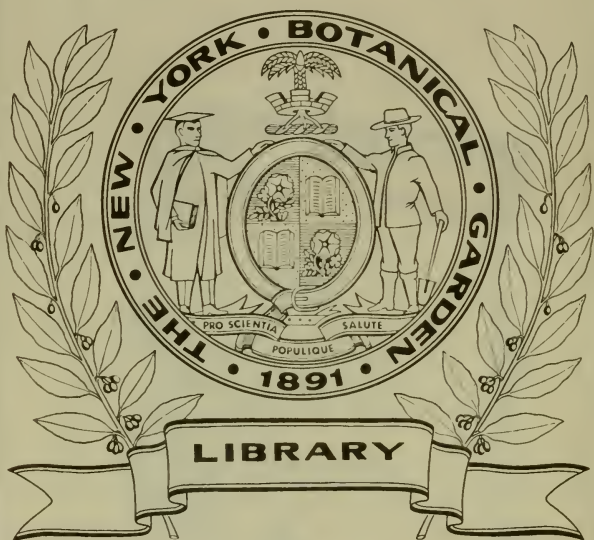


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Written for and printed in

"The Nation", 30 October 1913.

Written as an obvious protest against the modern methods of teaching botany, F. L. Sargent's "Plants and Their Uses: An Introduction to Botany" (Holt) presents a curious and perhaps helpful point of view. The author begins with the assumption that the obvious and most interesting questions to ask about a plant are "What is it? What is it good for? or What does it do?" With these as a guiding principle, it follows that the work differs radically from any of the textbooks now in use. For it lays emphasis, not upon processes such as photosynthesis, respiration, reproduction, and so forth, but upon the plants that touch the every-day existence of all of us, such as the foods, beverages, drugs, fibres, and the like. The first half of the book is taken up with descriptions and historical notes upon the introduction into cultivation of all the better-known economic plants. The usual routine ground is covered, but tersely and with some haste, and the chief emphasis is laid on industrial botany, if there be such a science. It is unfortunate that the first modern textbook that approaches botany from this side should have inaccuracies of statement and a certain lack of perspective. For instance, opium is a narcotic, not an intoxicant (p. 184); the Para rubber tree is *Hevea brasiliensis*, not *H. guianensis*.

parted widely, in form and spirit, from established conceptions, may be granted readily. His Hamlet, indisputably, was utterly un-Shakespearean, but his Othello, surely, was a masterpiece, at all events from his own point of view. In his broad contention that English actors are, almost of necessity, the best interpreters of English poetic masterpieces, Mr. Winter is on tolerably safe ground, if a possible exception be made in the case of the Germans; but there are exceptions to most rules, and there is no particular reason why an Italian, for instance, should not comprehend such parts as Othello and Coriolanus.

PLANTS AND THEIR USES

AN INTRODUCTION TO BOTANY

BY

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WITH NUMEROUS ILLUSTRATIONS



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PREFACE

The main purpose of the book is to show some of the educational possibilities offered by plants of every day use, and at the same time to guide beginners to such general ideas about plants as should form part of a liberal education.

There are a number of plants that every one ought to know because of their intimate connection with human welfare. These plants represent all parts of the vegetable kingdom, they are the very ones about which most persons have the greatest desire to learn, and they are mainly the ones which were first studied by mankind. Help the beginner, therefore, to learn at the outset as much about these economic plants as he is ready for; then help him to classify them scientifically, and he will be prepared to appreciate that wider view of the life of plants which inspires botany today. On this plan I have tried to write such a book as I believe would have been most useful to me when I was a beginner.

Botany taught by the historical method, as this procedure may be called, not only appeals from the start to the strongest practical incentives, but profits by the student's knowledge in many other departments, which knowledge it often enriches. Thus pursued botany also offers an exceptionally fine opportunity for cultivating scientific habits of mind and methods of work. These are sure to economize energy in every intellectual undertaking. The scientific attitude and scientific ways of proceeding control modern progress, and in no better way can one catch the spirit of these than by the scientific study of plants.

So closely similar are the needs of all who wish to make a good beginning that it becomes possible for a book like the present to serve many diverse classes of students. The

scheme is so elastic that no two classes need follow it in precisely the same way; but may vary the work within wide limits, emphasizing now this aspect, now that, hurrying over one part and dwelling upon another as circumstances shall determine. The text printed in small type may be omitted with younger classes, or with those requiring only a short course. The matter in larger type will then be found to proceed connectedly, and to be in no way harmed by the omissions made. If a still shorter course be desired the class may go through as many topics as there is time for, leaving the rest to be taken up if possible at some future time. Whatever ground has been gone over, if well studied, will then be so much to the good; and since the educationally more important subjects have been treated in the earlier chapters, the student may feel that even a little is worth while.

The figures used in this book are mostly copies from various well-known works as indicated by the authors' names in parenthesis under the figures; the remainder are from original drawings by the writer. Permission has been very kindly granted by Dr. N. L. Britton and Judge Addison Brown to use the figures from their *Illustrated Flora*.

In conclusion, I wish to acknowledge most gratefully the helpful criticisms and suggestions received from teachers and other friends during the progress of the work. Especial thanks are due to Charles W. Swan, M. D., for suggestions regarding medicinal and poisonous plants; to Mr. Henry J. Williams, Mr. George W. Rolfe and Professor Kenneth L. Mark for help on chemical matters; to Professor G. H. Parker for reading evolutionary parts; to Mr. A. B. Seymour for reading the chapters on cryptogams; and to the botanists of the Harvard Herbarium and University Museum for facilitating my work with books and specimens.

F. L. S.

CAMBRIDGE, MASSACHUSETTS
December, 1912

CONTENTS

PREFACE.	PAGE iii
------------------	-------------

CHAPTER I

THE STUDY OF PLANTS

1. Botanical questions.	1
2. The beginnings of botany.	1
3. Our dependence upon plants.	1
4. Human needs and the needs of plants.	2
5. How plants are named.	2
6. Early plant names.	3
7. Binomial nomenclature.	4
8. Species.	4
9. Varieties.	5
10. The genus.	6
11. The authority.	7
12. Plant families and higher groups.	7
13. The departments of botany.	8

CHAPTER II

CEREALS

14. What cereals are.	11
15. Characteristics of cereals.	11
16. Importance of grains in ancient times.	17
17. Earliest use of grains.	20
18. Oats.	25
19. Barley.	25
20. Rye.	25
21. Maize.	25
22. Rice.	25
23. Wheat.	28
24. Buckwheat.	29
25. The value of cereals.	30
26. Water in grains.	30
27. Ash.	30
28. Nutrients.	31
29. Carbohydrates.	31
30. Proteids.	33
31. Fats.	34

CHAPTER III

VARIOUS FOOD-PLANTS

	PAGE
32. Classes of food-plants.	35
33. Nuts.	35
34. Pulse.	40
35. Earth-vegetables.	41
36. Herbage-vegetables.	53
37. Fruit-vegetables.	85
38. Fruits.	88
39. Miscellaneous food-products.	91
40. Vegetable foods in general.	113
41. Food as fuel and building material.	114
42. Measures of energy.	115
43. Energy of vegetable foods.	116
44. Rations.	117
45. Food-plants in general.	122
46. The primitive centres of agriculture.	122
47. Relation between culture-period and native home.	123
48. The multiplication of varieties.	126
49. How varieties arise.	126
50. Artificial selection.	127

CHAPTER IV

FLAVORING AND BEVERAGE PLANTS

51. Food-adjuncts.	128
52. Spices.	128
53. Savory herbs.	137
54. Savory seeds.	137
55. Miscellaneous condiments.	137
56. Essences.	146
57. Non-alcoholic beverages.	150
58. Alcoholic beverages and stimulants in general.	156

CHAPTER V

MEDICINAL AND POISONOUS PLANTS

59. Medicines and poisons.	162
60. Non-poisonous drugs.	163
61. Poisonous drugs.	176
62. Plants poisonous to eat.	192
63. Plants poisonous to handle.	217
64. Poisonous plants in general.	219

CHAPTER VI

INDUSTRIAL PLANTS

65. Uses of industrial plants.	222
66. Fibers in general.	222

CONTENTS

vii

	PAGE
67. Surface fibers	225
68. Bast fibers.	228
69. Mixed fibers.	231
70. Pseudo-fibers.	239
71. Woody fibers.	240
72. Wood in general.	241
73. True woods.	256
74. Pseudo-woods.	272
75. Cork.	279
76. Elastic gums.	280
77. Resins.	287
78. Coloring matters.	290
79. Oils.	295
80. Fuel.	297
81. Useful and harmful plants in general.	302

CHAPTER VII

CLASSIFICATION AND DESCRIPTION

82. Systematic classification.	305
83. Early attempts at classifying.	306
84. Artificial systems.	307
85. The Linnæan system.	308
86. The natural system.	310
87. Technical description.	312
88. Early attempts at describing.	312
89. The Linnæan reform in terminology.	313
90. Terminology and nomenclature.	314

CHAPTER VIII

THE PARTS OF A SEED-PLANT

91. Flax as a type.	316
92. The seed.	316
93. The seedling and its development.	317
94. The flower and the fruit.	319
95. Physiological division of labor.	319
96. Organs and their functions.	321
97. Morphological differentiation.	322
98. Morphological units.	323
99. Members of the plant body.	323
100. Homologies.	326

CHAPTER IX

THE CROWFOOT FAMILY

101. General features.	328
102. The vegetative organs compared.	330

	PAGE
103. The reproductive system	343
104. Plant formulas	352
105. The family chain	355

CHAPTER X

VARIOUS PLANT GROUPS

106. The Magnolia Family (Magnoliaceæ)	358
107. The Laurel Family (Lauraceæ)	360
108. The Crowfoot Order (Ranunculales or Ranales)	361
109. The Poppy Family (Papaveraceæ)	361
110. The Mustard Family (Cruciferae)	362
111. The Poppy Order (Papaverales or Rhœadales)	363
112. The Rose Family (Rosaceæ)	363
113. The Pulse Family (Leguminosæ)	365
114. The Rose Order (Rosales)	367
115. The Linden Family (Tiliaceæ)	367
116. The Mallow Family (Malvaceæ)	369
117. The Mallow Order (Malvales)	370
118. The Parsley Family (Umbelliferae)	370
119. The Parsley Order (Umbellales or Umbellifloræ)	371
120. The Buckwheat Family (Polygonaceæ)	372
121. The Buckwheat Order (Polygonales)	372
122. The Birch Family (Betulaceæ)	373
123. The Beech Family (Fagaceæ)	374
124. The Beech Order (Fagales)	376
125. The Walnut Family (Juglandaceæ)	376
126. The Walnut Order (Juglandales)	376
127. The Willow Family (Salicaceæ)	377
128. The Willow Order (Salicales)	377
129. The Crowfoot Series (Archichlamydeæ)	377
130. The Heath Family (Ericaceæ)	378
131. The Heath Order (Ericales)	379
132. The Morning-glory Family (Convolvulaceæ)	379
133. The Nightshade Family (Solanaceæ)	382
134. The Figwort Family (Scrophulariaceæ)	382
135. The Mint Family (Labiatae)	383
136. The Phlox Order (Polemoniales or Tubifloræ)	383
137. The Gourd Family (Cucurbitaceæ)	383
138. The Bellflower Family (Campanulaceæ)	384
139. The Sunflower Family (Compositæ)	385
140. The Bellflower Order (Campanulales)	386
141. The Bellflower Series (Metachlanydeæ)	386
142. The Dicotyl Subclass (Dicotyledones)	386
143. The Grass Family (Gramineæ)	387
144. The Grass Order (Graminales or Glumifloræ)	388
145. The Palm Family (Palmaceæ)	388
146. The Palm Order (Palmales or Principes)	389
147. The Arum Family (Araceæ)	389
148. The Arum Order (Arales or Spathifloræ)	389
149. The Rush Family (Juncaceæ)	390

CONTENTS

ix

	PAGE
150. The Lily Family (Liliaceæ).	390
151. The Iris Family (Iridaceæ).	390
152. The Lily Order (Liliales or Liliifloræ).	390
153. The Orchid Family (Orchidaceæ).	391
154. The Orchid Order (Orchidales or Microspermæ).	391
155. The Monocotyl Subclass (Monocotyledones).	391
156. The Case-Seed Class (Angiospermæ).	391
157. The Pine Family (Pinaceæ).	392
158. The Yew Family (Taxaceæ).	392
159. The Pine Order (Coniferales or Coniferæ).	393
160. The Naked-Seed Class (Gymnospermæ).	393
161. The Seed-Plant Division (Spermatophyta).	393
162. The Vegetable Kingdom (Vegetabilia).	394

CHAPTER XI

KINSHIP AND ADAPTATION

163. The problem of origins.	428
164. The doctrine of special creation.	429
165. The doctrine of organic evolution.	431
166. Acquired adaptations.	441
167. Selected adaptations.	446
168. Acquirement versus Selection.	452
169. Sudden adaptations.	457
170. Evolution by choice.	461
171. Evolution in general.	464

CHAPTER XII

LIFE-HISTORIES

172. Cycles of life.	470
173. The Blue Algæ (Class Cyanophyceæ).	470
174. The Green Algæ (Class Chlorophyceæ).	476
175. The Brown Algæ (Class Phæophyceæ).	485
176. The Red Algæ (Class Rhodophyceæ).	487
177. The Seaweed Subdivision, Algæ in general.	491
178. The Fission Fungi (Class Schizomycetes).	492
179. The Yeast Fungi (Class Saccharomycetes).	495
180. The Pin-mold Fungi (Class Zygomycetes).	495
181. The Water-mold Fungi (Class Oömycetes).	499
182. The Spore-sac Fungi (Class Ascomycetes).	499
183. The Spore-base Fungi (Class Basidiomycetes).	501
184. The Mushroom Subdivision, Fungi in general.	503
185. The Spore-sac Lichens (Class Ascolichenes).	504
186. The Spore-base Lichens (Class Basidiolichenes).	508
187. The Lichen Subdivision, Lichens in general.	508
188. The Thallophyte Division, Lobeworts (Thallophyta).	509
189. The Liverworts (Class Hepaticæ).	513
190. The True Mosses (Class Musci).	519

	PAGE
191. The Bryophyte Division, Mossworts (Bryophyta).....	530
192. The Ferns (Class Filicineæ).....	532
193. The Scouring-rushes (Class Equisetinæ).....	542
194. The Club-mosses (Class Lycopodinæ).....	544
195. The Pteridophyte Division, Fernworts (Pteridophyta).....	548
196. Cryptogams and Phenogams.....	550

CHAPTER XIII

THE PLANT'S PLACE IN NATURE

197. The three kingdoms.....	561
198. The Inorganic Realm.....	562
199. The Organic Realm.....	569
200. Plants in general.....	574
INDEX.....	577

PLANTS AND THEIR USES

PLANTS AND THEIR USES

CHAPTER I

THE STUDY OF PLANTS

1. Botanical questions. When an unfamiliar plant attracts our attention usually the first questions we wish to ask are: What is it? What is it good for? or What does it do? Such questions have been asked from early times about plants in all parts of the world, and the classified knowledge which has been acquired in endeavoring to answer them has given us the science of botany.

In beginning our study of the subject it will be profitable for us to consider in a general way what it really means to answer questions of this sort, so that we may appreciate something of their importance and what they involve. Each question, as we shall see, has led to numberless others until the science has so broadened as to embrace every reasonable inquiry that may be made regarding plants.

2. The beginnings of botany. Like most people to-day, the earliest botanical writers concerned themselves more with the uses of plants than with their forms and habits. Thus Pliny, the most learned of Roman writers on natural history, significantly remarks that there were, to be sure, other plants in the hedges, fields, and roadsides than those he had described, but they had no names and were of no use. It is surely only natural that the uses of plants should be what first arouses our interest in them. Every one can appreciate most readily the advantages of knowing all we can about things which contribute so greatly to our welfare.

3. Our dependence upon plants. Let us consider for a moment how much we depend upon the vegetable kingdom. Every one knows that in all we eat and drink, the nutritious, strength-giving part comes either from plants or animals. As the animals which yield us food depend in their turn either

upon plants or upon plant-eating animals, it follows that if it were not for plants the whole animal kingdom, ourselves included, would soon starve. So too in the matter of clothing we depend partly upon the plants which yield cotton, flax, and similar materials, and partly upon those plant-fed animals which give us silk, wool, and leather. Forests yield the chief materials for ships and other means of transportation, for houses, furniture, and innumerable utensils. The fuel which cooks our food, heats our dwellings, and drives the machinery of factories, ships, and locomotives, comes either from plants recently alive or from coal-plants which died long ages ago and were buried in the earth. In sickness, too, the drugs which allay our suffering and help to cure us, are almost entirely of vegetable origin. So whichever way we turn we find plants serving us in most important ways—feeding us, clothing us, sheltering us, warming us, working for us, and making us well—indeed, our dependence upon them is so constant that we seldom realize how intimately our lives are bound up with theirs.

4. Human needs and the needs of plants. We must not forget that plants as well as animals are living things growing from infancy to old age, needing food and protection, and bearing offspring. Their various parts may be useful to us, but primarily are of use to the plants themselves. The plant-food which we take for our use, the plant had accumulated for its own purposes. The thorns which make a hedge effective against intruders, serve similarly as a defense to the shrub which bears them. Not only then as contributors to our welfare, but as sharers in the mysterious gift of life, should plants have a profound interest for mankind. How plants obtain their food, how they avoid injury, in what respects they are like animals, and how they differ from them—such questions soon press for an answer, and then it is seen that all plants, even the most humble, may have secrets of value to tell us.

5. How plants are named. Whenever many objects are to be studied and compared, it is necessary to have some convenient system of naming them and some method of expressing the various degrees of resemblance and difference

which may be found. The number of plants which botanists now have to deal with is estimated at about one hundred and seventy-five thousand. Only a small proportion of these plants have names in English, German, French, Italian, or other modern tongue; and even if they had, it would be an intolerable burden for students who need to consult the writings of foreign botanists to learn as many names for each plant as there are modern languages. Fortunately it has been agreed among botanists that each kind of plant shall have one botanical name, and only one, in all countries.¹ This name is Latin or of Latin form for the reason that the earlier botanical writings were in that language; and as educated people of whatever nationality are supposed to have some acquaintance with Latin, nothing could be more convenient for botanical purposes. For popular use, however, popular names are required and will be used chiefly, therefore, throughout the coarse print of the following pages.

6. Early plant names. The exact form of the name by which each kind of plant should be known was not decided until the middle of the eighteenth century. Then certain practical reforms were brought about mainly through the writings of the great naturalist Linnæus who is revered as the Father of Botany. Before this time many of the names which botanists used were exceedingly cumbersome. The difficulties under which students then labored are well illustrated by the following passage which occurs in a letter to Linnæus from his friend Dillenius:

“In your last letter of all, I find a plant gathered in Charles Island, on the coast of Gothland, which you judge to be *Polygonum erectum angustifolium*, *floribus candidis* of Mentzelius and *Caryophyllum saxatile*, *foliis gramineis*, *umbellatis corymbis*, C. Bauhin; nor do I object. But it is by no means Tournefort's *Lychnis alpina linifolia multiflora*, *perampla radice*, whose flowers are more scattered and leaves broader in the middle, though narrower at the end.”

The plant which this learned man had so much trouble in naming was afterwards called by Linnæus simply *Gypsophila fastigiata*—the name now recognized by botanists.

¹ Such, at least, is the botanical ideal. It is not always realized in practice. But mistakes and differences of opinion are surely to be expected in the naming of such a vast number of objects. Yet after all the actual confusion produced is comparatively slight, while the ideal pursued has advanced the science wonderfully.

7. Binomial nomenclature. To each of the different kinds of plants and animals which were known in his time, Linnæus gave a name like the one above, consisting of two parts. In doing this he made universal a principle very generally followed in the common names with which we are most familiar. Thus we speak of the White Mulberry, the Red Mulberry, and the Black Mulberry. Translated into Latin, these become the botanical names, *Morus alba*, *Morus rubra*, *Morus nigra*—the adjective part, as will be noticed, following the noun *Morus* according to the rule commonly observed in that language. So among the different kinds of oaks we have *Quercus alba*, *Quercus rubra*, and *Quercus nigra*; and to certain of the willows have been given the names *Salix alba*, *Salix rubra*, and *Salix nigra*. It will be seen that as the same component occurs repeatedly in the different names (just as in the names of persons there are many Smiths, Browns, and Robinsons and many Johns, Jameses, and Marys); so by adopting for plants the *binomial* or two-part system of naming, botanists are able to designate with perfect accuracy the many thousand kinds of plants, by means of a comparatively small number of words—a very much smaller number in fact than would be required if each kind had to have a name consisting of a single word. Thus, in the examples given it will be noticed that six words serve for naming nine different kinds of plants.

Another great advantage of the binomial method is that the name alone may tell quite a good deal about the plant, for, as we have seen, those sorts which resemble each other closely have the first part of the name identical. From this the reader would know, for example, that *Quercus aquatica* must be some kind of oak, and *Salix sericea*, some sort of willow.

8. Species. Ordinarily, there is no danger of being misunderstood when we speak of such and such “sorts” or “kinds” of plants, in the way that people commonly do; but when we come to a careful study of plants we find among them such variety in the degrees of resemblance and difference that the necessity arises for a more precise means of expressing ourselves. It thus becomes important to understand something of the distinctions which naturalists recognize between the different degrees of likeness among living things.

When from a dozen seeds out of the same pod, say of a kidney-bean, we raise as many plants, there are twelve distinct individuals no two of which are exactly alike in all particulars. Yet despite their individual differences, they re-

semble each other and the parent plant in a great many respects; and these peculiarities which they all have in common they share to an almost equal extent with innumerable other individuals. Taken together all these individuals which have this essential likeness form what is called a *species*. Thus, a *species* is a group of individuals regarded by experts as having about the same degree of resemblance as parent and offspring.

It is, as we have seen, a familiar fact that among the offspring of a single individual there are commonly various degrees of resemblance to the parent. The result is a more or less complete series of intermediate forms connecting the most dissimilar individuals one with another. Since among individuals known to be related closely such intermediate series commonly occur, botanists assume whenever connecting links of this sort are found between more or less dissimilar forms that the whole chain is so closely akin as to belong to one species. A striking instance of widely different forms connected closely by intermediate ones is afforded by the various sorts of cabbage and their kin (Figs. 63-70). These forms, including kale, cauliflower, kohlrabi, and Brussels sprouts, were doubtless derived, largely under man's influence, from the wild kale. Accordingly the name *Brassica oleracea* is applied not only to the wild plant but to all its cultivated descendants. There is no general English name applying to all the forms of this species.

9. Varieties. We have seen above that among the offspring of a single plant there will be minor differences, and that among the individuals of a species the differences may be very considerable. If in the examination of a number of specimens belonging to one species, a botanist finds certain individuals possessing in common some peculiarity or set of peculiarities which distinguish them clearly from the rest, as, for example, cauliflowers in contrast with other plants of the species *Brassica oleracea*, he calls the individuals thus distinguished a *variety*, and gives it a special name. The cauliflower thus becomes *Brassica oleracea* variety *botrytis*. Or, to take an example from wild plants, there are found among the individual trees that comprise the species called *Salix nigra*

certain ones of which the leaves instead of being curved merely at the tip, as in the majority of black willows, are "falcate" or curved throughout like a scythe blade. All the individuals having this peculiarity are accordingly regarded as forming a distinct variety, and when we wish to speak particularly of these we use the name *Salix nigra* variety *falcata*.

Cultivated varieties which are known, or supposed, to have arisen in comparatively recent times, and show only minor peculiarities, are commonly distinguished from varieties of wild plants and from certain very well-marked varieties in cultivation by being named in English, French, or some other modern language. Thus we speak of the "Baldwin" and the "Spitzenburg" varieties of apple. As subordinate kinds or subvarieties of cauliflower we have similarly the "early snowball" and the "autumn giant."

The question as to whether a certain group of individuals should be ranked as a species or as a variety is one which is often difficult to decide, and different botanists sometimes reach different conclusions. In all cases, however, a *variety* is understood to be a group of individuals included within a species and consequently connected with the other members of the species by a series of intermediate forms.

10. The genus. In the same way that those individuals which possess some special set of peculiarities constitute a variety, and just as there may be several varieties in which the individuals are enough alike to form a species, so different species possessing in common certain features of a more general nature are grouped into a *genus* (plural *genera*).¹

The name of the genus to which a given species belongs appears as the first component of the botanical name. In the examples already mentioned *Gypsophila*, *Morus*, *Quercus*, *Salix*, or *Brassica* is the generic part; *fastigiata*, *alba*, *nigra*, *rubra*, *aquatica*, or *oleracea*,

¹ The beginner can hardly be expected to grasp more than vaguely the distinctions here presented between genus, species, and variety; and the same may be true as well of certain other distinctions to be considered presently. His conceptions are likely to grow more definite, however, as his acquaintance with plants increases, and his efforts to gain such wider acquaintance will be much facilitated by starting with *some* conception, vague though it be, of what botanists mean by the groups of different rank which they distinguish.

the specific part of the name. Both parts are required to form the name of the species. *Alba*, *nigra*, etc., by themselves are not names.

11. The authority. It has sometimes happened that different botanists have given different names to plants of the same species, and the same name to plants of different species. To avoid any uncertainty as to just what plant is meant it is customary in technical botanical writings to place after a specific name the name (usually abbreviated) of the person or persons who first gave to the plant the name adopted. For example, if we write *Gypsophila fastigiata* L., it is plain to a botanist that the species so called by Linnæus is the one intended. Linnæus in this case is called the *authority* for the name. In popular or elementary books, like the present, authorities are usually omitted for the reason that only plants well known to botanists are apt to be mentioned, and the authorities for these may readily be found in the more technical botanies in case of need.

12. Plant families and higher groups. On the same principle that similar species form a genus, similar genera are grouped into a *family*; and families which have certain fundamental points of similarity are associated to form still more inclusive divisions of the vegetable kingdom. Thus the oaks (*Quercus*), chestnuts (*Castanea*), beeches (*Fagus*), and other trees which agree in having their flowers in tassel-like clusters, and their nut-like fruits held in something corresponding to a beech-bur, make up the beech family or *Fagaceæ*. The poplars (*Populus*) and willows (*Salix*) which also have tassel-like flower-clusters but only small seeds bearing slender silky hairs, constitute the willow family or *Salicaceæ*. Lilies and similar plants compose the lily family *Liliaceæ*; palms, the palm family, *Palmaceæ*; pine-like plants, the pine family, *Pinaceæ*, and so on. Plants like cabbage and mustard with flowers of cross-like form belong to the mustard family *Crucifereæ*.¹

So closely similar to the *Fagaceæ* are the members of the birch family, *Betulaceæ*, that botanists find it convenient

¹ It will be noticed that the botanical name of the families is formed usually by adding the termination *aceæ* to the main part of the name of a typical genus of the family. This termination corresponds to the English suffix *aceous*, meaning "having the qualities or characteristics of." The name is thus of adjective form, the noun *plantæ* being understood. Hence the full name of the willow family would be *Plantæ salicaceæ*, meaning salicaceous (or willow-like) plants. In a few cases like *Crucifereæ* (from *L. crux*, *crucis*, a cross; *fero*, I bear) the name expresses a peculiarity of the whole family.

to group the two families together into the beech order or *Fagales*. Similarly the *Pinaceæ* and another family resembling these cone-bearing plants form together the conifers, pine order, or *Coniferales*.¹

All plants which agree with the *Coniferales* in having no cases to contain their ripening seeds are grouped to form the naked-seedworts or Class *Gymnospermæ*;² while all the orders which develop their seeds in closed cases comprise the case-seedworts or Class *Angiospermæ*.³ Both together include all flowering and seed-producing plants, and so constitute the flowering plants, seed-plants, seedworts, or Division *Spermatophyta*,⁴ which together with the various divisions of flowerless plants make up the vegetable kingdom or Kingdom *Vegetabilia*.

From what has been said it is evident that even if we do not know the name of a plant much of importance may be told about it if we know the family to which it belongs, and quite a little if we know only its order or class. Regarding any plant the question, What is it? calls for much the same sort of answer as when we wish to identify a soldier. As with the latter we need to know the army, corps, brigade, regiment, battalion, and company to enable us to place him with military precision, so with the former to know its division, class, order, family, genus, species, and variety tells botanically its place in the vegetable kingdom. In knowing the position of a plant, however, there is this additional advantage that as resemblances and differences are expressed in the botanical groups to a much greater extent than in the military subdivisions we are just so much better informed regarding the true nature and peculiarities of the plant.

13. The departments of botany. The peculiarities considered in classifying plants are chiefly such as concern the form, construction, and arrangement of parts. An understanding of botanical classification means, therefore, a knowl-

¹ The termination *ales* in later botanical usage indicates the rank of order, but until recently has been used indiscriminately for various ranks.

² Gym''no-sper'mæ < Gr. *gymnos*, naked; *sperma*, seed.

³ An''gi-o-sper'mæ < Gr. *angion*, a case.

⁴ Sper'ma-toph''y-ta < Gr. *phyton*, a plant.

edge of the structure of plants, just as an account of the different kinds of steam-engines (*e. g.*, locomotives, including freight-engines, passenger-engines, switching-engines, etc.; stationary engines, including horizontal engines, pumping-engines, hoisting-engines, and so on) would be a description of the form and position of the different parts of their machinery. Moreover, not until we know about the different parts of a plant, as of a machine, are we in position to understand well what each part is for, and how they all work together. A knowledge of plant structure has thus a twofold importance. Similarly a knowledge of the materials which enter into the various parts of a plant, as of a machine, is necessary if we would understand its capabilities and usefulness.

So one question leads to another, the proper appreciation of one aspect of plants requiring also the study of other aspects. In this way have arisen the different departments of botany, each one representing a special point of view and all being necessary to a comprehensive understanding of the subject.

To the various departments have been given special names of which the following are the most important for a beginner to remember:—

Economic Botany views plants in their relation to man's welfare. It is concerned with all the kinds which man uses for food, medicine, clothing, shelter, ornament, or for other purposes; and all which are harmful to him as weeds, poisons, or pests. The ways in which these plants are useful or harmful, and to what extent, to what peoples, for how long, and why—such questions as these it seeks to answer as far as possible.

Chemical Botany is the study of the properties and quantities of the various substances found in plants. Since the value of a useful plant often depends upon the presence of some special substance, such as sugar, the economic botanist has frequent occasion to learn about the chemistry of the plants with which he deals. Such knowledge is also necessary to an understanding of the life-processes of plants.

Systematic Botany is concerned with the accurate descrip-

tion, naming, and classification of plants. It investigates especially the resemblances and differences which botanists depend upon in their systems of arrangement.

Geographical Botany seeks to discover the native home of each plant, its migrations, if any, and the nature of its habitat, *i. e.*, the surroundings amid which it grows wild.

Fossil Botany is the study of the remains of plants of former ages which have been preserved as fossils.

*Biological*¹ *Botany* is the study of plants in regard to their ways of life as shown in the form and activities of their parts. Questions which relate simply to the form or structure of parts come within the subdepartment *Vegetable Morphology*² or *Morphological Botany*. Such as concern simply the activities of parts, or the life-processes going on within them, belong to *Vegetable Physiology*³ or *Physiological Botany*. Finally, under *Vegetable Ecology*⁴ or *Ecological Botany* come all questions as to how the different parts are adapted by their form and behavior to serve the welfare of the individual and the species, *i. e.*, the relation of plants to their homes.

¹ Bi-o-log'-i-cal < Gr. *bios*, life; *logos*, logical account.

² Mor-phol'o-gy < Gr. *morphe*, form.

³ Phys-i-ol'o-gy < Gr. *physis*, nature.

⁴ E-col'o-gy < Gr. *oikos*, household.

Ecology considers the special ways in which plants solve the problems of their domestic economy, such as their manner of obtaining food, protecting themselves, and providing for their offspring. Ecology, also spelt œcology, is a word recently come into use among botanists, to designate a branch of botany which has been developed almost entirely within the memory of those now living. It has been used in rather various senses but generally with the meaning given above at least implied. Sometimes especial emphasis is put upon the peculiar associations or communities of plants that flourish in different kinds of homes, and upon the physical peculiarities of the homes themselves; but such matters are here referred in large part to geographical botany.

CHAPTER II

CEREALS

14. What cereals are. The ancient Romans, long before the Christian era, held each year at seed-time and harvest great festivals in honor of their goddess Ceres whom they worshiped as the giver of grain. In these celebrations offerings of wheat and barley, called *cerealia munera* or "gifts of Ceres," held a most important part. Thus it was that the bread-producing grains came to be known as *cerealia* or cereals. We now include under this name not only wheat and barley but also rice, oats, rye, maize or Indian corn, and a few other grains of less importance, such as buckwheat.

15. Characteristics of cereals. The general appearance of the most important grain-plants is shown in Figs. 1 to 15. As will be seen, they all agree in having narrow grass-like leaves, and slender upright stems bearing numerous flowers in "ears" or "heads," and finally, kernels enclosed by "chaff" or "husks." In all but maize each separate kernel is covered completely by two or more of these chaffy envelopes, and even in maize some thin papery chaff may be seen attached to the cob at the base of each kernel. All the cereals are annuals; that is to say, each completes its span of life within a year. All of those mentioned, except buckwheat, are grasses which have been more or less changed from their wild state by ages of cultivation.

Let us look more closely at the flowers of the oat. Although appearing rather unlike what we ordinarily call flowers, they have, as will be seen from Figs. 2 and 3, all the parts essential to a true flower. Indeed, because of their simplicity and perfection they afford a convenient standard with which to compare other flowers. In the center of the oat flower, as of flowers in general, is a *pistil*, in which may be distin-



FIG. 1.—The oat (*Avena sativa*, Grass Family, *Gramineæ*). Plant in flower, showing several leafy stalks growing from one root. Three of the stalks bear flower-clusters. About one-fifth natural size. (Bailon.)

guished (1) a lower swollen part, the *ovary*, containing a small egg-shaped body, the *ovule*; (2) a pair of elongated middle parts, the *styles*, each connecting the ovary with (3) a free, terminal part, the *stigma*, which is here like a little plume. Around the pistil are three *stamens* very like what are commonly met with in other flowers. Each stamen consists of (1) a double sac, the *anther*, in which are produced innumerable dust-like particles, the *pollen*, and (2) a threadlike part, the *filament*, on the upper end of which the anther is borne. When the anther is ripe it sheds its pollen, a particle of which coming to rest upon an oat stigma brings about the ripening of the ovule into a seed. As the ovule ripens, the ovary enlarges to keep pace with it, forming at last for the seed a firm protective covering which together with the seed constitutes the *grain*. Meanwhile the styles, stigmas, and stamens, having fulfilled their office, wither and fall off. The ripened ovary and its contents together with whatever parts ripen in connection with it (in this case two husks) constitute the *fruit*.

Since the purpose of the flower is to form seeds, and this is accomplished by means of stamens and pistils, these are called the

essential organs of a flower. A flower which has both is said to be *perfect*; if either alone, *imperfect*; or if with neither, *rudimentary*.

While the floral parts of the oat are being formed they are protected by papery husks called *bracts*, a bract being or-



FIG. 2.—Oat. *A*, Upper part of flower-cluster. *B*, a single spikelet in flower, with bracts spread somewhat apart. *C*, one of the outer bracts. *D*, an inner bract bearing an awn. *J*, pistil. *G*, lodicules. *A* and *B* about natural size, *C*, *D*, and *J*, enlarged. (Nees.)

dinarily a small leaf-like organ belonging to a flower-cluster. A little cluster of grass-flowers together with their bracts, is called a *spikelet*. At the base of the inner bracts are the so-called *lodicules* which by swelling spread apart the bracts so as to expose the anthers and stigmas at the proper time for shedding or receiving the pollen. An *awn* is a bristle-like appendage such as make up the "beard" of many grasses.

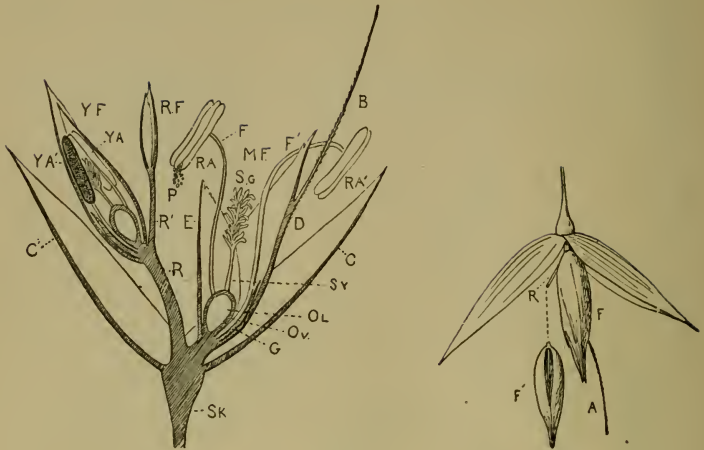


FIG. 3.—Oat. A spikelet (similar to B, Fig. 2) cut lengthwise to show the inner parts. Enlarged and somewhat diagrammatic. Sk, stalklet; R, R', its continuation as a little rachis within the spikelet; C, C', outer bracts; M, F, mature flower; Y, F, young flower not yet opened; R, F, rudimentary flower or pair of bracts with neither stamens nor pistils within; D, bract with awn (B); E, inner bract; G, lodicule; F, F', filaments bearing ripe anthers (RA, RA') from one of which pollen (P) is falling; Sg, stigma; Sy, style; Ov, ovary, containing an ovule (OL); YA, a young anther; YA', a similar one cut lengthwise to show the pollen forming within. (Original.)

FIG. 4.—Oat spikelet in fruit. F, the awned inner bract swollen with the ripe kernel which it enwraps; A, awn; F', another ripe "oat" separated from the little rachis (R) and turned to show its inner face where the edges of the bract enclosing the kernel are seen not quite meeting at the center. About twice natural size. (Original.)

A continuation of the stalk into a flower-cluster is called its *rachis*.

Every one should be able to tell at sight such important plants as the six principal cereals. When in flower they may be distinguished by the peculiarities mentioned in the following synopsis taken in connection with the figures.

THE PRINCIPAL CEREALS

<p>Flowers imperfect: staminate ones in a loose cluster or "tassel" at the top, pistillate ones in compact "ears" below; stem solid, often taller than a man.....</p>	<p>Spikelets each on a stalk of its own, forming a loose cluster.....</p>	<p>Spikelets erect, much flattened; outer bracts minute; stamens six.....</p>	<p>MAIZE</p>
<p>Flowers mostly perfect; stem hollow, seldom as tall as a man....</p>	<p>Spikelets drooping; bracts not flattened, the outer larger than the inner; stamens three.</p>	<p>Each joint of the rachis bearing a single spikelet.....</p>	<p>RICE</p>
<p>Spikelets borne directly on the main rachis, forming a compact "ear" or spike</p>	<p>A few of the lower spikelets rudimentary; the others with several perfect flowers.....</p>	<p>Each spikelet with two perfect flowers.....</p>	<p>OATS</p>
		<p>Each joint of the rachis bearing three spikelets, one or two of which may be rudimentary</p>	<p>WHEAT</p>
			<p>RYE</p>
			<p>BARLEY</p>



FIG. 5.—Rice (*Oryza sativa*, Grass Family, *Gramineæ*). P, upper part of rice plant, one-quarter natural size; S, a spikelet from the same; L, rain-guard or ligule at base of leaf-blade, inner view; natural size. (Martius.)

16. Importance of grains in ancient times. Many facts go to show that cereals must have been among the very first plants raised from seed. The Roman ceremonies, before referred to, were patterned after religious rites which had

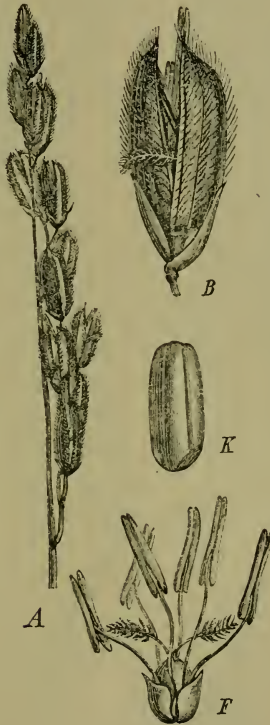


FIG. 6.—Rice. *A*, part of a flower-cluster of beardless rice, natural size. *B*, a spikelet of the same. *F*, a flower showing its six stamens, single pistil (with two styles and stigmas) and two lodicules. *K*, a ripe kernel. *B*, *F*, and *K* enlarged. (Nees.)

been practised for centuries by the Greeks, among whom wheat and barley were greatly prized. Passages in the Hebrew Scriptures show that these were the grains cultivated throughout Palestine and in the valley of the Nile; and it is an interesting fact that a grain of wheat has been found



FIG. 7.—Rye (*Secale cereale*, Grass Family, *Gramineæ*). A plant, a flower-cluster, two spikelets with bracts spread apart, a flower, and a kernel. (Baillon.)

embedded in a sun-dried brick from one of the Egyptian Pyramids believed to be over five thousand years old. Certain prehistoric remains of the Lake Dwellers in Switzerland



FIG. 8.—Wheat (*Triticum sativum*, Grass Family, *Gramineæ*). A plant and flower-cluster of bearded wheat, a flower-cluster of beardless or "club" wheat, a piece of the zig-zag rachis, a spikelet, a flower, and a kernel. (Baillon.)

show that wheat, barley, oats, and rye were in use among the ruder peoples of Europe, centuries before the Christian Era. The Chinese have record of the cultivation of rice in their country more than four thousand years ago. Until recent

times they observed annually a very ancient custom in which rice grains were planted by the Emperor with appropriate ceremonies in token of its great value to the nation. Finally, in the New World, evidences abound of the cultivation of maize ages before the coming of Columbus. Ears of Indian corn occur along with the most ancient remains in Mexico and Peru. Moreover, the Spanish conquerors found that in Mexico the natives worshiped an agricultural divinity to

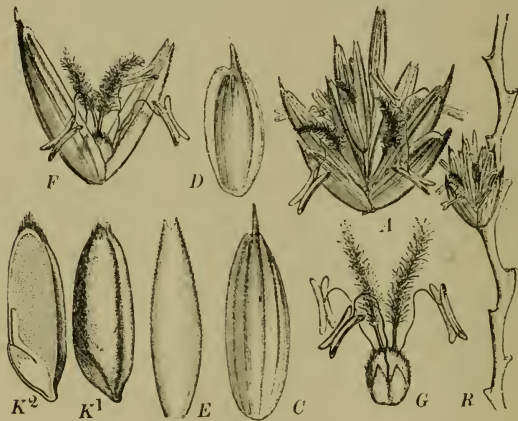


FIG. 9.—Wheat. *A*, spikelet of beardless wheat, enlarged. *F*, flower with bracts spread. *C*, *D*, *E*, bracts. *G*, pistil with stamens, and a pair of lodicules at base. *K¹*, *K²*, kernel. *R*, rachis. (Baillon.)

whom they brought the first-fruits of their maize-harvest, just as the Romans brought their offerings of grain to Ceres.

17. Earliest use of grains. Although we may be sure that the cultivation of the grains began many years before the time of our earliest records concerning them, we have no means of knowing how long ago they were first planted as a crop; nor have we any definite knowledge of how any one of them first came to be cultivated. Still there is good reason to suppose that before the advantages of planting were discovered, it was the custom to gather the wild grain when it was ripe, just as certain savage tribes do with other grains at the present day. Thus it would happen naturally



FIG. 10.—Common barley (*Hordeum sativum*, var. *vulgare*, Grass Family, *Gramineæ*). Plant, flower-cluster, spikelet, flower, and fruit. (Baillon.)



FIG. 11.—Two-rowed barley (*H. sativum*, var. *distichon*). Flower-cluster and base of a spikelet, slightly reduced. (Hackel.)

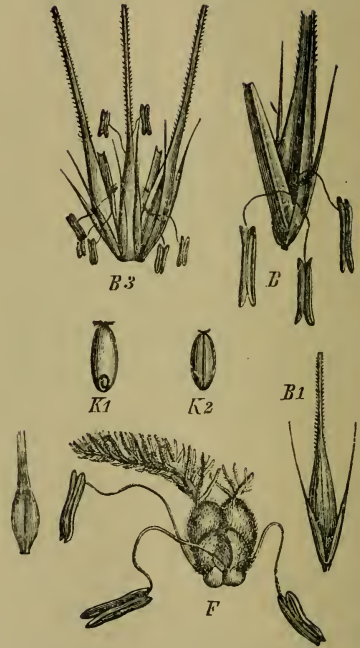


FIG. 12.—Six-rowed barley (*H. sativum*, var. *hexastichon*). *B3*, a group of three spikelets, as they appear together at a joint of the rachis. *B*, *B1*, single spikelets. *F*, a flower (one stigma partly removed). *K1*, *K2*, back and front views of kernel. All more or less enlarged. (Nees.)



FIG. 13.—Maize (*Zea Mays*, Grass Family, *Gramineæ*). A plant in flower. T, the "tassel" (a cluster of flowers having stamens but no pistils); S, stalk; L, leaf; E, E, E, the "ears" (clusters of flowers having pistils but no stamens); N, N, nodes (swollen joints of the stem); B, B, brace roots, which serve as guys helping to hold the stalk upright; R, earth roots; G, G, surface of ground. About one-twelfth natural size. (Original.)

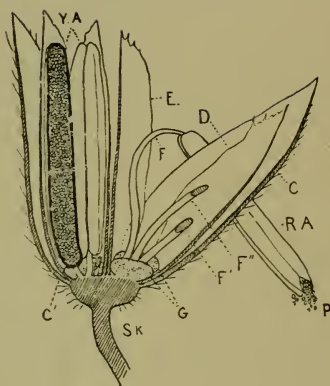


FIG. 14.—Maize. A spikelet from the tassel cut lengthwise to show its two flowers; the one on the right fully open, the other not yet mature. Sk, stalklet; C, C', outer bracts; D, E, inner bracts of the open flower; G, lodicules, which by swelling have spread apart the bracts; F', F'', filaments cut across; F, filament bearing ripe anther (R, A) shedding pollen (P); Y, A, young anthers, the left hand one cut to show the pollen. Enlarged. (Original.)

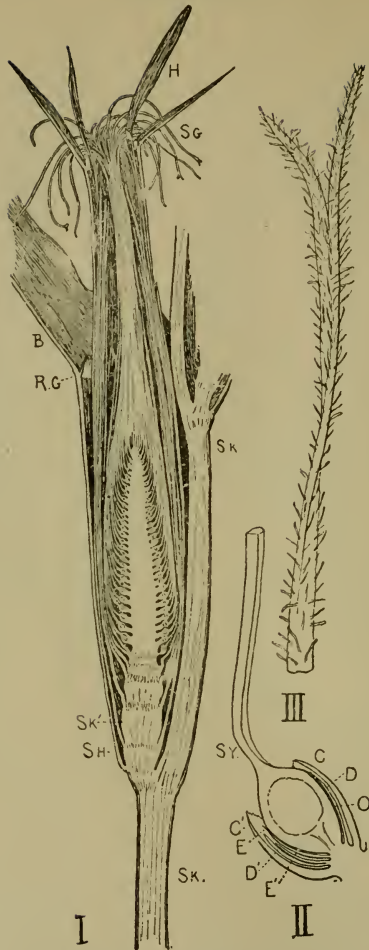


FIG. 15.—Maize. I. A young ear cut through the middle lengthwise. Sk, Sk, the main stalk; Sk', a short branch which bears the ear; Sh, sheathing lower part of the leaf which enfolds the whole ear and its husks; B, blade of the same leaf; R, G, the rain-guard which keeps rain from running into the sheath and promoting decay; H, the "husks" or large, more or less leaf-like bracts around the ear; Sg, stigmas (the "silk") protruding beyond the husks. About one-third natural size. II. A spikelet of the same ear, showing the bracts (C, C', D, D', E, E') and the ovary (O) and the lower part of the style (SY) of the single pistil. Enlarged. III. Upper part of stigma of the same, showing the delicate hairs that cover it. Enlarged. (Original.)

that the sort of grain which grew wild in a given locality would be the one first cultivated in that region, whence its cultivation would spread in course of time to other parts of the world. In Figs. 16 to 21 are indicated the region which is now believed to have been the native home of each cereal, and the range of its present cultivation. As will be seen by a comparison of the maps, five of the cereals are natives of the Old World, maize alone belonging to the new. All six, however, are cultivated successfully in America, and to-day the markets of the world are supplied largely by grain raised in the United States.

18. Oats thrive in northern regions where most of the other grains do not flourish. This grain forms one of the chief foods of the Scotch, Icelanders, and Scandinavians. Where other grains are used more largely as human food, it is especially valued as a fodder for horses.

19. Barley, in spite of its more southerly origin, grows even farther to the north than oats, and thrives equally in subtropical regions. Although anciently of great importance as a breadstuff, it is now used chiefly for malting (see section 29) and as fodder for domestic animals.

20. Rye will grow in a poorer soil than any other grain. This fact accounts for its importance in regions that are hilly or otherwise difficult of tillage. From it is made a dark-colored bread, largely used by the peasantry of Austria, Germany, and Russia. In Sweden rye is highly valued as a breadstuff by all classes.

21. Maize is one of the most important of the grains. The ease with which it may be grown in almost any climate, and the simple way in which the kernels may be prepared for eating, have made it almost as widely used among the savages of the Old World, as formerly among the American Indians. It is less valued as a human food in Europe than with us, but is universally recognized as one of the very best foods for domestic animals, particularly for use in fattening.

22. Rice grows best in hot countries, and as the varieties most used require to be submerged for a considerable period in order to develop properly, their cultivation is restricted to localities where yearly flooding may be practised. At

the same time, this peculiarity makes it possible to grow rice where no other grain will thrive. Enormous quantities are

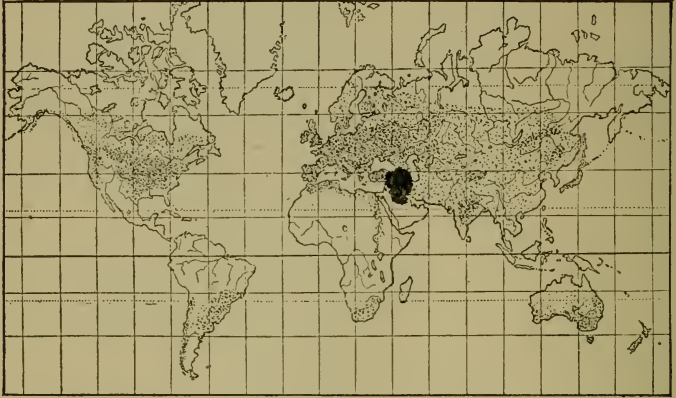


FIG. 16.—Map of the world showing, by full black, the probable native home, and by dotted area, the present range in cultivation, of wheat. (Original.)



FIG. 17.—Map showing, as in Fig. 16, native home and present range of barley. (Original.)

produced every year in the warm and moist regions of China, India, and the neighboring islands, and in our southern coast

States. Since it forms one of the principal articles of diet in the densely populated countries of eastern Asia, and has



FIG. 18.—Map showing, as in Fig. 16, native home and present range of rye. (Original.)



FIG. 19.—Map showing, as in Fig. 16, native home and present range of oats. (Original.)

come to be very widely used in other parts of the world, rice doubtless serves as food for more human beings than any other grain.

23. **Wheat.** Throughout the greater part of Europe and America wheat holds the first place among vegetable foods.

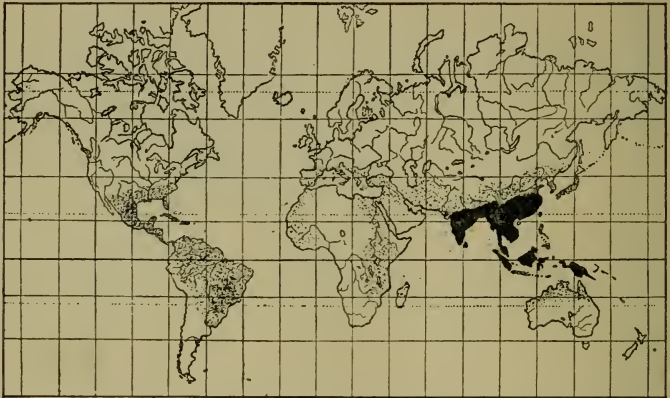


FIG. 20.—Map showing, as in Fig. 16, native home and present range of rice. (Original.)



FIG. 21.—Map showing, as in Fig. 16, native home and present range of maize. (Original.)

Now that railways and steamboats have made transportation easy, more and more wheat is being used; for whenever it is equally available it is usually preferred as a breadstuff

to any other grain. Although much wheat of fine quality is raised abroad, especially in Russia, France, and Austria-Hungary, our country produces more than any other.



FIG. 22.—Buckwheat (*Fagopyrum esculentum*, Buckwheat Family, *Polygonaceae*). *A*, upper part of plant, showing leaves and flower-clusters; natural size. *B*, a flower enlarged, showing the following parts:—in the center a single pistil on the ovary of which are borne three styles ending in rounded stigmas; around the pistil eight stamens in two rows, the inner row of three; between the rows of stamens at their bases, eight small protuberances (*nectar-glands*) which secrete a sweet liquid (*nectar*) from which bees make honey; outside of the other parts of the flower come a circle of five more or less leaf-like organs—the *sepals*—together constituting the “flower-cup” or *calyx* which in this case is white or whitish. *C*, the same showing the arrangement of its parts as they appear when the flower is halved vertically. *D*, stamens. *E*, the pistil enlarged. *H*, fruit, enlarged. *F*, the same cut lengthwise. *J*, the same, cut across, showing the flat curved embryo or rudimentary plantlet surrounded by seed food. *G*, embryo removed from the seed and viewed from the side. (Baillon.)—The plant grows luxuriantly in fields to a height of 0.5–1. m. It is smooth throughout. Bees which come for nectar transfer the pollen from flower to flower and so enable the plant to set good seed.

24. Buckwheat is sometimes included among cereals because it is cultivated for its grain. As will be seen, however, from Fig. 22 this plant differs very much from the

other cereals. It is a native of northern Asia where doubtless it has been cultivated for a long time; yet its introduction into other regions was comparatively recent. Like rye its chief merit is that it will yield a profitable crop on very poor soil. The flour made from it, however, is correspondingly poor in nutritive value. It is usually mixed with other sorts of flour to which it imparts an agreeable flavor.

25. The value of cereals. Why is it that the cereal grains have been valued so highly from the earliest times? What makes them so much better than other vegetable foods, and why are some of them superior to others? The fact that these plants ripen their seeds within a few months after planting, and under favorable conditions yield such a large return for the labor bestowed upon them, will doubtless partly account for the high favor in which they are held; but as much the same may be said of other vegetables of far less value as food, there must be some more important reasons. In order to understand these, we must know something of the chemical composition of cereals; that is to say, we must learn what substances are to be found in the different grains and in what amount.

26. Water in grains. Every part of a plant contains ordinarily a certain quantity of *water*—succulent herbage and fruits like the watermelon having a great deal, while woody parts, seeds, and grains have comparatively little. The quantity of water contained in a given specimen, is estimated by drying a known weight of the material at the temperature of boiling water, and then reweighing to find how much has been lost: the loss will be practically equivalent to the weight of water originally present. In the Food Chart on page 114 the student will find indicated the average percentage of moisture in each of the cereals and in various other vegetable foods as commonly found in the markets. A glance will show what a comparatively small amount the cereals contain. For this reason they keep remarkably well when stored, and take up very little room in proportion to the amount of nutriment they afford.

27. Ash. If the sample dried as suggested be burned until all of the combustible material is consumed, there will

remain a small quantity of *ash* or mineral matter, varying somewhat in the different kinds of cereals as shown in the chart. Upon further analysis this ash is found to consist of certain earthy substances (potash, lime, magnesia, soda, and silica) variously combined with phosphorus, sulphur, and oxygen. It is important to remember that such substances form the principal constituents of bones and teeth, and that cereals are particularly rich in the mineral matters specially required for building these hard parts of our bodies.

28. Nutrients. A large part of the grain consumed in burning, consists of *nutrients*, *i. e.*, nutritious substances, which form the main bulk. Besides this there is a small amount of woody material (*non-nutrient*) contained chiefly in the hull. When this indigestible covering is removed in the process of milling, the meal or flour which is left, represents therefore the nutritive part of the grain free from nearly all that is useless for food. Plainly, then, it is upon the composition of this inner part that the value of the grain must principally depend; and here, as we shall see, the most important differences are to be found.

29. Carbohydrates. If we knead a little wheaten dough in a considerable quantity of water, the latter becomes milky from the presence of a pure white substance which washes out from the dough, while there is left behind a curious, elastic, pale-colored mass sometimes called "wheat gum."

If we allow the milky water to stand for some time, a large part of the white substance will settle, thus showing that it is a fine powder which was merely suspended in the water, and not really dissolved. This white material is *starch*, as may be proved by adding to some of it a little iodine solution; this will turn it a dark bluish color, and starch is the only substance known to be thus affected.

If starch be boiled with a dilute acid for a sufficient time it becomes mainly converted into a kind of sugar known as *glucose*, or grape-sugar, an important constituent of the commercial "glucose" of which large quantities are used in confectionery. Chemistry teaches us that this change is made possible by the fact that both starch and glucose consist of the same elements,—namely, carbon, hydrogen, and

oxygen in nearly the same proportions,—the composition of starch being carbon, six parts; hydrogen, ten; and oxygen, five; as expressed by the formula $C_6H_{10}O_5$; while for pure glucose the formula is $C_6H_{12}O_6$. It will be noticed that in each there is twice as much hydrogen as oxygen; that is to say these elements are present in just the same proportion as in water, which, as is well known, has the chemical formula H_2O . A substance which is thus composed of carbon united with the elements of water is called a *carbohydrate*.¹ Not only do starch and glucose come under this head, but also other kinds of sugar, various sorts of true gum (such for example as that on postage stamps), and the substance known as *cellulose* of which wood, cotton, and paper are mainly composed. Among the cereal grains, although sugar is sometimes present to a notable degree, as in “sweet corn,” the amount of digestible carbohydrate as given in the tables may be understood as being almost entirely starch.

During the process of digestion in man and other animals starch is converted into sugar, and as such is absorbed into the blood and carried all over the system to serve either for making fat or for giving warmth and strength. Since only fluids can be absorbed, and since starch is composed of solid insoluble particles, the necessity of somehow converting the starch of our food into sugar, is obvious.

Similarly, when grains sprout, the starch in them undergoes a sort of digestion and becomes converted into sugar, largely *maltose* or “malt sugar” (formula $C_{12}H_{22}O_{11}$). This being soluble in the sap of the young plant, may be carried to the regions of growth where food is needed. This change of the insoluble starch into the soluble sugar is accomplished through the action of a substance called *diastase*, one of a remarkable class of substances known as *enzymes*² that have the power of bringing about such changes by their presence in comparatively minute amount. The process of malting consists in causing grain to sprout and allowing the conversion of starch to proceed until as much

¹ Car-bo-hy'drate < L. *carbo*, coal; Gr. *hydor*, water.

² En'zyme < Gr. *en*, in; *zyme*, leaven; so called because acting like the substance in leaven or yeast which produces similar changes.

sugar as possible is produced. At this point the plantlets are killed by heat so that they will not use up any of the sugar they have made. The sweet substance is then dissolved out by soaking the malted grains in water. From the liquid so sweetened, lager beer and other malt liquors are made by subsequent fermentation with yeast. Diastase separated from malt may be used instead of an acid to convert starch into sugar.

30. Proteids. Let us return now to that other constituent of the wheaten dough, the elastic material which remained after removal of the starch. This is known as *gluten*¹ and is a mixture of several substances which belong to the class known as *proteids*.² To this class belong also the substances which form the chief part of our own flesh and blood—and indeed, mainly constitute the living substance of all plants and animals. Hence, proteids must be regarded as the most precious of all food substances. Like the carbohydrates they contain carbon, hydrogen, and oxygen (though in somewhat different proportions), but in addition they always have a certain amount of nitrogen, and usually a little sulphur and phosphorus. The nitrogenous nature of the proteids is made evident by the pungent ammoniacal odor which is given off when any of them are burned,—ammonia being NH_3 . Although in chemical composition proteids are all very much alike, there are important differences in their solubility—some, like white of egg, dissolving in cold water, while others, such as those of the “wheat gum” are insoluble. Among the latter is a form of proteid called *glutin* or *gliadin* which gives to wheat-gluten its wonderful tenacity and elasticity.

It is a significant fact that wheat is the only one of the cereals which contains gliadin in any considerable amount, although it should be said that rye contains a closely similar proteid. Macaroni, which owes its consistency chiefly to gliadin, is therefore made only from wheat; and wheaten dough alone possesses just the right tenacity and elasticity for making the lightest, spongiest loaf. The lightest rye bread

¹ Glu'ten < L. *glutus*, tenacious.

² Pro'te-id < Gr. *protos*, before.

has wheat flour mixed with it. The fact that wheat contains in largest amount a nutrient with such remarkable properties as gliadin, is the chief reason why this grain was prized above all others in ancient times, and why it has come to be valued more and more highly as civilization has advanced.

31. Fats. One other constituent shown in the chart remains to be mentioned. This is the *fat* or *fixed oil*, called "fixed" because, unlike the "volatile" oils, it does not evaporate at ordinary temperatures. A little of this oil may be separated for examination by soaking "whole wheat" flour, bran, or corn meal in naphtha, and then pouring off the latter into a shallow dish. The naphtha will evaporate, leaving behind the oil which it had dissolved.

In chemical composition the fats agree with the carbohydrates in consisting of carbon, hydrogen, and oxygen; the difference being that there is always less than half as much oxygen as hydrogen. Like the carbohydrates their use as food is for yielding warmth and strength, and they may make the body fatter; but as in these respects fats are more than twice as effective as carbohydrates their importance in the various grains is much greater than would appear from the comparatively small amounts which are present. This fact enables us to understand the great value of maize, for example, in fattening animals.

With foods rich in oil there is this drawback, however, that after a limited time they are apt to spoil with keeping, while starchy foods remain practically unchanged as long as they are dry. Thus wheat, which contains less oil than maize, keeps better, and its deficiency in this ingredient we fully make up for by eating butter on our bread.

CHAPTER III

VARIOUS FOOD-PLANTS

32. Classes of food-plants. Having in the last chapter learned something of the uses and importance of the cereal grains, we may now profitably compare with them other food-plants many of which are almost as valuable as cereals although in different ways. It will be convenient to study them under the following headings: *nuts*, *pulse*, *earth-vegetables*, *herbage-vegetables*, *fruit-vegetables*, *fruits*, and *miscellaneous food-plants*.

33. Nuts have, like grains, an edible kernel; but this is generally much larger than in any grain, and is moreover protected by a much thicker and harder shell. The chestnut (Figs. 24-26), the filbert (Fig. 23), the walnut (Fig. 27), the butternut (Fig. 28), the hickory-nut (Fig. 30), the pecan (Fig. 29), the almond (Fig. 31), the peanut (Fig. 33), the Brazil-nut (Fig. 32), and the coconut (Figs. 34-36), plainly agree in possessing the peculiarities named, although they differ considerably from one another.

In view of the fact that nuts possess such large edible kernels, and are some of them even richer than the cereals in proteid, the question naturally arises as to why, with us, nuts are so much less used for food than the grains. The many years which must often elapse between the time of planting and the fruit-yield, the much greater bulk in proportion to food-material which they occupy when stored, and the additional labor required for separating the nutritive from the inedible part, are doubtless the drawbacks which very largely account for the inferior rank of nuts in our market; but there are also chemical reasons which will be apparent upon consulting the chart on page 114. With the exception of the chestnut, all we have mentioned contain an



FIG. 23.—Filbert or Hazelnut (*Corylus Avellana*, Birch Family, *Betulaceæ*). 1, a twig bearing on the right two loose, hanging, yellowish flower-clusters consisting entirely of staminate flowers and their scale-like bracts, and on the left and at the tip, two pistillate flower-clusters enclosed by bracts and bud-scales which permit only the crimson stigmas to protrude (natural size). 2, a single staminate flower, viewed from below, showing the numerous stamens and the scale to which they are attached (enlarged, the vertical line at the right showing the natural size). 3, a single stamen (enlarged). 4, a pistillate flower, cut vertically through the ovary, showing the two ovules (only one of which commonly ripens into a seed), the short style, and two stigmas which protrude beyond the bract-cup (enlarged). 5, the fruit, partially enclosed by the now leafy bract-cup (enlarged). 6, the nut removed, showing the scar where it was attached at the base. (5 and 6, natural size.) (Wossidlo.)—The plant is a shrub or small tree¹ 3-10 m. tall, much branched; twigs ash-colored, sticky-hairy; bark on older stems mottled bright brown and gray; leaves downy below; nuts brown.

¹ Shrubs and trees are distinguished from herbs by having woody stems above ground which live from year to year. A tree is a self-supporting woody plant which becomes several times taller than a man, and forms a single main trunk. A shrub differs from a tree in being usually of less height and having many well-developed branches starting from near the ground in place of a main trunk.

enormous proportion of oil. This, although of use as food, renders nuts more difficult of digestion than grains, and causes them to spoil with keeping after a comparatively short time.



FIG. 24.—Chestnut (*Castanea sativa*, Beech Family, *Fagaceæ*). A leafy twig, bearing flower-clusters composed mostly of yellowish, staminate flowers with a few greenish pistillate flowers near the base. About one-quarter natural size. (Baillon.)—The plant is one of the largest forest trees of the north temperate zone, sometimes in forests attaining a height of 30 m. Bark, on the trunk and older branches, dark, very hard, and with long deep clefts; when younger smooth and lighter colored; young twigs deep green, bronzed or purplish brown, covered with whitish dots. Leaves, polished, bright green above, smooth and paler below.

In spite of their disadvantages, however, chestnuts, walnuts, and peanuts form a very important part of the food of many Europeans, largely taking the place of cereals. In many tropical regions where cereals do not grow, immense

quantities of peanuts and Brazil-nuts are eaten, while in some places the coconut constitutes the chief, sometimes almost the only, food. The importance of nuts, to mankind,



FIG. 25.—Chestnut. *A*, twig bearing two clusters of pistillate flowers, and a small immature cluster of staminate flowers. *B*, a single cluster of three pistillate flowers protruding from among the bracts which form a cup around them. *C*, a single pistillate flower, showing six elongated stigmas and a bell-shaped calyx of six sepals formed above the ovary. *D*, the same, cut vertically to show the ovules at the base of the flask-shaped ovary. *E*, a single staminate flower, showing the numerous stamens surrounded by the calyx of six sepals joined at the base. The figures all somewhat enlarged. (Baillon.)

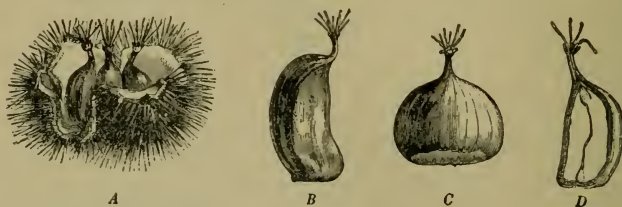


FIG. 26.—Chestnut. *A*, ripe fruit, showing the now spiny bract-cup or "burr" split open and exposing three nuts within. Reduced. *B*, one of the side nuts, showing at the tip the stigmas and calyx. About two-thirds natural size. *C*, the middle nut, showing the scar of attachment at base. *D*, a side nut, cut vertically to show the seed within containing a large embryo gorged with starchy food. (Baillon.)

therefore, is much greater than we commonly suppose, considering that with us they are used scarcely more than as luxuries.



FIG. 27.—Walnut (*Juglans regia*, Walnut Family, *Juglandaceæ*). 1, a spring shoot bearing young leaves; at *a*, a staminate flower-cluster, and at *b*, a cluster of three pistillate flowers. 2, a single staminate flower viewed from below, showing the numerous stamens, and three sepals and three bracts which cover them above; *a*, inner view of a single stamen; *b*, the same in side view. 3, a single pistillate flower, showing the two spreading stigmas protruding beyond the small calyx, which crowns the ovary. 4, the same cut vertically, showing the single ovule at the base. 5, a fruit with part of the husk removed, showing the rough-shelled nut within. 6, nut cut in half vertically, showing half of the four-lobed seed or "meat," within. (Wossidlo).—The plant is a handsome, widely spreading tree attaining a height of 20 m. Bark soon becoming thick and much cracked. Leaves smooth, dull green, bronzy to yellowish. Flowers greenish. Fruit-hull, green turning black. Wind carries the pollen from tree to tree.



FIG. 28.—Butternut (*Juglans cinerea*, Walnut Family, *Juglandaceæ*). A twig in autumn bearing a single leaf and a ripe fruit. Twig, in spring bearing two staminate flower-clusters. A single staminate flower viewed from above. A pistillate flower showing the two protruding stigmas. A nut removed from its husk, showing the deeply sculptured shell. The flowers, enlarged; the other parts reduced. (Britton and Brown.)—The plant is a forest tree becoming sometimes 30 m. tall; old bark roughish, gray; young twigs and leaves sticky-hairy; flowers brownish green; stigmas red; fruit green turning to brown, covered thickly with very sticky hairs, nut blackish.

FIG. 29.—Pecan (*Carya olivæformis*, Walnut Family, *Juglandaceæ*). Twig in spring after removal of all the leaves but one and all the staminate flower-clusters below it except the lower part of their stalks. At the tip of the twig is the small cluster of pistillate flowers. Three-branched staminate flower-cluster. Staminate flower, top view. Stamen. Fruit. Nut, after removal of the husk. Flower and stamen, enlarged. (Britton and Brown.)—The plant is a large slender tree, becoming 50 m. tall; bark somewhat rough; young twigs and leaves hairy; mature foliage nearly smooth; flowers greenish; fruit brownish green; nut light brown.

The native home of the various nuts and of other food-plants, the length of time they have been cultivated, and certain other matters of related interest, will be discussed at the end of this chapter.

34. Pulse, under which name are included peas (Figs. 37, 38), and beans (Figs. 39, 40),¹ agree with grains and nuts

¹ In the reference to the illustrations the reader will observe that the same Arabic numeral sometimes applies to more than one cut, Roman



FIG. 30.—Shagbark Hickory (*Carya alba*, Walnut Family, *Juglandaceae*). A single leaf. Staminate flower-cluster, under side, enlarged. Twig bearing a single fruit. Nut. (Britton and Brown.)—A large tree becoming 36 m. tall; bark shaggy in narrow plates, gray; young twigs and leaves slightly hairy becoming smooth; flowers greenish; fruit greenish brown; nut almost white.

in that the nutritive part is contained within the seed, but differ from them in that the seeds ripen in a rather thin-walled pod which opens at maturity by splitting in halves from end to end.

The very large amount of nutriment in proportion to bulk, together with the small percentage of water and oil (see chart) renders beans and peas among the very best foods for storage, and particularly adapts them for use upon long voyages. That they are highly nutritious is shown by the large amount of proteid they contain. This, however, is found to be of a sort resembling the proteid of cheese; and is not so easily digestible as that found in cereals.

35. Earth-vegetables we shall find to be a convenient

numerals being added to distinguish them. Thus in the above reference to the pictures of kidney-bean, Fig. 39 is understood as applying to Fig. 39I and Fig. 39II.

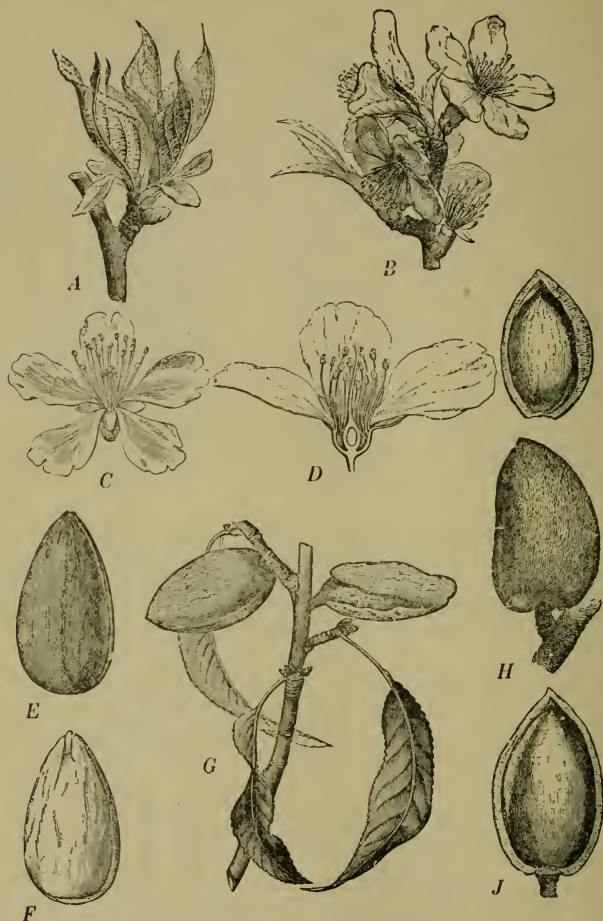


FIG. 31.—Almond (*Prunus Amygdalus*, Rose Family, *Rosaceæ*). *A*, twig bearing one unopened winter-bud and a cluster of young leaves expanding from another. *B*, a flowering branch. *C*, a single flower. *D*, the same cut vertically to show the single pistil with its small ovary at the base of an urn-like continuation of the flower-stalk at the rim of which are borne three sets of organs, namely: the stamens which are numerous and in two rows; then outside of these a single row of delicate enveloping organs, the *petals*,¹ which in the almond flower are

¹ We have here an example of a "complete" flower or one which has all the kinds of organs which are commonly present; that is to say, besides the

term to designate those garden esculents of which the nutritive part grows in the earth. This edible part may be either a *root-tuber* as in the sweet potato (Figs. 56, 57), a *crown-tuber* as in the beet, turnip, radish, carrot, and parsnip (Figs. 41-55), or it may be a *stem-tuber* as in the white potato and the Jerusalem artichoke (Figs. 59, I-IV), or a *bulb* as in the onion (Figs. 60, 61). A root-tuber consists entirely of a swollen root gorged with reserve food. A crown-tuber bears a crown of leaves more or less rosette-like, thus showing itself to be part stem and part root. By the term "tuber" botanists sometimes mean only a stem-tuber, but the word is more conveniently applied in a general sense to all short and much thickened roots or stems. A stem-tuber differs from a root-tuber in having "eyes" or buds regularly arranged in little pits along the sides; and from a crown-tuber in bearing no foliage-leaves, but instead minute appendages, one below each eye. If a stem-tuber be made to sprout, the buds will grow into leafy branches. A bulb differs from a tuber in consisting chiefly of readily separable scale-like parts or layers which are mostly succulent.

As will be seen from the chemical chart (page 114) the very large percentage of water in earth-vegetables presents a striking contrast to what we find in grains, nuts, and pulse. Notice also, particularly in the roots, the comparatively

white or rose-colored and five in number; and finally, outside of all, a row of sepals, which are green, and five in number. *G*, a twig bearing three leaves and two fruits of which one is shedding its leathery husk. *H*, a single fruit. *J*, the same, with half the husk removed, to show the nut which appears above with half its shell removed to reveal the seed within. *E*, the seed, covered by its thin brownish coat. *F*, the embryo gorged with food, shown after removal of the seed-coat. All more or less reduced in size. (Baillon.)—The plant is a tree closely resembling the peach tree in general form and in every part except the fruit. The flowers, appearing in very early spring, before the leaves, are remarkably beautiful. The fruit of the almond closely resembles a green peach; it differs from the peach mainly in having in place of the hard-shelled "stone" a rather soft-shelled nut which is covered by a leathery husk that commonly splits open when ripe.

pistil and stamens which are known as the "*essential organs*," and the sepals which constitute the calyx or outer floral envelope, it has an inner envelope made up of petals distinctly different in appearance from the sepals. The petals taken together constitute what is called the *corolla*, or "little crown" of the flower, and form commonly the most conspicuous part. The calyx and corolla taken together are called the *perianth*, especially if they are closely similar in appearance.

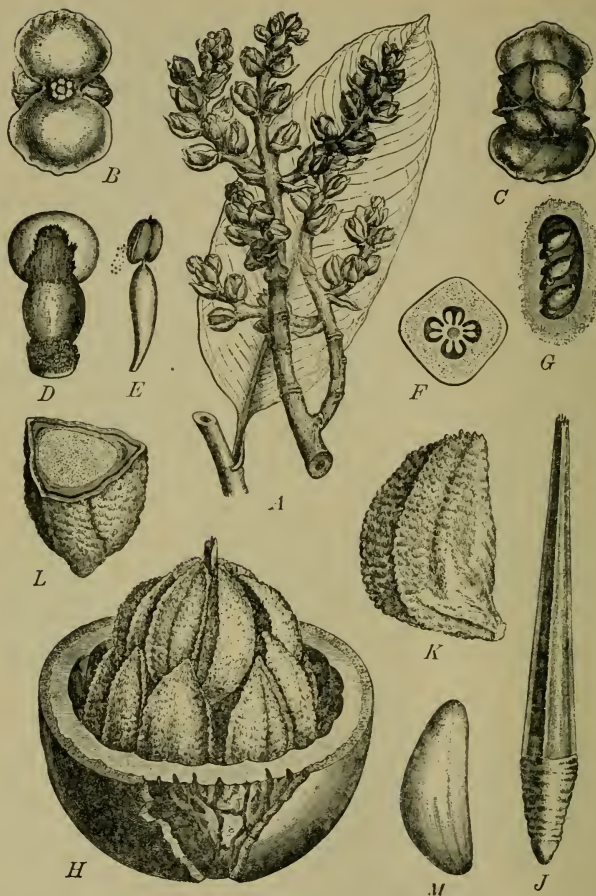


FIG. 32.—Brazil Nut (*Bertholletia excelsa*, Myrtle Family, *Myrtaceæ*). A, flower-cluster and leaf. B, expanding flower-bud viewed from below showing the under side of the two sepals. C, the same from above, showing upper side of sepals, and the six petals. D, the numerous stamens united by their filaments into a hoodlike body. E, upper part of a stamen enlarged. F, ovary cut across, to show the four cavities containing ovules. G, a single one of these cavities cut into lengthwise, giving a side view of the ovules, enlarged. H, fruit, with the upper part of its thick spherical wall removed to show the seeds within, packed about a central spindle. A part of the outer, softer layer of the wall is torn away in front, showing the channelled surface of the very hard inner layer. J, the central spindle. K, a nut in side view. L, the

same cut across through the middle, to show the thick seed-coat with its thin layers, and the large germ which fills it. *M*, germ, removed, showing the general form and the absence of distinguishable parts. (Berg, Humbolt, and Bonpland.)—The plant, which is one of the most majestic trees of the Brazilian forests, reaches a height of over 30 m.; leaves bright green; flowers with cream-colored corolla; fruits “nearly as hard and heavy as cannon-balls, fall with tremendous force from the height of 100 feet. . . . Persons are sometimes killed by them” (Wallace).

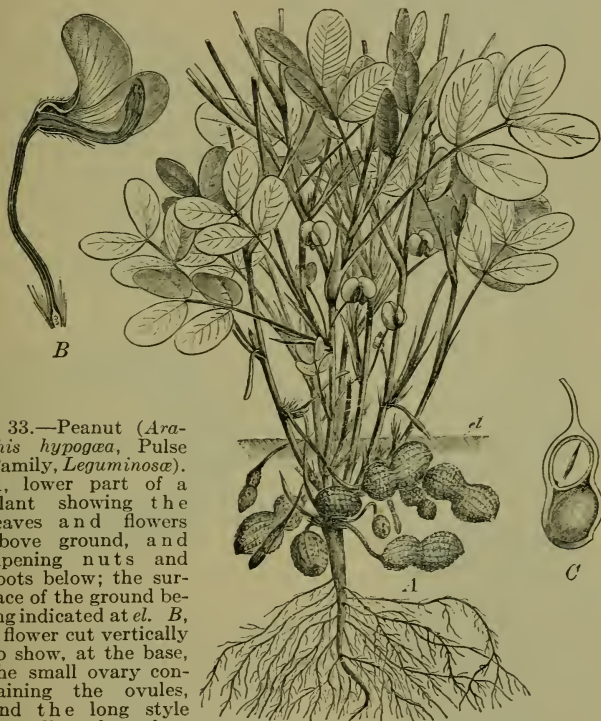


FIG. 33.—Peanut (*Arachis hypogaea*, Pulse Family, *Leguminosæ*).

A, lower part of a plant showing the leaves and flowers above ground, and ripening nuts and roots below; the surface of the ground being indicated at *el.* *B*, a flower cut vertically to show, at the base, the small ovary containing the ovules, and the long style extending through a slender tube which is surmounted by the calyx and corolla and is continued by a tube formed of the united filaments. *C*, a ripe nut cut lengthwise to show the two seeds. (Tanbert.)—The plant is an *annual*, *i. e.*, it completes its life from seed to seed in one year; stems and leaves somewhat hairy; flowers orange-yellow, fruit pale. Soon after pollen has come upon the stigma, the stamens and corolla are shed and the ovary is carried out beyond the calyx by a stalk which becomes 5–8 cm. long, and, bending downwards, soon buries the little ovary in the ground. Once buried the ovary ripens into the familiar pod-like nut. If it fails to get buried the ovary withers.

Once buried the ovary ripens into the familiar pod-like nut. If it fails to get buried the ovary withers.



FIG. 34.—Coconut (*Cocos nucifera*, Palm Family, *Palmaceæ*). Plants in fruit showing general form. (Baillon.)—The columnar trunk rises to a height of 20–30 m. and bears bright green leaves 6–7 m. long.

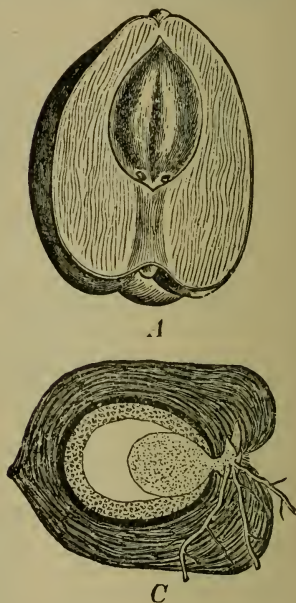
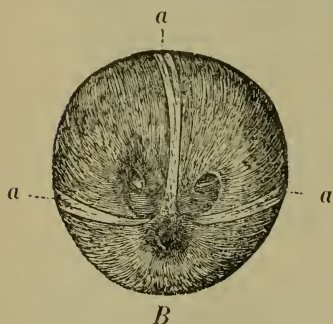


FIG. 35.—Coconut. *A*, fruit, showing husk cut vertically through the center, revealing the hard shell of the nut. *B*, nut viewed from below, showing the lines (*a, a, a*) along which the three pistils are united; and between them the three germ-pores from the lower one of which ordinarily the single germ emerges in sprouting. *C*, lengthwise section through the fruit sprouting; notice the thick husk into and

through which the young roots grow, the hard shell of the nut (shown black) within which is the layer of solid seed food (coarsely dotted), and the liquid food or "milk" (white) into which the enlarging cotyledon or "seed-leaf" (finely dotted) pushes its way and acts as an organ of absorption. (Warming.)—The husk is smooth and grayish brown, and is largely composed of coarse, tough fibers.



FIG. 36.—Coconut. A, flower-cluster with one of the immense bracts which envelop it while young, showing staminate flowers in upper part of branches, and pistillate ones near the base, much reduced. B, staminate flower. C, pistillate flower. B and C slightly reduced. (Original drawing from photograph.)—The flowers and enclosing bracts are various shades of yellow.



FIG. 37.—Pea (*Pisum sativum*, Pulse Family, *Leguminosæ*). Plant in flower and fruit, much reduced. (Nicholson.)—The plant is an annual, climbing by means of tendrils which terminate the leaves; stem and leaves pale green, smooth and covered with a delicate "bloom" which easily rubs off; flowers, white, bluish, purplish, or variegated.

FIG. 38.—Pea. *A*, flower. *B*, the same halved. *B'*, corolla, with petals separated, showing standard (*c*), wings (*a, a*), and keel (*c*). *C*, the stamen-tube and pistil, enlarged. *D*, pistil. *E*, pod shedding seeds. *F*, a seed, showing stalk (*f*), place of minute opening, the micropyle, through which moisture penetrates (*m*), raphe or ridge (*r*) and chalaza or end of ridge (*c*); *G*, embryo, laid open, showing cotyledons or seed-leaves (*c*), radicle or seed-root (*r*), caulicle or seed-stem (*t*), and plumule or seed-bud (*g*). (Warming.)

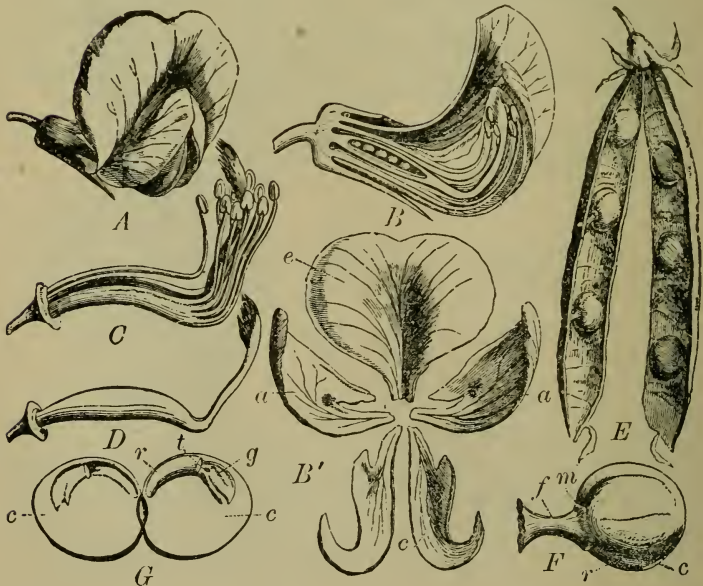




FIG. 39 I.—Kidney Bean (*Phaseolus vulgaris*, Pulse Family, *Leguminosae*). Plant of a twining, "running" or "pole" variety in flower and fruit $\times \frac{1}{2}$. (Vilmorin.)—The plant is a rough hairy annual vine or, in certain "dwarf" varieties, a bushy herb; flowers of various colors including white and lilac; fruit and seeds also of different colors and very variously marked.

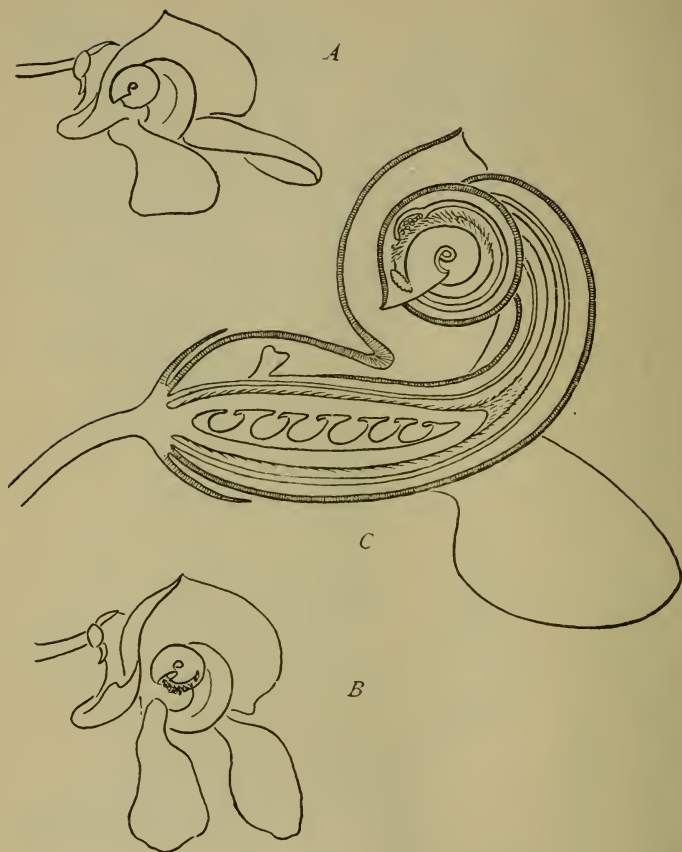


FIG. 39 II.—Kidney Bean. *A*, flower, about twice natural size. *B*, the same with wings pressed down as if by a bee sucking nectar; showing the stigma and pollen-covered end of the style protruding from the coiled tubular keel. A bee's head or back covered with bean pollen would be in position to deposit some of the grains upon the protruding stigma and thus enable the plant to set good seeds, while an instant later it would be touched by the pollen on the style and so receive a new load to take to another bean-flower. *C*, a flower cut in halves vertically to show the arrangement of parts before protrusion of the stigma. Enlarged and somewhat diagrammatic. (Original.)



FIG. 40.—Lima Bean (*Phaseolus lunatus*, Pulse Family, *Leguminosæ*). Plant of a twining variety in flower and fruit $\times \frac{1}{2}$. (Vilmorin.)—The plant is an annual closely resembling the Kidney Bean except that the flowers are greenish white and the pods are broad, flattened, and curved like a scimitar.

large amount of indigestible material (cellulose) in proportion to the proteid and other nutritive constituents. From this it follows that not only are earth-vegetables more bulky to store than grains and pulse (and, moreover, cannot ordinarily be kept longer than a few months) but in order to



FIG. 41.—Beet. (*Beta vulgaris*, Goose-foot Family, *Chenopodiaceæ*). Plant showing the appearance of the parts above ground at the end of its first year. $\times \frac{1}{2}$. (Original).—The leaves are smooth, green or more or less tinged with red; stem scarcely more than a "crown" covering the top of the swollen root which projects somewhat above the ground.



FIG. 42.—Beet. A plant in its second year, the underground parts cut vertically, to show the swollen root which is feeding with its store of nutriment the crown, which has given rise to several erect branches bearing leaves, flowers and fruit. (Original).—Plant, a *biennial*, i. e., requiring two years to complete its life, the first year storing up food which during the second year it uses to build flower- and fruit-bearing shoots; stem-branches, commonly deep red; flowers, greenish; fruit, dry, rough, and brown.



FIG. 43.—Beet. *A*, root. *B*, leaf. *C*, small flowering branch. *D*, a flower just opened. *E*, vertical section of a flower-bud showing a bract, (*b*), a layer of crystals in the ovary wall, *k*, and, nectar glands (*d, d*). *F*, stamen, back view. *G*, a flower the same as *D* but older. *H*, seed. *J*, the same cut in half, to show seed-coat and the germ coiled around the seed-food in the center. *A-C*, reduced, *D-J* variously enlarged. (Baillon, Volkens.)

get as much nutriment from them as from grains or pulse, a very much larger amount must be eaten. It should not be supposed, however, that the indigestible parts of what we eat are altogether useless; for it has been observed in various experiments that digestive organs commonly work to better advantage when the nutritious materials undergoing digestion are present not in concentrated form but diluted, as it were, with a certain amount of finely divided cellulose or other harmless material which may act mechanically.

36. Herbage-vegetables may be defined as those which yield us nutriment in shoots developed above ground. They



FIG. 44.—Turnip. (*Brassica campestris*, Mustard Family, *Cruciferae*). Plants showing fleshy roots, and rosettes of leaves, as they appear at the end of the first year's growth. $\times \frac{1}{2}$. (Vilmorin.)—Plant a biennial; root varying greatly in form and color under cultivation; leaves bright green; rough-hairy.



