—The odors of flowers, while frequently offensive to the human sense, are supposed to be attractive in most cases to the insects whose visits favor their pollination. They result from the evaporation of volatile oils. The glands by which these oils are excreted and in which they are stored may be distributed through the tissues of all or certain of the floral parts, or their presence may be restricted to the special appendages described below.

Nectar and Nectaries.—The nutritive substances other than pollen to be consumed by the visiting insect, known as Nectars, are produced by certain special glands and are stored in or upon contiguous receptacles called Nectaries. The presence of these nectaries is commonly responsible for the outgrowth of the appendages to which they are often attached (Figs. 63 and 65). At other times a part of the flower not conspicuously modified produces and holds the nectar.

Time of Activity.—The influences here described are in almost all cases exerted at certain times which are especially favorable for securing the desired results. In speaking of the perigone, it has been shown that the duration of flowers varies greatly. It may be further stated that those which perish quickly mature and expand at the particular time of day when pollination is most likely to occur. Those which last for several days enjoy a daily resting period and another period of greatest activity, the details of which vary in different species or classes. Commonly, the perigone becomes more or less folded or closed during this resting period, its form and coloration less conspicuous, the exhalation of odors entirely suspended or greatly restricted, and access to the nectar prevented altogether. At the same time that its functions are thus inactive, its position is such as to afford it protection of various kinds from dangers which are especially imminent during the hours in which it rests.

Sleep of the Flower.—This condition of inactivity or rest is commonly spoken of as the sleep of the flower. It occurs at such a period of the day as finds the agencies specially adapted to pollination in its case themselves enjoying their rest. As these again become active, the flower "awakens" and all the conditions above noted are reversed, or at least such of them as affect the flower in question.

Diurnal and Nocturnal Flowers.—Flowers in which this active period occurs during the day, whether they endure for but one day or longer, are called Diurnal; those in which it occurs at night are called Nocturnal. Besides the regular daily resting period, a great many flowers, by virtue of special sensitiveness, possess the power of assuming such a condition on special occasions when the conditions call for it.

Pollination by Birds.—Humming-birds, as well as insects, are active participators in the operations above recorded. Their operations in promoting cross-pollination in the *Cinchona* group have been largely responsible for some of the most far-reaching economic conditions and results in the history of the drug trade. In exceptional instances, still other animals take part in this work.

Participation by other Parts than the Flower.—It may be remarked in passing that these characters, like some of those which follow, are not restricted to the flower itself. Very frequently other portions of the plant adjacent to the flower will be expanded, brightly colored, and developed into special forms, while the odor of some flowers, due to the presence of glandular tissues, is shared by the foliage and other herbaceous portions, as in the lavender. Well-formed, large glands are present in the axils of the primary veins of the leaves of some species of *Cinchona*, although the precise function which they perform is by no means clearly established.

Provisions for Utilizing Insect-visits.—The special contrivances for utilizing insect-visits in effecting pollination are far more elaborate and varied than those for inducing them, which we have already considered, and our consideration of them cannot be extended beyond what is necessary to indicate their general nature and classification, and to serve as a key in understanding the complicated modifications which we have observed the typical flower to undergo. Usually the effects extend in two directions—(*a*) toward excluding the pollen from access to the stigma of its own flower, and (*b*) toward securing its access to that of another.

Dichogamy.—One of the most frequent methods of securing the former result is the maturing of the androecium and gynaecium at different times. This method is called Dichogamy.

Proterogyny and Proterandry.—By it the ovules of a flower are already fertilized before the mature pollen of that flower escapes from its thecae (Proterogyny), or else the pollen is matured and utilized before the stigmas of that flower are prepared for its reception (Proterandry).

Proterandry is well illustrated by Figs. 269 and 270. The former illustrates the anthers erect with their pollen ready for removal, while the stigmas are yet immature. The visit of an insect to such a flower cannot affect the stigma, but will result in the transportation of the pollen to another flower, perhaps in the condition represented by Fig. 270. Here it will be received upon an active stigma, the anthers having already perished and dropped beneath the margin of the corolla.

Figs. 271 and 272 illustrate proterandry assisted by a special mechanical device. The former represents a flower with closely syngenesious and introrsely dehiscent anthers.

Its style is two-cleft, the stigmas existing upon the inner faces of the branches, their outer faces being clothed with stiff hairs pointing upward. It is obvious that until these style-branches separate, pollination cannot take place. Before such separation occurs, the tip of the style is, by elongation, slowly forced up through the tube of the anthers. The anthers, with their contained pollen, are mature, and the pollen is, by the stiff hairs upon the backs of the style-branches, torn out from its receptacles and exposed to such agencies of transportation as may be prepared to act upon it. Cases are even known in which the tearing out of the pollen in this way is effected by a spasmodic shortening

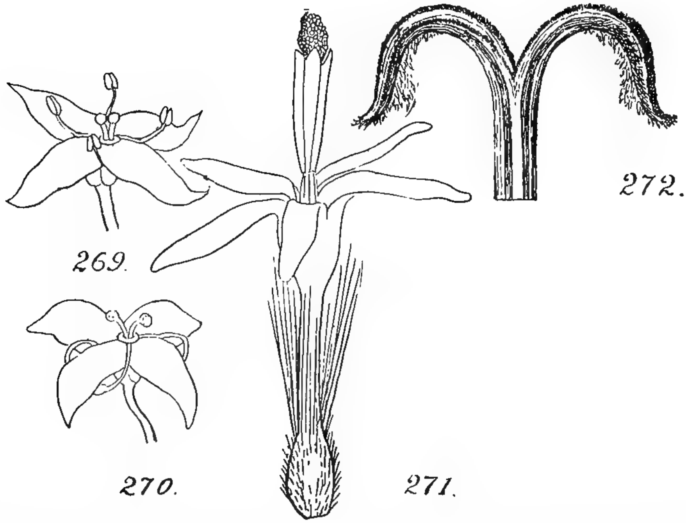


Fig. 269. Dichogamous flower of *Mitchella* in first stage. 270. The same, in second stage. 271. Dichogamous flower of *Vernonia* in first stage. 272. Style of same in second stage.

of the stamens upon the instant of contact by a visiting insect, the pollen being by the same process at once discharged upon the body of the latter. After the removal of the pollen, or after the death of such grains as fail to be removed, the style-branches separate (Fig. 272) in readiness to receive the pollen brought from some other flower. This method, or some modification of it, is very common among the *Compositae*, and illustrates how the study of pollination serves to explain many modifications of flower-structure otherwise inexplicable, and why the possession of the latter is regarded by the biologist as indicating a higher stage of development.

Dichogamy is very common among perfect anemophilous flowers, where self-pollination would otherwise commonly result, and it may be assumed to have been the first step toward the uni-sexual state, so common among flowers of that class. Careful notice should be taken of the fact that in dichogamy the retarded state observed in androecium or gynaecium is but temporary, and that the finally developed form is the same, whether the flower be proterandrous or proterogynous.

Dimorphism.—A far more profound modification is that in which there is a permanent change in the androecium (Fig. 273) of one flower and a similar change in the gynaecium (Fig. 274) of another, by which a similar result is obtained to that proceeding from dichogamy. Such a provision constitutes Dimorphism. By a modification of it, a third form of flower, intermediate between the other two, is produced, constituting Trimorphism. The explanation of the case of dimorphism here exhibited is as follows: An insect visiting flower No. 1 and thrusting his proboscis deeply into the corolla-tube in search of nectar, brings his body into contact with the stamens, and pollen is deposited upon it. The next flower visited may be one like No. 2, having a long style. The portion of the body which is now covered with pollen will then be brought into contact with the stigma, upon which the pollen is deposited. At the same time a different part of the body is being laden with pollen from the short stamens of flower No. 2, to be deposited upon the short pistil of still another flower, similar to No. 1. If perchance two flowers of the same form are visited in succession, the result is that an additional deposit of pollen is secured, or at most a portion of the pollen already being carried is left upon the stamens of the visited flower.

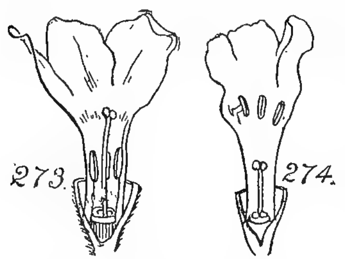


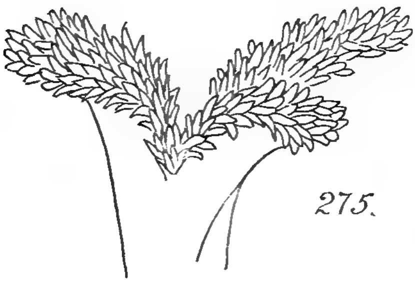
Fig. 273. Long-styled form of dimorphous flower of *Houstonia*. 274. The same, long-staminate form.

As will be seen by a consideration of typical examples of each, dimorphism is more intimately connected with the transferring of the pollen than is dichogamy, though the latter is rarely without some special provision for thus supplementing the effect which it produces in excluding the pollen from the stigma of its own flower.

In conclusion, it may be said that even if, by some failure in the provision here described, the flower should become self-pollinated, we have excellent reasons for believing that pollen from a different flower which might be deposited at the same time would find an advantage accorded to it by which it would be enabled to first reach and fertilize the ovules.

Coercion of Insect by Special Forms.—The assuming of a form convenient for the visiting insect, to which reference has been made, is very frequently interfered with for the purpose of forcing the insect into such a position as shall favor or compel the removal of the pollen, a labor which is by no means agreeable to it and which it not rarely seeks to avoid, as in the case of the bee, which cuts a hole at the base of some corollas, through which its food may be extracted.

No better illustration of such coercion of the insect by special form could be selected than that of the *Asclepias* (Fig. 276). The nectary is at *a*, in the bottom of a large slipper-shaped pouch. Into this pouch the insect would naturally thrust its proboscis in the direction of the



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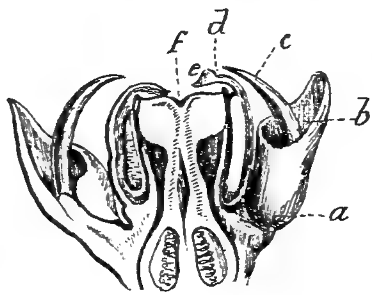

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Fig. 275. Highly magnified papillose stigmatic surface. 276. Vertical section of flower of *Asclepias*: *a*, nectary; *b*, blind pouch; *c*, horn; *d*, pollinium; *e*, glutinous corpuscle of same; *f*, stigma.

point *b*, thus avoiding contact with the pollen. The appendage *c*, however, cuts off this line of approach, separating the blind pocket *b* from the nectary *a*. In order to reach the latter, the insect is now forced to seek an entrance at the point *d*, his head being thus forced into contact with the pollen at *e*, which adheres and is carried away to be applied to the stigma *f* of the next flower visited.

In spite of the possibility of thus effecting a rough classification of some of the methods of securing cross-pollination, it is yet true that the great majority of instances are not subject to classification and must be denominated special, or else that they combine some special arrangements with such general methods as have been described.

Cleistogamy.—Flowers which are self-fertilized before expansion are Cleistogamous. Occasionally, fertilization takes place without the removal of the pollen from the anther.

Fixation of the Pollen.—The pollen thus transferred to the stigma must be fixed there in order that fertilization may follow pollination. This process is effected by contrivances little less elaborate, although more minute, than those which have been described. These contrivances relate in part to peculiarities of the pollen. As regards the stigma, fixation is effected most generally by means of the viscid secretion to which reference has been made, the stigma being essentially glandular in nature. Appendages in the form of hairs, scales, or papillae (Fig. 275) are very common. In some cases the divisions of the stigma are sensitive and close elastically upon the pollen as soon as it is deposited. With the fixation of the pollen upon the stigma, pollination is completed and preparations for fertilization begin.

FERTILIZATION

A knowledge of fertilization is of importance to the pharmacognosist only as it throws light upon the characters of the fruit, in which we include the seed as a part. Only the principal facts connected with the subject will, therefore, be here considered.

Internal Structure of the Ovule.—The gross appearance and parts of the ovule have already been described. Its internal structure is illustrated in Fig. 277.

The immediate function of the flower has been seen to be the production of spores. These spores are to act as reproductive bodies, which, like seeds, they can do only by germinating and growing in a suitable soil. This function of each will now be considered.

We have seen that the macrosporophyll is the carpel, its macrosporange the ovary. The macrospore itself is the large centrally located cell of the nucellus, which is to develop into the embryo-sac, *e*. The natural soil for the germination of this spore is the tissue of the nucellus where it is formed. Its germination takes place immediately and results in the development of the several distinct bodies figured in the illustration. Of these bodies, the oöspore or vegetable egg, *o*, is the ultimate female reproductive element.

The Gymnospermous Ovule.—The ovule of gymnosperms agrees in the possession of an embryo-sac, with several bodies corresponding to the oösphere of angiosperms, but with the other corpuscles not clearly developed. The foramen is secretory, so as to be adapted to acting upon the pollen-grain which it receives, as does the stigma in angiosperms.

The Female Gametophyte.—As is the product of seed-germination, so is the product of spore-germination a plant. The plant which results from seed-germination, and which produces spores, has been called a sporophyte. That which results from spore-germination, and the ultimate function of which is the production of seed, is called a gametophyte. Hence the mass contained within the embryo-sac is such a plant, the female gametophyte. It will rest in the state in which we now find it until its oösphere is acted upon by the male element, which we have yet to consider, and if such action does not occur, it will die and disappear.

Connection between Stigma and Ovule.—Between the ovule thus prepared and the stigma, there is an almost continuous connection through conducting tissue, extending through the body of the stigma, style, and placenta. The extent of this conducting tissue, like that of the stigmatic surface, is usually greater or less according to whether there are more or fewer ovules to be fertilized.

We have seen that the soil upon which the microspore is intended to germinate is the stigma, in angiosperms, and the foramen of the ovule in gymnosperms. The process of germination is dependent upon the following structural characters:

Structure of the Microspore.—The pollen-grain consists of a highly hygroscopic mass of tissue, partly vital and partly nutritive, the latter of variable composition, surrounded by a thin, non-perforated, highly elastic membrane, the Intine, and this in turn by a thicker, non-elastic covering, the Extine, or "Exine," bearing one or more complete perforations, very thin places, or otherwise modified points upon its surface. In exceptional cases there is instead but a single wall.

Germination of the Microspore.—The process of fertilization is illustrated by Fig. 278, and the ordinary phenomena are as follows: The pollen grain (*a*), fixed upon the stigma of the angiosperm, or upon the summit of the ovule of the gymnosperm, the hygroscopic contents absorb moisture from the secreting or transuding surface with which it is in contact, the mass increases in size and distends the intine which surrounds it. Shortly cell-division of its contents takes place, the combined changes constituting the germination of the microspore.

The Pollen-tube.—Through one or more of the perforations of the extine already existing, or forcibly made by this process, protrude prolongations of the pollen contents, still enveloped in a process of the intine. Such a prolongation is known as a Pollen-tube (*b*).

The Male Gametophyte.—A body of this kind, proceeding from the germination of a matured spore, is properly to be regarded, like its female homologue, as a plant body. It is to be noted, in passing, that it can be equally well produced by germination upon other surfaces which present the proper conditions.

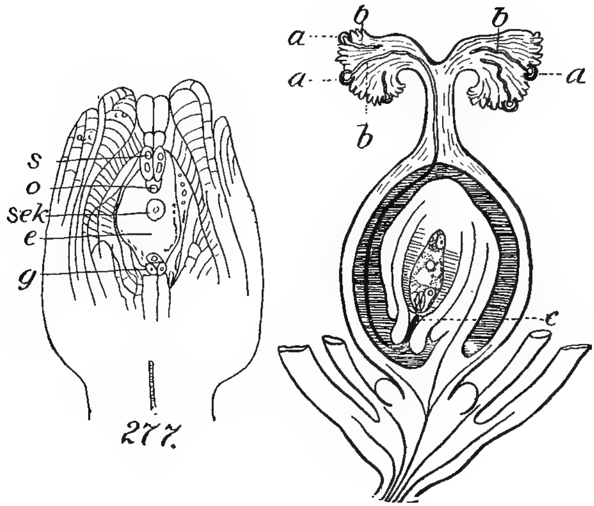


Fig. 277. Diagram illustrating structure of ovule: *s*, synergidae; *o*, oösphere; *sek*, nucleus; *e*, embryo-sac; *g*, antipodal cells. 278. Diagram illustrating fertilization: *a*, pollen-grains on stigma; *b*, pollen-tubes penetrating stigma and style and entering ovarian cavity, one of them entering the foramen of the ovule at *c*.

Following the same course of reasoning as in the case of the female gametophyte, we see that this pollen-tube is the male gametophyte. Its structure is not, or apparently not, even so highly developed as in the case of the other.

The Male Cell.—At its lower end are one or more little bodies which constitute the male element and which are to fertilize the oösphere which we have already observed within the embryo-sac. This fertilizing element is the Male Cell, or Antherozoid.

In some of the lowest of the flowering plants, and in most of the Cryptogams, this male cell is highly organized, with a specially formed body, is capable of locomotion, and possesses peculiar powers of nutrition. It is comparable with the spermatozoön of animals.

The Descent of the Pollen-tube.—The male cell or antherozoid is quite as incapable of reproducing by itself as is the oösphere, and its sole function is to act upon the latter, fecundating it. This is accomplished by the penetration of the loose cellular tissue of the stigma, then of the style, by the pollen-tube. Nourishment for its growth and movement is afforded partly by the contents of the pollen-mass and partly by absorption from the tissues of the stigma and style with which it is in contact. This process is known as the Descent of the Pollen-tube, and by it the male cell or antherozoid is brought into the ovarian cavity and into the immediate presence of the ovule. It then finds the foramen of the latter, contact and fusion of the male cell with the oösphere is effected, and fertilization is accomplished.

Among cryptogams, there are no such specially adapted sites provided upon the plant-body of the parent for the germination of spores, which reproduce upon any appropriate soil. They may be of two sexes, the macrospore resulting in a gametophyte which produces female cells, the microspore in one which produces antherozoids, or the one gametophyte may produce both organs. In either case, the antherozöids commonly travel to reach the female cell. Fertilization occurs very much as in phanerogams, but no seed is produced, as will shortly be explained, the embryo proceeding at once to grow and reproduce a sporophyte.

CHAPTER X

CARPOLOGY: FUNCTIONS AND STRUCTURE OF THE FRUIT

FRUCTIFICATION

Fructification and its Objects.—The changes effected by fertilization extend to all parts of the flower and even to other parts of the plant. A consideration of the objects of the process will prepare us to understand the nature of the changes. The objects are (1) the production and maturing of one or more seeds, including provisions for their protection and nourishment throughout the process, together with the nourishment of the parts which thus protect them; (2) provisions for their transfer, still enclosed in their container, to a suitable place for germination and the fixation of the latter there, or (3) provisions for their exit from such container and (4) their transfer after such exit to the place of germination and their fixation there. The combined processes connected with the attainment of these objects is Fructification, and the product thereof is the Fruit.

Fructification Results in the Death of Some Parts, the Stimulation of Others.—It is clear that the energies of the plant should not be called for in the further development or preservation of any parts of the flower which are not serviceable as a part of the fruit in the attainment of the above-named objects, unless possibly they may possess some other function foreign thereto, as, for instance, the action of the stamens of a flower in which fructification has already begun, in fertilizing the ovules of some other flower. We should, therefore, look (*a*) for the disappearance or death of all floral parts not thus serviceable, and (*b*) for the stimulation and development of those which are. That the first of these two objects is an immediate result of fertilization is strikingly and unhappily illustrated in the behavior of ornamental flowers in which the latter process is allowed to take place. Those who produce for the market the handsome and expensive flowers of orchids are obliged to carefully exclude insects from their greenhouses. Valuable flowers which, without fertilization, would last for several weeks, wither and die within a few days, or even hours, after such process has occurred. That the accomplishment of the second-named object is no less immediate is apparent upon considering the morphology of the fruit.

Parts Useless in Fructification.—The only portion of the flower which is certain to be in no case utilized in fructification, and, therefore, to disappear after fertilization, is the actual stigma, and the stamens when they are non-adherent. The stamens, as has been shown, may be serviceable for other purposes, so that their death depends rather upon the performance of their individual function than upon fertilization. In proterogynous flowers this function is actually stimulated by the completion of fertilization in their own flower.

Parts Useful in Fructification.—Upon the other hand, we are not certain of a requisition in every case for the preservation and development of any part other than the particular ovules which become fertilized, the ovarian walls of the pistil or pistils containing them (and in some cases only a part of these), and of the torus. The death or decay, therefore, of any or all of the other parts will be determined by the individual or class habit of the plant concerned.

Accrescent Parts.—To any part other than the ovary, which thus develops and enlarges as a part of the fruit, the term Accrescent is applied.

Accessory Fruits.—Fruits of which such accrescent parts form the conspicuous portion are called Accessory fruits.

New Parts Developed by Fructification.—Finally, we must note that new parts, of service in the fruit, frequently develop in the course of fructification, upon either pericarp or seeds, just as special appendages develop upon the floral organs for performing special function in connection with pollination. That such additional parts exhibit little, if any, development during the floral stage, is due to the fact that an enormous waste of energy on the part of the plant would thus be involved. Of all the flowers produced by a plant, only a minor portion usually accomplish fructification, and of all the ovules produced by any gynaecium only a minor portion usually produce seeds. The development of these superfluous flowers and ovules constitutes in itself a serious waste, but it is a necessary or, upon the whole, an economical one, as it tends in the end to secure the full degree of fructification by the plant. The development, however, upon such superfluous flowers or ovules, of parts which will be of value only in case fructification is effected, would be anything but economical. Hence the general rule that parts of the fruit which are of no use in effecting pollination and fertilization are not developed until after these functions are performed.

FRUIT

Structural and Physiological Senses of the Term.—There are two distinct senses in which the term "fruit" may be employed. In the first instance, we may regard it as the structural product of the development in fructification of a pistil, or in the second as an organ performing a certain reproductive function or functions. The limitations of our definition of the term will vary accordingly.

Entire Gynaecium as the Fruit.—In many cases the ripened gynaecium performs or may perform the fruit-function entire, as in the cherry, the strawberry, the blueberry, the so-called "seed" of the sunflower, or the pod of the bean or digitalis. In such cases the solitary ripened carpel (cherry and bean) or the aggregation of ripened carpels (as in the other illustrations), of a gynaecium, constitutes the fruit, from either point of view.

Either the Whole or Part of a Gynaecium as a Fruit.—In other cases the several carpels of a gynaecium are separate from first to last as pistils, as in the case of the buttercup. The entire collection then constitutes a fruit, being the product of a flower, but each of the individual pistils must also, from a physiological standpoint, be regarded as a fruit, inasmuch as it performs the fruit function independently.

Part of a Pistil as a Fruit.—Again we find, as in the case of the borage, that carpels originally coherent, separate before performing their function, so that we must regard each of the separated carpels, as well as the entire gynaecium, as in the nature of a fruit.

Part of a Carpel as a Fruit.—Occasionally even a carpel will itself divide into separate parts, each of which is equally entitled to be designated as a fruit, as in the case of the 2 carpels of the lavender, which separate into 4 nutlets.

Gynaecia of a Number of Flowers Forming a Fruit.—In still other cases the ripened gynaecia of more than one flower cohere and perform the fruit function as one body, as in the case of the partridge-berry, the fig, and the mulberry.

Finally, we note that many fruits can perform their function in either way—namely, by means of their carpels, or parts thereof individually, or as aggregations proceeding from a single flower (blackberry), or from many flowers (fig, hop, etc.). It is, therefore, to be noted that that which is at one time to be regarded as a fruit is at another time only a part of one, according to the manner in which it performs its function.

Kinds of Fruits.—From the foregoing considerations, we may deduce the following definitions of fruits:

A Fruit is a separate ripened carpel, or a separate part thereof, or an aggregation of ripened carpels, together with any adherent parts.

Multiple or Collective Fruits are those proceeding from the gynaecia of more than one flower.

Aggregate Fruits are those which proceed from a number of pistils of one flower.

Simple Fruits are those proceeding from a single pistil.

Apocarpous Fruits are those consisting of one carpel or of two or more non-coherent carpels.

Syncarpous Fruits are those consisting of coherent carpels.

Accessory Fruits are those in which some part other than the ripened ovary constitutes a conspicuous portion.

Structural Composition of the Typical Fruit.—The student cannot have failed to note in reading the above statements that the composition of the fruit is extremely variable and in some cases complicated. In accordance with this fact, the classification of the parts of fruits is open to great differences, according to the principles upon which the observer bases his classification. The typical fruit may be considered as that which consists only of the ripened pistil with the contained seed or seeds.

The Pericarp.—As a fruit is regarded as possessing but two portions, namely, the seeds and the Pericarp, the pericarp of such a typical fruit would consist of a ripened pistil exclusive of its seeds, but since, in many cases, the calyx, disk, or other part is closely adnate to the wall of the ovary and more or less indistinguishable from it, it becomes impracticable to restrict the term pericarp to a part consisting only of the pistil. Again we find that there are all intermediate forms and degrees of adnation and separation between the ovary and the accrescent parts of accessory fruits. It, therefore, appears most convenient to define the pericarp in a broad sense as the fruit with the exception of the seeds.

The Pseudocarp or Anthocarp.—When the pericarp consists chiefly of other elements than the ovarian wall it is called a Pseudocarp or Anthocarp.

Layers of the Pericarp.—When the pericarp is seen to consist of three demonstrable layers, these are called respectively Exocarp, the outer; Endocarp, the inner; and Mesocarp, the middle. When the exocarp is thin and membranous, like the skin of a plum, apple, or tomato, it is called an Epicarp, and when an endocarp is hard and strong inside of a fleshy layer, like the stone of a peach or the "core" of an apple, it is called a Putamen.

Modes of Performance of the Fruit Functions.—We shall now consider the manner in which the four objects of fructification are accomplished through the modifications effected in each of the floral parts and in the parts adjacent, by fertilization, including such new appendages as are thus caused to develop.

Growth and Maturity.—The development and maturity of the fruit are effected by the stimulation, through fertilization, of the nutritive functions of the pistil, the torus, adjacent portions of the plant, and through the combined influence of all the flowers, a similar stimulation of all portions of the plant.

Protection.—So far as the development of a protecting container for the maturing seed is concerned, the object in general demands the development of nothing more than the ovarian wall; but the effects of adnation and the requirements of the other objects result in the extension of this process to various other parts of the flower or even of its supporting parts. The development of such parts in connection with the ovarian walls will therefore receive attention in considering the methods by which such other objects are accomplished.

The Abortion of Septa and Cells.—It has been stated that not always are all of the ovarian walls involved in fruit development. A gynaecium possessing several pistils may fail to develop one or more of them in fruit, and when these are adnate into a compound ovary, as in *Vallesia,* one or more of them may likewise fail to develop. A several-celled ovary, as in *Calesium* (Fig. 279), may, after the fertilization of one or more ovules in one or more cells, permit the abortion of those in the other cells, the septa of the latter being then crowded against the outer wall by the growing seeds, or even disappearing, so that the fruit will contain a smaller number of cells than the ovary which produced it. The partial obliteration of cells in a similar manner is well shown in the fruit of *Diospyros* (Fig. 280).

Mr. J. H. Hart has contributed three fruits taken from one crop of a single plant (Fig. 285, *a*, *b*, and *c*), the first showing the development of all three of the ovarian cells, the others having respectively one and two of these aborted.

The Development of New Septa and Cells.—Additional walls, upon the other hand, may develop during fructification. *Datura* has a 2-celled ovary (Fig. 221), but a 4-celled fruit (Fig. 223), and this occurs regularly in the *Labiatae*. The newly formed walls are not always vertical. The fruit of *Aeschynomene* (Fig. 351) and that of *Sophora* (Fig. 352) divide transversely into one-seeded joints.

Special Defensive Provisions.—Concerning the protection of the fruit and seeds, we note that its full accomplishment often calls for other defensive provisions than those against merely mechanical forces, in the form of appendages constituting an armor. These are sometimes an outgrowth from the ovary itself, as in *Stramonium* (Fig. 282), sometimes upon an enclosing calyx (Fig. 283), an enclosing wall consisting of a hollowed branch, as in the prickly pear (Fig. 281), or sometimes upon

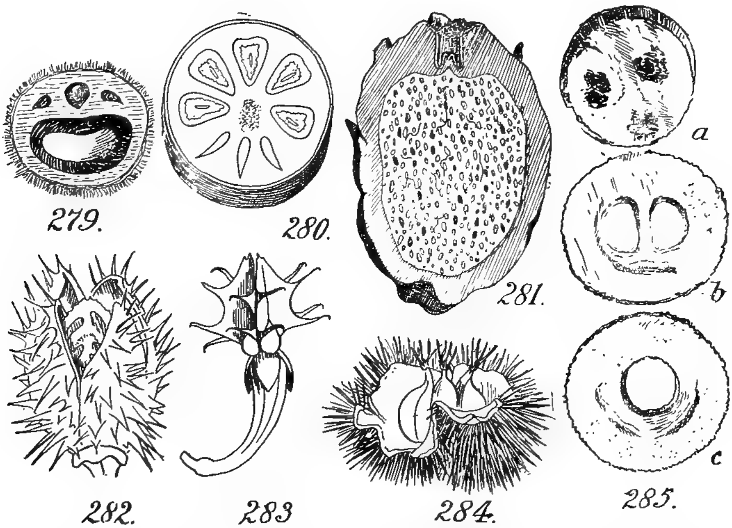


Fig. 279. Cross-section of young fruit of *Calesium*, the cells disappearing except that in which an ovule has been fertilized. 280. *Diospyros*, the same. 281. Fruit of *Opuntia*, immersed in prickly end of branch. 282. Fruit of *Datura*, with prickly ovary. 283. Of *Rumex*, with prickly calyx. 284. Of *Castena*, with prickly involucre. 285. Three palm-fruits from the same tree, with one or two, *a*, with none, of the cells aborted.

an enclosing involucre, as in the chestnut burr (Fig. 284). At other times the protection is secured by developing acrid or otherwise disagreeable pericarps, as the husk of the walnut or the pulp of the colocynth. These defences may be effective only during the maturing stage, as already pointed out, or their deterrent action may be permanent. In the same direction are to be considered the effects of poisonous principles proper and the inedible nature of a pericarp pending the maturing of the seed, but which afterward becomes edible.

Transportation of the Fruit.—The transfer of the fruit to the place of germination is secured by methods which for the most part admit of classification. We shall first consider those provisions which utilize the agency of the wind for this purpose.

Transportation by the Wind.—We note, first, that the weight of fruits to be thus transported is reduced to a minimum. They are in almost all cases one-seeded (Monospermous), the loss due to this character being made good by the fructification of a large number of flowers. The one-seeded condition of such fruits is not restricted to families which are characterized by it. Many fruits of the Leguminosae, which are commonly several- or many-seeded, as the pea and bean, become one-seeded when adapted to wind-transportation (Figs. 296 and 299). Fruits which are not one-seeded may divide into one-seeded parts, easily separable, to facilitate transportation by wind or other agencies, as has already been shown.

Morphology of Fruit-wings.—Such a state having been attained, the action of the wind upon them is next secured through the development of an expanded surface of some kind, commonly a wing or plume. In the *Platypodium* (Fig. 296) it is the entire wall of the ovary, in its original nature a pod, like that of the bean, which becomes developed into a wing. In the elm (Fig. 287) it is likewise the ovarian wall. In the carrot (Fig. 288) and the *Rumex* (Fig. 289) it is an enclosing accrescent calyx. In the *Piptoptera* (Fig. 290) it is two accrescent lobes of such a calyx. In the *Zinnia* (Fig. 291) a persistent corolla performs the same office. In the hop (Fig. 292) an accrescent bract is made to serve the office of a sail. The fruit of the *Cardiospermum* (Fig. 294) represents a class in which the thin pericarp, instead of being expanded into a wing, is inflated into a balloon-shaped receptacle, subserving a similar purpose. Plumes, consisting of the modified persistent calyx, are seen in the Valerian (Fig. 293) where it is present, though concealed by a circinate praefloration, from the flowering stage, while in the *Phyllactis* it is not developed until after fructification begins. A plumose style is seen in *Pulsatilla* (Fig. 286).

Transportation by Attachments.—We shall next note the cases, perhaps even more numerous, wherein use is made of passing bodies by providing such appendages as shall serve to attach the fruit to them. Fig. 298 represents the fruit of a *Rumex*, in which the calyx is divided into hooks for this purpose. Fig. 297 shows another species, in which this method is combined with wind transportation, a combination which is very common among the *Umbelliferae.* The accrescent calyx teeth (awns) of *Verbesina* (Fig. 295) are adapted to piercing passing bodies, while at the same time the adnate tube is winged. In *Bidens* (Fig. 300) similar awns are barbed and adhere very tightly to anything which they may pierce. In the case of the burdock (Fig. 301) it is an involucre which bears such hooks. Similar hooks are found upon the outer wall of the ovary itself in many cases. Sometimes the style is recurved at the apex, thus forming a terminal hook, while at others (Fig. 302) the apex, after performing the stigmatic function, falls away, but leaves a hooked lower joint to become effective in the fruit. The attachment is not always thus secured by means of distinctively piercing appendages. The surface may be rendered adhesive in other ways, as seen in the minute structures covering the fruit of *Desmodium*.

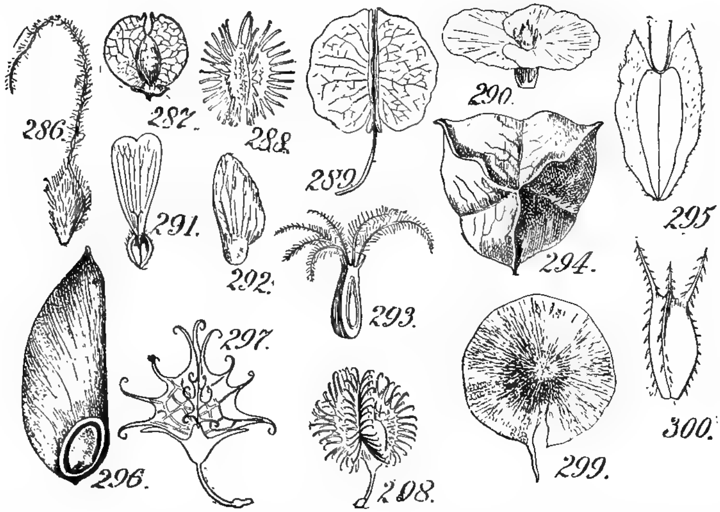


Fig. 286. Fruit of *Pulsatilla*, with plumose style. 287. Winged epicarp of *Ulmus*. 288. Of carrot. 289. Winged calyx of *Rumex*. 290. Of *Piptoptera*. 291. Winged petal of *Zinnia*. 292. Winged bract of hop. 293. Plumose calyx limb of *Valeriana*. 294. Inflated pod of *Cardiospermum*. 295. Winged akene of *Verbesina*. 296. Winged legume of *Platypodium*. 297. Winged and hooked calyx of *Rumex*. 298. The same, hooked only. 299. Winged legume of *Pterocarpus*. 300. Hooked calyx of *Bidens*.

Transportation through Edible Pericarps.—We shall next consider another large class of fruits, which depend for their transportation upon the possession of edible pericarps or edible portions of them. Such fruits may be eaten with the contained seed, as in the case of the strawberry or small cherries, in which case transportation is effected during the process of digestion of the pericarp; or, as in the case of the peach and plum, the fruit may be too large for such process, depending for transportation upon carriage by a parent to its young. In still other cases they are of such a nature that they can be carried and stored for winter use. The edible portion is in some cases, as in that of the banana, highly nutritious, while in others it is apparently eaten merely for its palatability or for its thirst-quenching properties.

Special Protection to Seeds of Edible Fruits.—Some special form of protection is commonly required for the seeds of edible fruits. That of the peach is enclosed in a hard stone, so that it shall not be abraded as the pulp is pecked or bitten away. Those of the cherry and strawberry are enclosed in similar hard coats, which resist the digestive process as well. The more or less laxative or purgative properties of many fruits doubtless contribute to such protection by the more prompt dejection of the seeds which is brought about by their action.

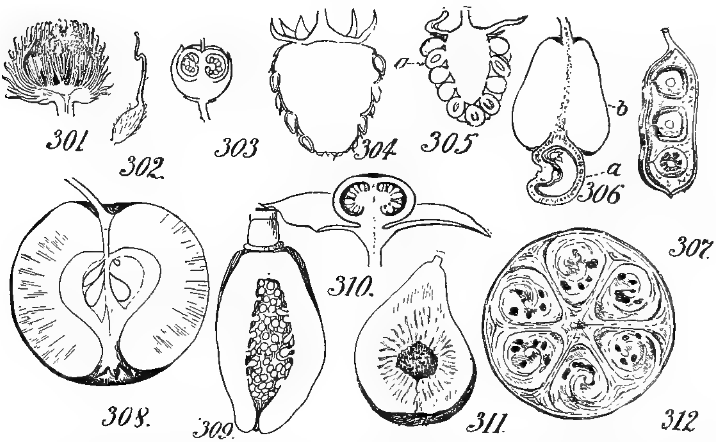


Fig. 301. *Lappa* fruit with prickly involucre. 302. Fruit of *Geum* with jointed style. 303. Fruit of *Gaultheria*, with fleshy calyx. 304. Of strawberry, with fleshy torus. 305. Of blackberry, with fleshy torus and ovaries. 306. Of cashew, with fleshy pedicel. 307. Of tamarind, with fleshy middle layer of pod. 308. Of apple, with fleshy calyx and disk. 309. Of papaw, with fleshy inner layer of ovary. 310. Of belladonna, with fleshy ovary. 311. Of fig, with fleshy hollowed end of branch. 312. Of watermelon, with fleshy placentae.