FIG. 45.—Turnip. Middle section of second-year stem which bears the flowers. A lower leaf. Flower-cluster with young fruit. Fruit, natural size. (Britton and Brown.)—The plant in its second year becomes about 1 m. tall or less; the lower leaves are hairy, the upper ones smooth; the flowers yellow.



FIG. 46.—Radish. (*Raphanus sativus*, Mustard Family, *Cruciferae*). Part of stem bearing leaves. Flower cluster. Fruit. (Britton and Brown.)—Plant an annual, or in cultivation behaving as a biennial; roots flattened, spherical or long-conical, variously colored, mostly white or red; stem and leaves bright green, more or less covered with stiff hairs; flowers pink or white.



FIG. 47.—Carrot (*Daucus Carota*, Parsley Family, *Umbelliferae*). Plant showing root and rosette of leaves at the close of the first year's growth. (Nicholson.)—The roots vary considerably as regards form and color, being conical, cylindrical, or globular; red, orange, yellow, or white; and from about 5–50 cm. long; leaves bright green, hairy.

include “pot-herbs” and certain “salads.” The most nutritive part is in some cases the tender and more or less thickened stem, as with asparagus (Figs. 62 I, II) and kohlrabi (Fig. 66). Sometimes as in kale, borecole, cabbage, and Brussels sprouts (Figs. 63–65, 67–69), watercress (Fig. 71), spinach (Figs. 72–74), and lettuce (Figs. 75–77) the leaves are of most importance. With celery (Figs. 78, 79) the leafstalk is the part employed, while in the cauliflower (Fig. 70) it is the much branched and thickened flower-stalk, together with the innumerable buds which it bears.

In chemical composition, and consequently in food value,

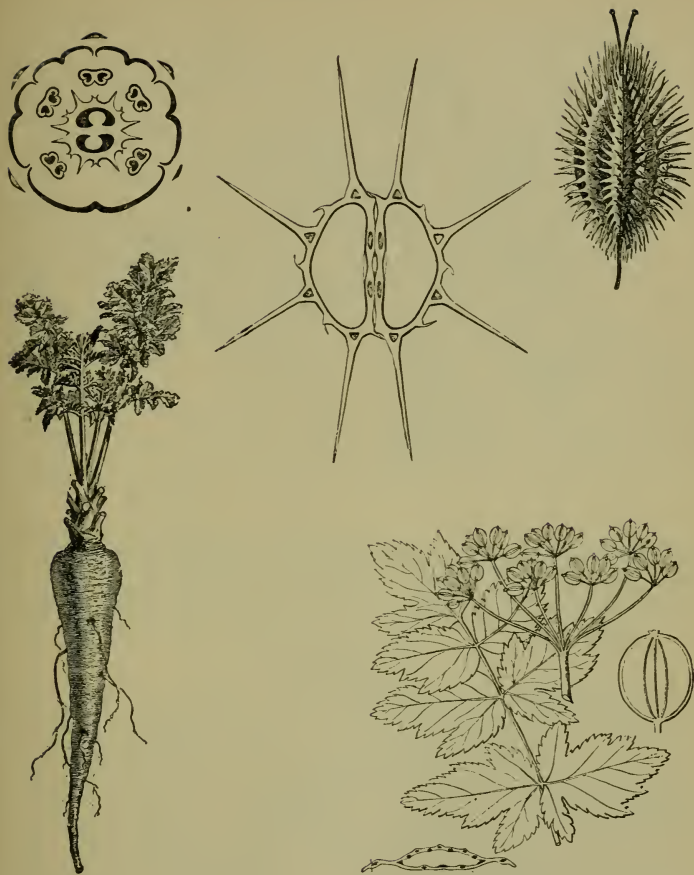


FIG. 48.—Carrot. Upper part of plant in flower and fruit. (Baillon.)—Plant a biennial, becoming about 1 m. tall; flowers mostly white, the central one of a cluster being usually dark purple.



FIG. 49.—Carrot. Flower, enlarged. (Baillon.)

FIG. 50.—Carrot. Flower, cut in half vertically. (Baillon.)



FIGS. 51-53.—The three upper figures. Carrot. Diagram of flower, showing the arrangement of the parts as they would appear if cut across and viewed from above. Fruit, viewed from the side. • Enlarged. Fruit, cut across, showing oil-tubes, at the bases of the long spines. (Baillon.)

FIG. 54.—Parsnip (*Pastinaca sativa*, Parsley Family, *Umbelliferae*). Plant at close of first year's growth, showing fleshy root and a few of the younger leaves, the older ones having been cut off. (Nicholson.)—The root varies somewhat in form but is commonly conical; the flesh whitish or pale yellow.

FIG. 55.—Parsnip. Part of leaf, reduced. Part of fruit cluster, reduced. Fruit, enlarged. *D*, half of the same cut across. (Britton and Brown.)—Plant a biennial or sometimes an annual, smooth or somewhat hairy, becoming 0.6-1.5 m. tall; leaves bright green; flowers similar in form to those of the carrot, but somewhat larger and yellow. Many insects are attracted by the clustered flowers.



FIG. 56.—Sweet Potato (*Ipomoea Batatas*, Morning-Glory Family, *Convolvulaceæ*). Stem, leaves and roots. $\times 1$. (Redrawn.)—Plant a *perennial* (i. e. growing more than two years) with creeping stems becoming 2-3 m. long; leaves dark green, glossy; flowers purple, closely resembling those of the common morning-glory; roots becoming fleshy, sweet, and yellow within; fruit dry.

herbage-vegetables are found to be a good deal like earth-vegetables. The chief difference is that the former have, on the whole, a somewhat larger percentage of water, and a smaller amount of digestible carbohydrate. As against these deficiencies, however, there is a decidedly larger proportion of proteid in relation to the other nutritious materials. For example in lettuce which has at once the most water and the least proteid of any of the herbage-vegetables given in the table, we find that about one-third of the nutritive material (representing nearly one-quarter of the total weight exclusive of water) is proteid; while in the sweet potato (which of all the earth-vegetables given, has the least water and next to the most proteid) the proportion of proteid to other nutrients is approximately 1 to 12 (being to the total weight of the material dried, nearly as 1 to 18).



FIG. 57.—Sweet Potato. Flower-clusters coming from leaf-axils, $\frac{1}{2}$. Flower, cut vertically; natural size. Fruit, $\frac{1}{3}$. Seed, cut in half vertically to show the folded germ in seed-food (dotted), $\frac{1}{4}$. (Original.)

FIG. 58, I. — White Potato (*Solanum tuberosum*, Nightshade Family, *Solanaceæ*). Base of plant growing from an old tuber and producing new tubers at the tip of underground branches of the stem. (Baillon.)—Plant a perennial continued from year to year by its tubers; stem erect, about 0.7 m. tall; leaves dull green, hairy; flowers lilac or white; fruit fleshy, green.





FIG. 58, II.—White Potato. Flowering branch. (Baillon.)

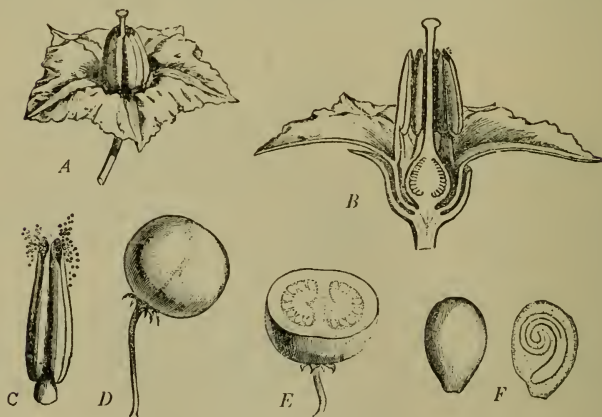


FIG. 58, III.—White Potato. *A*, flower, about natural size. *B*, flower cut vertically, enlarged. *C*, stamen, enlarged, showing at the tip of the anthers the pores through which the pollen escapes and falls upon an insect visitor. *D*, berry, inside view. *E*, same, cut across. *F*, seed, side view, and cut vertically to show the curved germ and the seed-food. (Baillon.)



FIG. 59, I.—Jerusalem Artichoke. (*Helianthus tuberosus*, Sunflower Family, *Compositæ*). Stem-tubers at base of stem, producing slender roots. (Vilmorin.)—The plant is a perennial herb, often 2 m. in height, closely resembling an ordinary garden sunflower.

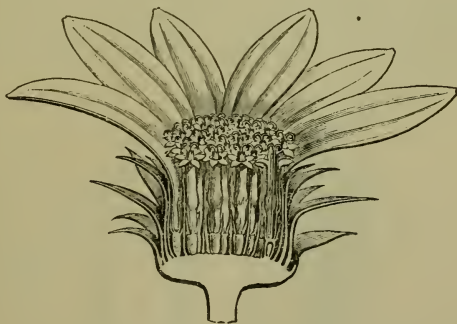


FIG. 59, II.—Jerusalem Artichoke. Flower-cluster cut vertically to show arrangement of the perfect florets forming a central mass or "disk," the neutral ray-florets surrounding them, and the protecting bracts or "involucre" looking like a calyx outside of all; the whole growing from the so-called "receptacle" or expanded top, of the floral stalk. (Baillon.)—Such a compact cluster of two kinds of flowers looks like one huge flower, and consequently becomes very attractive to many insects which transfer its pollen advantageously.

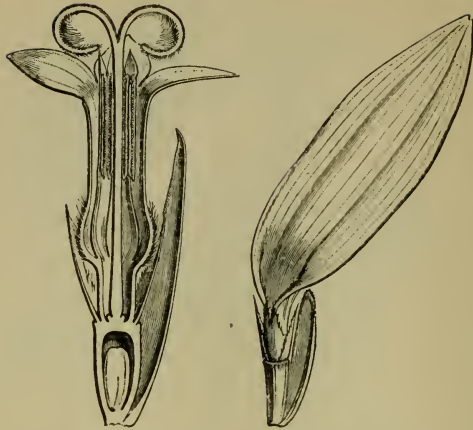


FIG. 59, III.—Jerusalem Artichoke. A disk flower enlarged and cut vertically to show the single pistil with two stigmas, long style with nectar glands at base, and one-celled ovary containing a single erect ovule; appearing above the ovary is a tubular corolla dividing into five petal-tips (of which but three are shown), and bearing as many stamens the anthers of which are united into a tube; also appearing above the ovary are slender sepals; and at the base of the flower a chaffy bract from the axil of which the flower arises. A neutral ray-flower having no stamens and only the vestige of a pistil in its rudimentary ovary, but showing a chaffy bract at its base, several sepals, and a much enlarged corolla formed as if by the splitting of a tube nearly to the bottom along its inner side. (Baillon.)

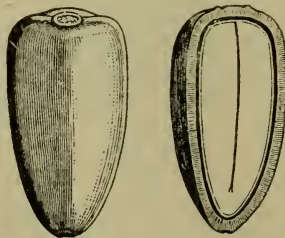


FIG. 59, IV.—Jerusalem Artichoke. Fruit, side view, enlarged. The same cut vertically to show the germ occupying the whole of the seed within. (Baillon.)

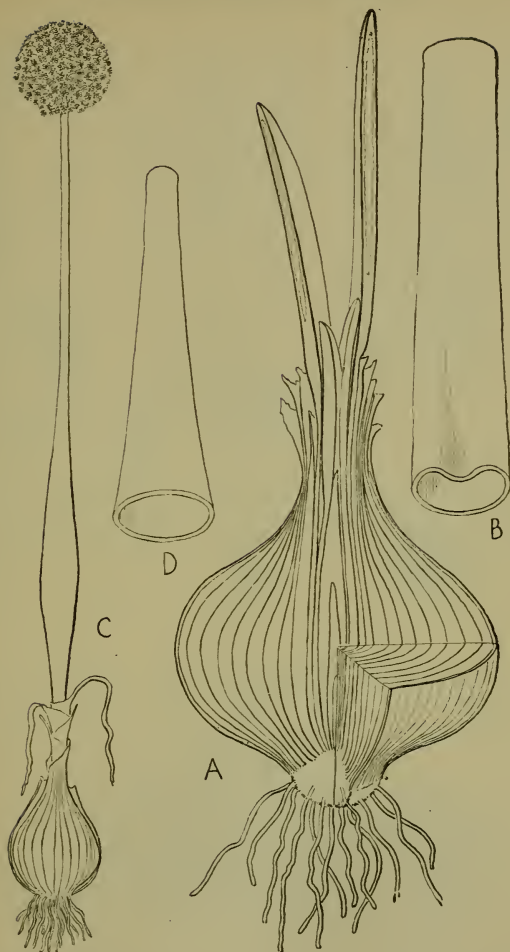


FIG. 60.—Onion. (*Allium Cepa*, Lily Family, *Liliaceæ*). *A*, bulb at the beginning of the second year's growth ($\frac{1}{2}$) cut to show the short stem from which roots spring below, and, above, last year's leaves of which there remain only the thickened bases forming the "coats of the onion" and filled with food now being used up by the new leaves developing from a bud at the center. *B*, upper part of a leaf cut to show its tubular form. *C*, plant toward the end of its second year ($\frac{1}{2}$); the upper (once green) part of the leaves having withered, are replaced by a green hollow stem (shown cut across at *D*) which bears a cluster of white flowers, and finally the fruit. (*A*, original; *B*, *C*, *D* redrawn from Reichenbach.)

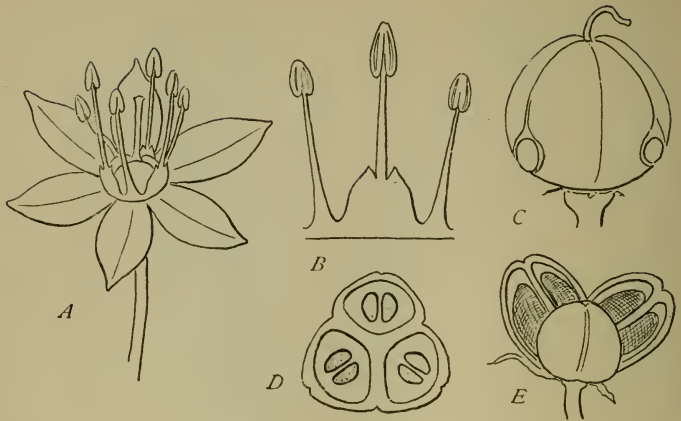


FIG. 61.—Onion. *A*, flower, enlarged. *B*, three stamens, showing their unequal size, and connection at the base. *C*, young pod. *D*, the same cut across to show the three compartments and their seeds. *E*, dry pod split open naturally to release the seeds. (Redrawn from Reichenbach.)

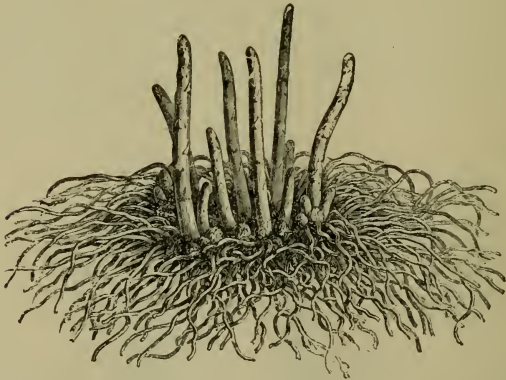


FIG. 62, I.—Asparagus (*Asparagus officinalis*, Lily Family, *Liliaceæ*). Mass of roots and fleshy spring shoots. $\times \frac{1}{3}$ (Nicholson.)—Plant, a perennial, of the seashore, sending up from its matted roots erect shoots which are at first simple and succulent but soon much branched and firm, about 1.5 m. tall, and of a pale green color; flowers greenish yellow; fruit fleshy, bright red.



FIG. 62, II.—Asparagus. *A*, upper part of a flowering branch. $\times \frac{3}{4}$. *B*, flower, enlarged. *C*, perianth and stamens of the same spread out. *D*, stamen, outer view. *E*, pistil. *F*, cross section of ovary. *G*, flower cut in half vertically. *H*, Diagram showing the arrangement of the parts of the flower. *J*, fruit, natural size. *K*, seed, enlarged, and in vertical section. (LeMaout and Decaisne.)

The relatively large proportion of mineral matter in the dry substance, *i. e.*, the entire substance free from water, of succulent vegetables and fruits deserves particular notice, for there is good reason to believe that certain salts here included impart to the fresh juice of these plants a peculiar value quite independent of their worth as nutriment. It has been observed that when, as on long voyages, men are deprived of food containing such vegetable juices, a serious and often fatal disease, known as scurvy, is likely to attack them. Sea captains and military commanders are now required by law to supply this need in the rations of their men (lime-juice is very largely used for the purpose), and scurvy is no

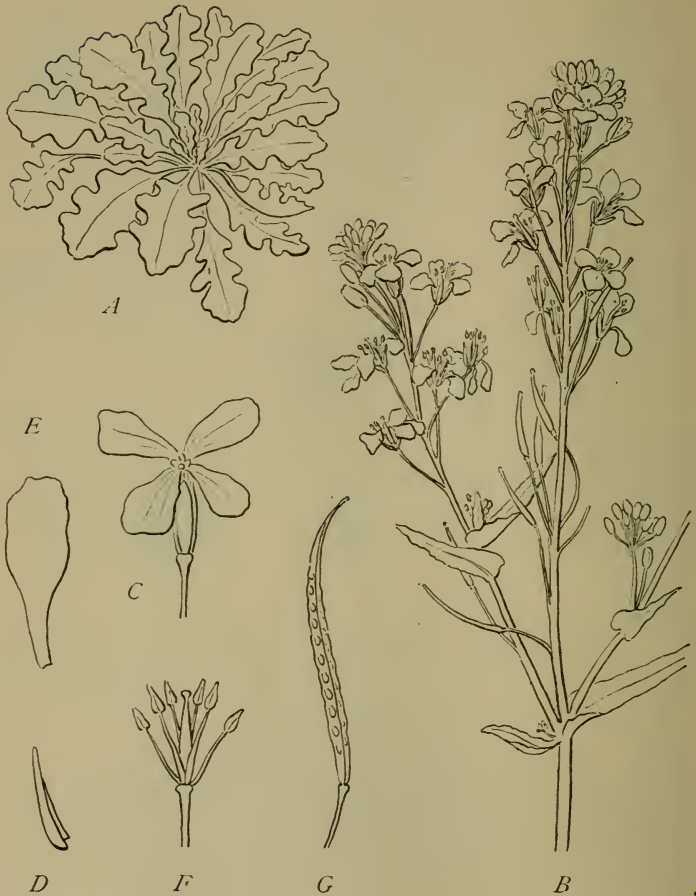


FIG. 63. Wild Kale (*Brassica oleracea*, variety *sylvestris*, Mustard Family, *Cruciferae*). A, plant in its first year showing rosette of leaves, much reduced. B, upper part of flowering stem developed the second year. Slightly reduced. C, a flower. D, a sepal. E, a petal, enlarged. F, essential organs of the flower. G, fruit. (A, Redrawn from Bailey, the others from Reichenbach.)—The plant is a biennial growing wild on rocky seashores, the first year producing only a rosette of leaves and the second year attaining often a height of 1 m.; stem and leaves rather fleshy, pale bluish green, smooth, covered with a waxy bloom; flowers yellow.



FIG. 64.—Wild Kale. *A*, flower cluster. *B*, flower with calyx and corolla removed to show the stamens and pistil. *C*, fruit. *D*, the same splitting open and exposing the seeds. *E*, seed cut across to show the folded parts of the germ within the seed-coat. (Baillon.)

longer feared. As these vegetable juices possess scarcely any nutritive value, the above facts clearly indicate that special salts dissolved in the juices have an important use in keeping our bodies in healthy condition.

The difference in chemical composition and food value between herbage-vegetables and the various underground parts and seeds already studied may be accounted for by the peculiar purpose which green herbage serves in the plant's life. Whereas food is stored abundantly in parts which are to live over the winter in order that new growth may be hastened at the return of favorable conditions, it is the foliage which makes the food that is stored away.

The making of food requires sunlight, and is accomplished by means of the green coloring matter characteristic of herbage. This pigment is termed *chlorophyll*.¹ It dissolves in alcohol, and the extract possesses the peculiar property

¹ Chlo'-ro-phyll < Gr. *chloros*, green; *phyllon*, leaf.



FIG. 65.—Garden Kale or Borecole (*B. oleracea*, var. *acephala*). Plant showing appearance at close of first year's growth. $\times \frac{1}{2}$. (Vilmorin.)

of showing two colors—green when the light shines through it, and red when the surface is strongly illuminated.

The raw materials out of which chlorophyll-bearing plants make their food are carbon dioxide (CO_2), water (H_2O), and dissolved mineral salts containing nitrogen, phosphorus, sulphur, iron, potassium, etc. The carbon dioxide, known as carbonic acid when dissolved in water, is a gas which forms about one twenty-five-hundredth of the atmosphere, and a somewhat larger proportion of all the natural waters of the earth. It is being breathed out continually by plants and animals, and so would increase enormously in amount were it not absorbed by the green parts of plants. Five per cent of the gas mixed with air acts like a poison when breathed in by animals, but even larger amounts are quite harmless to plants.



FIG. 66.—Kohl-rabi (*B. oleracea*, var. *gongylodes*). Plant in flower, much reduced. (Baillon.)



FIG. 67.—Common Cabbage (*B. oleracea*, var. *capitata*). Plant at close of first year's growth. Much reduced. (Nicholson.)



FIG. 68.—Savoy Cabbage (*B. oleracea*, var. *sabauda*). Plant at close of first year's growth, showing the characteristically blistered leaves. Much reduced. (Nicholson.)



FIG. 69.—Brussels Sprouts (*B. oleracea*, var. *gemmifera*). Plant at close of first year's growth. Much reduced. (Nicholson.)



FIG. 70.—Cauliflower (*B. oleracea*, var. *Botrytis*). Plant at close of first year's growth, with a few of the leaves cut away to show the fleshy, compacted flower-cluster. Much reduced. (Baillon.)



FIG. 71, I.—Watercress (*Nasturtium officinale*, Mustard Family, *Cruciferae*). Plant showing method of growth. ($\times \frac{1}{4}$) and a piece of stem bearing roots, leaf, and a young branch, natural size. (Vilmorin.)*



FIG. 71, II.—Watercress. Flowering branch. Flower (petals white). Fruit. Piece of pod cut lengthwise to show the two rows of seeds. (Britton and Brown.)



FIG. 72.—Spinach (*Spinacia oleracea*, Goosefoot Family, *Chenopodiaceae*). Plant, showing first year's rosette of leaves. (Vilmorin.)—An annual or sometimes a biennial; leaves smooth, deep green; flowers greenish; fruit dry.



FIG. 73.—Spinach. Flowering branch. (Baillon.)

FIG. 74.—Spinach. *A*, staminate flower, top view. *B*, pistillate flower, side view. *C*, pistillate flower, with part of ovary wall cut away to show the ovule within. *D*, fruit. *E*, the same, cut in half vertically showing seed and coiled germ. *F*, *G*, other forms of fruit. All the figures more or less magnified. (Volkens.)

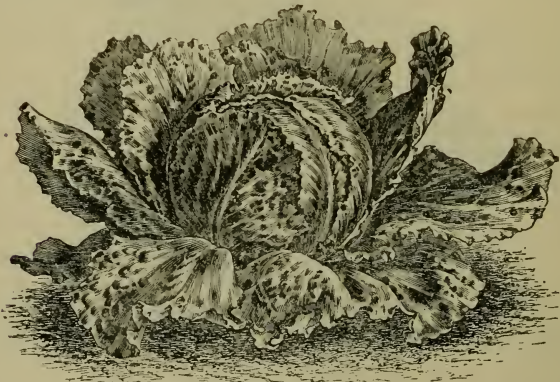


FIG. 75.—Lettuce (*Lactuca sativa*, Sunflower Family, *Compositae*). Plant during early period of growth, showing the compacted rosette of leaves. (Nicholson.)—The plant is an annual, smooth throughout, attaining a height of about 1 m., flowers yellow.



FIG. 76.—Lettuce. Plant in flower and fruit. (Atkinson.)—This is the wild form known as *Lactuca scariola* from which the garden varieties are believed to be derived. When growing in open land the leaves commonly arrange themselves in two vertical rows with one edge directed upward and the tips pointing northward or southward. It is thus a "compass plant" similar to that of our western prairies described by Longfellow in *Evangeline*, Part Second, Section IV. The parachute-like fruits are carried far by the wind, and are finally anchored by means of the spines near the base of the stalk.

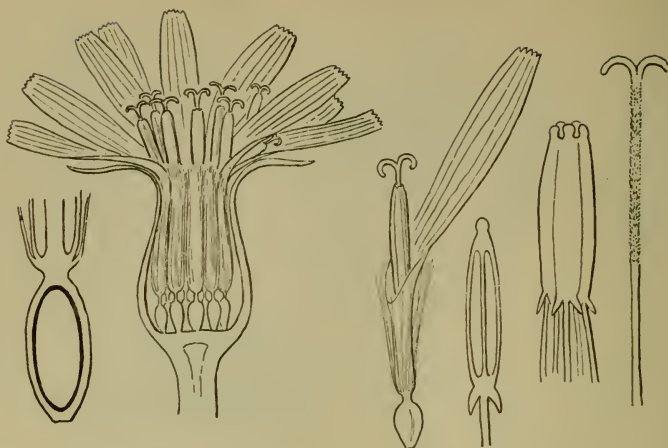


FIG. 77.—Lettuce. Flower cluster, enlarged. Base of a flower cut vertically to show the single ovule within the ovary, and how the calyx, corolla, and style grow out from it above. A single flower. An anther, inner view showing openings through which pollen is shed upon the style. The stamen-tube formed by union of the five anthers. Style and stigmas, showing the hairy region which pushes up through the stamen-tube like a bottle-brush carrying upon it the pollen to be rubbed off by insect visitors. (Redrawn from Thomé.)

When the raw materials above mentioned are present in a living part containing chlorophyll and exposed to sunlight, the energy of the sun's rays is utilized to separate the oxygen from the carbon and unite the latter with the elements of water to make a carbohydrate. The first food-product that we can detect is usually starch, but the giving off of oxygen (especially well seen in a water-plant) is evidence that food-making is in progress.

Fats and proteids may be formed from carbohydrates in various parts of the plant independently of sunlight; but while fats require only a diminution in the amount of oxygen, the proteids must have nitrogen, and often sulphur or phosphorous (derived from the salts above mentioned) combined with the carbon, hydrogen, and oxygen of the carbohydrates. Other elements found in the mineral salts aid in food-making by their mere presence. Thus a minute amount of iron is necessary to the formation of chlorophyll, and potassium



FIG. 78.—Celery (*Apium graveoleus*, Parsley Family, *Umbelliferae*). Plant in its first year, showing leaves and roots. (Nicholson.)



FIG. 79.—Celery. Leaf. Upper part of flowering stem, showing flower clusters and fruit. A flower, enlarged. Fruit. The same cut across. (Britton and Brown.)—The plant is a biennial, smooth throughout; leaves 25–50 cm. long, bright green (except when “blanched” by culture); flowering stem, erect 3–9 dm. tall; flowers white; fruit, dry, brown. The plant as it grows wild in salt marshes and by the seashore is somewhat poisonous, but becomes wholesome in cultivation.



FIG. 80, I.—Pumpkin (*Cucurbita Pepo*. Gourd Family, *Cucurbitaceæ*). Flowering branch. (Baillon.)—The plant is an annual climbing more or less by means of tendrils, and attaining a length of 7 m.; stem and leaves bright green, bristly hairy; flowers yellow; fruit variously colored in different varieties, and widely different in appearance as shown in Figs. 81, I-IV.

controls the making of carbohydrates, although neither the iron nor the potassium enter into the product. Much of the process of food-making as well as of the conditions under which it takes place, is as yet imperfectly understood by physiologists.

A living plant has been well compared to a food-factory where we may see the raw materials which go in and the products which come out, but where we can only guess as to what goes on inside, for on the door is written "No admittance." We know that in some way the body of a plant is built up of highly complex materials which it makes by recombining the elements of relatively simple substances. We know also that so long as it lives the plant is breaking down the complex compounds into simpler ones which it gets

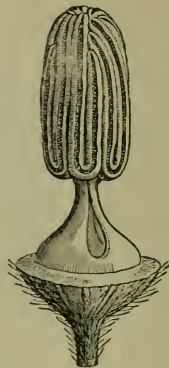


FIG. 80, II.—Pumpkin, staminate flower, cut vertically. (Baillon.)

FIG. 80, III.—Pumpkin, the same with calyx and corolla removed to show the united stamens, enlarged. (Baillon.)

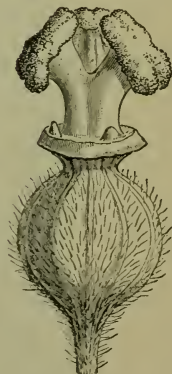
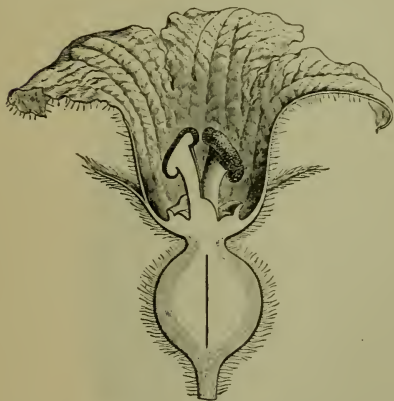


FIG. 80, IV.—Pumpkin, pistillate flower, cut vertically. (Baillon.)

FIG. 80, V.—Pumpkin, the same with calyx and corolla removed to show the three-branched style and stigmas. (Baillon.)



FIG. 80, VI.—Pumpkin, ovary cut across near the top. (Baillon.)

FIG. 80, VII.—Pumpkin, ovary cut across near the middle, showing the position of the ovules. (Baillon.)

FIG. 80, VIII.—Pumpkin, seed. (Baillon.)

FIG. 80, IX.—Pumpkin, seed cut lengthwise between the seed-leaves of the germ. (Baillon.)

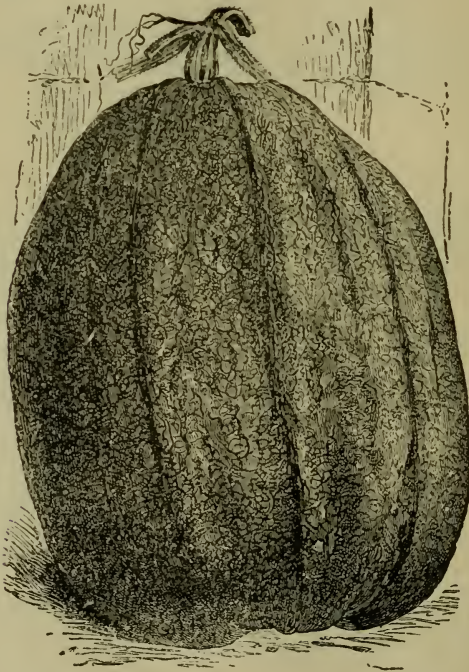


FIG. 81, I.—Pumpkin, fruit, $\frac{1}{2}$. Color grayish green. (Vilmorin.)



FIG. 81, II.—Long White Squash (*Cucurbita Pepo*, var.). Fruit and leaves.
 ½. Fruit pale, yellowish. (Vilmorin.)

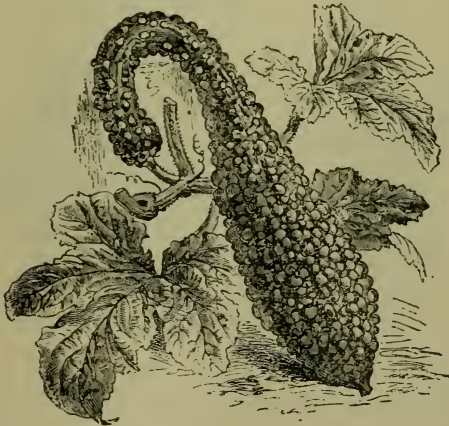


FIG. 81, III.—Summer Crook-neck Squash (*Cucurbita Pepo* var.). Fruit and leaves.
 ½. Fruit bright orange. (Vilmorin.)



FIG. 81, IV.—Scallop Squash (*Cucurbita Pepo*, var.). Plant showing leaves, flowers, and fruit. $\frac{1}{8}$. Fruit pale, yellowish. (Vilmorin.)



FIG. 82, I.—Hubbard Squash (*Cucurbita maxima*, var., Gourd Family, *Cucurbitaceæ*). Fruit. $\frac{1}{8}$. (Vilmorin.)—The plant as regards stem, leaves and flowers, resembles the preceding species; fruit variously colored.



FIG. 82, II.—Turban Squash (*Cucurbita maxima*, var., Gourd Family, *Cucurbitaceæ*). Leaves and fruit, $\frac{1}{2}$. Fruit greenish, yellowish, or reddish. (Vilmorin.)



FIG. 83.—Winter Crook-neck Squash (*Cucurbita moschata*, Gourd Family, *Cucurbitaceæ*). Leaf. Flowering branch. Pistillate flower. Staminate flower. Staminate flower bud, showing leaf-like sepals. (Nicholson.)—Plant similar to the preceding species, but soft-hairy and the leaves often with silvery spots; fruit variously colored.



FIG. 84.—Winter Crook-neck Squash. *l.* Fruit and leaves. (Vilmorin.)



FIG. 85.—Cucumber (*Cucumis sativus*, Gourd Family, *Cucurbitaceæ*). Flowering branch. (Nicholson.)—Plant a rough hairy annual, climbing by tendrils; stem about 1-2 m. long; leaves bright green; flowers yellow; fruit variously colored, smooth or prickly.

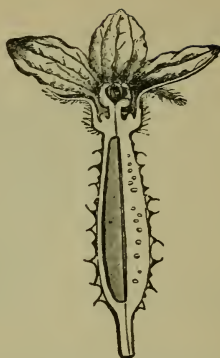


FIG. 86, I.—Cucumber. Staminate flower, cut vertically. (Baillon.)
 FIG. 86, II.—Cucumber. Pistillate flower, cut vertically. (Baillon.)

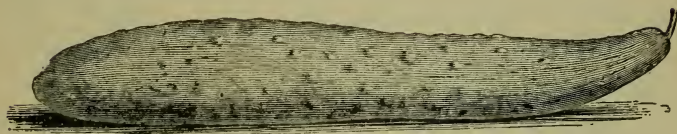


FIG. 87.—Cucumber, fruit. (Nicholson.)



FIG. 88.—Tomato (*Solanum Lycopersicum*, Nightshade Family, *Solanaceæ*). Plant in fruit. $\frac{1}{2}$. Fruit. $\frac{1}{4}$. (Vilmorin.)—An annual; stem and leaves soft hairy, dull green; flowers yellow; fruit red or yellow.

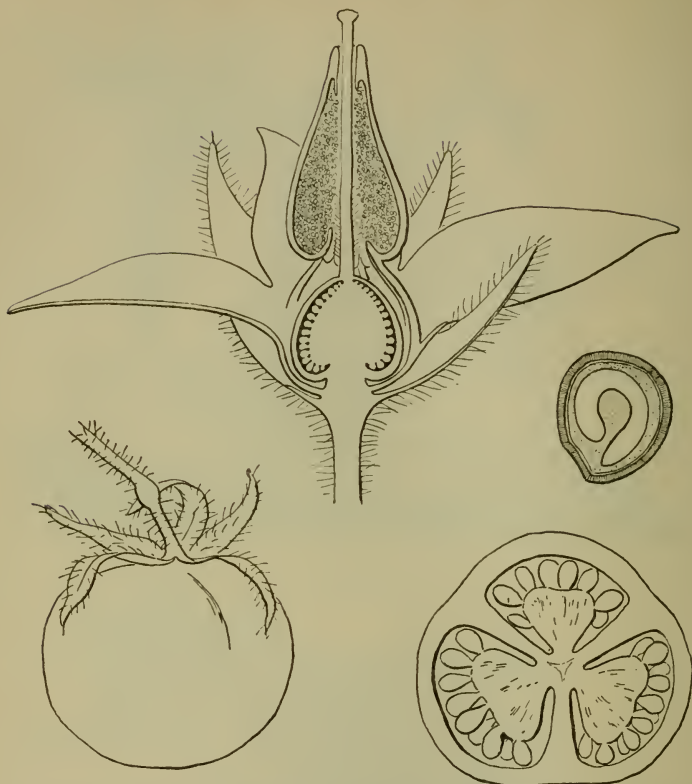


FIG. 89.—Tomato. Flower, cut vertically, enlarged. Fruit, side view. Same, cut across. Seed, cut vertically to show curved germ, in seed-food. (Redrawn from Nees.)

rid of as well as it can or allows to accumulate where they will do the plant no harm. The coloring matters and flavoring substances of the vegetables already studied are examples of such by-products.

All of the chemical changes taking place in the living parts of an organism are together called *metabolism*,¹ the constructive changes being distinguished as *anabolism*,² and the destructive ones as *catabo-*

¹ Met-ab'o-lism < Gr. *meta*, beyond; *ballein*, throw.

² An-ab'o-lism < Gr. *ana*, upward.



FIG. 90.—Egg Plant (*Solanum Melongena*, Nightshade Family, *Solanaceæ*). Plant in fruit, $\frac{1}{2}$. (Vilmorin.)—An annual; flowers similar in form to those of tomato, but violet in color; fruit dark violet, or whitish.

lism.¹ The forming of a carbohydrate in sunlight is called *photosynthesis*.²

Food-making being the peculiar task of green herbage renders foliage as a rule less useful than other parts for the storage of food. Hence we find leafy shoots accumulating food only incidentally, and then generally in largest amount where least exposed to light. *The main work of foliage is to utilize sunlight for the making of food, and in so doing it keeps the surrounding air fit for animals to breathe.*

37. Fruit-vegetables, as the name implies, are succulent fruits which are used in the same manner as herbage and earth-vegetables. The most important examples are the cucumber, the various sorts of squash and pumpkin, the tomato, and the egg-plant (Figs. 80–90). To these must be added the so-called “string-beans” and “wax-beans” which are merely varieties of the kidney-bean already noticed wherein the green esculent pod plays a more important part than the unripe seeds.

From the fact that they are used more as “vegetables” than as “fruits” we should expect fruit-vegetables to resemble more nearly the former in chemical composition. We find this to be the case. In their percentage of water,

¹ Cat-ab’o-lism < Gr. *kata*, downward.

² Pho-to-syn’the-sis < Gr. *photos*, light; *synthesis*, a putting together.



FIG. 91, I.—Apple (*Pyrus Malus*, Rose Family, *Rosaceæ*). 1, twig showing winter buds. 2, flowering branch. 3, flower cut vertically, petals removed. 4, fruit, leaves, and bud. 5, seed. 6, wood, cut across the grain; and magnified about 20 diameters. (Mouillefert.)—The plant is a small, often shrub-like tree with rounded head; young stems and under surface of leaves grayish woolly; flowers white or rosy; fruit very various in form and coloring.

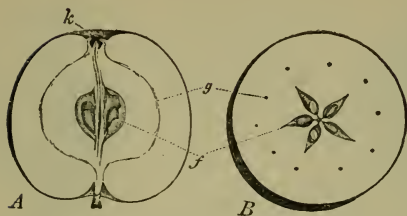


FIG. 91, II.—Apple, fruit, cut in halves vertically (A) and across (B), showing the withered sepals (K) once fed by the woody strands (g) which pass from the woody stem below through its enlarged upper part surrounding the core (f) or ripened pistil. (Focke.)



FIG. 92.—Pear (*Pyrus communis*, Rose Family, *Rosaceæ*). 1, flowering branch, 2, flower, cut vertically, 3, fruit, cut vertically, 4, diagram of flower. (Wossidlo.)—The plant is a tree, sometimes attaining a height of 25 m., and living to a great age; growing parts soon smooth; flowers white; fruit various in form and color, with the flesh gritty unless ripened off the tree.



FIG. 93, I.—Quince (*Cydonia vulgaris*, Rose Family, *Rosaceæ*). Flower, expanded, and cut vertically. (Baillon.)—The plant is a shrub or small tree, with slender, thornless branches; leaves hairy; flowers white or pink; about 5 cm. broad; fruit finely hairy, yellowish.

FIG. 93, II.—Quince fruit, cut vertically. (Baillon.)

ash, cellulose, digestible carbohydrate, and fat, as will be seen from the chart, there is a close correspondence between these and the other vegetables; while in the matter of proteid the fruit-vegetables hold a position intermediate between the class above and the class below them.

38. Fruits are eaten principally for their sweet or acid juices, and thus differ in general from what we call “vegetables.” Moreover, while “vegetables” are generally cooked, or at least are prepared for eating by the addition of oil, vinegar, mustard, or the like (as in the case of salads), fruits are more often eaten raw just as they are picked, except perhaps for the addition of sugar. As might be expected, however, the line between fruits and fruit-vegetables cannot be drawn with distinctness.

Out of the very large number of different kinds of edible fruits, we can here consider as examples only a few of the more important, namely, the apple, pear, quince, peach, plum, cherry, raspberry, strawberry, European grape, northern fox-grape, garden currant, muskmelon, watermelon, orange, lemon, banana, date, fig, and pineapple (see Figs. 91–111).



FIG. 91.—Peach (*Prunus Persica*, Rose Family, *Rosacæ*). *A*, flowering branch. *B*, flower, cut vertically. *C*, diagram of flower. *D*, ovary, cut across to show the two layers of the wall, the outer (dotted) which becomes fleshy, and the inner (white) which becomes hardened as the "stone" or "pit"; and the two ovules of which only one commonly becomes a seed. *E*, fruit with flesh cut in half vertically, showing the rough "stone" or inner hardened part of the ovary wall. *F*, the "stone" broken in half to show the single seed within. (LeMaout and Decaisne.) The plant is a tree; leaves smooth; flowers pink, appearing before the leaves; fruit downy.

As already intimated, the most significant features of the chemical composition of fruits are (1) the presence in considerable amount of peculiar acids, (2) the predominance of sugar in the dry substance, and (3) the presence of useful salts. These chemical characteristics are shown on the chart. It will also be noticed that the proportion of proteid is very small except in the banana which, in this respect, is typical of a certain class of tropical fruits, including the date and fig, that form a highly important source of nutriment in the regions where they grow. Starch may be detected in the banana; in the more juicy fruits, however, starch is absent.

The highly attractive flavoring matters upon which our enjoyment of fruits largely depends, are present in such exceedingly small amount that chemical analysis can hardly



FIG. 95.—Plum (*Prunus domestica*, Rose Family, *Rosaceæ*). Fruiting branch (Nicholson.)—The plant is a small tree with hairy twigs; flowers like those of peach but white; fruit smooth and with a bloom, the stone slightly rough.

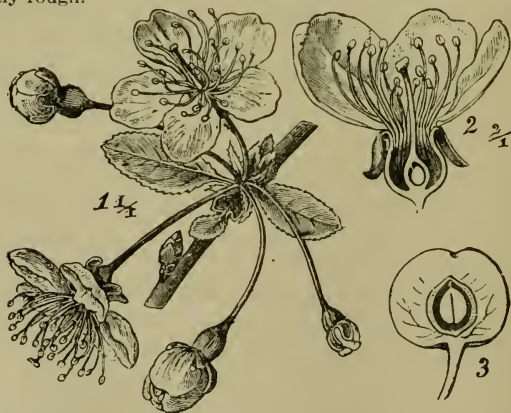


FIG. 96.—Sour Cherry (*Prunus Cerasus*, Rose Family, *Rosaceæ*). 1, flowering branch. 2, flower, cut vertically. 3, fruit, cut vertically. (Wossido.)—The plant is a rather low, round-headed tree with gray bark; leaves stiff and glossy; flowers white or reddish; mostly in advance of the leaves; fruit smooth, light or dark red, smooth, without bloom, sour or sometimes sweet in cultivation. This species together with the mazzard cherry (*P. Avium*) includes most of the varieties of cherry grown for their fruit.



FIG. 97.—European Raspberry (*Rubus idaeus*, Rose Family, *Rosaceae*). 1, flowering branch and leaves. 2, flower cut vertically. 3, fruit. 4, floral diagram. (Wossidlo.)—An erect, prickly shrub; leaflets whitish beneath; flowers white; fruit dark red, yellow, or whitish. This species together with our wild red raspberry (*R. strigosus*) which is closely similar to it, have produced our cultivated varieties.

take account of them. Nevertheless their importance as an aid to digestion is believed to be far from insignificant. As the fruit ripens, the various flavors and acids, and most of the attractive pigments, arise as by-products.

39. Miscellaneous food-products. Under this head we must consider the products of certain plants which do not properly belong to any of the foregoing groups. Thus in the common garden rhubarb or pie-plant (Fig. 112) the part commonly used is the leafstalk, just as in celery; but it can hardly be called a vegetable, for it is used quite like a fruit



FIG. 98, I.—Strawberry (*Fragaria vesca*, Rose Family, *Rosacæ*). Plant showing manner of propagating by means of slender horizontal stem-branches, called "runners" which develop roots and shoots near their scale-like leaves. (Baillon.)—The plant is thus a perennial herb; leaves sparsely hairy, light green; flowers white; fruit red. Besides this species *F. chiloensis*, *F. virginiana*, and *F. moschata*, have yielded cultivated varieties, the first being of most importance.



FIG. 98, II.—Strawberry flower, entire, and cut vertically. (Baillon.)

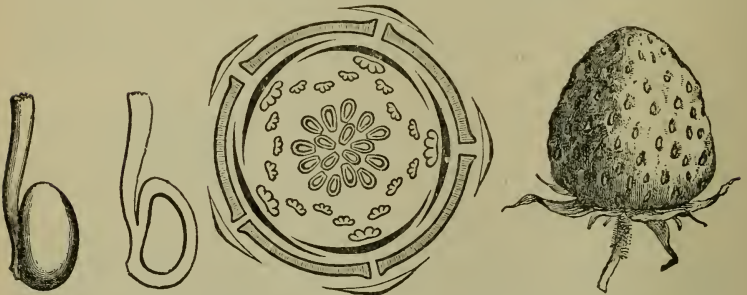


FIG. 98, III.—Strawberry pistil, entire, and cut vertically to show the single ovule within; and floral diagram. (Baillon.)

FIG. 99.—Strawberry fruit, showing the swollen end of the flower-stalk which becomes red and fleshy and bears the ripened pistils over its surface. (Baillon.)



FIG. 100.—Grapes (*Vitis labrusca* and *V. vinifera*. Grape Family, *Vitaceæ*). *A-F*, northern fox grape (*V. labrusca*). *A*, flowering branch. *B*, flower bud, one petal (at the left) beginning to separate. *C*, staminate flower, with petals fallen. *D*, pistillate flower with rudimentary stamens. *E*, ovary cut across. *F*, ovary, cut vertically. *G-M*, European grape (*V. vinifera*). *G*, flowering branch. *H*, berry, cut vertically. *J*, same, cut across. *K*, seeds, front view (*a*), back view (*b*). *L*, seed, cut across. *M*, seed, cut vertically from front to back (*a*), and from side to side (*b*). (Gilg.)—Woody vines climbing by tendrils; flowers greenish; fruit greenish, reddish, or dark purple often with a bloom.

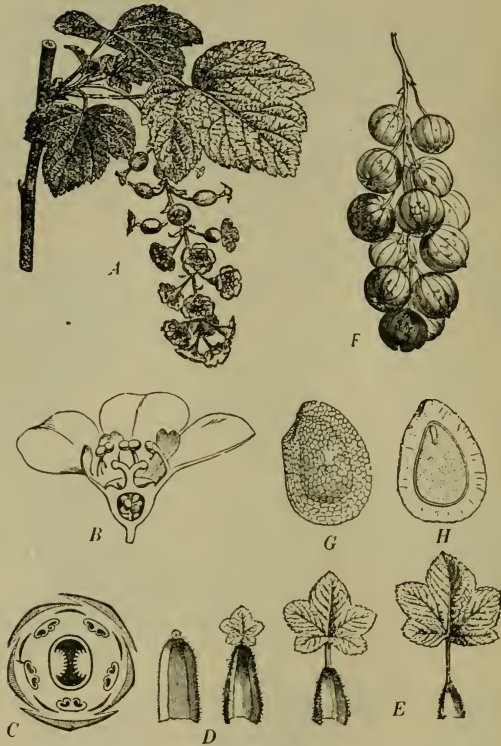


FIG. 101.—Common Currant (*Ribes rubrum*, Saxifrage Family, *Saxifragaceæ*). A, flowering branch. B, flower, cut vertically. C, floral diagram. D, bud scales. E, leaves. F, fruit cluster. G, seed, side view. H, same, cut vertically. (Baillon.)—Shrub; leaves becoming smooth; flowers yellowish-green or purplish; fruit shining, bright red, yellowish-white or striped. Includes all the cultivated varieties of red or white currants.



FIG. 102.—Muskmelon (*Cucumis Melo*, Gourd Family, *Cucurbitaceæ*). Shoot showing staminate flower at *a*, and pistillate flower at *b*. (Nicholson.)—A long-running, annual, herbaceous vine; hairy and prickly; flowers yellow, very like those of cucumber; fruit various in size, shape, and color, mostly dull-greenish or orange.



FIG. 103.—Muskmelon. Fruit, much reduced. (Baillon.)



FIG. 104.—Watermelon (*Citrullus vulgaris*, Gourd Family, *Cucurbitaceæ*). Vine bearing leaves, flowers, and very young fruit; *a*, staminate flower; *b*, pistillate flower. (Nicholson.)—Plant an annual herbaceous vine; leaves hairy or smooth; flowers yellow; fruit greenish with pale markings, smooth, globular or oval, sometimes 60 cm. long.



FIG. 105.—Watermelon, fruit. (Nicholson.)



FIG. 106.—Orange (*Citrus Aurantium*) and Lemon (*C. medica*, var. *Limonum*, Rue Family, *Rutacæ*). A–F, Orange. A, flowering branch. B, flower, central part, cut vertically and enlarged. C, pollen grains, much magnified. D, ovary, cut across. E, seed, cut vertically. F, seed, cut across. G–L, Lemon. G, flowering branch. H, flower, with petals removed, enlarged. J, anther, front view. K, same, back view. L, ovary, cut vertically, enlarged. (Berg and Schmidt.)—Both plants are small trees or shrubs with evergreen aromatic leaves and smooth stems; flowers white in the orange, and tinged with pink in the lemon; fruit with thick aromatic rind, and seeds imbedded in a pulp consisting of internal hairs swollen with a more or less acid juice.



FIG. 107, I.—Banana (*Musa sapientum*, Banana Family, *Musaceæ*). Plant showing flower cluster and young fruit. (Pechuel-Lœsch.)—What appears to be trunk consists of the leaf-stalks wrapped around one another, the stem being short and mostly underground. The height is about 6 m. or more.

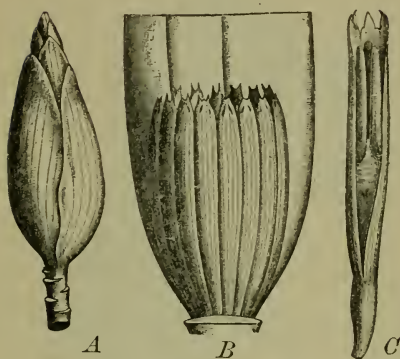


FIG. 107, II.—Banana. *A*, tip of flower cluster, showing the large purplish bracts which protect the mostly yellowish flowers till they are fully developed. *B*, a cluster of flowers behind a bract. *C*, a single flower (Petersen.)

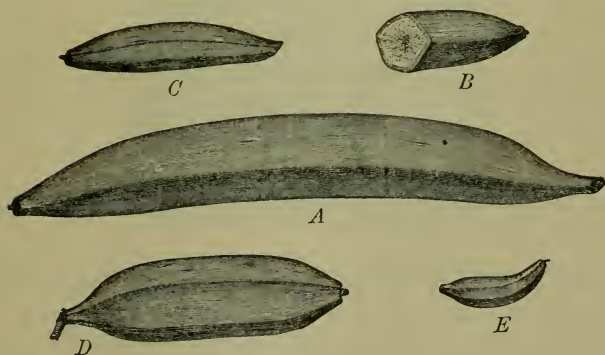


FIG. 107, III.—Banana, fruit of different varieties, showing range of size and form. *A*, Giant Pisang. *B*, Small Pisang. *C*, Silver Banana. *D*, Copper Banana. *E*, Dwarf Banana. (Pechuel-Löesch.)—The varieties long in cultivation have become mostly seedless through propagation by shoots.



FIG. 108.—Date (*Phoenix dactylifera*, Palm Family, *Palmaceæ*). Group of trees in an oasis of the Sahara desert. (Strasburger.)

on account of its strongly acid sap; in spite of its fruit-like qualities, however, it can still less be called a fruit.

Similarly in the olive (Fig. 113) we have a fruit which is put to a peculiar use. The pulp instead of being sour or sweet, abounds in a rich oil, which when extracted by pressure, is the most highly valued of vegetable oils for salads and in cookery. Peanuts and various other oily nuts, as also cotton seed and others rich in oil, yield a similar product which is



FIG. 109.—Date. *A*, fruit cluster, with large bract which protected the young flowers, $\times \frac{1}{2}$. *B*, staminate flower, slightly enlarged. *C*, pistillate flower, side view, twice natural size. *D*, same, top view. The flowers are yellow; the fruit, orange, brown, or black. (Redrawn from Turpin.)

often substituted for olive-oil; but although equally wholesome and of practically the same chemical composition, the nut-oils and seed-oils are inferior in flavor.

The sugar used in this country is obtained very largely from sugar-cane (Fig. 114). When full grown the stalks are crushed between rollers, which press out the sweet sap. This, upon evaporation of a certain amount of the water, yields crystals of cane-sugar which are separated from the thick, sweet liquid known as molasses. The crystals after further removal of impurities form the cane-sugar of commerce.

Exactly the same kind of sugar as that obtained from the sugar-cane is extracted also from the sugar-beet (a variety of the common garden beet) and from the sap of the sugar-



FIG. 110.—Fig (*Ficus carica*, Mulberry Family, *Moraceæ*). 1, flowering branch, showing leaf and urn-shaped receptacle which encloses the numerous minute flowers. 2, a single pistillate flower, with stalks of two others growing into the cavity of the receptacle; the actual size shown by the line at the left. 3, staminate flower. 4, fruit or ripened receptacle cut vertically to show the fleshy wall and the cavity filled with ripe pistils and sugary material. (Wossidlo.)—A shrub or tree becoming 5–10 m. tall; leaves rough above, downy beneath; fruit greenish, yellowish, reddish, brown, purplish, or black, often with a bloom, the flesh mostly reddish or yellowish.

maple (Fig. 248). Beets form the chief source of the sugar used throughout Europe and nearly half of that consumed in the United States.

As already stated in the last chapter (section 29) large quantities of what is known commercially as “glucose” (which is a honey-like syrup), are manufactured from the starch of maize or Indian corn, particularly for the use of confectioners. This product is chemically much the same as the sweet substance found in fruits, and is perfectly wholesome; it has, however, the disadvantage of being only about three-fifths as sweet as cane-sugar.

Another food-product, very much used in confectionery, is what is commonly called “cocoa,” or when sweetened and flavored, “chocolate.” This name “cocoa” is somewhat misleading, since it is also applied to the palm which yields the

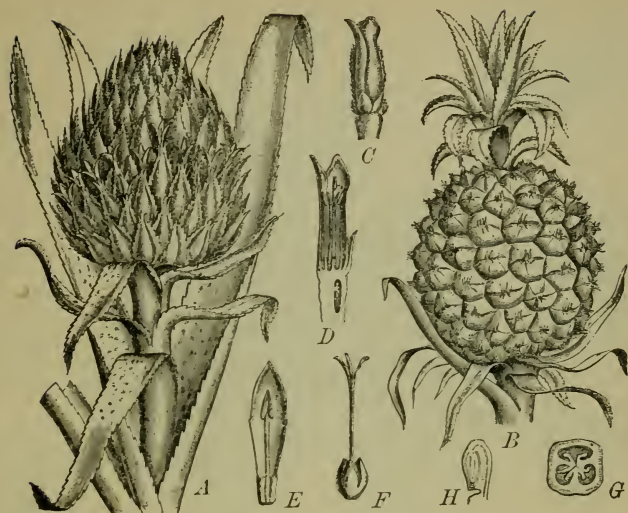


FIG. 111.—Pineapple (*Ananas sativus*, Pineapple Family, *Bromeliaceæ*). *A*, flowering shoot, bearing the cone-like cluster of flowers each protected by a bract. *B*, fruit, showing continuation of the shoot from its tip. *C*, a flower. *D*, same, cut vertically. *E*, a petal, with two scales at the base, and a single attached stamen. *F*, calyx and style with branching stigma. *G*, ovary, cut across. *H*, ovule. (Koch, Le Maout and Decaisne.)—A perennial herb with short stem and tough pale green leaves; flowers bluish; fruit reddish or orange. New plants are grown from the tuft of leaves crowning the fruit.

“cocoanut” and which is a plant totally different from the one that gives us chocolate, as may be seen by a glance at Figs. 115 and 34. *Cacao* is a much better name for the plant and product from which chocolate is manufactured, for it is the name commonly used in tropical America where the plant grows, and is applied to no other sort. It is the seeds which afford the cacao of commerce. Separated from the fleshy pulp of the somewhat squash-like fruits, the seeds are placed in tight boxes or otherwise massed with exclusion of air, and allowed to undergo for some days a process of fermentation or “sweating,” whereby their peculiar flavor is developed. This accomplished, they are dried by exposure to the sun, daily, for two or three weeks, when they assume a



FIG. 112.—Garden rhubarb (*Rheum Rhabarbarum*, Buckwheat Family, *Polygonaceæ*). Plant in flower, $\times \frac{1}{2}$. (Vilmorin.)—A perennial herb; leaf-stalks often red; flowers whitish; fruit brown and dry.

rich red tint and are ready for market. As will be seen from the chart, cacao possesses a very high nutritive value.

Starch in the particularly palatable forms known as sago and tapioca, is obtained from certain tropical plants which are especially rich in this form of food. The best sago comes principally from the spineless sago-palm, shown in Fig. 116. When full grown the tree is felled and the trunk cut into sections to facilitate the removal of the spongy pith-like interior, which is gorged with starch. By repeated washings the starch is separated from the indigestible material, and is then finally dried and granulated into small pearl-like masses for the market. A single tree will yield from four hundred to six hundred pounds of sago.

Tapioca is manufactured chiefly from the large fleshy roots of the bitter cassava (Fig. 117). Curiously enough the starch in these roots is associated with a milky juice which is decidedly poisonous. The poison, however, is of such a nature that it entirely disappears in the process of preparation.



FIG. 113.—Olive (*Olea europaea*, Olive Family, *Oleaceæ*). *A*, flowering branch. *B*, flower. *C*, corolla and stamens. *D*, calyx and pistil, cut vertically. *E*, fruit. *F*, same with the pulp cut through to show the "stone" within. *G*, seed, cut vertically between the seed-leaves. *H*, same, cut vertically across the seed-leaves. (Knoblauch.)—An evergreen tree or shrub, with grayish-green leaves, cream-colored, fragrant flowers, and purplish fruit.

This is essentially as follows. The roots are first reduced to a pulp, and then subjected to pressure, which forces out the milky sap together with a large quantity of starch. After standing a while, the starch settles from this poisonous fluid. The latter is then poured off, and the starch, spread upon iron plates, is heated until all vestige of poison has disappeared, and the starch-grains becoming somewhat gummy adhere together into small irregular masses which constitute the tapioca of commerce.

A seaweed known as carrageen or "Irish moss" (Fig. 118), found along the North Atlantic coast on both sides of the



FIG. 114.—Sugar-cane (*Saccharum officinarum*, Grass Family, *Gramineæ*). Plant in flower. *A*, part of spike, showing long silky hairs. *B*, spikelet detached. *C*, flower, showing stamens, pistil and lodicules at the base. (Bentley and Trimen.)—Perennial, attaining a height of 4 m.; stem variously colored, 2–5 cm. thick.



FIG. 115, I.—Cacao (*Theobroma Cacao*, Silk-Cotton Family, *Sterculiaceæ*). The plant is a tree 3–13 m. tall, with shining leaves, and brownish-red flowers which spring from the trunk and older branches, and produce yellowish, orange, or brownish fruits, somewhat resembling a squash. (Baillon.)

ocean, is used for food, generally in a sort of pudding, somewhat as tapioca. The whole plant is cooked, after having been dried and bleached in the sun at the time of gathering. The principal chemical constituent (see chart) is a mucilaginous carbohydrate which swells greatly in water and gives to Irish moss blanc-mange its jelly-like character.

Finally must be mentioned as widely cultivated for food the common field mushroom (Fig. 119) which, as the chart will show, compares favorably with many vegetables in the percentage of nutritious constituents. The statement is frequently made, however, by writers who ought to be better

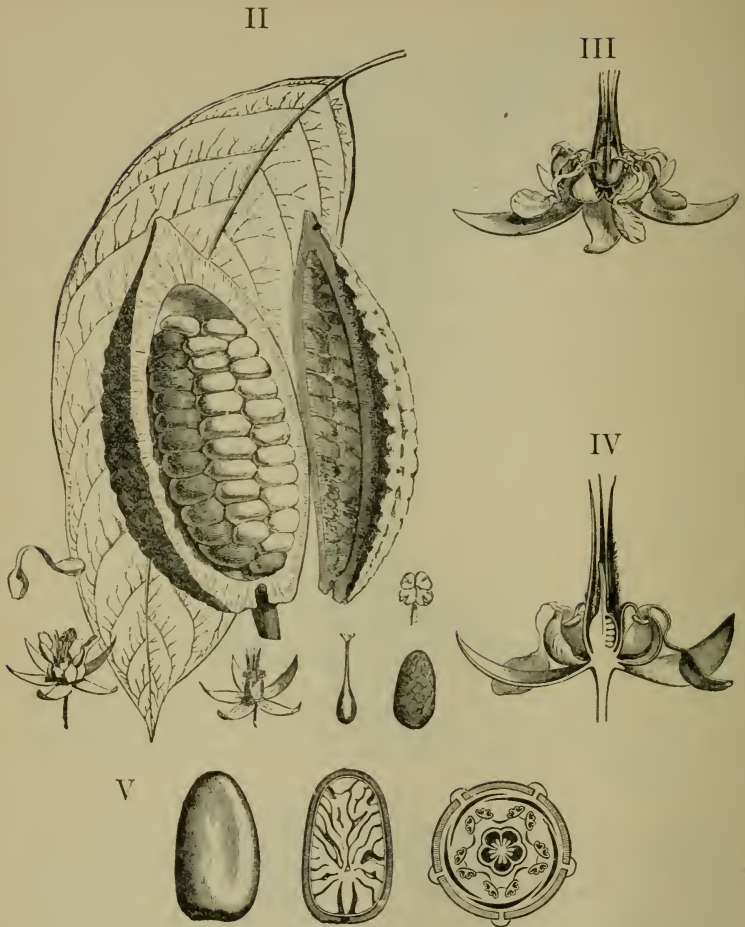


FIG. 115, II.—Cacao. Leaf. Flower, complete. Same with petals removed. A petal detached. A stamen, showing the four-celled anther. Pistil. Seed. (Baillon.)

FIG. 115, III.—Cacao flower, complete. (Baillon.)

FIG. 115, IV.—Cacao flower, cut vertically. (Baillon.)

FIG. 115, V.—Cacao. Seed, side view. Same, cut vertically, showing a wrinkled seed-leaf. Diagram of flower. (Baillon.)



FIG. 116, I.—Prickly Sago Palm (*Metroxylon Rumphii*, Palm Family, *Palmaceæ*). Tree about 10 m. tall or less; leaves very long and plume-like, prickly at base; flowers numerous, imperfect, on large special branches; fruit covered with hard woody scales. (De Colange.)

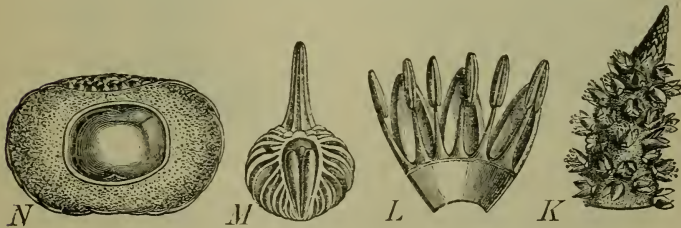


FIG. 116, II.—Smooth Sago Palm (*Metroxylon lacc*, Palm Family, *Palmaceæ*). *K*, tip of a flower-cluster branch. *L*, stamens on corolla of a staminate flower. *M*, pistil cut vertically, showing ovules and young scales. *N*, fruit cut vertically to show the seed surrounded by dry flesh and woody scales. (Blume.)—The plant is similar to the prickly sago palm but larger and without prickles.

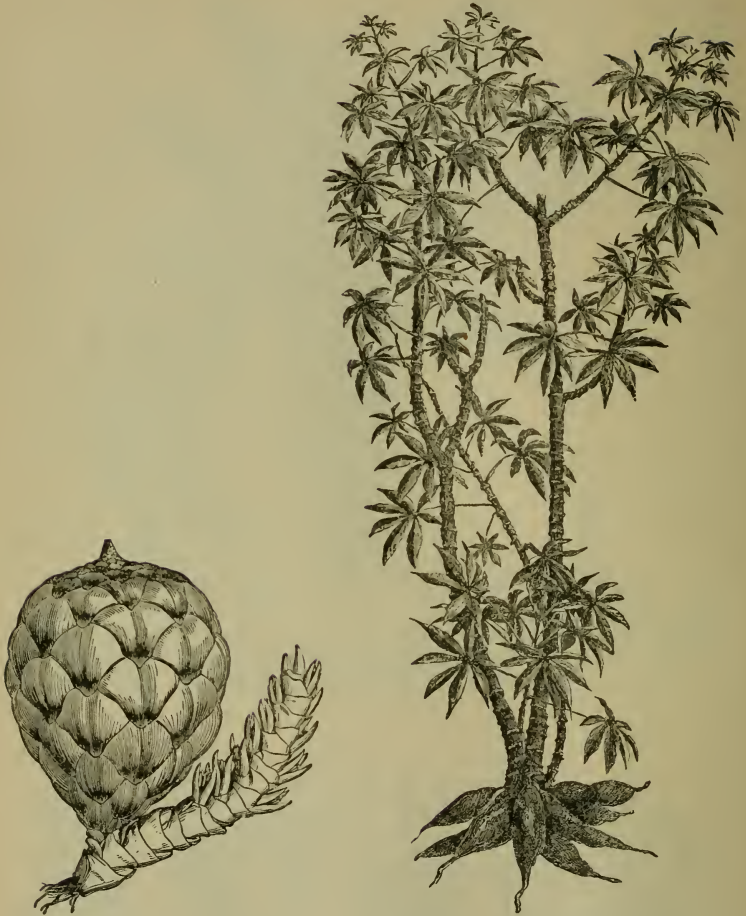


FIG. 116, III.—Prickly Sago Palm. Ripe fruit and remains of a staminate branch of the flower-cluster. (LeMaout and Decaisne.)—Three years are required to ripen this strangely armored fruit.

FIG. 117, I.—Bitter Cassava (*Manihot utilissima*, Spurge Family, *Euphorbiaceæ*). A shrub 2-3 m. tall, producing swollen roots weighing 10 kg. or more; flowers staminate and pistillate on the same plant; fruit dry, breaking apart. (Pax.)



FIG. 117, II.—Bitter Cassava. *A*, flowering and fruiting branch. *B*, staminate flower, cut vertically. *C*, pistillate flower, cut vertically. *D*, fruit. *E*, *F*, *G*, seed, viewed from front, back, and side. *H*, starch grains from the root, much magnified. (Pax, Martins, and Tschirch.)

informed, that mushrooms are as nourishing a food as meat. That this is an absurd exaggeration is seen from the fact that a pound of mushrooms contains less than one-sixth as much proteid as a pound of meat. Furthermore it has been ascertained that while the proteid of meat is almost entirely digestible, scarcely more than half of the proteid in mushrooms is available as nutriment. Still, mushrooms are sufficiently nutritious to warrant our using them much more than we do, especially certain wild forms which abound in our fields and woods, and of which some at least are preferable even to the cultivated species. The reason these wild forms are allowed to go to waste, is chiefly that there grow along with them certain poisonous species so nearly similar in appearance to the edible sorts as to have led ignorant persons to gather and eat them unwittingly, with fatal result; for unlike the poison in cassava root, that in poisonous mushrooms is not rendered



FIG. 118.—Carrageen (*Chondrus crispus*, Carrageen Family, *Gigartinaeæ*.) Various forms of the seaweed, about natural size, the form *a* showing the "fruit" as oval masses embedded in the branches. The whole plant is dark red or purplish when alive. (Luerssen.)

harmless by cooking. Unless one is well acquainted with the peculiarities by which edible and poisonous sorts may at once be distinguished, it is surely both foolish and dangerous to gather wild mushrooms to eat; nevertheless, such knowledge is not difficult to acquire with the aid of good pictures and careful descriptions, and to those who spend much time in the country the information may be of not a little value.

On the subject of poisonous plants we shall have more to say in a subsequent chapter. The only safe rule is for a person to avoid touching, and on no account to eat, any part of a plant which he does not surely recognize and know to be harm-



FIG. 119.—Field Mushroom (*Agaricus campestris*, Gill-mushroom Family, *Agaricaceæ*). Fruit-bodies, natural size, in various stages of growth. *a*, "button stage," in which the regions of stalk and cap are just distinguishable; *b*, a somewhat later stage, cut vertically to show the "gills" just appearing below the cap; *c*, a still later stage, similarly cut, in which the gills now fully formed are yet protected below by the membranous "veil"; *d*, stage in which the cap is almost expanded, showing on its under side the veil partly torn from the edge and exposing the pink gills; *e*, final stage in which the cap is fully expanded, and the veil, now entirely free from the rim, remains only as a ring around the stalk. (Luerssen).—The gills, at first pink, turn finally dark purplish brown, owing to the formation upon them of dark dust-like "spores" which fall from the exposed gills, are carried away by the wind, and give rise to new plants when favorably placed upon well-manured ground. These spores first produce a network of threads which feed upon the decaying materials, and finally send up the fruit-bodies above the surface.

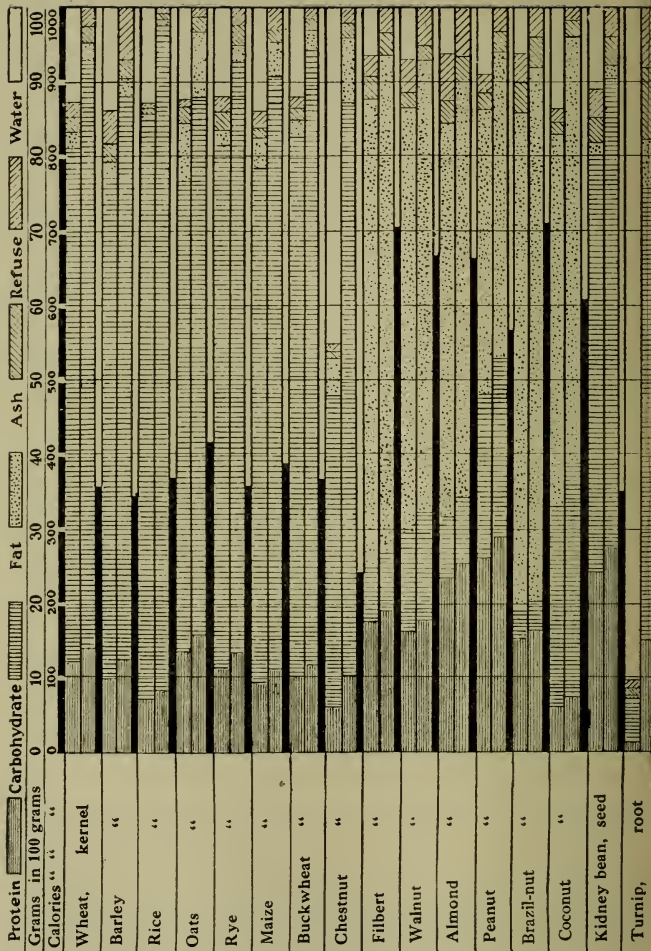
less. Every summer brings the sad news of children and older persons horribly poisoned through ignorance of our commonest plants. In a large proportion of these cases the plant eaten has been one which was thought to be harmless because it somewhat resembled a cultivated species or was mistaken for some harmless wild plant that is commonly eaten. Hence it should be remembered that, even though a wild plant looks like a familiar garden vegetable, there may be danger in eating or chewing any part of it.

40. Vegetable foods in general. In the foregoing sec-

tions, it has been shown that a classification of vegetable foods based upon the manner and degree of their usefulness is at the same time a fairly accurate grouping according to chemical peculiarities, the reason being that their use depends largely upon their composition. Guided by this principle we may now profitably compare vegetable foods with those of animal origin, so as to gain a better appreciation of their relative value in supplying human needs. A satisfactory understanding of the uses of food-plants clearly involves the study of this larger question.

41. Food as fuel and building material. Before proceeding to compare vegetable with animal foods certain fundamental facts regarding food in general must be considered. We know that so long as a man is alive and active, the parts of his body are wearing out from daily use, and he is losing heat. If deprived of food, his weight and strength decrease, while, on the other hand, if he is properly fed, nutritive materials become incorporated with the various parts of his body as fast as these wear away, and he finds his strength kept up by a constant supply of energy. Were it possible to conceive of a steam-engine which could derive from the fuel it consumes not only heat and power but also material to replace that used up in action, we should have a machine to which we might liken the human body in its use of food. If we could imagine, furthermore, a small locomotive able to do all this, and also to increase the size of its parts by the addition of extra material, so as to grow into a large locomotive, such a marvelously endowed machine would be very like the body of a child. Thus we see that food answers the double purpose of supplying us with building material and with fuel. But as already intimated in the last chapter, proteids, fats, and carbohydrates are not equally useful as sources of substance and energy.

As the chief wear in our bodies comes upon the muscles and other parts that are composed largely of nitrogen, and as neither fats nor carbohydrates contain this element, it follows that proteids, being nitrogenous, must be of the first importance as furnishing building material. This enables us to understand why it is that an animal deprived entirely



of proteids, although provided with abundant fats and carbohydrates will starve quite as truly as if it had no food whatever, whereas it may live indefinitely (although with danger to health) on a proteid diet¹ from which all fats and carbohydrates are excluded.

Since proteids alone will support life, we must conclude furthermore that they are also sources of energy, and the question may be asked, What need have we of fats and carbohydrates? While it is indeed true that proteids may serve as a source of energy, it has been found that the amount of energy derivable from the food we eat is very nearly proportionate to the amount of carbon present, and largely independent of the amount of nitrogen. It is estimated that an average man at moderate work needs daily less than ten grams of nitrogen and about two hundred and eighty grams of carbon; that is to say about twenty-eight times as much of the latter as of the former.² Since in proteids there is only about three and a half times as much carbon as nitrogen, it is clear that in order to obtain from them the necessary amount of carbon, a man would have to consume about eight times as much nitrogen as he had any use for. Not only would this impose an unnecessary burden upon the digestive organs, but so large an excess of nitrogen would be harmful in other ways before it could be eliminated from the system. Hence we must conclude that although proteids are absolutely essential as building material, their inadequacy as sources of energy requires that they be supplemented by carbonaceous and non-nitrogenous food-stuffs.

42. Measures of energy. As we have to depend for warmth and strength mainly upon fats and carbohydrates, it becomes important to inquire how these compare with each other in fuel value, for as already shown, these substances are to our bodies essentially as coal to a steam-engine. It was stated in the last chapter that fats afford more than twice as much energy as carbohydrates. We must now try to understand more fully what this means and at the same time secure a more exact expression of the relation thus vaguely

¹ It is of course assumed that the rations include a sufficient quantity of water and of salts.

² Physiologists formerly estimated the daily need of nitrogen at twenty grams, but recent experiments indicate that ten grams is amply sufficient.

indicated. When we were considering the amount of any substance in a given food, we were able to express the facts with perfect definiteness because we were dealing with what could be measured by weight and volume, and because we had the units (gram and cubic centimeter) by which the measurements could be expressed. Although neither heat nor mechanical force have weight or volume, they may nevertheless be measured as to their amount by means of suitable units. Such a unit for heat is the amount required to raise the temperature of one kilogram of water one degree of the centigrade thermometer. This amount of heat is termed a *Calory*.¹

From very careful experiments it has been calculated that if by means of a steam-engine, one Calory obtained from fuel could be entirely converted into mechanical energy, this would be sufficient to lift a weight of 424 kilograms, 1 meter, or 1 kilogram, 424 meters. The energy required to lift 1 kilogram, 1 meter, being called a kilogrammeter, we thus have in the expression $1 \text{ Calory} = 424 \text{ kilogrammeters}$, what is known as the "mechanical equivalent of heat."

43. Energy of vegetable foods. Experiments show that if completely burned,

1 gram of fat	yields 9.3 Calories
" " " carbohydrate	" 4.1 "
" " " proteid	" 4.1 "

These figures also indicate approximately the amount of energy which would be obtained from equal quantities of the same substances consumed in the human body. To estimate, therefore, the amount of energy obtainable from 100 grams of any food of which we know the chemical composition, we have only to multiply the percentage of each nutrient by the number of Calories yielded by a single gram, and add the products thus obtained. This has been done for the vegetable foods of which the composition is given in the chemical chart (Fig. 120); and the number of Calories is indicated by heavy lines having lengths proportionate to the amount of energy yielded by the foods they represent. Foods which yield much energy are commonly described as being "hearty": the lines in the chart may be said therefore to indicate the relative "heartiness" or fuel-value of common vegetable foods.

But it may be asked, Does a fat and a carbohydrate serve us in exactly the same way? Physiologists tell us that either *may* replace the other in our food, provided the amounts eaten represent an equivalent number of Calories; but there is this difference that, whereas carbohydrates (which, so far as they are digestible, enter the blood as sugar) are immediately after digestion available as a source of heat and muscular energy, fats require to undergo some preliminary transformation in the body, before they can be used, and are therefore less serviceable for immediate needs. Fat, how-

¹ Cal'o-ry < L. calor, heat.

ever, since it contains so much more energy than glucose in proportion to its bulk, is particularly well adapted for storage in our bodies as reserve material; and what is absorbed from our food needs to undergo scarcely any change before being laid away.

These differences in usefulness between fats and carbohydrates have been well expressed by comparing the latter to ready cash, and the former to money in a savings bank. This helps us to understand the benefit which pedestrians and bicyclists derive from the use of sweet chocolate. The large proportion of sugar (about 50%) yields up its energy immediately in time of need, while the considerable proteid offers material for the repair of muscular loss, and the abundant oil remains as a more slowly available reserve.

Likewise, the special craving which young people have for sweets, receives at once its explanation and justification when we remember the extraordinary activity which belongs properly to their period of life. It needs to be pointed out, however, that the quantity of carbohydrate eaten should be strictly proportioned to the amount of bodily activity; for otherwise there will be left in the system an excess of sugar, which may either go to produce an unhealthy accumulation of fat, or by undergoing acid decomposition, seriously disorder the digestive organs. Too much sweet food and too little exercise is one of the commonest causes of indigestion and obesity.

44. Rations. Recent experiments indicate that the needs of an average man would be fully met by a daily ration of 300 grams of carbohydrate, 50 grams of fat, and 50 grams of proteid.¹

This gives of nitrogenous material sufficient to cover an average daily loss of about 8 grams of nitrogen, and of carbonaceous fuel

¹ More or less variation from the above figures would of course be required to meet the needs of different ages, sexes, constitutions, and occupations. A discussion of such details cannot well be undertaken in this place. It should be said, however, that physiologists of the highest standing now admit that former estimates of the body's needs based upon records of the amount commonly consumed are too high for maximum efficiency. The standard which has been most generally adopted by American writers on nutrition calls for 125 grams of proteid, with sufficient fat and carbohydrate to yield a total of 3,500 Calories as the daily ration for a man at moderate muscular work. These figures were derived mainly from observation of what many healthy Americans actually eat, and are admittedly but rough approximations erring rather on the side of excess than deficiency. Good health is undoubtedly maintained on such an allowance, but this, of course, is no proof that eating somewhat less would not conduce to even better health and greater vigor. A very liberal allowance would be 400 grams of carbohydrate, and 100 grams each of fat and proteid for an average man.

enough to yield about 1,900 Calories or 805,600 kilogrammeters of energy, which has been found to be approximately the amount expended in 24 hours. If at first sight this seems to be an exaggerated estimate of the energy given out, it should be borne in mind that a very large share goes to keep up the warmth of the body; while of the remainder which is transformed into mechanical activity, a considerable proportion is used up in the muscular movements of the digestive organs, in breathing some 23,000 times, and in making more than 600,000 heart-beats, thus leaving only about one third of the whole available for locomotion and external work.

The main point which here concerns us regarding the make-up of a proper daily ration is the relative proportion of nutrients rather than their absolute amount. On the basis of the figures given, it may be stated roughly and in a general way that 1 part proteid, 1 part fat, and 6 parts carbohydrate, would ordinarily meet the daily needs of an average person, or in other words that one's food should be about $\frac{1}{8}$ proteid, $\frac{1}{8}$ fat and $\frac{3}{4}$ carbohydrate. In the rations recommended it is assumed that the foods chosen are easily digestible; for it is not what we eat but what we digest that nourishes us. For students and other brain-workers digestibility is of especial importance since their largely sedentary life leaves them but little surplus energy to spare for unnecessary digestive work.

A glance at the chemical chart (Fig. 120) will show that many vegetable foods do not have their nutritive constituents in anything like the standard proportion. This means that if a man were to obtain all his nourishment from such foods, he would have to eat too much of one ingredient (generally a carbohydrate) in order to get enough of another. When it is remembered that the dry substance of meats, fish, eggs, and other such foods of animal origin, consists almost entirely of proteids and fats, we see that here also there is a similar disproportion, although in another direction. Since, however, the constituents which are deficient on the one side, are in excess on the other, a mixed diet combining animal with vegetable foods, is most likely to be well-balanced.

From this point of view it is interesting to notice how generally the instincts of mankind have led them to prefer combinations of food wherein the components supplement

each other, and thus approximate to the chemical ideal. The appropriateness of combining bread and butter we have already had occasion to notice. Similarly in "crackers and cheese," "mush and milk," "eggs on toast," "meat and potatoes," and many other favorite combinations which will readily occur to the reader, we have the animal part poor in carbohydrate and rich in fat and proteid, supplemented by a vegetable food comparatively poor in these latter ingredients, but rich in sugar or starch. Sometimes, indeed, as in "pork and beans" we may have a highly valued combination in which not only the carbohydrate but also nearly all the proteid is furnished by the vegetable part, the animal portion being little else than fat; or, as in certain salads, we may have the fat represented almost entirely by olive-oil.

Those who prefer for any reason to abstain entirely from meat or other animal food may find adequate substitutes in various seed foods of highly nitrogenous composition, as the table clearly shows, provided the greater difficulty of digesting them does not offset their advantages, as is often the case with persons of sedentary habit. The recent military triumphs of the Japanese show in a striking way what hard physical work can be done on a diet consisting in very large part of rice. In most cases, however, it will be found that the vegetable foods are of value to us chiefly as contributing carbohydrates, and thereby supplying the most marked deficiency of foods derived from animals.

We have now an answer to our question regarding the special nutritive value of vegetable as opposed to animal foods. Both, as we know, yield us building material and fuel; and either the one or the other sort of food is used almost or quite exclusively by certain races of mankind, just as by herbivorous or carnivorous animals; and, furthermore, we have seen that whatever nourishes the animal kingdom, including ourselves, must be derived ultimately from plants. Nevertheless, the teachings of chemistry and the practice of the best-fed and most vigorous peoples agree in showing that while it may be desirable for us to depend mainly upon animal food for our nitrogenous materials and carbonaceous reserve, it is to vegetable foods that we must look to supply

TABULAR VIEW OF THE NATIVE HOME AND CULTURE-PERIOD OF IMPORTANT FOOD-PLANTS

Name	Native Home	Culture
Wheat (<i>Triticum sativum</i>)	Mesopotamia	Prehistoric
Barley (<i>Hordeum sativum</i>)	W. Asia	Prehistoric
Rice (<i>Oryza sativa</i>)	S. C. and S. E. Asia	Prehistoric
Oats (<i>Avena sativa</i>)	W. temperate Asia	Ancient
Rye (<i>Secale cereale</i>)	W. C. Asia (?)	Ancient
Maize or Indian Corn (<i>Zea Mays</i>)	Central America; N. South America	Prehistoric
Buckwheat (<i>Fagopyrum esculentum</i>)	Manchuria; C. Siberia	Modern
Chestnut (<i>Castanea sativa</i>)	S. Europe, N. W. Africa; North America (?)	Ancient
Filbert (<i>Corylus Avellana</i>)	Temperate Europe; Central Asia and N. Africa	Ancient
Walnut (<i>Juglans regia</i>)	E. temperate Europe; temp. Asia	Ancient
Butternut (<i>Juglans cinerea</i>)	E. United States	Recent
Hickory-nut (<i>Carya alba</i>)	Mississippi basin; E. United States	Recent
Pecan-nut (<i>Carya olivaeformis</i>)	W. Mississippi basin	Recent
Almond (<i>Prunus Amygdalus</i>)	Mediterranean basin; W. temp. Asia	Prehistoric
Peanut (<i>Arachis hypogaea</i>)	Brazil	Ancient
Brazil-nut (<i>Bertholletia excelsa</i>)	Amazon basin	Uncultivated
Cocunut (<i>Cocos nucifera</i>)	Colombia	Prehistoric
Kidney-bean (<i>Phaseolus vulgaris</i>)	South America	Prehistoric
Lima Bean (<i>Phaseolus lunatus</i>)	Brazil	Ancient
Common Pea (<i>Pisum sativum</i>)	S. W. Asia (?)	Ancient
Beet (<i>Beta vulgaris</i>)	Mediterranean basin; S. W. Asia	Ancient
Radish (<i>Raphanus sativus</i>)	Temperate Asia	Ancient
Turnip (<i>Brassica Rapa</i>)	Europe; W. Siberia (?)	Prehistoric (?)
Carrot (<i>Daucus Carota</i>)	C. and S. Europe	Ancient
Parsnip (<i>Pastinaca sativa</i>)	Central America	Ancient (?)
Sweet Potato (<i>Ipomoea Batatas</i>)	Andes of South America	Prehistoric
White Potato (<i>Solanum tuberosum</i>)	North America	Prehistoric
Jerusalem Artichoke (<i>Helianthus tuberosus</i>)	Persia; S. W. Asia (?)	Modern
Onion (<i>Allium Cepa</i>)	Europe; W. temperate Asia	Prehistoric
Asparagus (<i>Asparagus officinale</i>)	Europe	Ancient
Cabbage, Kale, etc. (<i>Brassica oleracea</i>)	Europe	Prehistoric (?)
Spinach (<i>Spinacia oleracea</i>)	Persia (?)	Ancient (?)

Lettuce (<i>Lactuca sativa</i>)	S. Europe; N. Africa; W. Asia	Ancient
Celery (<i>Apium graveolens</i>)	Temp. and S. Europe; N. Africa; W. Asia	Ancient
Cucumber (<i>Cucumis sativus</i>)	India	Prehistoric
Pumpkin, Gourd, etc. (<i>Cucurbita Pepo</i>)	N. South America to S. North America	Ancient
Winter Crook-neck Squash, etc. (<i>Cucurbita moschata</i>)	ditto	Ancient
Turban Squash, etc. (<i>Cucurbita maxima</i>)	ditto	Ancient
Tomato (<i>Lycopersicum esculentum</i>)	Peru	Ancient
Egg-plant (<i>Solanum Melongena</i>)	India	Prehistoric
Common Apple (<i>Pyrus Malus</i>)	Temperate Europe; S. W. Asia	Prehistoric
Common Pear (<i>Pyrus communis</i> , etc.)	ditto	Prehistoric
Common Quince (<i>Pyrus Cydonia</i>)	N. Persia; Asia Minor	Prehistoric
Peach (<i>Prunus Persica</i>)	China	Prehistoric
Common Plum (<i>Prunus domestica</i>)	N. Persia; Asia Minor	Ancient
Common Cherry (<i>Prunus avium</i>)	S. W. Asia	Ancient
Raspberries (<i>Rubus idaeus</i> , etc.)	North temperate regions	Modern
Garden Strawberry (<i>Fragaria chiloensis</i>)	Chili to California	Recent
European Grape (<i>Vitis vinifera</i>)	Mediterranean basin; W. temperate Asia	Prehistoric
Northern Fox-grape (<i>Vitis labrusca</i>)	N. E. United States	Recent
Garden Currant (<i>Ribes rubrum</i>)	N. temperate Asia and America	Modern
Muskmelon (<i>Cucumis Melo</i>)	India; S. W. Asia; tropical Africa	Ancient (?)
Watermelon (<i>Citrullus vulgaris</i>)	Tropical Africa	Prehistoric
Orange (<i>Citrus Aurantium</i>)	China; Cochlin China; E. India	Ancient
Lemon (<i>Citrus Medica</i> var. <i>Limon</i>)	India	Ancient
Banana (<i>Musa sapientum</i>)	S. Asia	Prehistoric
Date (<i>Phoenix dactylifera</i>)	S. W. Asia; N. Africa	Prehistoric
Common Fig (<i>Ficus Carica</i>)	N. Africa; E. Mediterranean region	Prehistoric
Pincapple (<i>Ananas sativus</i>)	West Indies; Central America	Ancient
Garden Rhubarb (<i>Rheum Rhaponticum</i>)	C. Asia	Modern
Olive (<i>Olea europaea</i>)	Asia Minor	Prehistoric
Sugar-cane (<i>Saccharum officinarum</i>)	Cochin China (?); S. W. China	Ancient
Cacao (<i>Theobroma Cacao</i>)	N. South America; Central America	Prehistoric
Sago-palm (<i>Metroxylon lane</i> , etc.)	Sunda and Molucca Islands	Modern (?)
Bitter Cassava (<i>Manihot utilisima</i>)	N. South America	Ancient
Carrageen (<i>Chondrus crispus</i>)	N. Atlantic coast of Europe and America	Uncultivated
Field Mushroom (<i>Agaricus campestris</i>)	North temperate region	Modern

us with energy which shall be immediately available at any moment for the work of life.

45. Food-plants in general. When considering the cereal grains, we found that important facts regarding their special value and present use were explained by the original geographical range and economic history of the species. We have now to conclude our study of food-plants by a comparison, from this point of view, of the other kinds with these, so that we may arrive at some further general ideas concerning them.

In the tabular view on pages 120-121 is given for each of the species already referred to, a brief statement of its native home and period of earliest cultivation, according to the opinion of recent authorities. Where these are doubtful an interrogation mark in parenthesis has been placed after the point in question.

46. The primitive centers of agriculture. We have already seen that the three grains, wheat, rice, and maize, which have played a supremely important part in the history of mankind, are each native to a region which is widely separated from the homes of the other two,—wheat being indigenous to Mesopotamia, rice to southeastern Asia, and maize to tropical America.

There is abundant evidence to show that it was in these regions, and in the lands immediately adjacent, that agriculture was first systematically pursued, and thus made possible the development of the great civilizations of antiquity.

It is certainly a fact of profound significance in human history that wheat, the most valuable of the grains, should be native to a region so near the junction of the three continents of the eastern hemisphere. Antiquarian scholars are of the opinion that from the fertile valley of the Tigris and Euphrates as a center, agriculture, with the civilization which it implies, extended to all the great peoples of Africa, Europe, and southern and western Asia. A more restricted civilization of later development and less importance was that which arose in the valley of the Hoangho and Yangtse-Kiang, and formed the beginning of the present Chinese Empire. Still later, although many centuries before the coming of Colum-

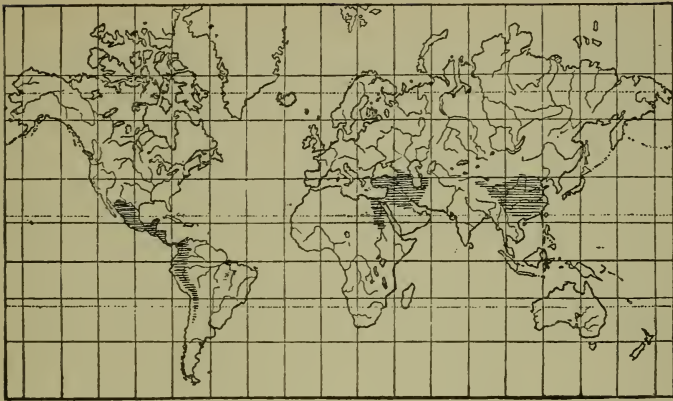


FIG. 121.—Map showing, by shaded areas, the three primitive centers of agriculture.

bus, an important agricultural center was established on the highlands of tropical America, and formed the basis of those remarkable civilizations of the Nahuas and Incas which the Spanish invaders overthrew.

These three primitive centers of agriculture (Fig. 121) are important for us to remember, since, when taken in connection with what is known of the native homes of cultivated plants, they help us to understand why certain species have been cultivated so much longer than others, and why they have come to be so important.

47. Relation between culture-period and native home.

It may be laid down as a rule that, other things being equal, the nearer the native home of a cultivated species is to the region forming one of the primitive centers of agriculture, the longer has that species been under cultivation; and, conversely, the more remote its native home from an agricultural center, the more recently has it come to be cultivated. This, indeed, is what we should expect in view of the probable beginnings of agriculture already considered in our study of the grains (section 17). Reference to the foregoing tabular view will afford some interesting confirmations of this general principle, which in turn will help us to an orderly (and there-

fore more easily remembered) arrangement of the facts in our minds.

Let us first consider the plants which were cultivated in ancient or in prehistoric times. As used in the tabular view the term *prehistoric* indicates, for plants of the Old World, a cultivation of over four thousand years, or in the New World of over two thousand years: *ancient*, means over two thousand years for Old World plants, or for New World species, a cultivation for more than five hundred years, or in some cases for over one thousand years. That is to say, the cultivation of the plants designated as prehistoric or ancient, preceded or was associated with the earliest civilizations of the hemisphere to which they belonged. With reference to their native homes we find that these plants fall readily into the following groups:—

I. *The Mediterranean Group*: plants of which the native range fell within, or was adjacent to, the region about the eastern end of the Mediterranean sea—the region wherein were developed the great Eurasian civilizations of antiquity, from which our own is principally derived. The plants included are wheat, barley, oats, rye, chestnut, filbert, walnut, almond, pea, beet, turnip, carrot, parsnip, onion, asparagus, cabbage, spinach, lettuce, celery, cucumber, egg-plant, apple, pear, quince, plum, common cherry, European grape, muskmelon, watermelon, lemon, banana, date, fig, and olive.

II. *The Oriental Group*: plants having their native home extending within or adjacent to the valleys of the Yangtse-Kiang and Hoangho, the seat of the most ancient of oriental civilizations. Under this head come rice, radish (?), peach, orange, and sugar-cane.

III. *The American Group*: plants indigenous to the highlands of tropical America or in lands adjacent thereto, that is, within or near the region occupied by the ancient civilizations of the Western Hemisphere. This group includes maize, peanut, coconut, kidney-bean, Lima bean, sweet potato, white potato, pumpkins and squashes, tomato, pineapple, cacao, and bitter cassava.

The plants which are indicated as of *modern* culture are believed not to have been cultivated by the ancients of the

Old World before the beginning of the Christian Era, or in the case of New World forms, to have been in cultivation, at most only a few centuries before Columbus discovered America. By plants of *recent* culture are to be understood such as have been introduced into agriculture since the discovery of America. A glance at the tabular view will show that none of these "modern" or "recent" plants are native to regions within or near to the primitive centers of agriculture. Some of these plants occur wild in both the Old and the New World; namely, raspberries, the garden currant, and the field mushroom. Those confined to the Old World are buckwheat, rhubarb, and sago: those of the New World are the butter-nut, hickory, pecan-nut, Jerusalem artichoke, garden strawberry, and northern fox-grape.

The Brazil-nut and "carrageen" are the only other food-plants included in our list. Of these the wild product so fully satisfies the demand, that the plants have never been cultivated, and their native homes are thus without special significance in the matter under consideration. It is, however, a confirmation of the principle above stated, that no plant of any considerable agricultural importance has been derived from regions which are remote from the primitive centers of agriculture, or cut off from early communication with them, even though the climate may be highly favorable. This is true of South Africa, Australia, and New Zealand.

The facts we have stated show plainly that the native home of a cultivated food-plant stands in close relation with its importance to mankind. That is to say, just as we found that a knowledge of the chemical composition of plant-foods enabled us to understand in what manner and how much they were used, so now it appears that to know the original geographical ranges of cultivated plants helps us to explain the time and area over which their use has extended. Of course, many other considerations often need to be taken into account in order satisfactorily to explain all that is known regarding the differences in extent and duration of such usefulness. What should be insisted upon is that geographical facts are of fundamental importance in discussing the economic history of food-plants.

48. The multiplication of varieties. Besides the effect which geographical range has exerted upon the spread and period of cultivation, the differences in the number of varieties that have arisen through human agency among cultivated plants may be attributed largely to the same important factor; since, as may be readily shown, the number of varieties in a given species is much influenced by the extent and duration of its culture. For, taken as a whole, the plants of ancient or prehistoric cultivation, as compared with those of modern or recent introduction, present a marked contrast in the greater number of different varieties which have come to be cultivated. Thus we have the common buckwheat, a "modern" plant, without any well-marked varieties, as against the "ancient" oats and rye, each with several varieties; and the "prehistoric" wheat, barley, rice, and maize, with scores or hundreds of varieties. If the comparison of the newer with the older be extended to nuts, vegetables, and fruits, a similar rule will be found to obtain; although it is true that more or less important exceptions will be encountered. These exceptions go to show that other elements besides time of culture would have to be taken into account in any attempt to explain fully why one cultivated species should have more or less varieties than another. But these other factors need not be here considered, since our present purpose is to point out that just as the area of use and the culture-period of a plant have been dependent largely upon the geographical relation of its native home to a primitive center of agriculture, so upon these factors, in their turn, have largely depended the number of varieties which have been artificially developed.

49. How varieties arise. Finally, a brief consideration of how such "artificial" varieties arise, will help us to understand why it is that long and widespread cultivation should tend to increase the number of these varieties. It will be remembered that when discussing what is meant by a "variety" as distinguished from a "species" (section 9) the statement was made that no two individual plants are exactly alike even though raised from seeds of the same parent. Sometimes the differences are very noticeable, and may af-

fect the plant as a whole, or any part, with reference to size, form, flavor, proportion of chemical constituents, time of appearance or ripening, hardness, and so on. Since in plants which are raised from seed, the special peculiarities of the parent are found to reappear in its offspring to a greater or less degree, it becomes possible for the farmer to preserve in future crops the peculiarities which please him, by taking his seeds from those individual plants which satisfy him best. Thus if early ripening is the quality desired, the earliest seeds are the ones chosen year after year, until in the course of several, or it may be many generations, furnishing earlier and earlier plants, the offspring finally produced from these selected seeds are found to ripen their product so much sooner than any other sorts that they are recognized as a new variety.

With many plants, such as strawberries, the seedlings are apt to vary so widely from the parent and from each other that the varieties are said to be "not true to seed": and in these cases it is the practice when once a seedling possessed of desirable qualities has been obtained, to propagate it by means of "cuttings" or similar detached portions of the parent plant instead of by seed.

Occasionally important differences appear among the individuals raised from cuttings or the like, and these may similarly form the basis of new varieties.

50. Artificial selection. Besides these principal ways in which cultivated varieties arise, there are some others the consideration of which must be deferred to a later chapter. What at present concerns us is the general truth that to a very large extent *human* or *artificial selection* exerts a controlling influence either upon the development or the perpetuation of varieties, and frequently upon both. Since the longer and more widespread the cultivation of a given plant has been, the more extensive and more varied must have been this influence, we should expect in general that the number of varieties of a cultivated plant would be proportional to the time and area of its cultivation; and this expectation we find to be justified by the facts.

CHAPTER IV

FLAVORING AND BEVERAGE PLANTS

51. Food-adjuncts. If by "food" we mean whatever is eaten to supply the building materials or energy needed by the body, it must follow that much of what is eaten is not food. Various substances, such as pepper, sage, caraway, horseradish, and vanilla, or beverages, like tea or wine, are taken with food for an entirely different purpose; namely, for their flavor or stimulating effect, and scarcely, if at all, as nutriment. Such materials may be distinguished, therefore, as *food-adjuncts*. The flavoring materials included under this head may be conveniently grouped as *spices*, *savory herbs*, *savory seeds*, *miscellaneous condiments*, and *essences*.

52. Spices are aromatic substances derived from hard or hardened parts of plants and used commonly in a pulverized state. For example, cloves (Fig. 122) are flower buds hardened by drying; allspice (Fig. 123), black pepper (Fig. 124), and red pepper (Figs. 125, 126) are dried berry-like fruits; mustard (Figs. 127, 128) is a seed; nutmeg (Fig. 129) is also a seed, and mace the fleshy network (dried) which surrounds it; cinnamon (Fig. 130) is the young bark of a tree; while ginger (Fig. 131) is a root-like stem which grows under ground.

The peculiar aroma of a spice is in general due to the presence of a volatile oil. *Volatile oils* bear a certain resemblance to the fixed oils, but differ from them in that they evaporate when exposed to the air, leave no greasy stain on paper, and all dissolve readily in cold alcohol. On account of the volatile nature of their flavoring constituent spices lose aroma when exposed to the air, especially after they have been ground.

Advantage is often taken of the ready evaporation of volatile oils to separate them by *distillation*. This process is essen-



FIG. 122.—Clove (*Jambosa Caryophyllus*, Myrtle Family, *Myrtaceæ*). *A*, branch bearing leaves, flower buds, and expanded flowers. *B*, a flower bud (such as form when dried the "cloves" of commerce) cut lengthwise to show the inner floral parts and the minute cavities near the surface containing the volatile "oil of cloves." *C*, petal showing oil cavities. *D*, stamen, *a*, front; *b*, back; *c*, side. *E*, pollen grain, *a* and *b*, different views, much magnified. *F*, fruit. *G*, seed cut across. *H*, embryo removed, side view. *J*, same with one seed-leaf removed, to show the seed-stem within. (Niedenzu.)—The plant is an exceptionally beautiful evergreen tree of pyramidal form 9–12 m. tall, with smooth grayish bark, thick glossy leaves containing numerous cavities like those of the flower, and filled with a similar fragrant oil which perfumes the air around; flowers and flower-buds rosy red, highly fragrant, produced through the year; fruit fleshy, grayish brown. Native home, Molucca Islands. In use from ancient times in the East.

tially as follows. The material to be distilled—say some clove spice—is heated in a vessel tightly closed except that from the top comes off a long tube which passes finally through cold water. The volatile oil, after being driven off as vapor by the heat, is changed back to a liquid upon being chilled. Sometimes the substance to be distilled is mixed with water, and in that case the volatile oil passes off with the steam. Both are condensed together, and flow from the chilled tube as a mixture of oil and water. These two substances readily separate, however, since neither will dissolve the other more than slightly, and the oil will either sink (as oil of cloves and a few others) or float.

Most volatile oils form films of peculiar form and often



FIG. 123.—Allspice (*Pimento officinalis*, Myrtle Family, *Myrtaceæ*). *G*, flowering branch. *F*, flower, lower part cut vertically. *H*, fruit, cut vertically, showing but one seed developed and this with a curved embryo which nearly fills the fruit, in the wall of which are numerous minute volatile oil cavities. (Niedenzu.)—Tree 10 m. or more in height with leathery aromatic leaves black-dotted beneath; flowers white; fruit fleshy, containing one or two seeds. Native to the West Indies and Central America, where they are often planted in rows called “pimento walks.”

beautiful color when a single drop is let fall upon a broad surface of perfectly clean water. The curious shapes assumed by the films are called *cohesion figures*.

The amount of volatile oil present in a spice is often exceedingly small, even when the aroma is strong. Ginger and black pepper have each about 1–2%; allspice 3–4.5%; nutmeg 2–8%. Cloves are remarkable in having 18% of volatile oil.

Oil of cloves is well known as a powerful drug, as is also the volatile oil of cinnamon. If taken in considerable quantities they act as poisons. The volatile oil of nutmeg is similarly poisonous if taken in more than small amounts. It is



FIG. 124.—Black Pepper (*Piper nigrum*, Pepper Family, *Piperaceæ*). *A*, fruiting branch, $\frac{1}{2}$. *B*, part of a spike showing three flowers, $\frac{1}{3}$. *C*, fruit, cut vertically to show the seed within, its minute embryo in copious seed-food, $\frac{1}{4}$. (Baillon.)—A woody vine, tall-climbing partly by means of roots; leaves evergreen; flowers minute; fruit red. Native home, India.



FIG. 125, I.—Red Pepper (*Capsicum annuum*, Nightshade Family, *Solanaceæ*). Fruiting plant, $\frac{1}{2}$. (Vilmorin.)—An annual or biennial herb of shrubby appearance; leaves smooth; flowers whitish; fruit juiceless, red, yellow, or violet, very various in form and color. Native home, South America.



FIG. 125, II.—Red Pepper. Fruiting branch of the "Chili pepper," $\frac{1}{3}$. (Vilmorin.)

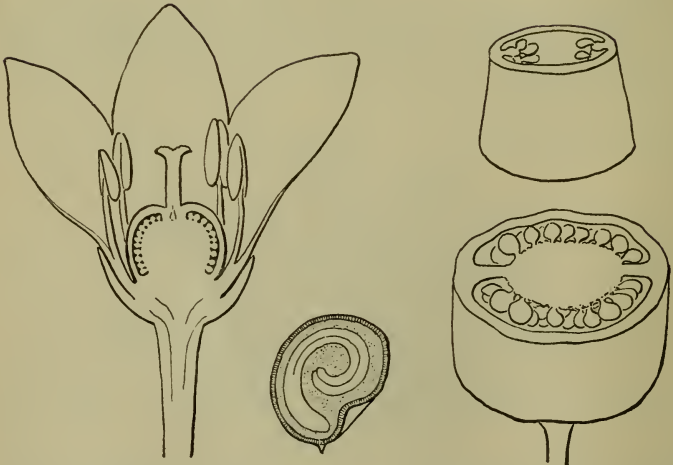


FIG. 126.—Red Pepper. Flower, cut vertically, enlarged. Fruit cut across near the top and near the base showing the single cavity above becoming two cavities below; about natural size. Seed, cut vertically, enlarged. (Redrawn from Berg and Schmidt.)



FIG. 127.—Black Mustard (*Brassica nigra*, Mustard Family, *Cruciferae*). Plant in flower and fruit, reduced. Pod. Seed, cut across showing the embryo with seed-leaves folded around the seed-stem, enlarged. (Britton and Brown.)—Annual, sometimes attaining a height of over 2 m.; leaves becoming smooth; flowers bright yellow; pods smooth; seeds dark brown. Native home, north temperate regions of Old World.

FIG. 128.—White Mustard (*Sinapis alba*, Mustard Family, *Cruciferae*). Stem with leaves. Top showing flowers and fruit, reduced. Pod, about natural size. (Britton and Brown.)—Plant an annual about 30-60 cm. tall; leaves hairy; flowers yellow; pod bristly; seeds light brown. Native home, temperate regions of Eurasia, and Northern Africa.

reported that the excessive use of this spice in India has resulted in dangerous, almost fatal consequences. In the small amounts necessary to give a mild and pleasant flavor to food all the spices in common use are not only wholesome to most persons but may be aids to digestion. Highly spiced food or strongly flavored confectionery, on the contrary, is apt to be unwholesome if much be eaten, and for young people positively injurious.

It is a curious fact that the volatile oil to which mixed mustard owes its aroma and pungency does not exist in the seed itself, but is formed, during the process of mixing, from a tasteless substance through the action of an enzyme. Like diastase this enzyme acts only in the presence of moisture, and is destroyed by a temperature of 100° C. Hence, if dry mustard be sifted into boiling water no pungency is developed.



FIG. 129.—Nutmeg (*Myristica fragrans*, Nutmeg Family, *Myristicaceae*). A, fruiting branch showing a ripe fruit with pulp opening to let out the mace-covered seed, $\frac{3}{8}$. B, stamens, enlarged. C, pistillate flower cut vertically, $\frac{3}{8}$. p, perianth; g, pistil containing a single ovule. D, seed surrounded by the net-like "mace" (a). E, same, cut vertically to show the aril (a), the seed-coat (s), the seed-food (looking as if it had been chewed and hence described as "ruminant"), and the embryo (e). (Luerssen, Baillon.)—The plant is a tree attaining 20 m. in height; leaves evergreen; flowers pale yellowish; fruit dull orange color, downy, the pulp splitting open at maturity; seed brown, enveloped by a blood-red aril which like the seed is aromatic. Native home, Moluccas.

Certain of the spices contain in addition to their volatile oil a considerable amount of fixed oil which may be readily expressed from them. Black mustard seeds contain 15–25% of fixed oil, white mustard 25–35%, and nutmeg 25–30%. In the manufacture of table mustard the fixed oil is commonly removed from the ground seeds by pressure. It resembles olive-oil, and is used in much the same ways.

While, as we have seen, the peculiar aroma of ginger and



FIG. 130, I.—Cinnamon (*Cinnamomum zeylanicum*, Laurel Family, *Lauraceæ*). Leafy branch with flowers and fruit. (Baillon.)—A tree attaining about 10 m. with thick rough bark, and young branches prettily speckled with dark green and light orange; leaves leathery, shining, evergreen; flowers whitish, of disagreeable odor; fruit a white-spotted purplish-brown berry. Although volatile oil is found in various parts of the plant no odor is perceptible at a short distance. Native home, Ceylon, India.



FIG. 130, II.—Cinnamon. Flower complete, and cut vertically. (Baillon.)
 FIG. 130, III.—Cinnamon. Floral diagram. (Baillon.)



FIG. 131.—Ginger (*Zingiber officinale*, Ginger Family, *Zingiberaceæ*). Plant showing roots, rootstock, leafy and flowering stems. Flower. Floral diagram. (Baillon.)—A biennial or perennial herb, about 60 cm. tall, with smooth leaves; flowers dingy yellow, aromatically fragrant; fruit a dry pod. Native home, India.

of black pepper is due to the volatile oils they contain, the hot biting taste of these spices depends to a considerable extent upon certain resinous substances which are present in small amount. A somewhat similar substance, of even greater power, causes the fiery taste of red pepper.

Spices have been of singular importance in the history of the world. In ancient times the spices of the East were among the most valued articles of commerce that were brought to the peoples about the Mediterranean. During the Middle Ages cloves, cinnamon, ginger, nutmeg, mace, and black pepper were considered to be as fitting presents for kings as gold and precious stones. Spices together with silk and jewels formed the principal merchandise of the caravans which at that time served as the chief means of communication between the nations of Asia and Europe. The great desire of European navigators to reach the Spice Islands of the East was the motive which led to many of the daring voyages of the 15th century, and impelled Columbus to brave the Western route that brought him unwittingly to the New World.

53. Savory herbs are such as have aromatic herbage which is used, either fresh or dried, to season or to garnish food. The most familiar examples are sage (Fig. 132, 133), thyme (Fig. 134), spearmint (Fig. 135), summer savory (Fig. 136), sweet marjoram (Fig. 137), and parsley (Fig. 138).

The flavor of each of these herbs depends upon the peculiar volatile oil which it contains, although only a very small amount of the oil is present. Thus there is but 0.2% in spearmint, 0.07% in thyme, and only 0.02% in sage. From this fact one can judge what powerful substances these volatile oils must be.

54. Savory seeds include cardamoms (Fig. 139), and the so-called "seeds" of caraway (Fig. 140), anise (Fig. 141), star anise (Fig. 142), coriander (Fig. 143), and celery (Fig. 79). Cardamoms are true seeds, while the others mentioned, although commonly spoken of as seeds, are in reality seed-like fruits. Savory seeds differ from spices in being commonly used whole rather than pulverized. They all agree in possessing a strong aromatic flavor which has led to their use in cookery. As with the savory herbs, their flavor depends upon the presence in each of a peculiar volatile oil, anise having 1-3%, cardamoms 4-5%, and caraway 6%.

55. Miscellaneous condiments. Horseradish and capers are food-adjuncts which differ so considerably from the others



FIG. 132.—Sage (*Salvia officinalis*, Mint Family, *Labiatae*). Plant in flower, $\frac{1}{2}$. Flower, $\frac{1}{4}$. (Vilmorin.)—A perennial herb with grayish, hairy, aromatic leaves; flowers blue; nutlets brown. Native home, Europe.

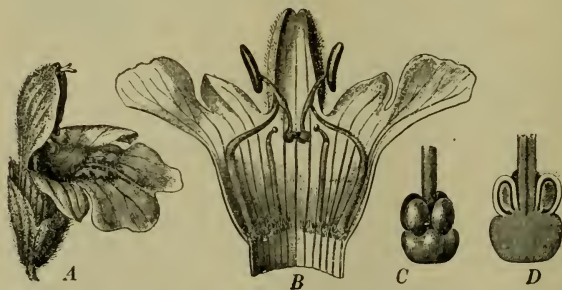


FIG. 133.—Sage. *A*, flower, enlarged. *B*, corolla split down the back and spread out to show the attachment and form of the four stamens; one pair is rudimentary, the others have curiously developed anthers, which are remarkably well adapted to secure the transfer of pollen by bees from one flower to another. *C*, base of pistil, showing the four young nutlets. *D*, the same cut vertically to show the single ovule in each section of the ovary. (Luerssen.)



FIG. 134.—Thyme (*Thymus vulgaris*, Mint Family, *Labiatae*). Plant in flower. (Briquet.)—A perennial, low and shrubby with whitish-hairy aromatic stems and leaves; flowers lilac or purplish; nutlets brownish. Native home, southern Europe.

FIG. 135.—Spearmint (*Mentha spicata*, Mint Family, *Labiatae*). Flowering top, reduced. Flower. Corolla, stamens, and pistil. (Britton and Brown.)—A smooth perennial herb; flowers pale purplish; nutlets brown. Native home, Europe.

FIG. 136.—Summer Savory (*Satureia hortensis*, Mint Family, *Labiatae*). Flowering top, reduced. Flower. Calyx. Nutlet, enlarged. (Britton and Brown.)—An annual with downy stems and leaves; flowers purple; nutlets brown; finely roughened. Native home, Europe.



FIG. 137.—Sweet Marjoram (*Origanum Majorana*, Mint Family, *Labiatae*). Flowering plant, $\frac{1}{2}$. Flowering branch, $\frac{1}{4}$. Flower cluster. (Vilmorin.)—A perennial herb becoming annual in cultivation, leaves downy; flowers whitish or purplish; nutlets brownish. Native home, Eurasia.



FIG. 138.—Parsley (*Petroselinum hortense*, Parsley Family, *Umbelliferae*). Flowering and fruiting top, reduced. Leaf, upper part. Fruit, side view, enlarged. One-half of fruit cut across to show the six volatile oil-tubes in the wall. (Britton and Brown.)—A mostly biennial herb, attaining 1 m. in height, smooth throughout; flowers greenish yellow; fruit brownish, aromatic. Native home, Mediterranean Region.



FIG. 139.—Cardamoms (*Elettaria cardamomum*, Ginger Family, *Zingiberaceae*). A, leaf. B, flowering branch. C, flower, $\frac{3}{4}$. D, same cut vertically. E, F, G, various forms of pods, $\frac{3}{4}$. H, seed, with covering, enlarged. J, K, seed, cut across and vertically, showing the seed-food (*p* and *e*) and the embryo (*em*). (Luerssen).—A perennial herb with leafy shoots 2–3 m. tall; leaves pale green; flowers whitish, purple-striped; pods pale yellowish; seeds brown. Native home, India to Java.

mentioned in this chapter as to require separate treatment. They agree in being used primarily for their sharp taste. Horseradish is the root of a familiar plant (Fig. 144) which owes its pungency to a minute amount of a volatile oil



Fig. 140.

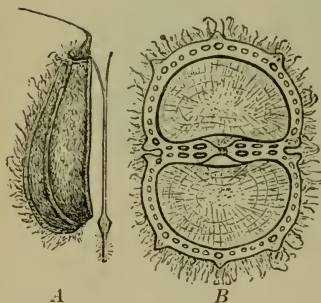


Fig. 141, II

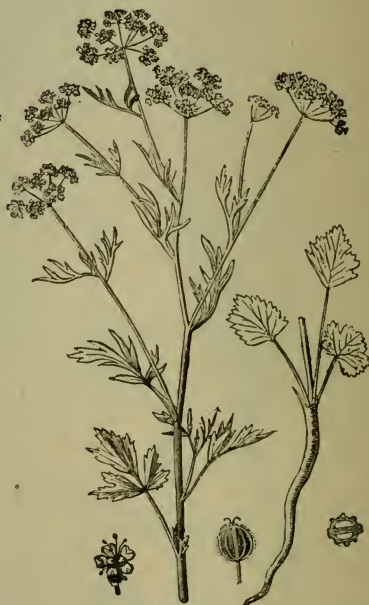


Fig. 141, I.

FIG. 140.—Caraway (*Carum Carui*, Parsley Family, *Umbelliferae*). Flowering and fruiting top, reduced. Leaf, showing broad attachment to the stem. Fruit, side view, enlarged. Same, cut across, showing six volatile oil-tubes in one-half. (Britton and Brown.)—A biennial or perennial herb, aromatic throughout, becoming 30–60 cm. tall; leaves smooth; flowers white; fruit brownish. Native home, Europe.

FIG. 141, I.—Anise (*Pimpinella Anisum*, Parsley Family, *Umbelliferae*). Fruiting top, and base of plant. Flower. Fruit, side view, and cut across. (Germain de St. Pierre.)—An annual about 40 cm. tall; smooth; flowers white; fruit downy, light greenish brown. Native home, Egypt and Asia Minor.

FIG. 141, II.—Anise Fruit. *A*, one-half of a fruit still attached to the slender stalk from which it finally separates. *B*, the two halves of the fruit cut across to show the numerous volatile oil-tubes in the wall. (Drude.)



FIG. 142.—Star Anise (*Illicium anisatum*, Magnolia Family, *Magnoliaceæ*). D, flower. C, fruit. B, a pod with seed cut vertically, showing its attachment to the axis (a), that of the seed to the pod (h), and the place of the minute embryo (m) in the copious seed-food. (Prantl.)—A, shrubby tree 6–8 m. tall; leaves evergreen, leathery, dotted with volatile oil-glands; flowers yellowish; fruit reddish brown. Native home, China and Japan.

FIG. 143, I.—Coriander (*Coriandrum sativum*, Parsley Family, *Umbelliferae*). Flowering and fruiting top. (Baillon.)—An annual growing about 1 m. tall, aromatic; flowers white; fruit yellowish brown. Native home, Southern Europe.



FIG. 143, II.—Coriander. Flower, enlarged. Same, cut vertically. (Baillon.)



FIG. 143, III.—Coriander. Fruit enlarged. Same, cut across. (Baillon.)



FIG. 144.—Horseradish (*Nasturtium Armoracia*, Mustard Family, *Cruciferae*). Plant in flower. (Baillon.)—A perennial about 60 cm. tall; leaves shining; flowers white, resembling those of mustard in form but smaller.



FIG. 145, I.—Caper-bush (*Capparis spinosa*, Caper Family, *Capparidaceæ*). Flowering branch showing spines, leaves, flower-buds (which form the condiment), flower, and young fruit. (Baillon.)—A straggling shrub about 1 m. tall; leaves glossy; flowers white with violet stamens; fruit dry. Native home, Mediterranean Region, and India.

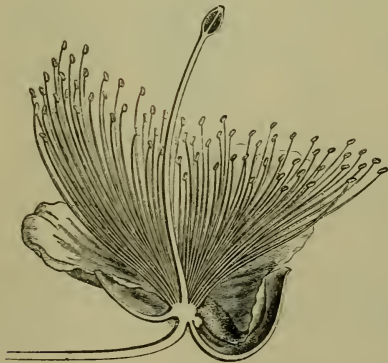


FIG. 145, II.—Caper-bush. Flower, cut vertically. The ovary is borne upon an elongated continuation of the flower-stalk. (Baillon.)

(0.06%) very similar to that of mustard if not identical with it. This oil is so powerful an irritant that it will raise blisters when applied to the skin. Capers are flower-buds of the caper-bush (Fig. 145), preserved in vinegar. They contain a peculiar acid, and a volatile oil similar to that found in garlic.

Under the head of miscellaneous condiments might also be included such sharp tasting vegetables as radish and onion which have already been considered.

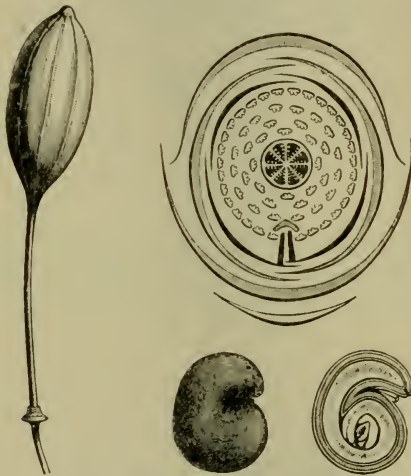


FIG. 145, III.—Caper-bush. Floral diagram. Pod. Seed, entire. Same, cut vertically. (Baillon.)

56. Essences are flavoring substances extracted from plants in various ways, often dissolved in water or alcohol, and always in liquid form. Peppermint obtained from the whole plant (Fig. 146), wintergreen from the leaves and fruit (Fig. 147), vanilla from the pods (Fig. 148 I), lemon from the rind of the fruit (Fig. 106), and rose from the petals (Fig. 148 II, 148 III) are familiar examples.

In peppermint, wintergreen, lemon, and rose the flavoring substance is a volatile oil. In vanilla it is a peculiar crystalline substance called *vanillin*, which curiously enough occurs

also in the sugar-beet root, and is manufactured artificially from oil of cloves and from pine wood. But these artificial products are inferior in flavor to the natural product extracted from the vanilla "bean."



FIG. 146, I.—Peppermint (*Mentha piperita*, Mint Family, *Labiatae*). Flowering top. (Baillon.)—A perennial herb, growing 1 m. tall, aromatic; leaves bearing numerous minute volatile oil glands; flowers pale purplish; nutlets seldom formed.

The oil of wintergreen is likewise manufactured artificially, but in this case the artificial product is indistinguishable from the natural one. Unlike most oils this sinks in water, being indeed the heaviest known of volatile oils. It is a



FIG. 146, II.—Peppermint. Flowers, enlarged about five times, showing the two sizes often present. (Baillon.)

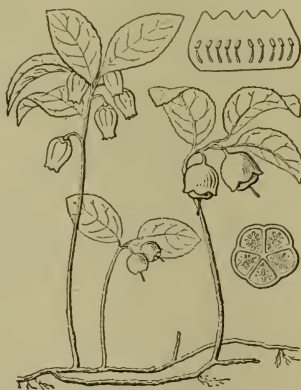


FIG. 147.—Wintergreen (*Gaultheria procumbens*, Heath Family, *Ericaceae*). Plant in flower and fruit, reduced. Corolla with attached stamens spread out. Pod, cut across. (Britton and Brown.)—An undershrub growing about 5–15 cm. tall; leaves evergreen; flowers white; fruit bright red, consisting of the fleshy aromatic calyx enclosing a dry pod. Native home, North America.



FIG. 148, I.—*Vanilla* (*Vanilla planifolia*, Orchid Family, *Orchidaceæ*.) Flowering branch, reduced in size, showing leaves and air-roots. *A*, lip of the flower, and along its back the "column" formed of style and stamens grown together. *B*, *C*, column, side view and front view, showing anthers (*a*) and rudimentary stamens (*s*). *D*, top of column, cut lengthwise through anthers. *E*, seed, much enlarged. (Berg and Schmidt.) A tall, climbing herb attaching itself to trees by means of air-roots; leaves thick; flowers yellow; fruit a pod ripening in two years, 16–30 cm. long, 7–10 mm. thick. Native home, Mexico.

powerfully acting substance possessing poisonous properties when used in more than very small amount.

57. Non-alcoholic beverages include those made from unfermented fruit juices, as, for example, lemonade; those made with syrups flavored with various essences, such as soda water mixtures; and those made by steeping the dried leaves of the tea-plant (Fig. 149), or boiling the prepared seeds of coffee (Fig. 150) or cacao (Fig. 115). The plants



FIG. 148, II.—French Rose (*Rosa gallica*, Rose Family, *Rosaceæ*). (Bailon.)—Shrub about 1.5 m. tall; leaves hairy beneath; flowers pink to crimson; fruit brick-red. Native home, Middle and Southern Europe, and Western Asia. This species crossed more or less with others is the principal source of "attar of roses."

yielding fruit juices or flavoring matters used for beverages, have already been sufficiently described for our present purpose.

Tea, coffee, and cacao agree in each containing a crystalline constituent which belongs to the class of substances known as *alkaloids*. That of tea has been called *theine*, of coffee *caffeine*, and of cacao *theobromine*. Theine and caffeine have been found by chemists to be identical, and to differ but slightly from theobromine.

Alkaloids differ chemically from oils and carbohydrates in containing nitrogen, and are distinguished from other



FIG. 148, III.—Scotch Rose (*Rosa spinosissima*, Rose Family, *Rosaceæ*). *A*, flowering branch. *B*, floral diagram. *C*, flower, cut vertically. *D*, pistil, with ovary cut open to show the single ovule within. *E*, fruit entire. *F*, same, cut vertically, to show the nutlets enclosed by the fleshy urn-like expansion of the flower-stalk which bears the other floral parts around its rim. (Baillon.)—Shrub about 1 m. tall, very prickly; flowers pink, white, or yellowish; fruit black. Native home, Eurasia. Although this species is not used for making attar it is here included as showing the floral structure more clearly than the more highly cultivated French rose.



FIG. 149, I.—Tea (*Thea sinensis*, Tea Family, *Theaceæ*). Flowering branch (Baillon.)—A shrub or tree growing 10 m. tall; leaves evergreen; flowers white, fragrant; fruit dry. Native home, China and India.

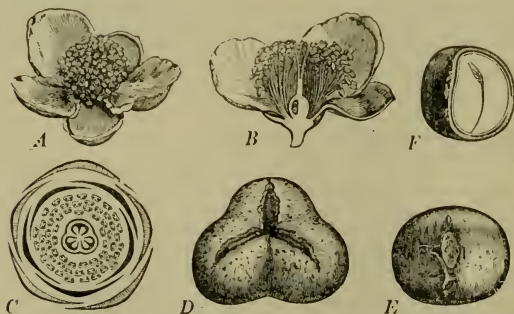


FIG. 149, II.—Tea. *A*, flower, entire. *B*, flower, cut vertically. *C*, floral diagram. *D*, fruit. *E*, seed, entire. *F*, same, cut vertically. (Baillon.)

nitrogenous substances by the fact that alkaloids form combinations with various acids in much the same way that ammonia and other alkalis will do. Among alkaloids are



FIG. 150.—Coffee (*Coffea arabica*, Madder Family, *Rubiaceae*). Plant, showing general form. Flower entire, and cut vertically. Fruiting branch. (Baillon.) A small tree growing about 6–8 m. tall; leaves evergreen, glossy; flowers creamy white, delicately fragrant; fruit a crimson berry. Native home, Abyssinia, Mozambique, and Angola.

included some of the most powerful poisons known and some of the most valuable medicines. Caffeine acts as a poison when taken in more than small amounts. Even in minute

quantity it often has upon the nervous system a marked effect, which may be injurious or beneficial according to circumstances. The coffee "bean" contains about 0.5-2% of caffeine, dried tea leaves about 1-3%. Theobromine, of which there is about 1.5% in the cacao seed, is found to be scarcely soluble in the fluids of the body, and thus exerts little if any effect.

The most active constituent of each of the three beverage plants we are considering is the aromatic substance to which its peculiar flavor is due. In black tea there is about .5%, and in green tea about 1% of a volatile oil which is mainly developed during the curing or preparation of the leaves for market. The commercial value of a tea depends mainly upon the flavor imparted by its volatile oil. This flavor is carefully tested by experts who are known as "tea-tasters," although curiously enough they smell rather than taste the samples submitted to them. Even so, the effect of the volatile oil upon the nervous system is so powerful as to cause giddiness and headache if the "tasting" be continued more than a few hours a day; and it is said that the most vigorous cannot pursue the work for many years without suffering serious consequences. The peculiar aroma of coffee is not found in the raw "bean" but is developed during the process of roasting; that of cacao arises during the process of fermentation which the seeds undergo before they are ready for market. In coffee the aromatic constituent is hardly as powerful as in tea, while in cacao it is so mild that vanilla and various spices are added as flavoring to make chocolate.

Finally, mention must be made of an astringent constituent belonging to the class of substances known as *tannins*. This forms about 10% of dry tea leaves. It is similar to the substance extracted from bark for tanning leather. Black ink is commonly made by combining tannin with a substance containing iron. When taken with food in considerable quantities this astringent interferes with digestion. Prolonged boiling extracts it in large amount from tea leaves; consequently tea so prepared is most injurious. Steeping for a short time, on the contrary, removes but little of the tannin, while it extracts practically all of the exhilarating and aromatic consti-

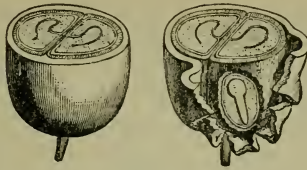


FIG. 150, I.—Coffee. Fruit, cut across to show the two seeds (the “coffee beans” of commerce). Same, with lower part removed to show position of the embryo. (Baillon.)

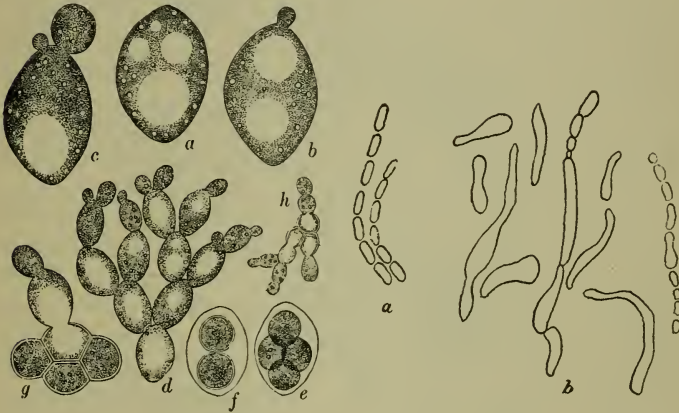


FIG. 151.—Yeast (*Saccharomyces cerevisiae*, Yeast Family, *Saccharomycetaceæ*). *a*, a single beer-yeast plant; greatly magnified; *b*, same sending forth a bud-like protrusion; *c*, same with bud more developed and a second one appearing; *d*, a colony produced by such budding without separation; *e*, a yeast plant divided into four within the enveloping wall; *f*, a plant dividing into two, each with a wall of its own, and thus able to resist adverse conditions for a long while; *g*, a cluster of four such resistant plants, one of which upon the return of favorable conditions is producing a budding colony; *h*, such a colony farther advanced. (Luerssen, Reese.)—Beer yeast, the form here shown—used not only for beer but for bread—is not found wild; but the closely similar wine yeast occurs regularly upon the surface of grapes and (in its resistant form in the soil of vineyards) so does not have to be added to the grape “must” in making wine. The plant is very pale brown or colorless.

FIG. 152.—Vinegar Ferment (*Bacterium aceti*, Rod-germ Family, *Bacteriaceæ*). *a*, ordinary form of plant, grouped into chain-like colonies, ^{1000x}; *b*, an irregular form occurring under very adverse conditions. (Migula.)—The plants are colorless, and form about themselves a mass of jelly which constitutes the “mother” of vinegar.

uents. A small amount of a tannin-like substance is found also in coffee, and in cacao. Cacao, although used as a beverage, is so nutritious that it should be regarded rather as a food than as a food-adjunct.

58. Alcoholic beverages and stimulants in general. Alcoholic beverages are either fermented or distilled.

Fermented beverages include beers or malt liquors, and wines. Beer, as already stated (sections 19 and 29), is made by fermenting a sweet liquid obtained chiefly from barley malt. In much the same way that the diastase in the sprouting grain changes the starch into sugar, an enzyme contained in the yeast which is added to the sweet malt liquid, changes its sugar into alcohol and the gas known as carbon dioxid. Yeast is a plant consisting of exceedingly minute bodies of the form shown in Fig. 151. These multiply very rapidly under favorable conditions of food supply and temperature. Hence a small amount of yeast added to a vat full of malt liquid soon becomes a considerable quantity. When the fermentation is well under way the liquid is put into air-tight kegs or bottles so that the gas produced may be retained. When the beer is poured out this gas rises to the surface and forms bubbles of foam. After the sugar is converted into alcohol and carbon dioxid gas, the alcohol may be turned into acetic acid (the acid of vinegar) by a plant similar to yeast (see Fig. 152) unless its action is prevented. This is accomplished mainly by the addition of hops (Fig. 153) which at the same time impart their peculiar flavor to the beer and give it a bitter taste. The preservative action as well as the flavor of the hops is due chiefly to a volatile oil of which the fruit contains about 1%. The stupefying effect of beer is also believed to be due in large part to the flavoring materials derived from the hops. Malt liquors contain about 4-10% of alcohol.

The process of fermentation may be observed readily by adding yeast to water sweetened with molasses and keeping the mixture for some hours in a warm place. Bubbles of carbon dioxid are given off abundantly and a faint smell of alcohol may be detected. If some of the fermenting mixture be boiled in a flask to kill the yeast, the neck of the flask being plugged with a wad of cotton wool (which will permit the

access of only pure air to the mixture), the fermentation will be stopped and the liquid will keep indefinitely. The killing or exclusion of yeasts and similar agents of decomposition from foods to be preserved is the secret of the process of "canning" or "tinning" meats, vegetables, and fruits.



FIG. 153.—Hops (*Humulus Lupulus*, Mulberry Family, *Moracæ*). 1, branch bearing staminate flower-cluster. 2, branch bearing pistillate flower-clusters, and leaves. 3, pistillate flower-cluster. 4, two pistillate flowers and their bract. 5, ripe cone-like fruit-cluster. 6, a single fruit. (Wossidlo.)—A twining perennial herb with rough stems, growing 10 m. tall; leaves rough, hairy; flowers, greenish; fruit, straw-colored. Native home, Europe, Asia, and North America.

Wine is made by expressing the juice of grapes or other fruit and allowing yeast (which occurs naturally on the surface of the fruit) to produce alcoholic-fermentation of the

sugar contained in the liquid. When this process has gone far enough the fermentation is stopped, generally by heating to kill the yeast and any vinegar ferment that may be present,



FIG. 154.—Juniper (*Juniperus communis*, Pine Family, *Pinaceæ*). Staminate flowering branch, $\frac{3}{4}$. Pistillate fruiting branch, $\frac{3}{4}$; *a*, staminate flower, enlarged; *b*, stamen, back view; *c*, same, lower view; *d*, two pollen grains; *e*, pistillate shoot; *f*, three ovules, and their scales, the front one bent down; *g*, same cut across; *h*, fruit, cut across, showing the three seeds in the aromatic pulp formed of the three scales grown together; *i*, seed, entire; *k*, same, cut lengthwise to show embryo and seed-food. (Berg and Schmidt).—Shrub with spreading branches, or a tree growing about 12 m. tall; leaves spiny-pointed, whitish above; flowers yellowish; fruit dark blue with a bloom. Native home, north temperate regions.

and the wine is kept in tightly closed vessels to exclude the air and all ferments. By standing thus, wines develop with age minute amounts of certain flavoring substances, mostly

volatile oils, or ethers upon which depends chiefly the value of the wine, and probably also to a considerable extent the diverse effects upon the human system of different wines of similar alcoholic strength. The proportion of alcohol in wines is about 10–25%. Strong wines have alcohol added after fermentation. Champagne is a wine containing a large amount of carbon dioxid gas.

Distilled alcoholic beverages include spirituous liquors, such as brandy, rum, whisky, and gin; and liqueurs such as absinthe. Spirituous liquors contain about 40–60% of alcohol. Brandy is made by distilling wine. Rum is distilled from molasses. Whisky and gin are both distilled from a sort of beer made from grain, generally maize, rye, or wheat. Gin differs from whisky in being flavored with the volatile oil of juniper berries (Fig. 154) and other aromatics. These flavoring matters act powerfully upon the system, and make gin an especially dangerous liquor.

Liqueurs are sweetened spirituous liquors containing peculiar flavoring matters, usually volatile oils. In the case of absinthe the flavor is due chiefly to the volatile oil of wormwood (Fig. 155). This is a very powerful drug, which, in comparatively small amount, produces violent convulsions. Absinthe acts similarly and is justly regarded as the most pernicious of all alcoholic beverages.

All food-adjuvants, as we have seen, are taken with food primarily for their stimulating effect on the system. This effect is shown by more copious flow of the digestive juices, and by generally increased activity of the digestive organs. The very savor of food as we say "makes the mouth water." This is not because stimulating substances bring any considerable amount of energy into the body, but because they set free energy which the body has derived from nutritive substances and stored ready for use. Yet, since energy must be expended in digestion, a certain degree of stimulation may be helpful or even necessary. On the other hand, since the release of too much energy works harm, overstimulation is sure to prove injurious; and the danger of overstimulating is the greater from the fact that stimulation is pleasurable even when carried beyond the point of safety. This point

of safety varies widely with different individuals, and in the same individual under different conditions of health and sickness, and at different ages. Stimulants, therefore, may be helpful or harmful according to the amount used and the bodily condition of the individual. Overstimulation is always followed by harmful reaction resulting in more or less exhaustion or derangement of the system which may lead to grave consequences, especially in the case of young people.



FIG. 155.—Wormwood (*Artemisia Absinthium*, Sunflower Family, *Compositæ*). Plant in flower. Leaf and flower-clusters. Outer floret, ♀, Inner floret, ♂. (Baillon.)—A perennial herb, about 1 m. tall; leaves white-silky; flowers greenish; fruit grayish. Native home, Europe.

All food which has an agreeable flavor is more or less stimulating. In vegetable foods as we know the flavor naturally belonging to the plant or developed by heat is often strongly marked and characteristic, as, for example, in turnip, parsnip, celery, cucumber, muskmelon, pineapple, peanut, and pop-corn; and this flavor is due commonly to the presence of a volatile oil, the amount of which, however, is so small that

overstimulation is not to be feared. On the contrary, the flavoring matter by its presence greatly helps the digestion of the nutritive substances in the food. These natural flavors of foods, as we may call them, are generally all that persons in good health require. Artificial flavors, as we may call the various aromatics added to food, may occasionally be used advantageously and with comparative safety to impart to insipid nutrients mild flavors similar to those of natural foods. Strongly stimulating beverages, however, such as tea, coffee, and alcoholic drinks are seldom necessary to health, and are often injurious to adults, while to young people they are frequently a source of lasting evils. The use of substances which act so powerfully on the nervous system should be regulated by the advice of one's physician.

The effect of artificial stimulants on the human body is much like that of a whip on a horse. We know it to be foolish and cruel to whip a colt, and it may ruin his chances of ever becoming a good horse. It is almost as foolish and may be dangerous to whip a willing horse, although a sluggish horse may need a touch of the whip occasionally to keep him up to his work; and emergencies sometimes arise when a horse must be vigorously whipped to obtain his utmost speed at any risk. So to a healthy child artificial stimulants other than the mildest are unquestionably pernicious; to a healthy adult they are unnecessary and generally harmful; to persons out of health, sometimes beneficial and sometimes injurious; while on rare occasions they are regarded by many physicians as a necessity for saving life. In such times of special need, however, stimulants are useful to a person only in so far as he has not previously by overuse deprived them of their power. It often happens that an intemperate person dies when a person who had always been temperate would be saved by the stimulant upon which the physician is depending.

CHAPTER V

MEDICINAL AND POISONOUS PLANTS

59. Medicines and poisons. It is an old saying that medicines are substances which make the sick well and the well sick. This saying expresses in a way the truth that among medicines are included some of the most powerful poisons known. In fact, most medicines are poisonous, and most poisons medicinal. Experience has shown also that when a fatal dose of a certain poison has been taken, life may sometimes be saved by giving, as an antidote, some other poison in quantity sufficient even to cause death if the first poison had not already been taken.

From these facts it appears that no line of separation can be drawn between medicines and poisons. By a *medicine* we mean any substance used for the cure or relief of disease; and by a *poison*, any substance capable of injuring the body by other than mechanical means so as to cause death or serious harm if taken in undue quantity. Even too much food may be harmful or perhaps fatal, and the same is true of the most harmless medicines, but in these cases the bad effect is so largely the mechanical result of excessive quantity that we do not say poisoning has taken place. Foods are sometimes used as medicines, as, for example, olive-oil and Irish moss. The same is true of food-adjuncts in general, and, as we have already seen, many of these if taken in more than small amount are poisonous. We may recall also the fact that certain foods, such as tapioca, are obtained from plants which contain deadly poisons. Similarly the tubers of the white potato when young or when green in color, contain a powerful poison. Thus it is plain, that edible, medicinal, and poisonous plants must not be thought of as entirely separate and distinct classes, but merely as groups made for practical convenience.

The number of plants which have been used medicinally is enormous. Many of these, however, have been found to be either so dangerous in their action or of so little value that they are now used if at all only by the ignorant. Nevertheless, the number of those still used in scientific medicine is rather large. Numerous also are the poisonous plants known to botanists. Plainly, in the present chapter only a small proportion of these can be considered. The ones chosen are typical examples of those classes of medicinal and poisonous plants about which it is most important for a beginner to know. The medicinal plants are thus divided: (a) those yielding *non-poisonous drugs*, and (b) those yielding *poisonous drugs*. Poisonous plants are grouped into (a) those *dangerous to eat* and (b) those *dangerous to handle*.

60. Non-poisonous drugs include various substances which may be more or less nutritious, stimulating, or irritating, or may be useful for their soothing influence upon inflamed surfaces, or for some other mild healing virtue. Some of the substances here included under this heading may perhaps under extraordinary conditions act as poisons; what is meant by calling them non-poisonous is that much larger quantities than are generally used would be required to produce any harmful effects under all ordinary circumstances.

The chemical compounds upon which their value mainly depends include mucilaginous or gelatinous constituents, astringents, fixed oils, and volatile oils. Various other substances of more or less importance occur in certain of the non-poisonous drugs but these need not concern us here, especially as many of them are not yet well understood by chemists.

Mucilaginous or gelatinous substances form the most important part of the drugs known as gum arabic, tragacanth, marshmallow, flaxseed, quince seed, elm bark, sassafras pith, Iceland moss, Irish moss or carrageen, and licorice root. Gum arabic is an exudation from the trunk and branches of the gum arabic tree (Fig. 156) and related species. When pure the gum consists essentially of a carbohydrate called arabin, the formula of which is $C_{12}H_{22}O_{11}$, the same as that of cane-sugar. Prolonged boiling with dilute acid converts

arabin into a kind of glucose sugar known as arabinose. A similar substance yielding arabinose forms about half of gum tragacanth, about one-third of the gum being a carbohydrate called tragacanthin ($C_6H_{10}O_5$) which differs from arabin in being insoluble, although it absorbs water and swells exceedingly. Tragacanth is an exudation from wounds made in the stems of the gum-bearing tragacanth shrub



FIG. 156.—Gum Arabic Tree (*Acacia Senegal*, Pulse Family, *Leguminosæ*). A, flowering branch. B, flower. C, pod, half, showing seeds. D, seed, cut between the seed-leaves to show seed-stem and seed-bud. E, seed, cut across. (Taubert.)—A tree about 6 m. tall; bark gray; leaves grayish; flowers yellow; pod yellowish. Native home, tropical Africa. This tree yields the best gum; several other species produce an inferior quality.

(Fig. 157) and related species. The root of the marshmallow (Fig. 158) contains about one-third of its weight of a mucilage, having the same formula as tragacanthin. The same formula is given also to the mucilage yielded copiously by the outer coat of the flaxseed (Fig. 279). A similar mucilage but with the formula $C_{18}H_{28}O_{14}$ is obtained in large quantities from the outer coat of quince seed (Fig. 93). The slipperiness of

the inner bark of our slippery elm and the closely similar English elm (Fig. 159) is due to the large amount of a mucilaginous carbohydrate which it contains. The pith of sassafras (Fig. 160) yields to hot water a similar mucilage.



FIG. 157.—Tragacanth Shrub (*Astragalus gummifer*, Pulse Family, *Leguminosæ*). *A*, flowering branch. *B*, leaf from which the leaflets have disappeared, leaving only the stiff thorn-like "rachis" and the toothed "stipules." *C*, flower. (Taubert.)—A shrub 30–60 cm. tall; flowers yellow; pod, small, one-seeded. Native home, Southwestern Asia.

The jelly-like constituent of the lichen called Iceland moss (Fig. 161) is a carbohydrate known as lichenin or lichen-starch ($C_{12}H_{20}O_{10}$). It is insoluble in cold water but becomes dissolved upon boiling, and forms a jelly when cooled. Lichenin is almost if not quite identical with the gelatinous constituent of carrageen or Irish moss (Fig. 118) which we have already studied. The chief remedial constituent found

in the root of the licorice plant (Fig. 162) is a bitter-sweet, yellowish compound forming a jelly with water.

The *astringents* present in vegetable drugs, or extracted from them, are various tannins, significant properties of which have already been described in section 57. As examples of drugs used more or less for their astringency may



FIG. 158.—Marshmallow (*Althæa officinalis*, Mallow Family, *Malvaceæ*). Flowering top. (Baillon.)—A perennial herb about 1 m. tall, downy throughout; leaves pale purplish; fruit dry. Native home, Eastern Europe.

here be mentioned the root of rhubarb (Fig. 163) and the bark and leaves of witch-hazel (Fig. 164), from both of which fluid extracts and other medicinal preparations are obtained.

As examples of *fixed oils* much used in medicine for their lubricating or soothing effect, there are in common use the

expressed oil of almond, olive-oil, and the oil of cacao seed known as cacao butter, already studied for their food value (in sections 33 and 39); and to these may now be added castor-oil and the oily drug lycopodium. Castor-oil, obtained from the seeds of the castor-oil plant (Fig. 165), is believed not to be taken up by the digestive tract as a food, but to owe its

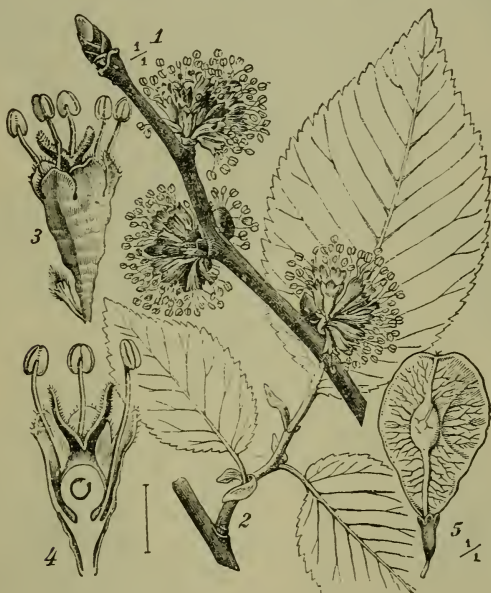


FIG. 159.—English Elm (*Ulmus campestris*, Elm Family, *Ulmaceæ*). 1, flowering twig. 2, leafy shoot. 3, flower, entire. 4, same, cut vertically. 5, fruit. (Wossidlo.)—Tree attaining 30 m.; leaves becoming smooth; flowers greenish or brownish; fruit yellowish. Native home, Eurasia and Northern Africa.

great medicinal value to its lubricant and mildly irritant properties. The sulphur-yellow powder known as lycopodium, obtained from the club moss (Fig. 166), consists of minute bodies called *spores* by means of which the plant perpetuates its kind. Each spore contains nearly 50% of a fixed oil, and the surface is remarkably repellent of water. A teaspoonful of the spores thrown into a bowl of water will

float as a thin layer, and one's fingers may now be repeatedly thrust into the water and withdrawn without becoming wet in the least. Its waterproof nature gives lycopodium some value as an application to moist, inflamed surfaces of the body, and makes the spores useful also as a covering for



FIG. 160.—Sassafras (*Sassafras officinale*, Laurel Family, *Lauraceæ*). *A*, flowering twig of staminate plant. *B*, branch bearing leaves and fruit. *C*, staminate flower. *D*, pistillate flower. *E*, stamen, showing nectar glands at base of filament, and anther opening by up-turned valves. *F*, pistil, cut vertically. (Berg and Schmidt.)—Tree growing 20–30 m. tall; young branches green; leaves becoming smooth, aromatic; flowers yellow; fruit blue on red stalks. Native home, Eastern North America.

moist pills to prevent their sticking together. The large amount of fixed oil contained in the spores renders them, moreover, very inflammable, and has led to their use in the manufacture of fireworks, and also as a means of producing artificial lightning in private theatricals.



FIG. 161.—Iceland Moss (*Cetraria islandica*, Shield-lichen Family, *Parmeliaceæ*). Plant, natural size, growing nearly erect from dry earth. (Luerssen.)—Upper surface brownish or olive, pale below, often red-stained at the base; "fruit" forming chestnut-colored patches on the uppermost lobes. Native home, North America and Eurasia.



FIG. 162.—Licorice (*Glycyrrhiza glabra*, Pulse Family, *Leguminosæ*). Branch in leaf, flower, and fruit. (Baillon.)—Perennial herb growing about 1 m. or more in height; leaves pale green; flowers violet or purple resembling those of a pea; fruit smooth. Native home, Mediterranean Region.

Volatile oils form the most important constituent of a number of non-poisonous drugs which we have already studied in the last chapter as food-adjuncts; namely, lemon, caraway, anise, cardamoms, spearmint, sage, ginger, and



FIG. 163.—Medicinal Rhubarb (*Rheum officinale*, Buckwheat Family, *Polygonaceæ*). Plant in flower. *A*, flower, entire, enlarged. *B*, same, cut vertically. *C*, pistil; *d*, nectar glands. (Baillon.)—Perennial herb growing 2 m. tall; leaves hairy; flowers greenish; fruit, dry, reddish. Native home, Central Asia.

hops. The drugs calamus, asafetida, and saffron are the only others of this class which call for mention here. Calamus consists of the underground stem of the sweet-flag (Fig. 167). It contains about 1% of a volatile oil to which it owes



FIG. 164, I.—Witch-hazel. (*Hamamelis virginica*, Witch-hazel Family, *Hamamelidaceæ*). Flowering branch. (Baillon.)—Shrub or tree growing about 8 m. tall; leaves downy on veins beneath; flowers yellow, appearing late in the fall; fruit pale brownish; seeds black, shot forcibly from the pods when ripe. Native home, Eastern North America.

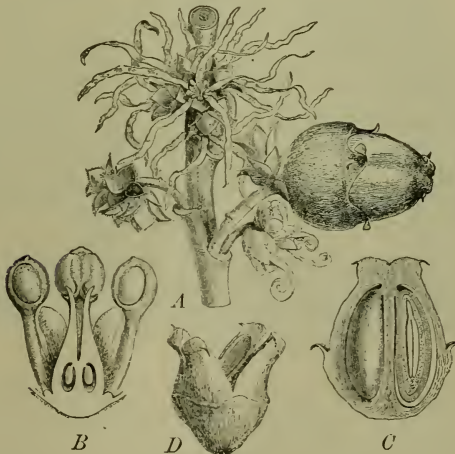


FIG. 164, II.—Witch-hazel. A, flowers and fruit. B, flower cut vertically and with petals removed. C, fruit, unripe, cut vertically to show the seeds. D, ripe fruit. (Baillon.)

its pleasant aromatic qualities. Asafetida is a gummy substance obtained by drying the milky juice which exudes from the cut roots of the asafetida plant (Fig. 168 I) and related



FIG. 165, I.—Castor-oil Plant (*Ricinus communis*, Spurge Family, *Euphorbiaceæ*). Plant in flower and fruit. (Baillon.)—A tree-like herb, growing over 12 m. tall in the tropics; leaves and stem often reddish; flowers greenish; fruit smooth or prickly, splitting apart violently and so hurling the seeds to a considerable distance. Native home, probably tropical Africa or India.

species. Many people regard it when in full strength as about the most ill-smelling of drugs. It is a curious fact,

however, that in spite of its odor asafetida is highly valued as a condiment and extensively used for that purpose in Persia and other oriental countries. Nor is its use as a food-adjunct confined to eastern peoples. Many of us have often relished it in gravies and sauces, little suspecting that the

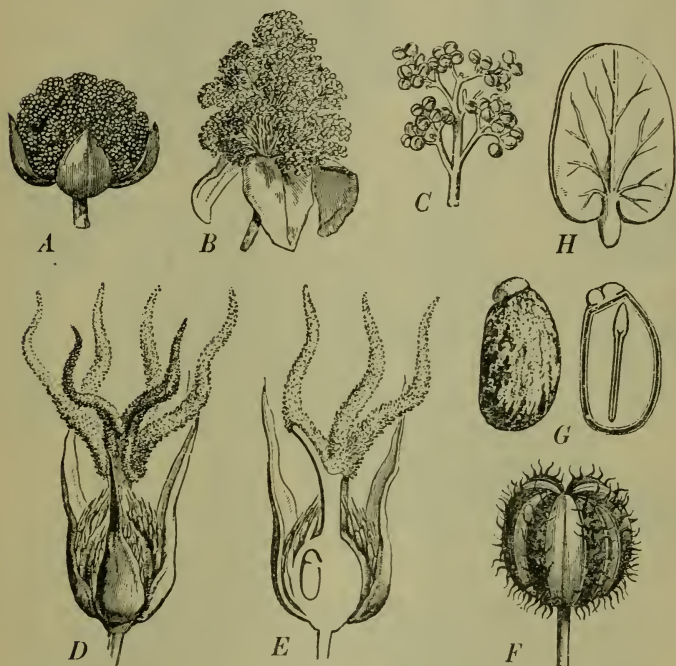


FIG. 165, II.—Castor-oil Plant. *A*, staminate flower, just opening. *B*, same, fully open. *C*, branching stamens. *D*, pistillate flower, entire. *E*, same, cut vertically. *F*, fruit. *G*, seed, entire, and cut vertically. *H*, Embryo. (Baillon.)

flavor we were enjoying was due to a substance which is ordinarily most repulsive. The volatile oil upon which the odor and flavor of asafetida depend is chemically very similar to the oil of mustard, which as we know is pleasant to eat only in minute quantity. Indeed it is almost always true of food-adjuncts that "a little more than a little is by



FIG. 166.—Club-moss (*Lycopodium clavatum*, Club-moss Family, *Lycopodiaceæ*). 1, plant in "fruit." 2, spore-case, with the scale-like leaf which bears it. 3, spores, highly magnified. (Wossidlo.)—A creeping evergreen with somewhat moss-like leaves, and stem attaining a length of 1 m. or more; spore-bearing cones yellowish; spores sulphur-yellow. Native home, Northern America and Eurasia.

FIG. 167.—Sweet-flag (*Acorus Calamus*, Arum Family, *Araceæ*). A, plant in flower, much reduced. B, flower-cluster, natural size. C, flower, with perianth spread, $\frac{1}{2}$. D, floral diagram. E, ovary, cut vertically, $\frac{1}{2}$. F, ovule, much enlarged. (Luerssen.)—Perennial herb about 60 cm. tall; flowers greenish; fruit fleshy, reddish. Native to North America and Europe.

much too much." The opposite effect upon us of the same substance according as it acts in larger or smaller amount is well illustrated also in very many perfumes, and, as we shall



FIG. 168, I.—Asafetida Plant (*Ferula assa-fatida*, Parsley Family, *Umbelliferae*). Plant in flower, and part of leaf. (Baillon.)—Perennial herb growing about 2-3 m. tall, with a milky juice of fetid odor; leaves bluish green; flowers pale yellow; fruit reddish brown. Native home, Southwestern Asia.

more fully show, in a large proportion of medicines. Saffron consists of the dried stigmas of the saffron crocus (Fig. 168 II). It contains about 7% of a volatile oil of agreeable flavor, and a small amount of a deep yellow coloring matter which

however is of remarkable strength. One part of saffron shaken up with 100,000 parts of water gives a distinct yellow tinge. The principal use of the drug is to impart an attractive color and flavor to medicinal preparations. Most of the



FIG. 168, II.—Saffron Crocus (*Crocus sativus*, Iris Family, *Iridaceæ*). Plant in flower. Same, cut vertically, Style and stigmas. (Baillon).—Perennial herb about 15–25 cm. tall; leaves hairy on the edge; flowers lilac or white, with style-branches bright red, appearing in autumn; fruit dry. Native home, Asia Minor.

volatile oils above mentioned are used in medicine mainly for their stimulating effect or for imparting a pleasant flavor to other drugs.

61. Poisonous drugs comprise substances which depend

for their power upon certain volatile oils, camphors, resins, alkaloids, and some other classes of compounds which we shall not need to discuss.

A considerable number of the medicinal plants containing *poisonous volatile oils* we have already considered under the head of food-adjuncts. Cinnamon, wintergreen, clove, peppermint, spearmint, thyme, nutmeg, horseradish, mustard, allspice, and black pepper, will be recalled as examples of more or less powerful poisons which nevertheless in very small amount are grateful and often beneficial additions to our food. They are used in medicine partly for their attractive flavor, partly for their stimulating or irritating effect, and partly as antiseptics.¹

Camphors are volatile substances, which form crystals at ordinary temperatures. They bear much the same relation to volatile oils that fats do to fixed oils, that is to say they are volatile oils of comparatively high melting-point. By camphor is most commonly understood the gum-like drug obtained by distillation from the wood of the camphor-tree (Fig. 169). This drug is conveniently distinguished as laurel camphor or laurinol. Its chemical formula is $C_{10}H_{16}O$. The volatile nature of laurinol is prettily exhibited by gently heating a little piece in the bottom of a glass tube held obliquely so that the vapor as it rises will come in contact with the cool glass at the upper end. Here will be formed snow-like crystals as the vapor condenses. Similar crystals may be noticed at the upper part of bottles in which camphor has been kept for some time. If small bits of laurel camphor be placed upon the surface of pure water contained in a perfectly clean vessel the fragments will float and display curious animal-like movements due to the liberation of camphor vapor. The movement is checked by the presence of even a slight trace of oil. Laurel camphor has many important uses which need not here be mentioned. It should be remembered, however, that taken internally it is a powerful poison, ten grains (about 0.65 grams) having proved fatal to a child.

¹ An antiseptic is a substance which is poisonous to the microscopic germs, or septic organisms as they are called, which cause fermentation, putrefaction, and certain diseases.

Peppermint camphor, also known as menthol, $C_{10}H_{20}O$, is a substance of closely similar properties which is obtained from the volatile oil of peppermint and related species of plants. Its important uses are too familiar to need mentioning. Although not so powerful a poison as laurinol, yet serious results may follow its careless internal use.



FIG. 169.—Laurel-camphor Tree (*Cinnamomum Camphora*, Laurel Family, *Lauraceæ*). Flowering branch, $\frac{1}{2}$. (Baillon.)—Tree growing 12 m. tall; leaves thick; flowers yellow; berry dark red. Native home, China and Japan.

Resins are non-crystalline solids or semisolids, soluble generally in alcohol, ether, and volatile oils, but insoluble in water. They contain the same elements as volatile oils, but with a larger proportion of oxygen. On this account and



FIG. 170.—Male-fern (*Aspidium Filix-mas*, Polypody Family, *Polypodiaceae*). 1, plant showing the rootstock which grows underground and produces roots below, and above gives rise to leaves which unfold from coils (*a, a*) and finally produce "fruit dots" or sori on the back, $\frac{1}{2}$. 2, rootstock cut across showing the woody vessels (*a, a*) through which the sap runs. 3, segment of the leaf, under side, showing sori or clusters of spore-cases (*b*) each cluster protected by a cover or indusium (*a*). 4, a sorus cut vertically across the indusium. 5, the same cut at right angle to 4 through the leaf (*a*), much enlarged to show the indusium (*b*), and the spore-cases (*c*). 6, a spore-case discharging spores. (Wossidlo).—A perennial herb; leaves about 30-100 cm. long; fruit dots brownish. Native home, Northern Europe and North America.

from the circumstance that they are commonly associated in plants with volatile oils it is supposed that they are derived from the latter by oxidation; but they are often complex mixtures of obscure chemical composition. Comparatively few resins are poisonous, and of these, only those contained in the drugs called male-fern and Indian hemp need here



FIG. 171, I.—Indian Hemp (*Cannabis sativa*, Mulberry Family, *Moraceæ*). Staminate and pistillate plants. (Baillon.)—An annual 1-3 m. tall; leaves roughish; flowers greenish; fruit dry. Native home, Central Asia.

concern us. It is the dried and pulverized underground stem of the male-fern (Fig. 170) and related species which constitutes the drug long known as a most valuable means of expelling tapeworms. The resin, which is the active constituent, has proved, however, in overdoses to be a violent

poison. The resin of Indian hemp (Fig. 171) is obtained chiefly from the pistillate flower-clusters and fruits. Under the name of "hashish" resinous parts of the plant are smoked as an intoxicant by Eastern peoples. Medicinally the drug is used for its quieting effect upon the nerves in certain diseased conditions. It is highly injurious when taken in overdoses, and terrible effects follows its habitual use as an intoxicant.

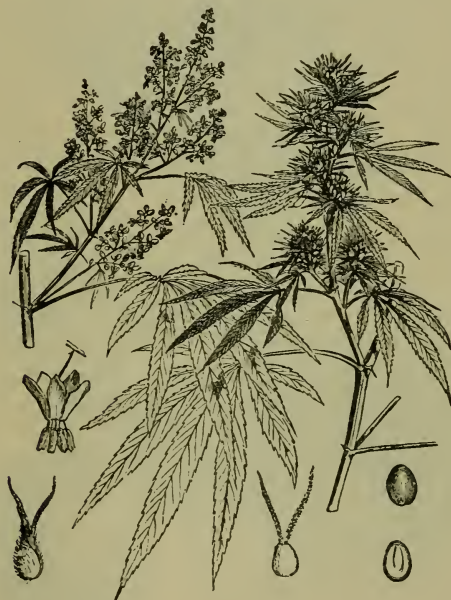


FIG. 171, II.—Indian Hemp. Staminate and pistillate flower-clusters. Staminate flower. Pistillate flower. Pistil. Seed, entire and cut vertically. (Baillon.)

Alkaloids, as we have seen, are vegetable substances which contain nitrogen, as well as carbon, hydrogen, and sometimes oxygen, and like alkalis form salts with acids. While certain of the alkaloids, as for example theobromine, which was referred to in the last chapter, are comparatively harmless in their action upon the human system, others, which are now to be considered, include some of the most powerful of poisons.

Out of the large number of drugs consisting of or containing poisonous alkaloids the few following may be taken as familiar examples: opium, tobacco, coca, atropine, quinine, strychnine, and aconite.

Opium is the dried milky juice which flows from wounds made in the seed-pods of the opium poppy (Fig. 172). It



FIG. 172, I.—Opium Poppy (*Papaver somniferum*, Poppy Family, *Papaveraceae*). Flowering and fruiting top. (Baillon.)—An annual about 1 m. tall; leaves pale green; flowers white, red, or purplish; fruit dry, smooth. Native home, Mediterranean region.

has been found to contain twenty different alkaloids. Of these morphine ($C_{17}H_{19}NO_3$) is the most important. The chief uses of opium in medicine are to relax spasm, relieve pain, and induce sleep. Among various oriental peoples large quantities are consumed by smoking and in other ways as an

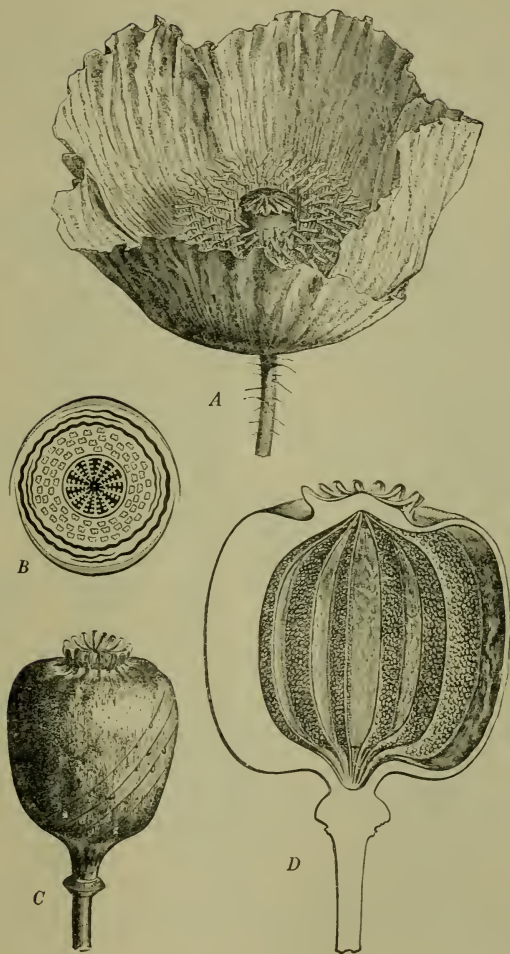


FIG. 172, II.—Opium Poppy: *A*, flower. *B*, floral diagram. *C*, fruit entire showing the oblique cuts made for obtaining the opium-milk. *D*, pod cut vertically to show the numerous seeds on the wall. (Baillon.)

intoxicant—a practice which leads to most degrading effects upon both mind and body.

Tobacco consists of the dried leaves of the tobacco plant (Fig. 173) which have been previously submitted to a process of curing or fermentation. During this process is developed a peculiar volatile substance to which the aroma of the tobacco is mainly due. The chief active constituent is the



FIG. 173.—Tobacco (*Nicotiana rustica*, and *N. Tabacum*, Nightshade Family, *Solanaceæ*). *A*, Turkish tobacco (*N. rustica*), flowering top. *B*, flower, entire. *C*, same, cut vertically. *D*, Virginia tobacco (*N. Tabacum*), flowering top. *E*, flower. *F*, pod, opening for discharge of seeds. *G*, seed. *H*, same, cut vertically. *J*, stigma. (v. Wettstein).—Turkish tobacco, an annual growing about 1 m. tall; leaves glutinous; flowers yellowish or greenish; fruit dry. Native home, South America and Mexico.—Virginia tobacco similar to the Turkish but growing 2 m. tall; flowers rose or purplish. Native home, South America.

alkaloid, nicotine ($C_{10}H_{14}N_2$), one of the most virulent of poisons. A single drop of pure nicotine will kill a dog. Smaller animals are killed by a whiff of its vapor. A child of eight died from an application to the scalp of juice expressed from fresh tobacco leaves. Medicinally, tobacco is used mainly for its quieting effect in certain nervous affections, but it is now rarely prescribed. No other plant, however, is so widely used as an indulgence. It is estimated that

over 800,000,000 people habitually smoke or chew tobacco, or take snuff. The effect of tobacco upon the user varies with differences of age, temperament, and manner of living. Thus an amount of indulgence which does not seem to have any ill effect upon the health of a man of middle age and



FIG. 174, I.—Coca (*Erythroxylon Coca*, Coca Family, *Erythroxylaceæ*). Flowering branch. Leaf. (Baillon.)—Shrub about 2 m. tall; leaves whitish green below; flowers yellow; fruit scarlet. Native home, Peru.

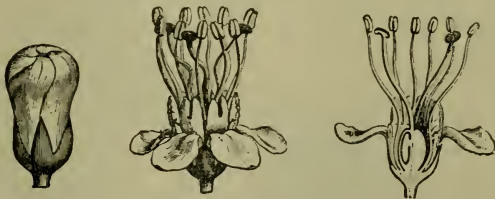


FIG. 174, II.—Coca. Flower-bud. Flower, entire. Same, cut vertically. (Baillon.)

phlegmatic temperament who leads an out-of-door life, is found to be plainly harmful to a young man, particularly one of nervous or excitable temperament, and especially if he leads an indoor life. Whether when taken in moderate

amount by persons of mature years, tobacco is always injurious, is a question with regard to which medical opinion is divided. All competent observers, however, are agreed that unrestrained use invites serious ills, produces enfeebled digestion, heart disease, and nervous debility, and may lead to insanity. Furthermore, all are agreed that even in very small amount, tobacco in whatever form is decidedly injurious to young persons, and that habitual use of it may quite unfit them for happy, vigorous life. It is a significant fact that those who are in training for athletic contests are forbidden to use tobacco.

The drug coca consists of the dried leaves of the coca shrub (Fig. 174). These leaves mixed with ashes or lime are chewed extensively by the Indians of western South America as a means of lessening the sense of hunger and fatigue. Moderate use by the native mountaineers seems not to injure them, but excessive use produces effects as bad as those following the abuse of opium. Foreigners are found to be especially susceptible to the injurious properties of coca; and although with us it is widely used as a medicine, it must be regarded, like opium, as an especially dangerous drug never to be taken except on advice of one's physician. The effect of coca upon the nervous system appears to be due partly to some volatile substance not yet satisfactorily determined, and to an alkaloid known as cocaine ($C_{17}H_{21}NO_4$). This alkaloid has the remarkable property of producing insensibility to pain within certain restricted regions of the body to which it may be applied. Thus a small amount of a weak solution dropped upon the eyeball permits a surgeon to operate upon that organ without causing the slightest pain.

Atropine ($C_{17}H_{21}NO_3$) is another poisonous alkaloid of important use in connection with the eye. An exceedingly minute quantity locally applied causes the pupil of the eye to enlarge, by relaxation of the surrounding muscles, and thus makes possible an examination of internal parts which are ordinarily invisible. The alkaloid is obtained from the leaves and roots of belladonna (Fig. 175) a very poisonous plant.

Quinine ($C_{12}H_{24}N_2O_2$) is one of many alkaloids obtained

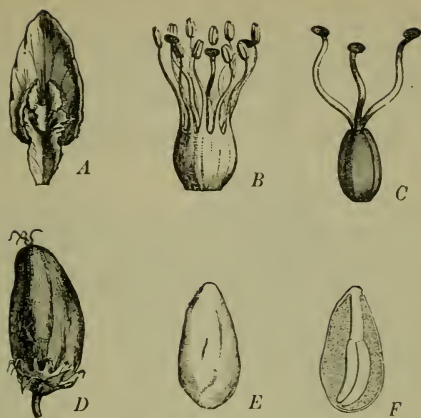


FIG. 174, III.—Coca. A, petal. B, stamens. C, pistil. D, fruit. E, seed, entire. F, same, cut vertically. (Baillon.)



FIG. 175.—Belladonna (*Atropa Belladonna*, Nightshade Family, *Solanaceæ*). A, flowering branch. B, flower. C, same, cut vertically. D, stamen. E, stigma. F, fruit. G, seed. (v. Wettstein.)—Perennial herb growing about 1 m. tall, very poisonous in every part; leaves dull green; flowers dull purple; fruit cherry-like, from green becoming red and dark purple. Native home, Europe and India.

from the bark of the Calisaya-tree (Fig. 176) and related species. Its great and widely recognized value in the treatment of malaria is explained by the fact that in quantities not seriously injurious to a human being the alkaloid acts as a deadly poison upon minute parasites which occur in



FIG. 176.—Calisaya-tree (*Cinchona Calisaya*, Madder Family, *Rubiaceæ*). A, flowering branch, $\frac{1}{2}$. B, flower. C, corolla and stamens. D, fruit. E, fruit with upper half of wall removed to show the packing of the seeds. F, fruit, cut across. G, seed, enlarged, and cut through the embryo, lengthwise. (Luerssen.)—Tree about 12 m. tall; leaves pale green; flowers pink; fruit dry. Native home, Andes of Peru.

the blood of malarial patients and are regarded as the cause of the disease. It is highly valued also as a tonic. Its intensely bitter taste is a property familiar to most persons.

Strychnine ($C_{21}H_{22}N_2O_2$), the principal alkaloid obtained from the seeds of the nux vomica tree (Fig. 177), is one of

the bitterest substances used in medicine. One part of strychnine gives a bitter taste to 700,000 parts of water. It is one of the most violent poisons, but in minute doses is highly valued as a tonic by physicians.

The drug aconite is the dried tuber of the monkshood



FIG. 177, I.—Nux Vomica (*Strychnos Nux-vomica*, Logania Family. *Loganiaceæ*). Flowering branch. (Baillon.)—Tree of moderate height; leaves glossy; flowers greenish or yellow; fruit orange. Native home, India and East Indies.

(Fig. 178). This species and nearly related ones are among the most poisonous of plants. The juice of an East Indian species is used by the natives as an arrow-poison which is so powerful as to kill a tiger within a few minutes after it has been even slightly wounded with one of the poisoned arrows.

The chief active principle is aconitine ($C_{33}H_{45}NO_{12}$) which is one of several poisonous alkaloids contained in the plant. Medicinally, aconite is used as an external application to re-

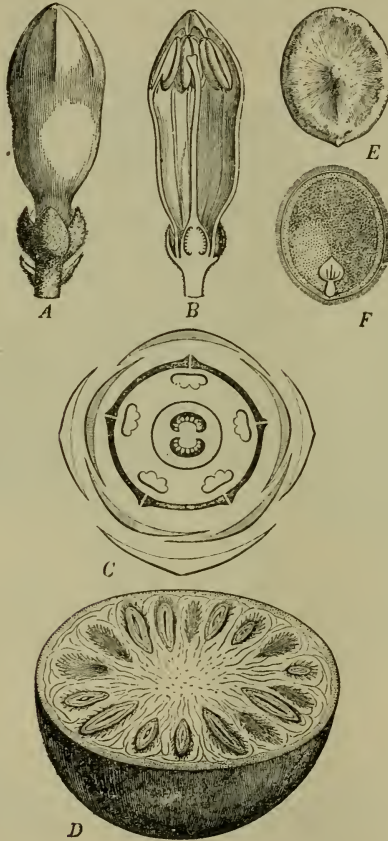


FIG. 177, II.—*Nux Vomica*. *A*, flower-bud. *B*, same, cut vertically. *C*, floral diagram. *D*, fruit cut across. *E*, seed, entire. *F*, same cut through embryo between seed-leaves. (Baillon.)

lieve pain; but from what has been said it is plain that great caution should be observed to prevent the introduction of a



FIG. 178.—Monkshood (*Aconitum Napellus*, Crowfoot Family, *Ranunculaceæ*). Plant in flower. Flower. Same, with calyx removed. Flower, cut vertically. Fruit. Flower with sepals detached. Floral diagram. (Baillon.)—Perennial herb about 1 m. tall, very poisonous; leaves dull green; flowers blue; fruit dry. Native home, Europe.

poisonous quantity into the blood through a scratch or other slight wound in the skin.

The plants which produce alkaloids or other poisons would seem to be protected against the ravages of herbivorous animals by means of these substances. All such animals, however, are not affected alike by them. Thus cattle eat poison-ivy without harm, and various insects are known to feed exclusively upon plants which are deadly poisons to higher animals. Commonly poisons are associated with rank odors or disagreeable tastes, but in some poisonous plants which are avoided by cattle and sheep there are no such warnings that we can discover. In the plant's economy the substances in question are to be considered simply as by-products which are sometimes protective. It is a curious fact that many plants may be poisoned by their own alkaloids. For example, an opium poppy is killed if watered with a solution of morphine.

62. Plants poisonous to eat. The number of poisonous plants which are to be found growing wild or in gardens is much larger than is generally supposed, and the cases of poisoning annually reported are more numerous than is commonly realized. While it will not be possible for us to deal with all the species that are dangerous, it will be sufficient for our purpose to select for special consideration those which have proved most likely to cause injury. A knowledge of these kinds, and of the ways in which poisoning by them has occurred, is not only highly important in itself as a means of safety, but will lead to certain rules of general application. It will be convenient for us to group the different kinds according to the parts which are most dangerous. Nevertheless it must be understood that when any part of a plant is poisonous every other part is to be regarded with suspicion.

One of the most common ways in which poisoning occurs is from the eating of *underground parts* of plants which resemble more or less closely species that are known to be edible. Thus it has often happened that young folks off for a ramble in the country come across some wild plant that suggests parsnip or some similar herb and has an attractive looking root which has perhaps been uncovered by recent

rains. Being hungry the trampers bite off a piece of the root, and finding that it tastes good they continue to eat it. Before long distressing symptoms appear, leading within a few hours to violent convulsions and perhaps death. The plant of which they have eaten is probably the water hem-



FIG. 179.—Water Hemlock (*Cicuta maculata*, Parsley Family, *Umbelliferae*). Lower stem and roots, cut vertically, $\frac{1}{2}$. Flowering and fruiting top, $\frac{1}{2}$. Part of leaf, $\frac{1}{2}$. Fruit entire, $\frac{1}{2}$. Half of same, cut across. (Chesnut).—Perennial herb 1–2 m. or more in height; roots spindle-shaped, 3–7 cm. long; stem rigid, hollow, smooth; leaves smooth, somewhat celery-like; flowers white; fruit becoming brown. Very poisonous throughout. Native home, North America, in damp soil.

lock (Fig. 179) one of our commonest swamp or brookside plants and one of the most deadly. Fatal cases like that described occur almost every year especially among children, and many cattle are poisoned by eating various parts of the plant. Sometimes poisoning results from drinking

water in which the roots have been bruised by trampling. The plant should be uprooted and destroyed wherever found. Another herb closely similar to the water hemlock and too common along waysides is the poison hemlock (Fig. 180). This is most probably the plant by which Socrates was poi-



FIG. 180, I.—Poison Hemlock (*Conium maculatum*, Parsley Family, *Umbelliferae*). Flowering and fruiting top. (Baillon.)—A biennial about 1-2 m. tall; stem, smooth, purple-spotted; leaves parsley-like, of mouse-like odor when bruised; flowers white; fruit brownish. Native home, Eurasia.

soned at the hands of the Athenians. Recent cases of poisoning have resulted from eating the root by mistake for parsnip, the leaves for parsley, and the seeds for anise. Children have been poisoned by blowing whistles made from the hollow stem.

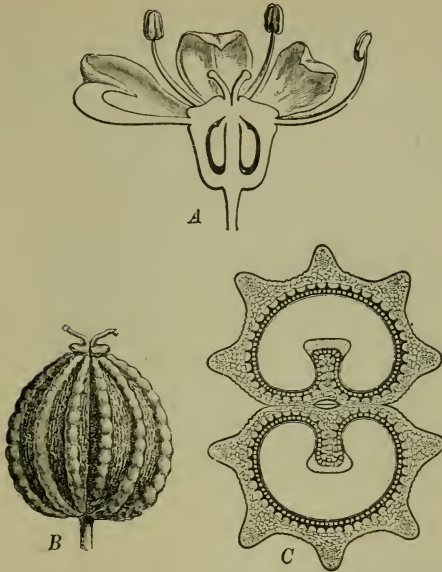


FIG. 180, II.—Poison Hemlock. *A*, flower, cut vertically. *B*, fruit, entire. *C*, same, cut across. (Baillon.)



FIG. 181, I.—Pokeweed (*Phytolacca decandra*, Pokeweed Family, *Phytolaccaceæ*). Flowering branch. (Baillon.)—Perennial herb 1–4 m. tall; leaves smooth; flowers greenish white; fruit fleshy, dark purple. Native home, United States. Root and seeds poisonous.

The common pokeweed (Fig. 181) the young shoots of which are often cooked and eaten like asparagus, is very dangerous as regards its root and fruit, and even the herbage may prove poisonous unless thoroughly boiled and the water changed. Death has resulted from eating the root by mistake for horseradish, parsnip, and artichoke. Children have died from eating the fruit, the seeds of which are especially

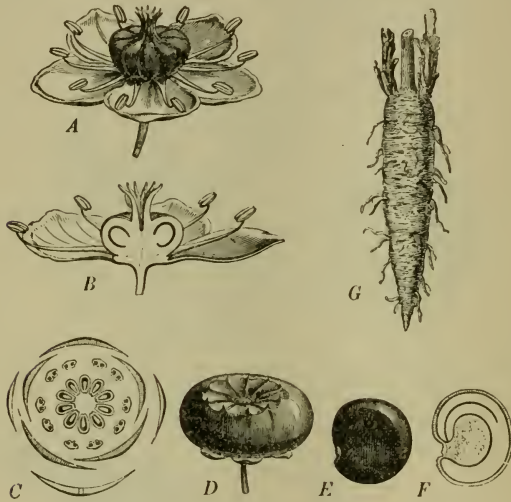


FIG. 181, II.—Pokeweed. *A*, flower. *B*, same, cut vertically. *C*, floral diagram. *D*, fruit. *E*, seed, entire. *F*, same, cut vertically. *G*, root. (Baillon.)

poisonous. Household remedies prepared from the plant are widely used, but the cases of poisoning from overdoses of it ignorantly taken show it to be an especially dangerous medicine. The monkshood (Fig. 178) common in gardens is another plant the roots of which have been mistaken for horseradish, with fatal results.

The *bark* of various trees and their roots is often chewed by young people, and often serious and sometimes fatal consequences have resulted from mistaking poisonous for harmless kinds. The locust (Fig. 182) and elder (Fig. 183) have proved especially dangerous in this respect.



FIG. 182.—Locust (*Robinia Pseudacacia*, Pulse Family, *Leguminosæ*). Flowering branch. (Baillon.)—Tree growing 24 m. tall, twigs spiny; flowers white and fragrant; fruit a flat brownish pod. Native home, Eastern North America.



FIG. 183.—Elder (*Sambucus canadensis*, Honeysuckle Family, *Caprifoliaceæ*). Fruiting branch with leaf. Flower. (Britton and Brown.)—Shrub about 1-3 m. tall, leaves nearly smooth; flowers white; fruit deep purple or black. Native home, Eastern North America.



FIG. 184.—Marsh-marigold (*Caltha palustris*, Crowfoot Family, *Ranunculaceæ*). Plant in flower. (Original.)—Perennial herb, growing 30–60 cm. tall; leaves smooth; flowers yellow; fruit dry. Native home, North Temperate regions.

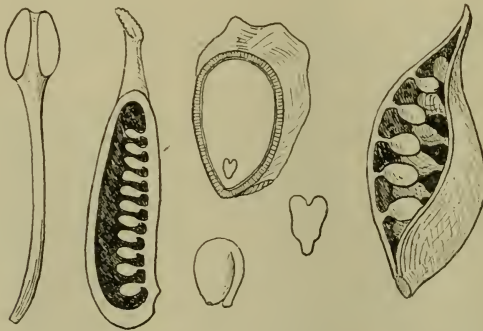


FIG. 185.—Marsh-marigold. Stamen. Pistil, cut vertically. Ovule. Fruit, splitting open to discharge the seeds. Seed, cut vertically. Embryo. (Redrawn from Gray.)