Origin of Edible Portion.—The origin of the edible portion is various. In the strawberry (Fig. 304) it is the complete torus, and this only. In the blackberry (Fig. 305) such a torus is combined with a partially fleshy ovarian wall upon each of the ripened pistils. In the rose (Fig. 59) it is a similar torus, but hollowed, probably with other elements combined. In the apple (Fig. 308) it is a fleshy-thickened disk, together with the adnate calyx lined by it. In the checkerberry (Fig. 303) it is the calyx only which becomes fleshy. In the gooseberry it is the calyx and the entire ovary, but without any disk, while in many other berry-like fruits it is the ovary alone. In the plum and cherry not all of the ovarian wall is edible, its endocarp becoming a putamen. In the lemon (Fig. 329), the papaw (Fig. 309), and the pumpkin it is the inner portion which is edible, while the outer is not. In the watermelon the placentae comprise almost the whole of the edible portion (Fig. 312), while in the tamarind it is the middle layer of the ovary (Fig. 307).

Edible Portions Not Pertaining to the Flower.—In all of the above-mentioned cases it is some one or more of the parts of the flower which eventually forms the edible pericarp, but there are numerous cases in which other parts of the plant contribute to or form the whole of such portion. In the Cashew (Fig. 306) the ovary (*a*) enlarges but little, while the pedicel (*b*) undergoes a great enlargement and becomes edible. In the cactus (Fig. 281) the end of the branch is hollowed out and the wall so formed becomes the edible pericarp of a single flower. In the fig (Fig. 311) we have a similar hollowed branch, but instead of being occupied by a single flower, the wall is lined by a great number of them.

Miscellaneous Methods of Transportation.—Besides the more common methods of seed distribution referable to the pericarp, which are thus subject to classification, we find numerous special devices which cannot here be enumerated in detail. Fruits which grow beside or in the vicinity of streams or other bodies of water are commonly adapted in some way for using the latter as a vehicle for transportation. They are frequently of a rounded form and of considerable weight, so that upon falling they will roll into the water, where they are then enabled to float by virtue of low specific gravity, due often to the presence in them of large cavities, as in the case of the cocoanut. The pericarp is in such cases usually furnished with some means of protection against the action of the water. The fruit of a species of *Avena* is so constructed that by the change of form and position of its long awns in dry and wet weather, respectively, it is enabled to travel.

Special Provisions for Preventing Transportation.—Finally, we must note that some fruits are protected by special devices against transportation. Thus, the mangrove possesses a seed which germinates while still attached to its parent and which does not sever its connections therewith until the young plant has descended many feet and fixed itself into the mud below. The peanut, after anthesis, drives its ovary beneath the surface of the soil, where its fruit is developed (Fig. 313). Plants possessing such habits are always highly gregarious, occupying the ground to the exclusion of all other species, thus securing their perpetuation even while their dissemination is prevented. The high degree of adaptation secured by the peanut is still further illustrated by its apparent power to support itself by means of these buried branches, should the parent stem in any way become severed; a very important protection, in view of the highly nutritious character of the herbage, which renders it liable to partial destruction by grazing animals.

313.

Fig. 313. Peanut plant, with buried fruits.

The Fixation of Fruits after Distribution.—The fixation of many fruits with their contained seeds is secured by a series of devices no less interesting than those which effect their distribution. Fruits like those represented in Figs. 75, 76, etc., are commonly more or less sharpened or narrowed at the lower end, which is much the heavier, so that they shall the more readily penetrate a favorable surface. Their bodies, moreover, are commonly toothed or hispid upward, so that the tendency is for them to sink more and more deeply until properly interred. The fruit of *Viscum,* whose seed can develop only upon the bark of trees, is intensely adhesive, so that in falling it does not readily bound away, but becomes adherent to the first solid body which it encounters.

Provisions for Scattering Seeds.—As a rule, fruits which are provided with special devices for their transportation are not designed for the discharge of the contained seed, which escapes accidentally or germinates while still enclosed. Provisions for the discharge of seeds, therefore, ordinarily apply only to such fruits as complete their function at the place of origin. For provisions for the distribution of such plants, we should naturally look to the seeds themselves; yet to this rule there are numerous exceptions, for many fruits which never leave the place of growth yet possess various devices for distributing their seeds over a greater or less area by virtue of forces inherent in their pericarps. The common name of the *Impatiens*, "touch-me-not," is derived from the habit of its fruit of exploding with much force, discharging its seeds meantime to a considerable distance. The fruit of *Hura* similarly explodes, and with such violence as to cause a report like the discharge of a firearm. *Elaterium* (Fig. 314), during the ripening process, collects by osmosis within its cavity an amount of liquid which exerts a powerful outward pressure upon the pericarp. When fully ripe, the slightest contact with another body causes the pericarp to leap away from its attachment, with the production of a hole at its base through which the seeds are expelled with much force.

Dehiscence.—The ordinary method of providing for seed discharge is by means of a splitting of the pericarp known as Dehiscence.

Dehiscent and Indehiscent Fruits.—A fruit so splitting is said to Dehisce, and is known as a Dehiscent or Dehiscing fruit. Other fruits are called Indehiscent. True dehiscence is longitudinal, although the term is not altogether denied to other forms, provided the line of separation is regular and constant (Figs. 325-327).

The Valves.—The parts into which pericarps dehisce are called Valves. The valves may separate entirely or remain attached in various ways.

Forms of Dehiscence.—Dehiscence may occur at the ventral or at the dorsal suture or at both. If at the ventral, then the carpel (Fig. 349), or each carpel if it be part of a polycarpellary pistil (Fig. 316), will be left entire. If the polycarpellary pistil have several cells, ventral dehiscence must involve the separation of the carpels by the splitting of their walls or septa, whereas in the one-celled form septa do not exist or are incomplete. Nevertheless, the principle is identical in the two cases, and the former mode is called Septicidal dehiscence (Fig. 316).

In such case the carpels, after separating through their septa, are not necessarily open, and unless the dehiscence shall follow the wall into and

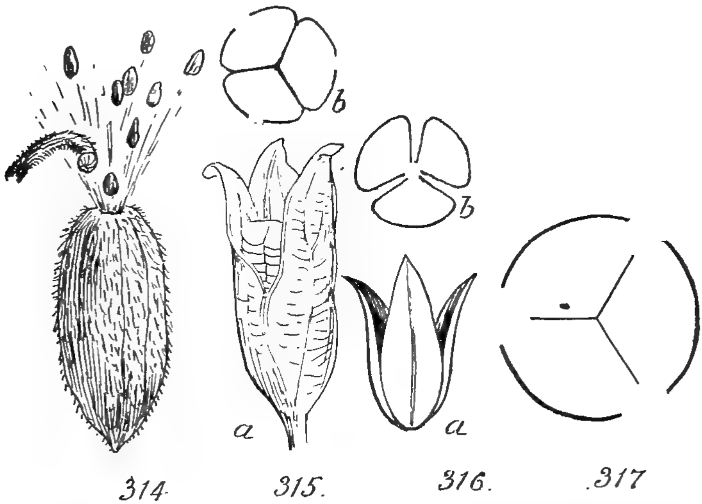


Fig. 314. Fruit of *Elaterium* discharging its seeds and watery contents. 315. Loculicidally dehiscent pod of *Iris*. 316. Septicidally dehiscent pod of *Hypericum*. 317. Transverse diagram of a marginicidally dehiscent pod.

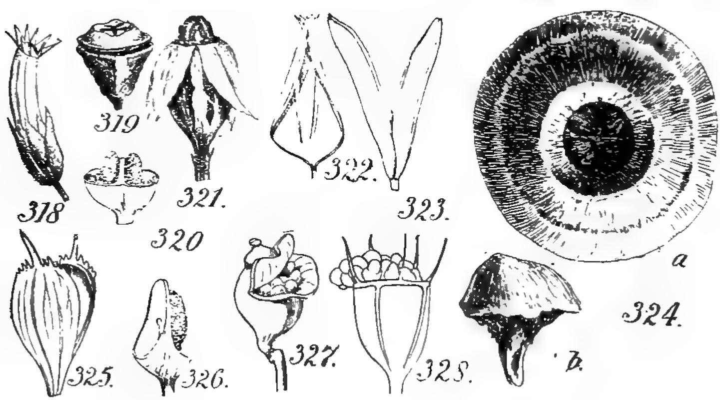


Fig. 318. Apical dehiscence of *Cerastium*. 319. The same, *Eucalyptus*. 320. Circumscissile dehiscence of *Mitracarpus*. 321. Basal dehiscence of *Jussiaea*. 322. The same in *Cinchona*. 323. Apical dehiscence of *Ladenbergia*. 324. Dehiscence by apical plug (*b*) in *Bertholetia*. 325. Apical dehiscence of *Psyllocarpus*. 326. Oblique dehiscence of *Staelia*. 327. Partial dehiscence of *Jeffersonia*. 328. Dehiscence by apical pore in *Siphocampylos*.

through the ventral suture, which it more frequently does not, the dehiscence will be Incomplete and the carpels may even act as separate indehiscent fruits. If dehiscence occur at the dorsal suture (Fig. 315) it must separate the wall of the cell into two parts, and this form is called Loculicidal dehiscence. By an intermediate form, the dehiscence takes place at the point where the septum joins the outer wall (Fig. 317), the Marginicidal form. Various other modifications and combinations of the two forms may be discovered, but do not call for a notice in this work.

Mechanism of Dehiscence.—Dehiscence is secured by a peculiar adaptation of the fibers to the other tissues and to the form of the fruit.

Incomplete Dehiscence.—Various forms of imperfect or incomplete dehiscence are those in which it commences at the apex and fails to extend itself to the base, as in *Cerastium* (Fig. 318) and *Eucalyptus* (Fig. 319), or in which it commences at the base and extends only partially toward the apex, as in *Jussiaea* (Fig. 321) and in *Cinchona* (322). Important pharmaceutical decisions have rested upon the question of basal or apical dehiscence. The true *Cinchona* barks have all proceeded from species whose fruits dehisce as represented in Fig. 322, while those of the trees yielding the false barks dehisce as represented in Fig. 323.

Special Terms for Dehiscence.—The manner in which true dehiscence passes into false or transverse dehiscence, called Circumscissile, is well displayed by Figs. 325, 326, and 320, viewed in the order named, all illustrations of closely related plants. A very curious form of special dehiscence is that of *Jeffersonia* (Fig. 327).

Rupturing.—Dehiscence is not the only method by which fruits open to discharge their seeds. Rupturing fruits are those which open by an irregular line.

Dehiscence by Pores.—Some portion of a pericarp may decay quickly, leaving an opening, or the same result may be secured by excessive shrinkage in drying of the more delicate tissue of some part of the Pericarp, as in Fig. 328. Openings of this kind are called Pores. Our consideration of this subject will close with an illustration of the fruit of the *Bertholetia*, or Brazil-nut (Fig. 324). The apex of this enormously thickened and strongly hardened pericarp consists of a small circular portion connected with the remainder by a circle of tissue which quickly decays, making the former removable as a plug and thus leaving an apical pore.

CHAPTER XI

CLASSIFICATION OF FRUITS

A PERFECT or even fairly satisfactory classification of fruits has never been presented, and this is impossible, except through a complete revision and uniform agreement of terminology, based upon a uniform set of principles. A classification of some sort is, however, an essential in pharmaceutical botany, and such an one is here presented as appears most serviceable to those for whom it is intended.

Two Principles Involved.—Among all the various systems which have been proposed, two fundamental principles have been observed—first, the morphological structure; second, the physiological features. By the first, fruits have been classed according to the character and number of the parts entering into their formation and the modifications which these have undergone in fructification; by the second, according to the structural and functional characters as seen in the complete fruit, without regard to their mode of origin. As characters of the latter kind exist for the sake of the offices which they are to fulfil, it is clear that physiology forms the basis of the latter method of classification. Although it is impracticable to follow either system without some regard to the other, it may be said that to follow in the main the morphological plan is the more scientific, the other the more convenient and the more practical, especially in economic work. The latter is, therefore, the plan which is here adopted. Fruits possessing pericarps fitted for transportation (*a* of our table) will then form the first of our two classes, while those fitted for discharging their seeds *in situ* upon maturity will form the second (*e* of the table).

For a few fruits not readily introduced to this key, and for some exceptions, the explanations which follow may be consulted:

	Fruits with pericarp designed for transportation (*a*).
	Fruits with pericarp not designed for transportation (*e*).
a	With fleshy pericarp (Carnose) (*b*).
	With non-fleshy pericarp (Siccose) (*c*).
b	With seeds embedded in a soft endocarp (*g*).
	With seeds enclosed in a putamen (*h*).

c	With an enclosing involucre, at least before maturity (*l*).	
	Without an enclosing involucre (*d*).*	
d	Vertically divisible in one-seeded parts (*i*).	
	A one-seeded part resulting from such division (*j*).	
	Transversely divisible into one-seeded joints (*n*).	
	Not divisible into one-seeded parts nor the product of such division (*k*).[1]	
e	Not transversely dehiscent (*f*).	
	Transversely dehiscent (*q*).	
f	Monocarpellary (*m*).	
	Dicarpellary, the valves separating from the placentae (*o*).	
	Not monocarpellary nor dicarpellary, with valves separating from placentae (*p*).	
g	Soft throughout .	Berry.
	With a soft, tough rind	Hesperidium.
	With a hardened rind .	Pepo.
h	Putamen of bony hardness; solitary	Drupe.
	Putamen of bony hardness; one of several which are coherent	Pyrene.
	Putamen of bony hardness; one of many which are non-coherent	Drupelet.
	Putamen thin and tough . .	Pome.
i	. . .	Schizocarp
	(If dicarpellary, with a carpophore .	Cremocarp).
j	Part of a cremocarp .	Mericarp.
	Not part of a cremocarp .	.Coccus, Nucula, or Nutlet.
k	Dehiscent, the valves separating from the two placentae	Most Silicles.
	With thin, winged pericarp . .	Samara.
	With inflated pericarp	Utricle.
	Pericarp, thickish in view of its size, not inflated, sometimes winged	Akene.
l	A non-glumaceous involucre, with contents	Glans.
	A one-seeded fruit from a glans . .	Nut.
	A glumaceous involucre with contents	A few Spikelets.
	A one-seeded fruit from a spikelet .	Caryopsis.
m	Dehiscing by one suture only	Follicle.
	Dehiscing by both ventral and dorsal sutures	Legume.
	(When spirally coiled .	Cochlea).

* Exceptions occur.

n	. . .	Loment.
o	Elongated .	Silique.
	Short .	Some Silicles.
p	.	Capsule.
q	. . . .	Pyxis.

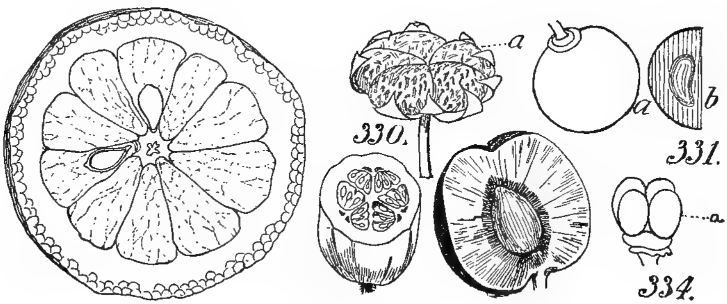
The fact, as stated above, that custom has not been uniform in the application of the principles of classification leading to the above terms, so that the latter are not employed in the same sense in different botanical writings, renders it necessary that such a key as that presented should be supplemented by a detailed consideration of the limitations and modifications of each class of fruits.

The Berry (Figs. 281 and 310).—A fruit with a pericarp fleshy throughout, with the exception of the epicarp. Good illustrations are the grape and the belladonna. In these, the fruit contains little or no cavity and the seeds are embedded in a soft pulp. This is the typical form, from which we see a variation in the Tomato, in the direction of a central cavity, which in the *Capsicum* becomes complete. The latter is frequently called a capsule and connects the berries with the latter class, but it is more properly grouped with the berries. A similar modification, though more slight, is found in the checkerberry (Fig. 303) and the cranberry. The term has also been applied to the pomegranate and similar fruits, but these, however soft within, possess a distinctly hardened exocarp and are not true berries. As will be seen farther on, comparatively few of the fruits which are designated as berries in common parlance are really such. The berry may possess one or more cells.

The Hesperidium (Fig. 329).—A berry-like fruit with a soft, but tough rind. The term has never been applied to other fruits than those related to the orange and lemon. They are several-celled.

The Pepo (Fig. 332).—A berry-like fruit in structure, usually hollow and with an indurated rind. It is one-celled. Good illustrations are the pumpkin and melon, and the application of the term is by most authors restricted to the fruits of that family (the *Cucurbitaceae*); but it is entirely proper to extend it to such very similar fruits of other families as the Calabash (in the *Bignoniaceae*) and the Pomegranate (in the *Punicaceae*).

The Drupe or Stone Fruit (Fig. 333).—A fruit with a sarcocarp and epicarp and a single thick bony putamen. Although typically one-celled and one-seeded, the term is applicable to similar fruits with several cells all enclosed in a single sarcocarp, but each seed possessing its own putamen. Each putamen with its own seed is then called a Pyrena or Pyrene. Familiar illustrations of the typical drupe among medicinal plants are the prune, sumach and pepper, and of the several-celled form that of the *Rhamnus*, (Fig. 331) and the *Phytolacca*. As in most classes of fruits, we find here a gradation into other classes, most commonly into the Schizocarp. A peculiar fruit, in its general structure related to the drupe, is the so-called legume of the tamarind, which possesses an exocarp similar to that of a pepo, a distinct edible sarcocarp and a crustaceous endocarp or putamen containing several seeds (Fig. 307).



329. 332. 333.

Fig. 329. The hesperidium (lemon). 330. Schizocarp of *Urena*. 331. Compound drupe, with detached pyrena, of *Rhamnus*. 332. Transverse section of a pepo. 333. The drupe (plum). 334. Dicarpellary schizocarp of Labiatae.

The Pyrena (Fig. 331).—(Already considered under Drupe.)

The Drupelet (Fig. 305, *a*).—Differs from the *Pyrena* in that it possesses not only its own separate putamen, but a separate sarcocarp as well. It is one of many small drupes belonging to an aggregate or multiple fruit.

The Pome (Fig. 308).—A fleshy fruit with a thin chartaceous or cartilaginous putamen. It is several-celled. The term is commonly restricted to fruits related to the apple.

The Schizocarp (Figs. 288, 330, and 334).—The typical schizocarp should be defined as a fruit which divides septicidally at maturity into one-seeded carpels. Because, however, schizocarps frequently vary in the constancy and completeness with which they undergo this process, they are defined as "divisible," rather than "dividing." There are, moreover, cases in which they divide into one-seeded parts of carpels. The comprehensive definition, therefore, should be "dry fruits septicidally divisible at maturity into one-seeded parts." Schizocarps are commonly provided with appendages for wind-transportation or for transportation by mechanical adhesion to passing bodies. Those forms which, as above stated, are intermediate toward drupes are to be classed in one or the other class, according to whether such appendages for distribution, or that of an edible pericarp, is the more pronounced. Even schizocarps which are not cremocarps may possess a carpophore, as in geranium, though commonly they do not.

The Cremocarp (Figs. 247 and 288).—A di-carpellary schizocarp, the carpels attached toward their summits to a slender carpophore, from which they usually only incompletely separate at maturity. The term is restricted to the fruits of the *Umbelliferae.* They are commonly provided with appendages for fixation to passing bodies, frequently for wind-transportation, and not rarely combine these two methods of distribution. (*Conium*, Celery, etc.) There is no class of fruits which possesses a greater importance in pharmacy, and hardly any whose histological features are of greater interest. The plane of separation is called the Commissure, a term applicable to a similar plane in other fruits. (See Mericarp.)

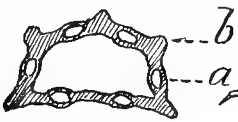
The Coccus, Nucula, or Nutlet (Fig. 330, *a*, and Fig. 334, *a*).—One of the divisions of a schizocarp, and its nature has been explained in considering that group. The term nutlet is commonly applied when the pericarp is hard and close to the seed.

The Mericarp (Fig. 247, either half).—One of the halves into which a cremocarp is divisible. Occasionally they are self-separating at maturity, but usually only incompletely so. They are one-seeded and possess a completely adnate calyx and disk. The pericarp almost uniformly possesses external appendages in the form of five or nine ribs, as is well shown in cross-sections (Fig. 335, *b*). When nine, they are commonly of two forms, alternating with one another. A part or all of them are much subject to extension into variously appendaged or pinnatifid wings (Fig. 336, *a*). Internally, the mesocarp is almost uniformly traversed upon both the faces and the backs of the carpel by tubes called Vittae (Fig. 335, *a*), commonly with suberous walls and filled with volatile oil. The dorsal vittae alternate in position with the ribs. Upon thin transverse sections these oil-ducts or vittae appear as perforations, and as to their number and position serve the most important purposes in diagnosis and identification, as do also the ribs. These fruits are dorsally compressed when broader from right to left (Fig. 336), laterally compressed when broader in the opposite direction.

Mericarps are of three classes: (1) The Coelospermous, characterized by the possession by the seed of a concave face (Fig. 337, *a*); (2) the Campylospermous, characterized by the possession of a longitudinally grooved face (Fig. 338, *a*); and (3) the Orthospermous, possessing a plane face (Fig. 335).

The Silicle.—(See Silique.)

The Samara.—An indehiscent fruit with a winged pericarp. They are commonly one-seeded, as well as one-carpelled, but may be more. Typically, it is the ovarian wall or the tube of an adnate calyx which develops the wing, but there is no reason why the term should not be extended to include similarly transportable fruits with wings consisting of the accrescent limb of a calyx (Figs. 288 and 289), or corolla (Fig. 291), or a surrounding alate bract (Fig. 292). Commonly the samara possesses but a single wing, unilateral, as in the ash (Fig. 339), or circular, as in the elm (Fig. 287), but not rarely more than one wing is present, as in the maple (Fig. 340), or many *Malpighiaceae* (Fig. 342).



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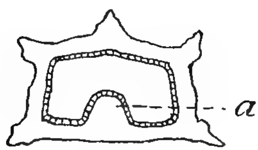

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Fig. 335. Transverse section of an orthospermous mericarp: *a*, vitta; *b*, rib. 336. Dorsally compressed mericarp, two of the ribs winged. 337. Coelospermous mericarp of coriander. 338. Campylospermous mericarp of *Conium*.

The Utricle (Fig. 341).—A one-seeded indehiscent fruit, the seed enclosed in a thin, bladdery or inflated pericarp. It is commonly one-celled, but occasionally several-celled. Ordinarily, utricles eventually become irregularly ruptured, but in a few forms there is a regular ventral opening, approaching toward dehiscence.

The Akene or Achenium (Figs. 74 to 80 and 344).—A small, indehiscent, one-seeded, seed-like fruit, the pericarp somewhat thickened and entirely distinct from the enclosed seed. The akene varies in many directions toward other fruits. In many cases the pericarp is inclined to be fleshy and in a few it tends toward dehiscence, thus simulating a follicle. Some forms of the akene are distinctly winged, so that they might, but for the relationship of the species yielding them to akene-producing species, be with equal propriety classed as samaras. They are in nearly all cases provided with some means for securing wind-transportation or for attaching themselves to passing bodies, and yet there are numerous cases in which such appendages have become entirely obsolete. For these reasons, it becomes a matter of extreme difficulty to frame a definition at once comprehensive and delimiting for this group. The inferior akene is sometimes distinguished by the term Cypsela (Figs. 74 to 80).

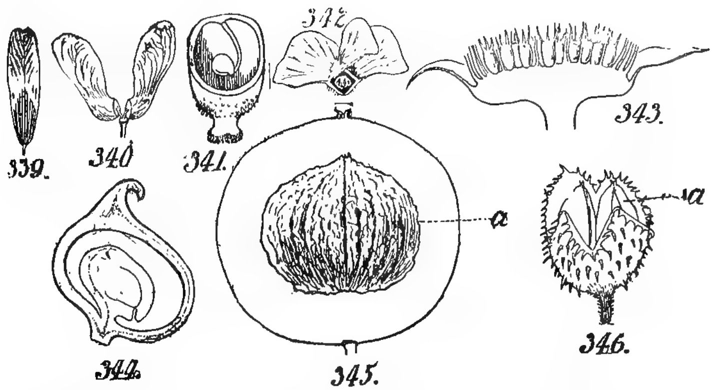


Fig. 339. Samara of ash. 340. Of maple. 341. Utricle. 342. Several winged samara of *Mascagnia*. 343. Vertical section of anthodium. 344. Vertical section of akene of buttercup. 345. Same of the glans of black walnut. 346. Glans of *Fagus*, or beech-nut.

Note should here be taken of the fact that the latter is characteristic of the largest of all families, the *Compositae*, in which the akenes of the head are massed and partially, or sometimes completely, surrounded and enclosed by an involucre, the whole constituting a multiple fruit to which the name Anthodium (Fig. 343) has been applied. The anthodium varies greatly in its character. Although usually many-flowered, it is commonly few-, or even in rare cases, one-flowered. In those cases in which the involucre completely encloses the akenes, it is commonly appendaged for distribution in an entire condition, as in the burdock. This condition connects the anthodium with the glans and the contained achenium with the nut. Indeed, it is almost impossible to distinguish structurally between fruits representing these two classes, as, for instance, those of *Xanthium* and *Fagus*.

The Glans (Figs. 345 and 346).—A fruit consisting of an accrescent and partially or (commonly) completely enclosing involucre containing one or more nuts. The involucre may be dehiscent, as in the chestnut and hickory-nut, or indehiscent, as in the black walnut (Fig. 345). In some of its forms, the involucre of the glans tends to become fleshy. Inasmuch, however, as the design of such pseudo-fleshy pericarps is not that of subserving transportation by their food-properties, they are more appropriately regarded as non-fleshy. While depending, like the grasses, upon their gregarious habits for perpetuation, nut-yielding plants are apparently in many cases distributed by the rounded form of their coats and the readiness with which they are transported by flowing water.

The Nuca or Nut (Figs. 345, *a*, and 346, *a*).—The relationship of the nut and its glans to the akene and its anthodium has already been pointed out. The nut is in all cases much larger than the akene and its pericarp commonly much thickened and very hard.

The Spikelet (Fig. 347).—A fruit possessing a glumaceous involucre and pertaining to the *Gramineae* (grass family) and related orders. This class of fruits, like the glans and nut, connects those fruits which are adapted to transportation with those which are not. Although, in general, these plants depend for their perpetuation upon a highly gregarious habit rather than upon provisions for distribution of their fruits, yet the spikelets of some grasses are unmistakably so designed, and are transported with their caryopses enclosed in the glumes.

The Caryopsis or Grain (Fig. 348).—A seed-like fruit produced in a spikelet, the ovarian wall and the seed-body closely adnate.

The Follicle (Fig. 349).—A monocarpellary fruit dehiscing by one suture only, this the ventral, except in rare cases.

The Legume (Fig. 350).—A monocarpellary fruit, non-fleshy and dehiscing by both ventral and dorsal sutures. Notwithstanding the definition thus given, we have to record the fact that in accordance with a different principle and construction, the title includes all fruits of the natural order Leguminosae. It, therefore, becomes necessary to point out that the fruits of this family are extremely variable, and this in directions which frequently carry them widely away from both the structural and the physiological characters of the legume. The peculiarities of the tamarind have already been pointed out. In the fruit of the *Inga* the dehiscent legume is filled with a large amount of juicy, edible pulp, in which the seeds are embedded. In other species this pulp is replaced by one of a powdery consistency, while in others it is fleshy or subcorneous. A great many legumes of this family are not only indehiscent, but winged and one-seeded, and thus are true samaras.

The fruit of the *Dipteryx* is one-seeded and is dehiscent, but the pericarp is enormously thickened and first fleshy, then spongy. That of the *Cassia Fistula* has its seeds enclosed in a pulp and partly separated from one another by transverse septa. It is thus apparent that many legumes pertain to our first, rather than to our second, division.

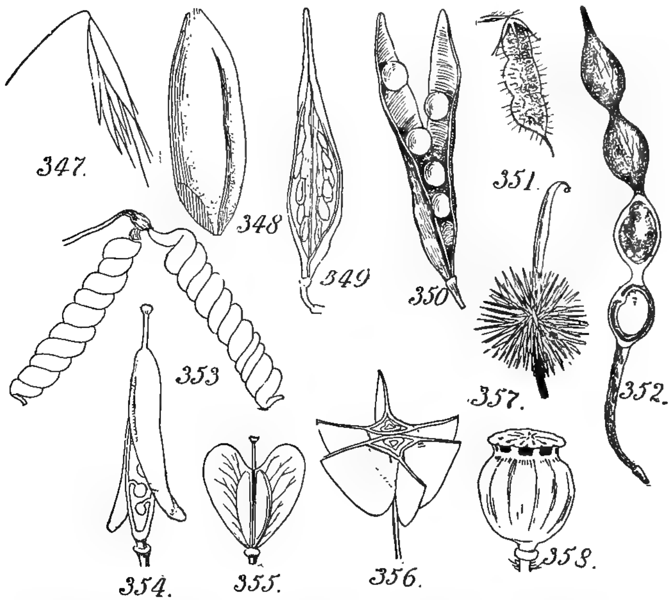


Fig. 347. Spikelet of a grass. 348. Caryopsis from last. 349. Follicle of *Asclepias*. 350. Legume of pea. 351. Loment of *Aeschynomene*. 352. Loment of *Sophora*. 353. Cochlea of *Prosopis*. 354. Silique of *Cardamine*. 355. Silicle of *Aethiomena*. 356. Silicle of *Hexaptera*. 357. Silicle of *Succowia*. 358. Capsule of poppy.

Two distinctive forms of the legume have become dignified by the application of special names, as follows:

The Loment (Figs. 351 and 352) is a leguminous fruit which may or may not be dehiscent, but which is separable at maturity by transverse divisions into one-seeded parts. In the *Aeschynomene* these parts are adapted to fixation to passing bodies, or occasionally also much flattened and expanded to act as samaras. In the *Sophora* (Fig. 352) the joints are smooth, hard and rounded, and highly elastic, so that, in falling upon the stony soil, they are adapted to bounding and running to a considerable distance. The term loment has also been extended to include those siliques which display a similar character.

The Cochlea (Fig. 353).—A legume which is spirally coiled.

The Silique (Fig. 354).—A di-carpellary dehiscent fruit, the two valves separating from the margins of the placentae at maturity, leaving the latter attached to the torus and to a false septum, which divides the silique into two parts. The principal modification of the silique proper is into the loment-like form which we have already considered. These loment-producing plants are commonly found in the vicinity of water, and their fruits are adapted to transportation by this method. A more important modification is into:

The Silicle (Figs. 355 to 357).—This differs from the silique not only in being short and broad, but in possessing ordinarily some form of adaptation to wind or other transportation, thus belonging in our first class.

The Capsule (Figs. 318 to 238).—The typical capsule is to be defined as a di- to polycarpellary longitudinally dehiscent fruit. From the typical form, however, it varies in several directions to such a degree

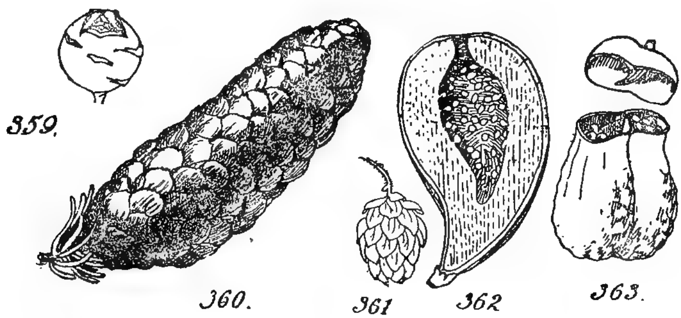


Fig. 359. Galbalus of *Juniperus*. 360. Strobile of *Picea*. 361. Strobile of hop. 362. Syconium of fig. 363. Pyxis of henbane.

as to render it impossible to frame a perfect definition. The capsule of the poppy (Fig. 358) opens by a number of small pores at the summit, and this is true of many other forms. In other cases the mode of opening is by various forms of irregular dehiscence intermediate between the longitudinal and the circumscissile. Finally, we must note that many fruits, like those of some species of *Passiflora*, which possess no regular or natural method of opening, are still classed as capsules by systematic botanists.

The Pyxis (Fig. 363).—A circumscissily dehiscent fruit.

The Syconium (Fig. 362).—A fruit consisting of a hollow branch, becoming fleshy, its inner surface the receptacle for many small, one-seeded, akene-like fruits.

The Aeterio (Figs. 304 and 305).—An aggregate fruit, with an accrescent fleshy torus and many crowded pistils.

The Strobile (Figs. 360 and 361).—A multiple dry fruit, its elements in the form of imbricated scales.

The Galbalus (Fig. 359).—A fruit similar to the last, but the scales fleshy or much thickened above, so that the form becomes more or less globular.

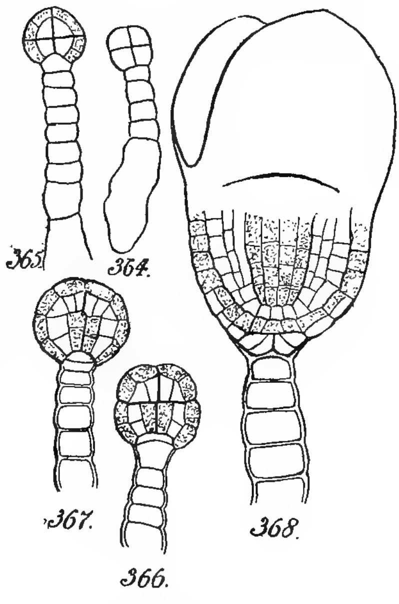
In conclusion, it may be remarked that to assign a name to a fruit is insufficient in most cases, especially in those of aggregate and multiple fruits, to designate its character.

CHAPTER XII

THE SEED

Changes in the Ovule.—As in the case of the parts entering into the formation of the pericarp, so in that of the part forming the seed—namely, the ovule—it is well to precede our study of the changes which it undergoes by a consideration of the objects to be attained thereby.

Development of the Embryo.—The essential feature of the seed is the possession as one of its parts of a more or less rudimentary plant, developed from the fertilized oösphere, and known as the Embryo, and capable of remaining for a more or less extended period, before germination, in a state of suspended animation.



Figs. 364 to 368. Figures illustrating development of the embryo; the vertical chain of cells is the pro-embryo, the uppermost of them becomes the caulicle and the enlargement the cotyledons.

The development of the embryo commences with the division of the fertilized oösphere into two cells, each of which grows and becomes capable of itself dividing similarly. The result of such cell-propagation is the production of a tissue and of a body which becomes elongated through successive transverse divisions of its cells, or certain of them, and broadened by their longitudinal division. Several progressive forms reached by the embryo during this process are shown in Figs. 365 to 368.

Provisions Required by the Embryo.—During the period intervening between the beginning and the completion of seed-formation the embryo requires nourishing, and provisions for this constitutes the first requirement of the process. The further development and growth of the embryo, between the time of germination and that of absorption by it from the external world, calls for additional nourishment. This can be met only by the storage as a part of the seed of an additional food-supply.

Protection of the seed-contents during its development is only partially afforded by the pericarp, and this office is supplemented by the coverings of the seed itself, while its similar self-protection between the periods of maturity and germination is a manifest necessity.

The transfer of the mature seed to the point of germination, or its dissemination, and its fixation in a favorable site, have already been referred to. We have seen that in many cases these offices are not provided for by the pericarp, and we must look for such provision to the seed itself.

Parts of a Seed.—The parts of the seed by which these several offices are performed we find to be as follows:

The Perisperm.—The source of food-supply during the germination of the macrospore and development of the gametophyte we have seen to be the portion of the nucellus external to the embryo-sac. Usually more or less of this material remains during at least the earlier period of the development of the embryo and contributes to the nourishment of the latter. Occasionally it persists even in the seed condition. It is then known as the Perisperm.

The Endosperm.—Inside the embryo-sac a further store of nutriment is caused to develop as a result of fertilization, this constituting the chief supply of the growing embryo. More or less of this also may persist, and usually does, upon the maturity of the seed. It is known as the Endosperm.

Albuminous and Exalbuminous Seeds.—As the embryo develops, it stores within its own body more or less nutriment. At maturity we may find that the entire store of nutriment has thus been transferred to the body of the embryo, and the seed is said to be Exalbuminous, or we may find more or less endosperm or perisperm, or both, when the seed is said to be Albuminous, and this external nourishment is known as the Albumin. In only a few seeds used in medicine does the albumin consist in any part of perisperm. The chemical nature of the albumin is extremely variable. It received its misleading name because of the similarity of its function to that of the albumin of the egg.