The danger attending the use of the *herbage* of the pokeweed as a pot-herb has already been noticed. Not infrequently deaths are caused by eating the leaves of poisonous wild plants picked by mistake for the marsh-marigold (Figs. 184,



FIG. 186.—Indian Poke (*Veratrum viride*, Lily Family, *Liliaceæ*). Upper and middle section of plant, $\frac{1}{2}$. (Chesnut.)—Perennial herb about 1-2 m. tall; leaves somewhat hairy; flowers yellowish green; fruit dry. Native home, North America.

185), or other spring “greens.” The plant which has proved most dangerous in this way is the Indian poke (Fig. 186). Another common herb which has sometimes been eaten for “greens” with fatal results is the jimson-weed (Fig. 187).



FIG. 187, I.—Jimson-weed (*Datura Stramonium*, Nightshade Family, *Solanaceæ*). Flowering and fruiting branch. (Baillon.)—A coarse annual about 1-2 m. tall; stem green; flowers white, heavy-scented, 5-10 cm. long; fruit dry. Native home, Asia (?).

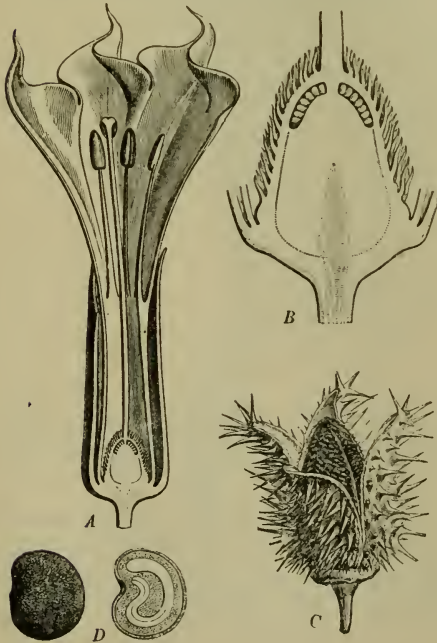


FIG. 187, II.—Jimson-weed. *A*, flower, cut vertically. *B*, base of flower cut vertically, enlarged. *C*, fruit opening to discharge the seeds. *D*, seed, entire, and cut vertically. (Baillon.)



FIG. 188, I.—Indian Tobacco (*Lobelia inflata*, Bellflower Family, *Campanulacæ*). Flowering top. Tip of flower-cluster. Fruit. (Britton and Brown.)—An annual, growing 1 m. tall or less; leaves hairy; flowers light blue; fruit smooth. Native home, North America.

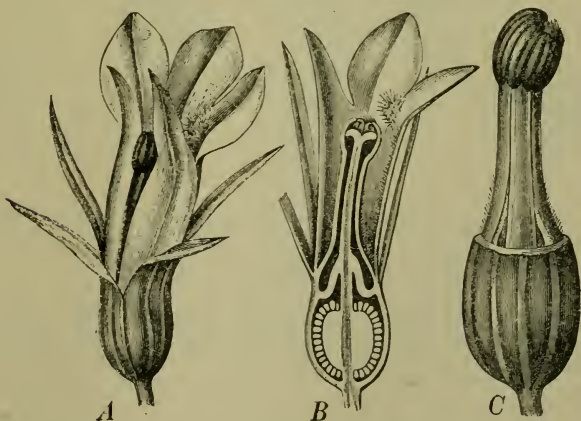


FIG. 188, II.—Indian Tobacco. *A*, flower, entire, ♂. *B*, same, cut vertically. *C*, flower, with calyx and corolla removed. (Luerssen.)

Young shoots of the elder (Fig. 183) eaten as a pickle have also proved poisonous.

The propensity which children have for chewing various leaves occasionally leads them into danger. A plant which they need to be warned against is the Indian tobacco (Fig. 188) that grows very commonly in pastures and might



FIG. 189.—Mountain Laurel (*Kalmia latifolia*, Heath Family, *Ericaceæ*). *a*, flowering branch, $\frac{1}{2}$. *b*, flower, $\frac{1}{2}$. *c*, cluster of fruits, $\frac{1}{2}$. (Chesnut.)—Shrub 1–12 m. tall; leaves evergreen; flowers pink; fruit dry, brownish. Native home, Eastern United States.

FIG. 190.—Sheep Laurel (*Kalmia angustifolia*, Heath Family, *Ericaceæ*). Flowering branch. Flower. Fruiting branch. Fruit. (Britton and Brown.)—Shrub 15 cm.–1 m. tall; leaves evergreen; flowers purplish or crimson; fruit dry, brownish. Native home, Eastern North America.

prove alluring perhaps on account of its common name. Every part of the plant is highly poisonous. It has been extensively used in quack medicines and has caused a large number of deaths. Very young plants of the mountain laurel (Fig. 189) and the sheep laurel (Fig. 190) are especially dan-

gerous from the rather close resemblance of the leaves of small seedlings to wintergreen or checkerberry leaves (see Fig. 147) which children are fond of chewing. The laurels are among our most poisonous plants and have a bad record particularly with reference to domestic animals.



FIG. 191.—Snow-on-the-mountain (*Euphorbia marginata*, Spurge Family, *Euphorbiacæ*). *a*, whole plant, $\frac{1}{3}$. *b*, seed pod. (Chesnut.)—Annual growing about 1 m. tall; upper leaves broadly margined with white; flowers greenish yellow; fruit dry. Native home, Western North America.

A peculiar danger attaches to the leaves of cherry-trees, especially of the wild black cherry. These trees frequently grow on the borders of pastures where cattle are kept, and it often happens that persons having broken off branches,

perhaps to get the fruit, throw the leafy twigs into the pastures within reach of the cattle. As the leaves begin to wilt a very powerful poison (prussic acid) is developed by fermentation, and many deaths to stock have occurred from their

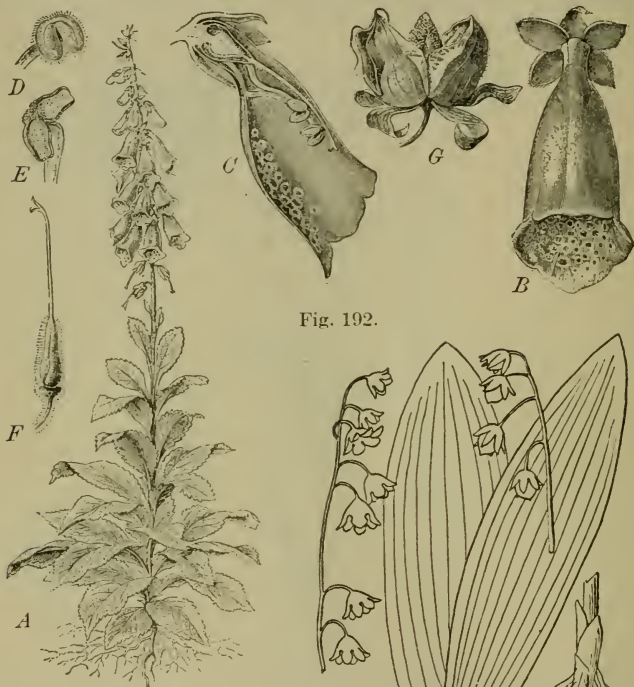


Fig. 192.

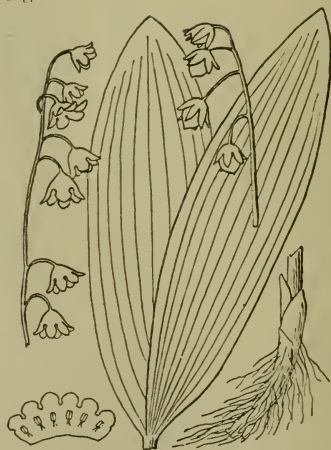


Fig. 193.

FIG. 192.—Foxglove (*Digitalis purpurca*, Figwort Family, *Scrophulariaceæ*). A, plant, in flower, reduced. B, flower, $\frac{3}{4}$. C, same, cut vertically. D, E, stamens. F, pistil. G, fruit. (v. Wettstein.)—Biennial or perennial 1 m. or less in height; leaves downy; flowers purplish rosy, or white, more or less spotted within; fruit dry. Native home, Europe.

FIG. 193.—Lily-of-the-valley (*Convallaria majalis*, Lily Family, *Liliacæ*). Root. Leaves. Flower-clusters. Corolla and stamens. Fruit-cluster. (Britton and Brown.)—Perennial herb; leaves smooth; flowers white, fragrant; fruit pulpy, red. Native home, Temperate Eurasia and Eastern United States.

eating cherry leaves in this condition. A similar formation of prussic acid takes place in the kernels of cherry stones in the presence of moisture. It is therefore dangerous to swallow the fruit whole or to eat many of the kernels. Children have died from so doing.

The *flowers* of poisonous plants are dangerous in two ways: (1) by affording a poisonous honey, and (2) by their at-



FIG. 194.—Wood-anemony (*Anemone nemerosa*, Crowfoot Family, *Ranunculaceæ*). Plant in flower. Flower, cut vertically. (Baillon.)—Perennial herb 7–20 cm. tall; leaves nearly smooth; flowers white or pinkish; fruit dry. Native home, Eurasia. The American wood-anemony (*Anemone quinquefolia*) is so like the species above shown as to be formerly regarded only as a variety of it differing chiefly in having smaller flowers and paler leaves.

FIG. 195.—Daphne (*Daphne Mezereum*, Mezereum Family, *Thymelæaceæ*). A, flowering branch. B, flower, entire. C, same, cut vertically. D, fruit, entire. E, same, cut vertically. (Baillon.)—Shrub 30–90 cm. tall; leaves very smooth; flowers rose-purple, fragrant; fruit fleshy, red. Native home, Europe.



FIG. 196.—Oleander (*Nerium Oleander*, Dogbane Family, *Apocynaceæ*). Flowering branch. (Baillon.)—Shrub 2-5 m. tall; leaves leathery; flowers deep rose-color or white; fruit dry. Native home, Mediterranean region.



FIG. 197, I.—Oleander. Flower, cut vertically. (Baillon.)

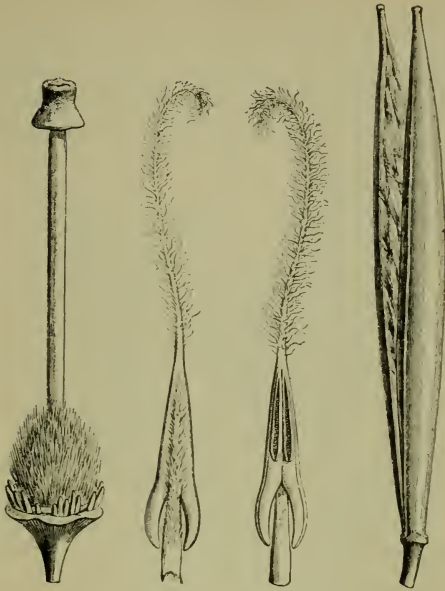


FIG. 197, II.—Oleander. Pistil. Stamen, outer view. Same, inner view. Pod, opening to shed the seeds. (Baillon.)

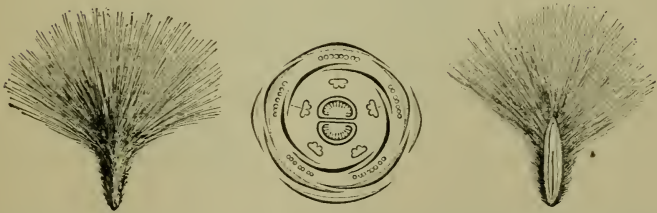


FIG. 197, III.—Oleander. Seed, entire, enlarged. Same, cut vertically. Floral diagram. (Baillon.)

tractiveness leading children to chew them or to suck the sweet nectar they contain. Poisonous honey is yielded by the plant known as snow-on-the-mountain (Fig. 191) which is becoming unfortunately common in gardens, and in some regions is a troublesome weed. Where the plant is abundant

much of the honey crop is rendered unfit for use. The laurels just referred to are also believed to yield poisonous honey.

Among the poisonous plants already mentioned, those having flowers which must be regarded as dangerously attractive to children are: poppies, tobacco, belladonna,



FIG. 198.—Black Nightshade (*Solanum nigrum*, Nightshade Family, *Solanaceæ*). Flowering and fruiting branch, $\frac{1}{3}$. (Chesnut.)—Annual 30–60 cm. tall; leaves smooth; flowers white; fruit a black berry. Native home, Eurasia and America.

monkshood, pokeweed, jimson-weed, locust, and elder. To these examples may be added the following which have shown themselves similarly dangerous: foxglove (Fig 192), lily-of-the-valley (Fig. 193), marsh-marigold (Fig. 184),

wood-anemony (Fig. 194), daphne (Fig. 195), and oleander (Figs. 196, 197).

More dangerous than any other parts of poisonous plants are the *fruits and seeds*, for the reason that they are often of tempting appearance and because fruits in general are good



FIG. 199.—Bittersweet (*Solanum Dulcamara*, Nightshade Family, *Solanaceae*). *a*, flowering branch; *b*, fruiting branch. (Chesnut.)—A somewhat woody vine 1–3 m. long; leaves smoothish; flowers violet-purple with greenish spots; fruit red. Native home, Europe.

to eat. In the case of the poison hemlock, the pokeweed, and the wild cherry we have already noticed the poisonous character of these parts. It is safe to regard all the other poisonous plants mentioned as further examples more or less dangerous in proportion to their attractiveness. That special

attractiveness, however, is not always a necessary element of danger in this matter, appears from the following instance which comes from New York. "Four children were playing in one of the public parks of the city where jimson-weeds were growing luxuriantly. The boys imagined themselves Indians and roamed about and ate parts of various plants. Three of them ate the seeds of the jimson-weed. One died



FIG. 200.—Mistletoe (*Viscum album*, Mistletoe Family, *Loranthaceæ*). Bunches of the plant growing upon a leafless tree in winter. (Kerner.)—Woody parasite, growing on various trees, principally apple and poplars, and attaining a length of 1 m. or more; leaves evergreen; flowers greenish; fruit a white berry with viscid pulp. Native home, Europe.

in a state of wild delirium; another was saved after heroic treatment; . . . the third who ate but few of the seeds was but little affected." This miserable weed has one of the worst records among poisonous plants. Many lives are lost through permitting this plant to grow in places frequented by children.

A few further examples of poisonous fruits and seeds require mention. The green berries of the white potato, although scarcely attractive to most people, have been eaten

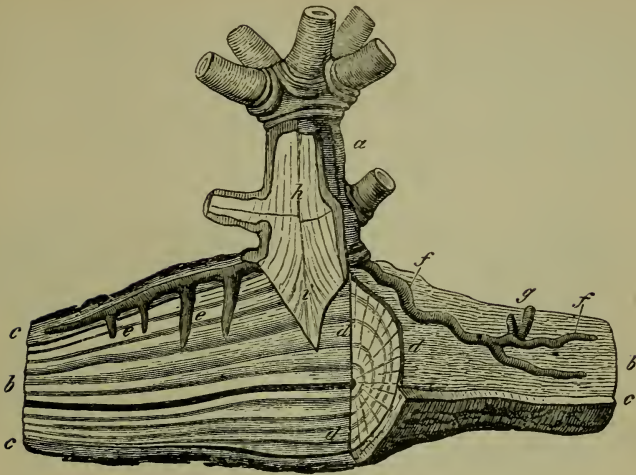


FIG. 201.—Mistletoe. Stem base showing mode of attachment to a branch of the "host" upon which it grows; *h*, wood of the mistletoe extending into the wood of the host as a primary "sinker" (*i*); *f*, *f*, cambium suckers growing between wood and bark, and sending through the bark buds, as at *g*, which become shoots; and pushing into the wood secondary sinkers, as at *e*. *e*: *b*, *b*, wood of the host cut half across at *d*, *d*, *d*, to show the annual rings of growth; *c*, bark. (Sachs.)

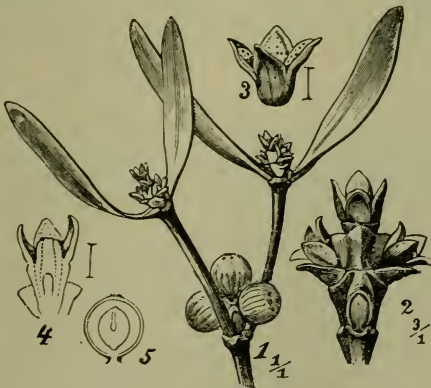


FIG. 202.—Mistletoe. 1, pistillate branch with flowers and fruit. 2, pistillate flower-cluster. 3, staminate flower. 4, pistillate flower, cut vertically. 5, fruit, cut vertically. (Wossidlo.)

with fatal results. The berries of the nearly related black nightshade (Fig. 198) and the bittersweet (Fig. 199) are somewhat poisonous, and from their bright colors especially liable to attract children. At Christmas, young children sometimes suffer from eating the white berries of the mistletoe (Figs. 200-202) used in decoration. Similar cases of

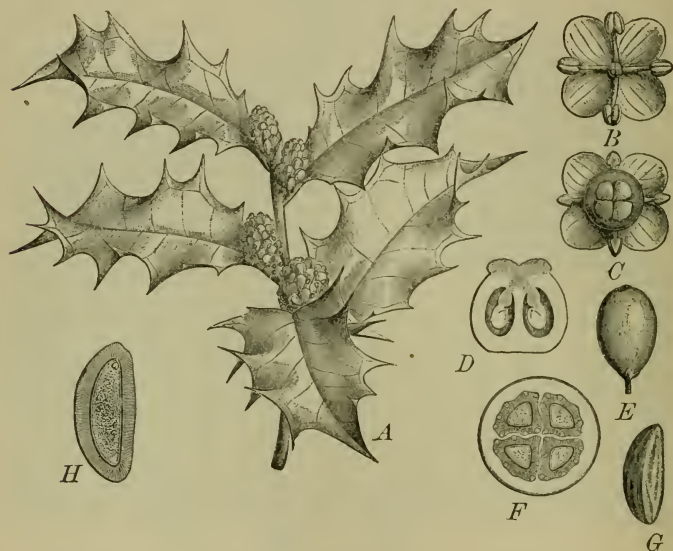


FIG. 203.—Christmas Holly (*Ilex Aquifolium*, Holly Family, *Aquifoliaceæ*). A, branch bearing leaves and staminate flowers. B, staminate flower. C, pistillate flower. D, pistil, cut vertically. E, fruit. F, same, cut across. G, seed. H, same, cut vertically. (Kronfeld, Reichenbach.)—Tree growing 12 m. tall, leaves evergreen; flowers whitish; fruit scarlet. Native home, Eurasia.

poisoning are recorded with regard to the scarlet berries of the Christmas holly (Fig. 203). The tempting red pulp surrounding the poisonous seeds of the yew (Fig. 204) while itself harmless has sometimes led children to eat the seeds, with fatal results. Young children are also liable to eat the pretty seeds of the castor-oil plant which is very commonly planted for ornament. These seeds are poisonous although,

as is well known, the pure oil expressed from them is quite harmless under ordinary conditions.

Some of the worst cases of poisoning occur every year from



FIG. 204.—Yew (*Taxus baccata*, Yew Family, *Taxaceæ*). Branches with leaves and staminate flowers (♂), ovule-bearing flowers (♀), and fruit (fr.); a, a single staminate flower; b, stamen with anthers still closed; c, same, with anthers open for discharging pollen; d, an ovule-bearing flower, the tip of the ovule seen projecting beyond the protecting scale-leaves; e, same, cut vertically, showing tip of the stem-branch at x; f, fruit, half ripe, showing the cup-like envelope (aril) growing up from the base of the young seed; g, ripe fruit; h, same, cut vertically; i, seed, cut vertically. (Eichler, Richard.)—Tree growing 20 m. tall; bark, reddish, flaky; leaves dark green above; fruit (aril) scarlet.

eating *poisonous mushrooms* or “toadstools.” While any intelligent person, under competent guidance can learn to distinguish the edible species of fleshy fungi which grow abundantly in our fields and woods, it is exceedingly danger-

ous to suppose that one knows, when one does not know. It is indeed hardly safe for one who has not had good botanical training to depend upon even accurate pictures and descriptions of mushrooms; and it is decidedly unsafe for the average person to rely upon information gained from popular writings upon edible fungi. Not a few cases of poisoning within recent years have been traced to the misstatements in, or the misunderstanding of, attractive books or magazine articles on the subject. Another fertile source of danger is belief in the so-called rules "for telling a mushroom from a toadstool," such for example as the oft-repeated saying that a piece of silver placed in contact with mushrooms that are being cooked will turn black if they are poisonous. This and all similar rules are worse than worthless for not only is one led by them to regard as poisonous many edible forms, but some of the deadliest species might be called edible. Nothing less than thorough acquaintance with all the botanical characters which distinguish our common species at different ages can be relied upon to enable a person to tell the difference between edible and poisonous mushrooms. There are *no* short cuts to such knowledge. The only really safe way for a beginner to learn about mushrooms with a view to eating them, is to be instructed by an expert botanist, in the field, or from fresh specimens. Until the student has learned the art of observing accurately he should distrust his own ability to determine specimens as edible with the aid of books alone. Meanwhile, it is desirable that he should learn something about our two most poisonous species since the majority of fatal cases have been due to eating specimens of these or closely similar forms. The most deadly of all fungi is the death-cup (Fig. 205). Its name is derived from the fact that the stalk is enveloped at its base by a cup. *Beware of any toadstool having such a cup.* As the fungus presents an especially attractive appearance and has a pleasant flavor it has tempted many persons to their death. The symptoms of poisoning do not appear for a number of hours after the fungus has been eaten, and by that time so much of the poison has been absorbed into the system that recovery is hardly possible. Scarcely less poisonous, but more common is the

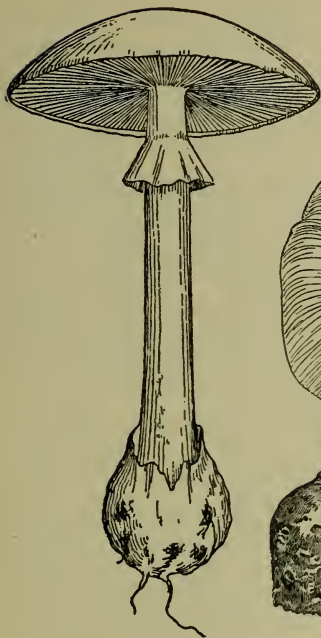


FIG. 205.



FIG. 206.

FIG. 205.—Death-cup (*Amanita phalloides*, Gill-mushroom Family, *Agaricaceæ*). Mushroom growing 7-20 cm. tall; cap white, straw-color, greenish, light brown, or yellow, uniformly or more or less spotted; smooth and satiny, convex at first, finally becoming concave; stalk white, and nearly smooth, bearing generally at the more or less swollen base a conspicuous cup-like envelope which may lie partly under ground, and near the cap a drooping ring or "frill"; gills white. (Chesnut.)—Native home, Europe and North America, mostly in woods. The most poisonous and one of most common of mushrooms, dangerous even to handle.

FIG. 206.—Fly-amanita (*Amanita muscaria*, Gill-mushroom Family, *Agaricaceæ*). Mushroom growing about 10-14 cm. tall, highly attractive in appearance, smell, and taste; cap strongly convex at first, becoming flat or concave, white, yellow, orange to bright red, commonly deeper-colored toward the center, sticky when moist, always bearing warts of a mostly paler color; stalk bulbous at the base, without a conspicuous cup but bearing around it flexible shaving-like projections pointing upward, and near the cap a frill-like ring; gills white. (Chesnut.)—Native home, Eurasia, South Africa, North America; mostly in woods. Scarcely less poisonous than the death-cup.



Fig. 207.



Fig. 208



Fig. 209.

FIG. 207.—Caper Spurge (*Euphorbia Lathyris*, Spurge Family, *Euphorbiaceæ*). *a*, upper half of plant, $\frac{3}{4}$; *b*, fruit, $\frac{1}{2}$. (Chesnut.)—Annual growing 1 m. or less in height; leaves in four ranks; flowers greenish yellow; fruit somewhat fleshy. Native home, Europe; growing in old gardens and as a weed in Eastern States.

FIG. 208.—Tall Buttercup (*Ranunculus acris*, Crowfoot Family, *Ranunculacææ*). Base of plant showing roots and leaves, $\frac{2}{3}$. Flowering top, $\frac{2}{3}$. Fruit enlarged. (Britton and Brown.)—Perennial herb, growing about 1 m. or less in height; leaves hairy; flowers bright yellow; fruit dry. Native home, Europe; common as a weed in Northern States and Canada.

FIG. 209.—Ditch Crowfoot (*Ranunculus sceleratus*, Crowfoot Family, *Ranunculacææ*). Base of plant, $\frac{2}{3}$. Flowering and fruiting top, $\frac{2}{3}$. Flower, enlarged. Fruit, enlarged. (Britton and Brown.)—Annual herb growing 15-60 cm. tall; leaves smooth; flowers yellow; fruit dry. Native home, Eastern North America and Eurasia.

handsome fly-amanita (Fig. 206), so called from its use as a fly-poison. It should be noticed that the base of the stalk instead of being plainly in a cup is bulbous and scaly. This fungus, like the death-cup, has a pleasant flavor; and after it has been eaten no sign of poisoning is noticed for several hours. Prompt medical treatment may then save the patient's life.

63. Plants poisonous to handle. The number of plants which poison the skin by contact is fortunately much smaller than the number of those poisonous to eat. Among the latter which have been already mentioned the death-cup, the fly-amanita, and the snow-on-the-mountain are the only ones poisonous to handle. The milky juice of the snow-on-the-mountain applied to the skin often causes intense itching and inflammation accompanied by blisters. The same is true of the juice of the nearly related caper spurge (Fig. 207) and of other spurges common in gardens. The colorless juice of several species of buttercups or crowfoots, especially the tall buttercup (Fig. 208) and the ditch crowfoot (Fig. 209), blister the skin. These and related species are sometimes used by European beggars to produce sores as a means of exciting compassion.

In the United States by far the worst and most frequent cases of poisoning by contact come from the poison-ivy (Fig. 210) and the poison-sumac (Fig. 211) of the East, and certain of their relatives which live in other parts of the country. Poison-ivy may be distinguished from other common vines for which it is apt to be mistaken, by the fact that its leaflets are in threes and its fruit white. Poison-sumac may be distinguished from the other common sumacs and other shrubs which it resembles, by the smoothness of its twigs and leaves and the even edge of its leaflets together with the slender cylindrical form of the part which bears them, the drooping of the flower-clusters and the greenish-white color of the hanging fruit. The symptoms of poisoning by either plant are inflammation with itching, swelling, and eruption. The poisonous principle of both species has recently been discovered to be a fixed oil, called cardol, which is soluble in alcohol. Hence the treatment recommended

is to rub thoroughly the affected part every few hours with a concentrated solution of sugar of lead in alcohol of 50–75% strength. As alkalis convert the oil into a harmless soap,



FIG. 210.—Poison-ivy (*Rhus Toxicodendron*, Sumac Family, *Anacardiaceae*). *a*, spray showing air-roots and leaves, $\frac{1}{2}$; *b*, fruit, $\frac{1}{4}$. (Chesnut.)—Climbing or trailing shrub becoming 6–15 m. long, sometimes erect and bushy; leaves smooth or downy; flowers green; fruit smooth, waxy, grayish. Native home, North America.

relief is also found by the application of a strong solution of cooking soda, as soon as possible after the poisoning.

A fixed oil similar to cardol has been found to be the cause of poisoning by two of our native orchids known as lady-

slippers (Figs. 212, 213). The symptoms are like those just described, and the treatment recommended is the same.

Fortunately there are many persons who are not affected by handling poison-ivy, poison-sumac, or either of the orchids mentioned; and there are other persons upon whom the effect is but slight. On the other hand, certain persons, particularly women and children, have skins so sensitive as to be poisoned by handling plants which are commonly regarded as harmless. Thus one occasionally hears of a person who cannot handle the herbage of the carrot or parsnip, or who cannot wash parsnip roots without being poisoned. In all such cases, as also in cases of poisoning by the other plants referred to in this section, the treatment recommended is much the same as that given for ivy poisoning.

64. Poisonous plants in general. The preceding sections have shown that serious or even fatal consequences may result from eating, chewing, or sucking various parts of poisonous plants, or from overdoses of medicines prepared from them; that the juice of certain plants causes painful effects wherever it touches the skin; and that merely handling other kinds produces similar effects with certain persons. We have seen also that the number of common plants, both wild and cultivated, which are poisonous in one way or another is much larger than is generally realized. The practical conclusions to be drawn from these facts are surely very plain, but as they cannot be too strongly emphasized it may be useful to embody them in the following summary:—

1. Never put into the mouth any part of any plant with which you are not perfectly well acquainted and know to be harmless beyond the possibility of a doubt.

2. Be especially cautious with regard to plants which are young or show only young spring shoots, or which have not come into blossom or fruit; for the younger a plant is, or the fewer parts it displays, the more easily it may be mistaken for some other kind.

3. Be suspicious of all plants which resemble those known to be poisonous; for such resemblance is likely to indicate relationship, and plants closely related are apt to possess similar properties. But never suppose a plant to be harm-



Fig. 211.



Fig. 212.



Fig. 213.

FIG. 211.—Poison-sumac (*Rhus Vernix*, Sumac Family, *Anacardiaceæ*). Fruiting branch. (Chesnut.)—Shrub or tree 2-15 m. tall; leaves smooth, shining green above, pale beneath; flowers green; fruit grayish. Native home, Eastern North America, in moist ground.

FIG. 212.—Showy Ladies' Slipper (*Cypripedium hirsutum*, Orchid Family, *Orchidaceæ*). Leaf. Flower. Fruit, $\frac{1}{3}$. (Britton and Brown.)—Perennial herb 30-60 cm. tall; leaves hairy; flowers white and crimson; fruit dry. Native home, Eastern North America. Poisonous to touch.

FIG. 213.—Yellow Ladies' Slipper (*Cypripedium parviflorum*, Orchid Family, *Orchidaceæ*). Base of plant. Flowering top, $\frac{1}{3}$. Stigma and stamens, enlarged. (Britton and Brown.)—Similar to the showy ladies' slipper but flowers greenish yellow, more or less suffused or streaked with madder-purple. Native home, North America.

less simply because it bears a general resemblance to certain well-known harmless species; for some of the most poisonous plants very closely resemble and are nearly related to species highly valued for food.¹

4. Place no confidence whatever in any "rules" for telling poisonous from harmless species.

5. Do not suppose that plants which are harmless to birds, cattle, or other animals, may not be poisonous to human beings; for many plants which are poisonous to us are eaten by various animals with impunity.

6. Learn to recognize at sight the species of your locality which are poisonous to handle. If possible get some one who knows the plants to point out specimens to you in the field, and show you the features by which they may be always recognized. Then let him test your knowledge on the matter to see if the characteristics of each species are firmly impressed on your mind. If you find you know well all the dangerous species you will feel safe in handling any others.

7. Never use medicines which you do not know to be entirely harmless, unless with the approval of your physician.

¹ In later chapters the student will be helped to recognize the more important families of plants, and will learn which of them consist entirely or almost entirely of poisonous species, and which families are comparatively harmless. Until he is able to classify the plants about him as to their families and is well informed regarding the extent to which relationship may be depended upon to indicate similarity of properties, safety requires that he should regard many harmless species with suspicion.

CHAPTER VI

INDUSTRIAL PLANTS

65. Uses of industrial plants. By industrial plants we mean those which yield raw materials or products used in the industrial arts; that is to say, in such industries as spinning, weaving, building, paper-making, tanning, dyeing, and painting. Industrial plants cannot be separated entirely from edible and medicinal plants any more than those economic groups can be distinguished sharply one from the other; for, as we shall see, there are industrial plants which also yield food or medicine or both.

As with the economic plants already studied, so with these, we shall find it convenient to classify them according to the useful products which they yield. Out of the immense number of industrial plants more or less useful to mankind, we can here consider only a few of the most important which yield *fibers, woods, cork, elastic gums, resins, coloring matters, tannins, oils, and fuels.*

66. Fibers in general. Next to food-plants those producing fibers have proved the most useful of all the vegetable kingdom, and have contributed most to the advancement of civilization.

Mankind while yet in the stage of savagery needed some sort of cordage easier to procure than sinews or strips of hide, and more suitable for bowstrings, snares, fish-lines, nets, baskets, and the like. He needed also some form of clothing less cumbersome and cooler than that afforded by the skins of animals. These needs were admirably met by twisting, plaiting, or weaving the flexible strands which he found strengthening roots, stems, and leaves, or by spinning the woolly covering of seeds. We know that sheep's wool and other animal fibers, including the silk of which the silk-

worm makes its cocoon, were used very early in certain regions as materials for fabrics, but in general it is safe to say that vegetable fibers have been far more extensively used than animal fibers even from prehistoric times.

As civilization has advanced, and man's needs have multiplied, the uses of vegetable fibers have also multiplied, and their importance in daily life has increased enormously. To-day as their properties are better understood and their wonderful possibilities more fully realized, these fibers are coming to be used more and more in place of animal fibers and other animal products. It is true that mineral fibers, such as asbestos and spun glass, and metals in the form of wire, are replacing vegetable fibers to a limited extent; but in spite of this the consumption of fibers from plants is steadily increasing. They are now used most extensively as materials for fabrics, cordage, plaiting, matting, wickerwork, thatch, brushes, stiffening, filling, paper, and various cellulose products.

Fabrics are made of especially flexible fibers spun or twisted into yarns, threads, or cords, which are then variously intertwined by weaving, braiding, knitting, or netting. According to its texture a fabric may serve for wearing apparel, house-furnishing, decoration, awnings, sails, tape, belts, girths, webbing, burlap, gunny bagging, hammocks, nets, or lace. The finer fabrics are among the greatest triumphs of human skill and constitute the most highly developed of fiber products. *Cordage* includes yarn or thread for sewing or needlework, twine, fish-lines, cords, ropes, and cables. These consist, for the most part, of especially strong fibers, which are twisted into strands and then "laid" or twisted again in such a manner that they will not freely untwist. *Plaiting* consists of flat fibrous strands sufficiently pliable to be folded into plaits or flat braids and used for straw hats, fine basketry, and the like. *Matting* consists of elastic fibrous strands woven or braided into mats or screens. *Wickerwork* is made of supple twigs, strips of wood or similar fibrous strands interlaced to form hampers and other stout baskets, or chairs and similar articles of furniture. *Thatch* consists of strips of fibrous material, overlapped and fastened so as to shed water, as on a roof. *Brushes*, including brooms and whisks, require fibers of special stiffness and elasticity. *Stiffening*, which is mixed with plaster like cow's hair to give cohesion, calls for fibers which are at once strong and able to resist the softening influence of the plaster. *Filling*, such as the stuffing used in upholstery, *calking* for the seams of water-craft, casks, etc., and *packing* for objects to be

transported, require light fibrous material so soft and elastic that it will fully occupy the spaces into which it may be crowded. *Paper* consists of fibers, especially rich in cellulose, which have been softened and compacted, and finally pressed into sheets or molded into other forms as papier-mâché. Besides the more familiar uses of paper for writing, drawing, printing, book-binding, boxes, and so on, there are many others of considerable importance. Thus we have paper garments, paper napkins and other substitutes for fabrics used in the household, paper pails and similar articles replacing wooden ware, paper canoes and paper car-wheels. Such wheels having steel hubs and tires, are found to wear far better than wheels made wholly of steel. Fine paper is nearly pure cellulose. The larger the percentage of cellulose in a fiber the better the paper it makes. Fibers rich in cellulose are also the source of various *cellulose products*, obtained by chemical means presently to be described. These products include gun-cotton which is a high explosive used in the manufacture of smokeless powder; collodion, of much use in surgery as a covering for wounds; celluloid, the well-known substitute for ivory, bone, tortoise-shell, and similar materials; and artificial silk which is coming to be used widely in place of the product of the silkworm.

From what has been said of the great variety of uses to which fibers are put, it follows that the term fiber must have a rather broad definition. Fibers may be either fine or coarse, flexible or stiff, elastic or soft. They differ also in structure and chemical composition, and in the part from which they are derived. They agree, however, in being comparatively slender structures, which although separately weak, form strong yet pliable articles of manufacture when twisted, woven, or otherwise intimately joined together. If we define fiber-plants as those which yield slender parts of economic use when thus united, it may be said that over a thousand species of them are known to be used more or less in various parts of the world. The great majority of these, however, are used only in restricted regions and are not cultivated. Less than fifty are of much commercial importance. Of these the most useful are the species yielding cotton, flax, jute, hemp, and manila.

Fibers may be classified most conveniently for our present purpose into the following groups: (1) *surface fibers*, more or less hair-like outgrowths; (2) *bast fibers*, consisting entirely of such tough strands as form the bast or strength-giving



FIG. 214.—Upland Cotton (*Gossypium herbaceum*, Mallow Family, *Malvaceæ*). Plant in flower and fruit. (Baillon.)—An annual in cultivation, growing 1–2 m. tall; leaves downy; flowers yellow; fruit dry; seed brown.. Native home, probably India.

part of the inner bark of stems; (3) *woody fibers*, composed entirely of wood; (4) *mixed fibers*, containing both woody and bast-like fibers; and (5) *pseudo-fibers*, which consist either of entire plants or of parts lacking both wood and bast.

67. Surface fibers occur upon stems, leaves, fruit, and seeds. The only one of much economic importance is *cotton*. This forms the woolly covering of the seeds of several species, principally the upland cotton (Figs. 214, 215) and the Sea Island cotton (Fig. 216). The former is the chief fiber plant of the world. To-day it is cultivated throughout the tropics and very generally in subtropical regions. The southern United States produce more than all the rest of the world. Two thousand six hundred years ago it was raised in India

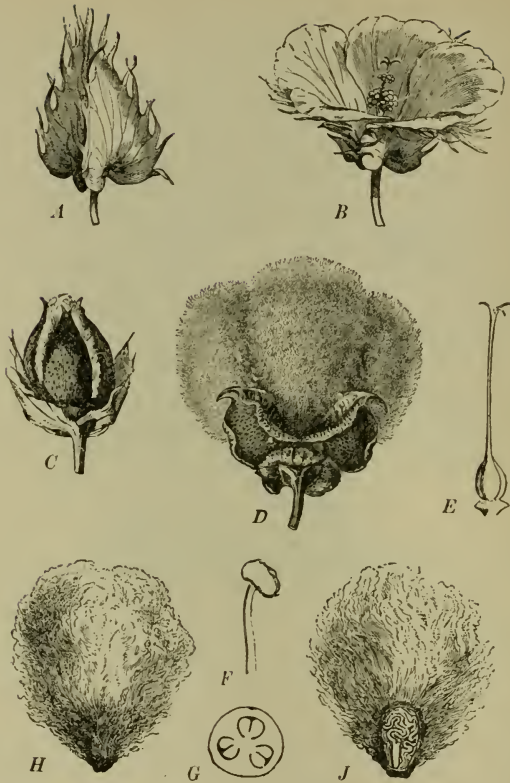


FIG. 215.—Upland Cotton. *A*, flower-bud. *B*, flower. *C*, unopened pod. *D*, open pod, displaying the masses of hairy seeds. *E*, pistil. *F*, stamen. *G*, ovary, cut across. *H*, seed showing mass of hairs (cotton). *J*, same, cut vertically, showing the much-folded embryo. (Baillon.)

whence its culture slowly spread. It was introduced into this country in 1774. Long before the coming of Columbus, however, Sea Island cotton was raised by the natives of tropical America.

Upland cotton yields much the larger amount of fiber which although strong is only about 1–2 cm. long. The Sea Island cotton has a finer fiber, about 2.5–4 cm. long, and is therefore the more valuable; but the yield of the plant is



FIG. 216.—Sea Island Cotton (*Gossypium barbadense*, Mallow Family, *Malvaceæ*). Flowering top, ♀. (Schumann.)—Similar to upland cotton but with seed black. Native home, West Indies.

comparatively small and the cultivation is mostly confined to islands or regions near the coast.

The fibers found on the seeds of each consist of simple, flattened and twisted hairs developed as outgrowths from the "hull" or seed coat. In the wild state these hairs catch the wind like thistle-down and so are of service to the plant as means of spreading abroad its seeds. Cotton raisers, however, select varieties which hold their seeds firmly in the pod till they can be picked out by hand. Through selection also the best varieties have lost the yellowish or buff color of their seed hairs, and have become nearly or quite white. At the same time there has been developed in cultivation the remarkable twist before mentioned. This twist is of the

highest importance. It favors the interlocking of the fibers in spinning and thus makes possible yarns which combine in a wonderful way extreme fineness, softness, and strength. No other fiber has this peculiar twist. Of all others the wool of sheep, from its curliness, most nearly resembles cotton, which indeed well deserves to be called "vegetable wool."

The separation of the fiber from the seed after picking is accomplished by a machine called a gin which either pulls the seed from the fiber by means of rollers, or tears away the fiber by the action of notched wheels revolving rapidly between the bars of a grating too narrowly set for the seeds to pass through. The ginned fiber is ready for spinning after various machines have removed impurities, and combed the fibers approximately parallel. After spinning, the yarn is bleached, or dyed if necessary, and may be then twisted into thread or other cordage, or may be woven or otherwise made into a fabric. The cleaned fiber rolled into sheets is cotton batting, widely used for filling. In their crude state, cotton fibers are covered with an oily varnish which repels water. When this layer is removed and the fibers thoroughly cleansed there is obtained a white, fleecy mass which is highly absorptive. This is extensively employed in medicine and surgery under the name "absorbent cotton." Like the best paper it is nearly pure cellulose. Many of the finer sorts of paper are made from cotton rags, waste from spinning mills, and fibers too short to spin.

Absorbent cotton treated with nitric and sulphuric acids becomes converted into nitrocellulose or guncotton. An intimate mixture of this with laurel camphor forms celluloid. Collodion is a form of nitrocellulose dissolved in ether and alcohol. Artificial silk is made by forcing collodion through exceedingly fine openings into running water, where the collodion at once hardens into a silky fiber, which after thorough washing becomes well adapted to the same uses as natural silk. The carbon filaments of incandescent electric lamps are charred cotton threads or sometimes carbonized strips of paper pulp. Cotton is the fiber chiefly used also for candle and lamp wicks.

68. Bast fibers form, generally speaking, the strongest



FIG. 217, I.—Flax (*Linum usitatissimum*, Flax Family, *Linaceæ*). Plant in flower. Young flower-cluster. Seed, entire and cut vertically. (Baillon.)—Annual, about 60 cm. tall; leaves smooth; flowers light blue; fruit dry. Native home, Southeastern Europe and Asia Minor.

and most elastic part of the framework of plants. In contrast with the woody part they contain commonly a larger proportion of pure cellulose and are thus comparatively little affected by agencies of decay or the various chemicals which destroy or soften wood. The bast fibers of greatest economic importance are flax, jute, and hemp.

Flax is next to cotton, the most useful and valuable of all fibers. It has an even wider range of uses, but as its prep-

aration requires more labor, it is more costly and hence more a fiber of luxury. The flax plant (Fig. 217) flourishes throughout the temperate zones, and was cultivated in the Old World even during prehistoric times. To-day the world's supply of flax comes chiefly from northern Europe.

The bast of a flax plant forms the main strengthening element of its stem, running near the surface where, plainly, the strain is greatest. These fibers consist of nearly solid cylinders of almost pure cellulose. The essentials of the process by which pure flax is obtained are, first rotting or "retting" the stems and then, after drying them, breaking the weakened parts into fragments, and finally beating and combing these away from the bast. After further combing to separate the longest and best fibers, and then bleaching, they are ready to be manufactured into the finest linen fabrics as well as such strong materials as canvas and duck, and the foundation of carpets and oil-cloth. The strongest thread and twine, and the finest lace are also made from flax, while from linen rags are made the best papers for writing and artist's use. From this paper, by treatment with sulphuric acid, a "vegetable parchment" is made which fully takes the place of the parchment formerly manufactured from the skin of sheep.

Jute is obtained from two closely related species (Fig. 218). Though cultivated from very early times in India the fiber has assumed commercial importance only within the nineteenth century. The bast is extracted from the stem in somewhat the same way as flax. In luster and fineness it rivals flax, but as it contains less cellulose it is inferior in strength and enduring qualities. Its most important use is for coffee-sacks, cotton-bagging, burlap, webbing, and similar coarse fabrics. It is coming rapidly into use, however, for finer fabrics, imitating linen and silk, and as a substitute or adulterant of hemp it is used extensively in cordage; but it is ill-suited for this purpose on account of its rapid deterioration.

Hemp (Fig. 171) is coarser than flax but longer and stronger. It is thus especially well adapted for twine, rope, and heavy cordage, and likewise for sail-cloth, bagging, and similar

coarse fabrics. Tarred ravelings of hemp rope are extensively used under the name of oakum for calking the seams of wooden vessels and also the joints of iron pipes, and the like. The plant has been grown and its fiber used for many centuries in the Old World. At present the largest supply comes from Northern Europe, and the best quality from Italy. The method of treatment is much the same as for flax.

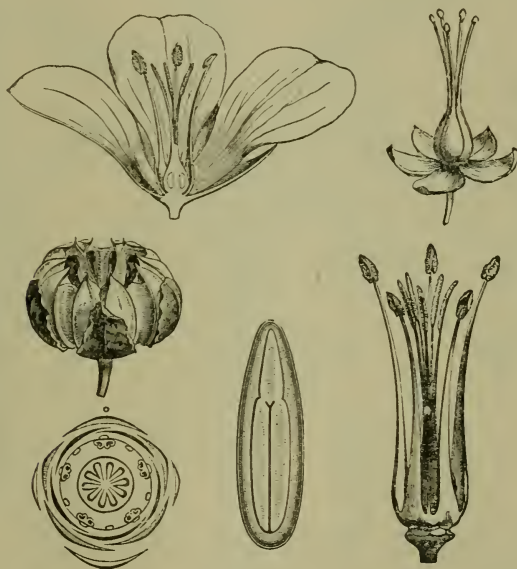


FIG. 217, II.—Flax. Flower, cut vertically. Pistil and calyx. Stamens and pistil. Floral diagram. Pod open for discharge of seeds. Seed, cut vertically. (Baillon.)

69. **Mixed fibers** consist of slender strands including both bast and wood so intimately united that it is difficult to separate one from the other. Such compound strands form the framework or skeleton of leaves, of many stems, and of certain fruits. The extraction of mixed fibers is commonly an easy matter from the fact that they are for the most part surrounded only by material so soft as to be readily removable. In other cases there is so little material beside the

fibers that isolation of the latter is unnecessary for many purposes. Manila, pineapple fiber, southern moss, straw, rush, maize-fiber, broom-corn, rattan, bamboo, coir, and vegetable sponge will serve as examples.

Manila, sometimes called "manila hemp," is obtained from the fleshy leafstalks of a banana-like plant (Fig. 219) grown almost exclusively in the Philippine Islands. The fiber is extracted by scraping away the surrounding soft



FIG. 218, I.—Jute (*Corchorus olitorius* (A) and *C. capsularis* (D), Linden Family, *Tiliaceæ*). A, flowering and fruiting top of pot-herb jute. D, flowering top of podded jute. (Schumann).—Annuals about 2-3 m. tall; leaves light green; flowers whitish yellow; fruit dry, elongated in pot-herb jute, globular in the other species. Native home, India.
FIG. 218, II.—Podded Jute. Fruit. (Baillon.)

parts with a dull knife. Both a coarse and a fine fiber are thus obtained, the latter coming from near the edge of the stalk. The former is much stronger even than the true hemp, and makes the best of cordage. It is highly valued also for mats, bagging, and sail-cloth, while from old ropes of it is made manila paper. Manila bagging serves for stiffening plaster of Paris in making the building material known as "staff" which is extensively used for the ornamentation of

temporary structures such as those of the Columbian and Pan-American Expositions. The fine fiber is woven by the natives into beautiful fabrics.



FIG. 219.—Manila Hemp Plant (*Musa textilis*, Banana Family, *Musaceæ*). Plant, flowers, and fruit. (Kew Bulletin.)—A tree-like perennial herb from the underground stem of which arise huge leaves whose overlapping stalks make a trunk 6 m. or more in height, and support not only the immense leaf-blades but the heavy cluster of flowers and fruit; leaves pale beneath; flowers inconspicuous, covered by reddish bracts; fruit green, filled with numerous seeds. Native home, Philippine Islands.

The leaves of the *pineapple* (Fig. 111) yield a similar fiber of extraordinary strength and fineness. From the finest of

this is made the celebrated piña or pineapple-cloth of the Philippines—said to be the most delicate and perhaps the most costly of vegetable textiles.



FIG. 220.—Southern Moss (*Tillandsia usneoides*, Pineapple Family, *Bromeliaceæ*). *A*, plant in flower, growing attached to bark. *B*, flower, enlarged. *C*, flower, cut vertically. (Wittmack.)—Perennial herbaceous air-plant hanging from trees to a length of 1-2 m., without roots, covered with grayish scales through which water is absorbed; flowers yellow; fruit dry; seeds hairy. Native home, Southern United States to Brazil.

FIG. 221.—Rush (*Juncus effusus*, Rush Family, *Juncaceæ*). Plant in flower, $\frac{1}{2}$. Calyx, corolla, and stamens. Fruit. Seed, edge and side views. (Britton and Brown.)—Perennial herb 3-12 dm. tall, smooth throughout; flowers greenish; fruit dry. Native home, North America and Eurasia.

The fiber extracted from the stem of the so-called *southern moss* (Fig. 220) by retting is strikingly like horsehair in appearance and stiffness, and is largely substituted for it as

a stuffing in upholstery. The whole plant also is used as packing material.

The *straw* of wheat, rye, barley, oats, and rice (Figs. 1–12) contains so little material besides the fibers, that the whole may be used for many purposes. This straw forms a valuable material for packing, filling of mattresses and the like, thatch, plaiting for straw hats, baskets, and mats; and for coarse paper and pasteboard. What is commonly known as straw matting—the best sort used in place of carpet—is most generally made of the stems of the *rush* shown in Fig. 221.

Coarse mats are sometimes made of the *husks of maize* (Fig. 15) which contain strong mixed fibers similar to those of the straw of the other cereals. These fibers and others like them from the stem and foliage leaves are extracted and put to many uses of which the most important is paper-making.

Broom-corn (Fig. 222) yields the tough, springy material from which most of our brooms and whisk brushes are made. This consists of the slender branches of the flower-cluster, ripened and deprived of their fruit. Each branch or stalk is little more than a bundle of mixed fibers.

Coarse brush material, as for street sweepers, is afforded by the similarly fibrous stems of the *rattan* (Fig. 223). When split or peeled they serve especially well also, under the name “reed,” for basketry, wickerwork, cane seats, etc.

The stems of *bamboo* (Fig. 224) are used widely for similar purposes, and for an almost endless number of other uses. In eastern countries the bamboos form the main dependence of the people in supplying a large share of their needs.

In tropical regions generally the coconut palm (Figs. 34–36) is also depended upon for an immense variety of uses—far too many to be here enumerated. Fibrous material obtained from the leaves has important domestic uses, but the fiber of greatest value is that known as *coir*, which is obtained from the nut husks by rotting away the softer material. Coir makes cordage of extraordinary lightness and elasticity especially valuable for cables and running rigging. Its most familiar use is for door-mats and other matting subject to very hard wear.



FIG. 222.—Broom-corn (*Andropogon Sorghum*, Grass Family, *Gramineæ*). A, flowering top of wild form, known as Johnson grass (*A. halepensis*) from which broom-corn and the various other cultivated sorghums are believed to have been derived. B, flowering top of a cultivated form (var. *vulgaris*) which differs from the form used for brooms (var. *technicus*) mainly in having a more compact flower-cluster. B♂, B♀, staminate and pistillate spikelets, enlarged. D, bract. K, fruit. G, lodicules. (Reichenbach.)—Annual 2-3 m. tall; stem solid; flowers concealed by bracts; fruit a grain. Native home, Mediterranean Region (?).



FIG. 223, I.—Rattans (*Calamus* spp., Palm Family, *Palmaceæ*). Plants showing their method of climbing over trees by means of grappling hooks at the end of the leaves. (Selleny.)—Woody vines sometimes attaining a length of 100 m. or more; leaves dark green above; flowers rosy or greenish; fruit polished. Native home, Tropical Asia and East Indies.

Fibers somewhat similar to those of the coconut husk form a network through the pulp of the sponge cucumber (Fig. 225). These when removed from the ripe fruit form



FIG. 223, II.—Rattans. Flowering and fruiting top (*Calamus adspersus*).
 A, seed. B, same, cut vertically. C, flower-cluster sheath (of *C. Bangka*). (Blume.)

the “vegetable sponge” which druggists sell for bathing purposes. In Japan it is used also in the manufacture of hats, as stuffing for saddles, etc.



FIG. 224.—Bamboo (*Bambusa vulgaris*, Grass Family, *Gramineæ*). Plants in leaf. *A*, cluster of spikelets. *B*, spikelet with stamens protruding. *F*, flower. (LeMaout and Decaisne, Knuth.)—A tree attaining 26 m. in height; stems hollow; leaves rough; flowers concealed by bracts; fruit a grain.

70. Pseudo-fibers are commonly more or less spongy masses of material which are most useful as absorbents, although serving also for other purposes. Amadou and peat-moss are good examples.

Amadou or *spunk* is a felt-like layer of exceedingly slender fibrils found within the rind of a shelf fungus (Fig. 226). Its most important use is as an absorbent in dentistry. Sheets of it resemble chamois or ooze leather and have been used for caps, table mats, etc.

Peat moss (Fig. 227) is largely used as packing material. It is especially valued by horticulturists on account of the

readiness with which masses of the plant absorb and retain moisture.

71. **Woody fibers** as here understood, are either slender twigs with the bark removed, or timber mechanically re-



FIG. 225.—Vegetable Sponge (*Luffa aegyptiaca*, Gourd Family, *Cucurbitaceae*). Tip of vine showing leaves, tendrils, and young flowers, $\frac{1}{2}$. Staminate flower, with corolla spread open. Pistillate flower, cut vertically. Fruit, $\frac{1}{2}$. Same, cut across. (Redrawn from Duthie and Fuller.)—Annual vine; leaves rough; flowers yellow; fruit 30–100 cm. long, greenish with ten darker ribs. Native home, tropics of the Old World.

duced to strips or shreds, or else chemically treated so as to separate the ultimate fibrils for paper pulp. *Osiers* from various species of willow (Fig. 228) afford woody fibers of the first kind which are extensively used for wickerwork. Thin flat strips of willow, poplar (Fig. 253), and other soft woods form the *chip* of which chip hats are braided. Similar strips of ash (Fig. 245), hickory (Fig. 30), and other hard woods which split easily and evenly make the *splint* which is woven into large market baskets, chair bottoms and backs,

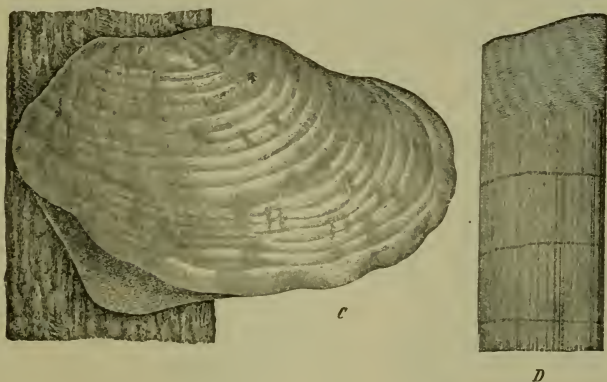


FIG. 226.—Amadou (*Fomes fomentarius*, Pore-mushroom Family, *Polyporaceæ*). *C*, fruit-body growing out like a bracket from the side of a tree, $\frac{3}{4}$. *D*, The same cut vertically, to show the numerous fine tubes extending downward vertically from which the dust-like spores fall. $\frac{3}{4}$. (Hennings.)—Brownish or grayish above, rich brown within. Native home, Eurasia, North America, parasitic on beech, etc.

and the like. White pine and spruce, shredded by machinery, yield the familiar packing material known as *excelsior*. Spruce and poplar are the chief woods used for the *wood pulp* from which the cheaper grades of paper are made, or as an ingredient in book papers of higher quality. Thus the paper of this book is made of cotton rags mixed with poplar pulp.

72. Wood in general. In economic importance woods rank next to vegetable fibers. Just as the great use of fibers is for clothing, which is almost as necessary to us as food, so the great use of wood is for buildings, which are scarcely



FIG. 227.—Peat-moss (*Sphagnum cymbifolium*, Peat-moss Family, *Sphagnaceæ*). 14, plant in fruit, $\frac{1}{2}$. 15, spore-case, with lid still in place, $\frac{1}{2}$. (Kerner.)—Plants soft, yellowish green or purplish; "fruit" dark brown. Native home, throughout the world in bogs and peat swamps.

less needful than clothing. Both materials serve us mainly by their mechanical strength, but with this difference, that whereas a fiber offers but little resistance except to stretching, a piece of wood maintains its form but little changed against severe mechanical strains of whatever sort. Hence the great use of wood for support in structures for shelter, storage, transportation, and repose; and its wide application to innumerable minor uses. The ready separation of vegetable fibers and the facility with which they may be twisted and interlaced is matched by the comparative ease with which wood may be shaped and joined.

The great importance of the wood-working trades, carpentry, joinery, turnery, and carving indicates something of the extent of our dependence upon the material in which they work. A further idea of the usefulness of this material may be gained from a brief review of the more important classes of things which are made wholly or in part of wood, and of the qualities they especially require in the material used.

Buildings require different qualities in the frame, the exterior and the interior finish. Strength, ease of working, and availability in large dimensions are the main needs for the framing timbers; resistance to weather or adaptability

to paint, for exterior finish; while hardness, as little shrinkage as possible, and an attractive appearance when polished are most desirable for interior finish.

Furniture has needs similar to interior finish and at the same time demands special strength.

Domestic utensils have no such need for beauty of material but generally require considerable strength and hardness.



FIG. 228, I.—Willow (*Salix sp.*, Willow Family, *Salicaceæ*). Staminate flowering branch. Pistillate flowering branch. (Baillon).—Trees with yellowish or greenish flowers, dry fruits, and hairy seeds. Native home, throughout the North Temperate Zone.

Boxes, including crates, need to be strong and when used for transportation, as light as possible.

Cooperage, whether “dry,” as flour barrels, or “wet,” as casks and tanks, or “white,” as tubs and pails, calls for wood which is stiff yet elastic and not liable to irregular twisting or warping even when in contact with fluid on only one side.

Vessels, including all sorts of water-craft, present in the hull somewhat similar requirements to wine casks, the chief difference being that the fluid must be prevented from leaking in instead of leaking out. As regards the spars, uniform

stiffness through considerable length together with lightness are most important.

Vehicles, in their running parts, require great toughness together with elasticity in order to meet the very severe and frequent shocks and wrenchings to which they are subjected; while on the body lightness and stiffness are especially desirable.

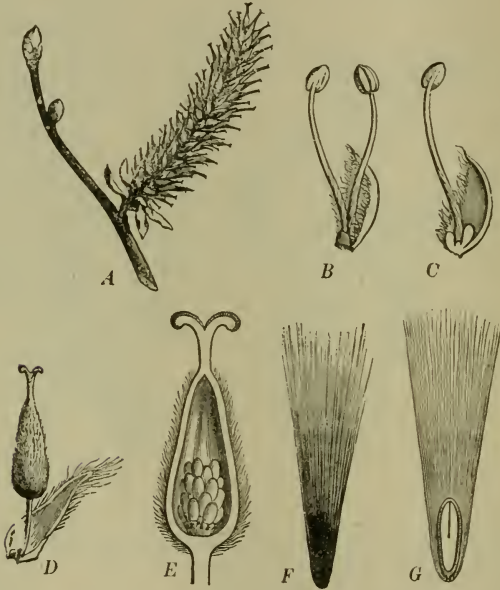


FIG. 228, II.—Willow. *A*, pistillate flower-cluster. *B*, staminate flower, enlarged. *C*, same, cut vertically. *D*, pistillate flower, enlarged. *E*, pistil, cut vertically. *F*, seed, entire. *G*, same, cut vertically. (Baillon.)

Harness though made mostly of other material may consist largely or wholly of wood, as with certain saddles, stirrups, hames, and yokes; and then, as being subject to much the same strains as parts of vehicles, needs scarcely less stiffness, lightness, and elasticity than they.

Road materials, including wooden pavements and railway ties, require blocks or logs of exceptional strength and dura-

bility to stand satisfactorily the heavy loads and the alternate drying and wetting to which they are subjected.

Fences require wood as durable under similar exposure but without the same mechanical strain.

Poles, as for flags and wires, need similarly to resist decay and also to meet about the same requirements as spars.

Trestlework, as for bridges and the like, needs especially stiffness with durability under exposure to weather.

Piling, as the foundation for bridges, wharfs, and so forth, needs not only to be stiff but to be durable under water or in contact with moist soil.

Mine timbering must be equally strong and at the same time able to resist decay under conditions of dampness much more trying than those of entire submergence.

Industrial implements, machines, and weapons, mostly require wood of especial toughness to serve for handles, cogs, spindles, gunstocks, and the like.

Canes and umbrellas call for fancy woods of attractive appearance and considerable stiffness, small dimensions being no drawback.

Surgical appliances such as splints, crutches, and artificial limbs are best made of wood that is both stiff and light.

Recreational appliances such as tennis-rackets, base-ball or cricket-bats, hockey-sticks, golf-clubs, croquet-mallets and balls, nine-pins, balls and bowling alleys, billiard cues, checkers, and chessmen, are made mostly of wood that is especially tough or hard.

Musical instruments such as violins, guitars, and pianos depend for their quality of tone mainly upon the resonance of the wood used in their construction.

Toys are made generally of woods which are most easy to work, and the same consideration largely influences the selection of woods for various *minor articles* such as spools, button-molds, shoe-pegs, toothpicks, and matches. Other uses of wood apart from its value as constructive material will be referred to later.

To the plant which produces it, as to us who use it, wood serves mainly for mechanical support. In large trees the trunk must be a column of great strength in order to hold up

the immensely heavy crown especially when loaded with snow and ice, and severely strained by wind. So also must the branches be joined with great firmness to the trunk, and be stiff enough to hold the foliage well in place. Even the leaves require a woody framework or skeleton to keep their soft, green parts spread open to the sunshine. The woody parts of leaves are continuous with the new wood of the stem which in turn connects with the new wood of the root. What is absorbed by the root is conducted as crude sap mostly through the new wood of root and stem to the food-making parts of the foliage. When as in many trees the new wood is formed next to the bark in successive layers it is distinguished as *sap-wood* so long as it retains its power of conducting sap. After a certain number of years, varying greatly in different kinds of trees, the wood is no longer useful in this way, but becomes more useful mechanically because of increased dryness, compactness, and strength. It is then known as *heart-wood* and is commonly distinguished from the sap-wood by a marked change in color. The color is due to the presence of substances formed as by-products of the plant's activities but of no further use to it, and therefore best accumulated in wood which has ceased to be a channel for sap. The sap-wood is also used by the tree to some extent for the storage of food substances, which have but little color, as for example the sweet sap of the sugar-maple. Such food makes the sap-wood a particularly good feeding ground for wood-boring insects and other parasites which injure or destroy the wood. Its greater liability to the attacks of these destructive agents, together with its inferiority to heart-wood in strength lead commonly to the rejection of sap-wood for constructive purposes; while for ornamental uses as well, heart-wood is furthermore preferred on account of its more attractive coloring. A still further advantage of heart-wood for economic use is the much larger masses of it which may be obtained from large trees. Thus we see that wood, especially heart-wood, is the great massive and resistant material of plants. In slender parts it is, as we have seen, either replaced by fibers or shares with them more or less the service of mechanical support. Viewed broadly, it may be said that wood cor-

responds to the bony skeleton of animals in contrast with their tendons and hairs to which we may liken internal and external vegetable fibers respectively.

A definition of wood in the economic sense requires that it be distinguished principally from fiber, because of the especially close similarity between them. Fibers, we have seen, are sometimes woody, while all true woods, as will presently appear, are fibrous. Cellulose is the main constituent of each. Woods and woody fibers contain in addition to cellulose more or less of a substance (or mixture of substances) known as *lignin*. This is of uncertain chemical composition though known to consist of the same elements as cellulose. Like that substance it permits water and gases to pass readily through it. It is distinguished from cellulose by turning yellow instead of blue when treated with sulphuric acid and iodine. It is the fact that wood is used in comparatively large, firm masses which chiefly distinguishes it from fibers; while it is the fibrousness of wood that most readily distinguishes it from cork and other massive materials to be presently studied. Let us then for our present purpose define wood as the comparatively hard mass of fibrous material which serves mainly for mechanical support in plants and in various artificial structures.

From earliest times wood has been the most widely useful material of construction. Our civilization has been developed largely upon its possibilities. In prehistoric times wherever it was abundant, wood was used almost exclusively for buildings, utensils, and implements; though in regions less favorably situated various substitutes of course had to be found. Even before skill in metal-working had been acquired men were able to shape wood by means of their rude stone tools into many highly useful forms. Thus, only the rudest means are necessary for making from a single log a "dugout" canoe capable of holding many men: a fire kept alive along the top of a fallen trunk burns or chars the wood so that it may be scraped away till the desired form is reached. With the coming of metal tools and their improvement from time to time, more extensive use could be made not only of wood, but also, and for the same reason, of stone and other hard

materials. With still further mastery over metals both wood and stone have lately come to be replaced rather extensively in building by iron and steel. Nevertheless, in spite of the increased facilities for obtaining and working its various rivals, wood is now being used more than ever. During the past fifty years, in this country, each decade has shown a large and steady increase in the amount of wood used proportional to the population. The reason for this must be sought in the remarkable advantages which wood possesses over all other materials for a wide range of uses.

The economic superiority of wood is well shown for example, by comparing it with metals such as iron and steel. (1) The supply of wood under proper forest management is practically inexhaustible and very widespread, while mines are not only exhaustible but strictly local. (2) Wood is cheap, and metals are dear because of the much greater labor required in metal-working. Even as lumber, after long-distance transportation, wood rarely costs more than 50 cents a cubic foot, the price of iron being from \$5 to \$10; while the much greater ease with which wood may be shaped, reshaped, and combined in structures makes it much less expensive to manufacture. (3) Wood is stronger than is commonly supposed. In tensile strength, *i. e.*, resistance to a pull lengthwise of the grain, a bar of hickory exceeds a similar bar of iron or steel of the same weight. Similarly the resistance to compression parallel to the grain (*i. e.*, against the ends of a stick) is found to be greater in a selected piece of hickory or hard pine than in a rod of wrought iron of the same weight and height. Though under certain conditions iron appears to be much stiffer than wood, it is found that a ten-foot beam of hard pine requires considerably more load to bend it by one inch than a similar bar of iron of same weight and length. (4) Wood endures a far greater distortion than metal without losing its power to recover the original form. (5) Wood does not rust or crystallize like metal, and, (6) as wood is a poor conductor of heat it is not only pleasanter to touch but when used as the chief material of dwellings and ships has none of the injurious effects of iron and steel. (7) Wooden beams though combustible, are often safer in case of fire than

iron ones because the latter twist out of shape at high temperature in a way to wreck the entire structure. (8) Being unaffected by wines or other weak acids, and imparting no disagreeable flavor, certain woods may be used for casks where metal would be objectionable or even poisonous. (9) Woods have an organic beauty unrivaled by metals. (10) The peculiar elasticity of certain woods render them incomparably superior to any metal as material for the resonant parts of violins and similar musical instruments. (11) Pieces of wood may be easily and strongly united simply by glueing, while metals require the more difficult operation of welding or soldering. As against wood it must be said (1) that it cannot be melted and cast or rolled; though by steaming, rods or sheets may be readily bent into curves of small radius; and when reduced to pulp, as we have seen, it can be pressed into almost any shape. (2) It shrinks or expands with variations of moisture, more than metals do under ordinary variations of temperature. (3) It decays unless proper precautions are taken to prevent, though under water wood lasts longer than steel or iron. (4) It is more easily crushed than iron and therefore is not so well suited for bearing the greatest weights or for resisting very heavy blows. (5) Finally, the greater hardness of many metals gives them obvious advantages over wood for sharp implements and a large variety of objects that have to stand severe wear. A great deal is often gained by combining wood and metal because the properties of one so largely complement those of the other.

A piece of wood consists essentially of a mass of extremely slender fibers or fibrils, each comparable to a fibril of cotton, but firmly cemented together. The valuable qualities of woods, and their defects as well, depend in great measure upon the character and arrangement of these fibrils and of similar parts associated with them. Therefore some knowledge of the structure of wood helps us to understand its properties and to tell one kind of wood from another; and thus should lead us to a more intelligent, economical use of the material. The fibrous nature of wood is clearly shown by its splintery fracture when broken across the grain and by

its separation into more or less delicate strands when crushed. Those who have had experience in chopping wood know that the ax cleaves as a rule most easily when cutting toward the center of the log; less easily in any other lengthwise direction, and least easily when directed slantingly or directly across the grain. This shows that the structural parts have a peculiarly definite arrangement. Something of this appears when we examine, for example, with a strong magnifier, the surface of a piece of pine wood, cut radially, *i. e.*, toward the center of the log. We see, as shown in Fig. 229, that the wood is made up mainly of very slender, thin-walled tubes

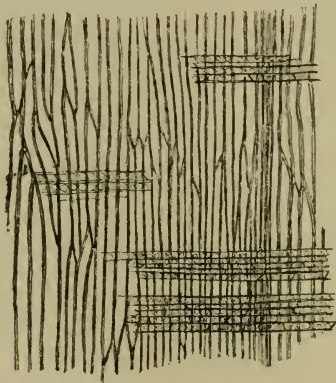


FIG. 229.—Radial section of white pine wood. Magnified about 50 diameters. (Original.)

each closed and tapering at the ends; and besides these are numerous flat bundles of much smaller tubes running at right angles to the others and radially. These bundles of finer structure are called *pith-rays* because they are somewhat similar in texture to a cylinder of *pith* in the center of the log, and some of them at least, are extensions of it. Their relative softness makes the wood most easily separated along the planes in which they lie. Even to the naked eye their peculiar sheen makes the pith-rays apparent on a radial surface, and gives an especially attractive prominence to them in what the dealers call “quarter-sawed” timber. It is plain also that the *fibrils*, by which name we shall understand

the closed longitudinal tubes that form the main part of wood, cannot be all just alike for they occur in alternating layers of darker and lighter color. Examination of these layers under the magnifier shows that in the lighter colored layer the tubes are of decidedly larger bore than those forming the darker layer. The pale layers of less compact material are called *spring wood*, and the more compact layers, *summer wood*, for reasons that will presently appear. On a tangential surface, that is to say, one cut with the grain but not toward the center of the log, these contrasted layers

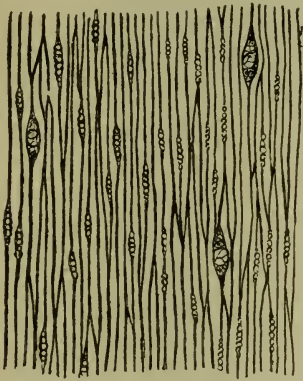


FIG. 230.—Tangential section of white pine wood, $\times 5$. (Original.)

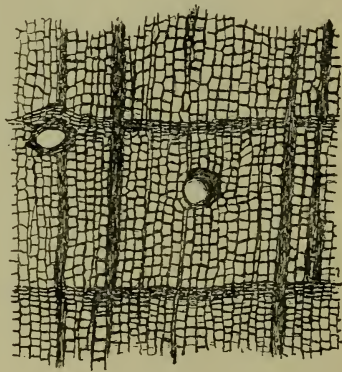


FIG. 231.—Transverse section of white pine wood, $\times 5$. (Original.)

appear as broader bands often in beautiful systems of curves. On such a surface the cut ends of the pith-rays are to be seen under the magnifier (Fig. 230) as small, very narrow spots or streaks. If now we examine a crosscut or transverse section (*i. e.*, a thin slice made at right angles to the direction of the fibrils) the magnifier will show us something more of the form and arrangement of the parts. As shown in Fig. 231 we can look through the central cavities of the tubular fibrils, and so get a better idea of their sizes and shapes and the thinness of the walls. They are seen to be arranged in radial rows, between which the pith rays often appear as more or less delicate lines of dense material. Here and there among

the fibrils we see circular holes many times larger than the fibril-cavities. These are long, tubular reservoirs called *resin-ducts* from the material they contain which oozes out at a wound. On longitudinal surfaces they appear as more or less conspicuous yellowish or brownish streaks.

In many woods there are no resin-ducts present, but there are numerous, commonly empty, canals sometimes considerably larger than resin-ducts and sometimes much smaller in diameter. They form a continuous system of tubes throughout the wood. Their appearance, viewed endwise, is shown for various woods in Figs. 235-241. They are known as *pores* or vessels, and in the sap-wood serve as pipes or reservoirs for conveying upward the crude sap absorbed by the roots or for storing it, together with more or less air, temporarily till needed. They thus share with the wood-fibrils the office of conduction which is performed alone by the fibrils of such woods as pine.

Figure 232 shows in a somewhat diagrammatic way the relative position of the various structural elements found in pine wood, with reference to one another and to the pith-cylinder within and the bark without. Between the bark and the wood is found a thin layer of soft, living material called the *cambium* (c) which is of vital importance because from it, after the first year, all the wood and bark is formed. At the beginning of each season's growth the cambium works vigorously and forms numerous full-size wood-fibrils, but as more and more new wood is added to the old, an increasing pressure results unless the bark yields readily to the strain. In many cases the bark holds firmly and this pressure is partly accountable for the fact that summer wood is commonly more compact than spring wood, which as we have seen results from the progressive flattening of the fibrils in the radial direction. Through the winter the outer bark becomes sufficiently cracked by the action of the weather to relieve the pressure upon the parts within; consequently at the return of spring the cambium can resume its work of wood-building under the most favorable conditions. As a result of these alternating changes of conditions, which in our climate are connected with the annual changes of temperature, we have

in the wood what are known as *annual rings or layers*. In warm regions where comparatively uniform conditions prevail throughout the year, many trees grow continuously and the wood shows no annual layers at all. Sometimes peculiar conditions affecting growth give rise to layers intermediate between the annual ones, and these subdivisions of

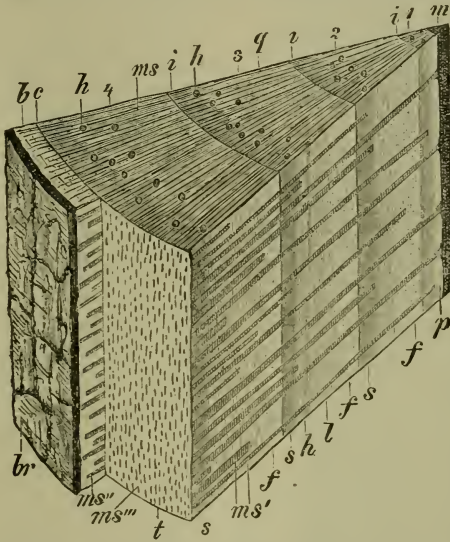


FIG. 232.—Wedge of a four-year-old pine stem cut in winter, showing, somewhat diagrammatically, a transverse surface (*q*), a radical surface (*l*) and a tangential surface (*t*); *f, f, f*, spring wood; *s*, summer wood; *m*, pith; *p*, first-formed wood; *1, 2, 3, 4*, the four successive annual rings of the wood; *i, i, i*, junction of spring and summer wood in successive years; *ms, ms', ms'''*, pith-rays extending through the wood; *ms''*, pith-rays extending into the inner bark (*b*); *h*, resin-ducts; *br*, outer bark, $\frac{1}{2}$. (Strasburger.)

the annual layers may pass entirely around the circumference or they may be only partial. They are deceptive, but to the practiced eye their true nature is usually apparent and wherever well-pronounced layers are present it is generally safe to regard such rings as marking a year of growth.

In the woody plants which form annual rings there is also formed each year in the new shoots a ring of strands each consisting of an inner wood-part and an outer bark-part with

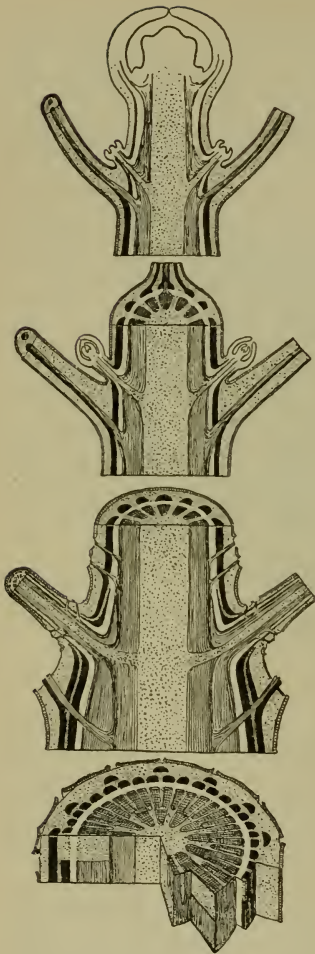


FIG. 233. — Diagram of maple stem showing the development of wood and bark through first and second years. At the tip is a mass of living formative material (shown unshaded) from the sides of which arise protrusions that finally become leaves. Also arising from the base of the very young leaves, are protrusions which develop into formative regions like that of the main tip, and, as growing-points, produce leaf-bearing branches of the main stem. In the center, around the axis, the formative material as it grows older becomes *pith* (shown as dotted), and this pith is continuous with that of the branches. The surface becomes changed into a skin or *epidermis* (shown by coarse shading), covering both stem and leaves. Parts of the formative material between the epidermis and the pith become variously hardened into bundles of fibrous material: around the central pith arise strands of wood (shown by fine shading); near the epidermis arise corresponding strands of bark (shown by black), surrounded by more or less pith-like material which may become green, corky, or otherwise peculiar (shown dotted like the pith); and between the rings of wood and bark is a layer of formative material which is continuous with that of the tip and is called the *cambium*. From this cambium in successive years new wood is added to that within and new bark to that on its outer side, and thus both wood and bark increase in thickness by annual layers. But on the outside the epidermis, and then the older bark, is pushed off or worn away so that the total thickness of the bark is limited. Both wood and bark are continued into the leaves, but not the cambium. The strands of wood and those of bark are so

connected as to form a sort of network through the meshes of which extend radially the plates of pith called *pith-rays*. (Original.)

a layer of cambium between. These strands connect with similar ones in the leaves, and are continuous below with the ring of strands forming between the wood and the bark which was fully formed when the season began (Fig. 233).

The cambium is a continuation of the formative living material out of which the whole young shoot is developed. The living part of such a tree as a maple or pine is thus seen to be like a mantle completely covering the older wood and lining the older bark, renewing each, somewhat as our skin and nails are renewed.

Some trees, such as palms, have no cambium. The trunk in such cases may be regarded as a sheaf of numerous mixed fibers embedded in pith, and growing upward by additions formed in the terminal mass of living material from which the continually expanding terminal bud is derived. As shown in Fig. 234, a cylindrical shaft is the result, instead of the tapering shaft formed by concentric conical layers where a cambium is present. A stem made up of tough strands thus embedded in pith, forms a flexible column often of considerable strength as a whole, and therefore well adapted to resist tropical gales and carry aloft a heavy crown of leaves, flowers, or fruit. At the same time such a stem is economically of some use as a log in rough building, but it does not make serviceable

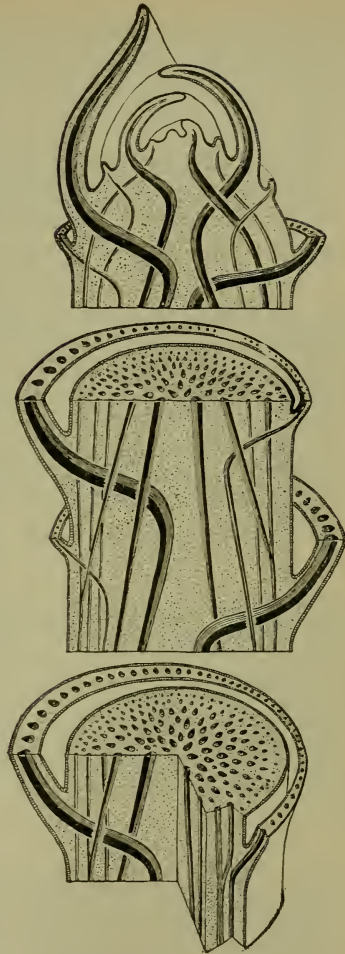


FIG. 234.—Diagram of palm stem showing development, for comparison with that of maple. Corresponding material is shaded as in the previous figure. Note the absence of a cambium, and the uniform diameter of the stem, which is here surrounded entirely by the bases of the leaves. (Original.)

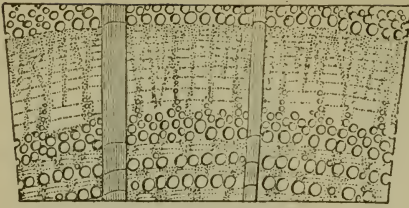


FIG. 235.—Transverse section of white oak wood, $\frac{1}{2}$. (Hartig.)

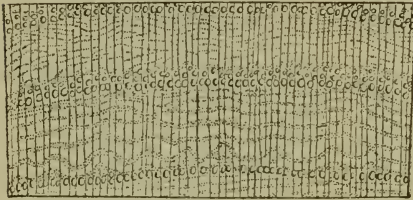


FIG. 236.—Transverse section of elm wood, $\frac{1}{2}$. (Hartig.)

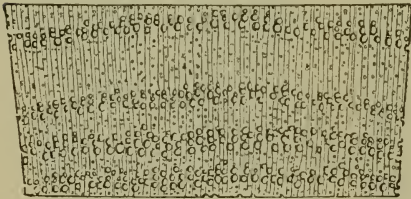


FIG. 237.—Transverse section of ash wood, $\frac{1}{2}$. (Hartig.)

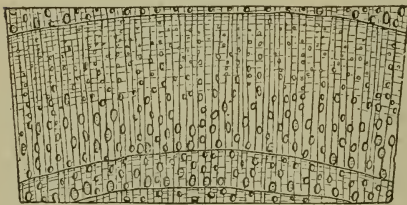


FIG. 238.—Transverse section of walnut wood, $\frac{1}{2}$. (Hartig.)

planks, and is quite unsuited for most of the uses of ordinary wood. Like bamboo, the hard shell of the coconut, and other materials sharing some of the essential properties of ordinary wood but differing from it decidedly in structure, the palm-trunk can scarcely be regarded as a true wood at all. Such materials are best called *pseudo-woods*, to distinguish them from *true woods* which are always formed by a cambium layer.

73. True woods.

The following include the more important woods commonly used in this country:—

Oak (Figs. 235, 242, 243) is used extensively for heavy construction in common carpentry and shipbuilding, and in car and wagon work on account of its extraordinary strength; also in the manufacture of farm implements and parts of machinery because of its hardness and toughness, while its unusual durability

leads to its use for piling, wet cooperage, and railway ties. The great beauty of the wood, especially on radial section as shown in "quarter-sawing," and its susceptibility of fine polish combined with its other valuable qualities make oak

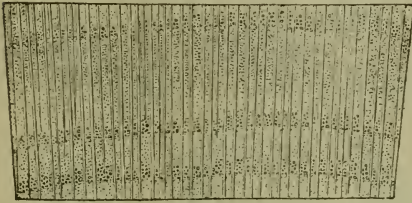


FIG. 239.—Transverse section of plum wood, $\frac{3}{4}$. (Hartig.)

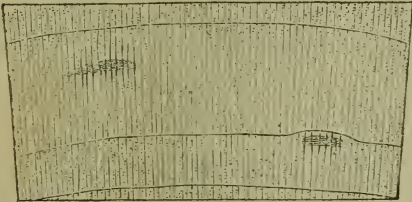


FIG. 240.—Transverse section of birch wood, $\frac{3}{4}$. (Hartig.)

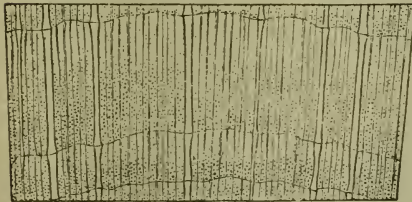


FIG. 241.—Transverse section of beech wood, $\frac{3}{4}$. (Hartig.)



FIG. 242.—Red Oak (*Quercus rubra*, Beech Family, *Fagaceæ*). Flowering and fruiting branch, $\frac{3}{4}$. At the base of the leaf is a pistillate flower. (Britton and Brown.)—Tree growing 40 m. tall; bark dark gray; leaves dull green; flowers greenish yellow; fruit reddish, requiring two years to ripen. Native home, Eastern North America.

one of the most highly valued woods for furniture and interior finish, and even for turnery and carving in spite of its coarse texture. Many species afford timber.

Chestnut (Figs. 24–26) though of less value than oak where much strength is required and of inferior beauty, is, on ac-

count of its great durability and ease of splitting, especially serviceable for fence rails and posts, poles, railway-ties, and cooerage; and it is strong enough to be of considerable use



FIG. 243.—English Oak (*Quercus pedunculata*, Beech Family, *Fagaceæ*). 1, flowering branch. 2, fruiting branch. 3, part of staminate flower-cluster. 4, anthers. 5, anther, cut vertically. 6, pistillate flower. 7, same, cut vertically. 8, winter twig. (Willkomm).—Tree growing 36 m. tall; bark grayish-brown or blackish, deeply furrowed; leaves dark green above, pale beneath; flowers greenish yellow; fruit brownish. Native home, Eurasia and Northern Africa.

in heavy construction, and handsome enough to be substituted for oak not a little in cabinet work and interior finish.

Elm (Figs. 236, 244) has a beauty of grain, especially on the tangential section, which is just beginning to be appreciated by joiners, though on account of its exceeding toughness and non-liability to split the wood has long been highly prized by car-, wagon-, and ship-builders, harness-makers, coopers, and turners. It is unexcelled for hubs.



FIG. 244.—American Elm (*Ulmus americana*, Elm Family, *Ulmaceæ*). Leafy branch, $\frac{1}{3}$. Flower-cluster. Fruit-cluster. Single fruit. (Britton and Brown.)—Tree growing 36 m. tall; bark gray, flaky; leaves slightly rough; flowers greenish; fruit yellowish brown. Native home, Eastern North America.

FIG. 245.—White Ash (*Fraxinus americana*, Olive Family, *Oleaceæ*). Leaf, about $\frac{1}{3}$. Fruit-cluster. Fruit. (Britton and Brown.)—Tree growing 40 m. tall; bark gray, furrowed; leaves dark green above; flowers bronze-green; fruit buff. Native home, Eastern North America.

Yellow locust (Fig. 182) closely resembles elm in its physical properties and is much used for many of the same purposes. It makes the best trenails (for fastening together the beams of vessels) and in this form is largely exported.

Ash (Figs. 237, 245) has a wide range of uses because it is at once hard, strong, stiff, tough, straight-grained, easily split, often beautifully figured, and susceptible of a good polish. It ranks among the most valued woods for interior finish, furniture, parts of implements, machines, harness, carriages, wagons, cars, and ships; and for staves, hoops, oars, tool-handles, clothes-pins, and various toys.

Sassafras (Fig. 160) though neither hard, strong, nor especially pleasing, is exceptionally durable and comparatively light. Hence it is valued in cooperage, for skiffs, and for fencing. Chests made of the wood are said to be somewhat proof against insects on account of the peculiar odor which is supposed to be repellent to them.



FIG. 246.—Black Walnut (*Juglans nigra*, Walnut Family, *Juglandaceæ*). Leaf, $\frac{1}{2}$. Staminate flower-cluster. Fruit. Nut with husk removed. (Britton and Brown.)—Tree growing 45 m. tall; bark rough, brown; leaves downy at least beneath; flowers greenish; fruit brown. Native home, Eastern North America.

FIG. 247.—Wild Black Cherry (*Prunus scrotina*, Rose Family, *Rosaceæ*). Flowering branch, $\frac{1}{2}$. Fruit-cluster. (Britton and Brown.)—Tree growing about 30 m. tall; bark rough and black; leaves smooth above; flowers white; fruit dark purple or black. Native home, Eastern North America.

Hickory (Fig. 30) is one of the very toughest and strongest of our woods, and has the advantage of being straight-grained. Its liability to decay or to be attacked by insects when buried or exposed makes it unsuitable for many purposes, but does not prevent its being an invaluable wood for carriage and wagon stock, for parts of implements and machinery, for tool-handles and timber-pins, and in harness work and cooperage. Several species are used.

Walnut, especially *black walnut* (Fig. 246) has long been a favorite ornamental wood particularly well adapted for join-

ery on account of its strength. The so-called *English walnut* (Figs. 27, 238) is similarly prized abroad; and, like the black walnut with us, is much used in turnery, particularly for

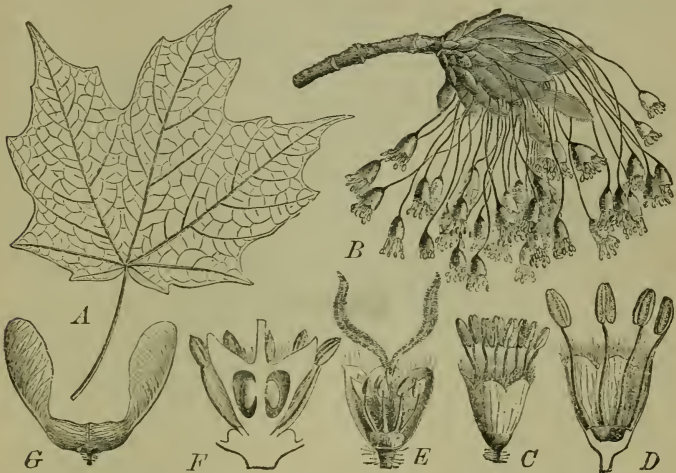


FIG. 248.—Sugar-maple (*Acer Saccharum*, Maple Family, *Aceraceæ*). *A*, leaf. *B*, flower-cluster. *C*, staminate flower. *D*, same, cut vertically. *E*, perfect flower, with part of calyx removed. *F*, same, cut vertically. *G*, fruit. (Pax.)—Tree growing about 36 m. tall; bark grayish; leaves dark green above; flowers greenish yellow; fruit greenish. Native home, Eastern North America.



FIG. 249.—Tulip Whitewood (*Liriodendron Tulipifera*, Magnolia Family, *Magnoliaceæ*). Leaf. Flower. Fruit. (Britton and Brown.)—Tree growing over 50 m. tall; bark brownish; leaves smooth; flowers greenish yellow, orange within; fruit pale brown. Native home, Eastern States.

gun-stocks. *White walnut* or *butternut* (Fig. 28) lacks the strength of the others but is nevertheless of considerable value for interior finish, cabinet work, and cooperage.



FIG. 250, Magnolia, Bull Bay (*Magnolia grandiflora*, Magnolia Family, *Magnoliaceæ*). Flowering branch. Floral diagram. Fruit. (Baillon.)
 —Tree growing 24 m. tall; leaves evergreen; flowers white, fragrant; fruit rusty brown; seeds bright red, dangling on threads. Native home, North Carolina to Texas.

Cherry as found in the lumber market is almost entirely the wood of the *wild black cherry* (Fig. 247) although the wood of other species may sometimes be offered. Its fine texture and attractive color make it one of the most desirable of finishing lumbers. *Plum* (Figs. 95, 239), very similar to cherry, is used similarly but more rarely.

Maple, especially *sugar-maple* (Fig. 248) has all the qualities necessary for flooring, paneling, and other interior finishing. It is highly valued also for the keels of vessels. As a material for furniture "curly" grained or "bird's eye" varieties are in great demand. Its fine texture and uniform hardness adapt it also for shoe-lasts and other form blocks, for shoe-pegs, showbill type, parts of pianos and other musical instruments, and for use in carving and turnery.

Tulip whitewood (Fig. 249) is used in enormous quantities for a great many purposes where fine texture, ease of working, and stiffness are required but not much strength. Interior finishing, furniture, carriage and wagon bodies, parts of implements and machinery, and many kinds of woodenware, boxes, and toys show the wide range of its usefulness.

Magnolia (Fig. 250), has a wood so closely resembling that of the tulip whitewood as to be frequently used for similar purposes.

Basswood, obtained from the linden tree (Figs. 251, 252), resembles the sap-wood of magnolia in appearance and properties. On account of its lightness, uniform texture, and pale color it is used especially for the bottoms of drawers, for carving and pyrography, and because of its stiffness serves well for trunks.

Poplar (Fig. 253) obtained from various species, is a very soft, light wood of limited use in building and furniture making; but found to be suitable for sugar and flour barrels, cracker boxes, crates, and certain articles of woodenware.

Birch (Figs. 240, 254) of various species is a wood resembling cherry in its properties, and when stained to imitate it, is often used in place of the more expensive material for interior finishing and furniture. It is used commonly also for spools, turned boxes, wooden shoes, shoe-lasts, shoe-pegs, wagon-hubs, ox-yokes, and many other carved or turned articles.



FIG. 251.—Elm-leaved Linden (*Tilia ulmifolia*, Linden Family, *Tiliaceæ*). Flowering branch. Flower, enlarged. Same, cut vertically. (Baillon.)—Tree 30 m. or more tall; bark grayish; leaves whitish beneath; flowers cream-color; fruit brownish. Native home, Europe.



FIG. 252.—Linden. Floral diagram. Fruit. Seed, entire. Same, cut vertically. (Baillon.)

FIG. 253.—Poplar, American Aspen (*Populus tremuloides*, Willow Family, *Salicaceæ*). Leafy branch, $\frac{1}{2}$. Leaf. Staminate flower-cluster. Pistillate flower-cluster. Pistillate flower. Seed. (Britton and Brown.)—Tree about 30 m. tall; leaves with stalk flattened at right angles to the blade; flowers greenish; fruit dry. Native home, Northern North America.



FIG. 254.—White Birch (*Betula alba*, Birch Family, *Betulaceæ*). 1, flowering branch. 2, fruiting branch. 3–6, staminate flowers. *6, stamen. 7, part of pistillate flower-cluster. 8, group of pistillate flowers, outer view. 9, same, inner view. 10, bracts. 11, 12, the same as ripened in the cone. 13, fruit. 14, winter twig. 15, a three-year-old twig, cut across. (Willkomm.)—Tree growing 24 m. tall; bark white; leaves and young twigs resinous; flowers yellowish; fruit brown. Native home, Eurasia.

Mahogany (Fig. 255) is pre-eminently the joiner's wood, being preferred to all others for cabinet making of all sorts, interior finish, and ornamental work in general.

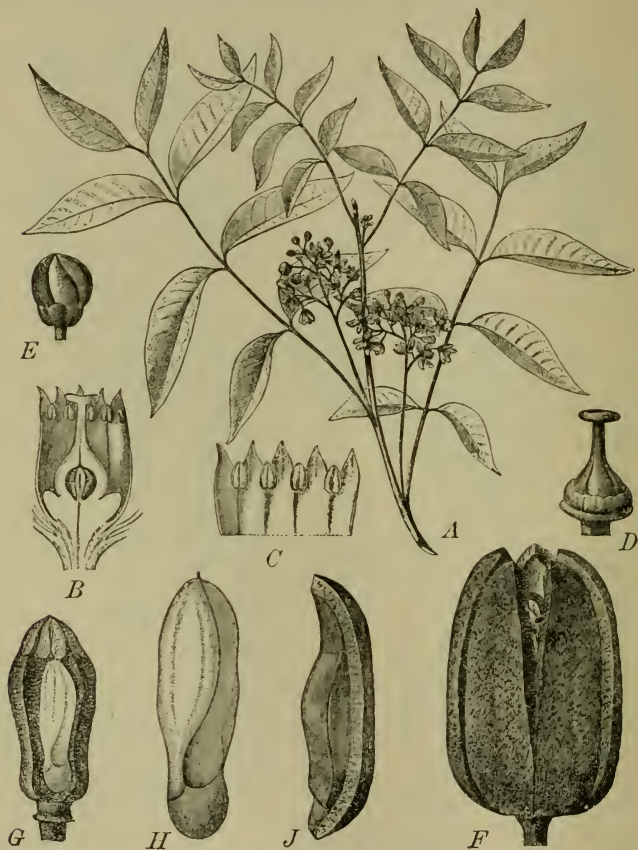


FIG. 255.—Mahogany (*Swietenia Mahagoni*, Melia Family, *Meliaceæ*). A, flowering branch. B, flower, cut vertically, with calyx and corolla removed. C, staminate tube. D, pistil. E, bud. F, fruit. G, central column of fruit with seed attached. H, seed. J, fruit-valve, side view. (Harms.)—Tree 21 m. tall; leaves smooth, flowers greenish yellow; fruit dry. Native home, Tropical America.

Orange-wood (Fig. 106) although attractive, is available only in such small quantities that its use is mostly restricted

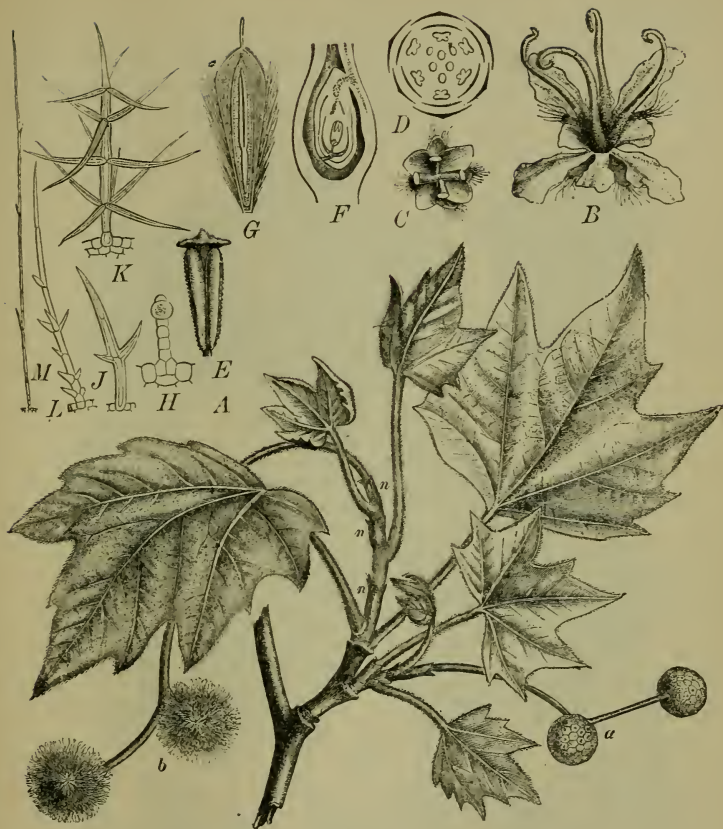


FIG. 256.—American Sycamore or Buttonwood (*Platanus occidentalis*, Plane-tree Family, *Platanaceæ*). A, flowering branch; at *a* staminate flower-clusters, at *b* pistillate flower-clusters, and at *n* the tubular stipules. B, pistillate flower, enlarged. C, staminate flower after loss of the anthers. D, floral diagram. E, stamen of Mexican sycamore. F, ovary, cut vertically. G, fruit, cut vertically. H-K, hairs from leaf, magnified. L, M, fruit hairs, magnified. (Schoenland, Niedenzu.)—Tree growing 40 m. tall; bark, cream-colored with patches of brown; leaves hairy; flowers greenish; fruit brownish. Native home, Eastern States.

to such minor articles as toothpicks, canes, and souvenir ornaments.

Sycamore (Fig. 256) is just coming to be appreciated as an ornamental wood capable of charming effects in cabinet work and interior finishing, especially with quarter-sawed



FIG. 257.—European Beech (*Fagus sylvatica*, Beech Family, *Fagaceae*). 1, flowering branch, showing staminate flower-cluster at *a*, and pistillate cluster above. 2, staminate flower. 3, pistillate flower, cut vertically. 4, ovaries, cut across. 5, fruit with cup and nuts. 6, nut. (Wossidlo.)—Tree growing 35 m. tall; bark smooth and grayish; leaves fringed when young; flowers purplish; fruit brown. Native home, Europe.

stock; though for parts less exposed to view, such as the inside of drawers, and for cooperage and boxes it is extensively used on account of its stiffness and strength.

Beech (Figs. 241, 257) resembles sycamore in its properties, and is used in somewhat the same ways by cabinet makers and turners.

Olive-wood (Fig. 113) on account of its hardness and attractive coloring is prized for many small articles of turnery and carving and for other ornamental purposes.

Apple-wood (Fig. 91) for its similar compactness and uniform, close grain is likewise highly valued for tool-handles, mallet-heads, knobs, and other articles of turnery.



FIG. 258.—Scotch Pine. (*Pinus sylvestris*, Pine Family, *Pinaceæ*). 1, young branch bearing a pistillate flower near the tip. 2, branch bearing staminate flowers. 3, cone, still closed. 4, same open for discharge of the seeds. 5, pistillate flower, $\frac{2}{3}$. 6-8, ovule-bearing scale, front, side and back views. 9, ripe scale with seeds attached. 10, same, back view. 11, seed and wing. 12, lower part of wing. 13, staminate flower. 14, 15, stamens. 16, 17, pollen grains, much magnified. 18, seedling. 19, branchlet bearing two foliage leaves. 20, leaves, cut across, enlarged. (Willkomm.)—Tree growing 36 m. tall; bark rough, brownish; leaves bluish-green; flowers yellowish; fruit reddish brown. Native home, Eurasia.

Pine (Figs. 229-232, 258) is used more extensively than any other kind of wood, and finds a place in almost every wood-working industry. The qualities which give it this pre-eminence are mainly that it works easily, is never too hard to nail (unlike oak or hickory), is for the most part very durable on account of the preservative effect of the resin it contains, and, for the same reason, is not much subject to the attack of insects. The several species which come into the market are sold either as hard or as soft pine but the difference is not always well marked. *Soft pine* (mainly white pine) is the principal wood used in common carpentry, and enormous quantities are consumed also in white cooperage, cabinet work, toy-making, pattern-making, and ship-building; and for crates, boxes, etc. *Hard pine* is most extensively used in heavy construction, especially for bridges and similar exposed work; and is unequalled for spars, masts, planks, ship-timbers, and heavy beams. It has especial advantages for flooring and exposed stairways on account of its durability.

Larch (Fig. 259) is very like hard pine in appearance, qualities, and uses. For ship's "knees" (*i. e.*, angular braces giving stiffness to the frame) the lower part of the tree as it curves naturally when growing in swamps has great advantages. Owing to its durability the trunk is valued also for telegraph-poles and railway-ties.

Spruce (Fig. 260) resembles soft pine in appearance and qualities and is commonly put to the same uses. Being remarkably resonant it is preferred to all other woods for the sounding-boards of pianos, and the bodies of violins, guitars, and similar stringed instruments.

Red cedar (Fig. 261) has just the lightness, softness, and even texture required for lead-pencils; and is used in very large quantities for that purpose, almost to the exclusion of other woods. It also finds a place in cabinet work and for cooperage; likewise for fence posts on account of its unusual durability in contact with soil.

Redwood (Fig. 262) closely resembles red cedar in appearance and qualities and has many of the same uses. Its great durability makes it highly valued for shingles, and its large

dimensions and rich color give it especial advantages for certain purposes in cabinet work and interior finish.

Hemlock (Fig. 263) is soft and stiff though brittle, commonly cross-grained, coarse, and splintery. It is of value chiefly for rough carpentry, and railway-ties.



FIG. 259.—European Larch (*Larix decidua*, Pine Family, *Pinacée*). 1, twig with long and short branches, and with a cone continuing as a branch at *a*. 2, twig with staminate and pistillate flowers. 3, staminate flower, $\frac{1}{2}$. 4-6, stamens. 7, 8, 9, scales from young cone. 10, ripe cone. 11-13, seed-bearing scales. 14, seeds, with and without wing. 15, short branch or "spur," cut vertically. 16, leaf, entire, and cut across. (Willkomm.)—Tree growing 30 m. tall; bark dark grayish-brown; leaves bright green; staminate flowers yellow; pistillate flowers purplish; fruit brownish. Native home, Europe.

74. **Pseudo-woods**, as we have seen, may be defined as more or less wood-like materials which, however, show no trace of pith rays or annual rings.

Under the name *porcupine-wood* the outer harder part of



FIG. 260.—Norway Spruce (*Picea excelsa*, Pine Family, *Pinaceæ*). 1, twig bearing staminate flowers. 2, twig bearing a pistillate flower. 3, ripe cone. 4-6, cone scales, bearing seeds. 7, seeds, with and without wing. 8, stamen, two views. 9, leaf, entire and cut across. 10, seedling, with seed-shell still attached. 11, same, older. 12, a "pineapple gall" produced by the spruce aphid (*Chermes abietis*). (Willkomm)—Tree growing 45 m. tall; bark reddish brown; leaves dark green, glossy; flowers purple; fruit brown. Native home, Europe. Much planted.



FIG. 261.—Red Cedar (*Juniperus virginiana*, Pine Family, *Pinaceæ*). Fruiting branch, $\frac{1}{2}$. Leafy tip. (Britton and Brown.)—Tree growing 30 m. tall; bark brownish, shreddy; leaves dull green; flowers yellowish; fruit light blue. Native home, North America.

FIG. 262.—Redwood (*Sequoia sempervirens*, Pine Family, *Pinaceæ*). Fruiting branch. (Nicholson.)—Tree growing over 100 m. tall; bark reddish brown; leaves mostly scale-like; flowers inconspicuous; fruit brownish. Native home, California.



FIG. 263.—Hemlock (*Tsuga canadensis*, Pine Family, *Pinaceæ*). Leafy branch, $\frac{1}{2}$. Staminate flower. Cone. Cone-scale. (Britton and Brown.)—Tree growing over 30 m. tall; bark flaky; leaves dark green above; flowers yellowish; fruit brownish. Native home, Eastern North America.

the coconut trunk (Fig. 34) is imported for the use of cabinet makers in ornamental work and to some extent for canes. Canes of rather curious appearance are made sometimes also from the mid-rib of the gigantic leaves of the *date-palm*



FIG. 264.—Tree-cabbage (*Brassica oleracea* var. *acephala*, Mustard Family, *Cruciferae*). Plant, $\frac{1}{2}$. (Vilmorin.)—Perennial herb growing 2 m. tall; leaves, etc., as in other forms of cabbage. Native home, Western Europe.

(Fig. 108). Another curious walking-stick is made from the stalk of an extraordinarily tall variety of *cabbage* (Fig. 264). The *bamboo* (Fig. 224) of which there are many species, has, as is well known, a very wide range of uses among which the most familiar to us are for canes and umbrella handles, fishing-



FIG. 265.—Bottle-gourd (*Lagenaria vulgaris*, Gourd Family, *Cucurbitaceæ*). Plant in fruit, $\frac{1}{2}$. Flower. (Vilmorin.)—Annual, climbing by tendrils to a length of 10 m. or more; hairy throughout; flowers white; fruit yellowish or orange, very various in form, sometimes 2 m. long. Native home, Old World Tropics.

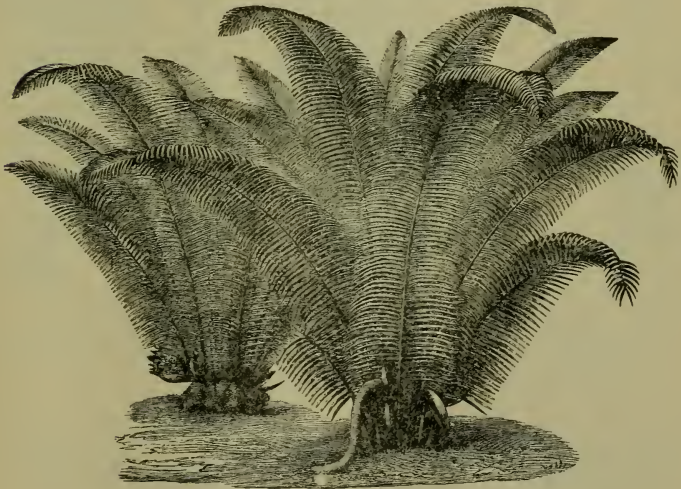


FIG. 266, I.—Vegetable Ivory (*Phytelephas microcarpa*, Palm Family, *Palmaceæ*). Plants, in flower, a staminate plant in front, and a pistillate one behind. (Karsten.)—Shrub with short stem sending up leaves 7-8 m. long; fruit dry. Native home, Tropical America.

rods, articles of furniture, and various ornaments. In tropical and eastern countries where bamboos flourish, the uses to which the light, strong stems are put would require pages to enumerate.

The hard parts of certain fruits may be considered also as pseudo-woods, and are sometimes put to minor uses of importance. The hard inner *shell of the coconut* forms the

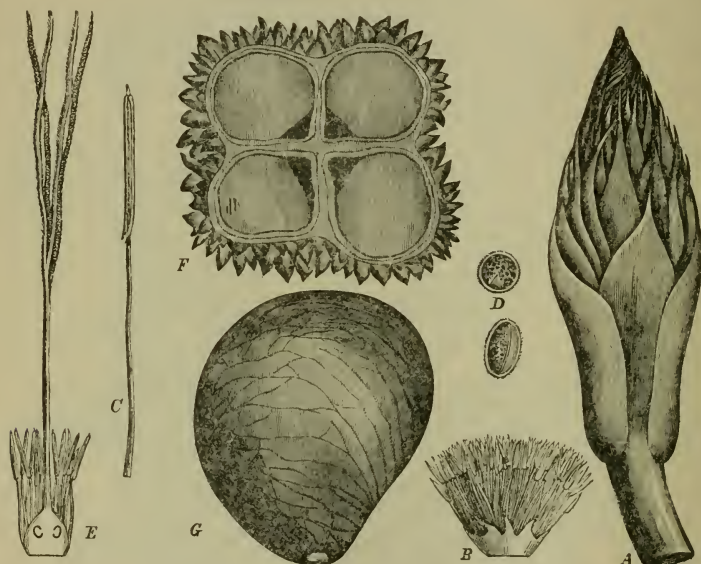


FIG. 266, II.—Vegetable Ivory. *A*, pistillate flower-cluster in bud. *B*, staminate flower. *C*, stamen. *D*, pollen. *E*, pistillate flower, cut vertically, showing pistil accompanied by rudimentary stamens. *F*, fruit, cut across. *G*, seed. (Karsten.)

bowl of the familiar coconut dipper. The shells of various *gourds* (Fig. 265) play a most useful part as vessels for holding liquid or storing food, in the domestic economy of many regions. Finally, may be mentioned the *vegetable ivory* (Fig. 266) which is a seed-food that takes the form of nearly pure cellulose. Large quantities of these seeds are imported and used in place of ivory or bone for umbrella handles,

knobs, buttons, balls, and various other small articles of turnery.

For the most part, pseudo-woods, although sometimes



FIG. 267.—Cork Oak (*Quercus Suber*, Beech Family, *Fagaceæ*). *A*, fruiting branch. *B*, twig with staminate flower-clusters. *C*, staminate flower. *D*, pistillate flower. (Redrawn after Schneider.)—Tree growing 15 m. tall; bark thick and spongy; leaves whitish, hairy beneath; flowers yellowish; fruit brownish. Native home, Southern Europe, and Northern Africa.

locally important, are of comparatively small use and need not here be further discussed.

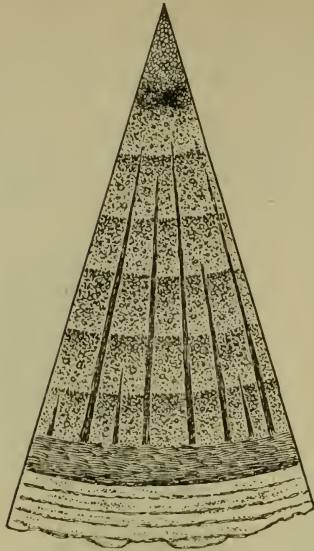


FIG. 268.—Cork Oak. Wedge of trunk cut across to show wood, with strong pith-rays and annual rings, and the thick bark consisting of the outer "virgin cork" (light colored) and the inner "cork mother" (dark colored). (Figuier.)



FIG. 269.—Harvesting Cork. (Figuier.)

75. **Cork** is the light, waterproof, compressible yet elastic material forming the outer bark of the cork oak (Figs. 267-269). Like true wood it is built up of annual layers formed by a cambium. It differs from wood in having the inner layers the younger, in being non-fibrous, and in containing about 70-80% of a mixture of waxy and tallow-like substances which is known as *suberin*. Very many plants produce cork in their outer parts, but only the cork oaks form masses sufficiently large to be of economic use.

The imperviousness to water, the elasticity, and the firmness of cork, upon which its economic value mainly depends, render it in the first place useful to the tree as a protection for the tender inner bark where processes of vital importance are carried on. Since these processes cannot proceed without free access of air the thick cork layer is found to be pierced by numerous breathing channels extending radially to the surface. Besides these channels rifts naturally occur in the outer bark as it is stretched by the increasing bulk of the wood within, and by the new layers of bark.

In the young tree the first few layers of cork are comparatively thick while those formed later are only about 1-2 mm. in thickness and soon become so brittle and so badly cracked as to be unfit for finer uses. Such inferior cork, suitable only for fuel, packing, fish-net floats, rustic work in conservatories, and the like, is all the tree ever produces if left undisturbed. But in cultivation when the trees are from fifteen to twenty years old all of this "virgin cork," as it is called, is cut away, great care being taken not to injure the tender part within known as the "cork mother" because it includes the cambium. The effect of this operation upon the tree is in every way beneficial. Henceforth the cork produced is more abundant, softer, and more homogeneous; the breathing channels are farther apart; and the cracks become far less troublesome. For a century and a half or even longer, at intervals of eight to fifteen years, slabs of fine cork 5-20 cm. thick are peeled from the trunk in the manner illustrated (Fig. 269). The harvesting takes place in summer when the inner bark adheres most firmly to the wood. After being stripped from the tree the slabs of cork are scraped so as to

clean the outer surface, are then flattened under pressure with the aid of heat, and finally tied in bundles for shipment.

By far the most important use of cork is for stoppers. It is estimated that the daily consumption amounts to twenty million. Cork stoppers are cut either by hand or by machinery. Large flat corks have to be cut so that the channels pass from top to bottom. Such corks require, therefore, the use of some sealing material such as wax, to make them impervious. Smaller corks are cut so that the channels go from side to side and hence are air-tight without sealing. In the cutting, about half the material, or more, becomes waste chips. So valuable are the properties of cork, however, that even in this form it may be utilized in important ways. Thus, pulverized and mixed with rubber or with boiled linseed-oil it forms when spread on canvas a floor covering at once durable and sound-deadening. Coarsely ground cork serves well on account of its softness and elasticity as packing for fruit, especially grapes; and, when glued to paper forms a safe wrapping for bottles in transportation. The same remarkable properties make masses of cork most effective buffers for vessels. In the form of thin sheets it has long been used as a material for insoles and hat linings. The lightness of cork has especially recommended it for artificial limbs, handles, net floats, and life-preservers; while the uniform texture and the ease with which it may be shaped have made it valuable to model makers and even to turners and carvers.

Although cork was known to the ancient Greeks and Romans, and there is record of its use by them for the soles of shoes and as stoppers for wine vessels, it has been generally used only within the last few hundred years.

76. Elastic gums, including india-rubber or caoutchouc¹ and gutta-percha,² are tough, more or less elastic and water-proof solids which separate as a curd from the milky juice of a number of tropical plants.

Small quantities of caoutchouc are present also in many of our native plants having a milky juice, but the amount is

¹ Pronounced koo'chuk.

² Ch pronounced as in church.

much too small to be of any economic significance. The use of this juice to the plant is not altogether clear; but from the fact that it flows readily from a cut and after a little while hardens upon exposure to the air, the conclusion seems warranted that it serves in part at least as a ready means of



FIG. 270.—Brazilian Rubber-tree (*Hevea guyanensis*, Spurge Family, *Euphorbiaceæ*). A, flowering branch. B, part of flower-cluster. C, staminate flower. D, same with calyx removed. E, pistillate flower, with calyx removed. (Berg and Schmidt.)—Tree growing 20 m. tall; leaves thin; flowers inconspicuous; fruit somewhat fleshy. Native home, Brazil.

covering wounds promptly with a waterproof protection against agencies of decay.

One of the most important American sources of *caoutchouc* is the Brazilian rubber-tree (Fig. 270). Long before the coming of Europeans the South American Indians made use

of crude rubber for various articles including water-vessels, shoes, and torches. Similar prehistoric use was made by the East Indians of the product they obtained from the india-rubber tree (Fig. 271) which yet remains one of the more important Asiatic sources of this remarkable substance.

Simple, primitive methods of obtaining the raw material are still practised very generally by the natives of to-day who in various parts of the world collect the rubber which is ex-

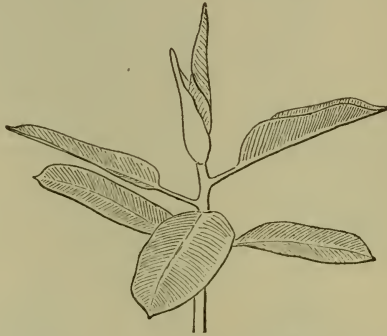


FIG. 271.—India Rubber-tree (*Ficus elastica*, Mulberry Family, *Moraceæ*). Tip of branch showing leaves, the youngest unfolding and still partly enwrapped by the protective stipule-case. (Original.)—Tree growing 30 m. tall; leaves thick and glossy; flowers similar to those of the fig (see page 102); fruit fig-like, greenish-yellow. Native home, Tropical Asia.

ported to Europe and America for manufacture. First, ax cuts are made in the bark of a good-sized tree in such a way that the milk which flows from the wounds will run into little cups so placed as to receive it. The collector on his rounds empties the contents of these into a larger vessel which he finally carries to where the milk is to be curdled. The separation of the caoutchouc from the whey-like part of the milk is accomplished variously; as for example, by mere exposure to the air, or by the addition of water or various salts; but the best rubber is obtained by the process of smoking as practised in Brazil. Over a smoky fire, made by burning Brazil-nut shells or certain palm seeds, the operator holds the broad end of a clay-covered paddle which has been dipped in the fresh milk, and turns it slowly till an even layer

of the rubbery curd has set. Then he dips the paddle into the creamy liquid again, and repeats the operation till successive layers form a cake of considerable thickness. The cake is then cut from the paddle, and hung up to dry until firm enough to pack for transportation. Crude rubber comes into the market also in the form of sheets, balls, or masses of various shapes; and is often mixed with a considerable quantity of clay, bark, and other impurities.

Rubber was first made known to Europe in the report of Columbus' second voyage, where the statement occurs that the Indians were found playing with elastic balls which bounced better than the "wind balls" of Castile. It was not, however, till after the middle of the 18th century that this elastic material came much into use. For many years it was scarcely more than a curiosity, serving in a practical way for little else than to rub out pencil marks. From this circumstance it gained the name "rubber" and was called "india-rubber" because of its importation from the West Indies. Caoutchouc did not come from Asia till much later.

As the unique properties of rubber—its unequaled elasticity combined with its great imperviousness to moisture—became more fully realized, effort was made to bring it into wide use. Thus, it was manufactured into elastic webbing, overshoes, waterproof garments, and various impervious fabrics. Such goods became popular for a while, but their use was much restricted by the fact that the best rubber obtainable was apt to harden and crack in cold weather, and to soften or grow sticky in summer. Moreover, it was found that unprotected surfaces of pure rubber adhere; and that articles made of it were often worthless after a few months keeping, and were ruined by contact with oils. Much futile effort was expended to remedy these defects. Finally in 1844, Charles Goodyear, an American, announced his discovery that mixing a little sulphur with caoutchouc, and subjecting it to considerable heat, produces a substance that is even more elastic than pure rubber, is unchanged by any temperature between -20° and $+180^{\circ}\text{C}.$, is less affected by oils or other solvents of the unchanged caoutchouc, does not become adhesive, and keeps well. This process of combining sulphur

with caoutchouc is called *vulcanization*. By using much sulphur and a high degree of heat hard rubber or vulcanite is produced.

The discovery of vulcanization revolutionized the rubber industry. Not only were the old uses greatly extended but new uses for rubber have so multiplied that caoutchouc now ranks among the most important products of the vegetable kingdom. The elasticity of soft vulcanized rubber makes it invaluable in various articles of dress, for many surgical purposes, for elastic bands, solid or pneumatic tires, for various parts of machines, and for rubber balls, toys, and innumerable other articles of minor use. Its imperviousness to water and air, combined with its flexibility, render it of greatest service for waterproof garments or coverings, submarine diving-dresses, flexible tubes or hose, water-bottles, air-cushions, life-preservers, portable boats, etc. Hard rubber takes a high polish and is very resistant to the action of acids and other corrosive fluids. Therefore it makes the best possible material for photographer's developing trays, certain parts of fountain pens, telephones, surgical instruments, etc., while it is a most excellent and inexpensive substitute for horn or shell in such articles as combs and handles. Both vulcanite and the softer vulcanized rubber are extensively used for insulation in electric work. Pure rubber on account of its remarkable adhesiveness is an indispensable part of the best surgeon's plaster, and of the rubber tape used in repairing bicycle tires and in electric wiring. The curious erasing power of rubber, whether pure or vulcanized, is possessed by no other substance to anything like the same degree; hence one of its earliest uses still remains one of the commonest and most important.

Caoutchouc as a raw material bears, as we have seen, somewhat the same relation to the milky juice of plants that cheese bears to the milk of animals. That is to say, it separates from the fluid part as curd from whey, and becomes solid by drying. Chemically, however, caoutchouc is quite different from the proteid of which cheese mainly consists. Pure caoutchouc is a *hydrocarbon*; in other words, it contains only hydrogen and carbon in its composition. Commonly

associated with it are various substances, regarded as impurities, among which are certain resins. These resins are believed to be derived from the caoutchouc through oxidation since they vary considerably in amount and differ chemically from the hydrocarbon merely by containing oxygen. Such compounds are appropriately called *oxidized hydrocarbons*, and are distinguished from carbohydrates by the fact that the oxygen and hydrogen they contain are not in the proportion of H_2O .

The distinctive characteristic of rubber is its extreme elasticity. A curious result of this is the heat developed when a piece of it is stretched. Thus a sudden warmth is perceptible when a rubber band is quickly stretched in contact with the lip. On account of this property means have to be taken in the manufacture of rubber to prevent overheating when large masses are vigorously worked.

Gutta-percha differs from india-rubber in being very firm and comparatively inelastic at ordinary temperatures, though at about $50^{\circ}C$. it becomes highly elastic and plastic. It resembles caoutchouc in flexibility, toughness, poor conductivity of heat and electricity, imperviousness to moisture, insolubility in dilute acids and in alcohol, and solubility in oil of turpentine, chloroform, naphtha, carbon bisulphid, etc. Unlike caoutchouc, however, gutta-percha is unaffected by fixed oils.

In chemical composition gutta-percha consists like caoutchouc, of a hydrocarbon similarly associated with resinous substances presumably derived from it by oxidation. Unless well purified soon after being collected the change into resin may go so far as to make the whole mass worthless.

Gutta-percha is obtained from several different species of trees all closely related to the taban-tree (Fig. 272) which was the original source. All are confined to the region of Sumatra and Borneo. Owing to the foolish practice of felling the trees to obtain the milky juice, what was for many years the main source of supply is now destroyed. More conservative methods of tapping, similar to those already described for caoutchouc-milk, give a continuous yield for many years. It has been also found that gutta-percha of the finest quality

may be extracted from the leaves by using solvents. In separating the solid from the liquid part of the milk obtained by tapping no special means are necessary. A hard "curd" soon forms. After removal of the worst impurities (sometimes facilitated by boiling) the raw material is pressed into cakes or lumps and is then ready for export.



FIG. 272.—Taban-tree (*Palaquium Gutta*, Sapodilla Family, *Sapotaceæ*). A, flowering twig. B, young fruit. C, flower. D, ripe fruit. E, F, seed. (Burck.)—Tree 13 m. tall; leaves rusty-hairy beneath; flowers white; fruit fleshy. Native home, Malaysia.

The general use of gutta-percha dates only from about the middle of the 19th century. It was first brought prominently into notice by Dr. W. Montgomerie, an English surgeon stationed at Singapore. He found the natives using this extraordinary material for ax handles, sword hilts, and the like. This suggested to him important uses for it in surgery

and various industrial arts; and, thanks to him, manufacturers soon came to realize that it was better adapted for certain purposes than any other substance.

Among the more important or familiar applications of gutta-percha may be mentioned its use as waterproof material in boot-soles, and as cement for leather, etc., its use for piping, for speaking tubes, various surgical appliances, golf balls, and molded ornaments. Its most important use is as insulating material for electric wires, especially cables. The great Atlantic cables and other submarine or subterranean electric lines, upon which modern civilization so much depends, owe their successful operation largely to the gutta-percha used to cover the wires and so protect them and at the same time prevent serious leakage of electricity.

77. Resins, like elastic gums, are derived from liquids exuded by plants, and serve as a protective covering for wounds. The common resin obtained from the pitch or turpentine of pines is a familiar example. More or less fluid at first, owing to the presence of volatile oil, the resinous sap solidifies on exposure to the air, partly through evaporation of the volatile constituent and partly through its oxidation. Finally it may become hard and brittle. In this condition resins resemble various gums. But true gums, as we have seen, are either soluble in water or absorb it indefinitely; while they are insoluble in ether, alcohol, carbon bisulphid, and oils. Resins, on the contrary, are insoluble in water; but are mostly soluble in the other liquids mentioned, at least when hot. Sometimes a gum and a resin are intimately united, forming what is known as a "*gum-resin*." Such a material is asafetida, which we have already studied. The name "gum" is also applied commercially to gum-resins, and resins, and even to rubbery materials; it is most convenient, however, to restrict the term as indicated above, except for "elastic gums" from which no confusion is likely to arise. When a considerable amount of volatile oil is associated with a resin the mixture (commonly of a honey-like consistency as in the turpentine of pines and firs) is distinguished as an *oleoresin*. Resins are always mixtures of several different oxidized hydrocarbons which agree in being

poor in oxygen and rich in hydrogen and carbon, very inflammable, and, from their large proportion of carbon, burning with a sooty flame.

More or less resinous material is contained in the great majority of plants, and in many cases it is abundant and valuable for use industrially. Rosin and copal, which are among the most important resins, will serve as typical examples.

Rosin is so much the most widely known of resinous materials that it is commonly called "resin" as if it were the only substance to which that name could apply. Chemically it is known as colophony. It is one of the products obtained by distilling turpentine. What is properly called turpentine as already stated is the oleoresin which flows from wounded surfaces of pines and similar cone-bearing trees. When this is distilled the volatile parts that pass over and are condensed form the familiar oil or spirits of turpentine, while the residue is rosin. The largest quantities are produced in our Southern States. Rosin is used as an ingredient in common varnishes, is combined with tallow in cheap candles, and is extensively used in the making of yellow soap, inferior kinds of sealing-wax, and various cements. In shoemaker's wax and certain medicinal plasters and ointments it enters as an important part. Musicians depend upon it to rosin the bows of stringed instruments, tin-men and plumbers use it as a flux in soldering, and it serves many other purposes in the industrial world. Its property of generating, when vigorously rubbed, that sort of frictional electricity called "resinous" has led to the use of rosin in certain forms of electric apparatus for experimental purposes.

Copal is a name applied rather indefinitely to a large variety of resins without much in common to distinguish them, but as strictly defined it is understood to include only such as occur naturally in hard masses resembling amber in appearance, and like that substance melting and dissolving only at a comparatively high temperature—a process requiring special precautions to prevent the resin and the solvent from catching fire. These resins make the best varnishes, and that is their main use. The botanical origin has long been

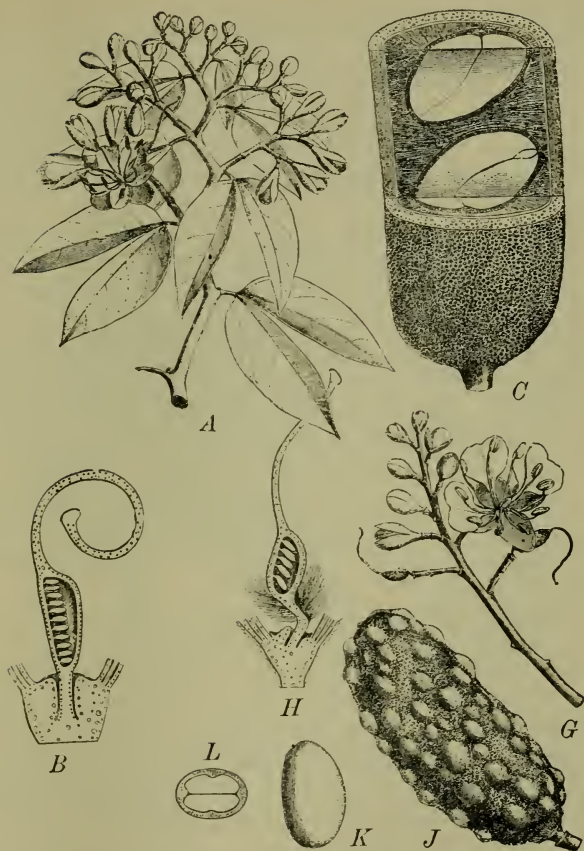


FIG. 273.—Courbaril-tree and Zanzibar Copal-tree (*Hymenæa Courbaril*, and *Trachylobium Hornemannianum*, Pulse Family, *Leguminosæ*). *A*, flowering branch of courbaril-tree. *B*, pistil and base of flower, cut vertically. *C*, part of fruit. *G*, part of flower-cluster of Zanzibar copal-tree. *H*, pistil and base of flower, cut vertically. *J*, fruit. *K*, seed. *L*, same, cut across. (Taubert.)—Courbaril-tree 16–20 m. tall; leaves smooth; flowers white; pod filled with a sweet, mealy pulp. Native of tropical America.—Zanzibar copal-tree of considerable height; leaves with translucent dots; flowers white; pod leathery, not opening. Native home, Tropical Eastern Africa.

uncertain, but it is now known that the finest copal of the East is a product of the Zanzibar copal-tree while the best South American copal is from the nearly related courbaril-tree (Fig. 273). The difficulty of tracing the product to its source arose from the fact that the best copal is dug by the natives out of the earth often in tracts of country from which all plants that could have produced it have disappeared. The hard resin, sometimes covered by an accumulation of three or four feet of soil, is all that remains to show the former existence of copal-trees at that place. It is a fossil. The happy accident of finding leaves, flower-buds, and flowers embedded in masses of Zanzibar copal, finally gave the last link in a chain of evidence connecting the resin with the species which produced it. The South American copal is found embedded in the earth at the base of courbaril-trees, and often contains bits of courbaril-bark. When the resin exudes from the tree and solidifies it is still too soft to be of commercial value; only the slow process of time, perhaps centuries, can bring it to that state of almost glassy hardness which renders it indispensable for making the most durable varnish.

78. Coloring matters of some sort are almost universally present throughout the vegetable kingdom. In many cases they can scarcely be supposed to be of any benefit to the plant which produces them but must be regarded as merely waste products of the plant's activity. This is very commonly true of the vegetable coloring matters used in the industrial and the fine arts as dyestuffs, pigments, inks, or the like. Such substances have been used from the remotest antiquity. In recent times, however, vegetable dyestuffs have come to be very largely replaced by various artificial compounds such as the well-known aniline dyes prepared by chemists from coal-tar. From among the vegetable pigments and dyestuffs that are still of importance in the arts gamboge, indigo, logwood, lampblack, and tan-bark may be selected as typical and familiar examples.

Gamboge is a gum-resin obtained from the Siamese gambogee-tree (Fig. 274) and other Asiatic species of the same genus. The resinous material flows from the bark through cuts,

and is collected in hollow joints of bamboo. In these it hardens into cylinders, which, after they are removed for export, are found to bear the marks of the curious receptacle. Gamboge mixes readily with water, and largely dissolves in oils and in alcohol. For this reason as well as for its bright transparent yellow color it is highly valued by artists as a pigment. It is widely used also to impart a golden tinge to



FIG. 274.—Siamese Gamboge-tree (*Garcinia Hanburyi*, Gamboge Family, *Guttifera*). Branch with pistillate flowers and fruit; *a*, pistillate flower; *b*, staminate flower; *c*, stamens; *d*, pistil surrounded by rudimentary stamens; *e*, pistil; *f*, same, cut vertically; *g*, ovary, cut across. (Baillon, Hanbury.)—Tree about 18 m. tall; leaves glossy; flowers yellowish; fruit cherry-like, reddish brown. Native home, Southern Asia.

varnish intended for certain purposes, especially in lacquer for metal work.

Indigo has been called the "King of Dyestuffs" in recognition of the permanency and strength of its deep blue color, and the supremacy it has maintained over all rivals from the time of its first use in India thousands of years ago even to the present day, although an artificial indigo is now coming into use. Curiously enough the blue coloring matter is not present as such in indigo-plants. It is derived from a sub-

stance called *indican* ($C_{26}H_{31}NO_{17}$) which is extracted by water from the leafy shoots, and, under the influence of an enzym which accompanies it, gives rise to a compound resembling glucose and to *indigo blue* ($C_{16}H_{10}N_2O_2$). A substance which thus decomposes into a sugar and some other compound is known as a *glucoside*. Indigo blue is insoluble in water and can therefore be separated along with certain impurities by filtration. The pasty mass retained is dried in cakes to form the indigo of commerce. The insolubility of indigo blue in water presents a peculiar difficulty to its use as a dye, yet at the same time gives it a great advantage when once it is incorporated with a fiber. The difficulty is overcome by taking advantage of the fact that indigo blue may be readily changed (in various ways which increase the proportion of hydrogen) into a colorless substance called *indigo white* ($C_{16}H_{12}N_2O_2$) which is soluble in dilute alkaline solutions and has the fortunate property of quickly changing back to indigo-blue on exposure to the air. The means commonly employed by dyers to change the indigo-blue is to add indigo to vats containing lime-water in which bran or molasses or some other substance is undergoing fermentation. When the indigo is all transformed and dissolved, a piece of white woolen or cotton soaked in the solution and then exposed to the air soon takes on a permanent blue color.

A considerable number of plants have been found to contain indican, and several different species are cultivated in India and other warm countries for the manufacture of indigo. Of these plants the most important one is the dyer's indigo shrub (Fig. 275).

Logwood is obtained from a small Central American tree (Fig. 276). It is exported in the form of logs from which the sap-wood has been removed. The coloring matter which it yields, is, like indigo, not present in the living plant but is derived from a colorless glucoside called *hæmatoxylin* ($C_{16}H_{14}O_6$) which in turn readily oxidizes to form the deep violet-purple compound known as *hæmatein* ($C_{16}H_{12}O_6$). It is interesting to observe that this transformation involves the loss of two atoms of hydrogen just as does the change of the white indigo into the blue. Unlike indigo, however,



FIG. 275.—Dyer's Indigo Shrub (*Indigofera tinctoria*, Pulse Family, *Leguminosæ*). Flowering branch; *a*, flower, enlarged; *b*, standard (uppermost petal), back view; *c*, wing (side petal), inner view; *d*, *e*, keel-petal, inner and outer views; *f*, flower with corolla removed; *g*, pistil. *h*, fruit, natural size; *i*, seed; *k*, same, cut vertically. (Berg and Schmidt.)—Shrub growing 2 m. tall; leaves downy beneath; flowers reddish yellow; fruit dry. Native home, Southern Asia.

logwood of itself does not make a permanent dye. It requires the use of a mordant, that is to say, some substance such as a salt of iron which fixes the dye upon the fabric. Thus used it makes one of the best blacks for wool or cotton. In combination with iron, etc., it is used also widely in the manufacture of writing inks.

Lampblack is the finely divided carbon deposited from the smoke of rosin or oil burned with slight access of air in

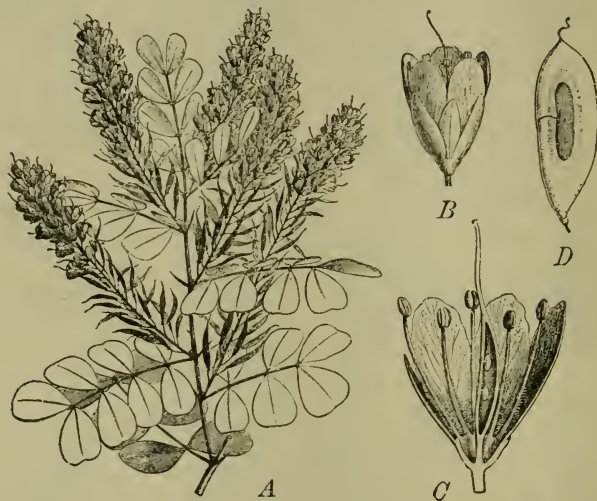


FIG. 276.—Logwood-tree (*Hæmatoxylon campechcanum*, Pulse Family, *Leguminosæ*). A, flowering branch. B, flower. C, same, cut vertically. D, pod. (Taubert.)—Tree about 8 m. tall; leaves smooth; flowers yellow, fragrant; fruit dry. Native home, Tropical America.

a special chamber. It is used extensively in the making of printing-ink, and forms the basis of india-ink and of various black pigments used in painting, leather-finishing, and the like. Lampblack is one of the most important of coloring matters.

Tan-bark is obtained from many trees, including hemlock (Fig. 263), oak (Fig. 243), willow (Fig. 228), chestnut (Fig. 24), larch (Fig. 259), and spruce (Fig. 260), which are rich in tannins. These substances, as already explained in sections 57 and 60, are astringents which are present in

various parts of many plants, and agree in forming an ink-like product when combined with an iron salt. Though chemically more or less diverse they mostly resemble indican and hæmatoxylin in being glucosides, and are believed to be usually waste products of the plant producing them. A property of tannins which renders them especially valuable to the dyer is that they are readily absorbed in solution by cotton, linen, and silk, and will then precipitate various dyes within the fiber, thus serving as a mordant. But the chief property which gives industrial importance to plants rich in tannins is the power which these substances have of so combining with animal skins as to render them permanently pliable and resistant of decay. Hence it is that a hide soaked, under proper conditions, in an extract of tan-bark becomes leather. At the same time, the staining powers of the tannin and associated substances may be taken advantage of to impart a strong color to the product.

79. Oils, whether fixed or volatile, are very generally present throughout the vegetable kingdom; and, as we have already seen, they are often of much economic importance as food or flavoring, and in medicine. They are of scarcely less value in the industrial arts, immense quantities of different vegetable oils being consumed in the manufacture of paints, printing-ink, varnishes, soaps, and perfumery, and as lubricants and illuminants.

As *vehicles for pigments* fixed oils are selected which not only will hold the particles of coloring matter in perfect suspension, and so make it easy to spread them evenly over a surface, but which also will harden promptly when thus spread into a film exposed to the air. Oils which harden in this way are called *drying oils* although the change which takes place depends not upon the evaporation of a volatile solvent, as in the drying of certain varnishes, but upon the absorption of oxygen which changes the oil into a varnish-like substance. *Linseed-oil*, which is obtained by pressure from the seeds of flax (Fig. 217), is the one most widely used by painters. Its "drying" qualities are much improved by boiling. For use in printing-ink the oil is boiled until it is very thick. Other drying oils which are somewhat superior to linseed-oil are

poppy-oil, from the seeds of the opium poppy (Fig. 172), and *nut-oil*, from the kernels of the English walnut (Fig. 27). These being comparatively expensive are reserved for fine painting.

Linseed-oil is invaluable also as a *solvent* for copal and other resins, with which it unites at a high temperature to form the highest class of varnishes. Entirely by itself it is used extensively to give an attractive "oil finish" to wood-work. In certain varnishes the volatile *oil or spirits of turpentine*, known commonly to the trade as "turps," is the solvent used, and is likewise indispensable to painters as a means of thinning their colors.

Any of the fixed oils combined with an alkali makes *soap*. When potash (or lye from wood ashes) is used soft soap is formed; hard soap being made with soda. Chemically the fixed oils are mixtures, in various proportions, of compounds called *glycerides*. A glyceride is so called because it consists of *glycerin* (the familiar sweetish substance soluble in water) combined with an acid. Linoleic, oleic, and palmitic acids are among the most important in vegetable oils. The glyceride of linoleic acid, called linolein, forms 80% of linseed-oil, and gives to this and to other drying oils their peculiar power of hardening by oxidation. Olein, the glyceride of oleic acid, is the main constituent of olive-oil. It is liquid at ordinary temperatures and becomes rancid by oxidation. Palmitic acid forms a glyceride, palmitin, which is not liquid at ordinary temperatures. It is the main solid constituent of coconut and other palm-oils. When any fixed oil is mixed with an alkali, the glycerides present are decomposed each into its peculiar acid and glycerin, and the acids unite with the alkali to form soap, leaving the glycerin free.

Inferior grades of *linseed oil* and other cheap oils are used for soft-soap. Oil from the *olive* (Fig. 113) is used extensively for castile, and other fine toilet soaps. Other hard soaps of various grades are made from "*cocoa-butter*" (see section 39), and oils from *coconut* (Fig. 36), *cotton-seed* (Fig. 215), *peanut* (Fig. 32), and *almond* (Fig. 31).

To give an agreeable odor to soap a large variety of volatile oils are introduced during the process of preparing the product

for market. The oils of *wintergreen* (Fig. 147), *marjoram* (Fig. 137), *coriander* (Fig. 143), *thyme* (Fig. 134), *caraway* (Fig. 140), and many others are thus used to a greater or less extent.

These same volatile oils enter also into the manufacture of *perfumery*; and for this purpose many other volatile oils are more or less in demand, as, for example, the oils of *nutmeg* (Fig. 129), *allspice* (Fig. 123), *sassafras* (Fig. 160), *peppermint* (Fig. 146), *spearmint* (Fig. 135), *orange-peel* and *orange-flowers* (Fig. 106), and the oil distilled from the wood of *red cedar* (Fig. 261). It is to the fragrant oil obtained from the bark of *white birch* (Fig. 254) that the characteristic odor of Russia leather is due.

None but fixed oils can serve as *lubricants*; and of these, only the non-drying ones are suitable. The vegetable lubricants most extensively employed are (1) *olive-oil*, used for this purpose mostly in southern European countries where a sufficiently good quality may be obtained at a low price, (2) *rape-oil* from the seed of a variety of turnip grown widely in northern Europe and India, and (3) *cotton-seed oil* used largely in this country.

As *illuminants* vegetable oils have not to-day the importance they had before the introduction of petroleum lamp-oil and paraffin candles. Nevertheless, large quantities of vegetable illuminants are still consumed, especially in regions where mineral or animal oils are comparatively expensive. Almost all the fixed oils in common use for other purposes have served for burning, but the non-drying oils are preferable. *Olive*, *peanut*, and *rape oils*, which are all rich in olein, are among the best. Palmatin, as we have seen, is an important constituent of *coconut-oil*. This substance separated from the more fluid parts of the coconut-oil and other palm-oils affords an excellent material for candles.

80. Fuel, whether as a source of heat or of power, being indispensable to the carrying on of almost every industry, and being also a necessity for steam-transportation, for the heating of buildings, and for cooking, it is plain that civilization could not have developed as it has, nor could it possibly go on, without this source of heat.

Anything which burns readily in the air will serve as fuel; and, indeed, various sorts of refuse are thus utilized: for example, wheat straw is made to run steam threshing-machines, and the crushed stalks of sugar-cane are used in the boiling of the juice. But, in general, wood, peat, and coal, and their products, charcoal, coke, and illuminating gas, are the fuels most extensively used.

Wood is the most used of all fuels. All woods when perfectly dry consist of nearly 99% of combustible material and about 1% of inorganic matter which remains as ash when the wood is burned. Air-dry wood contains about 25% of water, and in green wood it may be as much as 50%. This water reduces the fuel value not only as taking the place of combustible substances but also as using up the heat necessary for its evaporation. Hence the economy of well-seasoned fire-wood. The value of different fuels may be conveniently compared when stated in terms of the amount of water which a unit weight will evaporate. Thus, green wood is found to yield enough heat to convert about twice its weight of water at 100 C. into steam; air-dry wood about three and a half times; and perfectly dry wood over four times its own weight. So far as chemical composition is concerned soft woods should yield on burning about the same amount of heat as hard woods of equal dryness. In practice, however, considerable differences are found, depending in part upon the ease with which complete combustion may take place, as shown by the amount of smoke, and in part upon compactness of structure, and so forth. Wood as being a flaming fuel is especially well adapted for heating surfaces of large extent, as in the boilers of steam-engines. The small amount and the soft crumbly nature of its ash give wood a further advantage over peat and coal.

Peat consists of the more or less carbonized and compacted deposits of vegetable substances which accumulate in bogs and marshes, and, in the presence of water, slowly decompose. Peat-bogs form chiefly in northern countries. Near the surface they consist largely of moss like that shown in Fig. 227 with which, however, a number of other plants are found growing. In the deeper layers that have been buried for a



Fig. 277.—Coal Plants as they are supposed to have appeared growing in a swamp during the middle of the "Carboniferous Period" believed to be, very roughly, about 40,000,000 years ago. 1, a tree-fern (*Pecopteris*) with brace-roots; to the right, a climbing fern (*Sphenopteris*); below this a prostrate fern trunk (*Megaphyton*). 2. A giant "scouring rush" (*Calamites ramosus*). 3. A giant "club-moss" (*Lepidodendron*). 4. Other "club-mosses," two erect (*Sigillaria*), a conoidal prostrate trunk (*Syringodendron*), and a cylindrical one with large scars (*Ulodendron*); near these are climbing ferns (*Mariopteris*). 5. Large leaved gymnosperms (*Cordaites*); "wedge-leaf" plants (*Sphenophyllum cuneifolium*) trail on the right bank near the front. (Potomé.)

long period of time, the material is so transformed as to be like a soft, brown coal. In regions where wood is scarce peat is highly valued as a fuel. It is commonly more bulky than wood, and has from 5 to 15 times as much ash. Its heating power is about the same.

Coal, like peat, consists of the decomposed and compacted remains of plants. It differs from peat principally in being harder and more completely reduced to carbon. But peat passes into coal by insensible gradations so that none but an arbitrary line can separate them. The coal with which we are most familiar may be regarded as a peat-like material of very great antiquity,—so ancient that the plants from which it was formed have been extinct for many ages. Some idea of the appearance of certain of these coal plants may be gained from Figs. 277, 278. In comparison with wood and peat as a fuel, coal has the advantage of possessing greater compactness and more power of heating. It will convert into steam about 7 to 9 times its own weight of water. The most objectionable features of coal are its large amount of troublesome ash, which often interferes with good combustion, and its offensive smoke, which is excessive from soft coal.

Charcoal burns without flame or smoke, and has over twice the heating power of wood, or as much as the average coal. It is produced mostly by smothered combustion of billets of wood, commonly arranged in conical piles, and covered with earth. When wood is subjected to dry distillation creosote, wood-alcohol, and other volatile compounds pass into the condenser, leaving charcoal in the retort. The charcoal produced at the highest temperature yields most heat when burned, and is therefore of most use in metallurgy; that produced at as low a temperature as possible is the most inflammable and thus the most suitable for mixing with niter and sulphur to make gunpowder.

Coke bears somewhat the same relation to coal that charcoal does to wood. It is similarly obtained by smothered combustion in covered piles, or by heating in special ovens or retorts. Like charcoal it is nearly pure carbon, and is used extensively in metallurgy and for other purposes where a

smokeless fuel is required. It was originally a by-product in the manufacture of illuminating gas. Now it is manufactured expressly for metallurgical purposes, the ovens being so constructed that the inflammable gases driven off are made to serve largely as a source of heat in the process.



FIG. 278.—Fossil remains of a giant club-moss (*Lepidodendron* sp., Scale-tree Family, *Lepidodendraceæ*). From the coal period. (Baillon.)

Illuminating-gas is made by subjecting coal or wood to a high temperature in a retort, and collecting and purifying the gas given off. For obvious reasons coal-gas has proved to be a most convenient fuel especially adapted for household use in large cities.

The study of fuels leads one to think not only of the forests

of to-day and of bog-plants that lived perhaps hundreds of years ago, but in imagination one is led back to strange forests which disappeared from the earth many thousands of years ago and became turned to stone. Therefore, if we ask ourselves, Whence comes this material that men burn to get heat and power? the answer is, From the bodies of plants, some of which lived ages before the coming of mankind. And if we further ask, Whence comes the energy which all these plants have stored in their bodies, and left for us to set free? students of nature tell us, From the sun. That is to say, plants with foliage are the sunbeam-traps of our planet, and except for their marvelous ability to lock the energy of sunshine into the material of food and fuel, the life of the world as we know it would be impossible. How plants are able thus to store up sunshine, and why they do it, are questions to be answered only by the study of their processes of life.

81. Useful and harmful plants in general. From our study of some of the more important groups of economic plants we have learned not only that the very existence of the human race depends upon the vegetable kingdom but also that the progress of humanity at every stage has been profoundly influenced by the properties of plants and by man's knowledge of them. The needs of primitive man must have been met largely by wild plants. Through the cultivation of plants, as we have seen, civilizations were developed in those regions where the most useful plants grew most abundantly. The desire for spices and similar luxuries led to the discovery of America. The vegetable products of the New World are now revolutionizing human life to the remotest ends of the earth.

Our brief study of vegetable foods, food-adjuncts, medicines, and raw products has shown that what we take from plants for our own use has often a similar use for the plants themselves, though sometimes the use is quite different; and in some cases, so far as we can see, the product is of no use whatever in the plant's economy. In other cases it has been found that substances poisonous to us are also poisonous to the plants which produce them, just as the venom of cer-

tain animals may be fatal to themselves. Since, however, some of these plant poisons are among the most valuable of medicines, it is plain that no dividing line exists between harmful and useful plants. Judged in its relation to our welfare the same plant may be either useful or harmful according to what we do with it. Obviously, the more we know about their properties the less likely are we to suffer harm from plants, and the more likely are we to benefit by them.

The student should understand clearly that in this book the aim is only to introduce beginners to the study of plants. Our purpose is merely to lay a good foundation for future studies which shall further advance general culture. There has been no intention of giving here a complete outline of economic botany. Accordingly, a great many plants of high economic importance have not been mentioned; and some of the chief uses of plants, and some of the most serious ways of their working harm, have been passed over with bare mention, or have been ignored. Thus, in regard to the food of domestic animals but little has been said of the fodder raised for them, and nothing at all of pasture plants upon which some of the principal industries of the world depend. The many plants which afford bees the material for making honey and wax, and those which serve as food for silkworms or other insects of economic value have also been neglected. So also have we omitted reference to the plants which do great service in binding shifting sands that but for these sand-binders would devastate extensive areas: to those plants similarly used to prevent the washing away of soils; to trees set out as wind-breaks for protecting tender vegetation, as drainers of swamp land, or for shade and beauty; and to the innumerable flowers and foliage plants cultivated or collected for ornament. Likewise, among harmful plants neither weeds nor destructive parasites have been included.

Not only has our study neglected these groups of plants which especially affect the welfare of mankind but it has been forced to leave out of account some most extensive influences which vitally concern animals in general. For ex-

ample, there is the influence of forests upon water-supply, by which is meant their action as reservoirs feeding the streams gradually in spring, thereby avoiding floods, and at the same time keeping back plenty for the dry season. Then, too, there is the important action of plants in soil-making, and the purifying influence of vegetation upon air and water whereby they are made to serve better the needs of animal life.

All these various relations of plants to the life of the world, and to our own lives in particular, are as profitable and attractive matters of study as any that have claimed our attention; and the student will do well to learn all he can regarding them. It should be said, however, that many of these relations are best understood in the light of vegetable biology. Moreover, the student's pursuit of economic botany cannot well proceed much farther than we have here attempted to go, without his first acquiring such an elementary knowledge of systematic botany as the following chapters may help him to gain.

CHAPTER VII

CLASSIFICATION AND DESCRIPTION

82. Systematic classification. In Chapter I it was pointed out that the large number of plants which botanists have to study has made necessary some sort of classification or orderly arrangement into groups within groups. Plainly, one of the chief requirements of such an arrangement is that it shall bring nearest together those forms which are most alike, while it separates proportionately those which differ more or less from one another. Hence, in general, the most useful classification is that which indicates most truly the degrees of difference and resemblance by its manner of grouping the objects classified.

To construct a classification of plants which shall meet this important condition as fully as possible has long been one of the chief tasks of the science of botany. Indeed, so important has the solution of this great problem seemed to botanists that until comparatively recent times it has engaged their attention almost exclusively. From their labors has at last resulted a classification which, although still incomplete in certain parts, is yet wonderfully adequate in its main features; and whether we consider the vastness of the undertaking or the success already attained, we must recognize it as one of the greatest achievements of the human mind. By its means to-day the student is enabled to gain a wider and deeper knowledge of the world of plants than was ever possible to the most learned botanist of former times.

In the remaining chapters one of our chief aims will be to advance toward a general idea of modern systematic botany. Thus far in our study of useful plants, it has been most helpful to arrange them according to their uses; and it was sufficient for our purpose to mention merely incidentally

the family or other group to which botanists assigned each plant under consideration, leaving the resemblances and differences thus indicated to be realized more or less vaguely by the student. What was then vague we shall strive now to make more definite, and the student may be assured that very much of what he has been learning about economic plants will prove of service in the present study.

83. Early attempts at classifying. Perhaps the reader may ask why it is not sufficient for all purposes of study to classify plants according to their uses, somewhat as we have been doing. Such a method of classification was indeed employed by some of the earlier writers upon plants; and this was quite natural, since, as we have seen, they were concerned chiefly with plants in their relation to human welfare. But granting that every plant may be of some use (even though not yet discovered) we know that many are useful in more ways than one. Consequently, any classification according to uses would often have to include the same plant in several different groups. Moreover, the great majority of plants are not put to any special use, and affect our welfare only in the same general way as do the economic ones apart from their special uses. Hence, any attempt to classify all plants according to use would require us to have besides the economic groups, one general group that would include all plants; and in the subdivision of this group we should be face to face with the original problem.

One of the earliest attempts to avoid this difficulty was a division into herbs, shrubs, and trees. This grouping according to size and general appearance was a step in the right direction, and for certain purposes is found to be a serviceable arrangement even to-day. Yet, aside from the objection that when applied to all known plants each group includes an enormous number of sorts, there is the further disadvantage that such a classification requires one to place in different groups plants which resemble one another more closely than they do any others of the group in which they are placed. Thus, for example, certain oaks which are nothing but shrubs would on that account be separated from all the other oaks which are trees; the same is true of willows and of many

other genera that might be mentioned. Crude as this arrangement was, it afforded for many generations the best general classification of plants that anyone had to offer; and it was not until after the revival of learning in Europe, during the sixteenth century, that any important efforts were made to find a better way.

84. Artificial systems. An attempt was made to overcome the above objection regarding unnatural separation of sorts much alike, by calling the larger shrubs, trees, and the smaller ones, herbs, thus doing away altogether with the intermediate division. This, of course, lessened the difficulty in a way, but can hardly be said to have removed it. To make smaller groups, these two were again subdivided according to differences observed in this or that part. Thus, some writers made subdivisions according to the shape or arrangement of the leaves; others according to the form of the fruit or seeds; others still, according to peculiarities of some part of the flower; and so on, each writer basing his system upon characters taken from one or two parts. Many attempts of this sort were made during the next two centuries.

Some of these systems were decided improvements over the earlier classification, but even the most elaborate of them had the same fundamental weakness already pointed out in the arrangement according to size. We know that plants which differ a good deal as regards a single part may be very much alike in all other respects, while plants much alike in a certain part may be otherwise very different from one another. For example, the fruits of the almond and the peach differ much in appearance when ripe, but otherwise an almond-tree and a peach-tree are almost exactly alike. On the other hand, the root of the beet and of the turnip are often of exactly the same shape, while the plants are strikingly different in all other respects. It is plain, therefore, that any arrangement of plants based upon a single character or very limited set of peculiarities, is bound to be unsatisfactory, because it cannot accomplish the chief purpose of a classification, namely, to group nearest together the sorts that are most alike. In a word, these systems failed chiefly because they are *artificial*, and so not well calculated to ex-

press the resemblances and differences among plants as we find them in nature.

On the whole, as we have said, these artificial systems served to advance botanical knowledge; although after a while the increasing number of them became a serious burden to all who studied plants. Any system, it was thought, if only used by all, would be much better than having to use so many.

At last a practical way out of the increasing confusion was found by the clear-sighted Linnæus who came to the rescue much as he had done in the matter of plant names.

85. The Linnæan system. The great need for some system which would be used by botanists in general, could, of course, be met only by a classification that was more convenient than any of those already proposed. Linnæus was the first to see clearly that the necessary convenience could not be expected in his day from any attempt at a natural arrangement, for the plants to be arranged were as yet very imperfectly known. His predecessors had tried to produce a natural classification on an artificial basis, with results that were neither natural nor convenient. He aimed first of all at convenience, and to this end adopted a frankly artificial basis; yet in spite of this, as we shall see, his system proved to be more natural in many ways than any previously proposed.

In the Linnæan system, the old division into herbs and trees was entirely abandoned; all plants were divided into twenty-four "classes," according to the presence, number, or form of certain essential parts (pistils) of the flower; and these classes were so grouped that all flowering plants were separated from those which have no true flowers. The latter constituted Class 24, *Cryptogamia*¹ or cryptogams, which includes all plants such as seaweeds, mushrooms, mosses, and ferns, that are either destitute of parts such as we find in flowers, or if anything corresponding to such parts are present they are hidden from our unaided sight. The other twenty-three classes include all plants in which floral parts essential to the formation of seed, are manifest,—such

¹ Cryp-to-ga'-mia < Gr. *kyryptos*, hidden.

plants as are now often known as *Phenogamia*¹ or phenogams. Each class was again divided into several "orders" mostly according to the number, etc., of the other essential organs (stamens) of the flower. Under these orders Linnæus grouped all the genera and species of plants known in his day.

The distinctions upon which Linnæus depended were so easy to understand and remember, and afforded such a convenient means of classifying any plant, that the system soon gained an immense popularity, especially in England, and led to a widespread study of plants. Moreover, in his time, explorations in various parts of the world were bringing to light a great many kinds of plants and animals, previously unknown; and as Linnæus had also published a convenient classification of animals, most of those new discoveries were sent to him to name and classify. On the foundations so broadly laid systematic botany progressed much more rapidly and better than ever before, and during more than half a century the system of Linnæus remained practically the only one in use.

We have said that although deliberately artificial, the Linnæan system was remarkably natural in many respects. This is shown in the separation of the cryptogamic from the phenogamic plants; also in the fact that the species of a genus were always kept together, and in the association of many of the genera into orders corresponding to certain of the families recognized to-day.

To understand why this is, we must remember that plants which resemble each other in one particular have very generally other points of resemblance as well; hence, almost any artificial system is bound to be natural to some extent, and to what extent will depend on how far the characters chosen imply other points of resemblance. The reason why the Linnæan system was so natural, was that its founder had the sagacity to choose his characters primarily from the essential parts of the flower; for likeness in these parts involves a great deal of similarity in other respects. Thus, the

¹ Phe-no-ga'-mi-a (written also Phænogamia and Phanerogamia) < Gr. *phaino*, to be manifest; *gamos*, marriage: because the floral organs essential to the production of seed are manifest.

possession of true flowers implies the formation of seeds, and this in turn generally involves an elaborateness of structure in the plant as a whole far greater than is found in cryptogamic plants, which, as we know, lack true flowers and seeds; while among flowering plants it constantly happens (as the reader has doubtlessly already noticed in such familiar examples as the apple, pear, and quince) that close resemblance in the form of the seed-producing parts of the flower goes with fundamental similarity in all other parts of the plant.

With all these advantages it is no wonder that this remarkable system should have exerted the wide influence which it did; but after all it was too artificial to serve permanently as a final solution of the great problem of systematic botany. Thus, for example, the group with two stamens and one pistil includes such widely different plants as olive and sage, while sage is kept far removed from other mints because they have four stamens. No one realized more fully than Linnæus that his system was at best but a makeshift, fit only to serve the temporary needs of the science until botanists should be more extensively and more thoroughly acquainted with plants than would be possible for many years to come; and he regarded his work only as a stepping-stone to the final achievement of an adequate classification.

86. The natural system. As a contribution to the natural system which he firmly believed would be developed in course of time, Linnæus published a series of sixty-seven groups of genera which he called "natural orders." He confessed his inability to define these groups by giving characters which would apply to all the genera of an order, and at the same time serve to separate the orders one from another; and left it for future botanists to discover how far the groups he had suggested really express the fundamental resemblances and differences found in nature. The fuller knowledge of later times has largely justified a good share of these groupings; not a few of Linnæus' natural orders are substantially equivalent to families recognized to-day, and have a place in modern classification often under the

same or similar names. As examples may be mentioned the *Palmæ* or palms, *Gramina* or grasses, *Orchideæ* or orchids, *Compositæ* or composites, *Coniferæ* or conifers, and *Filices* or ferns.

During the life-time of Linnæus, the only other important attempt at a natural classification was made by Bernard de Jussieu, of France, who was a correspondent of Linnæus, and was in charge of the royal botanic garden at Trianon. Here he grouped the plants as far as he could in natural orders, but he published nothing. In 1789, two years after the death of Linnæus, Antoine Laurent de Jussieu, nephew of Bernard, published a classification of genera under natural orders, one hundred in number. These were carefully defined by suitable characters, and thus constituted the first thoroughgoing attempt at a natural system. Not only were the genera grouped into well-defined orders, but the attempt was made to group the orders into higher and higher series, expressive of their degrees of likeness.

On the foundation thus laid over a century ago the natural system now in general use has been slowly developing; the work of improvement is still going on, and more rapidly than ever before. Eventually the science of botany may boast of a systematic classification founded upon, and, in a way, expressing, a full knowledge of vegetable forms. Yet, as we shall hope to show in a future chapter, there are good reasons for believing that such an ideal classification will embody in very large part the distinctions at present recognized, or in other words, that the main features of a truly natural system are fairly well established. The next generation of botanists will doubtless have the advantage of a far better classification, especially of cryptogams, than that in use to-day; but we may well believe that their classification will be essentially the same in general principle and in its main features as that now used. To develop the present system has been a gigantic task, beset with many difficulties; and before we can rightly understand the outcome of all this botanical labor, we must consider still further the difficulties overcome. Until we have mastered certain of these ourselves we are not fitted either to appreciate or to use to

best advantage the important results which botanists have achieved in systematic classification.

87. Technical description. One of the most serious difficulties with which the earlier botanists had to contend was the problem of giving one another a clear idea of what each had seen. It is plain that so long as they failed in this, their discoveries were of little consequence. At first sight it may seem a simple matter enough to tell what one sees, and beginners often wonder why botanists use so many peculiar words in their descriptions. "What is the reason," they ask, "that ordinary English is not sufficient for the purpose?" If the reader has ever attempted to use "ordinary English" in the way proposed, he will realize that it is far from easy to give a clear account of the peculiarities of a plant in that way. The result is much as when a landsman ignorant of nautical terms tries to describe the features of a vessel so that it may be recognized. Success may not be impossible, but such a method of going to work is at its best clumsy, roundabout, and misleading. It was largely because the early botanists had nothing better to use than the ordinary language of their day, that it often proved impossible for others to tell what the plants were that they had tried to describe. But little progress towards a satisfactory classification of plants could be expected as long as descriptions were so vague and incomplete as to be largely unintelligible.

Since an ideal botanical classification represents, as we have seen, the expression of all the resemblances and differences among plants, its attainment must involve the use of words especially fitted to express unmistakably all the peculiarities that may be observed. Each part must have a special name, and the innumerable forms and features of each part must be indicated by simple words or phrases. Ordinary language has not been developed to serve any such botanical purposes any more than it has to serve similar nautical needs; hence, botanists have been forced to make a language of their own consisting largely of technical terms.

88. Early attempts at describing. Before the time of Linnæus, the attempt was made by many botanical writers to avoid the language difficulty by the use of pictures to

show what they meant, much as we have done in the foregoing chapters. A good picture is certainly to be preferred to a description that is not understood; but a little thought will show that pictures, however good they may be, cannot solve the whole difficulty. We cannot make a picture of a species, but merely of a single individual; and our conception of a species must be our idea of the features which all its individuals have in common. A number of pictures of different individuals might convey more of this idea, but even then peculiarities perceptible only by touch, taste, or smell could be indicated only by words. Moreover, even features that may be represented in a picture generally need the help of words to point out what especially calls for attention; and when species are compared and classified one arrives at important general ideas which cannot be pictorially expressed. Add to these shortcomings the greater labor and expense involved in publishing pictures, and it becomes evident that verbal means are needed.

For centuries, as we know, all learned works were written in Latin; consequently, it was from this language that the botanical terms were primarily taken. These were often common words to which a meaning was attached differing from the ordinary one, more or less, in its application; or, sometimes new words had to be coined and this was frequently done by latinizing words or combinations of words taken from the Greek.

As with the early attempts at forming systems of classification, so in the development of a botanical terminology or technical vocabulary, different writers went about the matter in different ways; and such independence of action naturally led in this case also to a good deal of confusion. From this embarrassment of riches, which threatened to be a serious hindrance to further progress, Linnæus, again, found the best means of practical relief, just as he did in the matter of classification and nomenclature.

89. The Linnæan reform in terminology. Being thoroughly familiar with the botanical writings of his predecessors, and endowed with a fine sense of fitness in language, Linnæus was able to choose the best terms which had come into use,

define them in a convenient way, and add others so far as necessary. The publication of this carefully prepared vocabulary gave the necessary material for making botanical description henceforward an art, while in his systematic writings Linnæus left examples of the art, well calculated to serve as models of excellence. In describing a plant his ideal was to state all that was necessary and nothing that was unnecessary to distinguish it from all other plants.

Since the time of Linnæus, botanical terminology has been enriched and improved in various ways to meet the needs which have arisen with wider knowledge; but the art of describing plants still remains very largely what its first great master made it. Pictures are no longer deemed necessary to make up for vagueness of description; when it is possible to use them, their scientific value is much increased because what they lack may be supplied in words, and the significance of what is represented can be made plain. Indeed, to one familiar with the terms used, a complete botanical description calls up so clear a mental picture of each part described, that a drawing sufficiently accurate for recognition might often be made even though no specimen of the plant had ever been seen. Surely this is a triumph such as ordinary language has never attained.

90. Terminology and nomenclature. Persons who have only a superficial acquaintance with botany are apt to think of it merely as a study of names, which hinder rather than help one in learning whatever botanists may know of general interest about plants. Doubtless the student of the foregoing chapters already feels that this is far from true; yet this false opinion conceals a truth which it will be worth while for us to consider.

Special names and descriptive expressions of various sorts do occupy a prominent place in the scientific study of plants, and these botanical technicalities doubtless present a more formidable appearance than the special terms of most other sciences. Yet, paradoxical as it may seem, the very fact that botanists use these means of expressing themselves, makes it much easier for a beginner to arrive at an understanding of what they have to say, and so to a knowledge of

plants, than would otherwise be possible. The unusual fullness of their special vocabulary enables botanists to tell what they know in the fewest possible words and with least danger of being misunderstood. False ideas are the greatest hindrance to the pursuit of knowledge; and whatever will lessen the danger of these, especially to the beginner, is sure to save labor in the end.

We have already seen (page 4) that the practice of having a double name for each species, instead of giving twice as much to remember, as if the name of each sort were a single word, almost halves the burden upon one's memory that one-word names would impose. The ease with which words are remembered depends, as we know, largely upon how frequently the word is encountered; hence, the student is helped not a little by the circumstance that a large majority of specific names are the very words from which the descriptive terms in common use have been derived. Furthermore, these descriptive terms, as well as the names of the parts of plants and of genera and other groups, are in large part made up of a comparatively small number of Latin and Greek words, which once learned serve as helpful aids to the memory, and, indeed, often enable the student to tell at sight the meaning of a new botanical word.

In our study of systematic botany we shall learn the more important descriptive terms as we need them in developing a general idea of the natural classification of plants. The student will learn how to distinguish some of the more important families and higher groups, so that when he examines a plant he can tell at least the sub-kingdom to which it belongs, usually also the class, sometimes the order, often the family, and in certain cases even the genus and species. At first we shall confine our study to those plants which produce flowers and seeds, leaving for later consideration the groups including ferns, mosses, lichens, mushrooms, and seaweeds.

CHAPTER VIII

THE PARTS OF A SEED-PLANT

91. Flax as a type. De Candolle, one of the most learned of French botanists, was wont to say that he could teach all he knew of botany from a handful of plants. What he had in mind was doubtless the great truth that among the resemblances of plants to one another there are some of such fundamental importance that it becomes possible to discern amid the endless variety of forms a few plans of structure upon which all plants are built. His handful of specimens would have been so chosen that each might exhibit especially well the features common to many kinds, and thus serve at once as a convenient standard of comparison and as a means of teaching truths of very wide application. A form which in this way is representative or typical of any group, naturalists call a *type*.

Flax (Figs. 217 I, II) will serve well as our type of phenogams or seed-plants because it possesses all the parts which they commonly show, and exhibits them in comparatively unmodified condition. Like all true flowering plants it produces seeds.

92. The seed may be compared roughly to an egg. Much as in a hen's egg, for example, we have the shell covering a mass of food material provided for the chick or germ which lies within it, so in the seed (Fig. 279A) we find a protective *seed-coat* (c) enclosing *seed-food* (f) and a germ or *embryo*¹ (e). Much of the food provided for the flax embryo is already stored within the little plant itself; what remains to be absorbed has been likened to the white of egg and is called the *albumen*² of the seed. The embryo within the seed is found

¹ Em'bry-o < Gr. *embryon*, germ.

² Al-bu'men < L. *albus*, white.

upon careful examination to be already a miniature plant, for it has a stem (s) bearing at its lower end the beginning of a root (r) which becomes apparent when the seed sprouts; while at the upper end of the stem are borne a pair of fleshy leaves (l) which after sprouting turn green, and between them a tiny bud (b) which is destined to grow into the stem, leaves, flowers, and fruit of the mature plant. Each of these parts of the embryo has been given a special name. The little stem which bears all the other parts is the *caulicle*.¹ Each of the first leaves is a *cotyledon*.² The bud at the top of the caulicle is known as the *plumule*,³ while the rudimentary root at the lower end is called the *radicle*.⁴

93. The seedling and its development. When the seed germinates, the radicle is the first part to appear (Fig. 279B). Soon it grows into a root (Fig. 279C) covered with hairs through which absorption of soil-water takes place. Meanwhile the cotyledons have been feeding upon the albumen to get material for their growth and for the elongation of the caulicle and root; and when finally this reserve food is exhausted, the empty seed-coat is cast off, the cotyledons become green and expand in the sunlight (Fig. 279D), and the plumule develops into a leafy shoot (Fig. 279E). As the root penetrates downwards into the soil it sends forth branches in various directions (Fig. 217I). At the same time the leafy shoot grows upward developing stem and leaves by the continual unfolding of a bud at its tip which began as the plumule (Fig. 279F).

The place at which a leaf joins the stem is called a *node*,⁵ and the length of stem between two nodes, an *internode*.⁶

¹ Caul'i-cle < L. *cauliculus*, diminutive of *caulis*, stalk < Gr. *kaulos*, stalk.

² Cot-y-le'don < Gr. *kotyle*, a shallow cup, which some cotyledons are supposed to resemble.

³ Plum'ule < L. *plumula*, a little plume, which the plumule of certain plants, such as the peanut or almond, somewhat resemble.

⁴ Rad'i-cle < L. *radiculus*, diminutive of *radix*, a root. The term radicle is sometimes used so as to include the caulicle, and caulicle is sometimes made to include the radicle as above defined; but the terms are coming to be understood in the sense here adopted.

⁵ Node < L. *nodus*, a knot, the joint being likened to a knot in a cord.

⁶ In-'ter-node < L. *inter*, between.

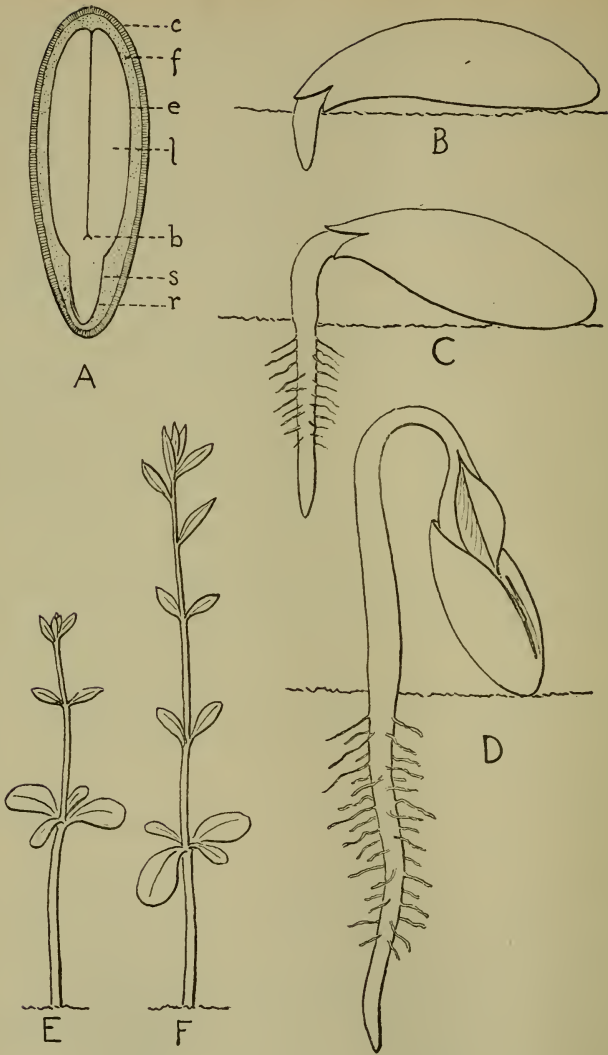


FIG. 279.—Flax Germination. A, seed, cut vertically to show the seed-coat (c), seed-food (f), embryo (e), with its seed-leaves (l), seed-bud (b), seed-stem (s) and seed-root (r). B, seed beginning to sprout; the seed-

After a while new buds appear on the sides of the stem at points just above the nodes (Fig. 280), that is to say, in the *axil*¹ or upper angle between leaf and stem; and these buds as they expand become lateral branches, which in turn may branch similarly. Finally, some of these buds, instead of producing more foliage, develop flowers (Fig. 217I).

94. The flower and the fruit. In the center of the flower (Fig. 217II) we find a *pistil*² containing *ovules*³ within an *ovary*⁴ from the top of which grow five *styles*⁵ each terminating in a *stigma*.⁶ Around the pistil are five *stamens*,⁷ each producing *pollen*⁸ within an *anther*⁹ borne on a slender *filament*.¹⁰ Enveloping the stamens are five *petals*¹¹ and five *sepals*.¹² Pollen falling upon the stigmas, brings about the development of the ovules into seeds while the ovary ripens into a fruit. Pistils and stamens thus being essential to the production of seed are called the *essential organs of the flower*, while the petals and sepals, more or less enveloping them, are called the *floral envelops or perianth*.¹³

95. Physiological division of labor. Even such a cursory examination as we have made of our typical plant is sufficient

¹ Ax'-il < L. *axilla*, arm-pit.

² Pis'-til < L. *pistillum*, a pestle, such as apothecaries use for pounding drugs in a mortar, pistils often resembling pestles more or less in form.

³ O'-vule < L. *ovulum*, diminutive of *ovum*, an egg.

⁴ Ov'-ar-y < L. *ova*, plural of *ovum*; *ary*, repository.

⁵ Style < Gr. *stylos*, a pillar.

⁶ Stig'ma < Gr. *stigma*, a spot.

⁷ Sta'men < Gr. *stamon*, a thread.

⁸ Pol'len < L. *pollen*, fine dust.

⁹ An'ther < Gr. *anthein*, to blossom.

¹⁰ Fil'a-ment < L. *filum*, thread.

¹¹ Pet'al < Gr. *petalos*, outspread.

¹² Sep'al < L. *separ*, separate, different.

¹³ Per'i-anth < Gr. *peri*, around; *anthos*, flower.

stem (caulicle) has just pushed through the seed-coat and is pushing the seed-root (radicle) into the ground. C, later stage in which the radicle has elongated and produced root-hairs, while the caulicle has pushed up the seed. D, still later stage in which the caulicle has become further elongated and arched and the seed-leaves or cotyledons are growing out of the seed. E, plantlet showing pair of cotyledons expanded and ready to act like leaves; also three pairs of primary leaves and a stem developed from the seed-bud or plumule. F, plantlet still older, showing, in addition, secondary leaves, formed one at a joint. (Original.)

to show not a little variety and complexity in the different parts which compose it, and one is aware that much more complexity of structure would appear upon further study. But why the plant should have such a complex structure may not be at first so obvious. We are helped to an understanding of the matter, however, by remembering that wherever there is much variety of work to be performed, it is an advantage to have the labor divided among different sets of workers, each fitted for their special share and coöperat-



FIG. 280.—Flax Bud cut vertically and much enlarged to show the development of the leaves from protrusions arising at the side of the dome-like stem-tip which consists of formative material. (Original.)

ing with the rest. This principle is shown clearly in the community to which we belong, where the labor of meeting the needs of the people as a whole is divided among farmers, miners, manufacturers, merchants, soldiers, teachers, and many other classes, while in each class the work is divided and subdivided again and again. The degree of specialization and coöperation found in such advanced communities as our own chiefly distinguishes them, as we know, from such less advanced communities as the Indian tribes which preceded us upon the American continent; and we say that this was

largely because their conditions of life were simpler and so their needs less than ours. Similarly we should find the higher plants, such as flax, contrasted most significantly with such lower forms as Irish moss in the extent to which they exhibit a differentiation of parts and mutual helpfulness throughout; and we should find a similar reason to hold good. Accordingly, we may not inaptly compare the roots, the stem and its branches, the leaves, and the parts of the flowers and fruit of our plant to the various classes of workers which we find in a civilized community, since the work of the whole is similarly divided among the parts and all labor for the common good. It is such an idea as this that naturalists have in mind when they speak of the *physiological division of labor* observable in a plant or an animal.

96. Organs and their functions. In either a plant or an animal any part having a special office to perform is called an *organ*,¹ the special office being known as its *function*.² Thus the root of our flax-plant is an organ the chief function of which is to absorb mineral substances from the soil. The function of the stem is mainly to support its leaves, flowers, and fruit advantageously; while the general function of its floral organs is to insure the production of good seed; and the function of its fruit is to bring about their dispersal. We often find the same function performed by different organs which are curiously unlike in other respects, as for example the function of support as performed by the tendrils of the pea (Fig. 37), the climbing roots of the poison-ivy (Fig. 210), and the grappling prickles of the rattan (Figs. 223I, II). Organs which agree in function are said to be *analogues*³ of one another, or to be *analogous*. According to their main functions the parts of our typical plant may be classified conveniently as organs of *nutrition* (*e. g.*, the root, foliage, leaves, and cotyledons); of *support* (the stem and its branches); of *protection* (the bark); of *reproduction* (the

¹ Or'gan < Gr. *organon*, an instrument or tool. Since animals and plants are made up of organs they are called *organisms*, and the materials which are present in them alone are called *organic*, to distinguish them from *inorganic* or mineral substances.

² Func'tion < L. *functio*, performance.

³ An'-a-logue < Gr. *ana*, according to, *logos*, relation.

flower); and of *dissemination* (the fruit). The first three of these groups, since they have to do primarily with the individual life of the plant, form what is called the *vegetative system*, while the others being concerned only with propagation and the care of offspring constitute the *reproductive system*.

97. Morphological differentiation. From what has been said of the life history of flax it is plain that the differentiation of its parts progresses as the plant grows older. We saw that the parts of the embryo within the seed are all much alike, as are also the young foliage leaves and floral organs within the bud; but as the plant matures and its needs become more varied the parts come to have different functions to perform and take on the various forms which fit them for their special kinds of work. Thus, the mature flax differs from the same plant in its infancy much as do the higher plants from the lower. But in spite of the progressive differentiation shown by a growing plant we feel that even its more highly specialized organs correspond somehow in a fundamental way with certain of the earlier or less specialized ones. Petals, for example, although widely different from cotyledons in function, are yet in some ways so much like them and like ordinary foliage leaves that cotyledons are often called "seed-leaves" while petals are familiarly known as "leaves of the flower." So, too, in comparing the parts of different plants we often find a fundamental likeness along with marked differences in function. Thus, the climbing roots of the ivy before mentioned are essentially the same in important particulars as the absorbing roots of flax.

Not only among plants but also among animals it is true that analogous organs may show important differences, and similarly that organs which are not analogous may be essentially alike as holding corresponding places in the fundamental plan of structure. A man's arm viewed as an organ for grasping is plainly the analogue of an elephant's trunk, and an opossum's tail; while viewed as a member of the body it corresponds to the fore leg of a horse, the flipper of a whale, and the wing of an eagle. Considerations of this

nature lead us to inquire; What is the fundamental plan of structure exhibited by our typical plant? and What may we rightly regard as the members of such a plant-body?

98. Morphological units. We have seen that the embryo flax is a miniature plant already possessing a stem-part, rudimentary leaves, and the beginning of a root. These parts we recognize as representing the main divisions of the plant, at least before it flowers, for we know that for many weeks as the plantlet grows it simply produces more root, more stem, and more leaves. If we examine minutely one of the leaf-buds (Fig. 280) we find it to contain a series of young leaves which are smaller and smaller as we approach the tip of the stem until finally they appear as mere lobes. Thus we see that a leafy shoot begins as a tiny dome-shaped mass of growing material, which as it elongates, becomes differentiated into (1) lateral lobes, which grow into leaves, and (2) a central or axial part constituting the stem which bears them. Soon in the axils of the young leaves appear growing points like the cone at the tip, and each of these becomes a bud which may develop into a leafy branch. Since corresponding parts arise at regular intervals, the whole shoot, especially as it grows older, takes the form of a series of segments or equivalent divisions each consisting of a leaf-part borne by a stem-section from which a bud or rudimentary branch may also develop. The embryo, we remember, had just these parts, and in addition bore a root. Often, such a shoot-segment cut from a plant and placed under favorable conditions for growth will send out a root, and develop other segments much as an embryo does; and, commonly, a cutting which consists of a single leaf attached to a bit of stem, is the least part of a flowering plant that can be made to grow independently. Hence such a segment consisting of an internode and its node, together with the leaf or leaves it bears, has been regarded as constituting, in a way, a unit of plant structure.