Protection.—Protection to the embryo may be afforded by the albumin when that is of the required consistency or composition, the conditions of the latter being a mere parallel of those already considered under the subject of the pericarp. More frequently, however, it is secured entirely through the coats of the seed.

The Seed-coats.—These may correspond to the coats of the ovule, though usually the primine is found to have disappeared. When it persists it takes the name of Tegmen, or Endopleura, the secundine becoming the Testa, or Exopleura. Rarely the secundine also disappears and the seed is Naked. The seed will also be naked when produced from a naked ovule.

The Micropyle.—When one or both of the coats persists, the point where the foramen, now closed, existed becomes the Micropyle.

The Aril.—Frequently the development of a new coat external to the others is induced by fertilization, and this is known by the general name of Aril. If it develop from the chalaza or a lower point, it is called an Arillus, or True Aril; if from the micropyle, an Arillode, or False Aril.

Dissemination.—The provisions of the seed for securing dissemination are in most respects comparable with those affecting the pericarp. Wind-distribution is preëminent, that by fixation to passing bodies is frequent, and that by means of an edible coat is rare.

Fixation.—The fixation of seeds disseminated without the pericarp is favored by their small size, enabling them readily to enter crevices and cavities, and by peculiarities of surface which favor the same process.

The large number and importance of medicinal seeds lend great importance to their study by the pharmacognosist, and this is especially true of the histology of all their parts. Inasmuch, however, as the subject of histology has been referred to a separate portion of the work, we shall here consider only such characters as can be distinguished by means of an ordinary lens.

The Hilum.—The hilum is in most cases readily perceptible, but is occasionally found only by minute examination. It is to be studied as to its position, size, form, surface, and color. Its position is sometimes fixed with reference to the form of the seed, as at the larger or smaller end, upon the broad side or on the edge, as well as with reference to the micropyle, adjoining it, at the opposite end or at some intermediate point. It is the last-mentioned character which determines the class of seed as to its tropism (see *Ovule*). In size the hilum may be a slight point, or it may cover a considerable portion of the surface. Its form is frequently characteristic, as heart-shaped (Fig. 370) or linear and channelled, as in Fig. 371. Its color frequently differs markedly from that of the remainder of the seed.

The Raphe.—The raphe, extending from the hilum to the chalaza when these do not coincide, is ordinarily not readily perceptible upon the surface. When it is so, as in Figs. 372 and 373, its appearance is of great diagnostic value and must be closely scrutinized. The chalaza in its simple form calls for no special attention.

The Strophiole.—If, however, an enlargement appears at this point (the *Strophiole*, Fig. 374, *a*), it must not be overlooked. The strophiole may develop into the arillus (Fig. 375), a partial or complete covering, and its characters call for the same attention which is requisite for the testa.

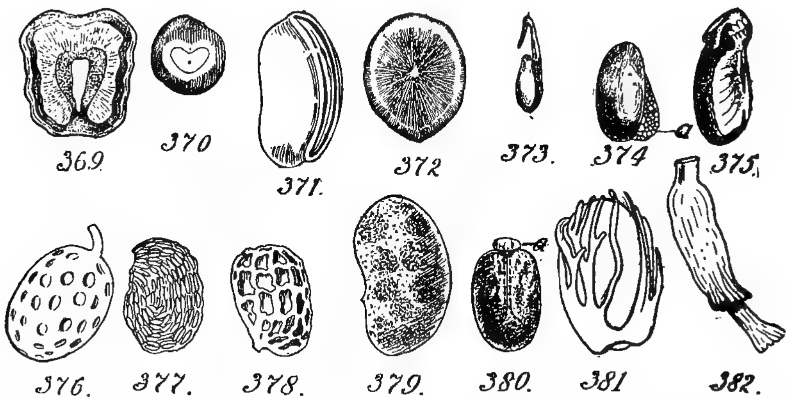


Fig. 369. Vertical section, seed of *Cardamomum*. 370. Cordate hilum, of *Cardiospermum*. 371. Linear hilum of Calabar bean. 372. Central hilum of nux vomica. 373. Seed of *Niederlinia* with conspicuous raphe and funiculus. 374. Seed of *Hypericum* with large strophiole at *a*. 375. Seed of *Hanetic* with partial arillus. 376. Pitted seed of *Sanvegesia*. 377. Reticulate seed of henbane. 378. Reticulate-pitted seed of tobacco. 379. Finely reticulated seed of *Datura*. 380. Seed of *Ricinus*, with caruncle at *a*. 381. Arilled seed of *Myristica*. 382. Seed of *Acorus*, with peculiarly appendaged micropyle.

The Testa.—The testa is not wanting in any medicinal seed. In general it is not closely adherent to the underlying tissue, and it can be readily removed. In its thickness, consistency, surface, color and appendages it yields important pharmacognostical characters. It may be pitted (Fig. 376), reticulate (Fig. 377), reticulate-pitted (Fig. 378) or hairy (Fig. 372), and the minute characters of its pits, tubercles, ridges, or hairs must not be overlooked. It may be dull or shiny, and its color may be uniform or variegated (Fig. 379). Its luster or shade of color is frequently of the greatest assistance in determining the age, freshness, mode of preparing or preserving, or other conditions on which the comparative medicinal quality of the seed depends.

The Caruncle.—The enlargement at the micropyle (the *Caruncle*, Fig. 380, *a*) calls for the same scrutiny as the strophiole. It may be variously appendaged (Fig. 382), and, like the latter, it may extend into a partial or complete covering, the arillode. The arillus, or arillode (Fig. 381), may be partial, as in nutmeg, or complete, as in the seed of the *Euonymus*.

Appendages.—Appendages to the seed do not always take the form of an aril of either class, nor is their origin confined to the points from which the aril develops. Either as aril or appendage from the general surface, they exhibit a great variety of form, of equal importance with

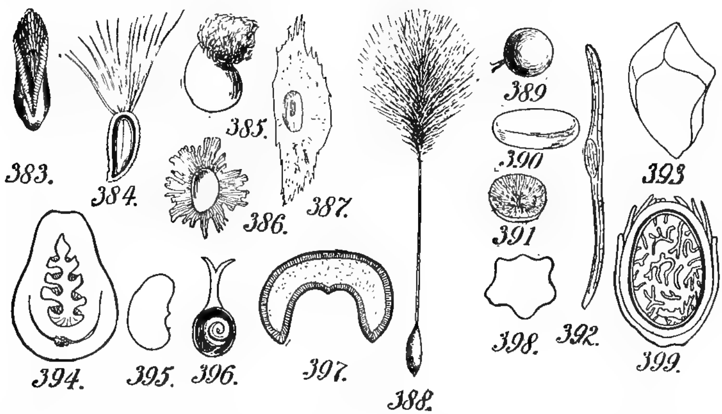


Fig. 383. Seed of *Eucharidium*, with fringed margin. 384. Penicillate seed of *Epilobium*. 385. Tufted seed of *Petrocoptis*. 386. Fimbriate-winged seed of *Danais*. 387. Winged seed of *Cinchona*. 388. Plumose-awned seed of *Strophanthus*. 389. A globose seed. 390. Lenticular seed of *Lens*. 391. Saucer-shaped seed of *Lecanosperma*. 392. Linear seed of *Nepenthes*. 393. A polyhedral seed of *Nolina*. 394. Serrated seed of *Akebia*. 395. Reniform seed of bean. 396. Cochlear seed of *Heliocharis*. 397. Crescent-shaped seed of *Menispermum*. 398. A lobed seed. 399. Nutmeg, with the albumin ruminated.

those which characterize the pericarp. Forms of especially frequent occurrence are exhibited by Figs. 383 to 388. Important distinctions sometimes exist between seeds bearing similar appendages, as regards the points from which the latter originate, as in the case of strophanthus, false and true.

The general form of the testa is, of course, that of the seed, and calls for terms applicable to the forms of solid bodies (Figs. 389 to 398).

The Tegmen.—The tegmen, when present, is extremely thin and tightly adherent to the nucellus, following closely all inequalities upon the surface of the latter, and occasionally having its intruded folds caught between the forming masses of the albumin and discernible upon section of the latter as slender veins, giving us the so-called Ruminated Albumin (Fig. 399).

The Albumin.—The albumin is characterized chiefly by its consistency, being bony, as in the ivory nut and date; horny, as in nux vomica; oily, as in the castor-bean and cacao; fleshy, mealy, etc. In sectioning the seed, note should be taken of the presence, number, position and forms of any cavities which may exist in it.

The Embryo.—The embryo calls for the most thorough and minute study as a basis for systematic work, though for the pharmacognosist only the more important details of its general structure need be considered. It has already been stated that it consists of one or more phytomers.

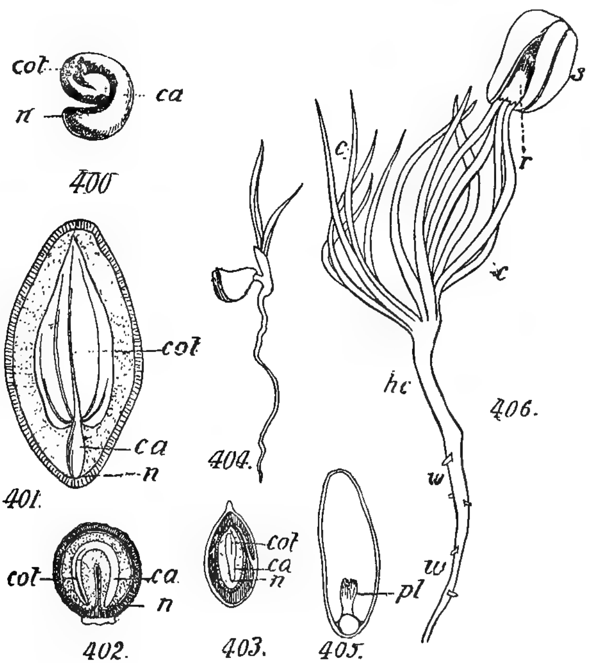


Fig. 400. Circinate embryo of *Campomanesia*: *n*, radicle; *ca*, caulicle; *cot*, cotyledons. 401. Section through seed of *Gynocardia*. 402. Centric curved embryo of *Gynocrambe*. 403. Centric straight embryo of *Frankeaia*. 404. Germinating monocotyledonous embryo. 405. Embryo of *Dipteryx* with pinnatifid plumule (*pl*). 406. Polycotyledonous embryo.

The Caulicle.—The chain of cells first formed is the pro-embryo, and this is supposed to act in transferring nourishment to the embryo. At its end, next to the cotyledons, develops the first internode of the coming plant, and this becomes the caulicle (*ca* in Figs. 400 to 403), in old works denominated the "radicle."

The Radicle.—The Radicle (*n* in the last-named figures) is the extreme tip of the caulicle, which points always in the direction of the micropyle. From this point the root is to be developed. The embryo may consist of nothing further than the caulicle, and even this may be of the most elementary character.

The Cotyledons.—Ordinarily, however, there develops at the node (the point opposite to the radicle) one or more Cotyledons, or Seed-leaves (*cot* in the figures).

Monocotyledons, Dicotyledons, and Polycotyledons.—Most seeds which possess but a single cotyledon (Fig. 404) are grouped together in a division of the Angiosperms, which for this reason are called Monocotyledons, those with two in the Dicotyledons. A few plants, mostly Gymnosperms, are polycotyledons (Fig. 406).

The Plumule.—The highest plants of their respective groups develop a second phytomer lying between the cotyledons, or if there be but one cotyledon, mostly enwrapped by it. This is the Plumule (Fig. 405, *pl*), which shows the same variation in the degree of its development as that which characterizes the lower. When its leaves are developed, they bear a closer resemblance, as in the figure, to the mature leaves of the plant than do the cotyledons, following out the law referred to in our introduction. Among dicotyledons, the plumule commonly pertains to exalbuminous seeds.

Direction of the Radicle.—Terms used to indicate different directions of the radicle refer to its direction with relation to the fruit, its direction in relation to the micropyle being, as has been stated, always the same. It is Ascending when it points toward the apex of the fruit, Descending when in the opposite direction, and Horizontal when intermediate. The latter form is Centrifugal when pointing toward the periphery, Centripetal when toward the axis.

Position of the Embryo.—The position of the embryo with reference to the albumin is always highly characteristic. It is Axile or Centric when in the center of the albumin (Figs. 402 and 403), whether straight or curved; Eccentric when within the albumin, but outside of its center (Fig. 407); Peripheral when lying upon the surface of the albumin. In the latter position it may be straight, simply curved (Fig. 408), or circinately coiled (Figs. 409 and 410).

The relative sizes of the embryo and the albumin vary from those in which the former is a mere speck in a large mass of the latter to that in which the proportions are reversed, or in which the albumin is entirely wanting.

Forms of the Embryo.—The embryo should in all cases be dissected from the contiguous parts and the relations of its parts to one another made out. It may be straight, variously curved, crumpled (Fig. 411), or variously folded. In the latter condition the radicle may be brought into juxtaposition with the edges of the cotyledons (Accumbent, Fig. 413) or with the face of one of them (Incumbent, Fig. 412). One cotyledon may enwrap the other (Fig. 414). When a single cotyledon partly encloses the greater portion of the remainder of the embryo it is sometimes called the Scutellum (Fig. 415). Some of the terms applicable to the consistency of the albumin are also applicable to that of the cotyledons.

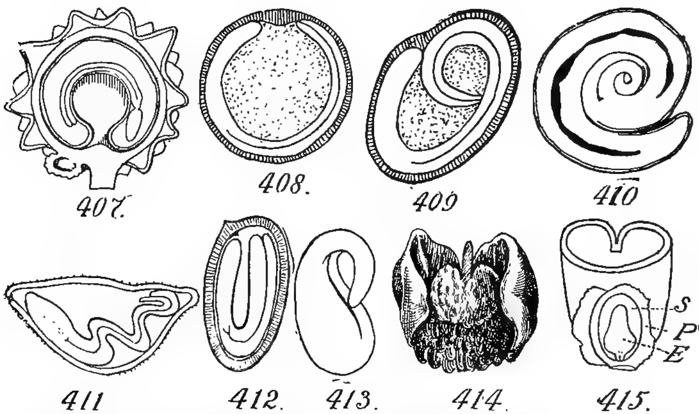


Fig. 407. Eccentric curved embryo of *Galium*. 408. Peripheral simply curved embryo of *Bosia*. 409. Peripheral circinately curved embryo of *Achyranthes*. 410. Circinately coiled embryo. 411. Crumpled embryo of *Suaeda*. 412. Incumbent radicle of *Calepina*. 413. Accumbent radicle of *Megacarpaea*. 414. Embryo of *Dryobolanops*, one cotyledon enwrapping the others. 415. Embryo of barley with scutellum (*s*).

The Taste.—Finally, the pharmacognosist will find it of importance in the case of seeds possessing a characteristic taste to inform himself as to the part, if any, to which such taste is restricted.

Reproduction Completed.—With the production of the seed, containing a distinct living individual separated from the parent and fitted for independent existence, reproduction can strictly be considered as completed, although the progeny is still in its infancy and its form not yet perfect.

Similarity of the Seed to the Bud.—The analogy between the seed and the bud is apparent. Each consists of one or more vegetative units ready to develop under proper conditions into a perfect semblance of the parent, and each is provided with a store of prepared nourishment to sustain it until able to manufacture such for itself. The distinction is in the radically different modes of origin, and in structure, leading to different powers of reproduction.

Examination of the Seed.—In the examination of the seed for the determination of the characters above defined, the most certain method is the examination of transverse and longitudinal sections by the use of the compound microscope, as will be explained in Part II of this work. It is not difficult, however, to determine all the essential characters of most seeds by the aid of an ordinary magnifying glass. The superficial characters of the seed should first be examined in the dry condition, after which it should be thoroughly soaked for a period varying from a few hours to several days, or the preparation may be hastened by gently boiling. Its superficial characters must be then again examined and compared with those previously observed. Especially must the relative positions of chalaza, hilum, micropyle, and raphe be accurately determined. A longitudinal incision is then to be made along one side and the coats removed, separately if possible. The examination of the testa, with the discovery of a much thickened line, will sometimes disclose a raphe which was overlooked in the superficial examination. In removing the coats, great care must be taken to avoid wounding the nucellus. The position of the embryo with regard to the albumin, if any, and its general form can now be readily ascertained. The embryo should finally be removed and its several parts studied. The most common error made by students is the mistaking of small one-seeded fruits, such as mericarps, akenes, and nuculae, for seeds, with the result that all of the parts and their relations are confused. The substitution of such terms as conium-fruit, coriander-fruit, burdock-fruit, and hemp-fruit for the incorrect terms "Conium-seed," etc., in common use, should be encouraged by all educated pharmacists in their daily business relations, as a correct idea of the nature of the parts employed lies at the foundation of a proper understanding of their composition and properties.

CHAPTER XIII

GENERAL STRUCTURE OF ROOT AND STEM

The Development of Different Tissues.—The development of the stem commences with the formation of the embryo, by the process explained at the beginning of our study of the seed. So long as the cells produced by this process are the same in kind, the body consists of but one tissue; but through differentiation and specialization among them, different tissues are soon developed.

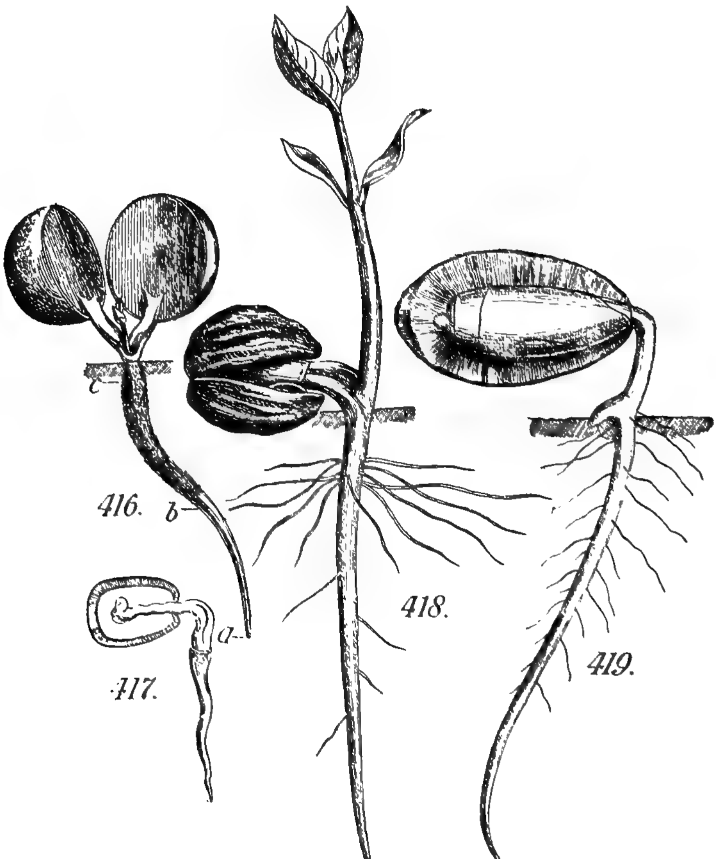
Meristem.—The power of cell-division and growth is lost by most tissue after a time, while in other parts it persists permanently. Any tissue or portion of tissue which possesses such power is called Meristem. Tissue may cease finally to exert meristematic power, or it may resume such power after a time. All meristematic processes cease upon maturity of seed, recommencing with germination.

Degree of Development Attained by the Embryo in the Seed-condition.—The point reached in the development of any plant-body in the embryonic condition—that is, at the maturity of the seed—does not depend in any degree upon the amount or kind of tissue or tissues developed, but altogether upon the habit of the particular class of plant. In some embryos, tissue differentiation cannot be seen to have taken place at the time of separation from the parent, while in others it has progressed very far, though never (unless germination has occurred) to the production of a true root. It is impossible, therefore, to fix upon any particular developmental stage of stem-structure as distinguishing the ungerminated embryo from the germinated plantlet. In the following sketch of its development, then, no note is taken of the resting period in the seed-stage, but the process is followed as though it were continuous from fertilization through germination and into the mature condition of the plant.

Although of primary importance scientifically, and of great interest, the phenomena of germination are not important from the standpoint of pharmacognosy, and a mere outline of them is here given.

Vitality of Seeds.—Animation is probably not entirely suspended during the resting period of the seed. That is, there is an apparent interchange of substance, due to vital action, between the seed and the surrounding atmosphere, although extremely slight, so long as the former possesses its vitality.

The evidence as to length of time during which seeds can retain their vitality is extremely contradictory, and the greatest diversity of opinion exists concerning this point. Our best authorities believe that we have no conclusive evidence that the period is longer than about fifty years, although, upon the other hand, we have no positive evidence that it is not very much longer.



Figures illustrating common forms of germination.

Germination.—*Conditions of Germination.*—Germination depends upon (1) a specific temperature, varying for seeds of different species and for those of the same species when they have become habituated to essentially different climatic conditions; (2) a specific saturation, also varying with different seeds—that is, the absorption of an amount of water bearing a fixed ratio to the weight of the seed: (3) a partially fixed degree of light exclusion; (4) the presence of free oxygen.

The Process of Germination.—Under these conditions, ready prepared nutriment is dissolved, other forms become digested by special vegetable ferments (Enzymes) present, heat is developed, cell-propagation and cell-growth take place, and the development and growth of a plant from the embryo commence. By the growth of the embryo, the radicle is protruded through the micropyle, the rest of the body soon following and leaving the embryo free from its coats, or the body may remain enclosed in the coats for some time. The radicle, if it does not already point directly downward, turns in that direction and develops into a root (Figs. 417 and 419). The cotyledons may then separate completely, leaving the plumule or second phytomer to develop from the apex, between them (Fig. 416), or the cotyledons may remain in contact, and the plumule or second phytomer burst forth from between the bases of their petioles (Fig. 418). The end of the embryo opposite to the radicle, if it does not already point upward, turns in that direction and develops as the apex of the stem.

The Epicotyl and Hypocotyl.—The stem above the cotyledons is called the Epicotyl, that below them the Hypocotyl.

Cellular Development and Growth.—The cellular nature of development and growth demands a general knowledge of histology for their understanding, so that we shall here consider, so far as possible, only the gross results of the processes, or such characters of the root and stem as can be demonstrated by other than histological methods. Such references to cellular structure as are here necessary are given rather figuratively than technically. The mode of growth in root and stem, and the structures resulting, are sufficiently different to require separate treatment. Although the forms of structure here considered as applying to the root concern only flowering plants and the very highest of the cryptograms, yet the description is applicable to all roots used in medicine.

Structure of the Root.—Upon examining a transverse section of the root in its rudimentary condition, it is possible to distinguish three bodies of tissue exhibiting characteristic differences in their cellular elements (Fig. 420).

The Plerom, Pleriblem, and Dermatogen.—The central portion is occupied by a solid cylinder called the Plerom (*a*). Outside of this there is a hollow cylinder called the Periblem (*b*), and still outside of this and upon the surface of the root a second hollow cylinder, the Dermatogen (*c*).

Structures Developed from the Dermatogen.—The last mentioned develops a primary covering called the Epidermis (Fig. 422, *a*).

The Root-cap.—The epidermis consists in its earliest stage, and therefore at the very tip, of a number of layers of cells which protect the apical growing point of the root, and is therefore called at that point the Root-cap (Fig. 416, *a-b*). Toward the summit of the root-cap the outer layers of cells successively wear off or are cast off, so that the epidermis becomes reduced to a single thickness of cells.

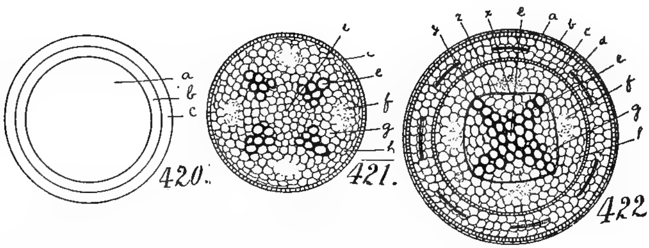


Fig. 420. Diagram illustrating arrangement of ground-tissues of root: *a*, plerom; *b*, periblem; *c*, dermatogen. 421. Plerom enclosed by endodermis (*c*), with first appearance of bundles: *e*, xylem-bundle; *f*, phloem-bundle; *g*, medullary-ray; *h*, pericycle; *i*, temporary pith. 422. The same in a more advanced stage, the outer portions also present: *a*, epiderm; *b*, hypoderm; *c*, endoderm (cortex between *b* and *c*); *e*, xylem-bundles now meeting at center; *f*, phloem-bundle; *g*, medullary-ray; *h*, pericycle; *x*, cambium of the primary phloem-bundle; *y*, of the primary xylem-bundle; *z*, of the primary medullary-ray.

The Root-hairs and Peliferous Layer.—Here it frequently develops a dense covering of Root-hairs which adhere tenaciously to the soil and perform various processes connected with absorption (Fig. 416, *b-c*). For this reason, this portion of the epidermis of the root is known as the Piliferous Layer.

The Epidermis Proper.—Still farther up these hairs have fallen away, and the single layer, after slight modifications, becomes converted into the epidermis proper. This has a variable duration in different plants and is consequently found covering the root for a greater or less distance upward. Almost always its duration is very short. It either disappears altogether, being replaced by a structure (Periderm) developed from the periblem, or in rare cases itself develops into the periderm.

Structures Developed from the Periblem.—The periblem of the root develops into the Cortex (Fig. 422 between *b* and *c*), consisting of a number, often a large number, of layers of cells.

The Hypodermis.—Its outermost portion, usually of one layer of cells, presents a different appearance from the subjacent layers, and is the Hypodermis (Fig. 422, *b*) in the case of the root becoming the Exodermis. The hypoderm lies against the inner face of the epiderm (*a*), while that persists, becoming afterward the superficial layer, and persists for a longer or shorter period. Its characteristics are of great importance in histological determinations.

The Endodermis.—The innermost layer of the primary cortex is even more distinct in appearance than the hypoderm, and is the Endodermis (*c*). It lies in contact with the outer surface of the structure developed from the plerom.

Disappearance of the Primary Cortex.—The production of primary cortex is quickly completed. If then the growth inside of it continues indefinitely it, in most plants, involves the destruction and disappearance of the primary cortex, which must be replaced by some other covering.

Provision by Phellogen for a New Covering.—A new meristematic region must then be established for the purpose of manufacturing such a covering. This almost always arises in some part, and it may be in any part, of the primary cortex. It is the Phellogen (Fig. 422, *d*). The phellogen may be in the form of a continuous circle or the usual form in that of blades or plates (*d*), variously placed and directed.

Periderm and Phelloderm.—Upon its outer surface the phellogen develops corky tissue, the Periderm, and upon its inner a secondary cortex, the Phelloderm. Occasionally it will produce only periderm or only phelloderm.

Secondary Periderm.—As the periderm becomes impervious to the nourishing fluids, it and all the tissues exterior to it must die, and may be cast off, a new phellogen then appearing farther toward the interior to form a new periderm, so that we may have successive periderms—the primary, secondary, and so on. This process is comparatively rare in the case of the root, very common in that of the stem.

The Bork.—In such cases, the corky layers which become successively superficial, observed in the scales of bark which peel off from tree-trunks, constitute the Bork or Rhytidoma. Bork is called Ring-bork when it forms a cylinder, Scale-bork when it occurs in detached plates. It must be noted that the origin of the bork, and, as will be shown later, its structural nature dependent thereon, will depend upon the depth at which the phellogen develops. The same feature will also determine the amount and character of the tissue, if any, existing between it and the structure developed from the plerom.

No Fibro-vascular Tissue Developed from Periblem.—No tissue developed directly or indirectly from the periblem is in the form of distinct and regular bundles of vessels, though irregular and isolated or anastomosing tubes are frequently developed by it.

Structures Developed from the Plerom.—*The Stele.*—The essential characteristic of the body developed from the plerom of the root is that it is invested by the endodermis and is free from any other endodermal development in any part. It, therefore, constitutes a Stele (all inside of *c*), which in the root is always in the form of a Central Cylinder.

Differentiation in the Cells of the Stele.—The plerom exhibits at first only slight differences in the appearance of its cells (Fig. 420, *a*), and a transverse section of it viewed with the microscope might be figuratively compared to looking down upon a honeycomb built in a cylindrical tin box, the latter representing the endodermis, and in longitudinal section to a longitudinal section through the same. This constitutes the Ground-tissue of the Stele. Farther away from the tip, however, it would be found that groups of its cells (Fig. 421, *e* and *f*) had elongated in a longitudinal direction, and these, to continue our illustration, might be compared to bundles of pencils or quills set in the honeycomb. Mingled among the elongated cells of the bundle, however, are many which have not elongated.

Medullary Rays.—These bundles would be arranged in a circle separated from one another by more or less of the honeycomb tissue, these separating portions corresponding to the Medullary Rays of the Stele (*g*).

The Pericycle.—From the endodermis they would be separated by one or more continuous circles of the honeycomb cells, corresponding to the Pericycle or "Pericambium" (*h*). For a time there would also be left a central portion (*i*), consisting of unchanged cells, forming a temporary Medulla or pith.

The Vessels.—The elongated cells, which constitute the important elements of the bundles, are joined end to end with other similar ones still farther up in the older part of the structure. At first the end walls of these abutting cells separate their cavities from one another, but later these disappear in those of some bundles, becoming perforated in those of others, so that the cavities become more or less continuous, forming the Vessels, extending throughout the root and into and through the stem above. The bundles thus formed are thus of two kinds, alternating in the circle.

The Xylem- or Wood-bundles.—Each of those of one kind (Fig. 422, *e*) extends gradually toward the center by the successive development there of vessels or cells associated with the vessels of the bundles. Upon meeting there, the bundles, of course, cut off the previously existing central communication between the medullary rays, which are now left as isolated plates or wedges between the bundles, the temporary pith being thus obliterated. These bundles, which meet at the center, are known as the Xylem-bundles or Wood-bundles, and constitute the woody portion of the root.

The Ducts.—The tubes formed as described above are the Ducts. In a few plants which we have to consider, the Gymnosperms, no series of cells lose their end-walls as above described so as to become converted into continuous tubes or ducts, though they connect by perforations.

The Phloem- or Sieve-bundles and Sieve-tubes.—The other bundles (Fig. 422, *f*) which have been described as alternating with the xylem-, or wood-bundles, possess as their important element those cells which become connected by perforations in the form of sieves, and are known as the Phloem-bundles.

Collectively they form what is known as the Sieve-tissue, or Cribrose-tissue, of the plant, and their intercommunicating tubes are the Sieve-tubes. This tissue characterizes the Gymnosperms as well as the Angiosperms. The phloem-bundles do not extend toward the center, as do the xylem-bundles, but stand isolated, each between two medullary rays, which respectively separate it from the xylem-bundle upon either side.

The Fibers.—In connection with the ducts, or their equivalents in the gymnosperms, and the other tissues of the xylem-bundles, strong fibers develop, the Wood-fibers, while in connection with the sieve-tubes and other tissue of the phloem-bundles very similar fibers, the Bast-fibers, usually develop. The phloem-bundles, therefore, ordinarily become Bast-bundles.

Fibro-vascular Bundles.—Vascular bundles in which fibers develop are known as Fibro-vascular bundles.

Secondary Growth of the Stele.—The condition now reached by the root constitutes the completed primary structure of its stele. The student should not fail to note that the primary structure refers only to the very smallest roots, and that he need not expect to encounter it in any roots in a condition to be used medicinally. His examination of roots in Pharmacognosy will, therefore, relate to the secondary structure, an account of which will follow. With the production of the primary structure, growth and increase in thickness may cease (most Monocotyledons), in which case the periderm changes which we have recorded will not occur. On the other hand, secondary growth may take place, in which case those changes are more or less completely induced.

Development of the Cambium.—In such case, the cells touching the phloem-bundles upon their inner faces and upon their sides become meristematic and proceed to produce xylem-tissue upon their inner faces and secondary phloem upon their outer, in contact with the primary tissue of that kind. Each such arc of meristem (Fig. 422, *x*) becomes the Cambium of that bundle.

Completion of the Bundles.—At the same time the cells lying in contact with the outer surfaces and with the sides of each xylem-bundle similarly become a cambium for that bundle (*y*), and sometimes produce secondary xylem, upon their inner faces, in contact with the primary xylem there, and secondary phloem upon their outer faces. By these processes each bundle which undergoes them, previously consisting of one kind of tissue, therefore an incomplete bundle, comes to consist of both kinds of tissue and becomes a complete bundle.

The Cambium-circle.—Connecting the cambium arcs of the adjacent bundles, a cambium arc (*z*) forms in the intervening medullary ray, and this produces secondary medullary ray tissue on both its inner and its outer face. There is thus formed a continuous cylinder of cambium (*x*, *y*, *z*), though a somewhat irregular and wavy cylinder, standing between the zone formed within by the primary and secondary xylem-bundles and their intervening portions of the medullary rays, and the outer primary and secondary phloem-bundles (when the latter develop) with their intervening portions of the medullary rays. Although this cambium forms a cylinder, as stated, it is usually referred to as the "Cambium-ring," or "Cambium-circle," because it presents this appearance in transverse section.

Continuous Multiplication of the Structures.—Provision is now made for the growth of all portions of the stele. Additional complete fibro-vascular bundles are now developed in the medullary ray spaces between the others, fed by a portion of cambium in a similar manner. New medullary rays also develop in the substance of the bundles. We thus have developed upon the inside of the cambium-cylinder a cylinder of xylem, solid except for the blades of medullary ray tissue penetrating it nearly to the center, and outside of the cambium-cylinder a hollow cylinder of phloem tissue or bast tissue, continuous except for similar, but of course much shorter, medullary rays.

It has been said above that the portions of the cambium-circle opposite to the primary wood-bundles "may" produce secondary wood upon their inner faces and secondary phloem upon their outer. While this does take place in some roots, it usually does not, only pericycle tissue forming at those points on both the inner and outer faces of the cambium.

The above constitutes the secondary structure of the root-stele, and any further growth which may occur, except for the development of branches, considered hereafter, is merely a continuation of the process described as secondary growth.

The Annual Rings.—When an annual resting-period in growth occurs, the ducts of the xylem produced toward the close of the year's growth will be conspicuously smaller than those produced at the beginning, so that conspicuous Annual rings are produced in many woods.

The Duramen and Alburnum.—After a tree has attained a certain age, the wood at the center dies, and becomes dryer and harder and of a different color from the living wood outside of it, and this dead portion becomes thicker year by year. It is called the Duramen, or "Heartwood," and it often contains medicinal or coloring matters. The outer is called the Alburnum, or "Sap-wood." It is the duramen only which yields the most of our colored cabinet lumbers.

Effects of Secondary Growth upon the Superficial Structure.—The effect of secondary growth upon the structures external to the bast-cylinder is extremely variable, according to the extent of such growth and the relations of the phellogen and its structure and the individual habit of the plant. It has been stated that the phellogen may develop in any part of the cortex. It may now be stated that it may, and, in fact, usually does, in the root develop in the bast-cylinder itself, so that all the parts external to it, and even portions of itself, will belong to the periderm, or in the rare case of Bork-casting by the root, will be cast off.

//**Origin of the Branches of the Root.**#—In all the classes which yield our medicinal roots, the branches start from the pericycle outside of a xylem-bundle at the point *h* (Fig. 421), as it is first developing, and grows through the surrounding tissue to and from the surface. If cross-sections have been cut through a root so as to pass through its branches also, the branches on the older part will appear as mature secondary roots. Those lower down will be successively less developed, appearing at length upon the younger portion as not yet having made their way through the overlying tissues to the surface. As the root first formed is called the Primary, so its branches are called Secondary. Their structural development is a repetition of that of the primary.

Continuity of Root-growth.—The continuity of growth in the root is uniform—that is, there is no division of it into joints or phytomers. There are hence no regular distances at which it branches, and when buds are produced upon it, as they are in rare cases, their points of origin are not so regulated.

Structure of the Stem as Contrasted with that of the Root.—(The following account of stem-structure refers only to the ordinary plants of the flowering class. At its close a brief reference will be made to such others as require attention for the purposes of pharmacognosy.)

The history of stem-development is best presented by contrasting it with that of the root, which has already been given. The three elementary tissues, dermatogen, periblem, and plerom, are also found in the young stem-structure. The epidermis and other tissues of the stem are more variable than the corresponding tissues of the root, and the details pertain for the most part to histology and to the special treatment of species or groups.

The Epidermis.—The most important distinction between the epidermis of root and stem may be mentioned as the presence in the latter of stomata, to be studied in connection with the leaf. There is no extra development from the dermatogen at the tip corresponding to the root-cap, nor of hairs similarly aggregated to those of the root, although hairs of many forms abound upon the epidermis of the stem. Stem-epidermis may consist of one or of several layers, and if the latter, they may be dissimilar in varying degrees. Rarely it is persistent, being usually thrown off through the growth of the parts within it, as has already been considered in the case of the root.

The Cortex.—The periblem of the stem develops structures in general similar to those of the root-periblem, the most important distinction being the production of a chlorophyll-layer. A primary cortex, usually somewhat thinner than that of the root of the same plant, is bounded externally by a hypoderm and internally by an endoderm, and may develop tubes similar to those mentioned as frequently pertaining to the root-cortex, but, as in that case, no true vascular bundles. The effects of growth within the primary cortex of the root, leading to the formation and casting off of bork, we have seen to be of rare occurrence. In the case of the stem, however, it is of very general occurrence, so that the entire account which has been given of the development and disposition of periderm and phelloderm may be applied with special force in the case of the stem.