99. Members of the plant body. A plant like flax is sometimes thought of as a colony of segments or in other words as a community of closely connected individuals each consisting of a stem-part and leaf-part, and capable of producing

a root, and so leading an independent existence. On this view each segment would correspond to an individual animal and its leaf-part and stem-part would be likened to the members of the animal body, such as the trunk and the limbs. Without accepting this extreme view of what constitutes an individual plant—a view not in accord with what we have learned about the development of the shoot—it may still be convenient to regard the bodies of the higher plants as built up of segments, much as zoölogists regard the bodies of many segmented animals like earth-worms and lobsters as consisting of a series of roughly comparable units; and, similarly, just as the limb of an animal viewed as one of the main divisions of the body or of a segment is called a member, so the main divisions of a plant-segment—the stem, the leaf, and the root—viewed not as organs but merely as parts differing in origin and position, may be conveniently distinguished as *members* of the plant body.

But the question at once arises, supposing it to be admitted that the vegetating plant may be roughly likened to a many-storied building, each story being a segment, and the whole supported on a root foundation, can we yet find corresponding units of structure in the flower? If the flower is composed of segments it is evident that the different members must be more or less disguised. As regards the floral envelopes we have already seen that their leaf-like nature is so thinly disguised that they are commonly recognized as “leaves of the flower.” Indeed, we have only to suppose the internodes of the stem-parts to have remained as short as they were in the bud, while the leaf-parts expanded, to see that so far as origin and relative position are concerned, the floral envelopes are essentially like a leaf-rosette. But the stamens and the pistil present greater difficulties. Still, when we come to compare other flowers with those of the flax, we shall find much evidence going to show that even stamens and pistils correspond in large part to leaves. One sort of evidence—not indeed conclusive, but yet significant—is the occurrence now and then of monstrous flowers in which actual green leaves occupy the place of the stamens and pistil, much as if the organs had determined to throw off all dis-

guise and exhibit their true nature.¹ The proof of a theory is in the using; for the present it will be enough for us to have gotten a preliminary idea of what the segment theory means when applied to our typical plant.

Other questions, closely connected with the foregoing one, are, What members may a segment have? and, How may these be distinguished under all their disguises? The flax embryo, as we have seen, represents a segment reduced to about its simplest terms. We here recognize an axial member bearing lateral members,—the stem-part and the leaf-part,—one implying the other. When the root-part appears we have another member which is also axial, but differs from the stem in being without leaves. As the root elongates there appear near its tip numerous hair-like projections which differ essentially from leaves in being merely superficial outgrowths not continuous with the innermost parts as is the case with leaves. Superficial appendages of this sort often occur in other plants on the stem and leaves as well as on the root. Such more or less hair-like outgrowths are best regarded as parts of members rather than as members. In the essential organs of the flower we meet with a difficulty regarding the real nature of the *pollen-sacs* and ovules or *egg-sacs* as we may call them. In the flax they both might be taken to be parts of the peculiar leaves which we regard as forming the stamens and pistil. But there are other plants, as we shall see, in which an ovule appears on the very tip of the stem or axis, while in some cases pollen-sacs seem to grow directly from the stem. We can then hardly call such organs parts of a leaf. On this account and for other reasons

¹ The theory of floral structure which likens a flower to a leaf-rosette originated with the poet Goethe to whom it was suggested by seeing a green rose such as occasionally appears in gardens. This theory has proved to be a helpful means of understanding the relation of the various parts of plants to the fundamental plan of structure; but as it tells only part of the truth it has been somewhat misleading, and it requires to be modified considerably from its original form to be in accord with more recent views of vegetable morphology. As developed above, however, it is believed that the theory will be found to avoid the unwarranted assumptions which have brought into it discredit, and to retain the features which have made it useful, while at the same time such modifications are made as will render it a valuable means of conveying modern views.

which will appear later, we are led to regard both pollen-sacs and egg-sacs as distinct members of the plant body. We thus come to the conclusion that our typical plant viewed morphologically is made up of members of the nature of stem, leaf, root, pollen-sac, and egg-sac; and that the whole body may be furthermore regarded as consisting of a chain of segments, each segment having at least a stem-part and a leaf-part and sometimes also other members.

A *root-member* may be defined in a general way as typically a descending axis; a *stem-member* as an ascending leafy axis; and a *leaf-member* as a lateral, transversely flattened out-growth from a stem. Since stems and leaves imply one another, it is convenient to speak of them together as forming a *shoot*. Thus in our flax embryo the caulicle, cotyledons, and plumule constitute the shoot as distinguished from the root-part. A *sac-member*, such as a pollen-sac or an egg-sac, is really, as we shall see later, a spore-case essentially like that of *Lycopodium* (Fig. 166,2). Pollen grains are spores; and each egg-sac contains one or more comparatively large spores within which an embryo arises. Thus a sac-member is known by what it produces. As to how these different members may be further distinguished we shall learn more fully when we come to compare other plants with our type.

100. Homologies. We have already seen that the terms analogy, analogue, and analogous, afford us a means of expressing physiological equivalence or similarity in function. To express morphological correspondence or similarity in origin and position naturalists use the companion terms *homology*,¹ *homologue*, *homologous*. Members of the same sort are said to be homologues of one another; any form of leaf-member, for instance, being homologous with any other form. Cotyledons and petals are homologues, because both are leaf-members, and they would accordingly be spoken of as homologous parts, homologous organs, or homologous members. The principal parts of our typical plant and their homologies as here understood are indicated in the accompanying diagram (Fig. 281).

The tracing of homologies forms the basis of morphology,

¹ Ho-mol'o-gy < Gr. *homos*, same.

just as the morphological study of plants forms the scientific basis of systematic botany. To a certain extent the conceptions involved are necessarily abstract, or, so to say, diagrammatic; for the parts of plants are thus viewed only in one aspect, and for the sake of being able to think of them



FIG. 281.—Diagram of a typical flowering plant showing the principal parts and their homologies. Root-members are black; stem-members, shaded with lines running lengthwise; leaf-members, shaded with lines across; and sac-members, unshaded. (Original.)

simply many facts are deliberately left out of account. The conclusions reached nevertheless may be true so far as they go, and are valuable aids to fuller knowledge; but the student should remember that natural objects are never diagrammatic and that Nature does not draw the sharp lines of distinction which we may find it useful to assume.

CHAPTER IX
THE CROWFOOT FAMILY

101. General features. In several respects the crowfoot family is the best one with which to begin our study of plant groups. It forms an especially serviceable standard of comparison because its members, as we shall see, are remarkably simple in their plan of structure—at least for seed-plants—and at the same time the various species display a wide range of variety in detail. Moreover, it was his careful study of this family which led the younger Jussieu to an understanding of those fundamental principles of classification which he applied so brilliantly in founding the natural system. To us it will present problems which once solved will simplify and illuminate all our future study.

Of the plants already examined the following, as we have seen, are of this family: marsh-marigold (*Caltha palustris*, page 198), tall buttercup (*Ranunculus acris*, page 216), ditch crowfoot (*R. sceleratus*, page 216), wind-flower (*Anemone nemerosa*, page 205), and monkshood (*Aconitum Napellus*, page 191). The family is made up of about 700 species in about 30 genera. From the few examples above given and a study of those shown in Figs. 282–297, we may gain, however, a fair idea of the range of peculiarities exhibited by the family as a whole. At first sight it may seem scarcely possible to find among plants which differ so much one from another any peculiarity or set of peculiarities common to all and yet not possessed by other seed-plants. Examination will show us, however, that as a group they may be distinguished at least by the lack of complicating features which other families show, and we shall find furthermore a few positive peculiarities which are more or less characteristic.

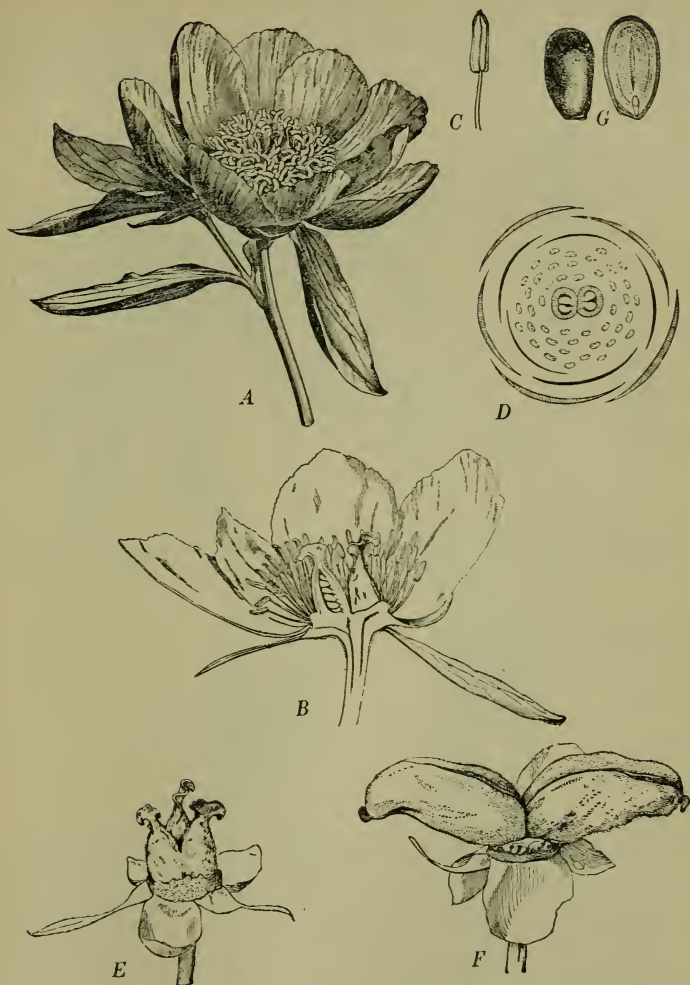


FIG. 282.—Peony (*Paeonia officinalis*, Crowfoot Family, *Ranunculaceae*). A, flowering branch. B, flower, cut vertically. C, stamen. D, floral diagram. E, flower, with stamens and petals removed. F, fruit. G, seed, entire, and cut vertically. (LeMaout and Decaisne.)—Perennial herb growing 1 m. tall; leaves dark green above; flowers crimson; fruit hairy. Native home, Europe.

102. The vegetative organs compared. Let us begin by comparing the marsh-marigold as a type of the family with the other representatives here illustrated. This plant we



FIG. 283.—Christmas Rose and Mouse-tail (*Helleborus niger* and *Myosurus minimus*. Crowfoot Family, *Ranunculaceae*). 1, Flowering plant of Christmas rose, $\frac{2}{3}$. 2, flowering plant of mouse-tail, $\frac{2}{3}$, with flower, enlarged, above. (Kerner.)—The Christmas rose is a perennial herb, about 30 cm. tall; leaves evergreen, glossy; flowers white or pinkish; fruit dry. Native home, Europe. The mouse-tail is an annual with greenish flowers and dry fruit. Native to Eurasia, Northern Africa, Australia, and North America.

know to be an herb (see page 198) because the parts above ground are too tender and succulent to live through the winter. The roots do persist however, and serve as store-houses for food which the plant uses in the following spring.

Thus it is enabled to live from year to year, or, in a word, is a *perennial*. Whenever we find an herb retaining the remains of more or less withered leaves and stems, or of shrunken roots

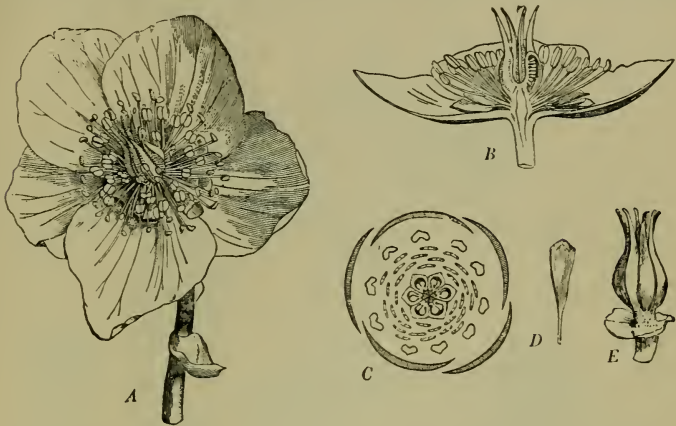


FIG. 284.—Christmas Rose. *A*, flower, entire. *B*, same, cut vertically. *C*, floral diagram. *D*, staminode. *E*, pistil. (LeMaout and Decaisne.)



FIG. 285, I.—Mouse-tail. Flower, entire. Same, cut vertically. (Baillon.)

evidently belonging to a previous year, and at the same time having organs, underground or near the surface, swollen with food evidently destined to supply material for the

growth of buds fitted to live over the winter we may safely conclude that we have a perennial plant. If, on the con-



FIG. 285, II.—Mouse-tail. Pistil, entire. Same, cut vertically. Staminode. (Baillon.)



FIG. 286.—Fennel-flowers (*Nigella sativa* and *N. damascena*, Crowfoot Family, *Ranunculaceæ*). *A*, flowering top of *N. sativa*. *B*, flower, cut vertically. *C*, stamen. *D*, staminode. *E*, fruit. *F*, pistil. *G*, seed, entire, and cut vertically. *H*, floral diagram. *J*, fruit of *N. damascena*, cut across. (LeMaout and Decaisne.)—Annuals with bluish or white flowers and dry fruit. Natives of the Old World.

trary, a full grown herb lacks all such signs of a previous year's growth or of provision for the future, it is clearly an

annual; while if there are signs (such as a swollen root or leaf-rosette) implying only a past year's growth with no provision beyond, the plant would be called a *biennial*, *i. e.*, one completing its life in two years.



FIG. 287, I.—Columbine (*Aquilegia vulgaris*, Crowfoot Family, *Ranunculaceæ*). Flowering top. Flower, entire and cut vertically. Pistil surrounded by rudimentary stamens. (Baillon).—Perennial herb 45–60 cm. tall; leaves finely hairy; flowers purple, violet, white, etc.; fruit dry. Eurasia. Common in gardens.

Nearly all the members of this family are perennial herbs. A few, such as the mouse-tail, are annuals; and there are some more or less woody forms, as for example, certain species of *Clematis* which are woody and climbing. None of the family are trees.¹

¹ The following signs are often used for brevity in botanical descriptions: ① for an annual, ② for a biennial, and ④ for a perennial herb; ∩ for a vine whether trailing, climbing, or twining; *h* for a woody plant; ⚔ for a small shrub, ⚔ for a large one; ⚓ for a shrubby tree and ⚓ for one of considerable size. To these we may add ○ to mean herbaceous as a counterpart to the sign for woody.

The stem parts of the marsh-marigold agree fundamentally with those of the flax plant in their general form and mode of branching, although differing in such minor details as slenderness and toughness. There is, however, a more significant

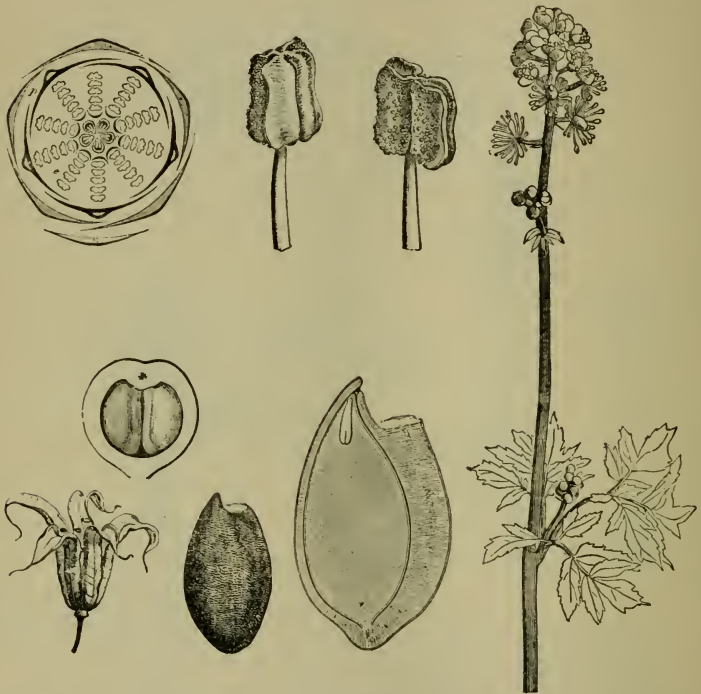


FIG. 287, II.—Columbine. Floral diagram. Stamens. Ovary, cut across. Fruit. Seed, entire, enlarged. Same, cut vertically. (Baillon.)

FIG. 288, I.—Baneberry (*Actæa spicata*, Crowfoot Family, *Ranunculaceæ*). Flowering top. (LeMaout and Decaisne.)—Perennial herb 30–60 cm. tall; flowers white or bluish; fruit fleshy, purplish or red. Native home, Eurasia, Northern States.

difference in the length of the lower internodes, which in the marsh-marigold and many other members of the family are so short that the foliage leaves are crowded together into a rosette. Somewhat similarly abbreviated internodes bearing scale-like leaf-members often remain underground, as in

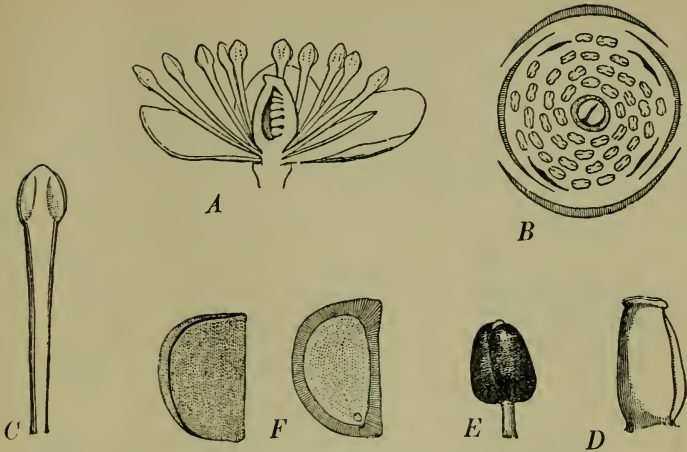


FIG. 288, II.—Baneberry. *A*, flower, cut vertically. *B*, floral diagram. *C*, stamen. *D*, pistil, enlarged. *E*, fruit. *F*, seed, entire and cut vertically. (LeMaout and Decaisne.)



FIG. 289.—Mountain Clematis (*Clematis alpina*, Crowfoot Family, *Ranunculaceae*). Part of plant climbing by means of its leaf-stalks used as tendrils. (Kerner.)—A somewhat woody climber with stems nearly 2 m. long, bright blue flowers and hairy-tailed fruits. Native home Eurasia and Northwestern North America; cultivated.

the wood-anemony and the Christmas rose, and persist over the winter as a reservoir of food upon which buds may feed the following spring. Such an elongated subterranean stem is called a *rootstock* or *rhizome*.¹ When, as in the bulbous crowfoot, the subterranean base of the stem becomes so much gorged with food as to be spheroidal or oblate in form it is termed a "solid bulb" or *corm*.²



FIG. 290.—Vine-bower *Clematis Vitalba*, Crowfoot Family, *Ranunculaceae*. A, flower-cluster. B, flower. C, same, cut vertically. D, stamen. E, pistils. F, floral diagram. G, fruit. H, base of fruit, cut vertically. (LeMaout and Decaisne.)—A somewhat woody climber growing 10 m. long; flowers dull white; fruit hoary. Native home, Mediterranean Region; cultivated in gardens.

Turning now to the foliage of our marsh-marigold we find the leaves to be of a form very common among seed-plants, and comparatively simple although more highly developed than the leaves of flax. In a marsh-marigold leaf we may distinguish a broadly expanded part, the *blade*, borne on a footstalk or *petiole*;³ which expands again at its base into a

¹ Rhiz-ome < Gr. *rhiza*, root, because of its root-like appearance.

² Corm < Gr. *kormos*, a pollarded tree-trunk.

³ Pet'-i-ole < L. *petiolus*, a little foot, diminutive of *pes*, *pedis*, a foot.

sort of sheath. The framework of the leaf when it reaches the blade divides into a number of main branches, or *ribs*. These radiate from the top of the petiole and may divide again into secondary branches, or *veins*, which finally are connected so as to form an irregular net-work by minute branches called *veinlets*. When a leaf has ribs radiating thus, like the bones in the palm of one's hand, it is said to be *palmately ribbed*, and when the veinlets form an irregular net-



FIG. 291.—Erect Silky Clematis (*Clematis ochroleuca*, Crowfoot Family, *Ranunculaceæ*). Flowering branches. Fruit. (Britton and Brown.)—Perennial herb, somewhat woody, 30–60 cm. tall; leaves silky-hairy beneath; flowers yellowish; fruit yellowish brown. Native home, Eastern United States.

work, it is *netted-veined*. The ribs and veins are also called *nerves* and their arrangement the *nervation* of a leaf, the arrangement of the veinlets being called the *venation*.

On comparing with the leaves of the marsh-marigold those of the ditch crowfoot we find the same general plan of structure but with the difference that the leaf base is narrower, and the blade is divided into branches corresponding to the ribs. The branches of the upper leaves are so narrow as to

suggest a resemblance to the toes of a bird, which has given rise to the name "crowfoot." In the tall crowfoot the branch-



FIG. 292.—Pasque-flower (*Anemone Pulsatilla*, Crowfoot Family, *Ranunculaceæ*). Plant in flower and fruit. (Baillon.)—Perennial herb about 20–30 cm. tall; leaves hairy; flowers blue or purplish; fruit hoary. Native home, Europe; cultivated in gardens.

ing of the blade is carried still further and follows the veins. A similar branching is shown in the leaves of monkshood and many other members of the family.

All the leaves so far considered agree in having the blade of a single piece however much it may be branched or subdivided. That is to say, the green pulp of the blade, although it may be but little developed between the ribs, is still continuous. Such are called *simple leaves*. When the green pulp is discontinuous between the ribs, as in the leaves of the Christmas rose, the blade becomes divided into secondary blades or *leaflets*, each of which may be borne on a little

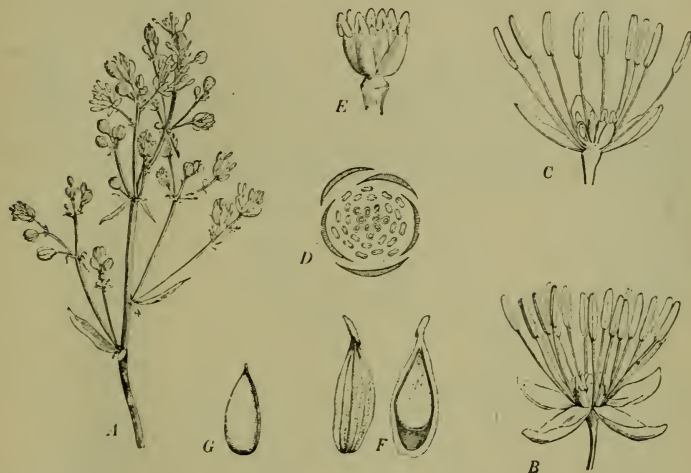


FIG. 293.—Meadow Rue (*Thalictrum flavum*, Crowfoot Family, *Ranunculaceæ*). A, flower-cluster. B, flower, enlarged. C, same, cut vertically. D, floral diagram. E, pistils. F, fruit, entire, and cut vertically. G, seed. (LeMaout and Decaisne.)—Perennial herb about 1 m. tall; flowers yellow; fruit dry. Native home, Eurasia.

stalk of its own, called a *petiolule*.¹ Such leaves are classed as *divided* or *compound*. If, as in this example, the leaflets or their petiolules spring directly from the main petiole the leaf is distinguished as *once-compound*; when, as in baneberries, the branching of the blade is carried a stage farther and the leaflets or their petiolules arise from branches of the petiole, the leaf becomes *twice-compound*; or the subdivision may be carried still farther, as in columbines. A leaf more than once compounded is termed *decompound*. Since in

¹ Pet'-i-o-lule < L. *petiolulus*, diminutive of *petiolus*, petiole.

all these cases the branching of the blade follows the palmate plan the leaves are conveniently described as *palmately divided*, or *palmately once-, twice-, or decompound*. The leaves of the Christmas rose and some other members of the family are peculiar in having the lateral divisions not quite separated, thus making them in a way intermediate between



FIG. 294.—Bracts and petals of peony connected by intermediate forms. Parts marked G are green; Y, yellow; and R, red. (Original.)

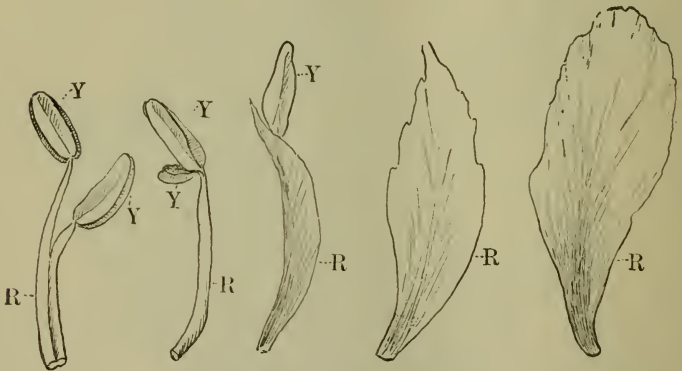


FIG. 295.—Stamens and staminodes of peony showing intermediate forms. Parts marked R are red; and those marked Y are yellow. (Original.)

simple and compound palmate leaves. Such leaves are distinguished as *pedate*.¹

The palmate type of leaf prevails throughout the crowfoot family, the only departures from the rule being a few such cases as the narrow leaves of mouse-tail in which the framework is unbranched or obscure, and a few cases in which a midrib or continuation of the petiole gives off lateral branches as in the leaves of the pasque-flower and clematis

¹ Ped' ate. < L. *pedatus*, having a foot.

(Fig. 291). The relation of the very narrow mouse-tail leaf to one of the marsh-marigold type may be understood by supposing the nerves to be reduced to a single rib. A leaf in which the framework consists of only one or two ribs, may be termed *costate*.¹ The simple leaf of the silky clematis may be likened to a less narrowed marsh-marigold leaf in which, however, the ribs are reduced to one midrib from which veins are given off on either side. Or, better, we may

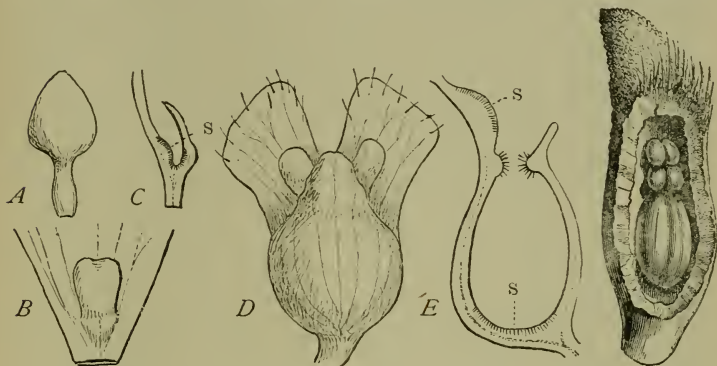


FIG. 296.—Stamines. *A*, *Anemone Pulsatilla*. *B*, *Ranunculus acris*, view from above. *C*, same, cut vertically; the shaded area (S) indicating the surface secreting nectar. *D*, *Nigella damascena*, view from above. *E*, same, cut vertically; secreting surfaces (S) shown as before. All variously enlarged. (Redrawn from Prantl.)

FIG. 297.—Ovary of an anemomy, opened to show the two pairs of rudimentary ovules above the single normal one, enlarged. (Baillon.)

view it as an elongated leaf in which the framework was at first divided palmately into three branches, the middle one of which again divided similarly, and this method of branching continued during the elongation of the blade. However we may view the nervation, such a leaf in which a single midrib, or direct continuation of the petiole, gives off several or many lateral branches, is distinguished as *pinnately nerved*. The leaves of the pasque-flower are described as *pinnately compound* or *pinnate*.² The leaflets of the Christmas rose are pinnately nerved, the leaf as a whole being palmate or pedate.

¹ Cos'-tate < *L. costa*, a rib.

² Pin'-nate < *L. pinna*, a feather, because the veins arise from the midrib as do the barbs of a feather from its shaft.

Most of the crowfoot family are like marsh-marigolds in having their leaves petiolate. In some cases there is no petiole. The leaf is then described as *sessile*,¹ a term applied to any stalkless organ of a kind which is commonly stalked.

As regards their arrangement the leaves of marsh-marigolds are like almost all the others of the family in being *alternate*, *i. e.*, one at each node. In clematises there appear two leaves at a node—such are called *opposite*—while in anemonies there are often more than two forming a ring, encircling the stem. Such a ring is termed a *whorl* or *verticil*,² and the leaves are said to be *whorled* or *verticillate*. When leaves are opposite they are of course virtually in whorls of two. Leaves forming a rosette may approach closely the verticillate arrangement, and it becomes a fair question whether verticils may not be after all merely rosette-like clusters in which the internodes have developed scarcely at all. This view is favored by the fact that internodes of perceptible length do sometimes separate the leaves of such verticils as those of anemony. Furthermore, in clematises the leaves before they expand often show one of a pair distinctly shorter (and therefore presumably younger) than the other, just as if they were really alternate but with only one of every two successive internodes developed. Although we may admit that the alternate arrangement passes readily into the verticillate even on the same plant, it is of course necessary in practical description to distinguish the types.

Students are sometimes puzzled as to how they may distinguish between a leafy shoot and a compound leaf, or between simple leaves and leaflets. They will be helped by remembering that a stem branch arises normally from the axil of a leaf-member, and is an axis bearing leaves in the axils of which buds may develop. Conversely leaf-members normally *subtend*,³ *i. e.*, stand just below, a bud or shoot, and are lateral members radially disposed about an axis and flattened, at least, when young, transversely with reference

¹ Ses'-sile < L. *sessilis*, sitting.

² Ver'-ti-cil < L. *verticillus*, the whirl or whorl of a spindle, which is a disk-like piece of wood or metal encircling it; hence, in botany a ring of parts similar to one another encircling an axis.

³ Sub-tend' < L. *sub*, under; *tendere*, stretch.

to it. Traces of this flattening may be observed commonly even in the petiole on the upper or inner surface, especially near the base. These tests applied to the foliage of columbines, for example, will show why it must be considered as made up of branched leaves—decompound leaves with many leaflets—rather than a branched stem bearing many simple leaves.

The stem and leaves of the marsh-marigold, as of marsh-loving plants in general, are quite smooth and unprovided with any hairy or other protective covering. Plants or parts in this condition are described as *glabrous*.¹ When covered with soft, downy hair they are said to be *pubescent*.² Many ranunculaceous plants, especially those growing in dry, sunny places (as for example the pasque-flower, the tall crowfoot, and the bulbous crowfoot) are pubescent, particularly when young.

103. The reproductive system. Turning now to the flowers of the marsh-marigold it will be noticed that they grow either at the tip of the main axis or on stalks which arise from the axils of upper leaves. On the side of the flower-stalks, or subtending them, may be sessile leaves or more or less scale-like leaf-members. Such leaves subtending a flower or a flower-cluster are called *bracts*,³ or when borne upon a flower-stalk they are termed *bractlets*. The stalk of a flower or flower-cluster is distinguished as its *peduncle*.⁴ We speak of a blossom or flower-cluster as an *inflorescence*.⁵ Thus we say that the inflorescence of the marsh-marigold consists of a terminal flower, and a few axillary ones, with bracts and sometimes bractlets. It should be noted that the terminal flower opens before the lateral ones, thus putting an end to further elongation of the main axis. Such an inflorescence is therefore called *determinate*. It is also described as *cymose* because the form of cluster which typically results from the determinate mode of growth is called a

¹ Gla'-brous < L. *glaber*, without hair.

² Pu-bes'-cent < L. *puber*, downy.

³ Bract < L. *bractea*, a thin plate.

⁴ Pe-dun'-cle < L. *pedunculus*, diminutive of *pes*, *pedis*, foot.

⁵ In-flor-es'-cence < L. *in*, in; *florescere*, begin to blossom.

cyme.¹ The inflorescence of the marsh-marigold is a simple cyme. A well-developed cyme is found in certain species of clematis. Here, as shown in Fig. 290, the axes repeatedly branch, making the cyme *compound*. In compound inflorescences the ultimate flower-stalks are called *pedicels*.² A whorl or cluster of bracts is an *involucre*;³ while the term *involucel*⁴ is applied to a whorl of bractlets. Thus the wood-anemone has an involucre of three leaf-like bracts situated far below the solitary flower. These are called bracts because in related species bracts similarly placed subtend peduncles, although as must be obvious the distinction between bracts and bractlets in such cases is rather arbitrary. Fennel-flower has an involucel of a few large bractlets very near the blossom. Most of the crowfoot family have simple, cymose inflorescences, usually of only a few flowers as in crowfoots, columbines, and the Christmas rose. Often, even in the genera mentioned, the flowers may be solitary, and this is usually if not always the case in mouse-tails, anemones, fennel-flowers, and peonies.

In contrast with these determinate inflorescences in which the terminal, upper, or inner flowers are the older, are inflorescences of the *indeterminate* type shown in baneberries and monkshoods. Here the upper flowers are the younger, and the main axis or *rachis*⁵ may elongate indefinitely, developing new flowers as it grows. When, as in the examples given, the main axis is longer than the peduncles, the cluster is termed a *raceme*.⁶ So typical is this of the indeterminate form of inflorescence that the term *botryose*⁷ of similar implication is given to it as being in significant contrast with cymose.

From the above it appears that in describing and naming inflorescences botanists have regard either to the manner in

¹ Cyme < Gr. *kyma*, a young sprout, because the younger flowers arise like sprouts from below. (Pronounced *siem*.)

² Ped'-i-cel < L. *pedicellus*, diminutive of *pediculus*, dim. of *pes*, *pedis*, foot.

³ In'-vo-lu-cre < L. *involucrum*, < *involvere*, enwrap.

⁴ In-vol'-u-cel < L. *involucellum*, a little wrapper.

⁵ Ra'-chis < Gr. *rhachis*, backbone.

⁶ Ra-ceme' < L. *racemus*, a bunch of grapes.

⁷ Bot'-ry-ose < Gr. *botrys*, a bunch of grapes.

which the branches arise and the relative position of the oldest flowers, or else to the general form as modified by more obvious features, like the relative lengths of the internodes. It is desirable to keep these two points of view distinct.

Viewed as to their system of branching, simple inflorescences, such as most of those we have been studying, are either of the cymose or the botryose type. Under the head of cymose inflorescences we should include a solitary flower which terminates a leafy axis, as in the wood-anemony; while a solitary flower, which, like that of the mouse-tail, springs from the axil of a foliage leaf would more logically be called botryose. When the branches of an inflorescence branch again it becomes *compound*, as in our example of clematis, (Fig. 290) which has a compound cyme, or cyme of cymes.

As to general form we may here distinguish: (1) *racemose* inflorescences or racemes, like those of monkshood and baneberry, which are simple and have pedicels all shorter than the rachis, thus giving an elongated cluster; (2) *paniculate*¹ inflorescences or *panicles*, which are more or less elongated and compound, as in Fig. 293; and (3) *corymbose*² inflorescences or *corymbs* (Fig. 290) which have the outer pedicels or branches about as long as the rachis, and those nearer the center progressively shorter so that the cluster as a whole is broad and more or less flat-topped. Corymbs often become racemose as they grow older, and compound corymbs, paniculate. Some botanists would restrict the terms raceme, panicle, and corymb to indeterminate inflorescences; but in practice these names are applied indiscriminately also to inflorescences of the determinate type which have assumed the forms above defined. Thus we may speak of a racemose, paniculate, or corymbose cyme.

In a flower of marsh-marigold we recognize many organs similar to those already observed in the flax but with some important differences. Thus in the center of the flower we find a cluster of pistils each with a single stigma, style, and ovulary cavity instead of a single pistil with several styles and stigmas and a single ovary with several cavities. Such

¹ Pan-ic'-u-late < L. *panicula*, a tuft.

² Cor-ymb'-ose < L. *corymbus*, a cluster of flowers.

simple pistils as those of the marsh-marigold are called *carpels*¹ and are regarded as representing each a single egg-sac leaf just as a stamen is a single pollen-sac leaf. Taken together the carpels form the *gynæcium*² of the flower, while the stamens collectively form the *andræcium*.³ Near the base of each carpel is a gland that secretes drops of a sweet fluid, called *nectar*⁴ which attracts insects, and from which they make honey. In each ovary of the marsh-marigold, as will be noticed, there are several ovules attached to that part of the wall lying nearest the center of the flower along a line running from top to bottom—such a line as would be made by the edges of a folded leaf where they came together. Thus the carpel of a marsh-marigold may be likened to a leaf bearing ovules along its edges and these joined so as to form an ovary. That part of an ovary wall which bears the ovules is called the *placenta*;⁵ and when as in this case it extends along the front side of the ovary (that toward the center of the flower) the placenta is said to be *ventral*.⁶ The opposite side or back of the carpellary leaf, commonly marked by a ridge representing the midrib, is distinguished as the *dorsal*⁷ aspect.

The ovules of marsh-marigolds are essentially like those of flax and of all the crowfoot family. We may distinguish in each ovule a little stalk, the *funicle*,⁸ which continues as a ridge, the *raphe*,⁹ along the side of the main part or *body* of the ovule. At the small end is a minute opening, the *micropyle*.¹⁰ An ovule which is bent so that the micropyle comes next to the funicle, or point of attachment, is termed *anatropous*.¹¹

¹ Car'-pel < Gr. *karpos*, fruit, as being essentially the fruit producing part.

² Gy-næ'-ci-um < Gr. *gyne*, female; *oikos*, house.

³ An-dræ'-ci-um < Gr. *andros*, male.

⁴ Nec'-tar < Gr. *nektar*, the drink of the gods.

⁵ Pla-cen'-ta < L. a little cake, from its cake-like form in certain cases.

⁶ Ven'tral < L. *venter*, belly.

⁷ Dor'sal < L. *dorsum*, back.

⁸ Fu'-ni-cle < L. *funiculus*, diminutive of *funis*, a cord.

⁹ Ra'phe < Gr. *rhaphe*, a seam.

¹⁰ Mi-cro-pyle < Gr. *micros*, small; *pyle*, gate.

¹¹ A-nat'-ro-pous < Gr. *ana*, back; *trepein*, turn.

Gynœcia essentially like those of marsh-marigold are found in Christmas roses, columbines, peonies, and monkshoods (Figs. 178, 282, 287, 284). In anemonies (Fig. 297), each carpel contains at first the rudiments of several ovules, but only one (the lowest) develops, the rest remaining mere rudiments. Many genera, as for example, crowfoots, mouse-tails, meadow rues, and clematises (Figs. 285; 290, 293) have only a single ovule in each carpel from the first. In a few cases it happens, as in fennel-flowers (Fig. 286) and certain species nearly related to the Christmas rose, that the carpels are more or less united with one another at the base, thus forming a *compound pistil* comparable to that of flax. As a result of this union of the carpels there is formed a single compound placenta which being at the center of the ovary is termed *axile*. It is obvious that a compound pistil, say of five carpels, requires less material than an equal number of separate carpels of the same size, just as it takes less bricks to build a chimney with five flues than it does to make for each flue a separate chimney. Almost all of the crowfoot family have *simple pistils*, *i. e.*, consisting of but one carpel. The number of simple pistils may be many, as in crowfoots, mouse-tails, and anemonies; several or few, as in Christmas rose, columbines, peonies, and monkshoods; or only one, as in baneberries.

When both stamens and pistils are present (as in nearly all of the crowfoot family) the flower is said to be *perfect*; it is *imperfect* when either set of essential organs is absent or rudimentary. Flowers having stamens alone are called *staminate*; those with pistils alone, *pistillate*. In certain species of clematis both perfect and imperfect flowers occur; such plants are termed *polygamous*.¹

Andrœcia consisting of an indefinite number of stamens like those of marsh-marigold occur in the wood-anemony, peonies, and certain species of clematis (Figs. 194, 282, 291). Among cultivated peonies we often find flowers which have become "double" as the gardeners say. In these the outer sta-

¹ Perfect flowers are symbolized in botany by the sign ♂, staminate by ♂, and pistillate by ♀. The expression ♂ ♂ ♀ would thus stand for polygamous.

mens are replaced by more or less petal-like leaf-members which, however, differ considerably in shape from the petals, and show clearly their closer homology with filaments by numerous intermediate forms (Figs. 294, 295). What here takes place as an abnormality throws light upon the homology of certain curious and puzzling organs often called "nectar-leaves" which take the place of the outer stamens in many flowers of the crowfoot family. In some anemonies—as in the wood-anemony—the outer stamens have anthers, while in other species like the pasque-flower the outer filaments are destitute of anthers but instead have swollen tips which secrete nectar (Figs. 194, 296 A). Antherless stamens are called *staminodes*.¹ The nectar-leaves are most probably of this nature. The Christmas rose has tubular staminodes; the mouse-tail, staminodes somewhat club-shaped and bent; crowfoots have them broadly expanded and petal-like; fennel-flowers, more or less petal-like with a peculiar pouch; while in columbines there is an outer set of colored staminodes forming trumpet-like spurs which secrete nectar copiously, and next to the carpels two inner sets of five each which produce no nectar and are very thin and colorless (Figs. 284D, 285II, 296B-E). It is not unusual for botanists to speak of the petal-like nectar-leaves of this family as petals, but this is not in accord with the modern view of their homology.

Most of the crowfoot family are like marsh-marigolds in having no corolla. In peonies are found unmistakable petals. These show that they belong to the perianth, not only by having a much wider base than the stamens, but also by the occurrence of transitional forms connecting them with sepals, as illustrated in Fig. 294. The series as there shown connects also sepals, bractlets, and bracts. Anemonies and fennel-flowers, as we have seen, have involucre or involucels which are sometimes so close to the flower as to be easily mistaken for calyx, and which indeed differ from calyces only in being separated from the floral whorls by a more or less developed internode. The case is especially deceptive when the sepals are *petaloid*, *i. e.*, brightly colored like petals, and the involucre is close to the flower. Flowers without a corolla are

¹ Stam'-in-ode < L. *stamen*, *staminis*, stamen; Gr. *eidos*, a form.

said to be *apetalous*.¹ When as in peonies the flowers have calyx, corolla, stamens, and pistils, they are described as *complete*.

Many of the crowfoot family have the calyx petaloid, as in marsh-marigolds, anemonies, clematises, Christmas roses, fennel-flowers, baneberries, columbines, and monkshoods. In mouse-tails each of the sepals develops near the base a tubular pouch or spur (Fig. 285).

Most commonly, the sepals, at least in the bud, overlap at the edges in such a way that some are wholly inside and some wholly outside, as shown in Figs. 282, 284. The sepals are then said to be *imbricate*,² and the same term applies to petals or similar organs thus overlapping. When the parts touch at the edges without overlapping, as for example the sepals of clematis (Fig. 290) they are *valvate*.³ The arrangement of floral parts in the bud is called their *æstivation*; ⁴ of leaves, their *vernation*.⁵

Almost all the flowers of the family have the parts of each whorl alike; that is, the carpels of a flower are repetitions of one another, likewise the stamens, the petals, and the sepals when present. Such flowers are called *regular*. A few of the family have *irregular flowers*, as for example the monkshood (Fig. 178) so called from the peculiar cowl-like form of one of the sepals which is larger than the others and partially enwraps them. The hood covers also a pair of staminodal nectaries. The stamens with anthers and the gynœcium are regular.

The stem part of the flower is called the *torus* ⁶ or *receptacle*. It represents the continuation of the flower-stalk or peduncle upon which the floral leaves grow. It is customary to speak of the way in which an organ is attached to its support as its *insertion*, or to say that the organ is *inserted* upon whatever bears it. Thus we say that the andrœcium and calyx

¹ A-pet'al-ous < Gr. *a*, without, *petalon*, petal.

² Im'-bri-cate < L. *imbricatus*, overlapping like roof-tiles.

³ Val'-vate < L. *valvæ*, folding doors.

⁴ Æs'-ti-va-tion < L. *æstivus*, of the summer.

⁵ Ver'-na-tion < L. *vernus*, of the spring.

⁶ To'-rus < L. *torus*, a swelling, as being the swollen end of the floral axis.

of marsh-marigold are inserted upon the torus below the ovaries, or that their insertion is *hypogynous*.¹ This implies that the gynœcium is inserted wholly above the other organs of the flower, or, in a word, that the ovaries are *superior*. Superior ovaries are found in nearly all of the crowfoot family. The torus is usually either convex (Fig. 290), conical (Fig. 293), or much elongated (Fig. 285). Peonies, on the contrary (Fig. 282), have the torus slightly concave so that it forms a shallow cup at the bottom of which the pistils are inserted, while around its rim are borne the stamens, petals, and sepals. Such insertion of the andrœcium and floral envelopes makes them *perigynous*² and the ovaries *half-inferior*. Wholly inferior ovaries occur as we shall see in other families but not in this.

Throughout the family the floral organs are *free*, that is to say each set is inserted on the torus independently and develops unconnected with other sets. Furthermore, with few exceptions, the organs of each set are *distinct*, that is, unconnected with one another. The chief exceptions are in certain species related to the Christmas rose and in fennelflowers where, as we have seen, the carpels have grown up joined together or are somewhat *coalescent*³ as botanists say when the parts united are of the same sort.

Another feature exhibited in general by the flowers of this family is the *alternation* of the parts, by which we mean that the members of one whorl or rosette stand in front of the spaces between the members of the next whorl or rosette, when of the same number. This is well shown in the floral diagrams, Figs. 178, 282, 284, 286, 287, 288, 290, 293. At first sight, this may not seem to be true of the stamens and staminodes of columbines and monkshoods but the alternation will be apparent when it is remembered that the parts are in whorls of five.

The *fruit* of a flowering plant is understood to include the seeds and whatever parts ripen with them. The ripened

¹ Hy-pog'y-nous < Gr. *hypo*, beneath; *gyne*, pistil.

² Pe-rig'-y-nous < Gr. *peri*, around.

³ Co-al-es'-cent < *co*, together; *alescere*, to grow up.

ovary is the *pericarp*¹ which may be *dry* as in marsh-marigold and nearly all the other genera, or may be *fleshy* as in baneberries. When the pericarp opens to release the seeds it is said to be *dehiscent*,² and the manner of opening, its *dehiscence*. The pericarp of marsh-marigold dehisces by a vertical slit, or *suture*³ along the ventral or inner side, *i. e.*, the side toward the axis of the flower. A dry fruit consisting of one carpel dehiscing by the ventral or by the dorsal suture alone is called a *follicle*.⁴ For other examples see Figs. 282, 287. A dry pericarp consisting of two or more carpels is termed a *capsule*.⁵ The fruit of fennel-flowers (Fig. 286) is a capsule in which each carpel dehisces by a short ventral suture near the top. A further peculiarity of the pericarp of the species illustrated is that except where the carpels are united, the wall separates into an outside and an inside layer, leaving a considerable empty space between.

Pericarps which do not open are said to be *indehiscent*. A small, dry, indehiscent fruit, like that of crowfoots, anemonies, and mouse-tails is termed an *achene*.⁶ A fruit like that of baneberries in which the whole pericarp is fleshy, is a *berry*.

In a seed, as we have seen (page 316), there is an outer protective layer, the seed-coat, enclosing the embryo and the seed-food or albumen. In marsh-marigold (Fig. 185) the seed-coat is of unequal thickness, the embryo minute and situated near one end of a comparatively large amount of albumen. Seeds essentially similar are found in the other members of the family.

In every part of the marsh-marigold, as we have seen (page 208), there is a colorless juice which is of sharp taste and poisonous properties if eaten fresh and raw. Such an acrid, watery juice containing a more or less poisonous, usually volatile, principle, is generally present throughout the family. Crowfoots, anemonies, and monkshoods, will be remem-

¹ Per'-i-carp < Gr. *peri*, around; *karpos*, fruit.

² De-his'-cent < L. *dehiscere*, yawn.

³ Su'-ture < L. *sutura*, a seam.

⁴ Fol'-li-cle < *folliculus*, dim. of *follis*, a wind bag.

⁵ Cap'-sule < L. *capsula*, dim. of *capsa*, a box.

⁶ A-chene' < Gr. *a*, not; *chainein*, yawn.

bered as affording other examples already discussed in Chapter V.

104. Plant formulas. We may be helped in summing up what we have learned from our various examples if we express their most significant structural characteristics by means of symbols arranged in a sort of tabular view as on page 353.

At the beginning of the formulas there given, the signs ①, 2, b, 3, ^ are used respectively for annuals, perennial herbs, woody plants, small shrubs, and vines, as already explained (p. 333). A comma indicates an alternative, and is to be read "or." Thus in the formula of *Pæonia* we have 2, 3, reading "perennial herbs or low shrubs." These signs since they apply to the plants as a whole come first in the formula. The letters which follow stand for various parts: L for leaves; L, leaflets; I, inflorescence; i, secondary inflorescence; B, bracts; b, bractlets; S, sepals; P, petals; FA, stamens (filaments with anthers); F, staminodes (filaments without anthers); CE, carpels (carpellary leaves with ovules, *i. e.*, egg-sac members); E, ovules well developed; e, rudimentary ovules; T, torus; C, carpels ripened into pericarps; E, seeds; G, embryo (germ); N, albumen (nutriment).

When the leaves are alternate, as in all the genera except *Clematis*, this is expressed by $L^1/1$ which signifies that there is a single leaf at each internode. In the exception noted $L^2/2$ means that the leaves are opposite, *i. e.*, two at a node. Palmate nervation is shown by the asterisk *, ternate by the dagger sign †, and pinnate by the double dagger ‡, which, as will be noticed, suggest by their form the arrangement of nerves they each represent. That a leaf is compound is implied by the presence of leaflets indicated by the small L.

In the formulas of *Anemone* and *Clematis* this shows that the leaves are but once-compound, while in the *Pæonia* formula L^{1-3} means that the leaves are once to thrice-compound, while L^{2+} in the *Aquilegia* and *Actæa* formulas stands for decompound.

When the inflorescence is of the indeterminate type an inverted comma follows the I as in the *Aconitum* and *Actæa* formulas; and when of the determinate type, as in the other examples, an inverted period is used. A solitary terminal flower, as in *Pæonia* and *Nigella*, is indicated by I·1. Where, as in *Caltha*, *Anemone*, and *Clematis*, additional flowers may appear forming a cymose cluster, I·1 + is used. When the plant has only solitary axillary flowers like *Myosurus* the expression becomes I'1. A cymose corymb, as of *Aquilegia*, is represented by I'/; while a raceme of the botryose type, as in *Aconitum* and *Actæa*, has I'', the short and the long oblique lines standing respectively for short and long pedicels. The presence of a small i, as in the formula of *Clematis*, implies a compound cluster. In this case it is shown to be of paniculate form because of the relatively short pedicels. Where the type and form of inflorescence varies as in *Ranunculus*, their special signs may be omitted. The

Paeonia \supset 2, $L^{1/1} \dagger L^{1-3}$ b_{1+}
 $I' 1 \text{ } \vartheta$ $S'' 5+$ $P'' 5+$
 FA^∞ $CE 5 \neq$ $E \hat{\infty}$ $T \circ$
 $Ci < 5 \neq$ E^∞ $G-N$

Caltha 2 $L^{1/1} *$ $b^{1/1, 0}$
 $I' 1+ \text{ } \vartheta$ $S'' 4+$
 FA^∞ $CE 5 \neq$ $E \hat{\infty}$ $T \circ$
 $Ci < 5 \neq$ E^∞ $G-N$

Helleborus 2 $L^{1/1} *, L$ $b_{1 \neq}$
 $I' 1+ \text{ } \vartheta$ $S'' 5$ $F 5+$
 FA^∞ $CE 5 \neq,)$ $E \hat{\infty}$ $T \circ$
 $Ci < 5 \neq,)$ E^∞ $G-N$

Anemone 2 $L^{1/1} * \dagger, L$ $B, b/2, 3$
 $I' 1+ \text{ } \vartheta$ $S'' 4+$ $FO-\infty$
 FA^∞ CE^∞ $Ei e_{4+}$ $T \circ$
 $Ci < \infty$ $E 1$ $G-N$

Nigella ① $L^{1/1} \dagger L$ $b/5, 0$
 $I' 1 \text{ } \vartheta$ $S'' 5$ $F 5+$
 FA^∞ $CE 5 \neq,)$ $E \hat{\infty}$ $T \circ$
 $Ci < 5,) \neq$ E^∞ $G-N$

Clematis 2, $b \circ$ $L^{2/2} \dagger \dagger, L$
 $I' 1+, i' \text{ } \vartheta, \vartheta \sigma \vartheta$ $S'' 4+ + FO-\infty$
 $FA^\infty, 0$ $CE^\infty, 0$ $Ei e_{2+}$ $T \circ$
 $Ci < \infty$ $E 1$ $G-N$

Aquilegia 2 $L^{1/1} \dagger L^{2+}$
 $I' \text{ } \vartheta$ $S'' 5$ $F 5$
 $FA^\infty F 5 \times 5$ $CE 5$ $E \hat{\infty}$ $T \circ$
 $Ci < 5$ E^∞ $G-N$

Ranunculus \circ $L^{1/1} *$
 $I' 1+ \text{ } \vartheta$ $S'' 5 \neq$ $F 5+$
 FA^∞ CE^∞ Ei $T \circ$
 $Ci < \infty$ $E 1$ $G-N$

Aconitum 2 $L^{1/1} *$
 $I' \text{ } \vartheta$ $S'' \frac{3}{2}$ $F \frac{5}{2-3} \neq$
 FA^∞ $CE 3-5$ $E \hat{\infty}$ $T \circ$
 $Ci < 3-5$ E^∞ $G-N$

Myosurus ① $L^{1/1}$
 $I' 1 \text{ } \vartheta$ $S'' 5+$ $F 5 \neq$
 $FA 5+$ CE^∞ Ei $T \circ$
 $Ci < \infty$ $E 1$ $G-N$

Actaea 2 $L^{1/1} \dagger L^{2+}$
 $I' \text{ } \vartheta$ $S'' 3-5$ $F 4+$
 FA^∞ $CE 1$ $E \hat{\infty}$ $T \circ$
 $Ci < 1$ E^∞ $G-N$

signs ♂, ♂, and ♀ have already been explained on page 347. As used in the *Clematis* formula they will be understood as meaning that the inflorescence may consist entirely of perfect flowers (as in the other genera) or may be polygamous.

The presence of bracts more or less like foliage leaves may generally be taken for granted, and so need not usually be expressed in a formula. Bractlets are more often absent, but it seldom matters much for our purpose whether they are present or not, and they rarely need to be taken into account. When either of these organs present noteworthy peculiarities they may be recorded as in the formulas of *Pæonia*, *Caltha*, *Nigella*, and *Anemone*, following the method for leaves as regards their arrangement, except that in case of involucre only a denominator is used because there is but one whorl. Thus in the formula for *Caltha* $b^{1/1,0}$ would read "bractlets alternate or none"; for *Nigella* $b/5,0$ means "with five bractlets forming an involucre, or none"; while for *Anemone* $B, b/2,3$ means "having bracts or bractlets two or three in a whorl."

The imbricate æstivation of sepals or petals is indicated by two apostrophes, following the S or P, as in the formula of *Pæonia*; the valvate, by an inverted comma opposed to an apostrophe, as in *Clematis*.

For each floral organ the number or numerical sign following a letter tells how many of the parts represented are present. The plus sign, +, means "or more," so that $5+$ would be read "five or more." The "plus or minus" sign, \pm , is to be read "more or less." The algebraic symbol of infinity, ∞ , stands here for "many" or "an indefinite number." As a companion sign, \propto may be used to mean few. When the absence of an organ needs to be noted a zero, 0, is used. A dash between numerical signs means "to"; thus, $3-5$ would be read "three to five"; $0-\infty$ "none to many." Simply a dash after a numerical sign means "or less"; thus $5-$ would be read "five or less."

When the numerical signs are in such fractional form as $\frac{3}{2}$ or $\frac{2}{3}$ (*Aconitum* formula) it shows that the flower is irregular so far as the organs so represented are concerned; otherwise, the flower is understood to be regular. If the numerator be an odd number it indicates that a single member of the set, more or less unlike the others, is uppermost, as for example, the hooded sepal of *Aconitum*: an even number, instead, shows that a pair of similar parts is uppermost, as is the case with the staminodes in the same flower.

Unless otherwise indicated the floral organs are understood to be free and distinct. Partial coalescence of parts, as in the carpels of *Nigella*, is indicated by placing after their numerical sign a small parenthesis: thus, for the example cited $CE\ 5 \pm)$ would be read "carpels five, more or less, partially coalescent below."

There being no indication to the contrary it is also to be understood that the floral organs regularly alternate, and that the anthers

dehisce by longitudinal slits. The expression $T \cap$ means that the torus is convex and implies that the perianth and andrœcium are hypogynous. When as in *Pæonia* they are perigynous this is indicated by $T \cup$ which represents the torus as concave.

The form of the ovules is shown by a mark placed over their numerical sign, a circumflex accent-mark meaning that the ovule is anatropous. Their ventral position is understood in simple pistils, while in compound pistils like that of *Nigella*, the single parenthesis after the number of carpels implies that the ovules are on an axile placenta.

When the pericarp becomes fleshy as in *Actæa* this is indicated by an exclamation mark after the *C*. When the pericarp is dry, as in *Caltha*, there is instead an inverted exclamation mark. Indehiscence is indicated by the sign $<$. When the pericarp dehisces along a ventral suture as in *Caltha*, etc., the sign $<$ is employed. In all the formulas the expression $G-N$ implies that the embryo is uncoiled within albumen.

The scheme of plant formulas which is here proposed and which will be further elaborated in the following pages, is an extension and modification of the floral formulas used by many botanists. As a sort of botanical shorthand of wide application it is believed that the student will find it not only labor-saving but helpful in grasping plant relationships. After a little use, what seemed strange will have become familiar and a glance will discover important characters that might easily escape notice in comparing equally full verbal descriptions.

105. The family chain. Having learned the signification of these symbols we are now in position to use the formulas as a ready means of comparing the main structural features of our representative genera to see how they are linked together. Take, for instance, *Caltha* and *Pæonia*. If we conceive of a marsh-marigold having a concave torus, a perianth differentiated into calyx and corolla, and pinnately compound leaves, such a plant would be classed as a peony. By these same features, however, it might be distinguished from all the other genera. Therefore, although closely linked with *Caltha*, *Pæonia* is placed on a line apart in the tabular view.

Helleborus differs from *Caltha* chiefly in having the carpels sometimes coalesced and in possessing staminodes. In these respects it is a link connecting *Caltha* with *Nigella* which has the carpels always coalescent, and differs from *Helleborus* only in having pinnate instead of palmate leaves, some of which may be so near the flower as to constitute an involucre, and in consisting of annual rather than perennial herbs.

Aquilegia, with its carpels distinct, is more like *Caltha*, but differs from both *Caltha* and *Nigella* in having the carpels always five, staminodes in two inner sets of five and one outer set of the same number, and in having the leaves ternately decomposed.

A monkshood is like a columbine except for irregularity of sepals and staminodes, absence of inner staminodes, indeterminate inflorescence, simplicity of leaves, and sometimes fewer carpels.

All the above genera agree in having numerous ovules, all of which may become seeds, contained in several or many carpels which become dry and dehiscent in fruit.

In *Actæa* the carpels are reduced to one, which becomes fleshy and indehiscent in fruit; the staminodes may be fewer, both they and the sepals are regular; and the leaves are ternately decomposed: otherwise the genus resembles *Aconitum*.

Passing now to *Anemone* we find its most striking differences from *Caltha* and the other genera already described to be the imperfect development of several of the ovules in each carpel, the ripening of only one ovule, the indeliscence of the fruit, and the possession of an involucre of two or three bracts. In these respects it forms a link between our type genus and *Clematis* where the rudimentary ovules are commonly fewer, and all the leaves (like the bracts in some species of *Anemone*) are opposite.

A still further divergence in *Clematis* appears in the occasional imperfection of the flowers, the valvate æstivation of the sepals, the ternate or pinnate nervation of the leaves, and the climbing habit and woody stem sometimes developed.

In *Ranunculus* we find a still further reduction of the ovules; an invariable presence of both essential organs and staminodes; imbricate æstivation of the sepals: alternate, palmate, simple leaves; and sometimes annual duration: thus being in some respects more nearly like *Caltha*, while in others it is more divergent.

Finally, an extreme of divergence by reduction or simplification is reached in the mouse-tails which may be regarded as annual crowfoots with only about five stamens, staminodes, and sepals, bractless, solitary flowers, and leaves with unbranched or obscure nervation. It may seem a long way from such plants to peonies; but, as we see, there are intermediate links binding them pretty closely together.

As the student examines other members of the same family he will find that they may be readily interposed as links in the same chain with those already studied. Indeed, the transitions will appear less abrupt than between the few examples to which we have confined ourselves. His experience will be much like that of a botanist with forms newly discovered. He compares them with the forms already known and links them with those which they most nearly resemble. Thus link by link are family chains forged in botanical systems. As in the present case, the chain may branch, and it might be questioned whether it would not be better to regard the branches as separate families. That depends upon how close the linkage appears to be, and as to that the judgment of experts may differ. In any event the definition of any family properly follows the attempt at natural grouping, and may require revision with advancing knowledge or change of view. Such changes in

classification the history of the science illustrates; yet progress is in the direction of stability, and certain chains, having held from the first, bid fair to endure. The integrity of the Ranunculaceæ, for example, seems assured in spite of the wide divergence of its extreme forms and in spite of the difficulty of defining its limits.

We have now to define the family as best we can. The generic formulas will help us to a formula for the family and this in turn will lead us to our definition. Taking the prevailing characteristics of each part as typical for the family, and neglecting the less significant exceptions to the general rule, we may express a generalized view of the salient features as shown in the formula of Ranunculaceæ on pages 404, 405.

The only invariable features here expressed are the anatropous ovule and the uncoiled embryo surrounded by albumen, and these as we shall see are common to a number of other families. But, as we shall also see in comparing the Ranunculaceæ with other groups, it lacks features which they possess.

Taking into account all the facts we have learned, the crowfoot family may be described as consisting of herbaceous or rarely woody plants, never trees, without milky juice, oil or other secretions in special reservoirs, but with a mostly colorless and odorless sap which is generally acrid, and in some cases renders the plant poisonous to eat or to touch; leaves mostly palmately branched, or at least palmately ribbed; flowers mostly regular and perfect with the parts free and distinct (with rare exceptions); sepals commonly five, generally petaloid; petals rarely present, often replaced by more or less petaloid staminodal nectaries of widely differing forms; stamens generally numerous; anthers dehiscent by slits; pistils almost always simple, numerous, few, or rarely solitary; ovules anatropous, many, few or solitary, sometimes rudimentary; fruit follicular, capsular, achenial, or rarely fleshy; the seeds with hard albumen surrounding a minute uncoiled embryo. Or, if we disregard all that is untypical, it may be said that whenever we find *an herb with the juice colorless and scentless, the flowers having all their parts distinct and free, sepals about five, and essential organs numerous*, we may be tolerably sure that our plant is one of the crowfoot family, although some departure from these characteristics would not necessarily exclude it from the group.

CHAPTER X

VARIOUS PLANT GROUPS

106. The magnolia family (*Magnoliaceæ*) is a comparatively small group well represented by magnolias (*Magnolia*, page 262), the tulip-tree (*Liriodendron*, page 261), and star-anise (*Illicium*, page 143). At first sight there might seem to be small resemblance between these and crowfoot-like plants; but let us see upon what points of difference we can exclude them from the crowfoot family.

The seeds are essentially the same as those of the crowfoot family in having a small uncoiled embryo in copious albumen. The fruit of star-anise consists of follicles, much like those of the marsh-marigold, though with only one seed in each; while the carpels of the tulip-tree ripen into achenes differing from those of anemonies mainly in having wing-like outgrowths. Such winged fruits are termed *samaras*.¹ The magnolia fruit consists of a cone-like aggregation of follicles differing from those of star-anise in dehiscing by a dorsal suture, and in producing one or two seeds which have a fleshy outer layer of bright color, and which dangle on slender threads when ripe. Neither the andrœcium nor the perianth present any new features. Nor do we find anything essentially different in regard to the inflorescence or the leaves except that in the tulip-tree and magnolia there are leaflet-like appendages at the base of the petiole. These *stipules*,² as they are called, serve as organs of protection for the unexpanded leaves. In these plants they soon fall off, and so do not appear in the figures. Well-developed stipules are shown

¹ Sa-ma'ra < *L. samara*, the winged fruit of the elm.

² Stip'ule < *L. stipula*, stubble, diminutive of *stipes*, stalk, the stipules in their relation to the petiole being likened to the short stubble standing at the base of a stalk of grain.

in figures 159,² and 271. Somewhat similar expansions serving for protection occur at the base of marsh-marigold leaves; but these, although suggesting stipules, are not regarded as sufficiently developed to deserve the name. The leaves of star-anise, as of the crowfoot family, are *exstipulate*,¹ that is, without stipules. Finally, as regards their *habit*,² or general appearance, the tulip-tree is, as its name implies, a tree, while the species of magnolia and star-anise are either trees or shrubs.

The result of our examination thus far is to show that star-anise in several particulars forms a good link connecting the tulip-tree with members of the crowfoot family, and we have not yet found a single feature which will serve to distinguish all of the magnolia family from all of the crowfoot family.

This resemblance will appear still more plainly if we express in formulas the facts observable in our examples. Let us indicate the presence of stipules by an inverted dagger sign, †; a wing on the pericarp by an inverted interrogation mark, †; and dorsal dehiscence by >. We may then write our formulas of Magnolia, Illicium, and Liriodendron³ as shown on pages 404, 405.

If we added to these examples other magnoliaceous genera we should of course introduce some new variations of structure, but these would afford us no better family characters. A formula typical of the family would still be the same as that given below the three genera mentioned.

Comparing our magnoliaceous formulas with the ranunculaceous ones we find that while prevailing features differ—so much so indeed as to make it desirable to group the plants in separate families—the departures from the type in one family often match those of the other.

There is, however, a general difference, not shown in the figures, which serves to separate the two groups. All members of the magnolia family have in the leaf-pulp, floral leaves, pith, and other soft parts, minute reservoirs of volatile oil, which are entirely lacking in the crowfoot family. These little reservoirs may be seen readily with a hand lens by viewing

¹ Ex-stip'u-late < L. *ex*, without; *stipula*, stipule.

² Hab'it < L. *habitus*, appearance.

³ The plant formulas referred to in this and succeeding sections, together with the ranunculaceous formulas already given, are grouped on pages 404-427 to facilitate their being compared with one another.

a leaf, petal, or slice of pith against the light, when they appear as translucent, scattered dots. This oil it is which renders the flowers of the family fragrant, and gives its flavor to the fruit of star-anise. Scarcely a trace of such odors are to be found in the crowfoot family.

We may therefore define the magnolia family as *woody plants having fragrant, solitary, regular flowers, more or less like those of the crowfoot family, but with minute reservoirs of volatile oil in various parts.*

107. The laurel family (Lauraceæ) consists also of woody plants with oil reservoirs similar to those of the magnolia family. This aromatic oil gives to sassafras (*Sassafras officinale*, page 168) and to cinnamon and camphor (*Cinnamomum*, pages 135, 178), as we have seen, their chief economic value. Between these and our examples of the magnolia and crowfoot families may also be found many other similarities, either in habit, form of leaves, or floral structure.

The morphology of the gynoecium in the laurel family is somewhat doubtful. Apparently there is only a single carpel, much as in the baneberry, but in sassafras the three-lobed stigma may be evidence of three carpels which coalesce so completely as to form a one-celled, one-styled pistil. A further peculiarity of sassafras is that the flowers are all imperfect and that the two kinds are always on distinct plants. The term *diœcious*¹ is applied to this condition.

A striking feature found throughout the family is the dehiscence of the anthers by uplifted valves. This is indicated in the formulas by FA[∨]. Another general peculiarity is that the concave torus often becomes fleshy and cup-like in fruit—a condition indicated by T[∪]T!. The sign ∞ meaning “or otherwise” when there are noteworthy exceptions, is also introduced in the formulas of this family, and ? is used to indicate doubt.

See pages 406, 407 for formulas of *Sassafras* and *Cinnamomum* and, derived from them (neglecting exceptions) a typical formula for the family.

Woody plants with minute reservoirs of oil, and regular flowers more or less like those of the crowfoot family but having the perianth and andrœcium mostly perigynous and the anthers

¹ Di-œ'ci-ous < Gr. *dis*, two; *oikos*, household; symbolized by ♂ : ♀.

always dehiscing by uplifted valves, constitute the chief members of the family.

108. The crowfoot order (Ranunculales or Ranales). A comparison of the three families we have been studying shows them to be closely linked together, much as are the genera within each family. By such linkage there is formed a natural chain of families including these and several others resembling them in important respects. Such a group of families is termed, as we have seen (page 8), an order. That which clusters about the crowfoot family takes significantly the name of the crowfoot order.

The prevailing characters of Ranunculales are expressed in the formula of the order given on pages 406, 407.

Neglecting the more variable or exceptional features we may say that the plants of this order, though differing widely in habit, foliage, and inflorescence, are characterized by having *usually cymose inflorescences of mostly perfect, regular, and hypogynous flowers with well-developed perianth often in whorls of three, stamens and carpels usually numerous, and all parts commonly distinct and free.*

109. The poppy family (Papaveraceæ) is represented sufficiently well for our purpose by the opium poppy (*Papaver somniferum*, pages 182, 183). Like all the other species of its genus, it contains instead of volatile oil a milky juice from which, as we have seen, opium is obtained. Many other genera of the family contain a similar juice which in some cases is bright yellow, and in others red. Sometimes the juice is watery.

The main structural features of *Papaver* appear in its formula on pages 406, 407.

The only new features calling for special notice concern the gynœcium which, unlike any in the crowfoot order (except possibly in the laurel family), consists of several carpels so united as to form a compound pistil with a one-celled ovary. That is to say, the carpellary leaves as they grow have the right edge of one coalescent with the left edge of its neighbor. The united edges of neighboring carpels thus form placentæ which lie along the outer wall of the compound

ovary. Such placentæ are termed *parietal*.¹ The capsule in poppies opens peculiarly by little pores like windows under the eaves of the overhanging stigma-ring. Such opening by pores, is called *poricidal* ² dehiscence.

With but slight modifications, not calling for special comment, the formula of *Papaver* becomes typical of the family as shown on pages 406, 407.

The family may generally be recognized as being *mostly herbs, commonly having a milky or colored juice, and hypogynous flowers with the floral envelopes most often in whorls of two, the stamens usually numerous, the pistil always compound, one-celled and with parietal placentæ, and the seeds albuminous with the embryo sometimes curved but neither coiled nor bent.*

110. The mustard family (Cruciferæ) agrees closely with the poppy family in general form and floral structure, as may be seen by comparing our figures of cabbages, turnips, mustards, and rape (*Brassica*, pages 54, 66–70), watercress and horseradish (*Nasturtium*, pages 70, 71, 144), and radish (*Raphanus*, page 55). The main family differences are in the bracts and bractlets, the number of stamens, and peculiarities of the gynœcium.

While the members of the poppy family have bracts and often bractlets of the usual sort (which therefore do not call for special notice), the members of the mustard family are almost unique in having no bracts within the inflorescence. Hence they are described as *ebracteate*.³ In a flower of the mustard family there are two outer and shorter stamens, alternating with two inner pairs of longer ones. Botanists regard these inner pairs as representing each a single stamen branched or divided into two.

The fact that a whorl is thus divided into sets is expressed in our formulas by the sign of division, \div , connecting the number in the whorl with the number of sets.

The carpels of the mustard family are normally only two,

¹ Pa-ri'e-tal < L. *parietalis*, belonging to a wall < *paries*, a wall; indicated by the symbol () placed after the number of the carpels.

² Por-i-ci'dal < L. *porus*, pore; *cædire*, to cut; indicated by the sign ° placed after that of the pericarp.

³ E-brac'te-ate < L. *e*, without; *bractea*, bract. Bo.

as in certain of the poppy family, but the ovary instead of being one-celled is divided into two compartments by a partition extending between the parietal placentæ. When ripe the carpels mostly separate from the placentæ and from this partition. Such a fruit is called a *siliqua*.¹ The ovules differ from any we have seen among the plants of the crow-foot order in lacking a raphe and being curved to a somewhat kidney-like form. When thus curved, ovules are described as *campylotropous*.²

The seeds are almost always exalbuminous and have the embryo commonly bent in various ways—a peculiarity expressed in the formulas by $G\wedge$.

Note how closely similar are the formulas of Brassica, Nasturtium, Raphanus, and Cruciferæ given on pages 406, 407.

As a definition of the family we have thus:—

Mustard family: *mostly herbs without milky or colored juice or oil reservoirs, often of sharp taste though pleasant flavor; ebracteate inflorescence; usually hypogynous flowers with all the parts in whorls of two (with the apparent exception of the four inner and longer stamens), the ovary divided into two cells by a partition joining the parietal placentæ; the fruit almost always a siliqua with exalbuminous seeds having the embryo variously bent.*

111. The poppy order (Papaverales or Rhœadales) comprises a few families well represented by the poppy and the mustard families and agreeing in having *mostly racemose inflorescences of complete, hypogynous, regular or irregular flowers with the sepals, petals, and stamens all distinct and free, and a compound pistil with parietal placentæ*. It is the union of the carpels by their edges which mainly distinguishes this from the crowfoot order.

For comparison we have a typical formula of the order on pages 408, 409.

112. The rose family (Rosaceæ) as illustrated by the almond (Fig. 31, page 42), apple (Figs. 91 I, II, pages 86, 87), pear (Fig. 92, page 87), quince (Figs. 93 I, II, page 88),

¹ Si-lique' < L. *siliqua*, a pod; $Cj\wedge$.

² Cam-py-lot'ro-pous < Gr. *kampylos*, curved; *trope*, a turn. E ∞ .

peach (Fig. 94, page 89), plum (Fig. 95, page 90), cherry (Fig. 96, page 90), raspberry (Fig. 97, page 91), strawberry (Figs. 98 I-III, page 92), and roses (Figs. 148 II, III, 298, pages 150, 151, 378), is seen to possess many features of floral structure resembling more nearly those of the crowfoot family than of any other family we have studied.

Note in the formulas of *Rosa*, *Fragaria*, *Rubus*, *Prunus*, *Cydonia*, and *Pyrus*, given on pages 408, 409, that the floral envelopes are mostly in fives, while the essential organs are commonly numerous, and that all are free and distinct, except sometimes the carpels, which then, unlike poppy carpels, have axile placentæ.

An unusual form of calyx is found in strawberries (*Fragaria*). Here the sepals have stipules which coalesce in pairs so as to form what looks like a calyx upon a calyx, and is termed therefore an *epicalyx*.¹ The only other features not before encountered belong to the torus and the fruit. Throughout the family the torus is concave or cup-like, and it is mostly free as in peonies and our examples of the laurel family. In roses (*Rosa*) it completely envelopes the carpels, and becomes fleshy and bright colored while the pericarps ripen into hard nutlets,² the whole forming a so-called "hip." The strawberry fruit consists mainly of the upper part of the torus,³ much swollen and bearing numerous achenes. Raspberries have the upper part of the torus comparatively dry, and in fruit the pericarps finally separate from it. As these ripen, an outer layer becomes fleshy while an inner layer hardens like an olive stone. A fruit in which the pericarp is thus differentiated is called a "stone-fruit" or *drupe*.⁴ In raspberries and thimbleberries the little drupes coalesce sufficiently to form a thimble-like mass after they separate from the torus. In blackberries, on the contrary, the little drupes remain attached to the part of the torus which bears

¹ E''pi-ca'lyx < L. *epi*, upon. S †

² The hardening of the pericarp is expressed in the formulas by two inverted exclamation marks.

³ A small *t* to represent part of the torus is used in the formulas instead of the large capital.

⁴ Drupe < L. *drupe*, a ripe olive. *Cij!*

them, or in other words, the pericarps *adhere*¹ to the torus, as botanists say of the union of dissimilar parts.

Such adhesion is represented in the *Rubus* formula by a bracket placed after the pericarp signs. The bracket is separated by a comma from the preceding signs to show that in this genus the pericarps are sometimes free. Similarly the expression *t_i,!*, means that the upper part of the torus may be either dry or fleshy in fruit, while *C_{ji}!* means that each pericarp is hard within and fleshy without, *i. e.*, *drupaceous*.

Each flower of plums, peaches, almonds, and cherries (*Prunus*) produces but a single drupe, and this has commonly but one seed within the "stone"; though occasionally as in "philopena" almonds both of the ovules develop. It should be noted that neither the "stone" of a peach, plum, or cherry nor the "shell" of an almond is part of a seed, but is the hardened inner layer of the pericarp, enclosing a seed or seeds.

The torus of quince (*Cydonia*) and of apples and pears (*Pyrus*), envelops the gynœcium, is adherent to the compound ovary, and both ripen together into the kind of fruit called a *pome*² in which the seeds are enclosed in a "core" consisting of dry, more or less parchment-like pericarps, surrounded by the fleshy torus. An adherent torus enveloping the ovary is said to be *epigynous*,³ a term likewise applied to the stamens, or the floral envelopes which it bears; and, indeed, to the flower itself having such a torus. The ovaries of epigynous flowers are termed *inferior*.

A typical formula for the family is shown on pages 408, 409.

The family includes *plants of various habit; without milky, colored, or acrid juice, and lacking reservoirs of volatile oil; but having often fragrant flowers more or less like those of the crowfoot family, but perigynous or epigynous; mostly stipulate leaves, and frequently luscious fruit.*

113. The pulse family (Leguminosæ). Examples: peanut (Fig. 33, page 45), pea (Figs. 37, 38, page 48), beans

¹ Ad-here' < L. *ad*, to; *hære*, stick.

² Pome < L. *pomum*, an apple or similar fruit. *T! C_i* <

³ Ep-ig'y-nous < Gr. *epi*, upon; *gyne*, pistil. T ⊂]

(Figs. 39, 40, pages 49–51), gum arabic tree (Fig. 156, page 164), tragacanth shrub (Fig. 157, page 165), licorice (Fig. 162, page 169), locust (Fig. 182, page 197), courbaril-tree and Zanzibar copal-tree (Fig. 273, page 289), indigo shrub (Fig. 275, page 293), and logwood-tree (Fig. 276, page 294).

See on pages 408–411 the formulas given for *Acacia*, *Hæmatoxyton*, *Hymenæa*, *Trachylobium*, *Pisum*, *Phaseolus*, *Robinia*, *Indigofera*, *Glycyrrhiza*, *Astragalus*, *Arachis*, and *Leguminosæ*.

In their floral structure many acacias, like the gum arabic tree, approximate closely to certain members of the rose family, notably in the numerous stamens, and regular calyx and corolla. In some species the filaments are more or less coalescent. Stamens thus united are said to be *monadelphous*.¹ The logwood-tree (*Hæmatoxyton*), the courbaril-tree (*Hymenæa*) and the Zanzibar copal-tree (*Trachylobium*) present irregular corollas, with the peculiarity that the uppermost petal is at first enfolded by the side ones, and these in turn by the lower pair. A large majority of the family, represented by peas (*Pisum*), beans (*Phaseolus*), and the other examples referred to, have what is called a *papilionaceous* ² corolla. This consists of five petals: one comparatively large called the *standard*, which is above the others and enfolds them in the bud; two side ones called the *wings*; and two lower ones grown together to form what is called the *keel*. A curious condition of the andrœcium commonly found with the papilionaceous corolla is that there is one uppermost stamen free from the other nine which are more or less coalescent. Such an andrœcium is termed *diadelphous*.³ Another peculiarity usually accompanying the papilionaceous corolla is the irregularity and coalescence of the sepals to form a calyx described as *gamosepalous* ⁴ and *bilabiate*,⁵ that

¹ Mon''a-del'phous < Gr. *monos*, one; *adelphos*, a brother; meaning in one brotherhood; indicated by the small parenthesis.

² Pa-pil'i-on-a'ceous < L. *papilio*, a butterfly—from the resemblance. This is expressed in the formula by $P''_{2\frac{1}{2}}$.

³ Di''a-del'phous < Gr. *dis*, two; $FA\frac{1}{2}$.

⁴ Gam''o-sep'al-ous < Gr. *gamos*, union; S_1 .

⁵ Bi-la'bi-ate < L. *bis*, two; *labium*, lip; S_3^2 .

is to say, consisting of sepals more or less united, so as to form an upper and a lower lip.

The most distinctive peculiarity of the family is its typical fruit, called a *legume*.¹ This consists of a single carpel which becomes dry and normally splits into two valves by dorsal and ventral sutures. As in the mustard family we found that the radish has an indehiscent pod of two carpels which is essentially a silique in structure, so here in certain genera we find pods of one carpel, essentially legumes, but without the usual mode of dehiscence. Peanuts, for example, though indehiscent, are plainly like pea-pods in most important respects, and both may well be called legumes.

A still stranger modification of legume is the fruit of *Hæmatoxylon* which dehisces into two valves but along lines midway between the ventral and the dorsal sutures, as indicated by $Cj < >$.

The great majority of our wild or cultivated members of the pulse family may be recognized by their having mostly *papilionaceous*, or at least *irregular corollas*, and a *single carpel which forms a legume*, while in other respects these plants are similar to those of the rose family.

114. The rose order (Rosales) includes several families which agree for the most part with the rose and the pulse family in bearing *botryose inflorescences of usually complete perigynous flowers, regular or irregular, having petals at least partly distinct, and pistils with a ventral or axile placenta*.

These features are indicated in the formula of Rosales on pages 410, 411.

115. The linden family (Tiliaceæ.) Examples: jute (Figs. 218 I, II, page 232), and linden (Figs. 251, 252, page 264).

See the formulas of *Corchorus*, *Tilia*, and *Tiliaceæ* on pages 410, 411.

The bracts of lindens (*Tilia*) and the andrœcium and fruit of the family present the chief peculiarities which call for present notice. The bracts of jute (*Corchorus*) present

¹ Leg'ume < *L. legumen*, beans, etc., or that which may be gathered by hand without cutting < *legere*, gather. Its sign is $Cj \diamond$.

no special peculiarities. In lindens, however, the lowermost bract of the flower-cluster is large, forming a sort of involucre, and adheres for a considerable distance to the peduncle. Jute flowers, which have the stamens in two whorls of five each, thus conforming to the numerical plan of the other floral organs, afford the simplest condition. In other species the stamens appear to be indefinite in number, but close examination would show them to be grouped into five clusters opposite the five petals. Each cluster is taken to represent the branches of a single one of the inner whorl of stamens, in much the same way that a pair of long stamens in the mustard family represent, as we have seen (section 110), a single branched stamen.

The fact that the stamen-groups are opposite the petals (hence regarded as being of the inner stamen whorl) is expressed by placing the sign || between P and FA.

Stamens in five clusters are said to be *pentadelphous*.¹ The stamens of the linden are always pentadelphous, and sometimes each cluster includes a staminode to which the anther-bearing filaments are coalescent. Throughout the family two pollen-sacs are borne by each filament which, however, divides more or less at the tip into a short stalk for each sac.

The fruit of jute is a capsule dehiscing by dorsal sutures into valves attached to the radial partitions. Such dehiscence is called *loculicidal*.² In lindens only one of the five carpels ripens, and commonly only one of the seeds which it contains. The pericarp becomes somewhat drupaceous so that the product of each flower resembles a small round almond. But a cluster of these nut-like fruitlets is formed by each inflorescence, and this cluster, borne on a common peduncle to which the bract still adheres, separates at maturity as a whole from the tree. The dry bract serves excellently as a

¹ Pen''-ta-del'phous < Gr. *pente*, five. FA $\infty \div 5$.

² Loc'u-li-ci''dal < L. *loculus*, a compartment; *cædere*, cut, because it is as if each compartment were cut into, so that in cross-section each division has a form something like the sign \perp which is used to distinguish this type of capsule in the formula of *Corchorus*.

sail to carry the fruit-cluster before the wind over smooth ground or a crust of snow.

The family comprises *mostly woody plants having mucilaginous juices; and often fragrant flowers with petals imbricate and distinct; stamens numerous, pentadelphous, and free; anthers with two pollen-sacs; and styles coalesced throughout.*

116. The mallow family (Malvaceæ). Examples: cotton (Figs. 214–216, pages 225–227) and marshmallow (Fig. 158, page 166).

See pages 410, 411 for formulas of *Gossypium*, *Althæa*, and *Malvaceæ*.

Several new features are presented in this family. An involucler is commonly present close to the flower, recalling the epicalyx of strawberries, but here we have bractlets in place of stipules. The æstivation of the corolla is such that one edge of each petal overlaps its neighbor, while the other edge is in turn overlapped by the next in order. Æstivation of this type is termed *convolute*.¹ The andrœcium appears to consist of a number of stamens borne upon a long tube enclosing the styles. This tube shows at the top, more or less distinctly, five projections which give evidence that the andrœcium consists really of but five stamens coalesced by their filaments to form the tube, and branched above into the numerous stalks bearing pollen-sacs. Curiously enough each branch bears only a single pollen-sac and is thus equivalent to but half of an ordinary anther.

The expression $FA \infty \div 5$] would read "stamens numerous, divided into five groups, monadelphous, and adhering to the petals." As a result of this adhesion the petals, although distinct, fall off in connection with the stamen-tube (as the fruit ripens) much as if they were coalescent.

The fruit of marshmallow (*Althæa*) represents a type very common in the family. Although indehiscent, the basal part of the several carpels, as they ripen, separate into as many nutlets, each containing a single seed. The fruit thus returns to a condition very like that of a cluster of anemone

¹ Con'vo-lute < L. *con*, together; *volvère*, roll. P'' is the sign.

achenes. A fruit thus splitting into one-seeded pieces is called a *schizocarp*.¹

The family comprises *mostly herbaceous plants rich in mucilage; with flowers often involucellate, seldom fragrant; petals convolute and distinct; stamens numerous, monadelphous, adhering to the corolla; anthers with only one pollen-sac; styles more or less distinct.*

117. The mallow order (Malvales) contains several families having *mostly cymose inflorescences of complete, regular, and hypogynous flowers; with the petals distinct (though often adhering to the pentadelphous or monadelphous stamens) and opposite the stamen-groups; and the pistils with axile placentæ.*

See pages 410, 411 for a typical formula of the order.

118. The parsley family (Umbelliferæ). Examples: carrot (Figs. 47-53, pages 55-57), parsnip (Figs. 54, 55, page 57), celery (Figs. 78, 79, page 75), parsley (Fig. 138, page 140), caraway (Fig. 140, page 142), anise (Figs. 141 I, II, page 142), coriander (Figs. 143 I-III, pages 143, 144), asafetida (Fig. 168 I, page 175), water hemlock (Fig. 179, page 193), and poison hemlock (Figs. 180 I, II, pages 194, 195).

See pages 410-413 for formulas of *Conium*, *Carum*, *Petroselinum*, *Cicuta*, *Coriandrum*, *Apium*, *Pimpinella*, *Pastinaca*, *Ferula*, *Daucus*, and *Umbelliferæ*.

The name *Umbelliferæ*, meaning "umbrella-bearers," was given to this family because almost all the members have inflorescences resembling umbrellas. This form of inflorescence, called an *umbel*,² may be likened to a raceme in which the internodes of the rachis are suppressed, thus bringing the bracts, when present, together as an involucre. In most of the parsley family, the inflorescence consists of a number of little umbels or *umbellules*,³ arranged in an umbel.

Usually all the flowers of a cluster are perfect. An interest-

¹ Schiz'o-carp < Gr. *schizo*, I split; *karpos*, fruit. $C_j < \div \infty$.

² Um'bel < L. *umbella*, diminutive of *umbra*, shade. I/.

³ Um'bel-lule < L. *umbellula*, diminutive of *umbella*. i/. Each umbellule may have a secondary involucre composed of secondary bracts which are symbolized by the B² which comes after the B.

ing exception is found in the carrot (*Daucus*) where there is often a central flower destitute of essential organs. Such a flower is described as *neutral*.¹

The sepals are commonly reduced to small tooth-like projections, or they may be so united into a narrow ring as to appear obliterated. The calyx-teeth do not touch in the bud; hence their æstivation is said to be *open*.² More or less irregularity of calyx and corolla occurs among the outer flowers of an umbel, though most of the flowers are but little if at all irregular.

The two-carpelled, inferior ovary ripens into a dry fruit which at maturity splits in halves, each half hanging from the top of a continuation of the torus, as shown in Fig. 141 II. Such a fruit is called a *cremocarp*.³ It is like a schizocarp except that it is the product of an inferior ovary. Each half has several more or less pronounced ribs; and, in the wall, parallel to the ribs, are often tubular reservoirs of volatile oil giving a characteristic odor to the fruit.

An odor similar to that of the fruit often pervades every part so that from an immature specimen or only a fragment it is often possible to recognize these plants by their peculiar, though indescribable, smell.

The stems have the rare characteristic of being hollow even at the nodes.

Herbs rich in volatile oil, but with watery sap; having leaves exstipulate; flowers regular or irregular, mostly in compound umbels, often involucrate; the petals and stamens five, the carpels two, styles distinct; and the fruit a cremocarp—such are the typical members of the family.

119. The parsley order (Umbellales or Umbellifloræ) includes two other families which agree with the parsley family in having *mostly umbellate inflorescences of small, complete, epigynous flowers, with the petals and stamens distinct and alternate, and the carpels with but a single ovule in each.*

For the formula of Umbellales see pages 412, 413.

¹ Symbolized by the sign ♂.

² Expressed in the formulas by S'.

³ Crem'o-carp < Gr. *kremao*, I hang; *karpos*, fruit. TCj < ÷ 2.

120. The buckwheat family (Polygonaceæ). Examples: buckwheat (Fig. 22, page 29) and rhubarbs (Fig. 112, page 104, and Fig. 163, page 170).

See pages 412, 413 for formulas of *Rheum*, *Fagopyrum*, and *Polygonaceæ*.

The stems of plants belonging to the buckwheat family are commonly swollen at the joints, and have above each node a thin tubular sheath formed by the coalescence of the stipules. These sheaths are called *ocrea*,¹ and the plants or leaves are said to be *ocreate*.

The parts of the flower are commonly in threes although there are some curious departures from the type. Thus in buckwheat (*Fagopyrum*) there are five sepals as against the six-leaved perianth of rhubarb (*Rheum*), but we may regard the missing sepal as represented by a bractlet which is absent in the other inflorescence. Again, the six outer stamens of rhubarb are to be regarded as three pairs, each pair formed from the division of one stamen into two; while in buckwheat the andræcium is similar except that one of the outer stamens has remained undivided, thus giving but eight in all. That there are three carpels is shown clearly by the three distinct styles, though there is but one cavity from the base of which arises a single ovule. This ovule differs from the others we have studied in having the micropyle opposite to the funicle, that is to say, in being straight or *orthotropous*.²

The family consists mostly of *herbs with a watery juice which is often peppery and sometimes pleasantly acid, without reservoirs of volatile oil; having stems often swollen at the joints; leaves ocreate; styles two or three, distinct; ovary containing a single, orthotropous ovule; and the fruit an achene.*

121. The buckwheat order (Polygonales) which contains only the above family, may be contrasted with the previous orders as having *mostly paniculate inflorescences of small, regular, perfect, hypogynous flowers, with the perianth,*

¹ Oc're-a < L. a legging. L↓).

² Or-thot'ro-pous < Gr. *orthos*, straight. Symbolized by a straight line over the numerical sign, Eī.

leaves, and stamens distinct and alternate, and the ovary with but one cavity and one ovule.

The formula of Polygonales is given on pages 412, 413.