The Central Cylinder.—The principal differences between root-structure and stem-structure are found in the developments from the plerom. Although, with the single exception, among important medicinal stems, of the male fern, there is but a single stele, in the form of a central cylinder, yet the development of its structure is markedly different from that of the root. Leaving out of consideration exceptions which are unimportant in pharmacognosy, we find that two distinct types of structure characterize respectively the monocotyledons and the dicotyledons and gymnosperms. The form characterizing the latter two will be first considered.

The Primary Bundles.—Vascular bundles originate in the plerom in the form of a circle, just as in the case of the root, the important difference being that each bundle consists, even in its primary state, of both phloem and xylem, with a cambium between.

The Open Collateral Bundle.—The typical form is that which in the root constitutes the secondary structure—namely, a bundle consisting of xylem within and phloem without the cambium arc, and this constitutes what is known as the Open Collateral Bundle.

Secondary Growth.—Secondary growth here consists in the addition by the cambium to each kind of tissue, and, in almost all cases, the development of new intermediate bundles and new medullary rays, as has been described in the case of the root. The result is that the general plan of structure attained is identical with that already recorded as ultimately attained by the most highly developed woody roots. There are, however, several differences which must be noticed.

The Medulla or Pith.—The most important is that the primary xylem-bundles do not progress toward and meet one another at the center, so that there is always left there a cylinder of the fundamental tissue, constituting the Medulla or Pith, which is connected through the primary medullary rays with the pericycle, or, after the disappearance of that and of the endodermis, with the cortex.

The whole structure in transverse section may now be roughly compared with the wheel of a wagon. The pith corresponds to the hub, the primary medullary rays to the spokes, the spaces between the spokes to the primary wood wedges, the felloe to the bast product, except that the spokes should be seen extending through it, and the tire to the periderm in its various forms of development.

Variations in Structure.—Although the details of tissue-arrangement pertain to histology, yet the deviations from the above relative positions of the phloem and xylem are of such very great importance in pharmacognosy that they are here referred to. We may have (1) the Bicollateral Bundle, in which a second fascicle of phloem is placed upon the inner face of the xylem; (2) the peculiarities characterizing the monocotyledons, which will be described later.

There are three ways in which the structure of the root or stem may be examined.

Directions of Sectioning for Examination.—1. A Radial section is a longitudinal section in a plane passing through the center.

2. A Tangential section is a longitudinal section in a plane which does not pass through the center.

3. A Transverse section is one passing exactly at right angles to the former two.

Appearance of the Radial Section.—The appearance presented by a radial section through a perfectly developed woody stem possessing open collateral bundles may now be described as follows, enumerating the structures upon either side from the center outward: (1) Pith; (2) wood wedges, with medullary rays, the latter, if primary, communicating with the pith at the center and outward with the cortex; if secondary, extending outward like the primary, but no farther inward than the limit of the ring in which it originates; (3) the cambium; (4) the bast bundles, separated by their medullary rays; (5) the phelloderm, phellogen, and periderm, the relations of which to one another and to the bast, and the structure of which, cannot be specified, owing to the extreme variation which they display in different stems. The composition of the bork, if any, will also depend upon the point of development of the phellogen and its form upon the form of the latter.

Appearance of the Transverse Section.—Upon a transverse section, the same structures as above recorded will appear, but instead of being in the form of thin strips upon either side of the center, they will be in the form of concentric rings around it. Thus the center is seen occupied by a circle of pith, outside of which is a zone of xylem or wood tissue, separated by longer or shorter medullary rays into its primary and younger wood bundles. Outside of the first annual ring is where the intermediate or secondary bundles make their first appearance. The secondary medullary rays (Fig. 423, *a*) will be found not to extend inward beyond the production of tissue of that year. Instead of appearing as blades, as they did in the radial section (Fig. 423, *b*), the medullary rays now appear as narrow lines. That is, we now see the edges of the blades whose sides were before seen. Passing outward beyond the last of the annual rings, which successively exhibit a greater number of wood-bundles and medullary rays, we reach the cambium-ring. Outside of this we find the phloem or bast bundles separated by medullary rays continuous with those of the wood cylinder, and still outside of this the periderm.

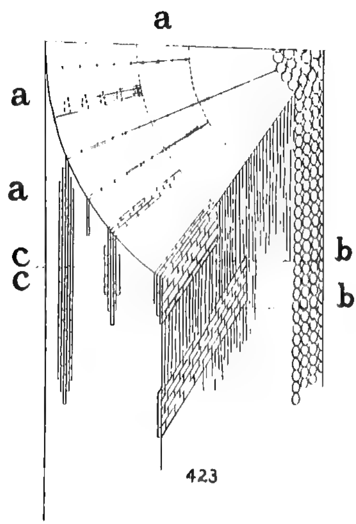
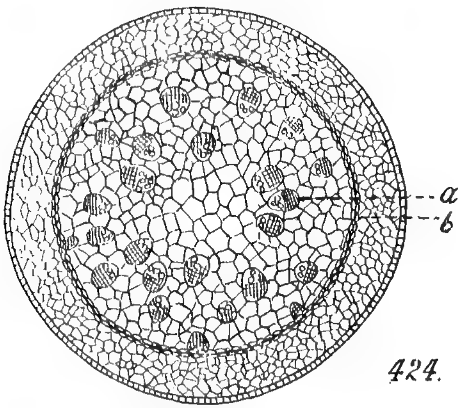


Fig. 423. Diagram illustrating section of woody portion of dicotyledonous stem: *a*, edges of medullary rays as seen in transverse section; *b*, sides of same as seen in radial section; *c*, ends as they would appear in tangential section.

Appearance of the Tangential Section. The appearance of a tangential section will depend, of course, upon the tissues through which it passes. If it cuts the medullary rays these will appear neither as the broad sides, as at *b*, nor the edges of blades, as at *a*, but as transverse sections of them, as at *c*. If the ray consists of but one row of cells in width, then such a row will be exhibited upon the tangential section, its vertical height varying from a very few to quite a large number of cells. If, upon the other hand, it possess a lateral breadth of several thicknesses of cells, of 5 in our figure, this condition will exist only at its middle portion. At its upper and lower limits it will ordinarily be reduced to the thickness of a single cell, so that the tangential aspect of a medullary ray is almost always that of an ellipse, broad or narrow, according to the number of rows of cells of which it consists, in contrast with the extent of its upward and downward extension.

In some stems the pith or medulla disappears more or less completely after a time, leaving a cylindrical hollow cavity. This may be continuous through the nodes or separated at those points by transverse partitions.

Structure of the Monocotyledonous Stem.—In monocotyledons (Fig. 424) we have the Closed bundle, in which the one element surrounds and encloses the other. In all medicinal monocotyledonous stems possessing such bundles, it is the xylem which encloses the phloem. If the two cylinders thus formed have a common center, which form is not very common, it is called a Concentric bundle. It is clear that in the last two forms a cambium cylinder, such as distinguishes the stele, possessing the form previously considered, cannot be formed. In such



424.

Fig. 424. Transverse section of monocotyledonous stem: *a*, closed bundles scattered through parenchyma; *b*, nucleus sheath, or endodermis.

plants indefinite growth in thickness of the bundles obviously cannot occur, and the same is true of the entire stele, unless new bundles shall develop in it. Usually this does not occur, but if the upper portion of the plant shall branch and continue to extend its leafy surface, meristem tissue will then form toward the outer portion of the stele, and from this new bundles will successively arise, so that the thickness of the trunk will keep pace with the extension of the crown, notwithstanding that the individual bundles do not increase in thickness after the completion of their primary structure. In stems possessing this form of bundles the latter (Fig. 424, *a*) are found more or less scattered through the fundamental or medullary tissue, though there is commonly more or less of a concentration of them in some one region, usually toward the periphery of the stele.

The Nucleus-sheath.—The endodermis of such plants is commonly known as a Nucleus-sheath (*b*).

Polystelar Stems.—Finally, we note that in many plants, represented among drugs by the ferns, the stem possesses a number, usually definite for the species, of vascular bundles, or groups of them, each invested by its own endodermis, each being thus a stele. Such stems are, therefore, called Polystelar. In such plants no epidermis is developed, the hypoderm, developed from the periblem, being superficial.

The Bark.—*Its Nature.*—The Bark is everything external to the cambium. It has been proposed to remove the word "bark" from common language, or to ignore its fixed common meaning, and to convert it into a technical name for the bork. Experience with English-speaking people leaves no hope that they will consent to give up a word employed so widely and in such important ways, and its technical use can apparently result only in the introduction of a confusion, which is more wisely avoided by the coining of some new name, if that of bork is seriously objectionable, which does not appear to be the case.

Importance of the Bark in Pharmacognosy.—Viewed from the standpoint of pharmacognosy, the bark, especially when detached from the remainder of the root or stem, is one of the most important portions of the plant. As has been seen, it is not a simple structure, but develops in part from the plerom, as well as from the periblem, and bears frequently, although this is not true of any detached medicinal bark, the epidermis as well.

Layers of the Bark.—In practice, the bark is commonly differentiated into three layers—the Endophloeum, that portion resulting from the plerom; the Mesophloeum, which is either the primary cortex, or the products of a phellogen developing external to the endophloeum, or both when they exist together; and the Exophloeum, consisting of a primary periderm. If, as is not the case in any medicinal bark, the epidermis persist, it will form the exophloeum. It has already been made clear that a bark can come to want successively its exophloeum, mesophloeum, and even the outer part of its endophloeum, as is seen in some Cinchona bark, from old trees.

The study of barks includes a close examination of the cellular elements, as a preparation for which histological work is absolutely necessary. Examination of its gross characters involves, as the more important features, its extreme and average thickness, its manifest layers, as seen with a lens on transverse or radial section, their relative thickness, color, markings, consistency as shown by fracture, their separability from one another, that is, into laminae, together with the surface characters of the latter, the external color and level markings, the presence and nature of parasites, and the color and inequalities of the inner surface.

The Laminae. — The laminae do not depend entirely upon different tissue composition. The same tissue, produced at different times, may present differences sufficient to result in different degrees of cohesion, as well as markedly different color, at different depths, so that separation may readily occur, or they may readily be distinguished in sections.

Section-markings.—Groups or radial or tangential rows of tissue-elements, differing from those adjoining, frequently produce gross markings on the section-surface.

Fracture.—The fracture of barks or of their individual layers is denominated in general as being brittle or tough. Various modifications are soft, earthy, granular, horny, waxy, fibrous, splintery, or flexible. A bark may be flexible in one direction and not in another.

The Outer Surface.—The outer surface is described in general as being harsh, rough, downy, smooth or shiny, and its luster may be waxy, vitreous, and so on. Some of the

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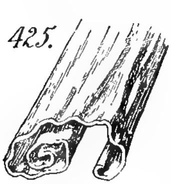

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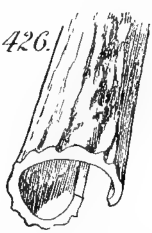


Fig. 425. Section of young *Calisaya* bark, showing wrinkling in drying. 426. Section of old *Succirubra* bark, showing ridging.

427.

Fig. 427. Quill of mature *Calisaya* bark, showing transverse and longitudinal fissures.

elements causing roughness may require microscopical examination for their demonstration, while others are otherwise manifest.

Ridges and Furrows.—Care must be taken to distinguish between ridging and furrowing of different kinds. One kind is caused by a longitudinal wrinkling in drying, as in young *Calisaya* (Fig. 425). Another is owing to transverse (as in old *Calisaya*) or longitudinal (in the same) fissuring (Fig. 427). Another is caused by the elevation of corky ridges, or rows of corky warts, which may or may not become confluent in variable degree (as in *Succirubra*, Fig. 426). Fissures may characteristically open in the crest of a ridge or in the otherwise unchanged surface.

Color-markings.—Most color-variegations are due to lichens or other parasites, and those due to lenticels are also very common. A single color or shade of color of the inner surface is rarely characteristic, as it changes very greatly with age in keeping; but a carefully arranged series of them may be made diagnostic in many cases.

The Inner Surface.—The important characteristics of the inner surface depend upon the projecting bast-bundles caused by contracting medullary rays. Very rarely, indeed, is the surface so free from these inequalities that it can be properly described as smooth. The slightest manifestation of the bundles gives the Striate condition. The striae must be examined as to length, straightness, direction as contrasted with the axis of the bark, apparent interconnection at the end, width, elevation, and sharpness, with the complementary characters of the intervening furrows or pits. Some barks show a tendency to separate into laminae which run obliquely out upon the inner face, appearing there as partially separated tongue-shaped splinters.

No attempt has ever yet been made to classify the markings of the inner surfaces of dried barks, and to provide a terminology for them. In the absence of this important treatment, it is difficult to teach the details of the subject, except by the use of the actual objects.

CHAPTER XIV

VERTICAL AND LATERAL EXTENSIONS AND APPENDAGES OF THE STEM

Origin of Branches and Leaves.—Examining a radial section of the tip of the stem (Fig. 4) we find, in addition to the structures already considered as belonging primarily to itself, protuberances, consisting of masses of meristem tissue belonging to the periblem and the dermatogen. Shortly, each of these tissue-masses assumes, in a general way, the condition of the primary growing point of the main stem. Some of them will develop into leaves, the structure of which will be considered farther on, others into branches, which latter process is a mere repetition of that already considered in relation to the primary stem. In either case, the vascular bundles exhibit a connection, variable in its details, with those of the stem from which it develops.

Arrangement of the Leaves and Branches.—The normal method is for a branch and leaf to develop together, the former in the axil of the latter, as already recorded. If two or more leaves, with their branches, develop at the same node, it results in the opposite or verticillate arrangement. If but one, then, of those developing at different levels, each is successively separated from the former by a uniform portion of the stem circumference, so that a spiral arrangement results. This spiral will be considered when we come to the study of the leaf.

Growth of the Internodes.—The point at which one or more leaves develop has already been defined as the node, and the portion of stem intervening between two nodes as the internode. At first the internodes are so short as to be scarcely perceptible, but they continue to grow in all parts until a length more or less definite for the species is attained, so that leaves and branches become separated by uniform vertical as well as circumferential spaces. This brings us to another great distinction between the stem and the root, in which latter we have found a continuous and uniform longitudinal development.

Axils in which Buds do not Develop.—The rule that a branch develops in each leaf-axil is habitually departed from in the leaf-representatives constituting the flower, and accidentally in some other cases. Its failure to develop may be temporary, although often very long continued, or it may be permanent.

Occasional Failure of the Leaf to Develop.—Upon the other hand, the subtending leaf may fail, accidentally, or in a few cases habitually, to develop, so that the branch does not show its axillary nature.

Abnormal Position of Branches.—Finally, we note that a branch may accidentally, or in some cases habitually, develop from some other point than the leaf-axil, or two or more may develop, at least partially, from one axil, either side by side or in a vertical row.

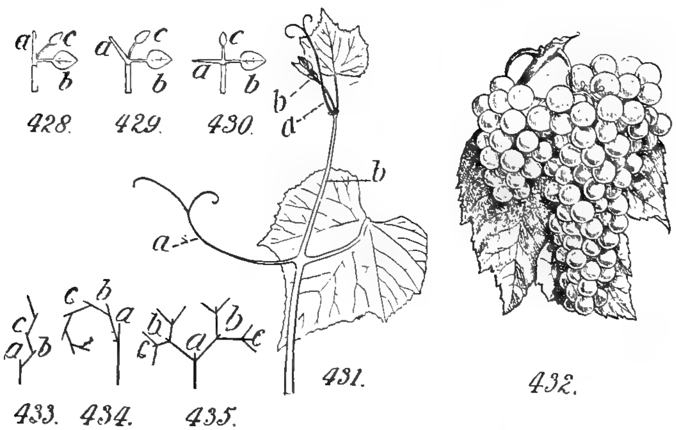
Not only may a lateral branch thus fail to develop, but the apical extension of the growing point may fail, accidentally or habitually, the growth being continued by means of one or more branches only.

Sympodial and Monopodial Stems.—When this method of growth is characteristic, the new branch taking the place of the suppressed stem which produced it, at each successive node, so that the stem becomes composed of a succession of one-jointed branches, the stem is called Sympodial, as contrasted with the term Monopodial, for the ordinary form, in which the apical growth, as well as that of the branches, is continued from joint to joint.

The natural result of such a series of branchings would be to produce an angular divergence of the axis at each joint, as the branch projects more or less laterally from its support. This, however, is usually not the case. In many plants the new branch takes the erect position of that which it has replaced, preserving the rectitude of the axis, and so tending to obscure the sympodial nature of its growth. In such cases, we must search for other indications of its nature. This subject will be understood upon reference to the accompanying diagrams (Figs. 428 to 430), in which *a* in each case represents the apical extension, *b* the leaf, *c* the axillary branch. It is seen that the positions of the three, with relation to each other, are the same in every case, the axillary branch being between the other two, no matter what changes in their directions may occur. In Fig. 429 the apical phytomer has been forced a little to one side, while in Fig. 430 it has become perfectly horizontal, the branch substituting it in the erect position. It is clear that in the last case, *c* might easily be mistaken for the main stem, *a* for a branch. If this view is taken, however, we are at once met by the difficulty that the supposed branch has no leaf at its base, that is, it is not axillary, while the leaf, *b*, has no branch in its axil. Both these difficulties entirely disappear when we regard the body between the other two as the branch.

A mistake becomes even more easy when one of the structures becomes modified into some unusual form. Thus, in Fig. 431, the terminal phytomer has become converted into a tendril (*a*). This tendril must be a modified main stem, a modified branch, or a modified leaf, and the decision is perfectly easy when we inquire as to its relation to the axil. In Fig. 432, where the apical portion has become converted into an inflorescence, followed by a cluster of grapes, the determination is the same.

In all these illustrations but one phytomer with its products is displayed. By viewing a series of them, we are able to determine a number of distinct forms of the sympodial stem, depending upon the order of its branching. In Fig. 433 the branches are borne alternately upon the two sides, and directed alternately to right and left, giving



Figures illustrating sympodial growth: Fig. 428. *a*, superposed phytomer; *b*, leaf; *c*, axillary phytomer or branch. 429. *a*, turned aside; *b*, assuming its place. 430. The change complete, the superposed phytomer become lateral, standing opposite the leaf. 431. (The grape) same positions as in 430: *a*, metamorphosed into a tendril. 432. *a*, converted into an inflorescence. 433. Alternating sympodial growth. 434. Unilateral sympodial growth. 435. Bifurcating sympodial growth.

a flexuous appearance to the sympodium; but it must not be forgotten that they may grow quite erect, the leaves alternating regularly upon the two sides and the stem appearing monopodial. No axillary branches will, however, be found. In Fig. 434 the branches develop successively upon the same side. In this case, also, the fully developed portion of the stem is straight and appears monopodial, except that the leaves are all upon one side (*secund*), but the peculiar direction taken by the undeveloped portion toward the tip indicates its true nature, as well as the absence of axillary branches. Fig. 435 represents a sympodial stem on which the branches are borne in pairs, the obvious result being a double symmetry, each branch successively ending in a pair of branches. This gives us the forked or Bifurcating form of sympodium, often called dichotomous, though this term refers strictly to one in which forking is caused by the vertical division of a terminal cell.

Superficial Appendages to Stems.—Besides modified or unmodified leaves or branches, stems may develop various other appendages. When these are merely superficial, they are called Trichomes. The characters of trichomes upon stems or leaves, particularly the latter, are of the utmost importance in diagnosis. Their study, however, save as to the surface characters which they collectively produce, pertains to histology. The gross surface character so produced will be taken up in connection with the leaf.

Fig. 436. Aculeate stem of *Chaetaea*. *a*, hooked prickles.

Emergences or Outgrowths.—When appendages are of deeper origin they are called Outgrowths or Emergences. These may contain vascular tissue, connected with that of the stem. Outgrowths are, for the most part, in the form of spines, hooks (Fig. 436, *a*), warts, suckers (Fig. 459, *a*, in this illustration a modified stem), or grasping organs. Usually organs of this kind are the results of modifications of other organs, rather than outgrowths. Both trichomes and outgrowths may be regularly or irregularly disposed.

Roots from Stems.—Roots may develop from branches which are subterranean or which rest upon the surface of the ground or are high above it. The latter may descend and enter the ground, fix themselves to a neighboring body for sustenance or support, or both, or extend into the atmosphere. They may even turn and enter a diseased or decaying portion of their own plant. They normally develop from the node only, but may develop from any other part or even from leaves.

Buds.—An undeveloped stem or branch, or the partially developed summit of one, is a Bud or Gemma. The bud may be in a process of continuous development of its lower elements into mature phytomers, with the continuous production of a new growing point, or it may pass into a resting state between successive seasons of growth. In the latter case it undergoes special modifications (*b* in Figs. 447, 448, and 450). Its outer leaves become developed previous to the resting stage, but not as foliage leaves. They become modified instead in various directions as to form, proportions, relative position, appendages, and exudations, to fulfil the office of protection as scales, and they subsequently fall away, never developing into foliage leaves. When no such provision is made, the bud is commonly destroyed, with more or less of the young stem tip near it, during the resting period. Occasionally the bud is protected for a time by a special covering, formed by the petiole of the subtending leaf. It is then called a Subpetiolar Bud.

CHAPTER XV

CLASSIFICATION OF ROOTS AND STEMS

CLASSIFICATION OF ROOTS

ROOTS may be classified as to their duration, their order in time of development, place or nature of origin, function, form, and consistency.

Duration of Roots.—As to duration, we have roots divided into two great classes, although the terms designating them are in general applied to the plant as a whole rather than to the root. Monocarpous plants are those which die after producing one crop of fruit; Polycarpous, those which produce successive crops. The former are Annual when they live but a single season—as the rag-weed and the sunflower; Biennial, when they devote the first season to the storing up in some receptacle, such as a fleshy root or bud, a supply of nutriment, and fruit and die in the second season. The term winter-annuals has been applied to those which begin their life during the latter part of the first season, fruiting early the next season, so that their combined life during the two seasons is less than twelve months, as in the case of wheat and rye. Such may, by being planted early in the season, finish their existence during one season, as in the case of spring wheat. Those monocarpous roots which devote a number of years to the preparation for fruiting, as in case of the century plant, belong to the Perennials. All Polycarpous roots belong, of course, to the perennials.

Order of Development.—*Primary and Secondary Roots.*—As to their order in time of development, the first root developing from the radical is the primary. All subsequently developed, whether from root or stem, are secondary, although those developing from secondary roots are sometimes designated Tertiary and so on.

The Tap Root.—If the primary root continue its development so as to constitute a branch-bearing axis, it is called a Main-root or Tap-root (Fig. 439). The ultimate behavior of the tap-root, when not of the fleshy-thickened storage class, depends upon the development of the leafy crown of the stem. The extent of root-growth and its development will agree with that of the stem-crown. Two forms of stem-crown are recognized, the one having its branches and leaves so disposed as to conduct the rain which falls upon them in toward and down the stem, the other conducting it outward, so as to fall from the periphery. An examination of the former class of plants may be expected to disclose a tap-root which maintains a vertical downward direction, its branching not being wide. Those of the second class will generally be found to have their tap-roots quickly dividing up into numerous horizontal branches which bear the greater part of their small absorbing rootlets around the periphery, just where they will catch the droppings from the periphery of the leafy crown.

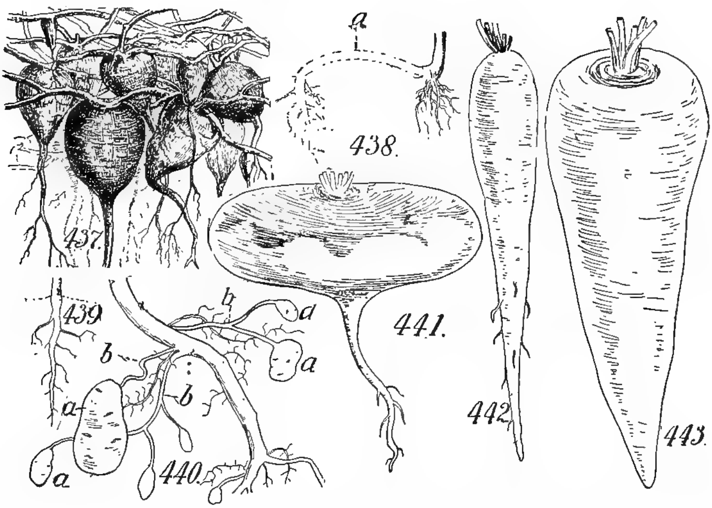


Fig. 437. Tubercles of Jalap. 438. Death of first portion of stem, its subsequent growth maintained by cluster of secondary roots. 439. Tap-root, with branches, of *Ambrosia*, 440. Underground portion of potato plant: *a*, tubers; *b*, rhizomes, the roots seen intermingled. 441. A napiform fleshy root. 442. Fusiform. 443. Conical.

The "Multiple Primary Root."—If the primary root of a very young plant divide at once into a number of approximately equal branches, it constitutes the so-called Multiple Primary Root. This term has, however, been applied to a number of root-clusters of similar appearance, but of very dissimilar origin. In some cases the primary root continues its vertical growth but does not increase in thickness to any appreciable extent. A number of similar roots then develop near its point of origin, so that a fascicle of similar roots at length results, as in the onion. In other cases a prostrate stem takes root from one of its nodes, the portion below this point (Fig. 438, *a*), with the original roots, perishing. To the cluster of roots thus resulting, although they are really secondary, the term "multiple primary" has also been applied. A true multiple primary root is of rare occurrence and does not exist among drugs.

Adventitious Roots.—All roots which are not primary, or branches thereof, and all branches of roots which are not developed in regular order of succession, are called Adventitious.

Place and Nature of Origin.—*Subterranean and Aërial Roots.*—As to their place and nature of origin, roots are Subterranean when they originate from points underground, whether from root or stem, and Aërial when they originate from points above the surface, whether from root or stem. A root may originate from an aërial point and afterward fix itself in the earth, as the Brace-roots of maize.

Fascicled Roots.—A number of approximately equal and similar roots occurring in a cluster, especially if they be fleshy-thickened, are denominated Fascicled.

Fibrous Roots.—Roots existing in the form of a mass of thin, fiber-like, approximately equal and similar elements are called Fibrous (Fig. 446).

Functions of Roots.—As to their functions, roots are known as Absorbing, Fixing, and Storage roots. A root of one kind may give origin to a branch of a different kind.

Haustoria.—Absorbing roots of parasitical plants are frequently greatly modified in structure to form Haustoria.

Rhizoids.—Fixing roots are usually designated as Rhizoids.

Storage Roots are usually much enlarged and possess a fleshy consistency and characteristic forms (Figs. 441 to 443).

Tubercles.—When only a limited portion of a root is fleshy-thickened, so as superficially to resemble a tuber, it is called a Tubercle, as the Jalap (Fig. 437). Care should be taken not to confuse this technical meaning of the term with its common use as designating a small tuber.

Forms of Roots.—As to their form, roots are simple, when they do not branch, or Branched, Cylindrical, Terete (which includes the cylindrical and that form which differs only in that it tapers), Napiform, when taking the form of a short, broad turnip (Fig. 441), Fusiform when spindle-shaped, as some radishes (Fig. 442), Conical or Cone-shaped (Fig. 443), Capillary when very thin, long and hair-like.

Consistency of Roots.—*Woody and Fleshy Roots.*—As to consistency, they are denominated as Woody and Fleshy. By "fleshy" or "non-woody" we do not mean that wood tissue is entirely lacking, but rather that the proportion of the cellular, parenchymatic, or fleshy elements is so much greater than that of the woody that a woody character is not apparent. In practical pharmacognosy, where dried roots are mostly observed, a number of other terms for consistency, as in the case of the bark, come into use.

CLASSIFICATION OF STEMS

Stems may be classified as to duration, order of development in time, position, and nature of origin, mode of extension, direction of growth and nature of support, modification of form or function, and consistence.

Duration.—As to duration, they are, like roots, Annual, Biennial, and Perennial.

Herbs.—Annual stems are those which die at the close of the season. They may or may not pertain to annual roots. Plants possessing them are called Herbs. Herbs are therefore either Annual, Biennial, or Perennial, in accordance with the character of the root, but their stems are always annual. The definition of an herb is a plant, the aërial portion of which dies at the season's close. The stem of an herb is denominated Herbaceous.

Biennial Stems.—Biennial stems are those which are produced, usually underground like that of the potato (Fig. 440, *b*), during one season, and perish after the production of their branches in the following season. Occasionally, however, like the cabbage, a biennial stem is aërial.

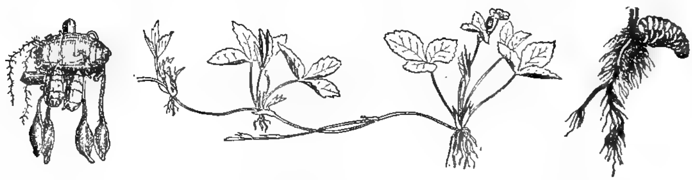
Tubers.—Fleshy-thickened and biennial portions of underground stems, such as the potato, are denominated Tubers (Fig. 440, *a*). Fig. 444 represents the underground portion of the *Curcuma*, and well displays the difference between tubers and tubercles.

Bulbs.—Basal biennial portions of stems which are invested by more or less fleshy-thickened storage-leaves are called Bulbs. Bulbs will be classified under the subject of buds.

Perennial Stems.—Perennial stems are those which live and extend their growth from year to year. They are Determinate when their growth of the season is self-limited and closes with the production of a specially prepared Winter-bud, which protects the growing point for continued growth the next season; Indeterminate, when no such bud is formed, growth continuing until the apical portion is destroyed by an inclement season. In the latter class we have the anomaly of a perennial stem with an annual tip.

Order of Development.—*Primary and Secondary Stems.*—As to their order of development in time, stems are Primary, Secondary, and so on, terms which are self-explanatory.

Place and Nature of Origin.—*Aërial and Subterranean Stems.*—As to their position and nature of origin, stems are Aërial or Subterranean, which terms are also self-explanatory. A secondary stem assuming an erect position from the base of the primary, like those of the Indian corn, is a Sucker. Such an one arising from a rhizome at a considerable distance from the original erect stem, as in the blackberry, is called a Stolon. A short secondary stem developing from the base of the primary is called an Offset. An elongated, slender one, lying prostrate and rooting at some of its joints, is called a Runner (Fig. 445).



444. 445. 446.

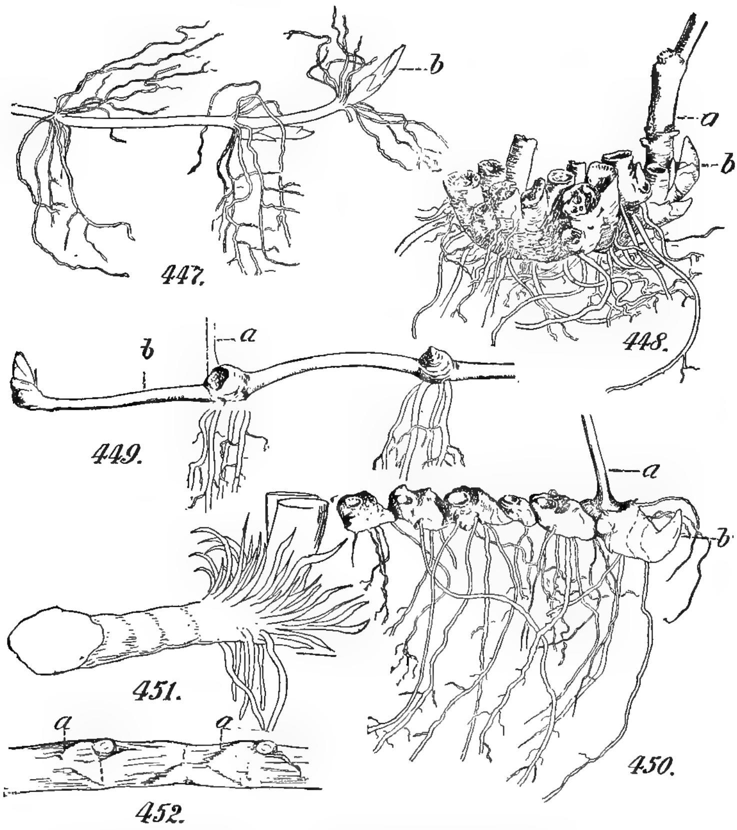
Fig. 444. Tubers of *Curcuma*. 445. Runner of strawberry plant. 446. Fibrous roots attached to scaly rhizome of *Gesneria*.

The Rhizome.—An underground stem, fleshy-thickened at least during the first year, so as to serve as a storage receptacle, and giving origin to an aërial summit or branch, is a Rhizome (Figs. 447 to 452).

Distinctions between the Rhizome and the Root.—A rhizome is very frequently mistaken for a root, but the differences, both internal and external, are well-marked. The internodes of the rhizome are commonly quite as uniform in length as those of the aërial stem. The nodes are usually conspicuous. Leaves exist upon them, commonly in the form of scales. Occasionally these scales are numerous and well formed (Fig. 446), but usually they are rather obscure, as in the potato, where they are mere semicircular or crescent-shaped ridges about the eyes. In the axils of the scales, buds are usually to be distinguished. These are the so-called "eyes" of the potato, and their development into branches is a familiar phenomenon. Internally, the structure of the rhizome is in general that of the stem, though fleshy tissue predominates.

The growth and duration of a rhizome may be indefinite, like those of stems, as in the case of the rhizome of *Podophyllum* (Fig. 449), or they may be restricted to one or to a definite number of years, after which the oldest existing phytomer perishes each year as a successive apical one is formed (Fig. 450, *b*).

Forms of Rhizomes.—Rhizomes are so numerous and important in pharmacy that their characters call for special attention. They are classed as short or elongated, the former term referring to those



Forms of rhizomes: Fig. 447. *Convallaria*, with annular roots: *a*, terminal bud. 448. *Cimicifuga*, its cup-shaped stem-scars much elevated. 449. *Podophyllum*, its internodes elongated. 450. *Polygonatum*, its cup-shaped scars depressed. 451. *Iris*, its roots aggregated at one end. 452. *Acorus*, with V-shaped leaf-scars.

the extreme length or shortness of which fall within certain fairly defined and restricted limits; the latter, those which either possess an indefinite extension, or the definite length of which is a great many times their thickness. Terms indicative of their form and consistency do not differ materially from those applied to other stems and to roots. They are almost always sympodial. They are very subject to flattening, the flattened surfaces usually looking upward and downward. The presence or absence of branches is always characteristic. The manner in which the roots take their origin is equally so. These may form a circle (Fig. 447) or be restricted to the under surface (Fig. 449). The number of roots developing from a node is usually fairly characteristic. So is the persistency or brittleness of these, and the characters of the stumps or scars which they leave, as well as their form, which is very often triangular or quadrangular in section. Their structure, as observed either with the lens or with the microscope, is characteristic and of diagnostic value. Sometimes the roots are not only restricted to a certain portion of the node, but in the case of short rhizomes are restricted to a definite portion of the latter (Fig. 451). The relative length of the internodes of a rhizome, as compared with its diameter or thickness, calls for close attention, and so does the absolute or measured length. The relations of the erect portions to the horizontal, and the stumps or scars left by the former upon their death or separation, constitute one of their most important diagnostic characteristics. Commonly, disarticulation occurs, with the production of a cup-shaped scar. This scar will be characteristic as to whether it form a depression in the general surface (Fig. 450) or be elevated upon a base (Fig. 448), as will the length of the latter, the form and depth of the scar, and the character of its edge. The size of the scar, that is, its lateral breadth as compared with the thickness of the internode, is also noteworthy. Leaf scars, or leaf remains, upon rhizomes call for the same examination as do the stem scars. They may surround the entire rhizome, in which case they are designated Annular, or they may be confined to the upper surface. If the latter, the scar may be of characteristic form, as linear, elliptical, circular, cordate, crescent-shaped, or V-shaped (Fig. 452, *a*). Finally, we note that annular or longitudinal folds, thickenings, wrinkles, or constrictions are characteristic of certain rhizomes as well as of roots, particularly in the dried state.

Mode of Extension.—*Simple and Branched Stems.*—As to their mode of extension, stems may be Simple or Branched. A stem denominated as simple is not necessarily entirely destitute of branches, as floral branches or small branches near the summit are permitted. It has already been shown that stems may develop monopodially or sympodially. The stem of a tree which continues, except in case of accident, to develop monopodially, as the Fir, is called Excurrent. One which after a time loses its main stem in a number of branches, as for instance the elm, is Deliquescent.

Acaulescent Plants.—The term Acaulescent, while strictly meaning stemless, can, of course have no such application, as all flowering plants possess a stem, even before germination occurs. The term is applied to those plants whose stems are so short as not to become conspicuous.

The Crown.—The stem of such a plant is called a Crown. The term crown is also applied to the branching or leafy portion of any stem.

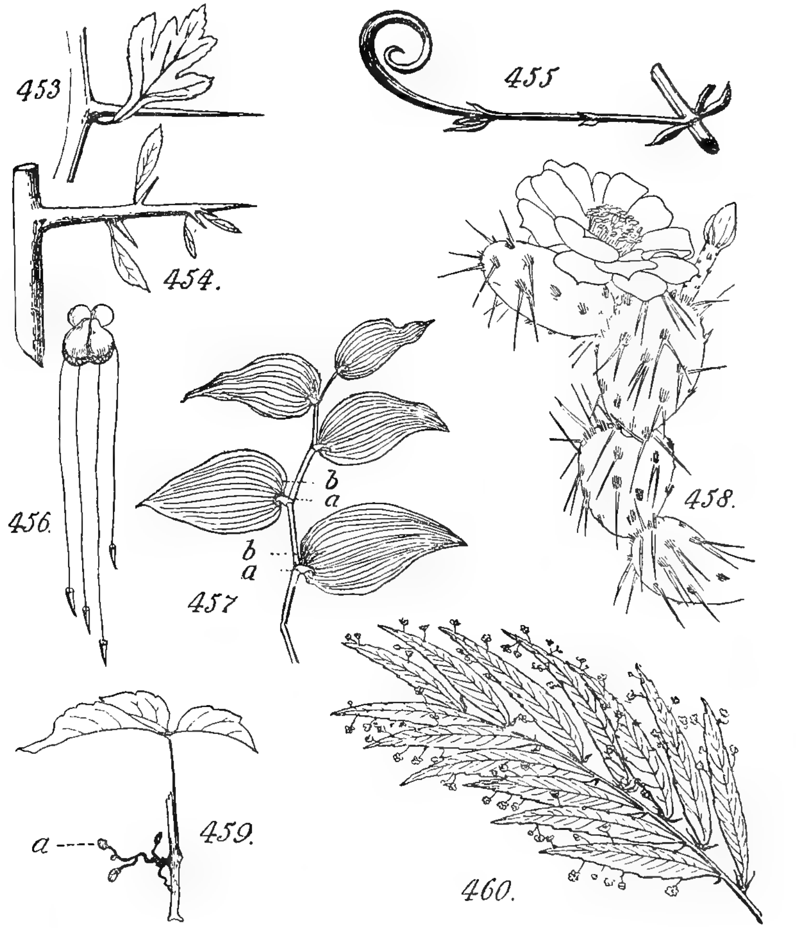
Trees, Shrubs, and Undershrubs.—A plant possessing a woody and erect stem rising singly to the height of fifteen (according to some authorities, twelve) feet or more is denominated a Tree, or Arborescent plant, although the precise application of such a term is impossible. A perennial woody stem which has not these characters is called a Shrub or a Fruticose stem. Very small shrubs appearing on causal inspection as herbs are called Undershrubs or Suffruticose plants.

Direction of Growth and Nature of Support.—As to the direction of their growth and the nature of their support, stems may be Erect, in which case they are erect through their entire length; Ascending, in which case the base for a greater or less distance rests upon the ground, the terminal portion becoming erect; Horizontal, in which case they are considered as having no other support than the parent stem, from which they extend at a right angle; Drooping, in which case they are first horizontal, the outer portion becoming pendant; Pendant, or "Weeping," when they are pendulous from their point of origin or almost therefrom; Decumbent, when at first erect or supported by the parent, the outer portion declined so far as to rest upon the ground; Reclining, when resting upon some means of support elevated above the earth, as over the tops or branches of other plants; Procumbent, when resting at full length upon the ground without rooting at the joints; Repent, or "Creeping," when prostrate and rooting at the joints (Fig. 445); Twining, when supporting themselves by the twining of the stem itself around a support; Climbing, when elevating and supporting themselves by other methods than a twining habit, the principal forms being the Cirrhiferous, when climbing by tendrils (Fig. 431), and Aculeate, when climbing by hooks (Fig. 436).

Modification of Form or Function.—*Modified Stems.*—As to modification of form or function, stems are subject to a somewhat elaborate classification.

They may be modified for the purpose of defence, that is into thorns or spines (Fig. 453), although not all thorns or spines are transformed branches. Some branches of this form remain so permanently, while others become foliaceous later and develop into branches of the ordinary form (Fig. 454).

For the purpose of climbing, they may become cirrhose, that is, converted into Tendrils. The tendril may consist of the apex of the



Illustrating modified stems: Fig. 453. Branch converted into thorn. 454. The same becoming leafy. 455. Branch of *Strychnos*, becoming a tendril. 456. Stem of *Lemma*, modified like a leaf. 457. Branches of a species of *Asparagus*, modified as leaves. 458. Condensed stems of *Opuntia*. 459. Branches of *Ampelopsis* metamorphosed into disks. 460. Branches of *Phyllanthus*, modified like leaves, but flower-bearing.

primary stem (Fig. 431), or one of the branches may become the tendril, as in *Strychnos* (Fig. 455). In the latter case the tendril will stand in the axil between leaf and stem; in the former it will stand upon the opposite side of the stem from the leaf, for reasons already explained. A stem may instead become converted into a sucking disk, as in the case of *Ampelopsis* (Fig. 459, *a*). In this case the tip of the branch or stem becomes flattened and attaches itself very tightly to the supporting surface; so tightly, in fact, that a portion of stone or a splinter of wood may be torn from its support before the disk can be made to separate from it. Plants which grow in the water or in places subject to inundation may have portions of their stems inflated into bladdery forms to insure a floating condition. Such structures are, however, more commonly of a leafy nature.

Cladoidia or Cladophylla.—Stems may become modified for the performance of the office of leaves. Such a stem is called a *Cladoidium* or *Cladophyllum* (Figs. 457 and 460). For this purpose the whole stem may become modified into a single leaf-like organ, as in the case of certain aquatics, in which case it is known as a Frondose Stem (Fig. 456). Upon the other hand, separate portions of the stem or separate branches thereof may become thus modified, as in the case of the so-called "leaves" of the species of *Asparagus* cultivated as a decorative plant under the name of Smilax (Fig. 457: *a*, leaf; *b*, branch). Sometimes a stem or a joint of one, at the same time that it becomes modified to perform the office of a leaf, performs the ordinary offices of a stem, or important storage functions as well, as in the case of the *Opuntia* (Fig. 458), and the *Phyllanthus* (Fig. 460). Such stems are called Consolidated. Branches like those in Fig. 460, modified to perform the leaf-function, are called *Phyllocladia.*

Many trees have been encountered by the author in tropical America, the stems and branches of which are hollow (denominated *fistulous*), affording permanent homes to myriads of ants, which, deriving their support from the tree, are supposed to confer some compensatory benefit upon it. They at least protect the tree against animal attacks, being in all cases extremely savage and venomous.

Besides such specially modified forms, a number of ordinary forms are characterized by the adjectives Terete, Cylindrical, Compressed, Triangular, Quadrangular, Alate or Winged, Costate or Ribbed, Channelled, Striate, and so on. In this connection the terms applicable to the superficial characters of barks already described, and those connected with leaf-attachment, to be described farther on, should be studied. In addition to the above-mentioned stem-forms, which admit of ready classification, we have a large number of modifications to effect special purposes, which must be considered individually. As these possess but a slight interest in relation to pharmacognosy, we refer the interested student to more general works on botany.

Storage Stems.—An important office of the stem is the storage of nutriment. All stems perform this office to a greater or less extent, but some are especially modified in form for the purpose. Of these, we have already specially referred to rhizomes and tubers.

The Bulb.—It remains, then, only to consider the various forms of the bud, including in this term all forms of the bulb. A bulb which, like the onion (Fig. 462), has its fleshy-thickened leaves in the form of broad sheathing organs, seen upon transverse section in the form of concentric rings, is called Tunicated or Coated. Those like the lily (Fig. 461), in which these leaves appear in the form of narrower projecting scales, are called Scaly. When in the axils of the scales we find

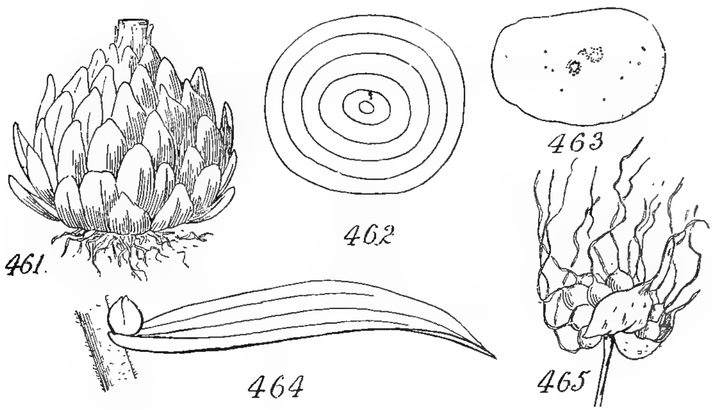


Fig. 461. Scaly bulb of *Lilium*. 462. Tunicated bulb of onion. 463. Corm of *Gladiolus*. 464. Axillary bud-bulb of tiger lily. 465. Terminal head of bulbs of onion.

smaller or secondary bulbs or buds, as in the garlic, it is a Compound bulb. When the texture of a bulb is so dense that its leaf-elements are not conspicuous, it is designated as a Solid bulb. When it is still more dense, as in the case of the Gladiolus (Fig. 463), so that the leaves are not to be distinguished by ordinary methods, it is a Corm. In some plants, the axillary bulbs, instead of occurring in the axils of the bulb-leaves, occur higher up in the axils of the ordinary foliage-leaves, as in the case of the tiger lily (Fig. 464). Their true nature as buds is in this case conspicuously shown, and they are sometimes spoken of as Bud-bulbs. In other related plants, similar bulbs are densely aggregated in a terminal umbel looking like an inflorescence, as in some species of onion (Fig. 465).

CLASSIFICATION OF BUDS

Buds proper admit of an elaborate classification, which, although not of such interest in pharmacognosy as to warrant its study here, is of fundamental importance in systematic botany, and furnishes a key to many problems which are otherwise abstruse.

Vernation and Praefoliation.—The study of buds is called Vernation, and that of the arrangement of the leaves composing them Praefoliation. In general, the arrangement of leaves in the bud admits of the use of terms similar to those applied to the parts of the perigone in a similar state.

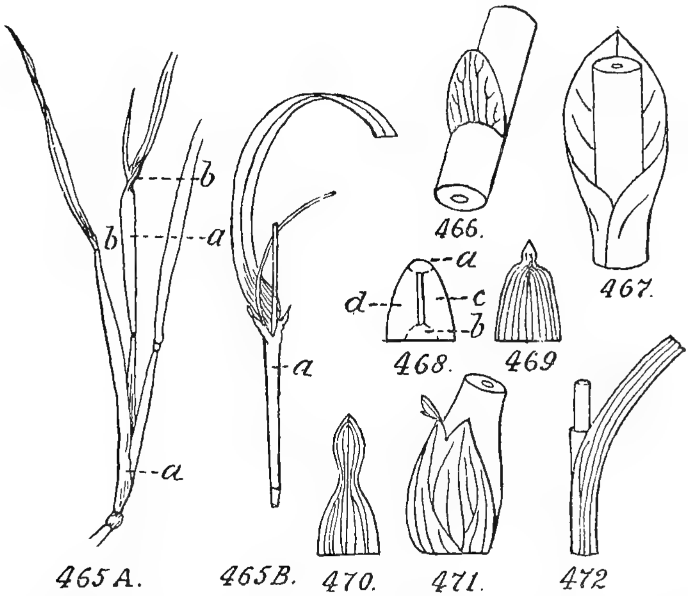
Classes of Buds.—Buds may be classified as to their structural form, their position, and parts.. A winter bud which protects itself by specially developed scales is known as a Scaly bud; one which does not, a Naked bud. A bud consisting only of leaves is a Leaf bud; one only of a flower, a Flower bud; one consisting of both, a Mixed bud. Solitary buds occurring in the axil of the leaf and developing at the regular time are called Normal buds. Any buds in addition to the normal bud, occurring in the leaf axil, are called Supernumerary. They may be situated above or at the side of the normal bud. The normal bud is sometimes situated a little above the actual axil, in which case it is called Supra-axillary. All the buds here noted are denominated Lateral, in contradistinction to the single terminal bud, but it is to be noted particularly that buds lateral as to their origin may become terminal through the effects of sympodial growth. Buds which develop at other points than the apex or axil—as, for instance, from an internode, a leaf, or, rarely, even from a root, as well as those of axillary origin, but developing out of their regular order—are called Adventitious. The latter form of adventitious buds, when resulting from retarded development, are known as Latent buds.

CHAPTER XVI

THE LEAF

Importance of Leaf-study.—To the pharmacognosist a thorough knowledge of the leaf is a necessity. Of its cellular structure, little can be learned without the aid of the compound microscope. Its gross parts were briefly referred to in our opening chapter, and these must now be studied in detail.

Development of the Leaf.—The varied forms of structure which leaves present can best be understood by considering them as modifications of an original or primary leaf and noting the changes in the latter which have occurred to produce them. It is apparent that such a primary leaf was a mere scale of small size, as indicated in Fig. 466. It then appears that any modern foliage leaf must have resulted either from the uniform growth and development of all the parts of such a scale, or from the greater relative growth of some one or more of its parts. The result of its uniform growth would be a leaf of the same form, but larger, its base sheathing the stem, as represented in Fig. 467. But leaves of this exact character are rare, from which it would appear that modern leaves generally represent unequal degrees of development of the different parts of the original leaf. Their attentive examination shows that the following parts of such a primary leaf have in different cases undergone independent enlargement and development. In Fig. 468, the portion *a*, cut off by the dotted line at the top, may represent the Apical region; that at *b* the Central-basal; the strip *a-b* the axial; and the remaining portions upon either side (*c* and *d*) the lateral. Let us assume first that the enlargement is confined chiefly to the central-basal portion. The base will then become converted into the form represented in Fig. 469, without the enlargement of the other parts there shown, this leaf being a mere sheath around the stem, bearing the original scale at its tip. Leaves of this form are rather common upon undeveloped or partly developed stems. They are called Leaf-sheaths, or often, for emphasis, Naked Sheaths. The edges of such a sheath may cohere after passing around the stem, giving us the Closed Sheath, as in the sedges (*a*, in Fig. 465 *B*), or they may remain free, giving us the Open Sheath of the grasses (*a*, in Fig. 465 *A*). Instead of passing around the stem, the edges may come together between the leaf and the stem, so as to produce a hollow tube, as in the *Sarracenia*. Let it next be assumed that the apical portion, as well as the central-basal, enlarges, with little enlargement of the axial or lateral portions. We shall then get a form in which a Lamina, or Leaf-blade, is superposed directly upon a Leaf-sheath. Such a leaf, expanded, would appear as in Fig. 470, if the blade were



Figures illustrating the origin and development of the parts of the leaf: Fig. 465 *A*. The grass-leaf: *a*, the open sheath; *b*, the ligule. 465 *B*. The sedge-leaf: *a*, the closed sheath. 466. The primordial leaf, a mere scale. 467. The same, as equally developed in all parts. 468. The same, divided into its different regions: *a*, the apical portion; *b*, basal portion; *c* and *d*, lateral portions with axial portion between. 469. The same, undeveloped except the basal portion, which becomes a sheath to surround the stem. 470. The same, with the apical portion also developed to form a blade, the lateral and axial portions undeveloped. 471. The same, with the lateral portions developed into stipules. 472. The stipules with their inner margins connate between the blade and stem, their outer connate around the stem, forming an upper sheath or ochrea. In 465 *A* they are connate only by their inner margins, between blade and stem, forming the ligule. (*Adapted from work of A. A. Tyler.*)

but little developed, or it might be developed equally in both parts. Both of these forms are frequently encountered. If now the lateral portions shall enlarge, the axial portion not much elongating, a lateral appendage must result at the base upon either side, as in Fig. 471. These are the Stipules. If the stipules, instead of existing separately in this way, shall incline together between the stem and the leaf, and their inner edges cohere, it is clear that they must form a small blade standing out upon the face of the leaf at its base, as *b* in Fig. 465 *A*. This is the Ligule. The free edges of the ligule may now pass around the stem, meeting and cohering upon the other side, thus forming a sheath above the basal portion, or true sheath (Fig. 472). Such a sheath is called an Ochrea. If, lastly, it be assumed that the axial portion *a-b* (Fig. 468) undergo an elongation much greater in proportion than the enlargement of the other parts, we shall have developed a long narrow division between the base and the lamina, as *c* in Fig. 3, which is the Petiole. It is thus seen that the view here taken will account for the origin of every part of the leaf. The few illustrations here shown refer only to certain combinations in the development of the different parts. As a matter of fact, such combinations found among existing leaves are innumerable, and this variety is increased by the fact that the growth in any one of these parts may be chiefly lateral or chiefly vertical, and that it may be confined wholly or chiefly to some special portion of the part. The student will, nevertheless, be able, by bearing in mind the typical possibilities here considered, to determine the plan of structure of most leaves. This view will also make clear the statement in the opening chapter in regard to the absence of the blade, petiole, or other parts from certain leaves.

It is interesting to note here that there is ample evidence to prove that the rudimentary or scale-like form of leaves existed upon the earliest flowering plants, so it would appear that the parts of their flowers were developed from such scale-leaves, rather than from the highly developed leaves which we now know. Against this, we have to consider that those floral parts were probably of correspondingly simple development, and that, in the higher plants of today, they have undergone a development which has kept pace with that of their leaves.

As to what constitutes the typical leaf, we are confronted by two views. Structurally considered, it must be such a leaf as represented by Fig. 467, but such leaves, as we now see them upon plants, do not apparently so well perform all the functions of the leaf as those which, like Fig. 3, have developed the modern leaf-parts.

The Leaf-Surfaces.—Very rarely has the leaf a terete form and a radial structure as seen in transverse section. Typically it is a flattened body. One flattened surface, the Ventral, faces upward or toward the stem which bears it, and is ordinarily spoken of as the upper surface. The under or outer surface is technically known as the lower or Dorsal. By a partial twist in the petiole, the surfaces may become laterally placed, the edges vertical. In a few leaves, the surfaces are normally in the latter position. Between the dorsal and ventral surfaces, there are usually differences sufficient to necessitate their description separately. In such descriptions, it is better to speak of the dorsal surface as being underneath rather than "below," as the latter term may confuse it with the basal region.

Anatomical Elements of the Leaf.—It has been shown that the leaf originates and develops as an extension of the periblem, covered by that of the dermatogen, and that it develops a stele which becomes continuous with that of the stem. In other words, its mode of development is precisely like that of a stem-branch. We have in it, therefore, all the elements which characterize primary stem-structure. The connection of the leaf with the stem is usually by a specially arranged and constructed tissue, forming a distinct organ, the pulvinus, which provides an articulation designed to afford a prompt and ready separation of the leaf at the conclusion of the performance of its function, as well as for certain movements and changes of position during life.

Just as branches of the cauline stele pass into leaf and branch, so do those from the foliar stele pass laterally into its expansions, and secondary and tertiary ones successively pass from them. These branches are very frequently joined at their distal ends to others (Fig. 525, *a*), as well as at their proximal ends to the parent system. Whether such is or is not the case, the result of the branching is the production of a framework or skeleton which forms a support to the parenchymatous tissue which fills its meshes and covers its surface, the latter being in turn covered by the epidermis.

Except as to the general characters which follow under leaf-classification, it is impossible to ascertain the structure of the cortex and epidermis of the leaf by ordinary methods, so that this subject is relegated entirely to the department of histology.

The Stipules.—Before proceeding to the study of the leaf-blade, which specially concerns us, certain peculiarities of the stipules, and of the petiole, may be considered. The original function of the stipules was probably to afford a protective covering to the bud. While this function still persists, it is doubtful if that of increasing the foliaceous surface has not come to be of greater importance. We should, therefore, expect them to develop tissues and forms resembling those of the leaf-blade, and such is the case, making them subject to the same classification and terminology in those directions as will be applied to the leaf-blade. They have, however, certain peculiarities of their own which here require attention. As to their presence or absence, leaves which possess them are called Stipulate; those which do not, Exstipulate. As they frequently fall with the expansion of the bud, there is great danger that a stipulate plant may be mistaken for one which is not.

As to their duration, in relation to the leaf-bud and leaf, the terms caducous, deciduous, persistent, and so on, are applied to them as to the parts of the perigone.

It has been shown that the two stipules of a leaf may unite with one another by either margin. They may also unite with either the petiole or margin of the leaf-blade, or with the stem of the plant, in which

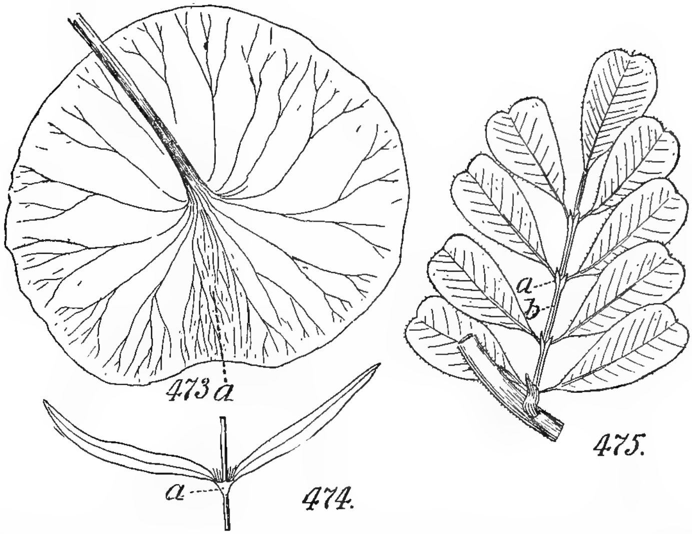


Fig. 473. Cordate leaf of *Nymphaea*, with the margins of the sinus connate at *a*. 474. Interpetiolar stipules of *Diodia*. 475. Stipulate compound leaf, with stipellate leaflets.

cases they are called Adnate. When leaves are opposite one another, the two stipules between them may unite with one another by their adjacent margins, forming the Interpetiolar Stipule (Fig. 474, *a*). Especial importance attaches to this class of stipules, because of the remarkable variation displayed in their subdivision and appendaging, and the great value of their characters in generic classification in certain families, especially in that highly medicinal one, the *Rubiaceae*.

In some cases, the stipules so closely resemble the foliage-leaves that, together with the blade, they present the appearance of a group of three leaves standing side by side. In the case of opposite leaves, this sometimes makes an apparent whorl of six similar leaves, or, through the union of the adjacent stipules, of four. In such cases, the leaves which are stipules can be distinguished from the others by their failure to develop axillary buds. The stipule is frequently transformed into one or more bristles, or even strong spines, and occasionally into a tendril (Fig. 565).

A secondary stipule, borne at the base of one of the divisions of a compound leaf, is called a Stipella (Fig. 475, *a*).

The Petiole.—Leaves possessing the Petiole; are called Petioled those wanting it are called Sessile (Fig. 478). Occasionally the petiole is present, but adnate to the stem of the plant, thus appearing wanting. In other cases, while quite free from the plant-stem, more or less of the base of the petiole will clasp it. Such a Clasping petiole must not be mistaken for a leaf-sheath, which, as we have seen, is not a true petiole at all, but the development of a different part of the primary leaf.

When the margins of the petiole throughout are herbaceous and in continuation with the blade, the petiole is said to be Margined or Winged.

When the margins of the petiole are less pronounced, but yet present and elevated, so as to form a groove upon its upper surface, the petiole is called Channelled.

Other characters of the petiole, such as its triangular or semicircular form in transverse section, its relative stoutness, and the character of its surface, need not be specially considered. Certain special modifications in the function of the petiole will be considered under modified leaves.

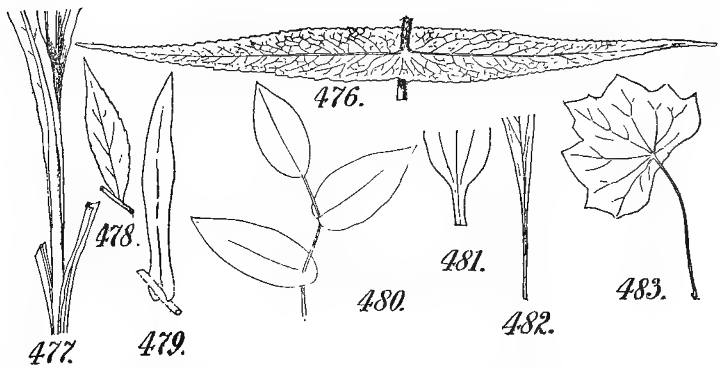
The attachment of the petiole to the leaf-blade is always really marginal, though by the cohesion of basal lobes (Fig. 473, *a*) it is often apparently intra-marginal or even central. Basal lobes may, upon the other hand, be adnate along the petiole, or the same appearance may be produced by the gradual differentiation of petiole into blade.

Petiolar Glands.—Glands of various forms often appear upon some part of the petiole, and their appearance is characteristic and of diagnostic value, as in distinguishing the species of *Prunus* and *Cassia*.

Duration and Retention upon the Plant.—As the duration of the leaf and its retention upon the plant have to do in part with the nature of the petiole, it may be here considered. Leaves are Annual, and the plants producing them deciduous, when their duration is through a single season only, and Evergreen, when they remain in their normal and active condition into the succeeding season. Evergreen leaves may be either biennial, the ordinary form, or perennial. Persistent leaves are those which remain upon the tree, but in a dead condition, being usually forced off by the growth of the following season.

The Lamina.—Coming now to the consideration of the leaf-blade, we note that it is to be studied, and its varieties classified, with regard to its relation to its support, its texture, surface, form—this including the general outline as well as special forms of apex and base—venation, margin, division, and modification of form and function.

Relation of the Leaf-base to the Plant-stem.—When a petiole or a lamina has grown fast for a portion of its length to the plant stem, it is called Adnate (Fig. 477). One whose base is heart-shaped and surrounds the plant stem, whether growing fast to it or not, is called Amplexicaul



Modifications of the leaf-base: Fig. 476. Connate-perfoliate (boneset). 477. Adnate to plant stem (*Verbascum*). 478. Sessile (*Solidago*). 479. Amplexicaul (*Aster Novae-Angliae*). 480. Perfoliate (*Oakesia*). 481. Margined (*Plantago*). 482. Continuous. 483. Intramarginal-peltate.

or Clasping (Fig. 479). When the basal lobes of a clasping leaf entirely surround the stem and become connate upon the other side, so that the stem appears to be growing up through a perforation in the leaf, the leaf is called Perfoliate (Fig. 480). When opposite leaves are connate by their bases they are called Connate or Connate-perfoliate (Fig. 476). When the bases of sheathing leaves clasp the stem in such a manner as to present a V-shape in transverse section, and one is superposed upon another in the same manner, they are called Equitant.

Relation of the Base to the Petiole.—As to the attachment of the blade to the petiole, the leaf is Peltate when this insertion is intra-marginal through the connation of the edges of basal lobes. A peltate leaf may be Centrally (Fig. 473), or Eccentrically (Fig. 483) peltate. When the petiole changes so gradually into the lamina that it is impossible to say where one begins and the other ends, we say they are Continuous (Fig. 482).

Texture.—As to their texture and consistency, the ordinary form of leaf, in which it possesses active chlorophyll tissue, is denominated Herbaceous, in contradistinction to the Scarious or Scariose form, in which it has a dry and papery texture. Herbaceous leaves are Membranaceous in their ordinary form, that is, not excessively thickened, Coriaceous when tough and leathery, Fleshy or Succulent when largely parenchymatous, thickened, and juicy. A leaf which exhibits translucent dots when held against a strong light, due to the presence of oil-glands, is called Pellucid-punctate.

Surface.—The surfaces of leaves may be classified in two ways: First, as to the characteristics of the individual trichomes which they bear; second, as to the general surface effects (Indumentum) which result from the latter. The former method, although it cannot be taken up in this part of the work, is of very great importance in the characterization of medicinal herbs and leaves, especially as it constitutes one of the greatest aids to the identification of powders. The latter method can only be studied with advantage by the actual examination of typical specimens, it being almost impossible to characterize the different forms by definition. A surface is Opaque when it is not shining or lustrous. It is Glabrous when it does not possess any trichomes in such forms as to detract from the smoothness of the surface. It is Glaucous when covered with a waxy exudation, imparting to it a peculiar whitish appearance ("bloom"), such as characterizes the surface of an ordinary black grape. It is Scurfy when covered with more or less of an indumentum in the form of granular or detached scaly masses. When the matter of such masses is more thinly distributed, appearing in the form of a powder rather than a scurf, the surface is called Pulverulent.

A Pubescent surface is a hairy surface which is not readily distinguished as pertaining to any one of the other specific classes.

If the hairs of a pubescent surface are very short and fine, so that the consequent roughness is reduced to a minimum, the surface is called Puberulent.

If a hairy indumentum is fine and of an ashy-gray color, the hairs not arranged in any regular direction, the surface is Cinereous.

If the hairs all lie in one direction, are closely appressed, and have a shiny or silky luster, the surface is called Sericeous.

If this luster is intensified and of a strongly whitish color, whether the trichomes be hairs or scales, the surface is denominated Argenteous.

Such hairs as are capable of producing a sericeous surface are themselves denominated sericeous or silky, even though they be in insufficient numbers to impart this character to the general surface.

A surface tending toward the sericeous, but not sufficiently pronounced, is called Canescent.

When there is a dense covering of more or less elongated and matted hairs, the surface is called Tomentose.

When such a covering is thin, its hairs less elongated, it is called Tomentellate.

Whene there is a covering of thinly distributed, elongated, moderately soft hairs, which are not closely appressed, the surface is Pilose.

When hairs are similarly distributed, but are elongated and coarse, the surface is Hirsute.

When similar coarse hairs are rather stiff, lie in one direction, somewhat appressed, and particularly when each develops from an elevated base, the surface is Strigose.

A surface which possesses an indumentum of scales is called Lepidote.

A surface is called Papillose when it is minutely warty, or tuberculate, due usually to glands underneath the surface.

When the indumentum consists of hard, elevated points, giving a roughness to the surface, the latter is Scabrous.

When such elevations are more pronounced, unyielding, and sharp-pointed, the surface is Hispid.

A surface which is roughened by the presence of numerous, closely-set wrinkles is Rugose.

When a surface is made up of small, blister-like elevations consisting of the arching interspaces between the veins, it is Bullate (Fig. 484). The opposite surface, containing the cavities of the bullae, is called Cancellate (Fig. 485).

When the hairy covering is chiefly confined to the margin, presenting itself in the form of a fringe of hairs, the term Ciliate is applied (Fig. 475).

A surface which is marked by spots differing in color from the remainder of the surface is called Maculate. If spots of any kind be small and dot-like, the term Punctate is applied.

Finally, it is to be noted whether the veins or ribs, and if so which of them, are prominent upon both sides or either side, or whether, upon the contrary, they are depressed (called Impressed) below the general surface. At times a rib or vein will not be impressed, but will yet be Channelled, and may appear impressed upon casual observation.

By the outline of the leaf, we refer to the general form of its margin, whether that be entire, or not. If not, then the general form of an outline is determined by connecting the extreme points of its margin with one another (Fig. 486, an obovate outline). It matters not, therefore, whether a leaf be entire, toothed, lobed, or parted, or even if it be entirely compound or decompound, its outline will be the same, provided a line connecting its extreme marginal points with one another possess a given form. The forms of leaves on this basis may be divided into three general classes—(*a*) those broadest at or about the middle, (*b*) those broadest at some point above the middle, (*c*) those broadest at some point below the middle.

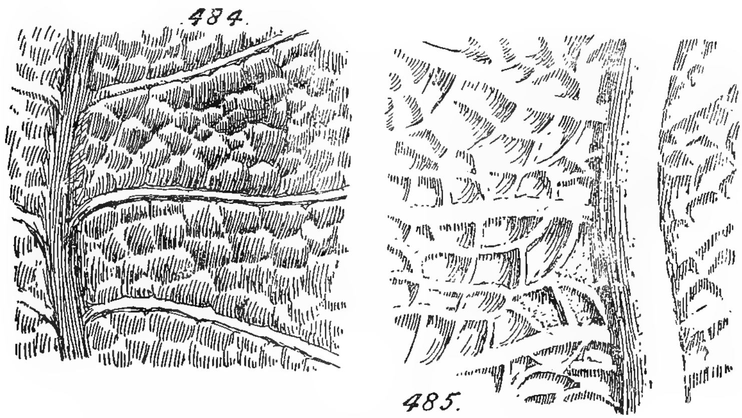


Fig. 484. A bullate upper surface. 485. A cancellate lower surface.

Of the first class, beginning with the narrowest, we have the Capillary or Hair-like forms, the Filiform or Thread-shaped (Fig. 491), the Acerose or Needle-shaped (Fig. 492), as those of the pine, and the Linear or Ribbon-shaped (Fig. 487), all of which are so elongated that they present the appearance of being about of uniform width throughout.

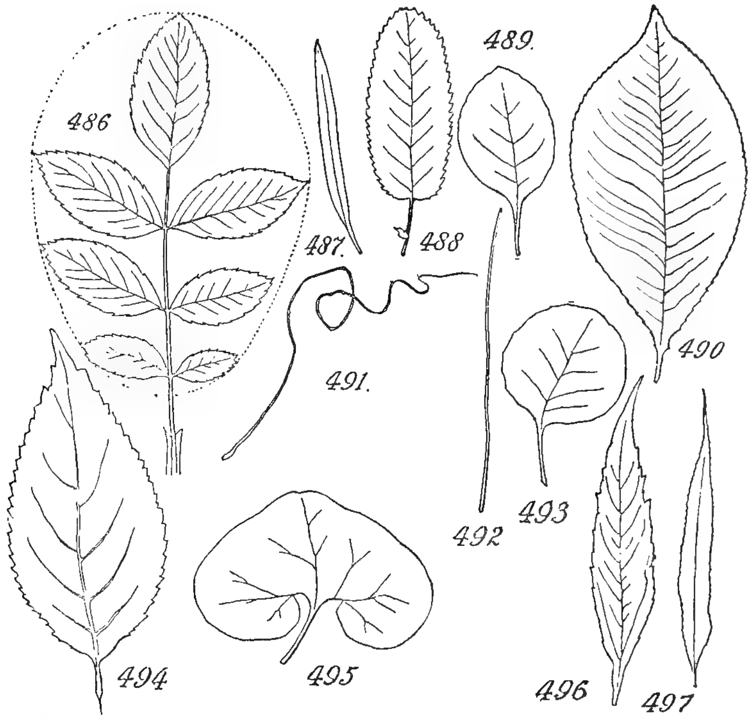
A leaf similar to but shorter than the linear, in proportion to its breadth, without regard to the character of its apex or base, is Oblong (Fig. 488).

One of similar form, but having a length of not more than twice or thrice its breadth, and narrower than a circle, is Oval (Figs. 489 and 490), a term which must not be confounded with Ovate.

If an oblong or an oval leaf possess a regularly rounded outline into and through the apical and basal portions, it is called Elliptical. We have, therefore, two forms of the elliptical leaf, denominated respectively Oblong-Elliptical (Fig. 488) and Oval-Elliptical (Fig. 489).

A circular leaf (Fig. 493) is called Rotund or Orbicular.

Finally, we have the leaf which is broader than circular—that is, its lateral diameter is greater than its vertical, and this is called Transversely Elliptical.



Leaf outlines: Fig. 486. Obovate compound leaf of rose. 478. Linear leaf of *Linaria*. 488. Oblong-elliptical (*Poterium*). 489. Oval elliptical (*Pyrola*). 490. Imperfectly oval (*Prunus*). 491. Filiform (*Drosera*). 492. Acerose (*Pinus*). 493. Rotund (*Pyrola*). 494. Ovate (*Collinsonia*). 495. Reniform (*Asarum*). 496. Lanceolate (*Solidago*). 497. Lancelinear (*Salix*).

Forms Broadest below the Middle.—Those which are broadest at some point below the middle or above the middle should, in description, besides being designated by the class-name of their form, have it specified in some way as to about the portion at which the greatest breadth occurs.

Beginning with the broadest ones, we have that which is broader than long and with a heart-shaped base, called Reniform (Fig. 495).

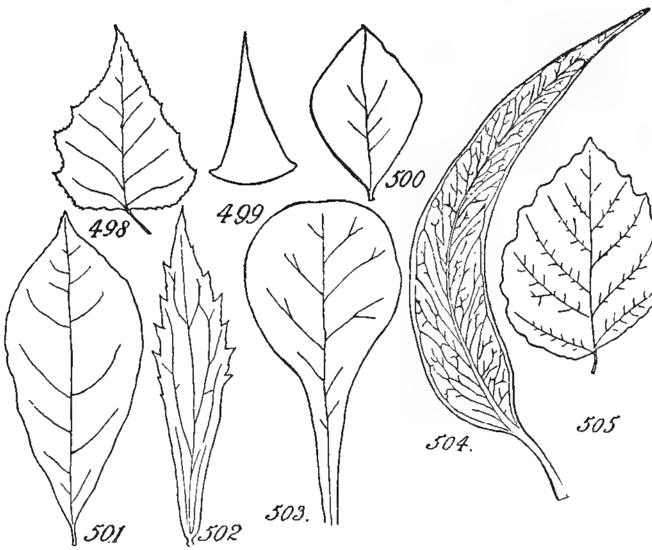
One which possesses a length greater, but not more than two or three times its breadth, is called Ovate (Fig. 494).

One of similar form, but its comparative length greater, is called

Lanceolate (Fig. 496). One which is ovate, but with the greatest breadth at the very base, the margins not or but little curved, so that it is approximately triangular, is called Deltoid (Fig. 498).