122. The birch family (Betulaceæ). Examples: filbert (Fig. 23, page 36) and birch (Fig. 254, page 265).

See pages 412-415 for formulas of *Betula*, *Corylus*, and *Betula-cæ*.

We meet in this family with the singular form of inflorescence sometimes called "pussies," or catkins, and known botanically as *aments*.¹ An amentaceous inflorescence is typically an elongated, often dangling, cluster of imperfect flowers which are in the axils of scale-like bracts. It is a special form of *spicate*² inflorescence, *spike*² being the general term for a racemose cluster of sessile or nearly sessile flowers. If the internodes of a spike fail to elongate the flowers become crowded into a *head* or *capitate*³ inflorescence. In the axil of each scale of a birch catkin we find three flowers (Fig. 254) closely crowded together and so forming the simplest sort of head. These heads of staminate flowers are borne along the sides of a slender hanging rachis, so that the whole compound cluster forms a typical ament. The pistillate heads occur on a stiffer rachis which commonly grows erect, and might therefore properly be called a spike although on account of its scale-like bracts botanists often speak of this inflorescence as a pistillate ament. In the pistillate inflorescence of hazels (*Corylus*) the little heads (here two-flowered) are so few and crowded as to form a compound head of heads.⁴

In the hazels the staminate flowers are solitary in the axils of the scales, thus forming simple aments; while the pistillate flowers are grouped in heads of two, and each flower is surrounded by an involucl formed of its special bract and its

¹ Am'ent < *L. amentum*, a thong or shoestring. Ij.

² Spi'cate, spike < *L. spica*, an ear of corn. I'.

³ Cap'i-tate < *L. capitatus*, having a head < *caput*, head. I'.

⁴ All these facts are expressed in the formulas by using an inverted exclamation point as the symbol of an amentaceous inflorescence, an inverted colon for spicate, and two inverted periods for capitate clusters. That the bractlets are adherent to the bracts by their lower parts is shown by the small bracket, j.

two coalescent and adherent bractlets. Plants with both staminate and pistillate inflorescences borne upon the same individual plant are termed *monœcious*.¹

The united bracts and bractlets of birches (*Betula*) ripen into dry scales forming a cone-like cluster of fruits made up of little samaras. In hazels the involucre becomes much enlarged in fruit, and each surrounds a much hardened pericarp which because of its hardness and indehiscence is called a *nut*.²

The family comprises *woody plants without oil reservoirs but with resinous warts or hairs on the younger parts; simple, stipulate leaves; and monœcious inflorescences, the staminate amentaceous, the pistillate in spikes or heads with coalescent bracts and bractlets, and the pistils of two carpels with axile placentæ.*

123. The beech family (Fagaceæ). Examples: chestnut (Figs. 24-26, pages 37, 38), oaks (Figs. 242, 243, 267, pages 257, 258, 277), and beech (Fig. 257, page 268).

See pages 414, 415 for the formulas of *Fagus*, *Castanea*, *Quercus*, and *Fagaceæ*.

The inflorescences of this family resemble those of the preceding family in being monœcious and in part amentaceous. It is in the bracts and the way they are borne that we find the most significant differences—differences which become more striking as the fruit matures. Indeed, botanists have here met with a morphological problem of more than ordinary difficulty in the preliminary question: What are the homologues of bracts which ripen with a beechnut, a chestnut-bur, or an acorn?

In the staminate inflorescences of beech (*Fagus*) and chestnut (*Castanea*) the bracts are obvious enough and are sufficiently like those of the birch family to require no special

¹ Mo-nœ'cious < Gr. *monos*, one; *oikos*, household. This is indicated by ♂-♀. If the staminate inflorescence differs in form from the pistillate the nature of each is shown by placing the inflorescence signs in corresponding order, *i. e.*, beginning with the staminate. Thus *Il'i'* would read "staminate inflorescence amentaceous, the pistillate spicate, both compounded of heads."

² In the formula this extra hardness of the pericarp is indicated by two inverted exclamation points.

comment; while the staminate flowers of *Quercus* are ebracteate. The pistillate flowers of beech are two in a head (Fig. 257) which is enclosed in a little cup or *cupule*¹ as it is called, bearing scales or spines on its outer surface. This cup eventually encloses completely the ripening nuts, and when mature splits into four partial valves to set them free. The cupule of chestnuts encloses three flowers, ripens into the spiny bur, and splits sometimes into four valves, and sometimes irregularly. Only one flower is in the scaly cupule of oaks (*Quercus*), and the single nut which constitutes the acorn is so little covered by the cupule as to make splitting of the cupule unnecessary.

Evidently the projections of the beech cup, the spines of the chestnut-bur and scales of an acorn-saucer are homologous, as is also the main part of the cupule of each. But where are the bracts? Do the four divisions of the ripened beech cup and chestnut-bur correspond to so many bracts which in the acorn-saucer remain coalesced? In that case the various outgrowths from the cupule would be regarded as mere projections like the spines on a leaf. This view is held by many botanists. Others maintain that the projections, spines, and scales are the free tips of bracts which have coalesced by their bases to form the body of the cupule. On this view the cupule would be an involucre of many instead of but four bracts. A third view regards the main body of the cupule as stem, that is to say, as a cup-like development of the secondary peduncle, bearing numerous bracts. Thus regarded, the acorn scales, the beech-nut projections, and the branched spines of the chestnut-bur, are homologized with bracts which are entirely distinct and free from the concave inflorescence-stalk. This last theory seems to be the one most easily reconciled with the facts as they appear in other members of the family as well as in those we have studied.²

¹ *Cu'pule* < *L. cupula*, diminutive of *cupa*, cup.

² This is the view adopted in our formulas. *i* does duty for the axial part of the ultimate inflorescences; *jj* ~ following shows that it becomes woody and concave like a perigynous torus; while < 4 shows that it dehisces into four valves; or < that it is indehiscent; and *Bj* ∞ that it bears numerous dry bracts. The other parts of the formulas should be readily understood from what has preceded.

The family consists of *woody plants without oil reservoirs or resinous excretions; but with simple, stipulate leaves; and monœcious inflorescences, the staminate mostly amentaceous, the pistillate more or less enclosed in a cupule, which bears distinct, scaly, or spiny bracts; and the pistils of three or more carpels with axile placentæ.*

124. The beech order (Fagales) comprises only the birch and the beech families. These agree in having *monœcious inflorescences with the staminate flowers mostly in aments, and the pistillate in spikes or heads; the flowers hypogynous or epigynous; the perianth leaves and stamens distinct and alternate; and the ovary with axile placentæ, and more or less completely divided into two or more cavities, all but one of which becomes obliterated in the fruit.*

See pages 414, 415 for the formula of Fagales.

125. The walnut family (Juglandaceæ). Examples: walnut (Fig. 27, page 39), butternut (Fig. 28, page 40), pecan (Fig. 29, page 40), hickory (Fig. 30, page 41), and black walnut (Fig. 246, page 260).

Formulas of Juglans, Carya, and Juglandaceæ are given on pages 414, 415.

In general appearance the inflorescences of the walnut family resemble those of the beech and the birch families, but there is a curious adherence between the bracts, bractlets, and perianth leaves, unlike anything we have seen. Those which belong to each flower are all more or less united to form what at first sight might be mistaken for perianth alone.

The fruit is mostly a drupaceous nut recalling the almond, but with the tough fleshy part dehiscing into four valves and differing also in having the epigynous torus as a component part.

The walnut family may be distinguished as consisting of *trees with scented, pinnately compound, exstipulate leaves; and monœcious inflorescences, the staminate amentaceous, the pistillate in heads; each pistil of two carpels; and the fruit a dehiscent drupe with a nut-like stone.*

126. The walnut order (Juglandales), contains only the

family from which it derives its name. It is distinguished from the other orders with *monœcious inflorescences, staminate aments and pistillate heads, by having the perianth leaves or the epigynous torus adherent to the bractlets and bract of each, and the ovary with but one cavity and one ovule.*

The formula of Juglandales is given on pages 414, 415.

127. The willow family (Salicaceæ). Examples: willow (Figs. 228 I, II, pages 243, 244) and poplar (Fig. 253, page 264).

Formulas of *Populus*, *Salix*, and *Salicaceæ* are given on pages 414, 415.

Much simpler flowers are here shown than any previously mentioned, although scarcely any new features are presented. The torus while cup-like in the poplars, is represented in the willows by one or two glandular projections which secrete nectar. It is plain that a cup divided, or failing to develop, at one or two places would be reduced to such flat projections.

A peculiarity of the fruit of both genera is that its two carpels dehisce along their dorsal sutures exposing the small hairy seeds to the wind.

This family which contains only the two genera mentioned, is composed of *woody plants without oil reservoirs, but sometimes with aromatic resinous secretions; the leaves simple and stipulate; the inflorescences amentaceous and diœcious; the pistil of two carpels with parietal placentæ; and the fruit a capsule with numerous tufted seeds.*

128. The willow order (Salicales) contains only the above family. *Diœcious aments of flowers without perianth but with numerous ovules, perigynous (?) torus, and free bracts,* distinguish this from the other orders.

The formula of *Salicales* is given on pages 416, 417.

129. The crowfoot series (Archichlamydeæ). A general view of all the orders which we have thus far studied shows them to agree (with but rare exceptions) in having no coalescence among the petals. All the leaf-parts of any flower are at first similarly distinct as they arise in the bud. Some-

times petals do not appear at all, but when they do it is as distinct projections from the torus, comparable to the first rudiments of foliage leaves as they form near the tip of a developing shoot. The same is true of sepals, stamens, and carpels, as illustrated in Figs. 298, 299 I. If, however, a gamosepalous calyx, a monadelphous andrœcium, or a compound pistil is to be produced, it happens sooner or later that those

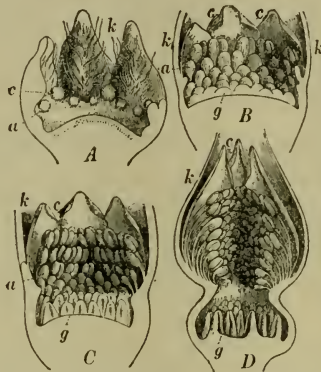


FIG. 298.—Flower of Rose (*Rosa alpina*, Rose Family, *Rosaceæ*) in early stages, cut vertically and enlarged. *A*, the sepals (*k*) are well developed, but the petals (*c*) and the stamens (*a*) are just appearing as minute knobs. *B*, sepals, petals, and stamens further advanced; and the pistils (*g*) just appearing as knobs on the dome of the stem-tip. *C*, later stage. *D*, still later stage in which the parts are still developing in the bud. (Payer.)

parts of the ring which connect the original projections begin to grow and the distinct parts are carried up on the rim or the tip of a tube or united mass of organs.

Flowers which as they develop retain the original distinctness of their petals, or which develop none at all, are termed *archichlamydeous*.¹ Such flowers, we have seen, characterize the crowfoot series which includes all the orders we have studied and a number of others resembling them in the peculiarity noted.

130. The heath family (*Ericaceæ*). Examples: wintergreen

¹ Ar''chi-chla-myd'e-ous < Gr. *archi*, first; *chlamys*, mantle; implying that the corolla, likened to a mantle, retains its original condition.

(Fig. 147, page 148), mountain laurel (Fig. 189, page 202), and sheep laurel (Fig. 190, page 202).

Formulas of Gaultheria, Kalmia, and Ericaceæ are given on pages 416, 417.

A corolla with the petals coalesced, as in the examples here given, is termed *gamopetalous*,¹ a corolla with distinct petals being *choripetalous*.²

When anthers open by pores the dehiscence is said to be *poricidal* as in the case of capsules which open similarly.

It will be noticed that the capsule of mountain laurel (Kalmia) dehisces by splitting through the partitions. Such dehiscence is distinguished as *septicidal*.³

The fruit of wintergreen (Gaultheria) is peculiar in having a loculicidal capsule enveloped in a fleshy enlargement of the calyx and torus.

The typical members of the family are *woody plants, often aromatic; having simple, exstipulate leaves; and perfect, gamopetalous flowers, with poricidal stamens, and a compound pistil, superior or inferior ovary and axile placentæ; the fruit being capsular, or berry-like.*

131. The heath order (Ericales) includes several families associated with the above through having *mostly regular and perfect, usually gamopetalous flowers, four to ten stamens nearly or quite free, the anthers mostly poricidal, and the ovary compound, with axile placentæ.*

The formula for Ericales is given on pages 416, 417.

132. The morning-glory family (Convolvulaceæ) is well exemplified by the sweet potato (Figs. 56, 57, pages 58, 59).

Formulas of Ipomœa and Convolvulaceæ are given on pages 416, 417.

The new features to be noted here are the æstivation of

¹ Gam''o-pet'al-ous < Gr. *gamos*, union; *petalon*, flower-leaf. P).

² Cho''ri-pet'al-ous < Gr. *choris*, separate.

³ Sep'ti-ci''dal < L. *septum*, partition; *cædire*, cut. Indicated by the sign \angle .

FIG. 299, I.—Flower of Oxeye (*Heliopsis scabra*, Sunflower Family, *Compositæ*). A–N, stages in the development of a tubular floret, enlarged. A, very young stage in which the flower (*fl*) is as yet without petals but is plainly distinguishable from its bract (*b*). B, shows the ringlike swelling (*k*) which represents the calyx, and five knobs (*c*) which are the beginnings of petals. C, a somewhat more advanced stage, just before the appearance of the stamens. D, showing the stamens (*a*) just appearing. E, same stage as D, cut vertically. F, later stage in which the beginnings of two carpels (*g*) appear. G, same stage, viewed from the side, showing that the petals or corolla lobes have curved inward protectively and are united below by a ring of tissue which by upward growth becomes the corolla-tube bearing the five lobes above. H, same stage, cut vertically; showing the upward growth of the carpels (*g*) leaving a hollow in the stem-tip (*torus*). J, later stage, cut vertically through the middle of the carpels (*g*) showing a deepening of the hollow in the torus. K, bud of middle age, showing the corolla-tube (*c*) with its five lobes well developed, and lower part of the pistil (*g*), enveloped by the torus, becoming plainly distinct as an “inferior ovary.” L, a somewhat later stage, cut vertically, showing the appearance of two styles (*s*), still distinct, and a young ovule (*o*) with its outer coat half-grown. M, bud almost ready to open; the two styles having grown into one (*s*); the anthers (*a*) joined into a tube; the sepals (*k*) distinct prominences on the top of the torus, a nectargland (*d*); and the ovule (*o*) completely formed. N, Tubular floret, open, showing anther-tube (*a*), corolla-tube (*c*), and inferior ovary (*g*). O–S, stages in the growth of a ray-floret. O, very early stage in which five petal-lobes appear, three of which, however, are distinctly larger than the other two. P, later stage in which the three larger lobes (*c*) have become much larger, while the two smaller ones have remained undeveloped. Q, ray-floret about half-grown, showing two of the three petal-lobes separate to the base. R, same, cut vertically between the two separate petals, showing the union of the middle one (at the

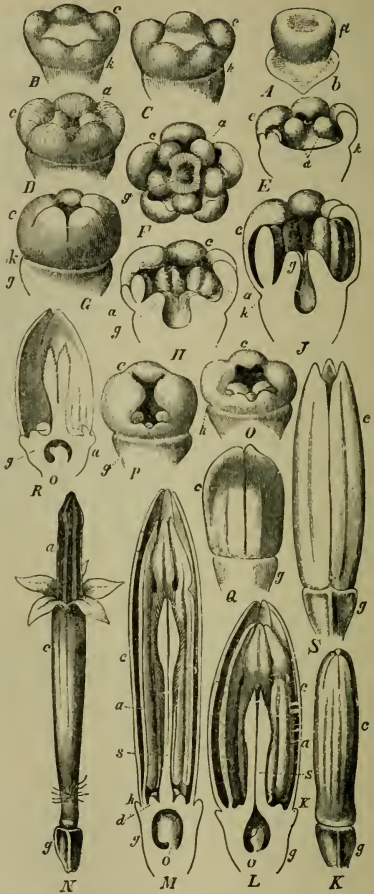




FIG. 299, II.—Creeping Bellflower (*Campanula rapunculoides*, Bellflower Family, *Campanulaceæ*). *A*, flowering branch. *B*, flower, cut vertically, enlarged. *C*, floral diagram. *D*, fruit opening by little doors at base, enlarged. *E*, seed, entire, and cut vertically, enlarged. (Le-Maout and Decaisne.)—A perennial herb 30–90 cm. tall; flowers blue; fruit dry. Native home, Eurasia; run wild from gardens.

the corolla and the dehiscence of the capsule. So complete is the coalescence of the petals in most members of the family and so flaring the corolla, that as it forms in the bud it becomes folded or *plicate*,¹ and the folds overlap in a convolute manner. Such æstivation may be described as *plicate-convolute*. The capsule of the morning-glory (of which the sweet potato is one species) differs from the other capsules we have studied in having the valves separate not only from one

Pli'cate < *L. plicatus*, folded into plaits. P ∨.

left) with one of the other two which together with the middle one are to form the strap-shaped corolla. *S*, somewhat later stage showing the three lobes of the strap-shaped corolla (*c*) and the inferior ovary (*g*). (Payer.)—A perennial herb about 1 m. or more tall; resembling a sunflower. Native home, Eastern United States; familiar in gardens.

• another but from the partitions within, the sutures coming at the margin of the partitions. Dehiscence of this type is termed *marginicidally septifragal*.¹

The family is a small one made up mostly of *round-stemmed herbaceous vines, with more or less milky juice; alternate, exstipulate leaves; regular flowers having a gamopetalous corolla, plicate-convolute in the bud, and having usually adherent stamens, the ovary being two to five-celled; and with the fruit, commonly a capsule, containing a few large albuminous seeds with folded embryo.*

133. The nightshade family (Solanaceæ). Examples: white potato (Figs. 58 I–III, pages 59, 60), tomato (Figs. 88, 89, pages 83, 84), egg-plant (Fig. 90, page 85), red pepper (Figs. 125 I, II, 126, pages 131, 132), tobacco (Fig. 173, page 184), belladonna (Fig. 175, page 187), and jimson-weed (Figs. 187 I, II, page 200).

No new signs appear in the formulas of *Nicotiana, Datura, Atropa, Capsicum, Solanum, and Solanaceæ* on pages 416, 417.

This large family may be distinguished as consisting of *mostly rank-scented, round-stemmed, herbaceous plants, with watery sap; leaves alternate, exstipulate; flowers regular or nearly so; the corolla gamopetalous, plicate-convolute, or plicate-valvate; ovary two-celled; fruit a capsule or berry containing many small albuminous seeds with the embryo coiled.*

134. The figwort family (Scrophulariaceæ) is exemplified by the foxglove (Fig. 192, page 204).

See the formulas of *Digitalis* and *Scrophulariaceæ* on pages 416, 417.

Round or square-stemmed, herbaceous or woody plants not strongly scented; the juice watery and often bitter; leaves alternate, opposite or verticillate, exstipulate; flowers irregular; corolla gamopetalous, imbricate in æstivation; stamens two to five, mostly four; ovary two-celled; fruit a septicidal or loculicidal capsule, containing many small albuminous seeds with the embryo uncoiled.

¹ Sep-tif'ra-gal < L. *septum*, partition; *frangere*, break. Cf †.

135. The mint family (Labiatae). Examples: sage (Figs. 132, 133, page 138), thyme (Fig. 134, page 139), spearmint (Fig. 135, page 139), summer savory (Fig. 136, page 139), sweet marjoram (Fig. 137, page 140), and peppermint (Figs. 146 I, II, pages 147, 148).

The formulas of *Mentha*, *Thymus*, *Origanum*, *Satureia*, *Salvia*, and *Labiatae* are given on pages 418, 419.

When a gamopetalous corolla has the two upper petals coalescing with one another more completely than they do with those at the side, and the two lateral ones in turn more completely coalescing with the lower petal, there results a two-lipped or *labiate*¹ form shown especially well in *Salvia* and most other members of the family. It should be noted, however, that more or less labiate corollas occur also in many genera of the figwort family and some other families of the group we are now studying. Typical members of the mint family are easily recognized as *square-stemmed, aromatic herbs with opposite leaves, labiate corolla and schizocarpic fruit of four nutlets. As in the figwort family the juice is watery, the leaves exstipulate, the petals imbricate, and the stamens generally four, but the seeds are exalbuminous and the embryo uncoiled.*

136. Phlox order (Polemoniales or Tubiflorae), embraces a number of families besides the four just mentioned. In general they are characterized by having *perfect, regular or irregular, gamopetalous flowers, with two to five stamens adherent to the corolla, and distinct; the anthers seldom poricidal; the ovary compound and superior.*

For the formula of Polemoniales see pages 418, 419.

137. The gourd family (Cucurbitaceae). Examples: pumpkin (Figs. 80 I–81 I, pages 76–78), squashes (Figs. 81 II–84, pages 79–82), cucumber (Figs. 85–87, pages 82, 83), muskmelon (Figs. 102, 103, page 95), watermelon (Figs. 104, 105, page 96), sponge cucumber (Fig. 225, page 240), and bottle-gourd (Fig. 265, page 275).

See pages 418, 419 for the formulas of *Cucurbita*, *Cucumis*, *Citrullus*, *Lagenaria*, *Luffa*, and *Cucurbitaceae*.

¹ La'bi-ate < *L. labium*, lip. P₃).

Most of the gourd family have the andrœcium so curiously developed as to be quite variously understood by different botanists. According to the view now most generally adopted there are typically five stamens. In some members of the family (not among the above examples), all five stamens are free, but usually four of them coalesce more or less completely in pairs, forming, as we may say, two double stamens leaving an odd one distinct. In such cases the flowers appear to have but three stamens. Along with this coalescence there goes an extraordinary elongation and bending¹ of the pollen-sacs as shown in Fig. 80 III. In some genera, as for example squashes, etc. (*Cucurbita*), there is a complete coalescence of all the anthers, which are then said to be *syngenesious*.²

In this genus and most other members of the family, three, much thickened, wedge-shaped, parietal placentæ almost completely fill the ovary, and bear on their recurved margins an indefinite number of ovules. The seeds as they ripen are imbedded in a soft pulp formed of the placentæ. Around this pulp, in the mature fruit, is a hard rind composed of the ripened ovary wall and the adhering torus. Such a fruit is called a *pepo*.³

The family is made up mostly of *herbaceous vines with watery juice; flowers solitary or loosely clustered, imperfect, regular, gamopetalous or choripetalous; stamens five, often appearing as three through coalescence, and sometimes syngenesious, the pollen-sacs often elongated and bent; ovary inferior with three parietal placentæ, fruit usually a pepo.*

138. The bellflower family (*Campanulaceæ*). Examples: Indian tobacco (Figs. 188 I, II, page 201) and bellflower (Fig. 299 II, page 381).

The formulas of *Campanula*, *Lobelia*, and *Campanulaceæ* are given on pages 418-421.

The corolla of Indian tobacco and other species of its genus

¹ This bending is expressed in the formulas by FA ∨.

² Syn''gen-e'sious < Gr. *syn*, together; *genesis*, generation. Such coalescence is symbolized by a small parenthesis placed after the stamen number and above.

³ Pe'po < L. *pepo*, a pumpkin. TC!j <.

(Lobelia) affords a case of partial coalescence somewhat different from any of our foregoing examples. The two uppermost petals are entirely free from one another, though coalesced with the side ones, and these with the lowest, so that all five petals are as if united into a tube which is split down the back.¹

In bellflowers (*Campanula*) the more or less bell-like corolla from which they take their name shows no irregularity.

Mostly herbs with milky juice; flowers solitary or loosely clustered, perfect, regular or irregular, mostly gamopetalous; stamens five, free or monadelphous and syngenesious; the pollen-sacs straight; ovary inferior with two to five axile placentæ; fruit capsular.

139. The sunflower family (*Compositæ*). Examples: Jerusalem artichoke (Figs. 59 I-IV, pages 61, 62), lettuce (Figs. 75-77, pages 72-74), and wormwood (Fig. 155, page 160).

Formulas of *Helianthus*, *Lactuca*, *Artemesia*, and *Compositæ* are given on pages 420, 421.

More than a tenth of all the species of flowering plants belong to this the largest family of seedworts. The very characteristic inflorescence is sometimes mistaken for a single flower, and was indeed called a "compound flower" by the early botanists. In reality, as will be readily seen, the small flowers are borne on a more or less flattened expansion of the peduncle, called the *receptacle*, and form a compact head surrounded by an involucre of bracts resembling sepals. As if to increase the deception the outer row of florets often have what are called *strap-shaped* corollas formed by a coalescence of the petals into one flat piece (Fig. 59 II, III), somewhat as in the Indian tobacco but more complete; and these corollas radiate so as to look like petals. The inner part of the head in such cases as the sunflower is made up of regular florets (Fig. 59 III). Many members of the family have only regular florets, while still others have all the florets strap-shaped or sometimes labiate.

The calyx may consist of a few papery scales, or of numer-

¹ This condition is indicated in the formulas by P^o 5).

ous bristles forming what is termed the *pappus*.¹ Sometimes through a prolongation of the torus above the fruit a sort of parachute is formed as in lettuce (*Lactuca*, Fig. 76). The one-seeded fruit of *Compositæ* is commonly called an achene, although morphologically it is very different from such a simple achene as that of the crowfoots.

In spite of wide diversities in structural detail the members of this vast family may generally be recognized as *herbs with milky or watery juice; flowers in dense heads having a calyx-like involucre, gamopetalous, regular or irregular; stamens five, syngenesious, but with distinct filaments inserted on the corolla, and the pollen-sacs straight; ovary inferior, with a single ovule; fruit achenial, often with pappus.*

140. The bellflower order (*Campanulales*), includes several families with *flowers perfect, imperfect, or neutral, regular or irregular, mostly gamopetalous; the stamens five, adherent to the corolla, distinct or more or less coherent; anthers not poricidal; ovary compound, inferior.*

The formula of *Campanulales* is given on pages 420, 421.

141. The bellflower series (*Metachlamydeæ*) in contrast with the crowfoot series or *Archichlamydeæ*, includes several orders which are characterized by the prevalence of a gamopetalous corolla. This, as showing a more advanced development of the perianth than we find in *archichlamydeous* flowers (see section 129), entitles the flower possessing it to be distinguished as *metachlamydeous*.²

142. The dicotyl sub-class (*Dicotyledones*) comprises the crowfoot series (*Archichlamydeæ*) and the bellflower series (*Metachlamydeæ*). These agree in being made up of seed plants with the embryo having two cotyledons or *dicotyledonous*.³ The parts of the flower are very generally in fours or fives, seldom in threes; the leaves are mostly netted-veined; and in the stem there may be distinguished a central core of pith surrounded by a ring or rings of wood and bark. See especially Figs. 232 and 233. Stems thus constructed

¹ Pap'-pus > Gr. *pappos*, grandfather, applied to the thistle-down in allusion to white hair. *STC*_i.

² Met'-a-chla-myd''e-ous < Gr. *meta*, beyond.

³ Di''cot-y-led'on-ous < Gr. *dis*, two; *kotyledon*, seed-leaf.

are called *exogenous*¹ or outside-growing, because new wood when formed is added on the outside of an older ring.

143. The grass family (Graminæ). Examples: oat (Fig. 1-4, pages 12-14), rice (Figs. 5, 6, pages 16, 17), rye (Fig. 7, page 18), wheat (Figs. 8, 9, pages 19, 20), barleys (Figs. 10-12, pages 21, 22), maize (Figs. 13-15, pages 23, 24), sugar-cane (Fig. 114, page 106), broom-corn (Fig. 222, page 236), and bamboo (Fig. 224, page 239).

Formulas of *Zea*, *Saccharinum*, *Andropogon*, *Oryza*, *Avena*, *Secale*, *Triticum*, *Hordeum*, *Bambusa*, and *Gramineæ* are shown on pages 420-423.

The grasses introduce us to a new sub-class, characterized partly, as we shall see, by having the leaf-veins running in a regular, more or less parallel system. Leaves with such a framework are said to be *parallel-veined*. Grass leaves always have the veins running lengthwise from base to tip.

Other noteworthy features of grass leaves are that the base is wrapped about the stem so as to form a sheath the edges of which overlap as shown in Fig. 13; and the blades extend from only two sides of the stem, thus coming into two vertical ranks.

Most grass stems are round and hollow like straws. Rarely, as in the stalk of maize, there is a solid cylinder of pith, through which run scattered bundles of firmer, more or less woody material, not forming true rings, but often so crowded toward the surface as to constitute a somewhat bark-like zone. From an erroneous idea that these scattered bundles originated near the center of the stem and were forced outward by new growth, all stems with scattered bundles were early described as "inside-growing" or *endogenous*²—a term still used conveniently, however, by way of contrast for stems of seed-plants of the non-exogenous type.

The bracts and bractlets of grasses in general are comparatively thin and stiff, like the husks or chaff of grain, and have received the special name of *glumes*.³

¹ Ex-og'en-ous < Gr. *exo*, outside; *genes*, producing.

² En-dog'en-ous < Gr. *endos*, within.

³ Glume < L. *gluma*, husk of corn. In our formulas the glumaceous character is denoted by the inverted exclamation mark as in B_j.

The grain-like fruit of typical grasses resembles an achene in being the product of a simple pistil with one ovule and in being dry and indehiscent. It differs mainly in having the seed-coat adherent to the pericarp. A fruit of this kind is distinguished as a *caryopsis*.¹

As shown in Fig. 9 the embryo is placed at one side of the albumen. On the side toward the seed-food is a somewhat shield-shaped organ, termed the *scutellum*,² through which the germ absorbs its nutriment when sprouting. Morphologically the scutellum is regarded by most botanists as the cotyledon of the embryo, enlarged and otherwise modified for its peculiar function. Unlike the embryo of dicotyledonous plants, the embryo of a grass, as of all the sub-class of seed-plants now to be studied, has but one cotyledon and is hence described as *monocotyledonous*.³

Grasses may be easily recognized as *mostly herbs with hollow, cylindrical stems; parallel-veined, two-ranked sheathing leaves; flowers enclosed by glumaceous bracts; and fruit a caryopsis*.

144. The grass order (Graminales or Glumifloræ) comprises *grass-like plants with glumaceous bracts, a one-celled superior ovary, and a solitary ovule*.

The formula of Graminales is given on pages 422, 423.

145. The palm family (Palmaceæ). Examples: coconut (Figs. 34-36, pages 46, 47), date (Figs. 108, 109, pages 100, 101), sago palms (Figs. 116 I-III, pages 109, 110), rattans (Figs. 223 I, II, pages 237, 238), and vegetable ivory (Figs. 266 I, II, pages 275, 276).

The formulas of Phœnix, Cocos, Calamus, Metroxylon, Phytelephas, and Palmaceæ on pages 422, 423.

Although in our examples the leaves are all pinnate and compound, many members of the family have simple palmate leaves, as for instance those from which the familiar palm-leaf fans are made.

¹ Car'y-op'sis < Gr. *karyon*, nut; *opsis*, resemblance. Its morphology is indicated in a formula by [CE] < G/N.

² Scu-tel'lum < L. a little shield.

³ Mo'no-cot'y-led'on-ous < Gr. *monos*, one.

The flowers of palms are borne on a fleshy rachis which is more or less branched and subtended by one or more large, thick bracts. Such a fleshy spike whether simple or branched is called a *spadix*,¹ and the large bract subtending it a *spathe*.²

Palms may be distinguished as *woody plants, usually with columnar trunks; large, plume-like or fan-shaped leaves; flowers on a mostly branched spadix formed within a spathe*.

146. The palm order (Palmales or Principes) includes only the family of palms, which from their majestic appearance and high importance were well called by Linnæus the Princes of the Vegetable Kingdom. From other orders *the woody trunks, large and often compound leaves, mostly branched spadix, conspicuous spathe, and the superior ovary with one or more cells, and one or more ovules*, will generally afford sufficient marks of distinction.

See formula of Palmales on pages 422, 423,.

147. The arum family (Araceæ) is exemplified by *Acorus* (Fig. 167, page 174.)

See formulas of *Acorus* and Araceæ on pages 422, 423.

Although the members of this large family differ very much in general appearance and in many details of structure, our common sweet flag represents quite well their essential features. As in the palms, there is a *spadix*, although it is always simple; and there is a *spathe* which, unlike that of the sweet flag, is generally highly colored. In our example, moreover, the *spadix*, while appearing as if lateral, is in reality terminal, having been pushed to one side by the peculiar elongated *spathe* which appears to continue the stem.

The family may be defined as consisting of *mostly perennial herbs, sometimes aromatic, often ill-smelling or acrid; with leaves of varied form, often netted-veined; and flowers in a simple spadix, subtended by a more or less petaloid spathe*.

148. The arum order (Arales or Spathifloræ) comprises

¹ Spa'dix < Gr. *spadix*, a palm-branch.

² Spathe < Gr. *spathe*, a broad flat blade or spatula. The exclamation marks used in the formulas after I and B indicate, as usual, the fleshy character, and the oblique line after B, its involucreal nature.

but one other family besides the above. Both are made up of *herbs with leaves of varied form, sometimes rudimentary or absent; regular flowers in an unbranched spadix, with one or more spathes; and the superior ovary having one or more cells and one or more ovules.*

See formula of Arales on pages 422, 423.

149. The rush family (Juncaceæ) is typified by the common rush. (Fig. 221, page 234.)

See formulas of Juncus and Juncaceæ on pages 422, 423.

At first sight the rushes appear somewhat similar to grasses, and indeed certain botanists have regarded them as belonging to the same order. The resemblance comes chiefly from the grass-like leaves of many species and the glumaceous character of the perianth.¹ The family may be defined as *herbs with regular flowers having a glumaceous perianth, either six or three stamens, and a superior, compound ovary.*

150. The lily family (Liliaceæ). Examples: onion (Figs. 60, 61, pages 63, 64), asparagus (Fig. 62, pages 64, 65), Indian poke (Fig. 186, page 199), and lily-of-the-valley (Fig. 193, page 204).

Formulas of Allium, Asparagus, Convallaria, Veratrum, and Liliaceæ are given on pages 424, 425.

One of the largest and most important, the lily family is generally easy of recognition as being composed *mostly of herbs with regular flowers having a petaloid perianth, six stamens and a superior, compound ovary.*

151. The iris family (Iridaceæ) is represented by saffron (Fig. 168 II, page 176).

See formulas of Crocus and Iridaceæ on pages 424, 425.

The Iridaceæ are *herbs having flowers like those of the lily family but with only three stamens, and an inferior ovary.*

152. The lily order (Liliales or Liliifloræ) comprises several families which are like the lily family in being *mostly herbs with leaves of varied form; inflorescence never spadiceous*

¹ Indicated in the formulas by the inverted exclamation mark.

though sometimes spathaceous; flowers mostly regular; the ovary compound, superior or inferior; and seeds of moderate number and mostly medium size.

See formula of Liliales on pages 424, 425.

153. The orchid family (Orchidaceæ). Examples: vanilla (Fig. 148 I, page 149) and lady's-slippers (Figs. 212, 213, page 220).

See formulas of Cypripedium, Vanilla, and Orchidaceæ on pages 424, 425.

Although in the flowers of this family we can recognize the fundamental type of structure exhibited by the lily-like families, it is here modified by many curious and elaborate complications. An orchid might be described as a lily with irregular perianth, one or two stamens inserted upon the style, the other four or five being suppressed or represented by staminodes, and with an inferior ovary so twisted as to bring the flower upside down. A flower thus turned is said to be *resupinate*.¹ However obscure the morphology of special parts may sometimes appear, orchids may usually be recognized as *perennial herbs, with irregular, resupinate, epigynous flowers, having a petaloid perianth, one or two stamens adhering to the style, and a capsular fruit with exalbuminous seeds.*

154. The orchid order (Orchidales or Microspermæ) contains but one other family. This agrees with the orchids in comprising *herbs similar to the epigynous families of the lily order but forming innumerable seeds of exceedingly small size.*

See the formula of Orchidales on pages 424, 425.

155. The monocotyl subclass (Monocotyledones) is made up of seed-plants having a monocotyledonous embryo, endogenous stem, and mostly parallel-veined leaves. Together with the dicotyl subclass they constitute

156. The case-seed class (Angiospermæ) which includes all the flowering plants forming their seeds in a case or ovary

¹ Re-su'pi-nate < L. *re*, back; *supinare*, bend. The twist is indicated in a formula by @ placed after T.

consisting of one or more carpels—or in other words—all that have an *angiospermous*¹ gynœcium. Nearly all seed-plants belong to this class.

157. The pine family (Pinaceæ). Examples: juniper (Fig. 154, page 158), pine (Fig. 258, page 269), larch (Fig. 259, page 271), spruce (Fig. 260, page 272), red cedar (Fig. 261, page 273), redwood (Fig. 262, page 273), and hemlock (Fig. 263, page 273).

See formulas of *Pinus*, *Larix*, *Picea*, *Tsuga*, *Sequoia*, *Juniperus*, and *Pinaceæ* on pages 424–427.

A considerable variety of opinion obtains among botanists regarding the morphology of the floral parts of the pine family. According to one view the catkin-like clusters, or at least the seed-producing ones, are aments of very simple flowers; while according to the other view what appears to be a catkin or spike is a cluster of stamens or of carpels, and thus represents a many-stamened or many-carpelled flower. Without discussing the relative merits of these rival interpretations, we may provisionally adopt the latter as being the simpler view and as best serving our present purpose.²

The carpels differ from those of the case-seed class (*Angiospermæ*) in being flattened structures; hence the ovules are exposed, or at least are not enclosed in an ovary. The gynœcium is therefore called “naked-seeded” or *gymnospermous*.³ In fruit the gynœcium and elongated torus form a *cone* with more or less woody scales and axis; or, as in the junipers (*Juniperus*), these parts may become fleshy and consolidated into a berry-like fruit.

The great majority of the pine family are easily recognized as *more or less resinous, mostly evergreen trees, producing cones*.

158. The yew family (Taxaceæ) is exemplified by the yew (Fig. 204, page 213).

See formulas of *Taxus* and *Taxaceæ* on pages 426, 427.

Simplification of floral parts here reaches an extreme. In

¹ An''gi-o-sperm'ous < Gr. *aggion*, a vessel; *sperma*, seed.

² In the formulas *T*_i indicates that the torus is here regarded as analogous to an ament rachis.

³ Gym''no-sperm'ous < Gr. *gymnos*, naked; *sperma*, seed.

the yew (*Taxus*) not only is the perianth lacking and the andrœcium reduced to a few stamens, but the gynœcium is only a solitary ovule borne directly upon the torus and without a carpel. This ovule ripens usually into a hard seed which is surrounded by a fleshy envelope formed by the upgrowth of a ring which at first encircles the base. Such an accessory seed-covering growing from below is called an *aril*.¹ In other members of the family the staminate flowers are more cone-like, and there are a few with much reduced carpels each bearing a single ovule which may ripen into a drupaceous seed.

The family consists of *mostly evergreen, woody plants, with comparatively little resin or none at all; having cones much reduced, or else the ovules solitary and without carpels; and the seed arillate or drupaceous.*

159. The pine order (Coniferales or Coniferæ) comprises only the two families given above. They are distinguished as *woody plants, with branched stem; unbranched, usually narrow, leaves; and imperfect flowers which have no perianth, but are often catkin-like, and commonly produce cones.*

See formula of Coniferales on pages 426, 427.

160. The naked-seed class (Gymnospermæ), embraces only a few orders besides the pine order, with only one or two families in each. They all agree in being seed-plants with gymnospermous gynœcium, and are for the most part destitute of perianth.

161. The seed-plant division (Spermatophyta) is coextensive with that branch of the Vegetable Kingdom commonly known as Phanerogamia, phenogams, or flowering plants, because characterized by the production of flowers containing at least either pollen-sacs or ovules. Since the production of seed is the function of these parts, and since no other plants produce true seeds containing an embryo, it is equally appropriate to speak of them as seed-plants, seedworts, or spermatophytes.

The system of classification (although not always the sequence of groups) adopted in the foregoing pages is sub-

¹ Ar'il <. *L. arillus*, a dried grape (for no obvious reason).

stantially that of Engler and Prantl whose great work on the natural families of plants is now most generally followed, at least, with regard to phenogams. In this classification there are recognized among seed-plants about fifty orders and two hundred and eighty families.

The eighteen orders, thirty-two families, and about a hundred genera of seed-plants included in this chapter are represented by formulas on pages 404-427 in order that the student may readily compare the more important structural characters of one group with those of another, and so gain a better grasp of the abstract ideas underlying a natural classification. Taken in connection with the accounts of the various groups given in the sections referred to by number before each formula, and with reference to the figures indicated in each section, the formulas will afford a most profitable means of reviewing the many details already studied, and will reveal some of their wider relations.

162. The vegetable kingdom (Vegetabilia) which includes all plants is regarded most conveniently as consisting of four main divisions assumed to be equal in rank.¹

The highest division, that of seedworts or spermatophytes, includes most of the forms we have been studying. These agree not only in producing seeds but also in having true roots, stems, and mostly green leaves, all traversed by more or less woody strands, known as *fibrovascular bundles*, which form a framework or skeleton, and conduct nutrient juices to every part.

True roots, stems, and green leaves, all provided with fibrovascular bundles, occur also in such plants as the male-fern (*Aspidium*, page 179) and the club-moss (*Lycopodium*, page 174); but these plants propagate by spores developed in minute spore-cases, and never produce seeds. Plants thus characterized form the pteridophyte or fernwort division. (*Pteridophyta*).

Next to these come such plants as peat moss (*Sphagnum*, page 242) which propagate by spores similar to those of fernworts but contained in more or less urn-like cases commonly much larger than fernwort spore-cases, and usually borne on

¹ This view differs somewhat from that of Engler and Prantl, but best suits our purpose as being the one most widely adopted at the present day.

conspicuous stalks; but these plants have no true roots, stems, or leaves with fibrovascular bundles, although often possessing very simply constructed parts resembling small roots, stems, and leaves. Humble green plants of this description make up the bryophyte or mosswort division (*Bryophyta*).

Finally come such comparatively simple forms as the so-called Iceland moss (*Cetraria*, page 169), the field mushroom (*Agaricus*, page 113), and the carrageen (*Chondrus*, page 112) which, although commonly propagating by spores that are sometimes in cases, have the cases either stalkless or otherwise plainly different from those of mossworts. True roots, stems, leaves, and fibrovascular bundles are never present, although the plant-body may be so lobed as to resemble somewhat that of higher plants. Hence these lowly organized plants form what is known as the thallophyte or lobewort division (*Thallophyta*).

Our three examples of the lobewort division each represent one of its three subdivisions. These may usually be distinguished by their different modes of life. The Iceland moss is an air-plant merely resting upon barren soil without having any means of drawing much nutriment from it, and is consequently dependent upon what it can get from the air. This mode of life is made possible by the somewhat spongy nature of the plant-body in which are embedded minute containers of chlorophyll that may become apparent upon wetting. Plants like this so-called "moss" which thrive in barren places such as the surface of rocks, bark, dead wood, and sandy soil are of the lichen subdivision (*Lichenes*). The field mushroom differs from all lichens in being entirely destitute of chlorophyll because it feeds directly upon animal or vegetable manure in the soil. Lobeworts which can thus dispense with chlorophyll by feeding upon animals or plants or their decaying remains are of the mushroom or fungus subdivision (*Fungi*). Aquatic lobeworts, whether of fresh or salt water, which like carrageen contain chlorophyll (sometimes more or less obscured by red, brown, or blue coloring matters) form the seaweed or alga subdivision (*Algæ*).

The following synopses show in tabular view the divisions

GENERAL SYNOPSIS OF THE VEGETABLE KINGDOM

Plant-body without true roots, stem, or leaves, and lacking a fibrovascular framework, but often with outgrowths more or less resembling roots; or with lobes or leaf-like expansions sometimes crowded along a stem-like axis: CELLULAR CRYPTOGAMS:

With or without chlorophyll; if with chlorophyll the spores not in a small urn-like case on a slender stalk: THALLOPHYTE DIVISION, LOBOPHYTES (THALLOPHYTES):

Living in fresh or salt water; containing chlorophyll which may be more or less masked by blue, brown, or red pigment: SEAWEED SUBDIVISION (ALGÆ).

Living on animals or plants or on their decaying remains; destitute of chlorophyll: MUSHROOM SUBDIVISION (FUNGI).

Living attached to rocks, bark, barren soil, and the like, but depending chiefly upon the air for nutriment; chlorophyll not apparent except when wet: LICHEN SUBDIVISION (LICHENES).

With chlorophyll, and producing spores mostly in a small urn-like case which opens by a lid or by slits, and is usually borne upon a slender stalk: BRYOPHYTE DIVISION, MOSSWORTS (BRYOPHYTES).

Plant-body with true roots, stems, and leaves, and a fibrovascular framework: VASCULAR PLANTS:

Without either true flowers or seeds, but propagating chiefly by spores produced in small or minute cases borne upon the leaves or in their axils; always with chlorophyll: PTERIDOPHYTE DIVISION, VASCULAR CRYPTOGAMS, FERNWORTS (PTERIDOPHYTES).

With true flowers, or at least with organs producing seeds; with or without chlorophyll: SPERMATOPHYTE DIVISION, PHENOGAMS, FLOWERING PLANTS, SEEDWORTS (SPERMATOPHYTES).

SYNOPSIS OF ONE HUNDRED FAMILIES OF SEEDWORKS

Abbreviations: st., stem; l., leaves; i., inflorescence; b., bracts; fl., flowers or floral; s., sepals; p., petals; sp., perianth; fa., stamens, or filaments with anthers; l., staminodes; a., anthers; ce., carpels with ovules; ov., ovary; t., torus; ft., fruit; sd., seeds; m., mostly; ex., except sometimes in (followed by number of family); 0, none; 1, solitary; ∞, several or many; +, or more; ±, more or less; -, to; alt., alternate; opp., opposite; wh., whorled; O., Order; F., Family.

SEEDWORKS:	sd. not ripened in a closed ov.; cotyledons 2-∞:.....NAKED-SEED CLASS, GYMNOSEPERMS (GYMNOSEPERMÆ)	
	sd. ripened in a closed ov.:	
GYMNOSEPERMS:	CASE-SEED CLASS, ANGIOSPERMS (ANGIOSPERMÆ)	{ st. m. endogenous; l. m. parallel-veined; fl. parts m. in 3's; cotyledon 1: MONOCOTYL SUBCLASS, MONOCOTYLÆ
		{ st. m. exogenous; l. m. net-veined; fl. parts m. in 4's or 5's; cotyledons 2: DICOTYL SUBCLASS, DICOTS (DICOTYLÆ) { p. 0, or distinct; CROWFOOT SERIES, LOWER DICOTS (ARCHICHLAMYDEÆ) p. ≠ united, ex. 79: BELLEFLOWER SERIES, HIGHER DICOTS (METACHLAMYDEÆ)
MONOCOTS:	1. <i>Cycad F. (Cycadaceæ)</i>	
	2. <i>Ginkgo F. (Ginkgoaceæ)</i>	
GYMNOSEPERMS:	3. <i>Yew F. (Taxaceæ)</i>	
	4. <i>Pine F. (Pinaceæ)</i>	
MONOCOTS:	5. <i>Grass F. (Gramineæ)</i>	
	6. <i>Sedge F. (Cyperaceæ)</i>	
GYMNOSEPERMS:	7. <i>Palm F. (Palmeæ)</i>	
	8. <i>Arum F. (Araceæ)</i>	
MONOCOTS:	9. <i>Pineapple F. (Bromeliaceæ)</i>	
	10. <i>Spiderwort F. (Commelinaceæ)</i>	
GYMNOSEPERMS:	11. <i>Rush F. (Juncaceæ)</i>	
	12. <i>Lily F. (Liliaceæ)</i>	
MONOCOTS:	13. <i>Amaryllis F. (Amaryllidaceæ)</i>	
	14. <i>Iris F. (Iridaceæ)</i>	
GYMNOSEPERMS:	15. <i>Banana F. (Musaceæ)</i>	
	16. <i>Ginger F. (Zingiberaceæ)</i>	
MONOCOTS:	17. <i>Orchid F. (Orchidaceæ)</i>	

sp. 0 or bract-like:	i. spicate: Pepper O. (Piperates) : fa. 1-10; cc. 1-4, united; sd. 1, albuminous: 18. <i>Pepper F. (Piperaceæ)</i>	i. m. amentaceous: {	i. dioecious: Willow O. (Salicales) : l. simple, stipulate: sd. hairy: 19. <i>Willow F. (Salicaceæ)</i>	i. monoecious: {	l. simple, exstipulate: Bayberry O. (Myricales) : 20. <i>Bayberry F. (Myricaceæ)</i>	l. pinnate, exstipulate: Walnut O. (Juglandales) : 21. <i>Walnut F. (Juglandaceæ)</i>	l. simple, stipulate: {	cc. 2; fr. m. cone-like: 22. <i>Birch F. (Betulaceæ)</i>	cc. 3 +; fr. nut-like, in cupules: 23. <i>Beech F. (Fagaceæ)</i>	i. m. cymose {	Nettle O. (Urticales) : {	trees with watery sap; l. alt.; fr. samaras or drupes: 24. <i>Elm F. (Ulmaceæ)</i>	trees with milky sap; or herbs with l. opp.; fr. m. fleshy: 25. <i>Mulberry F. (Moraceæ)</i>	herbs or trees with sap watery; l. m. opp.; fr. achenial: 26. <i>Nettle F. (Urticaceæ)</i>	sp. m. sepaloid: Sandalwood O. (Santalales) : woody parasites; l. opp.; fr. an epigynous berry 27. <i>Mistletoe F. (Loranthaceæ)</i>	s. m. petaloid: Buckwheat O. (Polygonales) : m. herbs; l. alt., ocreate; fl. hypogynous; fr. achenial: 28. <i>Buckwheat F. (Polygonaceæ)</i>	s. m. greenish or papery: {	fr. a utricle: {	b. 0 or greenish; s. greenish: 29. <i>Goosefoot F. (Chenopodiaceæ)</i>	b. papery; s. papery: 30. <i>Amaranth F. (Amaranthaceæ)</i>	fr. a berry; b. herbaceous; s. m. white: 31. <i>Pokeweed F. (Phytolaccaceæ)</i>	fr. a capsule: {	s. 2: 32. <i>Purslane F. (Portulacaceæ)</i>	s. 4 or 5: 33. <i>Pink F. (Caryophyllaceæ)</i>	s. greenish or petaloid: {	ce. 1-∞, distinct, trial: 34. <i>Water-lily F. (Nymphaeaceæ)</i>	ex. 35; Crow-foot O. (Ranunculales): 35. <i>Crowfoot F. (Ranunculaceæ)</i>	e. m. ∞: 36. <i>Barberry F. (Berberidaceæ)</i>	s. m. ∞: {	aquatic herbs with floating shield-shaped l.: 37. <i>Moonsed F. (Menispermaceæ)</i>	fr. a berry; a. without valves: 38. <i>Magnolia F. (Magnoliaceæ)</i>	fr. a drupe; a. without valves: 39. <i>Strawberry-shrub F. (Calycanthaceæ)</i>	fa. perfect; fa. { t. elongated: 40. <i>Nutmeg F. (Myristicaceæ)</i>	fa. distinct: { t. hollowed: 41. <i>Laurel F. (Lauraceæ)</i>	fa. dioecious; fa. monadelphous: 42. <i>Poppy F. (Papaveraceæ)</i>	fa. in 3 or 4 whorls of 3; a. with valves; s. ± united; p. 0: 43. <i>Mustard F. (Cruciferae)</i>	sd. exalbuminous; s. 4: {	sd. with oily albumen; s. m. 2: 44. <i>Caper F. (Capparidaceæ)</i>	sd. albuminous; s. 4: {	fa. m. 2 short and 4 long; ov. 2-celled:	fa. 4-∞, of about equal length ov. 1-celled:

<p>fl. perigynous, ex. 47, 49; e. 1-∞; Rose O. (Rosales):</p>	<p>sd. albu- minous:</p>	<p>cc. as many as s.; fa. as many or twice as many; m. fleshy herbs; herbs with l. alt., or woody plants with l. opp.; woody plants with l. alt.; fr. woody, 2-celled:</p>	<p>45. <i>Orpine F.</i> (<i>Crassulaceæ</i>) 46. <i>Saxifrage F.</i> (<i>Saxifragaceæ</i>) 47. <i>Wich-hazel F.</i> (<i>Hamamelidaceæ</i>) 48. <i>Plane-tree F.</i> (<i>Platanaceæ</i>) 49. <i>Rose F.</i> (<i>Rosaceæ</i>) 50. <i>Pulse F.</i> (<i>Leguminosæ</i>)</p>
<p>sd. m. ex- albu- minous; ex. 49:</p>	<p>fl. monocious; trees; l. alt. ocreate; fr. woody, in balls: fl. perfect or dicecious:</p>	<p>fl. m. papilionaceous; fa. 10, diadelphous; fr. a legume:</p>	<p>51. <i>Geranium F.</i> (<i>Geraniaceæ</i>) 52. <i>Orails F.</i> (<i>Oralidaceæ</i>) 53. <i>Flax F.</i> (<i>Linaceæ</i>) 54. <i>Coca F.</i> (<i>Erythroxylaceæ</i>) 55. <i>Rue F.</i> (<i>Rutaceæ</i>) 56. <i>China-tree F.</i> (<i>Meliaceæ</i>) 57. <i>Spurge F.</i> (<i>Euphorbiaceæ</i>)</p>
<p>fa. dis- tinct; , or few if unl- ted:</p>	<p>e. m. hang- ing, raphe ventral, micro- pyle up; Geranium O. (Geran- iales):</p>	<p>without secre- tory cavi- ties with oil or resin glands m. with milk tubes; fl. imperfect; p. 0; cc. 3;</p>	<p>herba- ceous; { l. palmately lobed or cut; l. 3-foliolate; l. simple, entire; woody; p. appendaged; l. sim- ple, entire; l. dotted with oil-glands; l. not dotted; m. imperfect; p. 0;</p>
<p>fl. hypogy- nous; e. m. l or but few in a cell:</p>	<p>e. m. hanging; raphe dor- sal micro- pyle up; Soap-berry O. (Sapinda- les):</p>	<p>fl. regular; e. m. with milk tubes; fl. imperfect; p. 0; cc. 3;</p>	<p>fl. regular; { l. deciduous; fr. drupa- ceous; sd. 1; l. m. evergreen; fr. drupa- ceous; sd. 4 + l. deciduous; fr. a 2-winged samara; fl. irregular; l. opp. palmate; fr. a leathery pod;</p>
<p>fa. united into 1 or 5 groups opp. the p.; Mallow O. (Malvales):</p>	<p>e. m. ascending; Buckhorn O. (Rhamnates):</p>	<p>fr. drupaceous or dry; trees, shrubs, or vines; fr. a berry; woody vines with tendrils;</p>	<p>58. <i>Samac F.</i> (<i>Anacardiaceæ</i>) 59. <i>Holly F.</i> (<i>Aquifoliaceæ</i>) 60. <i>Maple F.</i> (<i>Aceraceæ</i>) 61. <i>Horse-chestnut F.</i> (<i>Hippocastanaceæ</i>) 62. <i>Buckhorn F.</i> (<i>Rhamnaceæ</i>) 63. <i>Grape F.</i> (<i>Vitaceæ</i>) 64. <i>Linden F.</i> (<i>Tiliaceæ</i>) 65. <i>Mallow F.</i> (<i>Malvaceæ</i>) 66. <i>Sterculia F.</i> (<i>Sterculiaceæ</i>)</p>

- | | | | | | | | |
|---|---|--|--|--|---|--|---|
| fl. hypogynous; albumen little or 0; | e. m. ∞; p. a- | rietal; Violet | O. (Violales): | l. deciduous: | l. m. alt., without oil-glands: | 1. m. opp., with oil-dots or streaks: | 67. Tea F. (Theaceæ) |
| | | | | | | fl. irregular; fa. ∞; e. orthotropous: | 68. Gamboge F. (Guttiferæ) |
| fl. epigy- | nous, ex. | 72, 73: | l. obvious | l. minute or 0; s. ∞; p. ∞; Cactus O. (Opuntiales): st. very fleshy and spiny: | e. ∞ in each cell; { e. 1; fa. few; p. 0: | e. m. ∞: { without oil-glands; | 71. Cactus F. (Cactaceæ) |
| | | | | | | | with oil-glands: |
| O. (Myrtales): | e. 1 in each cell; { fa. 5: { fr. a berry or drupe: | Parsley O. { fr. dry, splitting in half: | (Umbellales): { fa. 4; fr. a berry or drupe: | O. (Myrtales): | fa. few; p. m. 2-4: | e. m. ∞: { without oil-glands; | 73. Brazil-nut F. (Lecythedaceæ) |
| | | | | | | | with oil-glands: |
| e. 1 in each cell; { fa. 5: { fr. a berry or drupe: | Parsley O. { fr. dry, splitting in half: | (Umbellales): { fa. 4; fr. a berry or drupe: | O. (Myrtales): | e. m. ∞: { without oil-glands; | fa. few; p. m. 2-4: | e. m. ∞: { without oil-glands; | 75. Evening-primrose F. (E. nothoraceæ) |
| | | | | | | | with oil-glands: |
| e. 1 in each cell; { fa. 5: { fr. a berry or drupe: | Parsley O. { fr. dry, splitting in half: | (Umbellales): { fa. 4; fr. a berry or drupe: | O. (Myrtales): | e. m. ∞: { without oil-glands; | fa. few; p. m. 2-4: | e. m. ∞: { without oil-glands; | 77. Parsley F. (Umbelliferæ) |
| | | | | | | | with oil-glands: |

fl. hypogynous, ex. 79: fa. m. free, alt. with p. or twice as many; Heath O. (Ericales): a. m. opening by pores: fa. on p. and opp. them, { herbaceous: Primrose O. (Primulales): style 1; fr. a cap- more: Ebony O. (Ebenales): fa. as many corolla-lobes:...

fa. on p., as many or fewer, and alt. with them: { p. not papery: { ce. 2, distinct or partly united; Gentian O. (Gentianales): stigmas united; sap milky: stigmas distinct; sap watery: ov. 2-celled; 1. ov. 1-celled; 1. exstipulate. styles united; pollen powdery; styles distinct; pollen waxy:...

ce. m. 2, { fl. regu- lar, ex. 88; Phlox O. (Polemoni- ates): { ov. not lobed nor forming nutlets in fr.; m. vines; ov. 4-lobed and forming 4 nutlets; not vines: { ov. not lobed: { ov. 4-lobed: { terres- trial; ex. 89, 90, 91: { fl. regu- lar; fa. m. 5: fl. irregu- lar; fa. m. 2 or 4: placenta parietal; fl. irregular: m. aquatic; ov. 1-celled; pla- centae axile:...

p. papery; i. m. spicate; l. simple, alt.; s. p. and fa. 4: Plantain O. (Plantaginales):

fl. epigynous: { a. distinct: Madder O. (Rubiaceae): { l. stipulate, m. blackening when dried: { a. m. united: { m. with tendrils; fa. = united in pairs; fr. m. a pepo: Gourd O. (Cucurbitales): without tendrils; fa. distinct or syngyneous: Bellflower O. (Campanulales): { i. not capitate and involucrate: { i. capitate and involucrate:...

- 79. Heath F. (Ericaceae)
- 80. Primrose F. (Primulaceae)
- 81. Sapodilla F. (Sapotaceae)
- 82. Olive F. (Oleaceae)
- 83. Logania F. (Loganiaceae)
- 84. Gentian F. (Gentianaceae)
- 85. Dogbane F. (Apocynaceae)
- 86. Milkweed F. (Asclepiadaceae)
- 87. Morning-glory F. (Convolvulaceae)
- 88. Borage F. (Boraginaceae)
- 89. Verbena F. (Verbenaceae)
- 90. Mint F. (Labiatae)
- 91. Nightshade F. (Solanaceae)
- 92. Figwort F. (Scrophulariaceae)
- 93. Bignonia F. (Bignoniaceae)
- 94. Bladderwort F. (Lentibulaceae)
- 95. Plantain F. (Plantaginaceae)
- 96. Madder F. (Rubiaceae)
- 97. Honeysuckle F. (Caprifoliaceae)
- 98. Gourd F. (Cucurbitaceae)
- 99. Bellflower F. (Campanulaceae)
- 100. Sunflower F. (Compositae)

and subdivisions of the vegetable kingdom, together with one hundred of the more important families of seedworts, and the orders and higher groups to which they belong. The characters given to distinguish them must be understood as being merely those which prevail throughout the group to which they refer, and not as being without possible exceptions besides those noted. The numbers in parenthesis refer to pages where further information regarding the families, or illustrated examples of them, may be found. These synopses show the place in a modern classification of every plant we have studied in the foregoing chapters. Familiarity with the distinctions given, obtained by practical use of the synopses, should enable students to tell at sight, for a large majority of the plants they may see growing wild or in cultivation, the family to which each belongs.

The student who has learned to know what is typical of the comparatively few orders and families which we have been examining, will be able to tell at sight the family or order in which, or near which, to classify more than half of the flowering plants he is likely to meet; provided, of course, he has observed carefully their structural features. This knowledge, and the acquaintance he has already gained with the most important descriptive terms, will facilitate his use of systematic works in which these and other families are described in more detail.

However far he pursues this line of study—as fascinating as it is exhaustless—the student will continually encounter plants which must be viewed as intermediate links connecting different groups, or as exceptions which make definite limitations practically impossible. These connecting links and exceptional cases seem to defy classification in any consistent arrangement, and have caused endless trouble to botanists in their attempts to construct a natural system. But at the same time it has happened that as botanists have come to study the significance of these exceptions they have found them revealing some very deep truths which have led to more and more satisfactory systems of classification. It behooves us therefore to examine the main beliefs which have been held in regard to the meaning of these connecting

links between species, genera, families, and wider groups. As will be observed, the very word "family" implies an idea of kinship. Here, indeed, is a key which if it fits, may unlock for us secrets of great importance. To try this key is the purpose of the chapters which follow.

				Caltha(101-105)	
2	$L^1/1^*$	$I'1 + \vartheta b_{1,0}$	$S''4+$		FA^∞
				Helleborus	
2	$L_1/1^*, L$	$I'1 + \vartheta b_{1\neq}$	$S''5$	$F5+$	FA^∞
				Nigella	
①	$L^1/1^\dagger L$	$I'1 \vartheta b/5,0$	$S''5$	$F5+$	FA^∞
				Aquilegia	
2	$L^1/1^\dagger L^2 + I''/\vartheta$		$S''5$	$F5$	$FA^\infty F5 \times 5$
				Aconitum	
2	$L^1/1^*$	$I'' \vartheta$	$S''\frac{3}{2}$	$F\frac{2}{0-3}$	FA^∞
				Actæa	
2	$L^1/1^\dagger L^2 + I'' \vartheta$		$S''3-5$	$F4+$	FA^∞
				Anemone	
2	$L^1/1^* \dagger, L$	$I'1 + \vartheta B, b/2,3$	$S''4$	$F0-\infty$	FA^∞
				Clematis	
2, b \curvearrowright	$L^2/2^\dagger \dagger, L$	$I'1 +, i' \vartheta, \vartheta \sigma \varphi$	$S''4+$	$F0-\infty$	$FA^\infty, 0$
				Ranunculus	
○	$L^1/1^*$	$I'1 + \vartheta$	$S''5 =$	$F5+$	FA^∞
				Myosurus	
①	$L^1/1$	$I'1 \vartheta$	$S''5+$	$F5 =$	$FA^\infty 5+$
				Pæonia	
2, 2	$L^1/1^\dagger L^{1-3}$	$I'1 \vartheta b1+$	$S''5+$	$P''5+$	FA^∞
				RANUNCULACEÆ	
○, 2	$L^1/1^*$	$I \vartheta$	$S''5 =$	$P0-\infty$	$F0-\infty FA^\infty, \infty$

marsh-marigold

CE $5 \pm$ E $\hat{\infty}$ T \cup $C_i < 5 \pm$ E_∞ G-N

Christmas rose

CE 5,) E $\hat{\infty}$ T \cup $C_i 5 < \pm,)$ E_∞ G-N

fennel-flower

CE $5 \pm$) E $\hat{\infty}$ T \cup $C_i < 5 \pm$) E_∞ G-N

columbine

CE 5 E $\hat{\infty}$ T \cup $C_i < 5$ E_∞ G-N

monkshood

CE 3-5 E $\hat{\infty}$ T \cup $C_i < 3-5$ E_∞ G-N

baneberry

CE 1 E $\hat{\infty}$ T \cup $C_i < 1$ E_∞ G-N

anemony

CE ∞ E $\hat{i}e 4+$ T \cup $C_i < \infty$ E 1 G-N

clematis

CE $\infty, 0$ E $\hat{i}e 2+$ T \cup $C_i < \infty$ E 1 G-N

crowfoot

CE ∞ E \hat{i} T \cup $C_i < \infty$ E 1 G-N

mouse-tail

CE ∞ E \hat{i} T \cup $C_i < \infty$ E 1 G-N

peony

CE $5 \pm$ E $\hat{\infty}$ T \cup $C_i < 5 \pm$ E_∞ G-N

CROWFOOT FAMILY

CE $\alpha \pm$ E $\hat{\infty}_{-e 0, \alpha}$ T \cup $C_i < \alpha, < \infty$ $E_\infty -$ G-N

					Magnolia (106)
5,5	$L^1/1^{\ddagger}$	$I' \vartheta$	$S''2-4$	$P''6-\infty$	FA_{∞}
					Illicium
5,5	$L^1/1^{\ddagger}$	$I' \vartheta$	$S''\alpha$	$P''\infty$	FA_{∞}
					Liriodendron
5	$L^1/1^{\ddagger}$	$I' \vartheta$	$S''3$	$P''3 \times 3$	FA_{∞}
					MAGNOLIACEÆ
5,5	$L^1/1^{\ddagger}$	$I \vartheta$	$S''3$	$P''3 \times 3$	FA_{∞}
					Sassafras (107)
5	$L^1/1^{\ddagger}$	$I'/I' \sigma: \varphi$	$SP''3 \times 3$	$FA \cup 3 \times 3 \times 3$	$F3, 3 \times 3$ $C1?$
					Cinnamomum
5,5	$L^1/1^{\infty * \infty}$	$I' I' \vartheta \infty$	$SP''3 \times 3$	$FA \cup 3 \times 3 \times 3$	$F3 \infty$ $C1?$
					LAURACEÆ
b	$L^1/1^{\ddagger}$	$I \vartheta$	$SP'' 3 \times 3$		$FA \cup 3 \times 3 \times 3$ $F3$
					RANUNCULALES (108)
		$I \vartheta$	$S 3 \neq$	$P 3 \neq$	$FA \infty, \alpha$
					Papaver (109)
①, 2	$L^1/1^{\ddagger}$	$I 1 \vartheta$	$S'' 2, 3$	$P'' 2 \times 2, 3 \times 3$	FA_{∞}
					PAPAVERACEÆ
①-5	$L^1/1^{\ddagger}$	$I \vartheta$	$S'' 2$	$P'' 2 \times 2$	FA_{∞}
					Brassica (110)
①-2	$L^1/1^{\ddagger}$	$I' \vartheta B 0$	$S'' 2 \times 2$	$P'' 2 \times 2$	$FA 2 \times 4 \div 2$
					Nasturtium
①-2	$L^1/1^{\ddagger}$	$I' \vartheta B 0$	$S'' 2 \times 2$	$P'' 2 \times 2$	$FA 2 \times 4 \div 2$
					Raphanus
①, ②	$L^1/1^{\ddagger}$	$I' \vartheta B 0$	$S'' 2 \times 2$	$P'' 2 \times 2$	$FA 2 \times 4 \div 2$
					CRUCIFERÆ
○	$L^1/1^{\ddagger}$	$I' \vartheta B 0$	$S'' 2 \times 2$	$P'' 2 \times 2$	$FA 2 \times 4 \div 2$

magnolia	CE_{∞}	$E_{\hat{2}-\infty}$	T_{\circ}	$Ci > \infty$	E_1	$G-N$
star-anise	CE_{∞}	$E_{\hat{1}}$	T_{\circ}	$Ci < \infty$	E_1	$G-N$
tulip-tree	CE_{∞}	$E_{\hat{1}}$	T_{\circ}	$C_{\hat{2}} < \infty$	E_{1+}	$G-N$
MAGNOLIA FAMILY						
	CE_{∞}	$E_{\hat{1}}$	T_{\circ}	$Ci < \infty-1, < \infty$	E_1	$G-N$
sassafras	$CE_{1?}$	$E_{\hat{1}}$	T_{\circ}	$T! C! <$	E_1	G
cinnamon, etc.	$CE_{1?}$	$E_{\hat{1}}$	T_{\circ}	$T! C! <$	E_1	G
LAUREL FAMILY						
	CE_1	$E_{\hat{1}}$	T_{\circ}	$T! C! <$	E_1	G
CROWFOOT ORDER						
	$CE_{\infty-1}$	$E_{\hat{\infty}}$	T_{\circ}			
poppy	$CE_{4-20 ()}$	$E_{\hat{\infty}}$	T_{\circ}	Ci°	E_{∞}	$G_{\circ} N$
POPPY FAMILY						
	$CE_{2-20 ()}$	$E_{\hat{\infty}}$	T_{\circ}	Ci	$E_{\infty, \alpha}$	$G-N$
cabbage, etc.	$CE_2 ()$	$E_{\hat{\infty}}$	T_{\circ}	$Ci^{\hat{2}}$	E_{∞}	G_{\wedge}
watercress, etc.	$CE_2 ()$	$E_{\hat{\infty}}$	T_{\circ}	$Ci^{\hat{2}}$	E_{α}	G_{\wedge}
radish	$CE_2 ()$	$E_{\hat{\infty}}$	T_{\circ}	$Ci <$	E_{α}	G_{\wedge}
MUSTARD FAMILY						
	$CE_2 ()$	$E_{\hat{\infty} \pm}$	T_{\circ}	$Ci^{\hat{2}}, <$	$E_{\alpha \pm}$	G_{\wedge}

RHOEADALES (111)

		I' ♀	S 2+	P 2+	FA ∞ , α	
						Rosa (112)
♂, ◌	L ¹ /1 ⁺ ♂L	I' ♀	S'' 5	P'' 5	FA ∞	Fragaria
♀ ◌	L ¹ /1 ⁺ ♀L	I' ♀ ∞	S'' 4♂	P'' 5	FA 20 =	Rubus
♀-♂	L ¹ /1 ⁺ ∞♂L, 0	I' ♀ ∞	S'' 5	P'' 5, 0	FA ∞	Prunus
♂-♀	L ¹ /1 ⁺ ♂	I' ♀	S'' 5	P'' 5	FA 20 =	Cydonia
♀	L ¹ /1 ⁺ ♀	I' ♀	S'' 5	P'' 5	FA 20 +	Pyrus
♂, ♂	L ¹ /1 ⁺ ♂, L	I' ♀	S'' 5	P'' 5	FA 20 =	ROSACEÆ
◌, ♀	L ¹ /1 ⁺ ♀	I' ♀	S'' 5, 4	P'' 5, 4, 0	FA ∞	Acacia (113)
♀, ◌	L ¹ /1 ⁺ ♀L ^{2, 0}	I' ♀ ∞	S'' 4 =,)	P'' 4 =,)	FA ∞ ,)	Hæmatoxylon
♂	L ¹ /1 ⁺ ♂L	I' ♀	S'' $\frac{2}{3}$	P'' $\frac{3}{2}$	FA 10	Hymenæa
♂	L ¹ /1 ⁺ ♂L	I' ♀	S'' 4)	P'' $\frac{3}{2}$	FA 10	Trachylobium
♂	L ¹ /1 ⁺ ♂L	I' ♀	S'' 4)	P'' $\frac{3}{2}$	FA 10	Pisum
◌ -	L ¹ /1 ⁺ ♂♂L	I' ♀	S'' $\frac{2}{3}$)	P'' $\frac{1}{2}+\frac{1}{2}$)	FA $\frac{1}{9}$)	Phaseolus
◌ -	L ¹ /1 ⁺ ♂♂L	I' ♀	S'' $\frac{2}{3}$)	P'' $\frac{1}{2}+\frac{1}{2}$)	FA $\frac{1}{9}$)	Robinia
♂, ♀	L ¹ /1 ⁺ ♂♂L	I' ♀	S'' $\frac{2}{3}$)	P'' $\frac{1}{2}+\frac{1}{2}$)	FA $\frac{1}{9}$)	Indigofera
♀ -♂	L ¹ /1 ⁺ ♂♂L	I' ♀	S'' $\frac{2}{3}$)	P'' $\frac{1}{2}+\frac{1}{2}$)	FA $\frac{1}{9}$)	

POPPY ORDER

CE 2 +()	E_{∞}	T_{\sim}			
rose					
CE $_{\infty}$	$E_{i \in 1,0}$	T_{\sim}	$T!$	$C_{ii} < \infty$	$E 1 \quad G-$
strawberry					
CE $_{\infty}$	$E_{\hat{1}}$	T_{\sim}	$t!$	$C_i < \infty$	$E 1 \quad G-$
raspberry					
CE $_{\infty, \alpha}$	$E_{\hat{1}}$	T_{\sim}	$t!, j$	$C_{ii}! < \alpha \neq,]$	$E 1 \quad G-$
cherry					
CE 1	$E_{\hat{2}}$	T_{\sim}		$C_{ii}! < 1$	$E_{1,2} \quad G-$
quince					
CE 5)	$E_{\hat{\infty}}$	$T_{\sim}]$	$T!$	$C_i < 5)$	$E_{\infty} \quad G-$
apple, etc.					
CE 2-5)	$E_{\hat{2}}$	$T_{\sim}]$	$T!$	$C_i < 2-5)$	$E 2 \quad G-$
ROSE FAMILY					
$C_{\infty-1,}$	$E_{\alpha} \neq$	$T_{\sim}]$	$T!, 0$	$C!, i \infty \infty -1$	$E_{\alpha} \neq \quad G-, N.$
gum arabic tree, etc.					
CE 1	$E_{\hat{2}+}$	T_{\sim}, \wedge		$C_i \hat{\diamond} \infty$	$E 2+ \quad G-$
logwood-tree, etc.					
CE 1	$E_{\hat{2}, \hat{3},}$	T_{\sim}		$C_i < >$	$E 1 \quad G \wedge$
courbaril-tree, etc.					
CE 1 $\hat{\alpha}$		T_{\sim}		$C_i <$	$E_{\alpha} \quad G-$
copal-tree					
CE 1	$E_{\hat{\alpha}}$	T_{\sim}		$C_i <$	$E_{\alpha} \quad G-$
pea					
CE 1	$E_{\hat{\infty}}$	T_{\sim}		$C_i \hat{\diamond}$	$E_{\infty} \quad G \wedge$
beans					
CE 1	$E_{\hat{\infty}}$	T_{\sim}		$C_i \hat{\diamond}$	$E_{\infty} \quad G \wedge$
locust					
CE 1	$E_{\hat{\infty}}$	T_{\sim}		$C_i \hat{\diamond} \infty, \alpha$	$E_{\infty} \quad G \wedge$
indigo-shrub					
CE 1	$E_{\hat{\infty}, \hat{\alpha}}$	T_{\sim}		$C_i \hat{\diamond}$	$E_{\infty} \alpha \quad G \wedge$

					Glycyrrhiza
㉔, ㉕	$L^1/1^{\dagger}L$	$I' \vartheta$	$S'' \frac{2}{3}$)	$P'' \frac{1}{2+2}$	$FA \frac{1}{9}$
					Astragalus
①-㉕	$L^1/1^{\dagger}L$	$I' \vartheta$	$S'' \frac{2}{3}$)	$P'' \frac{1}{2+2}$	$FA \frac{1}{9}$
					Arachis
○	$L^1/1^{\dagger}L$	$I' \vartheta$	$S'' \frac{4}{1}$)	$P'' \frac{1}{2+2}$	$FA 10, 9$
					LEGUMINOSÆ
○, ㉔	$L^1/1^{\dagger}L$	$I' \vartheta$	$S'' \frac{2}{3}$)	$P'' \frac{1}{2+2}$	$FA \frac{1}{9}$
					ROSALES (114)
		$I' \vartheta$	$S 5, 4, \frac{2}{3},$)	$P 5, 4, \frac{3}{2}, \frac{1}{2+2}$	$FA 10 \pm,), \frac{1}{9}$
					Corchorus (115)
○, ㉕	$L^1/1^{\dagger}$	$I' \vartheta$	$S' 5$	$P'' 5 $	$FA 5 \times 5, \infty \div 5$
					Tilia
㉕	$L^1/1^{\dagger}$	$I' \vartheta B/11$	$S' 5$	$P'' 5 $	$FA \infty \div 5 F 5), 0$
					TILIACEÆ
㉔, ○	$L^1/1^{\dagger}$	$I' \vartheta$	$S' 5$	$P'' 5 $	$FA \infty \div 5$
					Gossypium (116)
○, ㉔	$L^1/1^*4$	$I' \vartheta b/3$	$S' 5)$	$P'' 5 $	$FA \infty \div 5)$
					Althæa
○	$L^1/1^*4$	$I' \vartheta b/6-9)$	$S' 5)$	$P'' 5 $	$FA \infty \div 5)$
					MALVACEÆ
○, ㉔	$L^1/1^*4$	$I' \vartheta b/3+$	$S' 5)$	$P'' 5 $	$FA \infty \div 5)$
					MALVALES (117)
		$I' \vartheta$	$S' 5$	$P'' 5 $	$FA \infty \div 5,$
					Conium (118)
②	$L^1/1^{\dagger}L^{1+}$	$I/i / \vartheta B/\infty B^2/\infty$	$S 5)$	$P' 5, \frac{2}{3}$	$FA 5$
					Carum
○	$L^1/1^{\dagger}L^{1+}$	$I/i / \vartheta B/3 \pm B^2/3 \pm$	$S' 5,$)	$P'' 5, \frac{2}{3}$	$FA 5$
					Petroselinum
○	$L^1/1^{\dagger}L^{1+}$	$I/i / \vartheta B/\alpha B^2/\alpha$	$S 5)$	$P' 5, \frac{2}{3}$	$FA 5$

licorice						
CE 1	$E \hat{\infty}, \hat{\alpha}$	T_{\cup}	$Ci \diamond$	$E \alpha$	$G \wedge$	
tragacanth-shrub						
CE 1	$E \hat{\infty}, \hat{\alpha}_3$	T_{\cup}	$Ci < \infty$	$E 1$	$G \wedge$	
peanut						
CE 1	$E \hat{\alpha}_2, \hat{\alpha}_3$	T_{\cup}	$Ci <$	$E 2 \neq$	$G \wedge$	
PULSE FAMILY						
CE 1	$E \hat{\alpha} \neq$	T_{\cup}	$Ci \diamond$	$E \alpha \neq$	$G \wedge$	
ROSE ORDER						
CE 5±,	$E \hat{\alpha} \neq$	$T_{\cup},]$				
jute						
CE 5-)	$E \hat{\infty}$	T_{\cup}	$Ci \perp$	$E \infty$	$G \wedge N$	
linden						
CE 5)	$E \hat{2}$	$T_{\cup} I B i$	$Ci ! <$	$E 1, 2$	$G \wedge N$	
LINDEN FAMILY						
CE 5)	$E \hat{\infty} -$	T_{\cup}	Ci	$E \infty -$	$G \wedge N$	
cotton						
CE 5-3)	$E \hat{\infty}$	T_{\cup}	$Ci \perp_{5-3}$	$E \infty$	$G \wedge N$	
marshmallow						
CE ∞)	$E \hat{1}$	T_{\cup}	$Ci < \div \infty$	$E 1$	$G \wedge N$	
MALLOW FAMILY						
CE 5±)	$E \hat{1} +$	T_{\cup}	$Ci < \div \infty, \infty$	$E 1 +$	$G \wedge N$	
MALLOW ORDER						
CE 5±)	$E \hat{\alpha} \neq$	T_{\cup}				
poison hemlock						
CE 2,	$E \hat{1}$	$T_{\cup}]$	$TCi < \div 2$	$E 1$	$G-N$	
caraway						
CE 2,	$E \hat{1}$	$T_{\cup}]$	$TCi < \div 2$	$E 1$	$G-N$	
parsley						
CE 2,	$E \hat{1}$	$T_{\cup}]$	$TCi < \div 2$	$E 1$	$G-N$	

					Cicuta
2	$L^1/1 \dagger L$	$I/i / \vartheta B/\alpha, B^2/\infty$	$S'' 5 P'' 5, \frac{2}{3}$	FA 5	
					Coriandrum
①	$L^1/1 \dagger L^{2+}$	$I/i / \vartheta B/0, B^2/\infty$	$S'' \frac{3}{2} P'' \frac{2}{3}$	FA 5	
					Apium
○	$L^1/1 \dagger L^{1+}$	$I/i / \vartheta B/\alpha, B^2/\alpha, S5)$	$P'' 5, \frac{2}{3}$	FA 5	
					Pimperfecta
○	$L^1/1 \dagger L^{1+}$	$I/i / \vartheta B_0$	$S5) P'' 5, \frac{2}{3}$	FA 5	
					Pastinaca
○	$L^1/1 \dagger L$	$I/i \vartheta B_0$	$S5) P'' 5, \frac{2}{3}$	FA 5	
					Ferula
2	$L^1/1 \dagger L^{1+}$	$I/i / \vartheta \sigma \varphi B \infty B^2/\infty S5)$	$P'' 5, \frac{2}{3}$	FA 5	
					Daucus
①②	$L^1/1 \dagger L^{1+}$	$I/i \vartheta \delta B/\infty B^2/$	$S'' 5, \frac{3}{2} P'' \frac{2}{3}$	FA 5	
					UMBELLIFERÆ
○	$L^1/1 \dagger L^{1+}$	$I/i / \vartheta \infty B/\infty - B^2/\infty - S'' 5,)$	$P'' 5, \frac{2}{3}$	FA 5	
					UMBELLALES (119)
		$I/$	$S'' 5 \pm P'' 5 \pm$	FA 5 \pm	
					Rheum (120)
2	$L^1/1 \dagger \dagger$	$I' i' \vartheta$	$SP'' 3 \times 3$	FA 6 \div 3 \times 3	
					Fagopyrum
○	$L^1/1 \dagger \dagger$	$I' i' / \vartheta B 1$	$S'' 5 P 0$	FA 4 \div 2 + 1 \times 3	
					POLYGONACEÆ
○	$L^1/1 \infty \dagger$	$I' i' \vartheta$	$SP'' 3 \times 3$	FA 3 \times 3 \pm	
					POLYGONALES (121)
		$I' i \vartheta$	$SP'' 6-$	FA 6-	
					Betula (122)
b	$L^1/1 \dagger \dagger$	$Ii : i \sigma - \varphi B b_1$	$S 2,0 P 0$	FA 4 \div 2	
					Corylus
b	$L^1/1 \dagger \dagger$	$Ii, i \sigma - \varphi B b_1, B \times B 1 b_2) /$	$SP 0, S,$	FA 8 \div 4]	

water hemlock						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
coriander						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
celery						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
anise						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
parsnip						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
asafetida						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
carrot						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
PARSLEY FAMILY						
CE 2)	Eî	T _∞]	<i>TCi</i> < ÷ 2	<i>E 1</i>	<i>G-N</i>	
PARSLEY ORDER						
CE 5-2)	Eî	T _∞]				
rhubarb						
CE 3 ₀)	Eî	T _∞	<i>Ci</i> <	<i>E 1</i>	<i>G-N</i>	
buckwheat						
CE 3 ₀)	Eî	T _∞	<i>Ci</i> <	<i>E 1</i>	<i>G-N</i>	
BUCKWHEAT FAMILY						
CE 3 ₀)	Eî	T _∞	<i>Ci</i> <	<i>E 1</i>	<i>G-N</i>	
BUCKWHEAT ORDER						
CE 3-2 ₀)	Eî	T _∞				
birch						
CE 2)	Eî	T _∞ I <i>ji</i>] B <i>bj</i>	<i>Ci</i> < 1	<i>E 1</i>	<i>G-N</i>	
hazel						
CE 2)	Eî	T _∞ , ∞ B <i>b</i> / ₃	<i>Cii</i> < 1	<i>E 1</i>	<i>G-</i>	

				BETULACEÆ
b	$L^1/1^{\ddagger}4$	Ii·i·i·σ-♀ Bb ₁	SP 2+, 0	FA 2-10÷
				Fagus (123)
b	$L^1/1^{\ddagger}4$	I·i·i·σ-♀ B _{α, ∞}	SP" 4-6	FA 6-20
				Castanea
b	$L^1/1^{\ddagger}4$	Ii·i·σ-♀ B _{α, ∞}	SP" 6	FA _∞
				Quercus
b	$L^1/1^{\ddagger}4$	Ii, I·i·i·σ-♀ B _{0, ∞}	SP" 6	FA _∞
				FAGACEÆ
b	$L^1/1^{\ddagger}4$	Ii·i·σ-♀ B _{α, ∞}	SP" 6	FA _∞
				FAGALES (124)
		I, i σ-♀	SP 6-	FA _∞ -
				Juglans (125)
⊔	$L^1/1^{\ddagger}L$	Ii· B 1 σ-♀ b 2)]	SP 2-5 ₁	FA 6-20
				Carya
⊔	$L^1/1^{\ddagger}L$	Ii· B 1 σ-♀ b 2)]	SP 0, 1]	FA 3-10
				JUGLANDACEÆ
⊔	$L^1/1^{\ddagger}L$	Ii· B 1 σ-♀ b 2)]	SP 4±]	FA 3-40
				JUGLANDALES (126)
		I· σ-♀	SP 4±	FA 3-40
				Populus (127)
⊔	$L^1/1^{\ddagger}4$	Ii σ: ♀ B	SP 0	FA 4+
				Salix
b	$L^1/1^{\ddagger}i$	Ii σ: ♀ B	SP 0	FA 2+
				SALICACEÆ
b	$L^1/1^{\ddagger}4$	Ii σ: ♀ B	SP 0	FA 2+

BIRCH FAMILY

CE 2)	E $\hat{1}$	T $\sim, \sim]$	Bb $_1$	Ci < 1	E 1	G-
beech						
CE 3)	E $\hat{2}$	T $\sim, \sim]$ iii \sim < 4	Bi ∞	TCii <	E 1	G-
chestnut						
CE 4-6)	E $\hat{2}$	T $\sim, \sim]$ iii \sim < 4-	Bi ∞	TCii <	E 1	G-
oak						
CE 3)	E $\hat{2}$	T $\sim, \sim]$ iii \sim <	Bi ∞	TCii <	E 1	G-

BEECH FAMILY

CE 3+)	E $\hat{2}$	T $\sim, \sim]$ iii \sim	Bi ∞	TCii <	E 1	G-
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BEECH ORDER

CE 3 \pm)	E $\hat{1}$ +	T $\sim, \sim]$				
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walnut

CE 2 ()	E $\bar{1}$	T $\sim, \sim]$		TCiii <	E 1	G-
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hickory

CE 2 ()	E $\bar{1}$	T $\sim, \sim]$		TCiii <	E 1	G-
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WALNUT FAMILY

CE 2 ()	E $\bar{1}$	T $\sim, \sim]$		TCiii <	E 1	G-
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WALNUT ORDER

CE 2 ()	E $\bar{1}$	T $\sim, \sim]$				
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póplar

CE 2 ()	E $\hat{\infty}$	T \sim		Ci >	E ∞	G-
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willow

CE 2 ()	E $\hat{\infty}$	T $\sim \div 2, 1$		Ci >	E ∞	G-
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WILLOW FAMILY

CE 2 ()	E $\hat{\infty}$	T $\sim \div 2, 1$		Ci >	E ∞	G-
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		SALICALES (128)			
		I' ♂:♀	SP 0		FA 2+
					Kalmia (130)
5	$L^1/1, 3/3^\dagger$	I' ♀	S'' 5,	P'' 5,	FA ° 10
					Gaultheria
5	$L^1/1^\dagger$	I' ♀ b/2	S'' 5,	P'' 5,	FA ° 10]
					ERICACEÆ
b	$L^1/1^\dagger$	I' ♀	S'' 5-,	P'' 5,	FA ° 10-,]
					ERICALES (131)
		I' ♀	S'' 5-,	P'' 5-,)	FA ° 4-10,]
					Ipomœa (132)
∞	$L^1/1^*$	I' ♀	S'' 5	P'' ∨ 5)	FA 5]
					CONVOLVULACEÆ
∞	$L^1/1^* ∞$	I' ♀	S'' 5	P'' ∨ 5)	FA 5]
					Nicotiana (133)
○	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' ∨ 5,	FA 5]
					Datura
○ b	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' ∨ 5,	FA 5]
					Atropa
○	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' ∨ 5,	FA 5]
					Capsicum
○	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' ∨ 5,	FA 5]
					Solanum
○ b	$L^1/1^\dagger, L$	I' ♀	S'' 5,	P'' ∨ 5,	FA ° 5]
					SOLANACEÆ
○ b	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' ∨ 5,	FA 5]
					Digitalis (134)
○ b	$L^1/1^\dagger$	I' ♀	S'' 5,	P'' $\frac{2}{3}$)	FA $\frac{2}{3}$]
					SCROPHULARIACEÆ
○ b	$L^1/1^\dagger ∞$	I' ♀	S'' 5,	P'' $\frac{2}{3}$)	FA $\frac{2}{3} \equiv$]

WILLOW ORDER

CE 2 () E ∞ T ∩

American laurels

CE 5) E ∞ T ∩ Ci ∠ E ∞ G-N

wintergreen

CE 5) E ∞ T ∩ ST!Ci ⊥ E ∞ G-N

HEATH FAMILY

CE 5-) E ∞ T ∩, ∩] C ∞ E ∞ G-N

HEATH ORDER

CE ∞-2) E ∞ T ∩, ∩]

sweet potato, etc.

CE 2-4) E 2 T ∩ Ci † E 2 G ∧ N

MORNING-GLORY FAMILY

CE 2-5) E 2+ T ∩ Ci, ! E 2+ G ∧ N

tobacco

CE 2) E ∞ T ∩ Ci † E ∞ G-N

jimson-weed

CE 2) E ∞ T ∩ Ci †, ! E ∞ G-N

belladonna

CE 2) E ∞ T ∩ C! < E ∞ G ∩ N

red pepper

CE 2) E ∞ T ∩ C! < E ∞ G ∩ N

white potato, etc.