One still narrower, but of similar form, bearing the same relation to the lanceolate which the deltoid does to the ovate, is called Subulate, or awl-shaped (Fig. 499).

An ovate or oval leaf whose outline, instead of being regularly curved, is made up of four comparatively straight lines is called Trapezoidal or Angularly-ovate. Another term which is applied to it is Rhomboidal (Fig. 500).



Leaf outlines: Fig. 498. Deltoid (*Betula*). 499. Subulate (diagrammatical). 500. Rhomboidal (*Chekan*). 501. Obovate (*Lindera*). 502. Oblanceolate (*Solidago*). 503. Spatulate (*Antennaria*). 504. Falcate (*Eucalyptus*). 505. Inaequilateral (*Hamamelis*).

Forms Broadest above the Middle.—Most of the forms just referred to are paralleled by exactly similar forms in which the widest portion is above the middle. The names for these are formed by prefixing the syllable *ob* to the corresponding names of the other forms; as, Obovate (Fig. 501), Oblanceolate (Fig. 502).

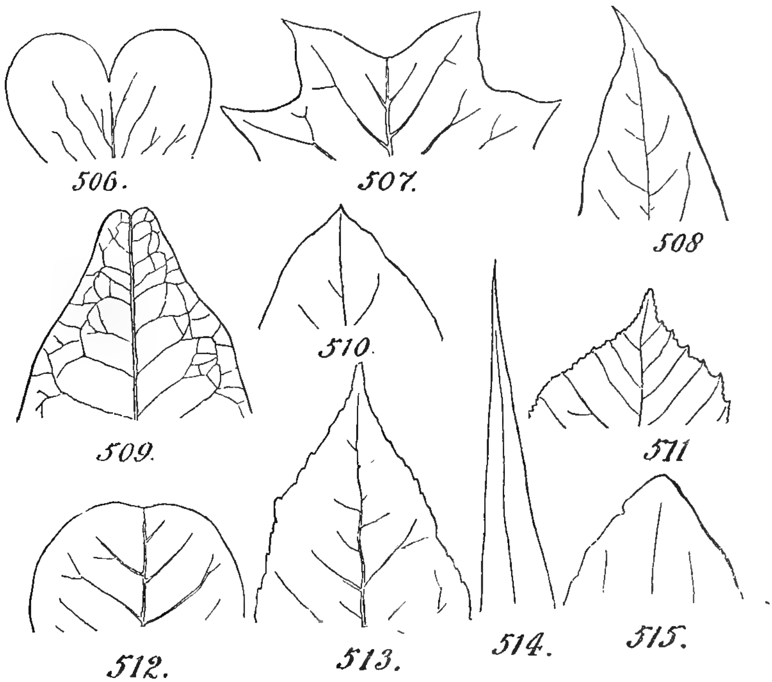
When an Obovate or Oblanceolate leaf possesses a broad, rounded apex, and a somewhat elongated lower portion, it is called Spatulate (Fig. 503).

The outline of a leaf is greatly modified when the portion upon one side of the midrib is longer or broader than that upon the other, giving us Inequilateral, Unequal, or Oblique forms (Fig. 505).

When such a leaf has its midrib laterally curved, it is styled Falcate or sword-shaped (Fig. 504).

Modifications of this as regards the comparative length and breadth of the leaf are Sickle-shaped and Scimeter-shaped.

Forms of the Apex.—A large number of terms are employed to indicate especially the form of the apex of the leaf.



Forms of apex: Fig. 506. Obcordate (*Oxalis*). 507. Notched (*Liriodendron*). 508. Abruptly acuminate and acute (*Ailanthus*). 509. Emarginate (*Pilocarpus*). 510. Acute (*Lonicera*). 511. Abruptly pointed (*Ulmus*). 512. Retuse. 513. Abruptly acuminate and obtuse (*Fraxinus*). 514. Tapering (*Panicum*). 515. Blunt (*Plantago*).

Beginning with one which is inversely cordate—that is, with the sinus at the Apex—we have the Obcordate form (Fig. 506). When the sinus is smaller, it is called Emarginate (Fig. 509), and when very slight, Retuse (Fig. 512). If the sinus be an angular one with straight sides, it is called Notched (Fig. 507). If the apex be abruptly terminated, as though cut across in a straight line, it is called Truncate. If any portion of the apex of the leaf be narrowed into a point, the leaf is called Pointed (Fig. 511, etc). If such narrowing be gradual, so that the point is considerably longer than broad, it is called Acuminate. If the acumination is preceded by an abrupt contraction, it is distinguished as being Abruptly Acuminate (Figs. 511 and 513).

If the narrowing be very gradual and not preceded by an abrupt contraction, the apex is said to be Tapering (Fig. 514); if still more drawn out, Attenuate. If the point of the leaf be extremely abrupt and very small, it is Mucronate when soft and herbaceous, Cuspidate when hard and stiff, like a tooth.

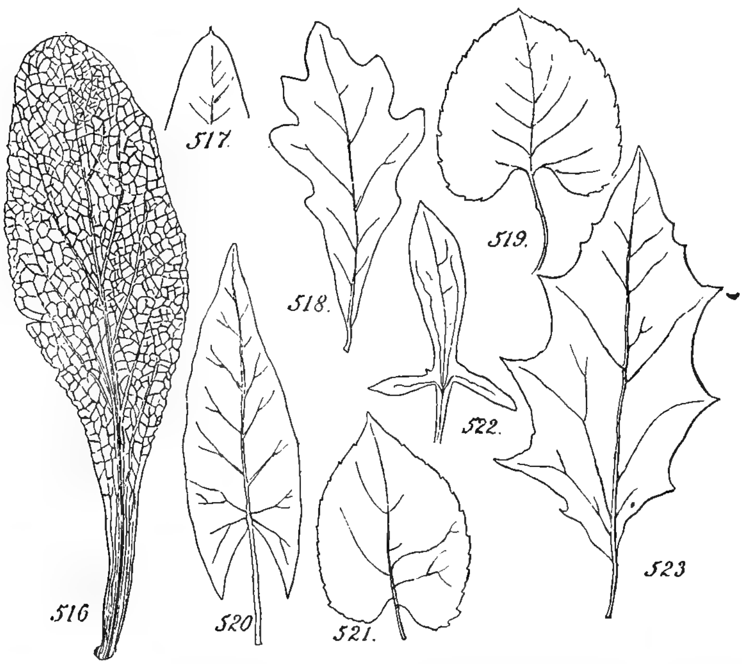


Fig. 516. *Digitalis* leaf, with produced base, rounded apex, reticulate venation. 517. Apiculate apex. 518. Cuneate base (white-oak). 519. Cordate and produced base (violet). 520. Sagittate base (*Polygonum*). 521. Auriculate base (*Aster*). 522. Hastate base (*Rumex*). 523. Oblique base (*Datura*).

Any of the above-mentioned forms may be either Acute, when the ultimate apex is sharp (Figs. 508, 510, and 514), Obtuse when not so (Figs. 511 and 513), Blunt when very obtuse (Fig. 515), or even Rounded (Fig. 516).

A leaf which has the midrib only extended into a bristle-shaped point is called Apiculate (Fig. 517), and this condition can apply to a cordate as well as to other forms of the apex.

Forms of the Base.—The special forms of the base of the leaf-blade yield a correspondingly large number of terms. The terms cordate, truncate, rounded, blunt, obtuse, acute, acuminate, and abruptly acuminate, require no definitions in addition to those which have been applied to similar forms of the apex.

When the two sides of the base are straight, and come to an acute point, it is called Cuneate or Wedge-shaped (Fig. 518).

A base the form of which yields later to a sudden downward prolongation or acumination is called Produced (Figs. 516 and 519).

In all forms of the cordate base the greatest care must be taken to specify the precise character both of the sinus and of the lobes. The former must have its form or outline specified, as well as the angle which it makes. It should, moreover, be carefully noted whether the leaf-base at the summit of the petiole be produced into the sinus, in which case it is called Intruded (Fig. 519). Sometimes the lobes of a cordate base will meet one another, or even overlap.

The forms of the lobes are also capable of taking descriptive titles similar to those characterizing the lamina in general. The principal of such terms are Auriculate, when the lobes are rounded similarly to the lobe of the human ear (Fig. 521); Sagittate, when pointing downward, and acute, like the lobes of an arrow head (Fig. 520); Hastate or Halberd-shaped, when turned outward (Fig. 522).

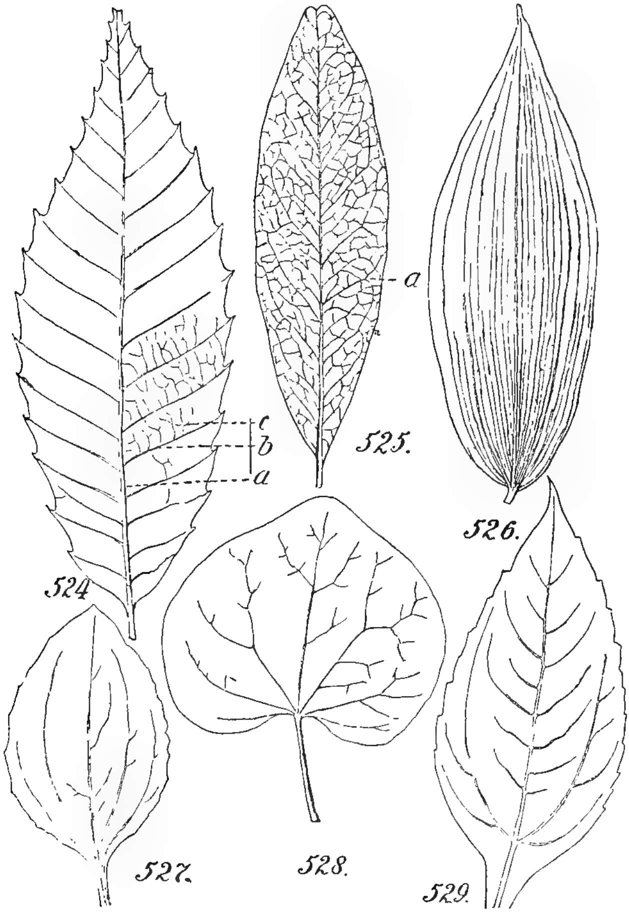
A base is Oblique or Inequilateral when descending lower upon one side than upon the other (Figs. 521 and 523).

Venation or Nervature.—Bundles which obviously separate from one another at or near or below the base of the blade, and maintain their course well toward the apex or margin, are called Costae or Ribs if equally prominent (Fig. 527), nerves if lateral and markedly less prominent than one or more of the central ones (Fig. 529).

The central one, whether there be others or not, is the Primary or Midrib (Fig. 524, *a*). Branches or ribs or nerves are called Veins, and they are distinguished as Secondaries (*b*) when departing from the midrib, Tertiaries (*c*) when departing from Secondaries, and so on. In palmately veined leaves, the central is called the Middle Primary, the other, the Lateral Primaries. The middle one is here also called the midrib, if distinctly stronger than the others. Secondaries of lateral ribs or nerves must be especially so designated in description. Very small veins are called Veinlets.

The greatest importance in descriptive terminology pertains to the classification of leaf-venation, owing to the frequency with which leaves must be identified in such a fragmentary state that there is little beyond the surface and venation, with possibly a portion of the margin, to assist us.

The forms all fall within two principal classes, which, in general, characterize respectively the monocotyledons and the dicotyledons. The former bears its principal veins more or less parallel with one another, and these are numerous. Such leaves are called Parallel-veined (Fig. 526).



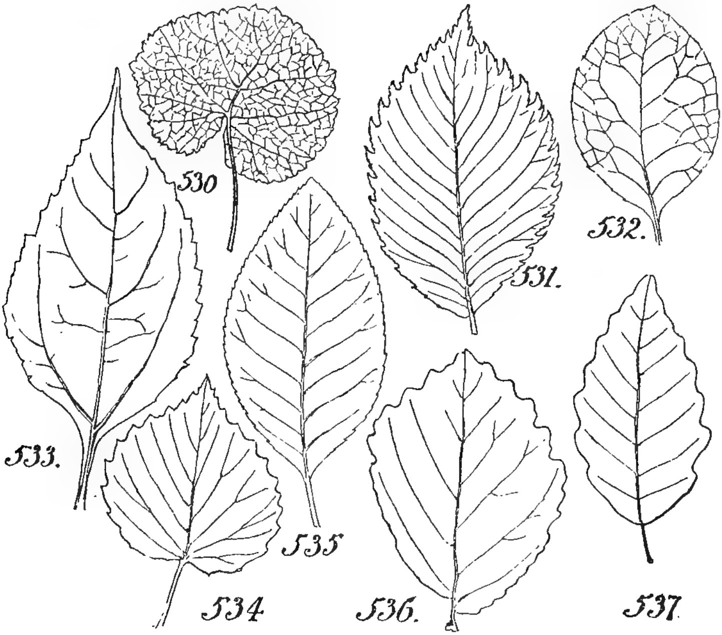
Venation or Nervature: Fig. 524. Pinnately veined leaf of *Castanea*: *a*, midrib; *b*, secondaries; *c*, tertiaries. 525. Reticulate leaflet of *Pilocarpus*: *a*, anastomosis of secondaries. 526. Parallel-veined leaf of *Convallaria*. 527. Flabellately costate leaf of *Plantago*. 528. Digitately veined leaf of *Cercis*. 529. Costinerved leaf.

In the second form there is but one, or a comparatively few original veins, and these give rise to successively developed branch systems, the whole forming a network or Reticulum. Such leaves are called reticulated or Netted-veined (Fig. 524, etc.). These veins may or may not anastomose or intercommunicate at their distal ends. When they do, the term Reticulate is applied to them in a special or restricted sense (Fig. 525). In leaves of the last-named class the details of the method of intercommunicating are very important. Thus, in some cases, the end of each secondary is arched upward into the secondary next above (Fig. 525). In such case it is important to note the comparative distance from the margin at which the communication takes place and the angle at which the two meet, as these characters are always constant in the same species. In other cases the secondaries (or the ribs, as in Fig. 568) are directly connected by straight and parallel secondaries or tertiaries, or in still others (Fig. 516) by an irregular intervening network of small veins. Secondaries connected by the first method are usually also connected near the base with the midrib by a number of curved tertiaries.

When the principal veins or nerves of a leaf are straight, it is called Rectinerved; when curved, Curvinerved. The latter term refers to a regular and characteristic curve, not to a crooked course. Some leaves are characterized by possessing waving or crooked nerves or veins.

Two great classes of netted-veined leaves are recognized, the one in which there is a main Rachis or midrib, from which secondaries extend regularly toward the margin. This form is known as the Penninerved or Pinnately veined leaf (Fig. 524). The number of pairs of secondaries, whether they originate exactly opposite to each other or somewhat irregularly, is within fair limits characteristic of the species, and should be stated. The same is true of the angle at which they radiate from the midrib. In the case of additional ribs or nerves of such a leaf, their number and stoutness as compared with the midrib, their comparative length and the position which they take in the leaf are all important. The second great class of netted-veined leaves is that in which a number of approximately equal ribs radiate from the basal region. Such leaves are known as Palmately or Digitately Veined (Figs. 527 and 528). There are, of course, many forms of intergrading (Figs. 529 and 568) between such leaves and pinnately veined leaves with secondary ribs or nerves. Sometimes the nerves start from the very base of the leaf, in which it is called Basinerved (Fig. 528); at others from the lower portion of the midrib, when it is called Costinerved (Fig. 529). When the ribs or nerves are manifestly continued downward into the petiole, the leaf is called Flabellately nerved (Fig. 527).

The Leaf-margin.—The manner in which the leaf-margin comes to deviate from an entire condition has already been indicated. Three special forms of toothing are recognized, in accordance with the form and direction of the teeth. When the latter point in an outward direction the margin is called Dentate (Fig. 534); when toward the apex of the leaf, Serrate (Fig. 533). When, instead of being pointed, the teeth are rounded, the margin is Crenate (Fig. 530).



Margins: Fig. 530. Crenate (*Dalibarda*). 531. Doubly serrate, the teeth appressed (*Ulmus*). 532. Obsoletely serrate (*Gaultheria*). 533. Serrate. 534. Dentate (*Viburnum*). 535. Serrulate (*Viburnum*). 536. Repand (*Hamamelis*). 537. Sinuate.

Diminutives of these terms, indicating that the teeth are very small, are Denticulate, Serrulate (Fig. 535), and Crenulate. To any of these terms the word "Minutely" may be prefixed as indicating that the teeth are still smaller. Of each of these three principal forms there are a number of sub-forms.

When the teeth bear smaller or secondary teeth, the word "Doubly" is prefixed (Fig. 531, doubly serrate).

When serrate teeth have their points very strongly directed toward the apex or appearing as though pressed inward against the margin, they are called Appressed (Fig. 531, partly). They may even be Incurved. When, upon the other hand, the ends of the teeth are turned outward, they are called Salient. When the points of the teeth are very fine and produced in the form of bristles they are called Spinulose (Fig. 524).

When a margin shows indications of being dentate, serrate, or crenate, but the teeth are not distinctly pronounced, the adjective Obscurely is prefixed. For this word that of "Obsoletely" is substituted when the leaf possesses a relationship such as to make it probable that its ancestral forms were more strongly characterized by this condition (Fig. 532).

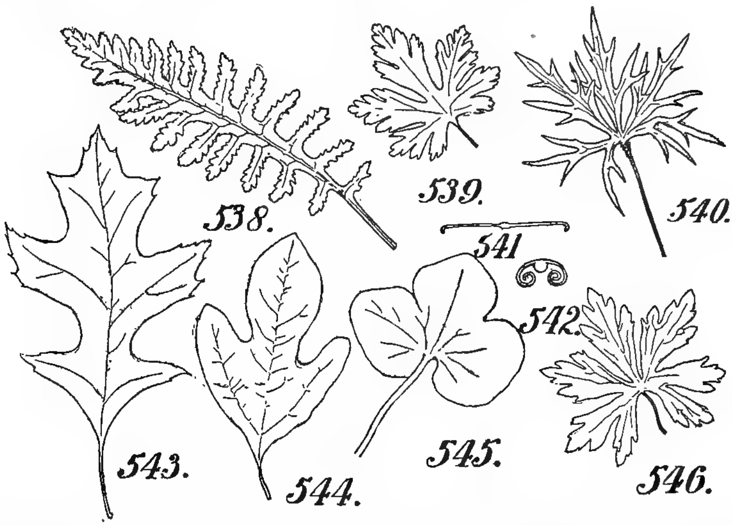


Fig. 538. Pinnatifid (*Pedicularis*). 539. Palmatifid (gooseberry). 540. Laciniately divided (buttercup). 541. Slightly revolute. 542. Strongly revolute (*Rosmarinus*). 543. Lobed, the lobes acute, the sinuses obtuse (*Quercus*). 544. Both lobes and sinuses obtuse (*Sassafras*). 545. Lobes obtuse, sinuses acute (*Hepatica*). 546. Incisely parted (*Geranium*).

When the teeth and their sinuses are all connected in such a way that the margin represents a wavy line, the latter is called Repand or Undulate, or Sinuate (Figs. 536 and 537). When a leaf is so deeply toothed that the sinuses reach well toward the middle portion (Figs. 543 to 545) the term Lobed is substituted for those above defined.

When the division, by a sharp sinus, extends more than half-way to the middle, yet not very near to the midrib, it is called Cleft (Fig. 539).

When reaching almost to the midrib (Fig. 538) or to the base in case of a digitate leaf (Fig. 546), it is called Parted, and when all the way, Divided (Figs. 540 and 559). The divided leaf is, however, not the same as the compound leaf, inasmuch as the separation of its blade into distinct leaflets is not complete. (Compare Figs. 547 and 555.)

The cleft, parted or divided leaf, is either Pinnatifid (Figs. 538, 556, etc.) or Palmatifid (Figs. 540 and 546), according to the character of its venation. In all forms of lobed, cleft, parted or divided leaves, it is necessary that the detailed characters of the lobes and of the sinuses should be specified. The lobe may be acute, while the sinus is rounded (Fig. 543), or the reverse may be true (Fig. 545), or both may be acute or both obtuse (Fig. 548). The sinuses as well as the lobes frequently possess definite and characteristic outlines, indicated by terms such as have already been defined in connection with the leaf. When the teeth and sinuses are outlined by straight lines and sharp terminations, as though notched out by a pair of scissors, the margin is said to be Incised (Figs. 540 and 546). When the divisions and sinuses are long and narrow in addition to being incised, it is called Laciniate (Fig. 540). When the margin of a leaf is turned downward or backward or rolled backward, it is said to be Revolute. Ordinarily the revolution is very slight (Fig. 541), but occasionally, particularly upon drying, it will be found extreme, each half of the leaf forming a roll, the two meeting back of the midrib (Fig. 542).

Before proceeding to speak of the forms of compound leaves, it should be stated that when one of the terms above defined (and the same is generally true of descriptive terms used in other parts of the work) terminates in the ending *ate* or *oid*, it sometimes indicates that the condition tends toward but does not quite reach that named by the term to which the ending is appended. For example, triangulate means inclining toward triangular. The student will also note that between nearly all the forms of leaves and the characters indicated by the terms above defined, there are intermediate forms connecting them with others.

Inasmuch as it is necessary in description for such forms to be indicated, the method is resorted to of employing the two terms connected by a hyphen. Thus, Lance-ovate, or Ovate-lanceolate (Fig. 497) indicates that the form is intermediate between lanceolate and ovate; crenate-dentate and serrate-dentate are similar illustrations.

A similar intermediate condition is sometimes indicated by prefixing the term *sub*, thus sub-cordate, sub-sessile, sub-acute. Other intermediate terms very commonly employed are acutish and obtusish.

The Compound Leaf.—In the lobed leaves which we have already examined, even the most deeply divided of them, the lobes are seen to be connected with one another at the base by portions of the common blade, so that a complete division of the blade into separate parts has not taken place. In the leaves which we are now to examine, such separation has occurred, and the lamina has become divided into a number of distinct secondary blades (Figs. 548, 554, etc.). Leaves of this kind are called Compound, and their divisions, Leaflets.

If the leaflets are themselves compound, the leaf is Decompound. Decompound leaves are spoken of as once compound, twice compound, etc., according to the number of successive divisions. Leaflets may be distinguished from leaves by the fact that no buds are found in their axils. Leaflets are subject to the application of the same descriptive terminology as leaves.

Leaflets of the first division are called Pinnae, those of subsequent divisions, Pinnules.

The continuation of the petiole passing up among the leaflets, that is the midrib of the compound leaf, is the rachis (*b*, Fig. 475).

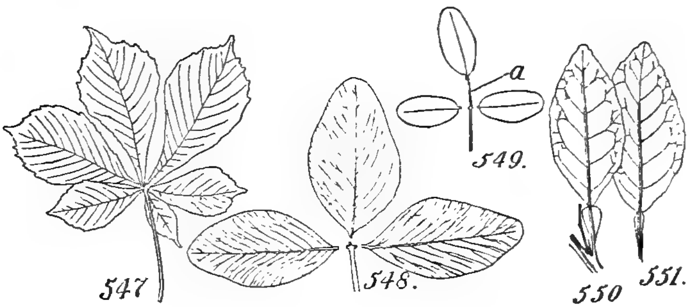


Fig. 547. Palmately compound leaf (*Aesculus*). 548. Palmately trifoliolate leaf (*Trifolium*). 549. Pinnately trifoliolate leaf (*Lespedeza*). 550 and 551. Unifoliolate compound leaves of orange.

When, as in Fig. 548, the compound leaf has no rachis, its division being on the same plan as the lobing of the palmatifid leaf, it is Palmate, or Palmately compound. When the rachis does exist, corresponding to the pinnatifid type (Figs. 549 and 554), the leaf is Pinnate, or Pinnately Compound.

Before proceeding to define the distinct forms of the two classes, we note that it is not always possible to identify them with readiness. For example, the ancestral form of the leaf of the orange was pinnate, but at the present time we find that only the terminal leaflet remains, there being usually at the base more or less of an indication of the two lateral leaflets which once existed (Figs. 550 and 551). Such a leaf cannot, therefore, be properly designated as simple, and we designate it as a Unifoliolate compound leaf.

Compound leaves with three leaflets, usually designated as Trifoliolate, frequently give us considerable difficulty in determining whether they are pinnately or palmately compound. The question is to be decided in accordance with the point at which disarticulation of the terminal leaflet occurs. If palmate, the base of the blade must be the point at which the three petioles separate, so that when disarticulation occurs no rachis will remain extending beyond the point of attachment of the two lateral leaflets (Fig. 548). In the pinnate form such a rachis

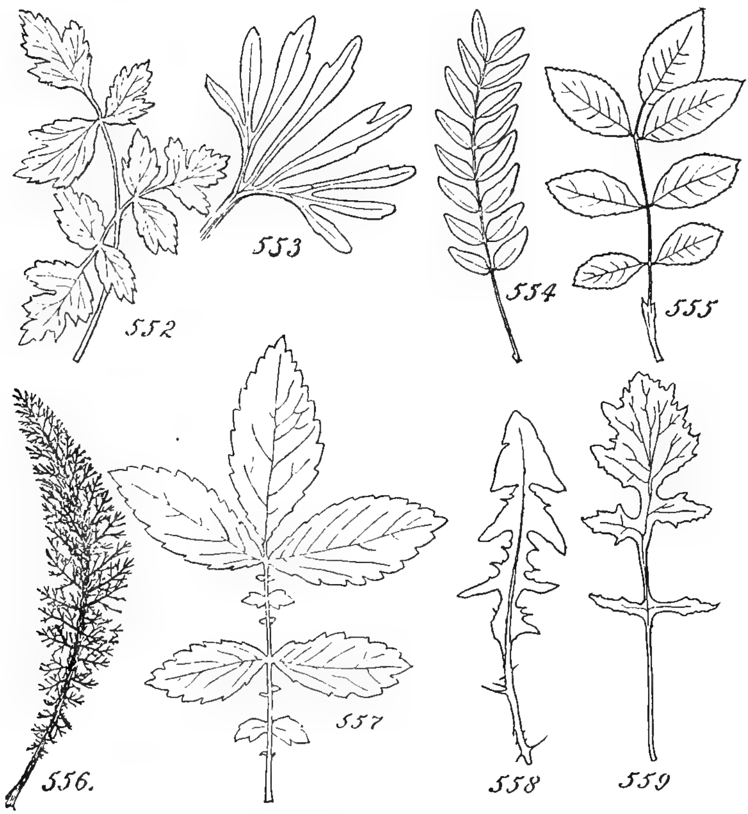


Fig. 552. Triternate leaf. 553. Pedate leaf (violet). 554. Pari-pinnate leaflet of *Geditschia*. 555. Impari-pinnate leaf of rose. 556. Millifoliolate leaf of *Achilldea* 557. Interruptedly-pinnate leaf of *Agrimonia*. 558. Runcinate leaf of dandelion. 559. Lyrate leaf of *barbarea*.

(Fig. 549, *a*), although frequently very short, does exist. In the family *Leguminosae*, the question of whether a leaf is pinnately or palmately trifoliolate is of fundamental importance in classification.

A three-parted palmately compound or divided leaf is called Ternate; a five-parted one Quinate, a seven-parted one Septate.

A palmatifid (or palmate) leaf, with very narrow divisions, is called Pedate (Fig. 553).

If the divisions of such a leaf are similarly compound or divided, appropriate terms are formed, such as Bi-ternate (Fig. 552), Tri-ternate, and so on. Similarly named sub-divisions of the pinnate form exist, the bi-pinnate (Fig. 563), tri-pinnate (Fig. 556), and so on.

These terms are also sometimes applied to the similar divisions of pinnatifid leaves. Just as we have found that the number of pairs of primary veins of the simple leaf is generally characteristic of the species, so we find that the number of pairs of pinnae, technically known as Jugae, is equally so. This number, therefore, should always be stated, the leaf being designated as Bi-jugate, Tri-jugate, Multi-jugate and so on.

Two classes of pinnate leaves are recognized, in accordance with their termination in a pair or in a single terminal leaflet. Those ending in a pair (Fig. 554) are called Pari-pinnate, Even-pinnate, or Equally-pinnate, the others (Fig. 555) Impari-pinnate, Odd-pinnate, or Unequally-pinnate.

When the divisions of a pinnate or a pinnatifid leaf are alternately large and very small (Fig. 557), it is called Interruptedly-pinnate or Pinnatifid.

When the leaflets or divisions are turned backward so that they point more or less in the direction of the base (Fig. 558), the leaf is Runcinate.

When the terminal division is very much larger, especially broader, than the lateral, the leaf is Lyrate (Fig. 559).

Modified Leaves.—Coming now to consider the subject of characteristic modifications in the form and function of the leaf, we note that some of them pertain to the entire leaf, others to its individual parts. We also note that in some of the modifications the entire leaf or one of its parts retains the ordinary functions of absorption and assimilation, the new function being added thereto either by partial change of the entire leaf, or the complete modification of one or more of its parts, while at other times the original functions are entirely lost.

Carnivorous Leaves.—The function of absorbing and assimilating the ordinary forms of nutriment is sometimes supplemented by that of absorbing and assimilating animal tissue. In this case the leaf provides special forms of apparatus for enticing, intoxicating, or mechanically catching, killing and digesting the animal, commonly an insect.

The Pitcher Plant.—One of these forms is illustrated in the pitcher plant (Fig. 560), in which one portion of the leaf becomes converted into a vessel containing liquid of variable origin and complex composition. Upon the outer portion of the pitcher a line of glandular tissue stretches downward. The insect feeds upward along this line of secretion, which so changes its nature toward the top of the pitcher, that by the time the insect reaches that point he is more or less intoxicated, and on crossing the margin, or quickly thereafter, falls into the liquid and is drowned, digestion promptly occurring by means of enzymes excreted into the liquid by special glands located upon the inner face of the pitcher.

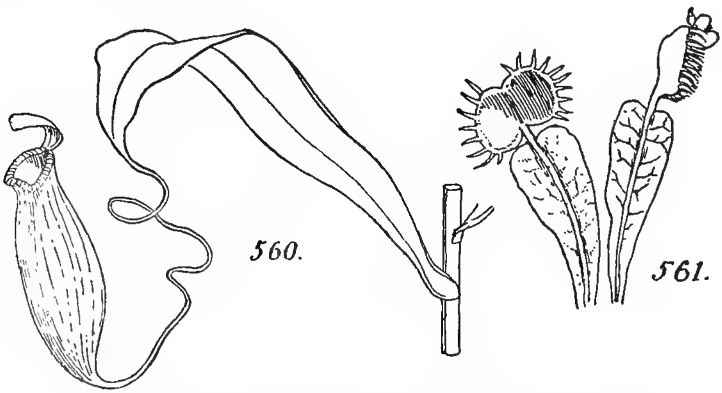


Fig. 560. Modified (pitcher) leaf of *Nepenthes*. 561. Modified leaf of *Dionaea*

The Venus's Fly-trap.—Another form is the well-known Venus's fly-trap (Fig. 561), which secretes a nectar by certain glands which surround its margin. The insect, alighting upon this point, is instantly seized through the spasmodic coming together of the two lateral halves of the leaf, which act precisely like the jaws of a trap. Digestive fluids are then immediately poured forth from special glandular tissues on the leaf-surface and digestion and absorption take place. That the nutrients thus absorbed are of service to the plant has been proved by elaborate experiments, in which the effects of such feeding have been estimated by comparing their reproduction with that of other similar plants, similarly treated in all respects except that they were deprived of this form of food.

Etiolated Leaves.—In other cases, the plant being nourished by means of fully prepared nutrients absorbed from other leafy plants (host-plants) upon which they are parasitic, the leaves lose the chlorophyll tissue upon which their ordinary functions depend, and are known as Etiolated leaves. They become reduced in size and scale-like in form.

Plants which grow in excessively dry or desert regions, and which are thus very liable to suffer from excessive evaporation, ordinarily have their leaves modified in some way so as to guard against this

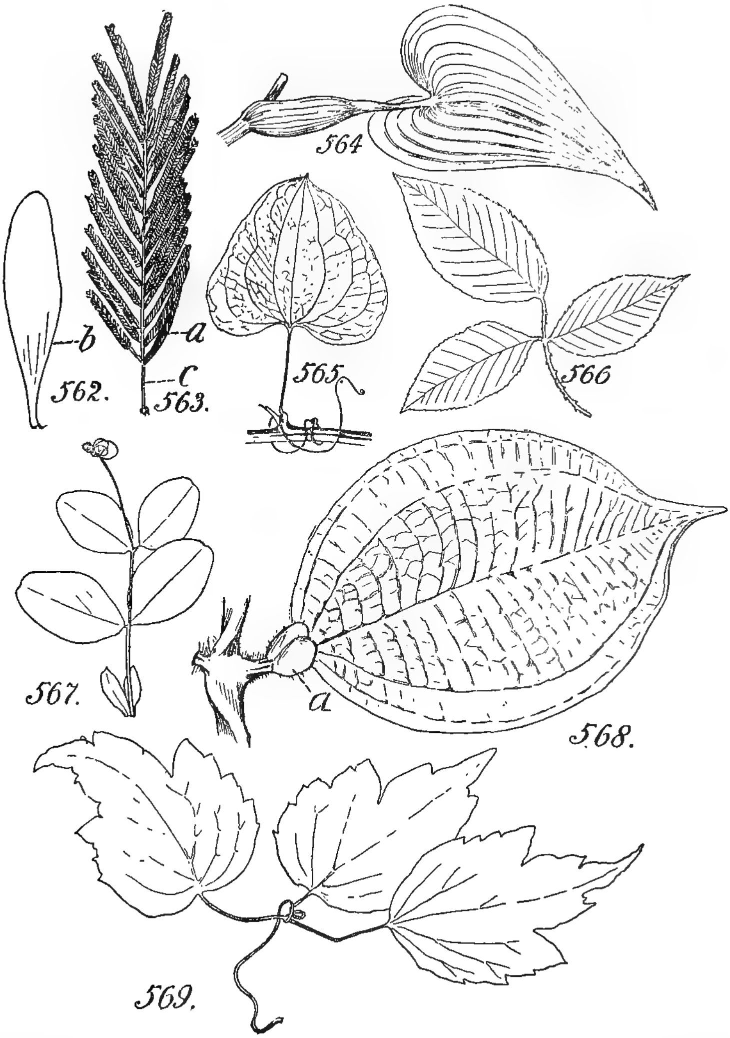


Fig. 562. Phyllodium of *Acacia*. 563. Leaf of *Acacia* with blade present. 564. Leaf of *Eichornia* with inflated petiole. 565. Cirrhose stipules of *Smilax*. 566. Aculeate leaf of *Rubus*. 567. Cirrhiferous leaf of pea. 568. Leaf of *Tococa*, its inflated petiole the home of ants. 569. Cirrhose petiole of *Clematis*.

tendency, and are called Xerophytic. They may become merely reduced in size or may be otherwise modified, so as to reduce the amount or the degree of activity of their epidermal tissue, or they may disappear altogether, or become transformed into organs of a different character. In one of these forms the leaf becomes converted into a spine, or a group of spines, each consisting of one of the teeth. In this condition the leaf serves an important function in protecting the plant against destruction by desert animals.

Phyllodia.—At other times the blade (Fig. 563, *a*) entirely disappears, a false blade (Phyllodium, Fig. 562), of much less activity as an evaporating organ, becoming formed by the flattening out or expansion of the petiole (Fig. 553, *c*). A phyllodium is readily distinguished from a leaf-blade in that its broad surfaces are directed laterally instead of vertically, as in the true lamina.

Leaves as Floating Organs.—Leaves or their petioles frequently become modified into floating organs in aquatic plants, as in the case of the bladdery-inflated petioles of the *Eichornia* (Fig. 564).

Somewhat similar inflated organs exist upon the petioles of some plants and serve as the homes of colonies of ants, which are efficient in protecting the plant against the attacks of certain animals (Fig. 568, *a*).

Leaves as Climbing Organs.—The office of climbing is frequently performed by a portion of the leaf. In some cases, as the *Clematis* (Fig. 569), the petiole of the leaf becomes twining for this purpose. At other times the apex of the rachis (Fig. 567) becomes a tendril, either simple or branching, while at others the entire leaf becomes thus modified. In the *Smilax* (Fig. 565) it is the stipule which is thus changed. In other cases (Fig. 566) climbing is effected by means of hooks developed upon some portion of the leaf.

Floral Leaves or Bracts.—Besides protecting the plant by becoming converted into spines or spine-bearing organs, as above described, the leaf is subject to various other modifications having this object in view. Reference has already been made to such modifications in the form of bud scales. For the protection of the flower exist the epicalyx and such scales, called Floral Leaves or Bracts, as have been described in our opening account of the flowers of the willow.

Floral leaves or bracts do not always exist merely for purposes of protection. In very many cases they are functionally a part of the flower structure, surrounding either single flowers or clusters of flowers, and serving by their large size or brilliant colors, or both, to attract insect-visits, precisely the same as has been described in reference to the perigone. Through the floral bracts thus modified, we get a direct transformation into the parts of the perigone, as has already been sufficiently explained. It is also important to note that a direct relation is to be traced between the definite arrangements of foliage and floral leaves, as will be considered under Phyllotaxy, and the arrangement of the parts of the flower itself; so the characteristics or praefloration are seen to be directly dependent upon the phyllotaxy and praefoliation.

Phyllotaxy.—In view of the established fact that the development of the branches follows that of the leaves, it becomes clear that the arrangement of the latter determines the entire symmetry of the plant, with all the far-reaching consequences in connection with both vegetation and reproduction. Certain definite laws of phyllotaxy having been ascertained, the forms resulting become, in their different manifestations, of nearly fundamental importance in classification and in diagnosis.

The Whorled Arrangement.—We find that either one or more than one leaf is developed from a node. In the latter case the arrangement is called Verticillate or Whorled, and the circle a Whorl or Verticil. If the Whorl contain but two members, they are called Opposite—that is, the centers of their points of insertion are separated by one-half the circumference, or their Divergence is 180 degrees. Usually the other nodes are similarly clothed, except that in all of the higher plants the leaves of each pair Decussate with those of each adjacent pair—that is, a leaf of one whorl is over the center of the sinus of that next below (Fig. 570). Four vertical rows (Orthostachies) of leaves thus appear upon such a stem (Fig. 573). If, instead, there be three leaves to the whorl, six orthostachies will result; if four, eight; and so on. It frequently happens that the number of leaves in the upper or lower whorls will contain only half the number of leaves in the others, and still higher up the whorled arrangement may be lost, the leaves becoming arranged as in the form next considered.

The Alternate or Spiral Arrangement.—By the other arrangement the nodes produce solitary leaves, so that each leaf is successively produced at a higher level. If a line be traced from the point of origin of one leaf to that of the one next above, and continued in the same direction, so that it exactly meets the point of insertion of another, and then of another, and so on, it will at length meet one exactly over the point of starting—that is, a second leaf in the same Orthostachy (Fig. 571). It will then be found that the line followed is a spiral, which has passed once or more around the stem. Such a spiral is called a Cycle, and if its line be continued, it will form other similar cycles above and below. It is observed that a cycle will be limited by two adjacent leaves of one

Orthostachy. Thus, if leaf No. 4 is the next in the orthostachy, to which leaf No. 1 belongs (Fig. 574), three leaves will belong to that cycle. A cycle containing three leaves makes but one turn of the stem. A cycle is expressed in the form of a fraction, its numerator indicating the number of times it encircles the stem, its denominator the number of leaves which it includes, so that the cycle last described must be indicated by the fraction one-third. The angular divergence of its leaves is 120 degrees. If the next leaf in the same orthostachy as No. 1 be No. 6 (Fig. 572), then that cycle will contain five leaves. A cycle containing five leaves makes two circuits of the stem, so that its exponent

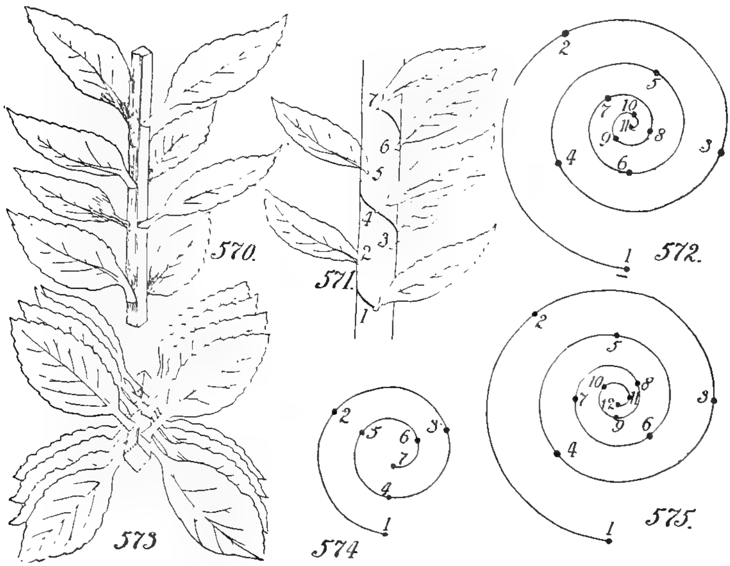


Fig. 570. Decussating opposite leaves. 571. Alternate or spiral leaf-arrangement. 572. Diagram of the same, the $\frac{2}{5}$ arrangement. 573. Diagram of 570, showing its 4 orthostachies. 574. The $\frac{1}{3}$ spiral. 575. The $\frac{3}{8}$ spiral.

will be two-fifths. If the second leaf of the orthostachy were No. 9, the appropriate fraction would be three-eighths, the cycle making three turns and containing eight leaves (Fig. 575). It will thus be observed that these fractions form a series, in which each possesses a numerator equal to the sum of the numerators of the two preceding and a denominator equal to the sum of the denominators of the two preceding. No cycles occur among the higher plants with which we are concerned, which can be indicated by any fraction not thus formed.

Noticing these fractions still further, we observe that the denominators will indicate the number of orthostachies upon the stems which they represent, and that the value of the fraction will represent the divergence of, or part of a circle between, any two leaves adjacent in the cycle or spiral—that is, the number of degrees between such leaves will equal that fractional part of 360 degrees.

Antidromy.—As to the direction which the spiral takes, it may be either from right to left or from left to right. It is supposed that each kind of plant, at least of the higher classes, produces two forms or "castes," depending in some not yet perfectly determined way upon the relative positions of the respective ovules from which they originate. The tendency of these two castes to manifest their growth or development in opposite directions has been called Antidromy. Among numerous other phenomena attributed to antidromy is this starting of the leaf-spiral in opposite directions in plants of the two castes of any species with this form of phyllotaxy.

The Scattered Arrangement.—Occasionally, leaves appear to be irregularly disposed upon the stem—that is, they are not whorled, nor does the law of alternate phyllotaxy appear to apply to them. This arrangement is called Scattered, and the explanation is different in different cases.

Tufted Leaves.—When a stem is so shortened that the leaves are crowded upon it in the form of a regular rosette, as in the house-leek, the arrangement is called Tufted.

Fascicled Leaves.—When similarly short, but the leaves few and irregularly crowded in a little bunch, the arrangement is Fascicled.

The two regular forms of leaf arrangement above described can be traced in greater or less perfection through floral bracts and involucres, and into and in many cases partly or wholly through the flower itself. While such arrangement in the flower is in many cases entirely verticillate and in most cases partly so, it has been quite clearly shown that many flowers have certain of their parts arranged upon the spiral plan.

CHAPTER XVII

ANTHOTAXY

The arrangement of flowers is called their Anthotaxy, and this name is also applied to the study of inflorescences.

The Inflorescence.—That part of a stem or branch which bears the flowers, or the flower when solitary, is more or less distinctly modified in form, surface, modification of its leaves, extent and character of branching, and frequently also in the direction taken in the arrangement of its parts. In connection with its flowers it is called the Inflorescence.

The stem of an Inflorescence, that is, the portion which is below its lowest point of branching or flowering, or below the flower when solitary, is called the Peduncle (*a* in Figs. 576 and 583). This name is also applied to the corresponding portion of a branch of an inflorescence if that branch bear more than one flower, it being in that case a Secondary Peduncle (Fig. 584, *d*).

The Rachis.—If the peduncle is continued above its first point of branching, in the form of a central support along which the succeeding branches or the flowers are arranged, this portion is called the Rachis (Figs. 583 above *a* and 586, *a*).

The Scape.—A peduncle which rises directly from or near the ground is called a Scape (Fig. 576, *a*).

The Pedicel.—The stem of one of the individual flowers of an inflorescence of more than one flower is called a Pedicel (*c*, in Fig. 584). A flower or an inflorescence may be devoid of pedicel or peduncle, when it is Sessile.

The arrangement of the inflorescence-leaves and their floral branches, while based upon the phyllotaxy, and traceable thereto in most cases, exhibits more or less real or apparent departure therefrom, and calls for special designations and classification.

The Determinate form of Anthotaxy.—The forms of flowering are divided into two series in accordance with the apical or lateral location of the initial flower—that is, the flower which is first in order of development. If the terminal bud develop into a flower (Fig. 576) its further extension is impossible, except by the rare and abnormal process of Proliferation. Inflorescences so limited are called Determinate or Definite.

Vertical Extension by the Branches.—Although vertical extension of the original stem of a determinate inflorescence is not possible, it can take place through the branches, the same as in other sympodia. The effects of such development are the same as in other forms of sympodial growth in which there is a transformation of the apex of the original stem—as, for instance, in our explanation of such a mode of development of the tendril (Fig. 431). To apply this principle in the case of an inflorescence, we have only to assume a flower developed at the tip of every branch in Figs. 433 to 435. Flower *a* would develop first; *b*, although the second in order, and hence a branch, and afterward *c*, would be more elevated, and would thus seem to prolong the vertical extension of the stem. The development being successively by nodes whose original points of origin were successively lower than that of the terminal flower, is structurally and really Descending or Basipetal, even though by the upward growth of the successive branches they be at successively higher levels, the order apparently in the opposite direction. By the development at each node of a pair of opposite branches we get the apparent bifurcating or dichotomous form (Fig. 435). If but one branch grow from a node, and these successively from right to left, the zig-zag or Flexuose form of rachis is produced (Fig. 433), and if constantly from the same side, or apparently so, the Circinate (Fig. 434).

The descending or basipetal nature of the definite inflorescence is clearly shown when the successive branches remain short, each successively developed flower remaining at a lower level than that which preceded it (Fig. 581).

The Centrifugal Form.—Instead, however, of assuming either of these two states, in which the flowers remain at different levels, the branches may radiate and elongate to different degress, ceasing their elongation when their flowers have been brought to a uniform height, so that a more or less flat-topped inflorescence results, the order of development being from the center outward, or Centrifugal, as in the branches of Fig. 584.

Cymose Inflorescences.—This form represents the true Cyme, and because of their relationship to it this entire series of inflorescences is often denominated the Cymose. It will thus be seen that in different forms of the cymose inflorescence, we may have the flowers all brought at length to a uniform level, those of successively later development brought to successively higher points, or left at successively lower levels. This fact demonstrates that the cymose or descending nature of an inflorescence cannot be determined by noting the relative heights of the flowers themselves, but only by noting the order of their development.

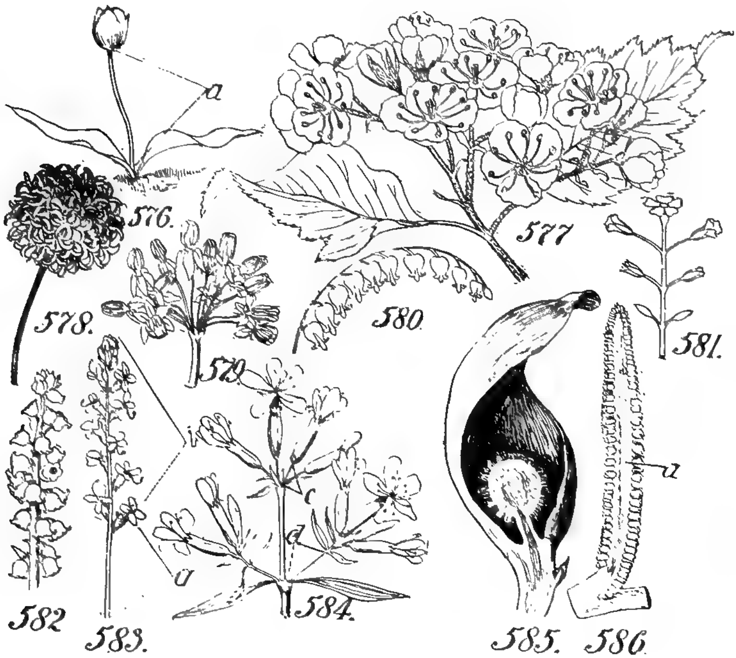


Fig. 576. Scapose 1-flowered peduncle of tulip. 577. Corymb of *Crataegus*. 578. Head of *Cephalanthus*. 579. Umbel of *Asclepias*. 580. Secund raceme of *Bicuculla* 581. A descending inflorescence. 582 Ordinary raceme. 583 A spike. 584. Compound cyme of *Saponaria*. 585 Globular spadix enclosed in spathe of *Spathyema*. 586. Cylindrical spadix of *Acorus*.

The Indeterminate Form of Anthotaxy.—In the second series, the first flower to develop is structurally the lowest of the cluster, the succession being upward, Ascending or Acropetal (Figs. 582 and 583). If the successive branches develop less rapidly than their predecessors, the result is again a flat-topped inflorescence, with the development from the outside to center, or Centripetal (Figs. 577 and 579). The branches and flowers may be separated on obvious peduncles and pedicels, or these may be not apparent, the flowers being sessile. In accordance with the characters above explained, we obtain the following simple forms of anthotaxy:

Series 1

Ascending, Acropetal, Indefinite, Indeterminate, Centripetal, or Botryose Forms.

A. With the rachis not elongated.

1. The Capitulum or Head, with the flowers, and branches, if any, sessile or so regarded (Fig. 578).
2. The Corymb, with the rachis manifest, though short, and its pedicels or branches elongated so as to produce a flat-topped inflorescence (Fig. 577).
3. The Umbel, similar to the Corymb but with the rachis not manifest, so that the pedicels or branches all appear to start from one point at the summit of the peduncle (Fig. 579).

B. With the rachis elongated.

4. The Spike, with the flowers, or branches, if any, sessile or so regarded (Fig. 583).
5. The Catkin or Ament, a spike with slender rachis and bearing usually staminate or pistillate flowers, crowded and subtended by scales (Figs. 8, 11, and 15).
6. The Raceme, similar to the spike or ament, but having the flowers pedicelled (Figs. 580 and 582).

When either the head or spike possesses a thick, fleshy, rachis it is called a Spadix (Figs. 585 and 586).

Series 2

Descending, Basipetal, Definite, Determinate, Centrifugal, or Cymose Forms.

1. The Glomerule, corresponding to the head in all respects save that the central flower first develops.
2. The Fascicle, similar to the glomerule except that the flowers are few and loosely clustered.
3. The Cyme, similar to the corymb or umbel, save that the central flower is the first to develop (Fig. 584).
4. The Scorpioid Raceme. Similar to the raceme, except that each successive node and flower upward is lateral to that next below. The apex of the scorpioid raceme is circinately coiled (Fig. 434).

Compound Inflorescences.—Before proceeding to consider certain special forms and modifications of the inflorescences above defined, it should be remarked that most of the forms may be compound. By this we mean that the cluster is made up of a number of branches whose order of development is the same as that of the elements of which they are composed. That is, the raceme may possess a number of branches, each of which is a smaller or secondary raceme, or if not a raceme, at least a small inflorescence of the ascending or centripetal form. Similarly, an umbel may be made up of branches, each of which is a smaller umbel, the Umbellule. A cyme will be made up of cymules, and so on. A Panicle is a compound raceme which assumes the form of a pyramid. Any form of inflorescence not a true panicle, but assuming the shape of one, is styled Paniculate.

Complex Inflorescences.—Complex forms of inflorescence differ from the compound in that the order of development of the several flowers upon a branch is of a different kind from that of the several branches themselves. For exmaple, the Thyrsus or Thyrse is a paniculate form in which the lowest branch is the first to develop flowers, so that the order of development of the branches is ascending, but within a branch the terminal flower will be the first to develop, so that the order of development of its flowers is descending. In the same way, each branch of an umbel may terminate in a head; or we may have a fascicle, each branch of which is a raceme.

The Anthodium.—The term Anthodium has already been defined in considering the forms of the fruit, under Multiple or Collective Fruits. The same term is applied to an inflorescence yielding the collective fruit of that name (Fig. 587). It is in reality nothing more than a head closely subtended, surrounded or enclosed by an involucre (*a*). The anthodium is characteristic of the great family *Compositae,* and is of so much importance in classification that its modifications call for special attention. The involucre should be studied as to whether it is single, double, or multiple—that is, whether it consists of one, two, or more circles of scales; as to whether these are equal in length or whether the outer or inner are successively shorter; whether they are entirely free and distinct, or adnate by their bases or connate by their margins; as to whether they are appressed, or with more or less of their apical portions recurved or spreading; especially as to the general form of the involucre as a whole, the terms used being the same as those previously applied to the perigone, and as to the characters of the individual scales, these being practically the same as those which have already been considered in connection with the leaves. The body consisting of the combined tori of all the flowers of the anthodium, is called a Receptacle (*b*). It is to be studied as to its being solid or hollow; as to its general form, and especially the form of its upper surface, whether concave, plane, convex, rounded, or conical; as to its being smooth in surface, honeycombed or otherwise pitted (foveolate), and if the latter, the special characters of the pits and their margins; and as to its being naked or clothed with hairs or scales, and the characters of the latter in their every detail. The head is then to be considered as to the character of its flowers. If these are all sexually similar, the head is said to be Homogamous; if different, Heterogamous. If the flowers are all ligulate, the head is Liguliflorate. If it possess a disk (*c*), of tubular flowers (*d*), it is Discoid. If this disk is surrounded by one or more circles of

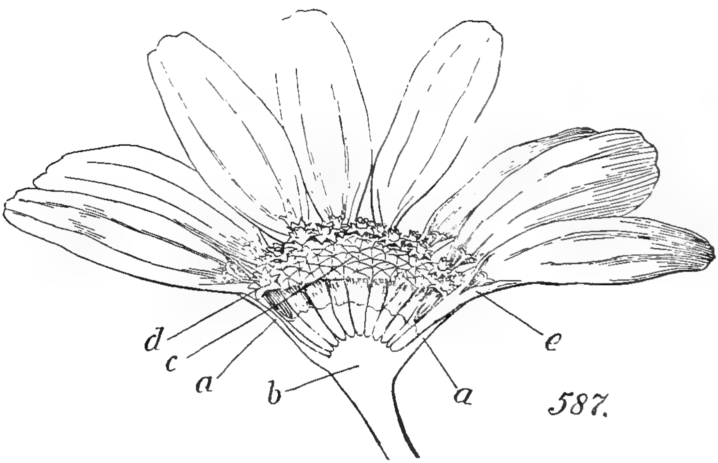


Fig. 587. Vertical section through an anthodium: *a*, involucre; *b*, receptacle; *c*, disk; *d*, disk-flower; *e*, ray-flower.

ligulate flowers called Rays (*e*), it is Radiate. If the ray-flowers and disk-flowers are of the same color, the head is Homochromous; if different, Heterochromous. The flowers must next be studied as to their sex. The ray-flowers are commonly pistillate, while the disk-flowers are perfect, or the disk-flowers may vary among themselves in this particular. Very commonly, the ray-flowers are entirely neutral. Even if pistillate, they may be sterile. If both classes of flowers are fertile, the akenes which they produce may be heteromorphous, those of the disk being commonly compressed, those of the rays commonly triquetrous. Occasionally the heads are dioecious or monoecious. In one tribe of the *Compositae* the corollas are bilabiate. The character of the pappus (Figs. 74 to 83) is invariably of the utmost importance, as are the forms of the style-branches and the appendages borne by these at the apex and by the anthers at apex and at base (see Androecium and Gynaecium).

Inflorescence-leaves or Floral Leaves.—Many special terms are applied to the forms of inflorescence-leaves, that is, the bracts subtending its branches and the pedicels of the flowers, as well as those borne upon the pedicel. Ordinarily they are conspicuously smaller than the other leaves borne by the plant.

With this reduced size, other modifications are noticeable, especially the shortening or loss of the petiole and a general tendency toward reduction to the scale-form, this tendency counteracted in variable degree by a contrary tendency to preserve the characteristic leaf-form. These leaves are commonly spoken of as the Reduced Leaves of the Inflorescence. To this class belong the leaves of the involucre and the scales often found upon the receptacle of the anthodium already considered. Individually, they are spoken of as bracts, the secondary ones bractlets, and the ultimate very small ones bracteoles. Ordinarily the changes here outlined as marking the development of the foliage-leaves into the inflorescence-leaves are gradual, but in many cases there is an abrupt transition from the one form to the other.

A circle or cluster of bracts at the base of an inflorescence is termed an Involucre, and this term is also applied to a single very large bract occupying the same position, although this is more commonly known as the Spathe. In most cases the modifications of leaves forming the scales of involucres are entirely different from those of bracts occurring singly. They are usually much larger than such bracts, their form is usually specialized in some way, and they are very frequently highly colored, serving the same purpose as neutral flowers. The bracts of involucres are often amalgamated so as to form a cup or tube.

Many one-leaved involucres are very peculiar, and their morphology even more difficult to understand. The supposed leaf is sometimes a phyllocladium. In some cases the flower appears to rise out of the modified or unmodified leaf itself, as in the *Tilia*, the explanation in these cases probably being that adnation exists between the inflorescence and the leaf.

One group of Families, the grasses and grass-like plants, do not possess any obvious perigone, its place being supplied by peculiarly formed, adapted, and arranged bracts, in the form of scales or chaff, and technically called Glumes, which give to this group of families the title Glumaceae. In the rushes, these glumes really are a true perigone, which is trimerous. In the sedges (Family *Cyperaceae*,

Fig. 588) the scales (*a*) are solitary, subtending each flower. In the grasses (Family *Gramineae*) the glumes are arranged in pairs, each pair subtending a short branch, which may bear only one, several, or many flowers, the whole known as a Spikelet (Fig. 589). Typically, there is besides the two glumes of the spikelet (*a*) an additional pair of scales (*c*) for each flower (*b*). Thus, if there be but one flower in a spikelet, it possesses two pairs of scales. If more than one, then there is a separate pair of scales for each flower, besides the one pair pertaining to the spikelet as a whole. The scales of the spikelet are called the

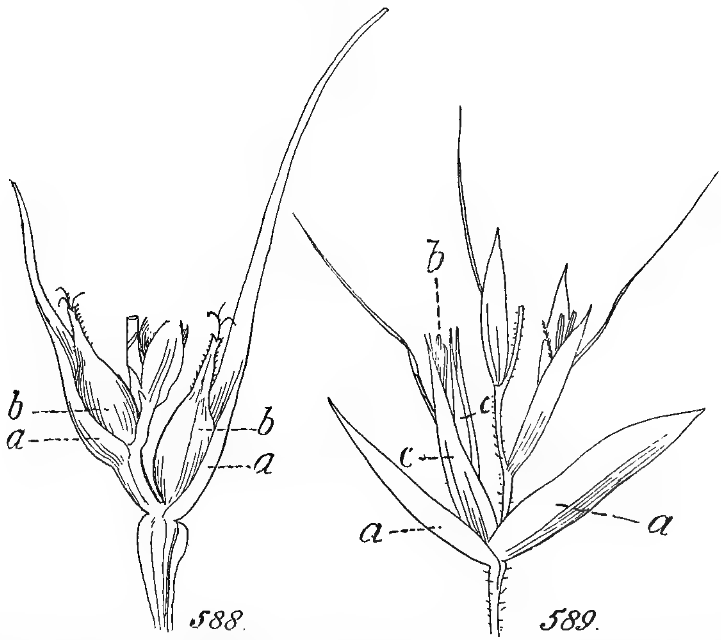


Fig. 588. Distichous arrangement of flowers of a sedge, each scale (*a*) containing a flower (*b*). 589. Spikelet from the inflorescence of a grass: *a*, glumes of the spikelet; *b*, a flower; *c*, palets of the flower.

Glumes, Glumes Proper, or Lower Glumes; those of the individual flowers (*c*) Palets or Upper Glumes. Much complexity in the relations of the glumes ensues as a result of suppression of both glumes or both palets, of one of either or of each, or of two of one and one of the other, and so on. The character of the individual glumes must be carefully studied, as in the case of the involucral scales of the anthodium. The character of the terminal appendages which they bear is of special importance.

With this study of the inflorescence we are brought again to the individual flower, with the study of which we commenced.

CHAPTER XVIII

GENERAL CHARACTERS OF CRYPTOGAMS

Essential Characteristics.—The essential characteristic of the flower, distinguishing it from all other similar reproductive structures, is its possession of a special tissue which constitutes a soil in which the microspore germinates, and in which the male gametophyte develops and grows. Plants destitute of such an organ are therefore known as Flowerless Plants. An equally great or even greater distinction is found in the fact that the embryo of such plants, resulting from the conjunction of the male and female gametes, is not located in a resting body (the seed), but must continue its uninterrupted development into the sporophyte. They are, therefore, often designated as Seedless Plants. Flowerless or seedless plants are technically known as cryptogams.

Alternation of Generations.—Our account of the development and reproduction of Phanerogams has shown that each individual passes alternately through two different forms of life, each of which is represented by its characteristic body form. Those plants which present themselves conspicuously to view as trees, shrubs, and herbs are sporophytes, producing spores in ovules and anther cells, these spores germinating to produce respectively the male and female gametophytes, which constitute the other form of the plant body, or the alternating generation, and which are too minute to be seen with the naked eye. The sexual elements borne upon these gametophytic plants unite to produce an embryo which is the young body of a new sporophytic generation, and which is enclosed in the seed. Such an alternation of generations occurs also among Cryptogams. In some cases the inconspicuous generation is the gametophyte (Fig. 599), as in Phanerogams; in other cases the relations are reversed in this regard (Fig. 596). Among many of the lower forms this process does not occur, each plant always reproducing to form a body exactly like itself, with no indication of generations presenting distinct forms.

The Cryptogamous Plant-body.—Great as are the differences seen among Phanerogams, even greater ones are to be seen among those of Cryptogams. They frequently present themselves as herbs, shrubs and trees, with well-developed leaves, borne upon regularly occurring phytomers. In other cases, the stem-structure is well developed, while the leaves are rudimentary in different degrees, from those which want only the most perfectly developed leaf-structure to those which are mere scales, consisting of a single layer of flattened cells. By far the greater number, comprising the lower classes, have nothing which can be described as homologous with the leaf, the plant consisting of a simple body which, presenting many different kinds and degrees of variation in form, habit, and function, yet never shows any indication of the regularly jointed structure characteristic of the higher plants, nor any leaves.

Equally great is the variation observed among the roots. Many of the higher forms possess true absorbing roots, but probably a great majority of roots among Cryptogamous plants are false roots or rhizoids, existing for purposes of fixation only.

Lacking, as these plants do, the elaborate structures whose characteristics have enabled us to identify, describe, and classify the higher plants, we are obliged to look for such characteristics among the different arrangements of their cells. Since this work requires the aid of the compound microscope and considerable technical skill, entirely new methods of examination become necessary. We do not, therefore, find it practicable to consider them in detail here.

The cellular structure of these plants may extend itself in the three directions of solid bodies, giving us masses of tissue, or they may multiply in two directions only, giving us flat or superficial bodies, or they may be joined merely end to end, producing filamentous forms. These bodies may each constitute a single plant, or their cells may cohere merely by habit, each living equally well if separately detached; or they may normally live in a separated condition, thus giving us perfect plant bodies, each consisting of but one cell, the unicellular plant.

These unicellular plants, furthermore, vary most widely in their own structural characters. They may be of microscopical size, or they may become many feet in length. They may possess the simplest structure, or they may develop large cavities, which are divided and subdivided by processes developed from the wall, and be shaped into remarkable forms, yet without true cell division or multiplication.

Vegetation.—Regular vegetative processes are of course required wherever growth occurs, wherefore we must look for them among even the simplest forms. In many cases, these processes are as simple as the bodies themselves. Absorption from a surrounding fluid medium by the entire body of the plant, with the simplest of chemical transformations, may exist, or roots or other special organs of absorption, with complicated systems of metabolism and conduction, may be developed. Chlorophyll is present in the higher groups, and the vegetative processes are very similar to those which we have before considered. In other classes chlorophyll is wanting, and the plants are hence unable to perform the constructive assimilation which we have found among most Phanerogams, but ready formed compounds, or those readily broken down into the required form, must be found for their support.

Reproduction.—We find among the reproductive processes in Cryptogams almost as great a diversity as among their other characters. Not only do both vegetative and sexual forms exist, as among Phanerogams, but while many groups exhibit both forms, others possess only the vegetative. Among the higher classes, the vegetative forms of reproduction are quite elaborate, involving phytomer-like parts, either singly or in bud-forms, while in other cases it can occur by single leaves or parts of them. Among the lower classes, where phytomers and leaves are unknown, these processes are necessarily simpler. In their higher members, masses of tissue, often specially constructed, called gemmae or buds (but of course not conspicuously homologous with the buds which we have studied), separate to form new plant-bodies, the process being called gemmation. In other cases the process is the simplest possible one of cell-division.

Sexual reproduction among cryptogams is too variable to be here considered, even in a general way. In no Cryptogamous plant, however, is there developed any structure which combines the varied functions of that which among Phanerogams is called the flower. The extension of this term to any reproductive organ of the former group, merely because certain homologies have been discovered between them and the flower, is misleading, as it tends to magnify slight resemblances into a higher degree of importance than great differences, and it furthermore subverts the original and fully established meaning of a common term into a new, even if it were a strictly accurate, application.

When alternation of generations occurs, with the production of distinct gametophytes, the male cells, in the form of antherozoids, are usually provided with some independent power of locomotion for reaching the female element, known as the Central Cell, within a distinct organ called by various names.

It has already been stated that the spores germinate for the production of these gametophytes in any suitable soil, and that the resulting embryo continues its development without passing into a resting or seed stage.

PRINCIPAL GROUPS OF CRYPTOGAMS

The main groups of the cryptogams are indicated in the following table:

1. Thallophyta or Thallophytes.
    (*a*) Fungi.
    (*b*) Algae.
    (*c*) Lichenes or Lichens.
2. Bryophyta or Bryophytes.
    (*a*) Hepaticae or Liverworts.
    (*b*) Musci or Mosses.
3. Pteridophyta or Pteridophytes.
    (*a*) Equisetaceae or Horse-tails.
    (*b*) Lycopodiaceae or Club-mosses.
    (*c*) Filices or Ferns.

Each of these groups will be briefly considered, in so far as relates to its contributions to the materia medica.

Thallophyta.—*The Fungi.*—The Fungi comprise plants destitute of true chlorophyll, and therefore incapable of building up their own food from elementary substances. Their structural and physiological characters are exceedingly varied.

To the Fungi belong the Bacteria, contributing the great majority of disease germs, in the special uses of which we are yet to find the most important part of our materia medica. The study of this group pertains to the subject of Bacteriology.

To the Fungi belong also the yeast plants, valuable medicinal agents, but unicellular, and to be studied only in the microscopical laboratory.

Among the drugs of interest to commercial pharmacognosy, occur only Kefir grains, Taka-diastase, Ergot, and the Agarics, all of which belong in the higher divisions of the group.

The vegetative portion of the Fungi consists of a tissue called Micelium, formed of filaments, often growing into large and dense masses. In many, this micelium, after forming into a hard mass, becomes dormant, and constitutes a resting body called the Sclerotium (*e. g.*, Ergot), which later, under suitable conditions, gives origin to the spore-bearing body. Some of the Fungi have no higher mode of reproduction than that of simple division (fission), although almost all of them reproduce by means of spores. These spores are borne in various ways (Fig. 591), as to both their minute and conspicuous structures. In the higher forms, such as the mushrooms, this body consists of a stem bearing a cap or Pileus (Fig. 590, *a*), which bears the spores underneath, on gills, teeth, or some similar support (Fig. 591).

The Algae.—The Algae are almost without representation in the materia medica, although they yield important food supplies, especially in Japan. Even Chondrus, the most important member in drug commerce, is in reality only a food, while Fucus acts rather by inorganics, absorbed by it from the sea-water, than by any organic principle of its own.

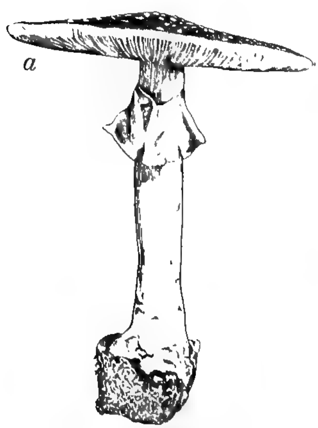


Fig. 590. Amanita phalloides.

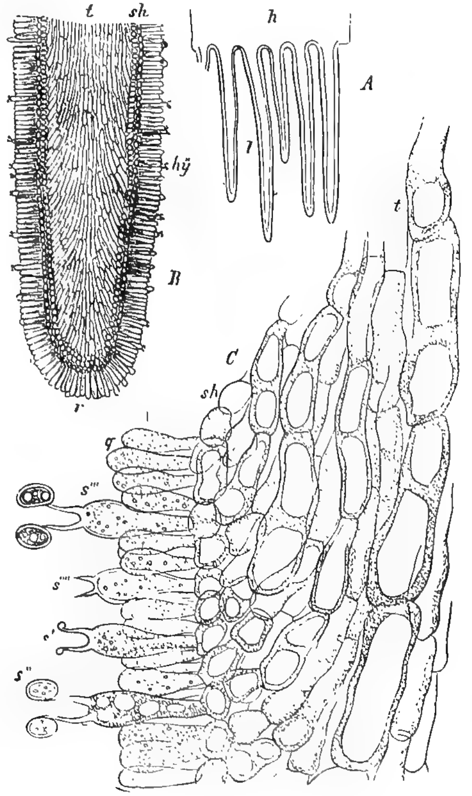


Fig. 591. Showing parts of Mushroom—*Agaricus (Psalliota) campestris: A*, a section across a number of gills, *h;* the hymenophore, *l;* the lamellae or gills, one of which is more highly magnified in *B*, *t*, the central hyphal tissue; *hy*, the *hymenium*, or spore-bearing surface; *C*, a portion of gill still more highly magnified, *t;* the hyphae, *q;* the *basidia* upon which the conidia or spores are borne, *s*, *s'*, *s''*—conidia in different stages. (Sachs.)

The Algae are essentially aquatics, and differ from the Fungi in possessing chlorophyll or some similar substance, by which they are enabled to build up their food supplies from inorganic matter.

The last mentioned plant is among the highest of this class. The thallus, or plant body (Fig. 592), consisting of a loose aggregation of single cells, has a well-developed foot, the disk, by which it clings to rocks. The stem is branching and bears the reproductive bodies (Fig. 593) at the ends of its branches.

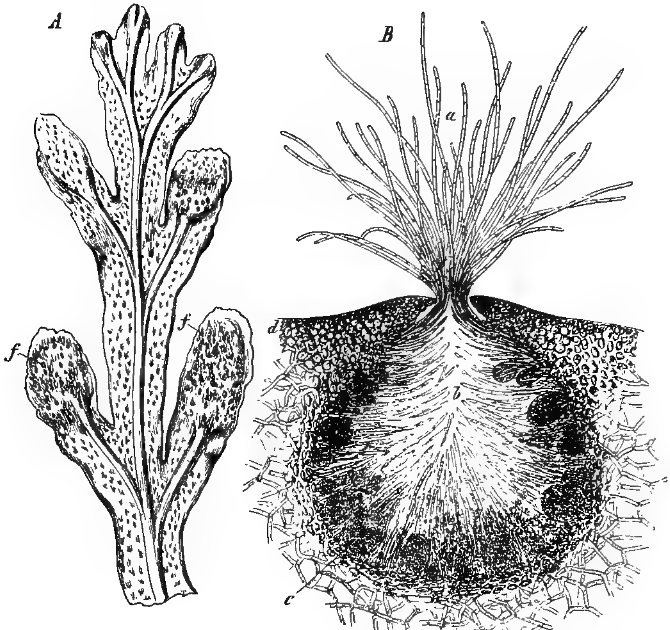


Fig. 592. Rock Weed, *Fucus: A*, portion of branch bearing reproductive organs, *f; B*, an enlarged section through a reproductive organ, the female conceptacle, showing egg cells, *c;* the cavity, *b;* false parenchymatic tissue, *d*. (After Thuret.)

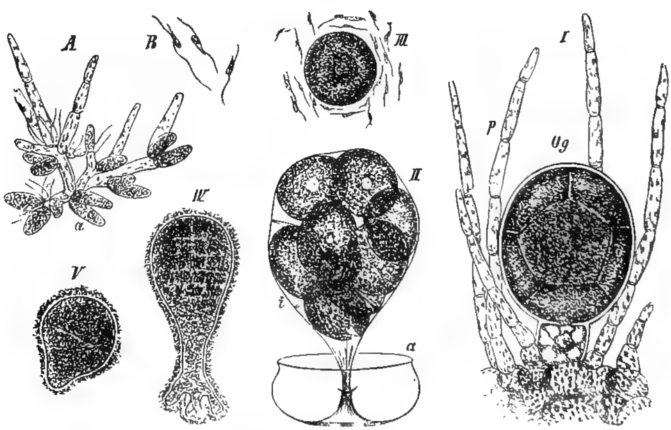


Fig. 593. The sexual organs of *Fucus: A*, the antheridia, or male organs, *a*, borne on paraphyses; *B*, antherozoids or gametes; *I*, the oögonium or female organ, *og;* paraphyses, *p; II*, the oöspores (oöspheres), preparing to be set free; *III*, a free oöspore, being fertilized; *IV*, *V*, young *Fucus* plants.

Different sexes are borne on different plants. The female organ consists of a number of simple ovaries (Oögonia) (Fig. 592, *c;* Fig. 593, *og*), grouped together in a Conceptacle. Each oögonium contains eight Oöspheres. These oöspheres are set free and are fertilized by motile Gametes, the Antherozoids, which are produced in conceptacles of another plant.

The Lichens.—Most systematists now regard the Lichens as belonging to the Fungi. They may be defined as Fungi parasitic on certain Algae. In this form of parasitism each plant supplies some indispensable contribution to the other, the relation being therefore called Symbiosis. The body of the Lichen, more particularly in the larger forms, is made up of the Fungus mycelium (Fig. 595, *sh*). The thallus may

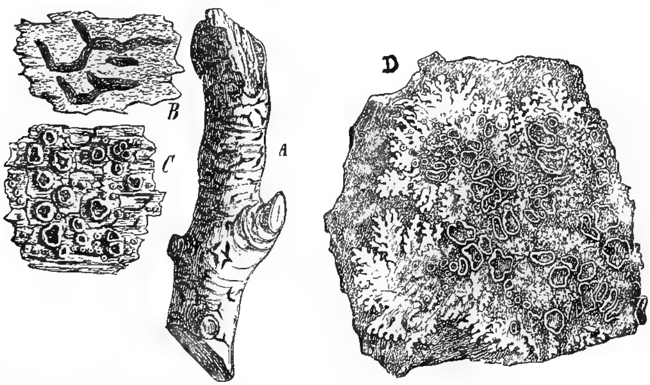


Fig. 594. General view of several Lichens: *A*, crustaceous (*Graphis*); *B*, a portion of this same lichen more highly magnified, showing apothecia; *C*, a crustaceous lichen, *Pertusaria; D*, a sub-foliaceous thallus of *Parmelia* with numerous spore-bearing bodies, apothecia. (Sachs.)

be large and flat, leathery and leaf-like (foliaceous, Fig. 594, *D*), or upright and branching (fruticose), or close-clinging to the bark of trees, looking like a colored stain on rocks (crustaceous, Fig. 594, *A*, *C*). In most cases the spores are born, eight together, in little sacs called Asci, which are themselves reproduced in variously colored closed or open Apothecia (Fig. 594, *D*).

The Bryophyta.—In this class the conspicuous generation is the gametophyte which, in the higher divisions (left hand, Fig. 596), becomes a well-developed plant with stem and leaves. Its male reproductive organs are the Antheridia (Fig. 597, *a*); its female are the Archegonia. The effect of reproduction is the production of an embryo, which immediately germinates while upon the gametophyte, sending its foot down into the tissue of the latter, and developing upward into a sporophyte (Fig. 596, *s*, *t*, *c*), which is the Capsule. These ripened spores, in turn, germinate to produce a new gametophyte which, in its embryonic state, is called the Protonema. It will be observed that the

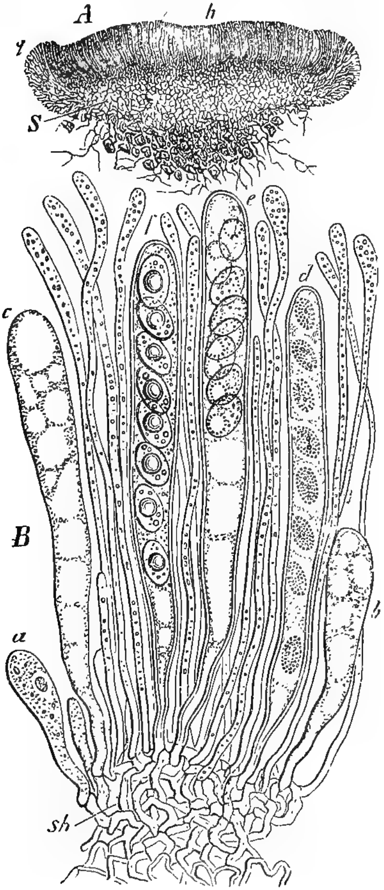


Fig. 595. An Ascomycetous Fungus—*Peziza*—*A*, showing section through complete spore-bearing body—the apothecium; *h*, the hymenium; *s*, the hyphae, forming false tissue; *B*, enlarged section of a portion of above showing *a*, *b*, *c*, *d*, *e*, *f*, *asci*, in various sizes and in various stages of spore development taking place within them, spores are mature in *f*, *sh*, the false parenchyma made up of intertwining hyphae.

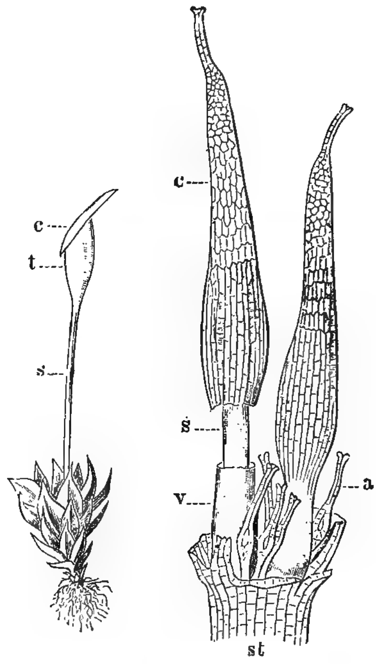


Fig. 596. Showing the development of sporophyte of moss: *St*, apex of stem, bearing the female organs; *a*, the archegonia; from these, after fertilization, the young capsules spring, *C*, *S*, *V*; *C*, the calyptra; underneath which is found lid or operculum; *t*, the capsule; *s*, the leafless stem of sporophyte or pedicel. (Frank.)

relative positions of sporophyte and gametophyte are exactly the reverse of what they are in the flowering plant.

Although the hair-cap moss is somewhat used in medicine, yet neither the Hepatics nor Mosses may be considered as worthy of note in commercial pharmacognosy. In the Mosses, the top of the stem or branch bears a number of bracts or modified leaves, which constitute the Perichaetium. From amidst these bracts the Pedicel (Fig. 596, *s*) rises from the foot and bears the capsule upon its summit. Through

Fig. 597 The male organ, antheridium of mosses (*Funaria*): *A*, antheridium, with escaping antherozoids (*a*); *B*, a single male element *b*, in mother cell; *C*, free, with two cilia.

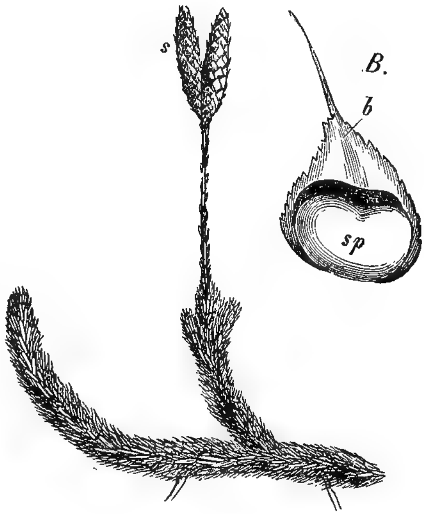


Fig. 598. *Lycopodium: S*, the cone-like spore-bearing leaves; *B*, an enlarged sporophyll leaf; *b*, the blade, and *sp*, the sporangium which contains the spores.

the center of the capsule the Pedicel is continued as the Columella, and at its summit it is closed in until mature by one or more coverings. By a special organ, the Peristome, consisting of a number of teeth, it is possible for the capsule to be closed during wet weather and opened for the distribution of its spores when it is dry.

The Pteridophyta.—All three groups of this division contribute more or less important articles to the commercial materia medica.

Equisetaceae.—In this group again we have, as in the flowering plant, a gametophyte which is microscopic, although, unlike that of the flowering plants, it is produced entirely disconnected from the sporophyte. From it develop hollow-stemmed plants which are commonly known as horse-tails or scouring rushes. The latter name is in allusion to the large amount of silica produced in their superficial tissues, on account of which they are frequently used for scouring purposes. Medicinally they have practically no use, although it is said that poisonous properties exist in one or more of them.

Lycopodiaceae.—The club mosses, like the horse-tails, are said to contain some poisonous species, but their interest in drug commerce resides wholly in the use of the spores of some species, under the name of Lycopodium or vegetable sulphur. In the species yielding this product there are two forms of leaves, those upon the fruiting portion differing materially from those of the main stem (Fig. 598). In this group the spores are all similar (Homosporous), while in some of the lower groups they are of two forms (Heterosporous). As in the class last considered, the gametophyte is microscopic, while the sporophyte is the conspicuous generation. Upon the upper surfaces, or in the axils, of the leaves of the fruiting branch the spore-cases (Fig. 598, *sp*) are solitary. In collecting Lycopodium, it is customary to pull off these tops and allow them to dry thoroughly, whereupon the spores are easily shaken out.

The Filices.—The ferns contribute a number of important articles to the materia medica, the principal of which is Aspidium, or Male Fern.

From a pharmacognostical viewpoint, the chief difference between the ferns and the flowering plants is in the stem-structure. The main stem is usually under ground, although often aërial and sometimes assuming the dimensions of a shrub or tree. In the Hawaiian Islands these trunks furnish timber for large and heavy planking. The peculiarity of the fern-stem is its possession of a number of steles, each having its own endodermis. As compared with the stem of an ordinary dicotyledon, that of the fern presents the structural appearance of being a fascicle of stems, bound together by an interstellar tissue. This indication is borne out by the peculiarities of the structures which fill the office of the leaves of other plants, and which are known as Fronds. While thus taking the place of ordinary leaves and appearing to be such, these are seen, on closer examination, to be the homologues not of leaves, but of stems, each of them originating from and representing one of the steles of the compound stem. There is, moreover, no such division of the stem into phytomers as we see in the flowering plants.

It is not necessary to study the main stem in order to discover the wide difference between the leaf and the fern frond, for if one but watches the development and behavior of fronds, especially in certain groups, as the *Gleichenias*, he will be struck by the fact that it is, in its real nature, more like a green and flattened stem than a leaf. These facts have led many morphologists to look upon the fern-frond as a structure distinct in kind from the leaf.

In the ferns we again find the gametophyte small and inconspicuous (Fig. 599), while the sporophyte is the generation familiarly known to us. These sporophytes may be herbs, shrubs, or trees, and many of them are climbers.

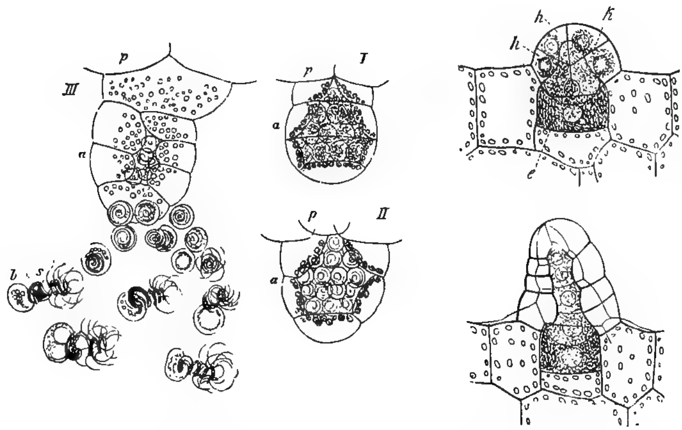


Fig. 599. Organs of reproduction in the ferns: *I*, *II*, *III* (*p*), prothallium or gametophyte; *a*, the male organ, antheridium in various stages of growth of antherozoids, which in *b* are shown free and provided with cilia; *e*, oöspore or egg cell; *E*, the archegonium—developing into young fern plant—*h*.

The sporangia may be borne on the lower surface of the one form of frond possessed by a species, or the sporophyll may be entirely different from the other fronds. In the former case, the sporangia are grouped in little masses, forming rusty- or dark-colored spots on the surface which are known as Sori or Fruit-dots. These may be naked, or partly or wholly covered by the reflex and modified margin of the frond, or by special bract-like membranes, developed from the surface of the frond. Such a membrane is called an Indusium. When the sporophyll is of special form, the modes of arranging, enclosing, or protecting the sporangia are various. Upon these characters, and upon those of the sporangia themselves, is chiefly based the classification of the ferns.

CHAPTER XIX

BOTANICAL CLASSIFICATION AND ANALYSIS

Reference was made in our introductory chapter to the object of Systematic Botany as being the arrangement of plants in a system or series which should indicate approximately the successive order of their appearance in existence, that is, of their development, or of their creation, as commonly expressed. The Cryptogams or flowerless plants undoubtedly existed first, and from some one or more of their sub-divisions the flowering plants developed. The former are therefore regarded as "lower" than the latter, and are treated as the basal or fundamental division of plants. Similarly, certain of their divisions occupy the relation of having existed before others and of having given origin to them, and are therefore regarded as occupying the lower positions in the cryptogamic series. By determining those relations for the various sub-divisions, we obtain grounds for arranging all the cryptogams in a sequence of which it may be said, in general, that the lower came first to exist and the latter are newer in creation. By applying the same methods, the Phanerogams are formed into a similar series.

It must not be understood that these groups occupy an unbroken serial relation to one another, like the rounds of a ladder. They would do so had each group given origin to only one other, and had all the groups maintained their existence, or even left evidences of having existed, so that their relative positions could be assigned them. Instead of this, a formerly existing group frequently, probably usually, gave origin to several new forms, many of which became the starting points for others, so that the system is more like that of the branching of a tree than of a series of steps. Furthermore, it has frequently happened that a recent form has continued in existence, while that from which it originated has perished and left no record. So great an influence have those conditions exerted that we have various groups now in existence, which show no special relationship to any other, and we have to assign them somewhat arbitrarily to their positions. For these and similar reasons, our system is at the best faulty and incomplete, and the nature of the case is such that it probably must always remain so. In spite, however, of all these imperfections, steady and great progress has been and is being made, and this natural system of classification must be regarded as a most useful attempt to indicate just such genetic relationships as exist among human beings.

The divisions and sub-divisions thus established stand as follows:

Divisions.—Of which there are two, the *Cryptogamia* and *Phanerogamia,* the latter being now often called *Spermatophyta,* as the production of seeds is regarded as their most important characteristic.

Sub-divisions.—Leaving out of consideration the divisions of the Cryptogamia, we find the Phanerogamia divided with two sub-divisions, the *Gymnospermae* and the *Angiospermae,* the latter the higher.

Classes.—Leaving out of account the Gymnospermae, the Angiospermae are divided into two classes, the *Monocotyledons* and the *Dicotyledons.*

Series.—The Dicotyledons are divided into three series, the *Thalamiflorae, Disciflorae and Calyciflorae.*

Cohorts.—Each of the series named above is divided into a number of Cohorts, or orders. Thus the Thalamiflorae have 6 cohorts, namely, *Rânales, Parietales, Polygalinae, Caryophyllineae, Guttiferales,* and *Malvales.*

Families.—Each cohort consists of a number of *Families,* of which there are about 300 among flowering plants, the *Ranunculaceae* or Buttercup Family and the *Compositae* or Daisy Family being examples.

Sub-families and Tribes.—Families, if large or heterogeneous, are often divided into *Tribes,* or into *Sub-families,* the latter then divided into Tribes. Thus, the Ranunculaceae contain 5, the Compositae 13 tribes.

Genera.—Families, either directly or through their tribes, are divided into genera, of which the most modern authorities recognize between 8000 and 9000 in all the families of flowering plants. The genera are very irregularly distributed among the families. Thus, the family *Columelliaceae* contains but one genus, *Columellia,* while the *Compositae* is made up of some 800 of them.

Species.—Genera, either directly or through a number of *Sub-genera,* are made up of species, of which there are probably not far from 250,000 now described among flowering plants. These are very irregularly distributed among the genera, many of the latter containing but one species, while others contain hundreds. *Solanum,* probably the largest genus, has been credited with as many as 1200 species.

A species is considered as an ultimate individual kind of plant, like the Red Maple, the ordinary medicinal Wild Cherry, or the Two-leaved Pink Ladyslipper.

Varieties.—Varieties frequently exist among the individuals of a species. It is practically impossible to establish rules for determining whether two closely related forms are two species or two varieties of one species, and there is hardly a point upon which our botanists are more at a disagreement than in estimating these cases. It may be said that a variety is a form of a species which depends either upon a natural tendency to vary, or upon modifications brought about by different climatic conditions or other environment, but which, in either case, is not permanently fixed, its descendants being liable under various conditions to reassume the characters of the parent. The characters of a species are, upon the other hand, supposed to have become permanently fixed. It may, of course, vary, but there is no special tendency for it to vary in the direction of the ancestral form more than from it, in a new direction.

Forms.—Variations which are not at all fixed, and clearly temporary in their nature, as the occurrence of a white flower among plants habitually blue-flowered, give rise to *Forms*. These are hardly considered worthy of names.

Botanical Analysis.—This consists in the determination of the botanical position and name, if it have one, of a plant, by comparing it with published descriptions until that one is found with which it agrees. To make such comparisons individually, and without system, would prove interminable among such a vast number of species, and the system of classification above mentioned is employed to reduce to a minimum the time and labor required. The process is essentially one of successive exclusions of the plant under study from more or less extensive divisions and subdivisions.

By determining that our plant produces flowers and seeds, we exclude it from the Cryptogamia, approximately half of the vegetable kingdom. Another similar act excludes either the Angiospermae or Gymnospermae and another, if it be an Angiosperm, from either the Monocotyledones or Dicotyledones. As the process continues, it becomes somewhat more complicated. The first steps may be positively taken by deciding a single point, but farther on, in determining the family, genus, and species, groups of characters have to be considered together, and held in mind at the same time for comparison. This is in general due to the fact that the characters separating the primary groups are older in time, and therefore more constant and less inclined to vary, while those characterizing the lesser groups are more recent in their origin, and much inclined to vary in different individuals. They are, therefore, less trustworthy and have to be considered in connection with others. It is for this reason that the most frequent differences of opinion concerning classification among botanists relate to genera, species and varieties.

CHAPTER XX

BOTANICAL NOMENCLATURE

In naming a plant, the object is to apply a name which does not and cannot be made to apply to any other. A familiar illustration is the name of the common Red Maple. In scientific circles the name "Red Maple" cannot be regarded as sufficiently exact and definite, because in different localities it is known as Soft maple, Swamp maple, White maple, and Early maple; while doubtless different maples are called "Red" in different localities.

Scientific accuracy, therefore, renders it indispensable that a system of botanical or scientific names, as distinguishable from the common, vulgar, or trivial names, shall be employed. The name *Acer* is, therefore, applied to the genus to which the maples belong, and this is known as the generic name of all the species of Maple. One of the rules of nomenclature requires that no other genus shall bear this name. In order to distinguish the different species of *Acer,* each must have, in addition, its specific name, the Red Maple receiving the specific name of *Rubrum.* It is, therefore, to be known as the *Rubrum Acer,* although the Latin form, with the generic name preceding, is employed thus, *Acer rubrum,* the specific name, except in certain cases, beginning with a small letter. By another rule of nomenclature, only this particular *Acer* may be called *rubrum,* although this name may be applied to plants in other genera than *Acer.* It is clear now that this combination of generic and specific names yields a complete name, and this is called the Binomial, which may not be applied to any other plant in the world, while either its generic or specific name may be.

It often happens that a plant name is for one reason or another abandoned by some, or most, or even all botanists. It is not then permitted that it be given to another plant, because it is liable at any time to be used again in its old application by other botanists, so that we should then come to have two plants of that name.

In spite of the rules here stated, it frequently does happen, very frequently has happened in the past, that a botanist, ignorant or careless that a certain name has been used, applies it to some other species, thus causing a duplication. In such a case the name *Acer rubrum* could not inform us with certainty which species was referred to by the writer or speaker. It might, for example, be an *Acer rubrum* made by Linné in 1753 or one so named by some one else in 1880. It is therefore necessary to add to the plant-name the name of its author, thus, *Acer rubrum* Linné. This necessity for the use of the author's name is semi-barbarous, and is a mere monument to the lack of system in plant-naming which once existed. With the perfect systematizing of nomenclature this necessity will pass away. For convenience, it is customary to abbreviate the name of the author thus, L. for Linné, Reichb. for Reichenbach, or Benth. for Bentham. The generic name may also be abbreviated in many cases by writing only its first letter, followed by a period, thus, *A. rubrum* L. This of course can only be done when it is well understood to what genus the writer is referring. For example, in the above cases, where we have been speaking only of *Acers*, the abbreviation "A." can be employed with entire satisfaction.

A name in parenthesis will sometimes be found interposed between the generic and specific names thus, *Acer* (*Negundo*) *aceroides*. This indicates that the genus consists of two or more sub-genera, the one in this case being *Negundo*. It is not customary to indicate the sub-genus in this way, but a writer often desires for some special reason to do so.

The name of an author enclosed in parenthesis is often seen standing between the specific name and that of the author, thus *Acer aceroides* (Moench) Gray. This means that the botanist named in the parenthesis assigned to the plant its specific name, but connected it with some other genus, the later author, whose name follows the parenthesis, having transferred it to the present genus, thus creating the present binominal. In all cases where a plant is thus transferred to a different genus, it must retain its original specific name, unless the genus to which it is so transferred already has a species with that name, in which case a new specific name must be assigned, this necessity being to avoid binomial duplication.

When the name of the author in parenthesis is not followed by another, it means that the writer claims that this binomial has never been printed and that he must henceforward be cited as its author.

We frequently see a trinomial used as the name of a plant, thus, *Viola tricolor alba*, no parenthesis being used for the middle name. This indicates that the species *Viola tricolor* sometimes exhibits a form possessing white flowers, and that this form is regarded as a variety of the species. The name *alba* is in this case called the *varietal* name. Another way of writing it, but which has not the sanction of botanists, is "Viola tricolor, var. alba."

The use of capitals and italics in printing botanical names is not, except in special cases, of botanical significance or authority, though attempts have been made to so treat it. Literature and individual taste supply the rules for this usage. This statement does not, however, apply in the case of the initial of the generic name or of the name of the author.

It has been shown above how two plants may come to have the same name assigned to them. In even a greater number of instances have several different names come to be applied to the same plant. The extent to which this has occurred may be realized from the fact that more than eight hundred thousand names exist for the two hundred and fifty thousand known flowering plants, this being an average of more than three names for each plant. Since only one name can be recognized for a plant and only one plant for a name, it follows that all others must be regarded as synonyms and should not be used. Until a comparatively recent period very autocratic methods have ruled in the selection and application of names under these circumstances. Each country has had but a few, or even but one botanist who assumed authority, and these have, in most instances, acted irregularly and inconsistently in selecting and applying their names. Now, however, most botanists recognize the importance of having some uniform custom, based upon sound principles, and the attempts in this direction are likely to result in great improvement.

The fundamental rule of nomenclature is that the first names, generic, specific, and binomial, ever given to a plant, beginning with the year 1753, shall be permanent, provided that they do not involve errors. Such errors may be literary or botanical. Literary errors may consist in wrong spelling or inflection, or in a composite derivation, part of the name being taken from the Greek and part from the Latin. Such errors do not justify the substitution of another name, but only a correction, with as little change as possible. Botanical errors justifying the substitution of a new name are numerous and varied. The most common is the reference of the plant to a wrong genus, as calling a *Rubus* a *Rosa*. Whoever discovers such a mistake is required to refer the species to its proper genus, but its specific name must if possible remain unchanged. The name of the author of the specific name then goes in parenthesis, as already explained. Not all changes of this sort indicate actual errors. The lines of distinction between two genera are often very arbitrary, the different opinions of different botanists being apparently equally well founded. One botanist will thus regard as of one genus plants which another divides among two or more genera.

Another very common error in the past was that of assigning to a genus a name which had already been applied to another. This, of course, necessitates a re-naming of the genus, all the specific names remaining unchanged and their authors cited in parenthesis as already explained.

Errors in specific names have occurred most frequently through the re-naming of a species which has already been published under a different name. In such cases, when the error is discovered, the name last given must fall. A difference of opinion has existed as to whether such a discarded name should be permitted to be afterward taken up and applied to a newly discovered plant. If the error in the first use of the name were beyond question, no harm would result from so doing, but such is not the case. In numerous cases botanists have disagreed as to the specific identity of two plants. One regards one of the plants as a mere accidental or temporary state of the other and discards its specific name. If, now, the discarded name be applied to some other species of that genus, there is danger that at any time the original opinion may be revived concerning the previous application of that name. This having in the meantime been applied to another species, we have the same name applied to two species. For this reason conservative botanists hold that just as a generic name once discarded may never be given to another genus, so a specific name, once dropped, may never be applied to any other species in the same genus. This constitutes the important rule often referred to, as in the expression, "Once a synonym (or homonym) always a synonym."

The whole subject of nomenclature and the rules which have been formulated for it are very extended and complicated, but the most important principles upon which the rules are based have here been explained.

CHAPTER XXI

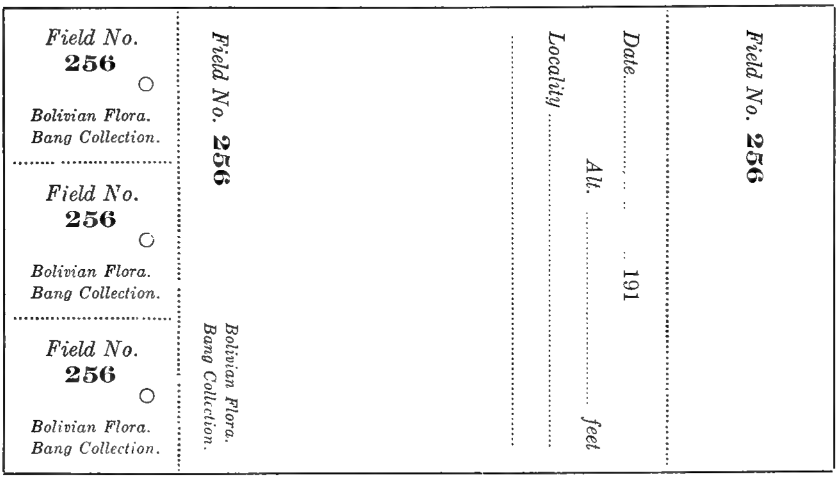
THE COLLECTION AND PRESERVATION OF BOTANICAL SPECIMENS

The study of botany cannot be properly pursued without the preservation of specimens. The mistake is very general of assuming that such material is required only in case of the making of a permanent herbarium. It is necessary besides as a temporary expedient in the thorough study of plants. A plant is not studied until all its parts have been examined. As the mature fruit is rarely present with the flower, and as the stem, leaves and underground portions are liable to present different characters at different seasons, it becomes necessary to make several collections from the same plant and to preserve them to be studied together. There is, moreover, a waste of time involved in using the summer season for dissection and study, when the attention should be directed to field-work.

Specimens may be preserved in alcohol or in formaldehyde or other solution, or they may be preserved by drying. The latter method is usually employed and is the more generally useful, although it possesses certain disadvantages which will be referred to further on.

Alcoholic specimens are made by simply immersing the material in alcohol and sealing perfectly. Very fleshy specimens may require a change of alcohol after a time. An improvement on this method is to immerse them in 50 per cent. alcohol for a few days, then transfer them to 75 per cent. alcohol and later to that of full strength (95 per cent.). Alcohol is liable to remove coloring matters and many other substances, as well as to extract the natural water, thus giving to the specimens a shriveled or wrinkled appearance. The use of a formaldehyde solution obviates both of these difficulties, even the most delicate colors being in most cases perfectly preserved. The strength of the solution ranges from 3 to 9 per cent., ordinary water being employed as a vehicle. In the case of fleshy fruits and some other substances, it is found necessary to pour off the first solution and apply a fresh one after a few days, and this renewal may be called for from time to time as the specimens show signs of deterioration. Under the very best of conditions, it must be expected that some changes will occur in the appearance of specimens preserved in solution, and the same is true of those prepared by drying, so that it becomes necessary to take careful notes regarding plants at the time of their collection.

The Record Book.—The record is to include the collection number of the specimen, which is also to be attached to the specimen at the same time, the date, locality, altitude, habitat, habit of the plant, color and any other facts not likely to be readily recognized in the dried specimen.



The best form of note-book is one containing 100 pages like that here figured, a convenient size for which is 4 x 7 inches and printed on very strong and tough paper, such as cartridge-paper. The numbers borne on these pages are to be printed by machine, so as to avoid all possible form of error. Through the holes in the tags at the bottom of the page strings are to be tied and the tags are to be firmly attached to the specimens. When the specimen is studied later there can thus be no possible question as to the specimen to which the notes refer. When the specimen is finally mounted in the herbarium, the remainder of the page should be torn out and glued to the sheet, the tag still remaining attached to the plant as indisputable evidence of identity. With great care, a similar assurance is possible without these elaborate provisions.

Besides the notes referred to above, it may be necessary to note the dioecious character of a plant, in which case that of the other sex must also be sought. This should be given the same number, followed by the proper sexual sign or by the letter *a* or *b*. If the leaves are not yet developed when the flowers appear, as is frequently the case with early spring flowers, an estimate should be made of the time when the leaves will probably be ready for collection and the number of the plant entered in an engagement calendar under the proper date at which the place should be again visited. The same thing is true in case the fruit is not ready at the time of the collection of the flowers. In these cases it is best to attach a tag to the living plant at the time of the first collection to avoid all possibility of confusing two species in the final complete collections.

Selecting the Specimens.—This matter of representing all parts of the plant and the same parts at different seasons is of special importance in case of pharmaceutical studies. Even the winter-buds and the underground portions in the winter season should be secured. One of the most important points is to secure the root-leaves of ordinary herbaceous plants, as well as the peculiar leaves of trees and shrubs which often grow upon root-suckers or upon young specimens. It is also wise to cause the germination of seeds and to preserve the seedlings with the remainder of the specimen. Pharmaceutical specimens moreover should represent the bark and the wood and these may with profit be taken separately from root, stem and branch.

Ordinary herbarium specimens, when finally completed, should not exceed sixteen inches in extreme length by ten inches in width. Even specimens of three or four feet in length may be easily reduced to this size by kinking and folding them at the proper points without entirely separating any part. Underground port ons, when not too large, should remain attached. Inconveniently thick portions, such as tubers or fruits, may be split and one or both parts preserved, or the centre may be cut out so as to reduce the thickness. In the case of large specimens, it will frequently be found necessary to remove a portion of the leaves. This should be very judiciously done, those retained being left at different points upon the specimen so as to show the successive modifications, and portions of the petioles should be left so as to indicate their position. In case of large plants, such as shrubs and trees, where only a branch can be preserved, it is important to select this branch from a part where growth has been free and unrestricted and a natural symmetry attained. With each specimen, a few loose flowers and buds should be preserved for dissection purposes.

Preserving the Specimen.—Specimens thus taken should be at once transferred to a portfolio carried into the field. Various forms of portfolios are for sale by botanical supply houses. They may be made of cardboard, wood-board, wooden lattice work or wire frames, and they should be carried in a strong pair of straps, similar to the ordinary shawl-strap. The portfolio should contain a number of double sheets of paper of about 11 x 17 inches. Nothing better can be obtained than single pages of an ordinary New York daily newspaper once folded. Within this fold the specimen, with tag attached, is to be laid, its leaves and flowers as straight as can be, one or more of each turned with the face, and others with the backs uppermost. While being carried in the portfolio, they should be subjected to strong pressure to prevent wrinkling, and none of the parts must be allowed to project beyond the edges of the paper.

Within twenty-four, and much better within six or eight hours of the time of collection, the folds, with specimens contained, are to be transferred to the dryers. At this time, each specimen should be gone over, its leaves and flowers perfectly straightened out and arranged in the position desired when dry. It is often desirable to introduce several thicknesses of bibulous paper inside of the specimen sheets, so as to make the entire thickness correspond with that of any excessively thick portion of the specimen, such as a large root, fruit or tuber.

The dryers are to consist of some thick bibulous paper. When little collecting is to be done, blotting paper is desirable, but when collecting is upon an extensive scale, this is far too expensive and perishable. Various forms of dryers of excellent quality are for sale by the botanical supply houses, but, in drying on a large scale, it has been found possible to effect considerable saving by improvising them out of some suitable material. The author has found the best method to be to obtain rolls of thick, gray house-sheathing paper, 36 inches in length. This may then be cut into 12-inch lengths, and folded to a size of 12 x 18 inches. When the amount of the material drying is large, it is better cut in 24-inch lengths and folded to 24 x 18 inches. Dryers of this size will then accommodate two specimen sheets lying side by side. There are so many varieties and qualities of house-sheathing on the market, that careful selection is necessary. For plant-dryers it should be free from mineral and coloring matters, tar and sizing, and its quality should be tested by its ability to take up moisture readily. As a general statement, it may be said that that grade ordinarily denominated "poor" by builders should be sought. The number of dryers between two layers of specimens should be determined by the amount of herbage possessed by the latter, by the condition of the weather and climate, the facilities for frequent changes of dryers and other similar conditions. In hot, dry weather only one folded dryer is required for ordinary herbaceous plants of temperate climates, provided the dryers are changed twice or even thrice a day. In bad weather, or with thick, water-laden specimens, or when the plants must remain more than twenty-four hours in the dryers without change, four folded dryers are required. By using a large number of dryers in the best of weather, it is frequently possible to dry ordinary specimens with but one change of dryers; or even without change, to secure specimens of the first quality.

Powerful pressure should next be applied. Weights, screws or levers may be employed for this purpose, but no other method is equal to the use of straps. These should be made of the heaviest and best leather obtainable, should be $1\frac{1}{4}$ or $1\frac{1}{2}$ inches in width and provided with a large strong buckle, the holes not more than two inches apart and punched to within two feet of the buckle. The length of the straps should be proportional to the size of the bundle drying. For extensive collecting, straps of 8 feet are required. The straps should be laid only a few inches apart and the bundle laid upon them so that the buckle barely projects from under the edge. The straps should be drawn firmly into place without drawing the buckles from their place. The operator now stands upon the bundle and stamps it firmly at all points, so that no parts of the specimens are left without a firm application of the dryers. The straps are then drawn as tightly as possible and secured. A strong man can thus secure pressure of 500 or 600 pounds, all of which is required for a pile of dryers two feet or more in height. Even then it will be found, after the lapse of two or three hours, that the pressure has become almost completely relaxed, owing to the wilting and shrinking of the specimens, and the straps must be tightened. The pile should now be stood upon the end on a dry stone or wooden support, a pole frame being best. The flat side should be exposed to the sun, or quite as good, to the heat of the kitchen range. When possible, the dryers should be changed twice a day for the first day or two. The dryers into which the sheets are to be transferred should be perfectly dry and if possible hot from the sun. When it is not possible to expose them to the sun just previous to making a change in the morning, they should be wrapped tightly in a rubber cloth when brought in from the sunshine of the previous afternoon, as dryers not thus protected will absorb a considerable amount of moisture during the night. It is to be considered that the first hour in perfectly dry, hot dryers contributes quite as much to the beauty of the specimens as the succeeding five hours.

In making the change, the specimen sheets are to be transferred to the fresh dryers without opening. Under the above treatment, in hot and very dry weather, most specimens will be dried perfectly in from three to four days. Upon the tablelands of Mexico and similar localities only half of this time is required. Many plants, such as orchids or cactuses, may require all summer for drying and are even frequently worn out in the process of changing before they become dry. Such plants may be dipped for an instant in boiling water before being dried. This process, while it greatly expedites drying, is apt to make the specimen turn black.

Great judgment is required to avoid regarding a specimen as dry before it really is so. The test is to see that any part will snap off in attempting to bend it. Even after the specimens are perfectly dry they should not be sealed up at once, as they are liable to undergo a sweating process during the succeeding day or two. They should be tied tightly in bundles and these bundles exposed to the sun for an hour or two on several successive days, after which they may be sealed up, a good method being to wrap them tightly in waxed paper, this protected by heavier paper, for transportation through a moist climate.

Poisoning the Specimen.—Various methods have been resorted to for poisoning specimens so as to make them proof against the attacks of the small insects which infest the herbarium, but in no case have the results proved permanent. Arsenical and mercural solutions have been most employed. Upon the whole, a saturated alcoholic solution of corrosive sublimate is the most satisfactory poisoning agent. Theoretically, the corrosive sublimate soon becomes converted into calomel, but in practice its effects, if it be thoroughly applied, last for a great many years. It may be poured upon the specimen, applied with a brush, heavily sprayed from an atomizer, or the specimen dipped into it. It is to be treated as a very dangerous poison, not only internally, but highly irritating to eyes, nose, and lungs and capable of poisoning by inhalation of the spray.

When insects are found attacking mounted specimens, the latter should be enclosed in a tight case and subjected for some hours to the vapor of carbon disulphide.

Mounting the Specimens.—For permanent mounting in the herbarium, sheets of standard size ($16\frac{1}{2}$ x $11\frac{3}{4}$ inches) should be used and the paper should be white and very heavy. Much paper now made of wood-pulp quickly becomes yellow or brown, and scrupulous care to avoid this quality should be taken. The specimens are to be secured by the use of white glue applied over the entire surface and the stems and branchlets should also be strapped down with strips of gummed linen. Before attaching a specimen to the sheet, it should be carefully examined to see that it exhibits both surfaces of the leaves, as well as both the inner and outer surfaces of the flowers. Finally, an appropriate label is to be gummed to a convenient part of the sheet, preferably to the lower right-hand corner.

Wood specimens and other parts which cannot be attached to the sheets may be preserved in suitable boxes or cabinets, according to the taste and means of the collector. In all such cases, careful reference should be made upon the label of each part of a specimen to the existence of the other parts elsewhere.

Collecting Specimens for Immediate Examination in the Fresh State.—For this purpose, various forms of tin case, commonly known as vasculums, are provided. In these cases, specimens placed without free access of air and light and without the addition of anything more than their natural moisture, may be preserved perfectly for many days. In the absence of proper vasculum, any tin pail or tin box with a tightly fitting cover may be used. The author has found it very convenient to carry with him a square yard of thin rubber cloth, which may be folded tightly and carried in the pocket without any inconvenience, and used when occasion requires.

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