CE 2) E ∞ T ∩ C! < E ∞ G ∩ N

NIGHTSHADE FAMILY

CE 2) E ∞ T ∩ Ci †, ! E ∞ G ∩ N

foxglove

CE 2) E ∞ T ∩ Ci ∠ E ∞ G-N

FIGWORT FAMILY

CE 2) E ∞ T ∩ Ci ∠, ⊥ E ∞ G-N

					Mentha (135)
○	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' 5), \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{2}$]
					Thymus
○	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{2}$]
					Origanum
2	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{2}$]
					Satureia
2	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{2}$]
					Salvia
○, b	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{0}$]
					LABIATÆ
○, b	$L^2/2^\dagger$	$I'i \cdot \vartheta$	$S'' \frac{3}{2})$	$P'' \frac{2}{3})$	FA $\frac{2}{2}$]
					POLEMONIALES (136)
		$I \vartheta$	$S 5), \frac{3}{3})$	$P 5), \frac{2}{3})$	FA 2-5]
					Cucurbita (137)
○ ~	$L^1/1^\dagger$	$I \infty \sigma - \varphi$	$S'' 4-7$	$P'' 5)$	FA $\vee 2) 2) 1), F 3$
					Cucumis
○ ~	$L^1/1^\dagger$	$I \infty \sigma -, : \varphi$	$S'' 5$	$P'' 5),$	FA $\vee 2) 2) 1), F 3$
					Citrullus
○ ~	$L^1/1^\dagger$	$I \infty \sigma - \varphi$	$S'' 5$	$P'' 5$	FA $\vee 2) 2) 1), F 3$
					Lagenaria
○ ~	$L^1/1^\dagger$	$I \infty \sigma - \varphi$	$S'' 5$	$P'' 5$	FA $\vee 2) 2) 1), F 3$
					Luffa
○ ~	$L^1/1^*$	$I \infty \sigma - \varphi$	$S'' 5$	$P'' 5$	FA $\vee 2) 2) 1), F 3$
					CUCURBITACEÆ
○ ~	$L^1/1^\dagger$	$I \infty \sigma - \varphi$	$S'' 5$	$P'' 5)$	FA $\vee 2) 2) 1), F 3$
					Campanula (138)
○	$L^1/1^\dagger$	$I \infty \vartheta$	$S'' 5),$	$P'' 5)$	FA 5
					Lobelia
○	$L^1/1^\dagger$	$I \infty \vartheta$	$S'' \frac{2}{3}$	$P'' \frac{2}{5})$	FA 5)]

mint

CE 2÷2 E $\hat{2}$ T \cup *Ci* < ÷ 4 E 1 G-

thyme

CE 2÷2 E $\hat{2}$ T \cup *Ci* < ÷ 4 E 1 G-

marjoram

CE 2÷2 E $\hat{2}$ T \cup *Ci* < ÷ 4 E 1 G-

savory

CE 2÷2 E $\hat{2}$ T \cup *Ci* < ÷ 4 E 1 G-

sage

CE 2÷2) E $\hat{2}$ T \cup * *Ci* < ÷ 4 E 1 G-

MINT FAMILY

CE 2÷2 E $\hat{2}$ T \cup *Ci* < ÷ 4 E 1 G-

PHLOX ORDER

CE 5-2) E $\hat{\infty}$ - T \cup

squash, etc.

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* < E ∞ G-

cucumber, etc.

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* < E ∞ G-

watermelon

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* < E ∞ G-

bottle gourd

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* < E ∞ G-

sponge cucumber

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* ° E ∞ G-

GOURD FAMILY

CE 3 () E $\hat{\infty}$ T \cup] *TC!i* < E ∞ G-

bellflower

CE 3-5) E $\hat{\infty}$ T \cup] *TCi* ° E ∞ G-N

Indian tobacco, etc.

CE 2) E $\hat{\infty}$ T \cup] *TCi* \perp E ∞ G-N

				CAMPANULACEÆ
○, b	$L^1/1^\ddagger$	$I \infty \vartheta$	$S'' 5, \frac{2}{3})$	$P'' 5,), \bar{5})$ FA 5,)
				Helianthus (139)
○	$L^1/1, \frac{2}{2}^\ddagger$	$I'' \vartheta \delta B/\infty b$	$S'' 2+ P'' 5, \bar{5})$	FA 5]
				Lactuca
○	$L^1/1^\ddagger$	$I i'' \vartheta B/\alpha$	$S'' \div \infty P'' \bar{5})$	FA 5]
				Artemesia
○	$L^1/1^\ddagger L$	$I' i'' \vartheta \varphi B/\alpha$	$S 0 P'' 5, \bar{5})$	FA 5]
				COMPOSITÆ
○	$L^1/1 \infty$	$I' i'' \vartheta \infty B/\alpha$	$+ , bS'' 5 \div \alpha \neq P'' 5, \bar{5}) \infty$	FA 5]
				CAMPANULALES (140)
		$I \vartheta \sigma \varphi \delta$	$S \infty$	$P 5, 5, \bar{5}, \frac{2}{3})$ FA 5,),]
				Zea (143)
①	$L^1/1$	$I' i'' : \varphi - \sigma Bbi$	SP 0	FA 3
				Saccharum
2	$L^1/1$	$I' i'' : \vartheta Bbi$	SP 0	FA 3
				Andropogon
2	$L^1/1$	$I' i'' : \vartheta \sigma B bi$	SP 0	FA 1-3
				Oryza
①	$L^1/1$	$I' i'' : \vartheta Bbi$	SP 0	FA 6
				Avena
①	$L^1/1$	$I' i'' : \vartheta \delta Bbi$	SP 0	FA 3
				Secale
①	$L^1/1$	$I' i'' : \vartheta Bbi$	SP 0	FA 3
				Triticum
①	$L^1/1$	$I' i'' : \vartheta \delta Bbi$	SP 0	FA 3
				Hordeum
①	$L^1/1$	$I' i'' : \vartheta , \delta B bi$	SP 0	FA 3
				Bambusa
b	$L^1/1$	$I' i'' : \vartheta \sigma \varphi Bbi$	SP 0	FA 6±

BELLFLOWER FAMILY

CE 2+)	E ∞	T ∪]	<i>TCi</i>	<i>E∞</i>	<i>G-N</i>
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sunflower, etc.

CE 2 ()	E î	T ∪]	<i>TCi <</i>	<i>E 1</i>	<i>G-</i>
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lettuce

CE ()	E î	T ∪]	<i>TSCi <</i>	<i>E 1</i>	<i>G-</i>
-------	-----	-------	------------------	------------	-----------

wormwood

CE 2 ()	E î	T ∪]	<i>TCi <</i>	<i>E 1</i>	<i>G-</i>
---------	-----	-------	-----------------	------------	-----------

SUNFLOWER FAMILY

CE 2()	E î	T ∪]	<i>STCi <</i>	<i>E 1</i>	<i>G-</i>
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BELLFLOWER ORDER

CE 2-5), ()		T ∪]			
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maize

CE 1	E î	T ∪	<i>Bb</i>	<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	-----------	------------------	------------

sugar-cane

CE 1	E î	T ∪		<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	--	------------------	------------

broom-corn, etc.

CE 1	E î	T ∪	<i>B</i>	<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	----------	------------------	------------

rice

CE 1	E î	T ∪	<i>B</i>	<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	----------	------------------	------------

oat

CE 1	E î	T ∪	<i>B</i>	<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	----------	------------------	------------

rye

CE 1	E î	T ∪		<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	--	------------------	------------

wheat

CE 1	E î	T ∪		<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	--	------------------	------------

barley

CE 1	E î	T ∪	<i>b</i>	<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	----------	------------------	------------

bamboo

CE 1	E î	T ∪		<i>[CEi <</i>	<i>G/N</i>
------	-----	-----	--	------------------	------------

				GRAMINEÆ
○	$L^1/1$	$I' i' : \vartheta \sim Bbi$	SP0	FA 3±
				GRAMINALES (144)
		$I \sim Bi$	SP0 ∼	FA 3+
				Phoenix (145)
5	$L^1/1 \dagger L$	$I! i: \sigma : \varphi B! / S'' 3$	P'' 3	FA 3×3
				Cocos
b	$L^1/1 \dagger L$	$I! i: \sigma - \varphi B! / S'' 3$	P'' 3	FA 3×3
				Calamus
~	$L^1/1 \dagger L$	$I! i: \sigma ; - \varphi B! / S'' 3$	P'' 3	FA 3×3]
				Metroxylon
5	$L^1/1 \dagger L$	$I! i: \sigma \varphi \vartheta B! / S'' 3, 1$	P'' 3,)	FA 3×3]
				Phytelephas
5	$L^1/1 \dagger L$	$I! \sigma : \varphi B! / \alpha S'' 3$	P'' 5-10	FA ∞
				PALMACEÆ
±	$L^1/1, * \dagger L$	$I!, i: \sigma' \varphi B! / S'' 3$	P'' 3+	FA 3×3
				PALMALES (146)
		$I! B! /$	S'' 3 P'' 3	FA 3×3
				Acorus (147)
2	$L^1/1$	$I! \vartheta B! /$	SP'' 3×3	FA 3×3
				ARACEÆ
○	$L^1/1$	$I! \vartheta \sim B! /$	SP'' 3×3 ∼	FA 3×3 ∼
				ARALES (148)
		$I! B! /$	SP'' 3×3 ∼	FA 3×3 ∼
				Juncus (149)
2	$L^1/1$	$I \cdot \vartheta$	SP'' i 3×3	FA 3×3, 3
				JUNCACEÆ
2	$L^1/1$	$I \cdot \vartheta$	SP'' i 3×3	FA 3×3, 3

GRASS FAMILY

CE 1	Eî	T _∞	[CEi <		G/N
------	----	----------------	--------	--	-----

GRASS ORDER

CE 1,2-3()	Eî	T _∞			
------------	----	----------------	--	--	--

date

CE 3	Eî	T _∞	CI! <	E 1	G-N
------	----	----------------	-------	-----	-----

coconut

CE 3 ()	Eî	T _∞	CIi!! <	E 1	G-N
---------	----	----------------	---------	-----	-----

rattan

CE 3)	Eî	T _∞	CIii <	E 3	G-N
-------	----	----------------	--------	-----	-----

sago

CE 3()	Eî, $\hat{\alpha}$	T _∞	CIii <	E 3	G-N
--------	--------------------	----------------	--------	-----	-----

vegetable ivory

CE 5=)	Eî	T _∞	CI! < α	E α	G-N
--------	----	----------------	----------------	------------	-----

PALM FAMILY

CE 3+,),()	Eî	T _∞	CI! ∞ <	E 1+	G-N
------------	----	----------------	----------------	------	-----

PALM ORDER

CE 3,), ()	Eî+	T _∞			
------------	-----	----------------	--	--	--

sweet-flag

CE 3)	E $\bar{\alpha}$	T _∞	CI! <	E α	G-N
-------	------------------	----------------	-------	------------	-----

ARUM FAMILY

CE 3=)	E ∞	T _∞	CI! <	E α =	G-, N
--------	------------	----------------	-------	--------------	-------

ARUM ORDER

CE 3=)	E ∞	T _∞			
--------	------------	----------------	--	--	--

rush

CE 3),()	E $\hat{\infty}$	T _∞	CI \perp	E ∞	G-N
----------	------------------	----------------	------------	------------	-----

RUSH FAMILY

CE 3),()	E $\hat{\alpha}$ +	T _∞	CI \perp	E ∞	G-N
----------	--------------------	----------------	------------	------------	-----

				Allium (150)
○	$L^{1/1}$	$I/ \vartheta Bi/_{2+}$)	SP'' 3×3,) FA 6]	
				Asparagus
○ b	$L^{1/1}$	I/ ϑ	SP'' 3×3,) FA 6]	
				Convallaria
2	$L^{1/1}$	$I' \vartheta$	SP'' 3×3) FA 6]	
				Veratrum
2	$L^{1/1}$	$I' i \vartheta \sigma \varphi \infty$	SP'' 3×3) FA 6]	
				LILIACEÆ
○ b	$L^{1/1}$	$I' \vartheta$	SP'' 3×3,) FA 6,]	
				Crocus (151)
2	$L^{1/1}$	$I' \vartheta$	SP'' 3×3) FA 3]	
				IRIDACEÆ
2	$L^{1/1}$	$I' \vartheta$	SP'' 3×3) FA 3]	
				LILIALES (152)
		$I \infty, B/$	SP'' 3×3,) FA 3+,]	
				Cypripedium (153)
2	$L^{1/1}$	$I' \vartheta$	SP'' $\frac{2}{1}$ × $\frac{1}{2}$ f $\frac{0}{1}$ × FA $\frac{0}{2}$	
				Vanilla
2 ~	$L^{1/1}$	$I' \vartheta$	SP'' $\frac{2}{1}$ × $\frac{1}{2}$ FA $\frac{0}{1}$ × f $\frac{0}{2}$	
				ORCHIDACEÆ
2	$L^{1/1}$	$I' \vartheta$	SP'' $\frac{2}{1}$ × $\frac{1}{2}$, f $\frac{0}{1}$ × FA $\frac{0}{1}$ × f $\frac{0}{2}$, FA $\frac{0}{2}$	
				ORCHIDALES (154)
		I'	SP'' 3×3, $\frac{2}{1}$ × $\frac{1}{2}$ FA 6-1	
				Pinus (157)
5	$L^{1/1, /_{1-5}}$	$I \sigma - \varphi$	SP 0 FA ∞	
				Larix
5	$L^{1/1, / \infty}$	$I \sigma - \varphi$	SP 0 FA ∞	
				Picea
5	$L^{1/1}$	$I \sigma - \varphi$	SP 0 FA ∞	

onion, etc.

CE 3) $E\hat{1}+$ T_{\sim} $Ci\perp$ $E\alpha$ $G-N$

asparagus

CE 3) $E\hat{\alpha}$ T_{\sim} $C!<$ $E\alpha$ $G-N$

lily-of-the-valley

CE 3) $E\hat{\alpha}$ T_{\sim} $C!<$ $E\alpha$ $G-N$

Indian poke

CE 3) $E\hat{\alpha}$ T_{\sim} $Ci\angle$ $E\alpha$ $G-N$

LILY FAMILY

CE 3) $E\hat{\alpha}$ T_{\sim} $Ci,!$ $E\alpha$ $G-N$

saffron, etc.

CE 3) $E\hat{\infty}$ $T_{\sim}]$ $TCi\perp$ $E\infty$ $G-N$

IRIS FAMILY

CE 3) $E\hat{\infty}$ $T_{\sim}]$ $TCi\perp$ $E\infty$ $G-N$

LILY ORDER

CE 3) $E\hat{\alpha} \neq$ $T_{\sim}, \sim]$

lady's-slipper

CE 3 ()] $E\hat{\infty}$ $T_{\sim}] \textcircled{D}$ $TCi\perp$ $E\infty$ $G-$

vanilla

CE 3 ()] $E\hat{\infty}$ $T_{\sim}] \textcircled{D}$ $TCi\perp$ $E\infty$ $G-$

ORCHID FAMILY

CE 3 ()] $E\hat{\infty}$ $T_{\sim}] \textcircled{D}$ $TCi\perp$ $E\infty$ $G-$

ORCHID ORDER

CE 3), () ,] $E\hat{\infty}$ $T_{\sim}] \textcircled{D}$

pine

CE ∞ $E\hat{2}$ Ti $TiCii$ $E\hat{2}2$ $G-N$

larch

CE ∞ $E\hat{2}$ Ti $TiCii$ $E\hat{2}2$ $G-N$

spruce

CE ∞ $E\hat{2}$ Ti $TiCii$ $E\hat{2}2$ $G-N$

				Tsuga
5	$L^1/1$	$I_{\sigma-\varphi}$	SP 0	FA ∞
				Sequoia
5	$L^1/1$	$I_{\sigma-\varphi}$	SP 0	FA α
				Juniperus
5	$L^{2+}/2+$	$I_{\sigma-\varphi}$	SP 0	FA α
				PINACEÆ
5	$L^1/1^\infty$	$I_{\sigma\varphi}$	SP 0	FA ∞
				TAXUS (158)
b	$L^1/1$	$I_{\sigma:\varphi}$	SP 0	FA α
				TAXACEÆ
5	$L^1/1$	$I_{\sigma\varphi}$	SP 0	FA α
				CONIFERALES (159)
		$I_{\sigma\varphi}$	SP 0	FA $\infty-$

hemlock					
CE ∞	E $\bar{2}$	Ti	<i>TiCii</i>	<i>E$\bar{2}$2</i>	G-N
redwood					
CE α	E $\bar{5} \pm$	Ti	<i>TiCii</i>	<i>Eii 5 \pm</i>	G-N
juniper					
CE α	E $_{1,2}$	Ti, \circ	<i>TC!</i>	<i>E$_{1,2}$</i>	G-N
PINE FAMILY					
CE ∞	E $\bar{2} \pm$	Ti	<i>TiCii,!</i>	<i>E$_{2} \pm$</i>	G-N
yew					
C 0	E $_{1}$	Ti, \circ		<i>Ei!!</i>	G-N
YEW FAMILY					
C $0-\infty$	E $_{1}$	Ti, \circ		<i>Ei!! \infty</i>	G-N
PINE ORDER					
CE $\infty-$	E $\bar{2} \pm$	Ti, \circ			

CHAPTER XI

KINSHIP AND ADAPTATION

163. The problem of origins. Kinship among living things implies a common origin. We know that kin always resemble one another more or less closely, and this likeness we attribute to their inheriting similar features from the same ancestor. Two individuals which differ from each other no more than do offspring of the same parents, we regard as belonging to the same species; and because of such likeness among the members of a species we feel sure of their having descended from an original ancestor or ancestors which had essentially the same characteristics.

No one doubts that all the kidney-bean plants in the world are the descendants of a plant or plants having the characteristic features of a kidney-bean; but, as we have seen, there are numerous varieties of this species which differ strikingly from one another; often more widely than do many species of the same genus. Why then may not all the species of beans be descended from a more remote ancestor, and so be as truly akin as the members of one species? And if the species of this genus are thus related why not also, though in less degree, the genera of the pulse family, the families of the rose order, the orders of the case-seed class, the classes of the seedwort branch, the branches of the vegetable kingdom, and, indeed, all groups of plants and animals according to their several degrees of resemblance? Why may it not be true that a natural system of classification expresses kinship?

To some readers it may appear profitless to pursue inquiries so remote, and they naturally ask, How can we know or why should we care about the origin of living things? Our answer must be that while of course we cannot know about this absolutely, we may be more or less sure that our conclu-

sions are right, and in so far as we really desire to understand the world about us with a view to living in it as best we may, we cannot help wishing to have our beliefs regarding origins harmonize with what we do know. So far as they are in accord with facts, such beliefs help us to put our facts in order so that we may use them to best advantage in living and thinking. Our supreme test of the value and truth of any such belief is the extent to which it enables us to fit fact with fact, and leads us to new facts of importance. Our method must be to apply this test to those beliefs which have been most widely held about the origin of living things. We may be sure that every such belief expresses important truths because of the many facts it must explain in order to be widely accepted. It is, of course, our business to seek truths of importance wherever they may be found, and to adopt the most promising belief until a plainly more truthful view is presented.

164. The doctrine of special creation. Linnæus embodied the belief of his own age and of former times in the famous saying, "We reckon so many species as there were distinct forms created in the beginning." This belief assumes that in somewhat the same way as men have fashioned artificial objects for various uses, so superior beings or one Supreme Being of transcendent wisdom and power, created in the beginning originals of all the different kinds of plants and animals, fitting each to occupy its proper place, and endowing each with the power of perpetuating its like in progeny. In other words, all the living representatives of each species are regarded as the descendants of a first original or pair which was specially created by God, as a distinct and entirely new production, in the most suitable part of the earth, when the world was young; from which place and since which time the species has been distributed over the area that it now occupies. Furthermore, the peculiarities which characterize its living representatives are held to be the same that were impressed in the beginning upon the original progenitors of the species.

The view above outlined is known as the doctrine of *fixity of species*, or *special creation*, or as *creationism*. Since it

proved to be satisfactory to the best thinkers of many ages, including many eminent naturalists, it must have afforded a reasonable explanation of numerous facts, and we may be sure therefore that it contains important truth.

A species does seem to be fixed in the sense of having natural limits beyond which unlikeness among its members cannot go. Thus even breeders of domesticated varieties find that they cannot induce more than a certain amount of modification in any one direction. For example, careful experiment has shown that if seeds from a wild carrot be planted in rich soil, and then seeds from the offspring with largest root be similarly planted and tended, and the same process of selection and planting be continued for several generations, there will finally be obtained as large rooted plants as any in cultivation. But sooner or later a size is reached beyond which the root does not increase; and if the most highly cultivated carrot-plants scatter their seed over neglected ground, as too often happens, the plants which are thus allowed to "run wild," as the saying is, soon become indistinguishable from the wild carrots which are pernicious weeds.

Another common experience of breeders is their inability to obtain fertile offspring by mating individuals of different species. It is true that pollen from a white oak may cause the ovules of a post-oak to develop into seeds which may grow into trees perceptibly different from either parent; and such hybrids are occasionally met with in nature. But when carefully observed it is usually found to be true either that hybrids are incapable of bearing offspring, or that such offspring as they have are apt to belong unmistakably to one or the other of the parent species. Many of the so-called hybrids of horticulturists are merely crosses between varieties of the same species and their fertility does not affect the above rule. Here, then, seems to be another definite limit circumscribing a species as if some law of fixity had been imposed upon it from the beginning. Many naturalists have maintained that in case of doubt as to whether two forms are true species or merely varieties, the power to produce perfectly fertile offspring may be used as a final test. Species thus viewed

become definite units of classification, which although sometimes difficult to separate in practice are in theory none the less absolute.

Those who have studied plants and animals most closely have always marveled at the ways in which each kind fits its natural *environment*, that is to say all the conditions under which it naturally lives. Thus among plants the absorption of food materials and the making of food, its storage for future use and its protection from harm, require not only a perfect working together of parts within the organism, but a nice adjustment of all to the surroundings. The structural features and habits of behavior which enable any organism to meet the usual requirements of its life are spoken of as *adaptations* to its environment.

Creationism views the wonderful adaptations of plants and animals as manifestations of the Creator's wisdom in so forming the progenitor of each species that its descendants shall all fit well into the places they are to occupy. It recognizes kinship only among the individuals of a species. The resemblance among species of the same genus, or among the subdivisions of higher groups in a natural system, it regards as indicating merely similarities of plan which the Creator was pleased to follow, much as an architect uses similar features more or less varied in different parts of a design.

165. The doctrine of organic evolution expresses a somewhat different view, which, however, is not so fundamentally opposed to creationism as might appear from the violent controversies waged between creationists and evolutionists during the nineteenth century. Evolutionists have repeatedly confessed their faith in God as the Author of the universe. Nor; as we shall see, do they deny that the descendants of a given organism may continue essentially unchanged for an indefinite period. As to adaptations, evolutionists have revealed a wealth of marvelously perfect examples greater than the creationists ever dreamed of.

What then was the need of a new doctrine of origins? One reason for dissatisfaction with the old view was that the more thoroughly plants and animals were studied, the less did species appear to have such definite limits as the crea-

tionists supposed to exist. Naturalists of eminence frequently differ widely as to the number of species into which the forms of a given genus should be divided. It often happens that one botanist recognizes several times as many species as another admits in the same genus. For example, one says there are but thirty species of rose, while another makes the number three hundred. Then too, the test of fertility in the offspring proved in practice to be disappointing. It was found that certain forms which no one had ever doubted to be distinct species did sometimes produce fertile hybrids; while, on the other hand, undoubted varieties hybridized imperfectly. Therefore, it was urged, if no one can tell which forms have come from one original ancestor and which from another, what is the use of supposing, as the creationists do, that resemblance between species means something entirely different from resemblance between varieties?

Another weak point in creationism was its underlying idea that the plants and animals of to-day are of the same forms which have lived upon the earth from the earliest times. Geologists in their study of the earth's crust found fossil remains of many species differing often greatly from any now living. As a rule the more ancient the forms, the less they are like those of modern times. That is to say, fossils show that old forms have continually given place to new ones during the course of geologic ages. Furthermore, contrary to the original supposition of creationism, that conditions upon the earth's surface have remained substantially the same since the appearance of life, the rocks show that extreme changes of climate have taken place. For example, scored ledges, transported boulders, and other evidences of glacial action prove that during the last geological period, the region from Pennsylvania northward was buried under a vast sheet of ice much as Greenland is to-day, while long before that time the coal plants of Pennsylvania flourished in a climate of subtropical warmth. To these geological facts creationists adjusted their belief by supposing that the older species were destroyed when they were no longer suited to a changed environment, and that new creations adapted to the new conditions then took their place. Thus instead

of one beginning there were many. But if creation be conceived of as a frequently recurring process, why limit the frequency? Why not admit that creation is going on continually and that each birth may be a new beginning? Such a continuous creation of new forms fitted to new conditions is precisely what evolutionists suppose to have taken place. When a creationist comes to believe that the Creator is continually making new forms out of old ones, so that by the accumulation of small changes through many generations great differences result, his theory of creation has already evolved into the doctrine of organic evolution. Modern botanists adopt the evolutionary point of view.

The word *evolution*¹ means primarily an unrolling or unfolding. A bud evolves as it expands into a flower. The oak evolves from the acorn germ. In this process of unfolding its possibilities the organism passes through successive stages each differing slightly from the one which went before, and from the one which follows; but showing extreme differences between the earliest and the latest stages. The evolution of a species is conceived of by analogy to be a similar unfolding of possibilities through a series of generations, in the course of which new features arise, are inherited, and become more and more pronounced as slight changes continue to appear in parts which had already been slightly changed. Fundamental resemblances between any two individuals or types are thus accounted for on the supposition that they have inherited from a common ancestor the features they have in common, while the differences they exhibit are regarded as representing the sum of those small individual differences which have continually arisen and been transmitted along their diverging lines of descent. Hence, broadly speaking, the degree of likeness becomes a measure of the closeness of kinship.

On this view it follows that a truly natural system of classifying organisms is an arrangement expressing degrees of kinship as inferred from all the resemblances and differences that can be observed. If we knew enough about all

¹ Ev-o-lu'tion < L. *evolutus* pp. of *evolvere*, unroll, unfold <e, out; *volvare*, roll.

the different kinds of plants that have ever lived, we might have a classification of the vegetable kingdom which could be represented diagrammatically by an enormous tree, made up of innumerable segments which would correspond to successive generations of species. The twigs of one branchlet would stand for the species of a genus; the branchlets of a minor branch for the genera of a family; while these minor branches and those larger and larger would represent in turn families, orders, classes, and, finally, the main branches of the kingdom.

Let us suppose, now, that our evolving tree of life as it grew was gradually buried, all except the tips of the twigs which thus formed a flat top growing just above the surface of the ground. Such a buried tree may show in a rough way the nature of the facts presented to the evolutionist for interpretation. Before him on the earth are living species arranged in groups of groups according to their various degrees of resemblance. Below ground he may find a few more or less fragmentary remains of creatures which lived and died in ages past. By their resemblances to forms still living he is able to tell roughly to what branch they may belong, and if the extinct forms have peculiarities intermediate between the characteristic features of living groups this would indicate to him a kinship between these groups which he might not have suspected. For example, certain coal plants, as we shall see, which resemble both ferns and gymnosperms led botanists to recognize a much closer kinship between these groups than the living forms had made apparent.

But by far the greater part of the buried generations have left no remains and may be reconstructed only conjecturally by reasoning backward to the ancestral traits from the peculiarities possessed in common by their supposed descendants. Sometimes it has happened that striking confirmation of such reasoning has been found. Thus, to take an example from the animal kingdom, zoölogists were led to believe from certain anatomical resemblances between birds and reptiles that these groups were closely akin and must have descended from a type combining the fundamental characteristics of both; then the fossil remains of a creature

having wings and feathers like a bird, but with the toothed jaws and long, jointed tail of a reptile were discovered in rocks of just the age required by the theory.

Such backward reasoning of course yields trustworthy results largely in proportion to the fulness of our knowledge regarding all the forms of the group studied, and all stages of their life. The younger stages are especially noteworthy in tracing kinship, for it has been found as a general rule that the earlier the stage at which related organisms are compared the closer are the resemblances. We have already seen an example of this rule in our comparison of the development of flowers belonging to the crowfoot and the bluebell types. If we compare such flowers as those in Figs. 298, and 299 I we find that in the earliest stage both have five distinct petals; but while in the rose these petals continue to grow separate, in the oxeye the whole corolla-base soon begins to grow as a continuous ring carrying upward the petal rudiments so that they finally appear as teeth or projections on the margin of a bell. Hence, we may suppose a degree of kinship between the rose and the oxeye, or the flax (Fig. 217 II) and the bluebell (Fig. 299 II), which a comparison of their mature flowers would not so clearly reveal, and the fact that the mature corolla of the rose is essentially like the young corolla of the oxeye indicates that the ancestor common to both was more like a rose than an oxeye; or in other words, that the bluebell type of corolla has been the more highly evolved, while that of flax or rose has more nearly retained the ancestral form.

Many such facts incline evolutionists to believe that the successive stages passed through by an individual in its development correspond more or less closely to the various forms which appeared successively in its line of ancestry.

The development of an individual organism from egg to adult is termed its *ontogeny*,¹ while the evolution of the group to which it belongs is distinguished by the term *phylogeny*.² It is commonly accepted as a general rule by evolutionists that ontogeny epitomizes phylogeny, and this is called the *law of recapitulation*. We shall have occasion, however, to notice in our attempts to apply this law in the

¹ On-tog'en-y < Gr. *onta*, things existing; *gennaō*, to produce.

² Phy-log'en-y < Gr. *phylon*, a tribe.

tracing of kinship that it is often obscured by the workings of other laws. Recapitulation is understood to be a consequence of the general rule that organisms inherit as far as possible all the peculiarities of their ancestors, and so have similar young stages; but new features may appear even in the young which can be inherited only by obscuring or obliterating the old.

Sometimes bluebell flowers are found having distinct petals, and so resembling what evolutionists suppose to have been the remote ancestral form. Such exceptional adult forms resembling younger stages or presenting features which on other evidence may be regarded as ancestral, are classed as *reversions*. It is a common experience of breeders to observe some striking peculiarity of an animal or plant disappear in the first generation of offspring and then reappear in those of the second or some subsequent generation. This reappearance is called *atavism*¹ and seems to differ from reversion only in the remoteness of the ancestor to which the descendant reverts. Reversions are of interest to the evolutionist as often affording confirmation of views of kinship otherwise made probable. It should be borne in mind, however, that many abnormalities have no claim to be called reversions.

Another clue to kinship is found in *rudimentary organs*, such for example as the imperfectly developed ovules of anemonies. The presence of these presumably useless organs may be explained by supposing them to be vestiges inherited from an ancestor which had in each ovary several perfect ovules; and when we find such a plant as the marsh-marigold, very like an anemony except for having perfect ovules in place of the rudimentary ones, our conviction that these plants are closely akin is much strengthened. Furthermore, these rudimentary ovules in anemonies serve to bridge the gulf which separates those members of the crowfoot family which have several ovules from those which have only a single one in each ovary, for they seem to preserve a stage in the process by which several ovules were crowded out.

In the light of what we have learned of the general principles of evolution let us now re-examine the members of the Ranunculaceæ represented in the family chain on page 353, and see to what more definite conceptions they may lead us. The family chain diagram may be taken to represent a top view of the branches of a family tree, the rectangles standing for living genera, and the links connecting them for the forks of extinct or buried branches. This same family tree viewed from the side, the branches being swung round

¹ At'a-vism < L. *atavus*, a great-grandfather's grandfather.

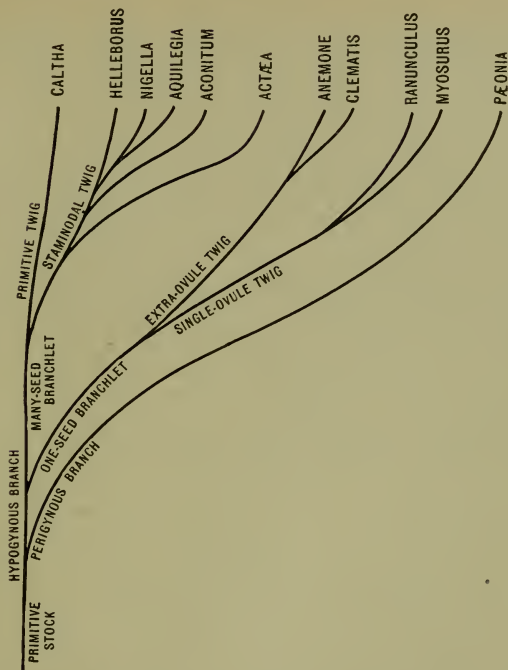


FIG. 300.—Family tree of Ranunculaceæ, illustrating the evolution of the group as provisionally suggested in the text (pp. 437-440).

into one plane, is shown in Fig. 300. If our idea of the kinship of the different genera be correct, this diagram represents the branching lines along which we may suppose these members of the family to have evolved. All that lies below the terminal twigs is supposed to be buried; and, in a general way, the further a branch or line of descent extends to the right the more is it supposed to depart from the original ancestral form.

Our vertical diagram thus indicates that of all the living forms of Ranunculaceæ, *Caltha* most nearly resembles the ancestor of the family. According to this view the story of the family's evolution would be somewhat as follows. Among the descendants of *Caltha*-like moisture-loving plants which grew in a remote geologic age, some retained for innumerable generations the characteristics which fitted them for living under the comparatively uniform conditions afforded by protected moist situations, and are represented to-day by our marsh-marigolds. In these have survived a most primitive type of flower, hypogynous, with many-ovuled, distinct

carpels, numerous stamens of ordinary form, and a regular perianth of almost leaf-like sepals; and a very simple form of palmate leaf and herbaceous stem. Certain other descendants of the primitive stock showed in very early times a modification of the torus and perianth (resulting in perigynous flowers with the perianth differentiated into a well-defined calyx and corolla), also an advance in complexity of leaf-form, and more or less woodiness of stem. The plants of this branch were thus able to thrive under the more exacting conditions of open fields, and have become the highly developed sturdy peonies of to-day. Very early in the development of what we may call the hypogynous branch of the family, there appeared some more or less *Caltha*-like forms, in which the carpels did not open at maturity, but separated like seeds from the parent plant. This change of habit made it unnecessary for more than one seed to mature in each carpel, so the result was an achenial instead of a follicular fruit. Those descendants which retained rudiments of several ovules became in time either forms of *Anemone* or of *Clematis* according as they developed the peculiarities of this or that genus; while similarly those in which the reduction to one ovule was complete, gave rise to such plants as buttercups and mouse-tails. In much the same way we find those descendants which comprise the more primitive subbranch with its many-seeded carpels becoming differentiated into forms retaining the original follicular fruit, and forms in which the fruit is indehiscent and fleshy, as in *Actæa*. Along the lines with follicular fruit the appearance of forms with certain of the stamens changed into more or less conspicuous nectaries give rise to a departure from the *Caltha*-like forms, which in turn became differentiated into those in which the corolla remained regular and those in which more or less irregularity was shown, as in monkshood. Finally, the regular-flowered forms with staminodes developed such peculiarities as the spurs of *Aquilegia*, and the curious follicular capsule of *Nigella*, by which the modern genera of this subgroup are now distinguished.¹

¹ It might fairly be asked whether entirely different lines of descent from those here given would not as well explain the modern forms upon which our reasonings have been based. Undoubtedly this is true. Thus, instead of supposing the progenitor of the family to have been an herb like the marsh-marigold we might perhaps with more probability assume it to have been a shrub or tree resembling a woody peony or a magnolia; for in other families there is much evidence in favor of the view that herbaceous seed-plants have had woody ancestors. But in this family we have no direct proof that its earliest members were woody, and for us to make the assumption would complicate our reasoning without rendering any clearer the general principle we are trying to make plain. Let the student, therefore, take our crowfoot family tree simply as representing one out of many possible ways of accounting for the facts at hand, and as liable to modification whenever new light appears on the problem. It is merely intended to illustrate the kind of reasoning that biologists employ in the absence of evidence from fossil remains, and

If we trace the evolution of a given form backward to its beginning we come to more and more primitive conditions. Mouse-tails, for example, we should derive from ancestors resembling buttercups in having a shorter torus, more stamens, spurless staminodes, and broader leaves. It seems reasonable to suppose that these mouse-tail-buttercups left no unmodified descendants, and so were not exactly like any living form of buttercup, although we might fairly presume that they showed more of the relatively primitive buttercup structure than of the peculiar mouse-tail features. These buttercup-like ancestors would be traced back to progenitors more nearly resembling anemonies in which rudimentary ovules still bore witness to a previous many-ovuled stage, when also certain of the outer stamens were showing only rudimentary anthers and were secreting nectar on broadened filaments. The step from this form, from which both mouse-tails and anemonies descended, to the marsh-marigold-like ancestors of the family, requires us to imagine little more than a previous full development of the ovules and anthers which later became reduced, and a more ordinary form of filaments and carpels.

In the above examples of the way an evolutionist conceives the changes in a group to have progressed, innumerable details of the process have necessarily been omitted for the sake of simplicity. Many branches would have to be interpolated if all living genera of the family were to be represented, and there is no knowing how many dead branches should be shown to make the family tree complete. It must, of course, be frankly admitted that the conclusions are largely guesswork supported only by circumstantial evidence, for no remains of the very perishable ancestral forms of the crowfoot family have come to light. Our examples, however, are typical of evolutionary schemes in general, and so may help our understanding of the theory of evolution. One prevalent misconception which it should correct is the notion that forms now living are supposed to have been derived from ancestors just like other recent forms. On the contrary,

the kind of conclusions they reach by such means. That such conclusions are at best far from satisfactory goes without saying; but herein lies a challenge to do better, and a spur to further study.

evolutionists believe that more or less modification is the rule among all the descendants of a given form, and that only rarely has it happened that ancestral forms have persisted for ages unchanged. Thus, in regard to the last examples, the most we should be willing to say is that mouse-tails were probably derived from plants something like the more primitive forms of recent buttercups, such as the ditch crowfoot (Fig. 209); that these ancestral crowfoots came from plants something like our marsh-marigold; and so on. It is thought that single traits or a few traits in combination, are more apt to survive through long periods than the many peculiarities characterizing a complex structure.

Closely connected with the erroneous view above mentioned is the notion that all the modern representatives of a group can be arranged in a single series beginning with the most primitive, and passing on to the most highly evolved through survivals of the intermediate stages or "connecting links." From what has been said it will be obvious that such an arrangement would be possible only on condition that all the forms which had ever appeared were actually represented by living descendants and that modification had occurred only in one direction. As a matter of fact, gaps, often great, between related forms are continually met with. Indeed, if the "connecting links" of the past, represented by the dead branches of our tree, had not disappeared there would be no possibility of classifying living forms into groups and subgroups, for there could be no limits to any group. Sometimes within a group it is as if Nature had as yet done little or no pruning, and the result is most bewildering to those who attempt a classification of the forms. No two students of the group are likely to agree as to where lines of demarcation should be drawn. Such a group is that of the roses previously mentioned. But even here, for all the embarrassing wealth of connecting links, it is quite impossible to arrange the forms in a single series. There are many diverging series which branch again and again. Their relationships as inferred from their degrees of likeness can best be expressed by a branching system, and while of course the systematist must deal with his groups one after another in simple sequence,

he cannot make such a sequence adequately express his idea of their kinship.

If we are warranted in supposing that all members of the crowfoot family are the descendants of plants like our marsh-marigold we may assume with scarcely less probability that plants closely similar to these primitive marsh-marigolds were the ancestors of all of the crowfoot order, and indeed that from plants having very much the same primitive characteristics came, in the course of geological ages, all of the dicotyls and perhaps all the monocotyls as well. Our mental images of ancestral forms are necessarily dim in proportion to the remoteness of the form conceived, and are likely to change as we receive new light. Yet these mental diagrams of things no longer to be seen help our seeing of the things about us. From the evolutionary point of view all life takes on a new significance. The possibility of gaining some glimpses of how the living world came to be as it is, makes all life more deeply interesting. Details of structure or behavior in a humble plant may lead us to some of the greatest truths of life.

166. Acquired adaptations. The belief that all existing organisms are the more or less modified descendants of relatively primitive forms, is now as generally held by naturalists as is the belief in universal gravitation among astronomers. Yet astronomers are still striving to understand how it is that the force of gravity can act as it does; likewise naturalists are still debating the fundamental question as to how inherited modifications have arisen. That somehow plants and animals have evolved is now taken for granted; but there are wide differences of opinion as to the way in which the changes have been wrought.

In these few pages we can glance only briefly at the leading views now held regarding the origin of species. Each theory aims to account for the appearance of those peculiarities of structure or behavior which distinguish one group from another; as for instance the climbing habit of clematis and the long, mostly hairy-tailed fruit which is found nowhere else in the family except with certain anemonies inhabiting wind-swept fields. Peculiarities of this sort are

often connected in some helpful way with the life of the individual—hairy appendages insuring to achenia widespread dissemination by wind, and the power to climb facilitating economically the quick exposure of green parts to sunlight. In such ways an organism, as we have seen, is adjusted, often marvelously well, to its environment; and we call the adjustments which promote its welfare adaptations. It is with questions of the origin and inheritance of adaptations that the debates of evolutionists are mainly concerned. We must, therefore, at the outset examine carefully just what is meant by an adaptation.

Every individual plant or animal is found to have the power of modifying its form or behavior in response to outside influences, and such modification is often beneficial. Indeed we need not distinguish here between form and behavior, for even structure is but the result of growing in certain ways, and growth is merely a slow kind of behavior. So we may say that each living thing, in so far as it is alive, has a certain limited power of adaptation through direct response to environing influences. As a seed sprouts, its little root turns toward the place of greatest moisture, while the young leaves are directed toward the light, and if the illumination be feeble the stem helps the leaves by elongating more than it would if the light were stronger. A tree exposed to strong winds of one prevailing direction takes on a one-sided form thereby reducing the strain. Herbs which in rich moist soil produce tall stems and ample foliage before they flower, will on a sandy roadside bloom as soon as they have made a few small crowded leaves and are only a few inches high, thus, doing the best they can under adverse conditions. Dandelions grown on a mountain side look very different from those grown in the lowlands (Fig. 301), and the peculiarities of each seem to fit in especially well with the contrasting conditions. Such cases of advantageous adjustment made during the life of an organism may be termed *individual adaptations*. From these we must distinguish *characteristic adaptations*, or advantageous peculiarities belonging to whole groups. Of such adaptations the characteristics of clematis above referred to may serve as examples;

or we might take a mountain species of buttercup (Fig. 302) which differs from near relatives of the lowlands in having a stunted, compact form well suited to alpine conditions and a rosette of leaves somewhat resembling those of our moun-



FIG. 301.—Common Dandelion (*Taraxicum officinale*, Sunflower Family, *Compositæ*). P, plant as it grows in the lowlands, reduced in size. M, plant as it grows at high altitudes, reduced in the same proportion as P. M', the same plant as M less reduced. (Bonnier.)—Native home, Europe; very common as a weed in America.

tain form of dandelion. A peculiarity supposed to have arisen in response to some direct influence of the environment is said to be *acquired*. If it be characteristic of a group it is called an *acquired character*, while in so far as it serves to fit the organism for the special conditions of its life it is an *acquired adaptation*.

It has been thought by many naturalists that the differences among plants and animals may best be accounted for as peculiarities which have arisen in individual acquisitions, these having become hereditary and thus characteristic after many generations of similar response to a similar environment. Suppose, by way of example, that some of the seedlings from primitive marsh-marigolds grew in a rather dry locality and were more or less shaded by overgrowth. They might be expected to respond to the lessened light by elongation of the internodes and leaf-stalks, while a



FIG. 302.—Pigmy Buttercup (*Ranunculus pygmaeus*, Crowfoot Family, *Ranunculaceæ*). Plant. Flower. Fruit. (Britton and Brown).—Perennial (?) herb 5–12 cm. tall; flowers yellow; fruit dry. Native home; northern America and Eurasia.

finger-like lobing of the blades through increased growth along the ribs and scant growth of the pulp between the stem would be fortunate as enabling the leaves to catch more of what little light there was. But the less favorable conditions for food-making would render it impossible for them to form and feed as many seeds as the marsh plants had done; hence some of the later-formed ovules would be more or less starved. From the good seeds formed by these pioneer plants and scattered in the vicinity, a second generation would arise, the individuals of which would respond similarly to the same trying conditions. Innumerable generations might follow,

similarly responding, and if each generation were influenced ever so little by the responses of the generations before, that is to say, if the acquired peculiarities were inherited to any extent, the foundations laid by the pioneers would be built upon by their descendants. As a result we should have in successive generations the stems growing longer, and the leaves more branched and finally becoming compound. An increased sensitiveness to light might be accompanied by greater sensitiveness to contact and this might lead to a coiling of the leaf-stalks around neighboring twigs, thus establishing the habit of climbing by means of which better exposure to light would be most economically secured through utilizing for support the very bushes which had made the shade. As a consequence of the starving out of the upper ovules there would result finally a fruit the upper part of which had become a mere tail-like projection surmounting a one-sided indehiscent base. A general hairiness which had been developed in all the exposed parts of the plant in response to the dryness of its new environment might especially affect the fruit as being now especially exposed, and might lead even to an elongation of the tail which would thereby become well adapted for enabling the wind to carry the precious seed high over surrounding shrubbery. In some such way as this it is conceivable that the characters of a clematis may have evolved.

The first naturalist to suggest that organisms had evolved through the accumulation of acquired characters was Jean Baptiste Lamarck, of France, who flourished in the early part of the nineteenth century. His doctrine is called *Lamarckism*, or as modified by his more recent followers, *Neo-Lamarckism*. Lamarckians have advanced much evidence to show that acquired characters are often adaptive and may be inherited; but while most naturalists might concede the possibility of such characters being now and then adaptive, the great majority of evolutionists have remained unconvinced that acquired characters are ever fixed by inheritance. So far as we know, acquired characters do not long survive the conditions under which they arise. Cultivated plants escaped from cultivation soon become, as we have seen,

indistinguishable from wild plants of the same species. But might not very long subjection to changed conditions finally fix an acquired character? Possibly, and it should be said that the botanical evidence is perhaps more favorable to this view than the zoölogical; but if the facts can be explained without relying upon suppositions hardly possible to verify, we may build upon a safer foundation.

167. Selected adaptations. Dissatisfaction with Lamarck's explanation of modification through acquirement, deterred most of his contemporaries from accepting the theory of evolution, and it was not until Charles Darwin and Alfred Russel Wallace offered an explanation based upon acknowledged facts that evolutionism was welcomed at all widely by scientific thinkers. The new doctrine is generally known as Darwinism, because Darwin's contributions in support of it were most extensive and important, although both Darwin and Wallace, working quite independently, came to substantially the same conclusions, and announced them at the same meeting of the Linnæan Society of London in 1858.

Darwin felt that the problem of how one species changes into another might best be attacked by studying the modifications which plants and animals undergo when domesticated. We have already seen (page 126) how much has been accomplished with cultivated plants by artificial selection,—farmers taking their seed from those individuals which please them best and continuing to pick out for propagation year after year the plants which show most fully those most desirable features. Here it would seem as if hereditary peculiarities were surely depended upon, and that the most striking departures from an original form represented the sum of many small differences in one direction accumulated through successive generations by inheritance. Darwin reasoned that if it could be shown that plants and animals in nature were continually subjected to agencies which favored the propagation of individuals possessed of slight hereditary peculiarities contributing to their welfare, the most perfect adaptations would be accounted for and the origin of species scientifically explained.

What natural agencies can be supposed to exert a selective

power at all comparable to man's influence in developing artificial varieties? In the first place Darwin pointed to the fact that every kind of plant or animal produces more offspring than can possibly come to maturity; for if none died without issue, the progeny of one individual or pair of individuals would shortly cover the whole earth. Thus fifty dandelion plants from one, each bearing fifty-fold, and so on for nine generations, would make more than enough dandelions to occupy every foot of dry land on the globe. Innumerable individuals of innumerable kinds are continually producing offspring in large numbers. Since many more are produced than can mature it appears that a competitive struggle for life must be going on throughout the living world; and, he argued, so intense is this struggle that if some individuals had an adaptational peculiarity which gave them even a slight advantage over their rivals, such favored individuals would be the ones to survive and leave offspring. Some of their offspring would be sure (judging from breeders' experience) to inherit the same peculiarity, and these favored offspring would in turn transmit it more or less enhanced to certain of their descendants, and so on along lines of favored individuals in which the peculiarity in question would become more and more pronounced. This improvement would continue up to the point of adapting the organism as perfectly as possible to its environment. In this way a favored race might become a new species through survival of the individuals best fitted to a slowly changing or slightly changed environment.

The natural agencies which favor the survival of certain races in the struggle for existence Darwin compared in a metaphorical way to the human agencies which control the production of cultivated varieties. Both Man and Nature, he argued, act by selecting through successive generations certain peculiarities. Man chooses to encourage what pleases him. His method is *Artificial Selection*. Nature encourages only those peculiarities which best fit the organism to its environment; her way Darwin called *Natural Selection*. The phrase has been often misunderstood through failing to take it merely as a symbol of the way certain natural forces act.

Darwin defined natural selection as meaning "the preservation of favored races in the struggle for existence." He accepted Herbert Spencer's phrase, "survival of the fittest" as a good equivalent.

The theory of natural selection assumes, then, a struggle for existence among contemporary individuals in a given environment—a struggle resulting from vastly more of each kind being produced than can possibly survive, and so intense that even a slightly advantageous peculiarity may be enough to secure for its possessor both life and offspring. Such favoring peculiarities, according to the theory, are to be found in the small differences observable among individuals of the same kind living in the same environment. Hence we need not suppose them to be acquired, and we may safely regard them as hereditary because experience shows that peculiarities of this sort are regularly inherited. Since these slight departures from the parent form take various directions under the same circumstances, they are termed *fluctuating variations*, in distinction from *definite variations*, which are all in the same direction, as must be the case with those due to the same influence—like a direct effect of the environment—acting upon similarly constituted organisms. Darwin did not pretend to explain the origin of fluctuating variations further than to regard them as constitutional peculiarities resulting from the interplay of internal forces. These he saw might be so delicately balanced as to be readily disturbed by change of environment, and he recognized that a change of conditions commonly induces variability, and so gives a wider range of differences for selection to work upon, as when a horticulturist desiring to develop a new variety subjects his seedlings to unaccustomed conditions. But in so far as the variations are in different directions, they must be regarded as *induced* by the change rather than produced directly by it, and so may be spontaneous rather than acquired.

Darwin's theory carried to its extreme by his modern followers, known as Neo-Darwinians, denies that acquired peculiarities are ever fixed by inheritance. Only what was inborn in the parent, they say, can be transmitted to the

offspring, and the more often such peculiarities have appeared in the line of ancestry the surer they are to reappear in all the descendants. Neo-Darwinism is thus in sharpest contrast with Neo-Lamarckism. The thoroughgoing Darwinian of to-day rejects all direct influence of the environment as a factor in organic evolution. Assume spontaneous variations, he would say, and let some of them be in adaptational directions, then in the struggle for existence which is always going on, the life and death of rivals will turn upon which has inherited the better equipment, and upon this will also depend the chance of transmitting to offspring the qualities which saved the parent's life. Every gain in efficiency of adaptation will thus be preserved and successive gains accumulated till highest efficiency is reached, and when the most perfect adaptation has been secured it will be maintained indefinitely so long as the environment remains essentially unchanged. Since there are often different ways of attaining the same end, and so fitting different individuals successfully into the same environment, and since also there are different environments to which a variable species may accommodate itself, such a species may give rise to several species in the course of many generations. If the intermediate forms or "connecting links" from being less perfectly adapted than the extreme forms should eventually succumb in the struggle, and so become extinct branches of the genealogical tree, gaps would appear between the surviving forms permitting us to define them as distinct species. A longer continuation of the same process would result in the differentiation of genera, families, and higher groups.

Let us see how the theory of natural selection would apply to our supposed evolution of clematis. Imagine many thousand primitive marsh-marigold individuals inhabiting moist localities surrounded by drier spaces. These plants would be sure to vary somewhat in their ability to withstand occasional dry seasons. Among the millions of seeds produced by the tougher individuals a good share would surely be scattered along the edge of the drier spaces where there would yet be enough moisture for them to sprout. Those of the seedlings which had come from the toughest parents and

had inherited most fully their toughness would gain a foothold where the less favored of their fellows could not survive, and, since the adversities of the new environment would try them more and more as they grew older, only the very toughest of them could produce seed. Still it might fairly be supposed that a few, at least, would do so. Most of these seeds would fall on the drier soil, the seedlings therefore would similarly compete, and the winners be selected from among the very toughest. Such rigorous selection might be expected to insure a progressive toughening in successive generations of drought-defying plants, and a continuation of the process might be expected to result in a gradual invasion of the drier spaces by much toughened descendants of the moisture-loving form. Once accustomed to the drier soil they would have become less fitted for a wet locality and their progeny would consequently be excluded from the old home. During the gradual adaptation of the new form to its drier environment, the individuals might *acquire* more or less adaptative peculiarities and so far as the toughness was not impaired thereby, these new features would be permitted by natural selection and might appear in successive generations just as if they were inherited. From marsh-marigold-like ancestors might thus evolve primitive anemonies through the indirect effect of drier conditions acting along the same lines and producing the same results as Lamarckians maintain would come from the direct effect of the same environment. During their evolution these anemonies might become differentiated into sun-loving and shade-loving species by the survival of those individuals best fitted to grow in sun or shade respectively. Success in the dry open fields would be favored by having the leaves lie next to the ground, so as to avoid as much as possible the withering effect of drying breezes, while in the shade it would be advantageous to have the leaves elevated so as to catch the light. This may account for the occurrence of ground rosettes in the anemonies of the open, and the prevalence of raised rosettes, borne upon an elevated lower internode, in anemonies of the wood. These latter might similarly be differentiated through natural selection into shade-enduring anemonies on the one hand, and climb-

ing clematises on the other, according as the individuals of successive generations were born with the ability to make the most of the little light, or the ability to climb into the sunshine above. Now, since we are deriving these climbing plants from rosette-bearing ancestors it is easy to see how rosettes might pass into whorls of a few leaves and the few be reduced to two. We should then have the opposite leaves, characteristic of clematis, arising as an incidental result of the development of the climbing habit. So likewise the peculiarity of having four sepals, which characterizes the genus, may be an incidental result of the opposite leaf-arrangement, for we have only to suppose that such a fundamental change of habit in the growth of the foliage-leaves would show also in the arrangement of the floral leaves since these would be in a primitive condition readily permitting the change. Other changes involved in passing from the marsh-marigold-type to the clematis-type of flower and fruit, which we have already seen to be advantageous under the drier, sunnier, and windier environment, may be easily imagined to have been effected by the accumulation through heredity of innumerable spontaneous variations, each very slight but of vital importance to its possessor in the struggle for existence.

According to the view above outlined, more and more highly developed groups would be separated from relatively primitive ones through the perpetuation of slight yet favorable fluctuating variations, fitting their possessors to occupy the more and more trying environment. At the same time the more primitive forms would survive under the less exacting conditions and perfect their simpler structure. Incidentally there might be preserved through successive generations acquired peculiarities of an adaptive sort or even nonadaptive ones, provided they were not seriously injurious; or, under the same proviso, there might be perpetuated such a characteristic feature as the plan of four in the calyx of clematis, which had arisen as a merely incidental result of some other modification. A peculiarity depending in this way upon another peculiarity is called a *correlated character*. Occasionally features of no conceivable use to their possessors,

as for instance the so-called rudimentary ovules of *clematis*, may escape entire obliteration. Characters of this sort are termed *vestigial*. Both vestigial and correlated characters imply adaptations—the one past and the other present—and thus may be said to result indirectly from natural selection; while even the acquired characters permitted by natural selection are most likely to survive when adaptational. Hence we may conclude that the central idea of Darwinism is the gradual accumulation through inheritance of slight *selected adaptations*.

168. Acquirement versus selection. We have seen that the chief difficulty which the Lamarckians have to face comes from their unproved assumption that acquired characters may be fixed by inheritance. The Darwinians on the other hand in their efforts to avoid this difficulty have fallen into others which we must now examine. Darwin tells us that he made it a rule to note down every fact or criticism adverse to his theory as soon as it came to his attention; for, as he shrewdly observes, what is unfavorable to one's view is most likely to be forgotten. With the utmost candor he discussed in his writings every objection known to him. He was thus his own severest critic, and since he pointed out to his opponents their most effective lines of attack, there rightly belongs to him a share in whatever victories they gain in the cause of truth against his theory. Surely no one would rejoice more genuinely than he in any better explanation of the workings of evolution.

Since natural selection operates only through adaptive variations we should expect that the various systematic groups of plants and animals, representing as they do the surviving branches of the evolutionary tree, would be very generally definable by adaptive characters or at least by characters which clearly imply adaptations past or present. But on the contrary it is just this sort of character which is found to have least systematic value, and therefore as a rule we find systematic groups most clearly defined by peculiarities which so far as we can tell have no relation whatever to the vital needs of the organisms possessing them. In tracing the supposed evolution of *clematis* we chose a few

features as adaptive as possible; but even here we have to admit that the features which best distinguish clematises from anemonies are the ones that are least obviously adaptive. Thus, for example, it would seem to be highly improbable that the life of a plant or the welfare of its offspring could ever depend upon whether it had four or five sepals, and in our endeavor to connect this character with some adaptative feature we had to make a succession of roundabout suppositions. Yet most species of clematis are distinguished from anemonies by this very character, while the sharpest distinction between the flowers of these genera is in the æstivation. Here purely mechanical causes seem sufficient to account for clematis having the valvate form while anemony has the imbricate arrangement. A review of our generic, family, and ordinal definitions will show that the main dependence of systematists is upon just such non-adaptive characters as those of floral plan, leaf arrangement, or mode of branching. If from this very large class of non-adaptive characters we subtract all the cases which give evidence of being either vestigial or correlative, we have left a considerable number inadequately accounted for by natural selection. It does not help matters for Darwinians to plead that we are very ignorant of the functions of all living things, and hence that peculiarities seemingly useless may really be useful; for questioning our ability to distinguish what is useful from what is not tells against our suppositions regarding the uses of parts quite as truly as it does against a belief in their uselessness. Lamarckism seems weakest when it attempts to account for highly developed adaptations; Darwinism when it deals with non-adaptive characters.

We are led into further difficulties by Darwin's assumption that the great intensity of the struggle for existence resulting from over-production would suffice to perpetuate even slightly useful peculiarities. If we ask ourselves what really happens to the large number of seeds ripened by each generation, we cannot fail to see that the struggle which Darwinians suppose to result from this immense number is much overdrawn. I am writing these lines in a pine grove. The trees are loaded with cones and from them come whirling

down thousands of seeds. But after hunting seedlings within and around this grove for many years I find that scarcely one in many thousand seeds ever gets a chance to sprout. There is seldom any crowding of the seedlings. The nearest neighbors may be many feet or many yards apart, and the saplings are much fewer than the seedlings. Some advantageous position with reference to light or depth of soil would account fully for their survival without any reference to small peculiarities in the plants themselves. Moreover, at bearing-time the question as to which trees shall send seeds to such favorable spots seems to be decided not so much by any peculiarities of the trees themselves or their seeds as by the strength and direction of the wind at a given moment and the obstacles that may happen to stand in the way. It does not appear that fitness is decisive. There is some crowding. Indeed the grove itself might be called a crowd of pine trees. But this crowding simply shows how many plants can grow for many years close together by individual adaptation to one another. The signs of such mutual accommodation are much more apparent than any signs of competition. As applied to this grove the idea of an intense "struggle for existence" among its components would seem to be quite fanciful. One might urge that a Darwinian need not suppose any new species to be arising under the conditions described. Very true; but our illustration was not chosen to show how species arise. It was selected as fairly representing conditions to be met with on every hand—conditions essentially similar to those under which all evolutionists believe that new species have somehow originated.

An extreme case such as might be afforded by desert conditions increases our difficulties. Desert plants are always few and far between. There always seems to be room for many more. Competitions depending upon a surplus of individuals would appear in general to be quite out of the question. To be sure, each individual may be supposed to have a hard time growing under such severe conditions; but the fact that it lives there shows that it can stand them, and it seems to be enabled to do so by means of extraordinarily

perfect adaptations to its strange environment. We are warranted in believing that these plants could not live there unless they had some such adaptations, but just where extreme adaptations are most necessary there is least competition to account for them. But may not the environment operate selectively nevertheless? Perhaps, but even so it is not through the struggle of numerous competing individuals: any one of them that is favorably situated and is just able to stand the worst of the drought has as good a chance to increase and multiply as the toughest of all. It may also be pointed out that the most marked features of desert plants—such for example as extensive root system, succulent or greatly reduced foliage, hairy or thickened skin for checking loss of water, and an armament of thorns for defense against animals—are the ones most easily accounted for as originating from direct effect of the environment or individual response; while as regards the defensive armament, which is often cited as a most perfect adaptation, it must be said, that grave doubts are raised as to its being of much use in the very cases where it is most forbidding, since few if any large browsing animals are found in those localities where the most highly developed armaments occur. In such cases any selective influence is hard to imagine.

Naturalists have found many cases in which a selective influence, supposing it to exist, would have no opportunity to act upon small fluctuating variations in the Darwinian way. The climbing habit of clematis will serve to show what is meant. The coiling of the leaf-stalks by unequal growth stimulated by contact with a support, is an undoubtedly useful power; but this power, it would seem, can be of service only after it is developed; a very slight curving of the stalk could not anchor a leaf. Therefore we cannot reasonably suppose that the power to coil was developed from slight curving rendered more pronounced in successive generations by natural selection. Here it is the first step that counts, and it is just this step that the theory of natural selection is often unable to take.

Artificial selection, not being restricted in its operation to variations of use to the plant, does not offer so close an

analogy with natural selection as Darwinians commonly assume. Nevertheless, cautious observation of plants and animals under domestication is sure to throw important light upon what happens in nature, for the artificial conditions being more under control, it is easier to estimate the effects which a given factor (such as heredity for instance) may safely be counted upon to exert. Some quite unexpected results have been reached through studies in the history of garden vegetables by Dr. E. L. Sturtevant of the New York State Agricultural Experiment Station. Wishing to gain what evidence he could of "the extent of variation that has been produced in plants through cultivation," he examined all pictures and descriptions in the old herbals—many of them entirely trustworthy records although published two or three centuries ago—and compared them with the more important recent records and with living examples of the forms now in cultivation. It seemed not unreasonable to expect that among so many plants, cultivated for centuries, at least a few examples would be found in which extreme types such as cauliflower, Brussels sprouts, kohlrabi, and other derivations of the wild cabbage, might be connected by a series of slightly differing connecting links. In not a single case has such a series been found. So far as may be judged from the evidence, new types are not developed from other types by the cumulative selection of slight variations in a given direction; but they come suddenly, and each is distinct from its first appearance. All that the selection of slight variations ever accomplishes is the improvement up to a certain point of features already well marked; and experience shows that this point is soon reached. A compact fleshy inflorescence, as of the cauliflower for instance, may be made more compact and more fleshy within certain rather narrow limits, and the highest degree of perfection can be maintained only by the most careful cultivation and generous enrichment of the soil. We have already seen that carrots under cultivation exhibit similar limitations. Such facts are as unfavorable to Lamarckism as to Darwinism since both suppose that types have always evolved through slight changes.

Without going further into the difficulties which Lamarckians and Darwinians have had to meet in their endeavors to apply either theory, it must now be apparent that neither of them gives promise of affording complete general satisfaction to students of nature. It is hard to believe that acquired characters or fluctuating variations are often accumulated in a way to bring about the development of new species. One is thus driven to ask whether there is any possible way of explaining the course of organic evolution without depending upon these discredited assumptions. Some of our foremost naturalists believe that this great problem may be solved through the further study of variations, and on the basis of recent discoveries a new theory is developing with which we may hope to incorporate the main truths that have recommended Lamarckism and Darwinism to their advocates. Sudden adaptation, such as we have seen to be implied in the evolution of clematis, and have found to be one of the chief stumbling blocks of former theories, is made the corner stone of the theory we have now to consider.

169. Sudden adaptations. Professor Hugo de Vries, an eminent botanist of Amsterdam, Holland, was led to a new view of the process of evolution by studying for a number of years the descendants of some large-flowered evening primroses which had been imported from America and had escaped from a garden near his home into a neighboring field where they grew in great profusion.¹ Among these escaped plants De Vries found a large amount of fluctuating variation in every part, and frequent abnormalities, but what especially attracted his attention was the appearance of two well-characterized forms which he recognized at once as new to science. One of these was distinguished by a short style and no stamens, while the other was peculiar in having smooth leaves of particularly beautiful appearance. Each was represented at first by only a few specimens confined to a particular part of the field as if derived from the seeds of

¹ By an odd coincidence these plants are of the form known as *Æno-thera Lamarckiana*, sometimes called *Æ. biennis* var. *Lamarckiana*, or *grandiflora*. The flowers, curiously enough, have the striking peculiarity of opening suddenly at dusk.

a single plant. These three forms were found to come true to seed and when crossed the seedlings were like one parent or the other; or occasionally other new forms were produced, with or without crossing, which were as unlike the parent form as were the two new forms first discovered. In the course of seven generations several such new forms appeared, numbering in individuals about eight hundred out of a total of about fifty thousand plants raised. Similar forms also appeared in the field. All these new forms were distinct types differing from one another in several particulars such as shape and color of leaves, flowers or fruit, and annual, biennial, or perennial habit; and although growing together they did not intergrade. They were thus as sharply definable as species are, and they could be regarded as true species except for the fact that their differences distinguished parent from offspring. De Vries regarded them as elementary species equivalent to what botanists have been calling well-marked varieties, races, or subspecies, and as representing the abrupt changes through the accumulation of which species and higher groups arise. He calls variations of this sort *mutations*,¹ the new forms being termed *mutants*. Hence we may designate as *mutationism* this new theory of evolutionary change.

Mutationism supposes that from time to time, especially under the influence of changed conditions, some of the individuals of a species bear offspring distinctly different from the parent, often in several particulars, and that the set of peculiarities thus suddenly arising is completely hereditary even when individuals of the new form are crossed with other forms of the same species. That is to say, the progeny from parents of two different mutations are like one or the other parent, and never intermediate as is often the case with crosses between fluctuating variations. If mutations again mutate and we have mutants of the second or higher degree, their hybrids may be wholly like one parent or the other, or may be apparently intermediate from having inherited one or more peculiarities from one parent and the rest from the other; but such cases of apparently intermediate forms show new combinations of elements rather than elements of an

¹ Mu-ta'tion < L. *mutatio*, a changing.

intermediate sort, each element being always hereditary unless it gives place to a new element through mutation. While the parent form may continue to be inherited unchanged by certain descendants for innumerable generations the descendants of a mutation to which it has given rise may mutate again and again, until finally a form has arisen characterized by so many new elements that it is no longer capable of producing offspring like those of the original ancestral form. Then a new species has appeared; and by a similar differentiation through many successive mutations, there would arise genera, families, and groups of higher order.

Whether the peculiarities of a mutation are beneficial or not is immaterial provided only they do not unfit the organism for living under the conditions where it occurs. If it can gain a foothold either in the same environment as that of its parent or under some other set of conditions a new race or new species may be started. It has been commonly assumed by naturalists that every slightest peculiarity of an organism must have some important relation to its welfare whether apparent to us or not, since otherwise we could not understand its fitting into the environment under which it thrives. On this view we should have to suppose that all the peculiarities of the new forms of escaped primroses represent sudden adaptations; but in that case it must be admitted that very diverse adaptations fit about equally well into the same environment. The assumption that every trait must be connected with some use, seems, however, to be quite gratuitous. This supposition is not at all necessary to the theory of mutations, although, as we have seen, it is a necessary incumbrance to the theory of natural selection. On the new view we may suppose that a mutation presents features which may be more or less beneficial, indifferent, or even more or less injurious; yet if it gets into an environment which permits such a form to live, then the traits of each description may become characteristic of a surviving group. We all know that however useless or undesirable defects or bad habits may be, they are not necessarily fatal, and are sometimes perpetuated. Thus we can account for the fact that many characters of the highest

systematic importance seem to have nothing whatever to do with utility.

Yet, we know that many organs do serve marvelously well the needs of the organism. There is no reason, however, why their adaptive features may not have arisen through mutations, even without selection, and we have seen that initial stages in the development of many an adaptation are of so little use that selection could not reasonably be supposed to act on them. At the same time it is of course not impossible in other cases that natural selection may operate under certain conditions now and then occurring. Variations of the mutative sort would then serve especially well as steps in the process of species-making, because of the way in which they are inherited, while fluctuating variations might also sometimes contribute to the result, provided incompatible features did not arise as mutations. For the most part, however, selection may now be supposed to play only a subordinate rôle in organic evolution, its effects showing chiefly in the maintenance of a certain standard of perfection in an established type. A plant grows where it can, and it can grow at all only by having the chance, and being fit to take advantage of it. When we have said this we have expressed about all that it is necessary to admit of the doctrine of natural selection. We must remember also that selection has at best but a negative value; it cannot originate anything, it can only favor certain individuals by weeding out others. As to mutations, the reader has doubtless already become aware of their striking likeness to "special creations."

If it could be shown that acquired characters may be passed over from one mutation to another, we might suppose that a direct influence of the environment is instrumental in originating species. We know that it does control individual peculiarities often in a striking way, and may not improbably account for the constant appearance of features sometimes attributed to other causes. The great difficulty often is to decide which of several possible causes may have brought about a given result; and only long continued, careful experiments can give a satisfactory answer. So far as we may judge from such extended observations as those of Dr. Stur-

tevant and others, the direct effects of external agencies like the effects of selection are confined to modifying types rather than originating them.

Those of my readers who have played with a kaleidoscope will remember that as the cylinder is moved slowly forward or back gradual changes in the design take place, and any favorite arrangement may be recovered by simply moving the cylinder back to the place where that arrangement appeared,—all this being possible so long as the cylinder does not move beyond a certain point; for if it gets ever so little beyond that point there is a sudden rearrangement of the elements thereby forming an entirely new design, which may in turn be modified as before by restricted changes of position. The gradual modification of the design within definite limits is like the modification of a type as effected by fluctuating variations or acquired characters; the sudden change is like a mutation upsetting the previous equilibrium and establishing a new equilibrium which is not at all disturbed by vacillating modifications.

170. Evolution by choice. To make the foregoing analogy complete we should have to imagine a kaleidoscope with the power of self-movement; for whatever may be the factors which bring about mutations, the process is somehow influenced from within. A living thing is active as well as passive. The idea is thus suggested that organic evolution may have as its controlling factor some power of choice, essentially like our own, residing in all living organisms—a will as truly free, although apparently very different because exercised under very different conditions. This is a hard saying, but perhaps we shall find it to contain important truth.

Doubtless to many readers the idea of plants willing or choosing in any way whatever will appear quite absurd. "How is it possible," they will urge, "to conceive of voluntary action in vegetable life?" Let us try to consider the matter without prejudice. Surely, as we watch plants they *seem* to act spontaneously, to improve opportunities, and, some of them at least, appear to have gained experience. All observers would agree that a climbing shoot or a root-tip acts almost as if it were intelligent. If the reader will admit that

plants in their responses to outside influence are sometimes capable of acting in one way rather than in another way which is equally possible, then all that is essential to what is here meant by choice will be conceded, and he may be willing to entertain an hypothesis which squares well with what we know of all living things. In such a hypothetical view we need not suppose that every action of every creature is an act of will. Many of our own acts are, as we say, mechanical or habitual. We may well suppose that most of the behavior of lower organisms, including the behavior of growth, is of this sort. Nor do we need to suppose that consciousness more than very remotely like our own accompanies any of the actions or reactions of plants. All the hypothesis requires is that sometimes, even with dimmest consciousness, any organism may be free to choose at a critical moment between alternatives profoundly affecting its constitution.

By way of example let us suppose the seeds of a primitive buttercup to be carried near the seashore and to begin to sprout. Such plants are not accustomed to so much salt as would then be in contact with their roots. Here is a change of condition, favorable, as we have seen, to the occurrence of mutations. It has been found by experiment that plants of the same kind placed under the same conditions will absorb different amounts of the same substance, as, for instance, common salt. Thus of several seedlings the same in kind and age, growing with their roots in the same salt solution, some will absorb a larger percentage of the salt than others, and, indeed, may be poisoned while others survive. Sometimes even the same individual may respond differently at different times. Now, what we may suppose to happen, according to our hypothesis, in the case of the buttercup seedlings is that some of them might choose to keep out so much of the salt that they could not get water enough to live; others might let in so much salt as to be poisoned by it; while still others might let in just enough salt to permit their having sufficient water, but not so much salt as would kill them. The survivors, as a consequence of their choice, would have their sap saltish and thus every organ would be affected in an unwonted way. Their seeds would start with

some salt in them already, and this might favor the seedlings enduring a larger amount of salt as they grew. Sooner or later the constitutional equilibrium of the plants would be so disturbed that a mutation would result. Several successive mutations might occur as seeds fell into saltier and saltier localities. At last would appear a form like our seaside crowfoot (Fig. 303) able to thrive where the salt is strong and showing many marks of its effect. The first mutation would give an hereditary salt-preferring type, while a succes-



FIG. 303.—Seaside Crowfoot (*Ranunculus Cymbalaria*, Crowfoot Family, *Ranunculaceæ*). (Britton and Brown.)—Perennial herb 4–22 cm. tall; leaves fleshy, smooth throughout; flowers yellow; fruit dry. Native home, Northern North America and Eurasia.

sion of mutations caused by similar responses would produce a distinct species.

The case of our stranded buttercups might be paralleled by an animal which in time of famine, was reduced to the choice of eating or rejecting unaccustomed food, and as a result of eating enough of it to sustain life, being modified in its habits and structure to the point of producing mutations. Whatever share in the final result of such an evolutionary process we may attribute to acquirement or to selection we are still free to believe that it is the choice of

individuals confronted by alternatives which ultimately decides whether a given path shall be followed or not. That is to say, external conditions and previous decisions while they restrict the range of choice yet permit of choosing. Of course the reader will not suppose that our imaginary examples afford any real proof of volition in plants or animals. If either do have the power of choice we cannot hope to prove it any more than we can prove that we have such a power ourselves. What has been said is meant merely to show how one who believes that every living thing can choose, may think of evolutionary processes in terms of his belief. With this bare hint of a way of avoiding the pitfalls which await any purely mechanical explanation or any theory of evolution by chance, the reader must be left to make such further applications of the hypothesis as he can. We may call this view, which refuses to regard any living creature as a mere mechanism, Evolution by Choice, since for want of a better name it will serve to emphasize the essence of the belief, which is that a certain measure of self-control is inherent in every organism and that upon this inscrutable power hangs the destiny of the living world.

171. Evolution in general. The creation of living things by successive steps, one growing out of another, is viewed by modern science as part of a gradual process of world-making which is understood to proceed in a somewhat similar manner. That is to say, the entire universe is believed to have evolved and to be evolving according to laws of change which have been the same from the beginning and will be the same to the end, or forever, if the process be endless.

The view most widely accepted is that from a vast nebula or vapor-like mass of incandescent star-dust, like those now seen in various parts of the heavens, our solar system for example with its central sun, its whirling planets and their moons, has slowly developed during countless ages, through the agency of gravitation acting together with other properties of matter. During the course of its evolution each sphere is supposed to pass from a nebulous condition to a ball of glowing liquid, which, as it cools forms at first a solid crust,

and finally becomes cold and firm to the core. This view of world evolution is called the *nebular hypothesis*.¹

According to the nebular hypothesis, as the molten interior of our earth lost heat it shrunk away from the solid crust, which, following it warped and wrinkled in an uneven way somewhat as the skin of a drying apple wrinkles to fit the shrinking pulp. When the earth was cool enough at the surface to permit condensation of the atmospheric watery vapor and its fall as rain, seas began to form in depressions between the upheaved regions of dry land. Subterranean forces, connected with the further loss of heat, continued to wrinkle the land into chains of mountains. Meanwhile storms, controlled by heat from the sun, brought water to the highlands from the sea to which it returned in streams cutting through the land and carving the surface into varied shapes. The rock waste carried seaward settled off shore, as layers of gravel, sand, or mud. These deposits in time became compacted into solid rock and were slowly upheaved again above the level of the sea. This new land was again washed into the sea or may have sunk beneath it and been covered by newer washings which later may have been again upraised. From such working over of the crust, most of the land, with its many layers of rock or soil (which is rock waste on its seaward way) came to be as it is. From the many changes thus wrought—some gradual, some sudden—involving wide sway of air and water currents, and the continual though slow redistribution of rock materials—from all this has resulted a greater and greater variety of climate and soil—in a word, a progressive differentiation of the conditions affecting life. This differentiation represents more and more

¹ A rival view known as the planetesimal hypothesis has of late years been gaining ground among geologists. This differs from the nebular hypothesis in supposing that such a solar system as our own evolves by the slow aggregation of innumerable small cold solid bodies (planetesimals) moving through space in rings or orbits like those of our planets. They are consequently drawn together without much violence into larger and larger masses by mutual attraction until there is formed a central sun and planets none of which at any time are altogether gaseous or liquid. Once these larger spheres are formed, other forces than those of mere shrinking with loss of heat are assumed to account for such geologic changes as those of which we have evidence.

varied sets of conditions offering fresh opportunities for living things.

Life as we know it is possible only below a certain temperature. The greatest heat in which living things are found to grow is that of certain hot springs where, it is reported that a centigrade thermometer registers about 55° (equivalent to 131° Fahrenheit). It will be remembered that water scalds at about 60° C. or 140° F. Under these extraordinary conditions, certain microscopic plants of most simple organizations are found to thrive.¹ It is fair to assume therefore that living creatures could not have appeared upon the earth until the crust had so far cooled that the waters were considerably below their boiling-point. Since the simplest forms of life we know and the oldest fossils we have, are aquatic, it is probable that the first living things appeared in the water; and since all the animals we know depend directly or indirectly upon vegetable food, it seems most likely that the earliest organisms were plants and that from them animals evolved.

Confining our view to the vegetable kingdom, which here chiefly concerns us, we may picture to ourselves its evolution as proceeding in a general way from plants of comparatively simple organization, to those whose structure is more and more complex, greater morphological differentiation accompanying fuller physiological division of labor. Such increase in complexity we speak of as *progress* from lower to higher organization, without meaning to imply that the higher forms are any more perfectly adapted than the lower to their respective environments. Indeed the simpler forms may be so well adapted to the less trying conditions that they may *persist* through countless generations essentially unchanged, provided they have the opportunity to live in the kind of environment which suits them. Thus we find to-day, growing in water, plants which may be fairly supposed to have retained the main features characteristic of the progenitors of the vegetable kingdom.

¹ Experiment shows that the spores of other very simple plants are not killed by a temperature considerably above that of boiling water, but they cannot grow under such conditions.

Many types of structure have become *extinct*, because changing conditions no longer afforded a suitable environment, or, perhaps because no mutations of the old form could adapt it to new circumstances of peculiar difficulty. Relics of types which the world has thus outgrown have occasionally come down to us as fossils caught in the deposits which became rock in ages past.

Sometimes a group, or perhaps part of its members, may have escaped extinction through the appearance of mutations



FIG. 304.—White Water Crowfoot (*Ranunculus aquatilis*, var. *capillaceus*, Crowfoot Family, *Ranunculaceæ*). Plant, about $\frac{1}{2}$. Flower. Fruit. (Britton and Brown.)—Perennial (?) herb about 30 cm. long; leaves submerged; flowers white; fruit dry. Native home, North America and Eurasia.

fitting the individuals to live under less exacting conditions which therefore would permit simpler structure. Thus a buttercup able to live in water without being drowned could dispense with much of its root system and stiffening framework and so come to resemble, in the adaptation of its vegetative organs to an aquatic life, a lower form of plant none of whose ancestors had been terrestrial. The white water crowfoot (Fig. 304) of our ponds and streams is a buttercup which we have every reason to believe has thus descended from a land species. In so far as a type of organism or organ

becomes simplified in the course of its evolution and, so passes to a lower level of structure, it is said to *degenerate*. Much more extreme instances of degeneration will be dealt with in the following chapter.

It thus appears that degeneration, persistence, and extinction of types accompanies the general progress which characterizes organic evolution. In the evolution of human society likewise we find degeneration, persistence, and extinction of races along with a general progress of mankind from savagery to civilization. Here as in the evolution of lower organisms we may observe adaptation to changed conditions through sudden or gradual modification. Migrations also play an important part and have many consequences, among which conflicts are the most apparent although not necessarily the most significant. Periods of greater progress have been times of greater peace. Conflicts destroy or test; they do not create. Men or races unfit to live, if such there be, of course are better dead, and those menacing the progress of mankind are better subdued; but it is surely a partial view of human affairs that regards the world as one vast battlefield whose horrors have fostered the most precious characteristics of civilization. However inevitable mortal conflicts have been, however fierce the struggle of competition, and however necessary it may have been to kill the worse that the better might live, we cannot say that anyone has been made better by the killing. Yet we may be sure that human advance toward the most perfect and abundant life has been delayed, and that whatever real progress Man has made has been in spite of his competitive struggles. The economies of co-operation and the advantages of mutual service achieve what competition never can. Mere struggle for supremacy when fiercest destroys most of what is best. Man's mastery over nature and over his lower self has come through learning and choosing the better way.

The evolution of mankind and that of lower organisms are alike in so many ways, it is thought that each may throw light upon the other. In human progress we recognize as the controlling factors of change: Opportunity,—offered by the environment; Experience,—representing its effect; Choice,—as the response to it, guided by Ideals. Of these the pivotal

factor is Choice, for by it opportunities are improved, experience determined, and ideals pursued. What we ourselves and what former generations have chosen to do or endure is most largely responsible for what we are. Thus human affairs center about the human will. So throughout God's world we are led to look for some opportunity offered to every creature, some experience by which it may profit, some choice of its own, and some divine guidance.

Man's choosing of the better way has led him heavenwards toward the highest, fullest life. As from a mountain side he may now look back and with the mind's eye catch glimpses of his path and of the forking paths of fellow creatures many of whom have been as comrades at different stages of the long, long journey. Traced backward all the paths seem to converge at the horizon as if all had come from the same point. Some of them, as they advance, keep to the level of the sea continuing always much the same; others climb for awhile to higher levels, then turning aside and traversing an easy plateau end at a precipice; still others after climbing for a while decline to lower levels; while others yet keep climbing and attaining various heights. Man's path soon left the kingdom of plants, and ascending through the realms of worm, fish, reptile, and brute has reached at last the mountain path which leads beyond the clouds.

Viewed broadly the progress of the world is seen to be orderly, and shall we not say, well ordered? New forms of life have come promptly to enjoy the ever increasing opportunities afforded by the evolving earth. Advance has been made not without difficulties, which being overcome have brought out the finest traits. Nor has there been lacking continual occasion for mutual help, and this has ever multiplied the blessings of life.

CHAPTER XII

LIFE-HISTORIES

172. Cycles of life. Every creature which completes its span of life passes through various stages of development from germ to adult, and may in turn give rise to similar germs which may continue the process in endless round. Hence, until we are acquainted with the cycle of changes which normally characterizes a certain kind of plant or animal, we do not know it at all thoroughly; but as with adult structures so with life-histories, the knowledge of a few typical examples gives a general knowledge of many because of the inheritance among kin of fundamental resemblances. Moreover, since the life of the individual, as we have seen, more or less clearly repeats the series of ancestral forms, a knowledge of life-histories throws an important side light upon the relationship of different groups and helps us to picture the earlier stages through which a type has passed in its evolution.

In the comparatively small space here available we cannot hope to do more than glance at the form and behavior of a few typical plants through the various stages of their lives. We shall, however, choose examples exhibiting so wide a range of peculiarities that the student may gain finally a comprehensive view of the vegetable kingdom sufficient for an introduction to more special study.

173. The blue algæ (Class Cyanophyceæ). Among the useful plants we have studied the only alga is the so-called carrageen or "Irish Moss" (see page 112), and this, as we shall see, belongs to one of the most highly developed classes of seaweeds. It agrees with the great majority of algæ, however, in being aquatic and containing chlorophyll, and in being without true stem-, leaf-, or root-members. Before

passing to a more detailed examination of the higher algæ it will be most instructive for us to study some of the simpler forms. About as simple as any are the exceedingly minute plants which for want of a better name we may call tint-ball algæ (*Chroococcus*), and which when highly magnified present

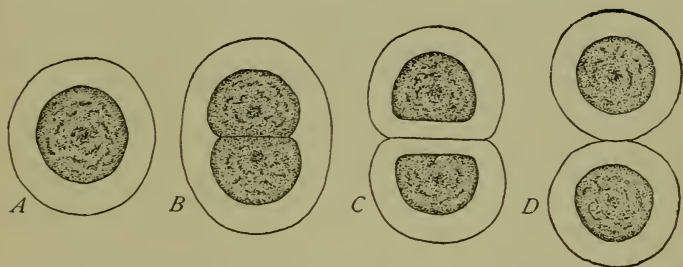


FIG. 305.—Tint-ball Alga (*Chroococcus turgidus*, Tint-ball Family, *Chroococaceæ*). *A*, plant as ordinarily seen; magnified about 400 diameters. The inner shaded mass of protoplasm is bluish green, surrounded by a transparent gelatinous envelope. *B*, same, beginning to divide into two plants. *C*, the division advanced by the formation of a double wall between. *D*, the division complete. (Redrawn from Kirchner.)—Found in swamps and on wet rocks throughout the world.

the appearance shown in Fig. 305. An individual (*A*) consists merely of a spheroidal mass of rather firm consistency and blue-green color, surrounded by a transparent gelatinous envelope. Near the center of the mass may be seen under favorable circumstances a comparatively small, somewhat denser spot. After the plant is dead, the application of pure water dissolves out a blue substance—called *phycocyanin*¹—leaving the yellow-green chlorophyll. This in turn if dissolved out by alcohol leaves a colorless, minutely granular material which examined chemically would be found to consist of a highly complicated mixture of proteids. To such a mixture of organized proteids the name *protoplasm*² has been given. This when active forms the living part of the plant. Whatever is alive in any plant or animal is protoplasm. Hence protoplasm has been called “the physical basis of

¹ Phycocyanin < Gr. *phykos*, seaweed; *kyanos*, blue.

² Protoplasm < ML. *protoplasma*, the first creature made < Gr. *protos*, first; *plasma*, anything formed.

life." Its exact chemical constitution is not known, nor does it seem likely that it ever can be known; for to analyze a sample of protoplasm chemically is to kill it, and dead protoplasm surely differs in important ways from protoplasm alive. Moreover, through the many complicated reactions going on within, any active mass of protoplasm is doubtless continually changing its composition. One of the products of the activity of the protoplasm of a tint-ball is the blue substance above mentioned; another product is the chlorophyll by means of which it is able to make food in the sunlight like any other plant containing leaf-green. Still another product is the gelatinous material forming the envelope by which the little mass of protoplasm is surrounded. Chemical tests would show that this envelope consists of a kind of cellulose. The food which the protoplasm is able to make from the substances it absorbs through its cellulose shell from the surrounding water, is used by the plant as material for growth. That is to say, it uses the food to make new protoplasm out of which come new coloring matters, new cellulose, and other organic products. As the growth of the sphere is mainly in one direction it becomes elongated into an ellipsoid as shown at *B*. Meanwhile, the denser central part of the protoplasm has similarly elongated and finally divided into distinct halves. These halves move toward the ends of the ellipsoid, thus becoming surrounded on all sides by the thinner protoplasm. Soon there appears in the ellipsoid a plane of separation extending through the center at right angles to the long axis; then each of the portions of protoplasm on either side of this plane becomes larger and rounder, and each along the plane of separation builds a layer of cellulose which presently appears as a cross partition (*C*). At last, as a result of further growth and rounding we have two distinct spherules of protoplasm, each with its central, denser part and each surrounded by its own cellulose envelope essentially like the original tint-ball. Thus through growth and division one plant has become two. These plants may remain attached to one another and each of them may divide again and repeat the process a number of times without separating. The result then is a colony in

which all the stages in the life-history of the individual may often be observed.

We need a few technical terms to designate such parts as have just been described. A mass of protoplasm capable of more or less individual activity is called a *cell*.¹ All plants, and all animals as well, consist of one or more cells. Usually in plants the protoplasm is inclosed by a cellulose envelope known as the *cell-wall*, all within which is then distinguished as the *cell-contents*. Since a cell-wall implies at least the previous existence of living cell-contents, the term cell may be applied even to the empty chamber from which all life has gone. In the living protoplasm a comparatively large, dense kernel, more or less clearly marked off, is termed the *nucleus*,² the rest of the protoplasm being distinguished as the *cytoplasm*;³ while any liquid part of the cell-contents is called *cell-sap*; and the entire protoplasmic part, a *protoplast*. The process through which one cell becomes two by enlarging and splitting in halves is known as *fission*.⁴

Successive fissions often take place in such a way that the partitions are in planes at right angles to one another, with the result, shown in the tint-balls, that more or less cubical groups of cells are formed—an arrangement which sometimes passes into a globular or irregular one through changes in the direction of growth or division. If instead of forming partitions at various angles, the cleaving planes are always parallel, so that successive fissions are in the same direction, then we have a chain or row of cells. This is what happens in the colonies of algæ known as “fallen stars” (Nostoc, Fig. 306), because of the sudden appearance of their glistening balls when swollen by rain. Here numerous blue-green cells, like beads on a string, are embedded in a copious mass of jelly secreted by the protoplasm; for instead of forming distinct cell-walls this mucilaginous cellulose, for the most part, becomes homogeneously fused. At intervals in the

¹ Cell < L. *cella*, a small room or hut.

² Nu'cle-us < L. a little nut or kernel < *nux*, nut.

³ Cy'to-plasm < Gr. *kytos*, a hollow or cell. Originally a synonym of protoplasm, the word cytoplasm has now taken on the restricted sense above defined.

⁴ Fis'sion < L. *fissio*, a dividing.

chain somewhat larger cells are formed, each with a distinct wall. Certain of these cells, called *heterocysts*¹ have most of their protoplasm replaced by a pale or colorless cell-sap and

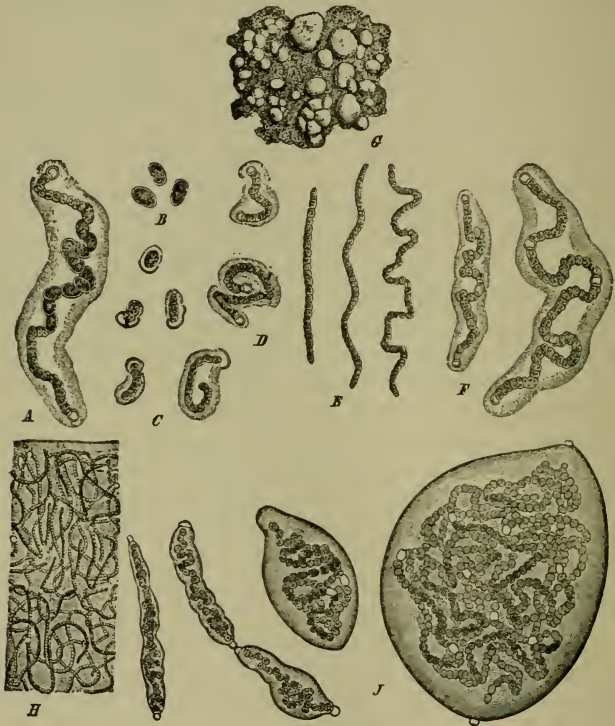


FIG. 306.—Fallen Stars (*Nostoc* spp., Fallen Star Family, *Nostocaceae*). A-F, *Nostoc paludosum*. A, chain-colony with resting spores near the middle and heterocysts at the ends, $\frac{3}{2}\mu$. B, resting spores. C-F, germination of resting spore, and stages in the formation of a new chain-colony. G-J, *Nostoc sphaericum*. G, gelatinous balls as they appear in moist earth, $\frac{3}{8}$ natural size. H, part of a slice cut through the ball, $\frac{1}{2}\mu$. I, single ball, $\frac{1}{2}\mu$. J, early stages in a growing colony, $\frac{2}{3}\mu$. (Janczewski, Thuret.)—Protoplasts bluish green, enveloped in a gelatinous mass which they produce. Found mostly in water or on moist earth in various parts of the world.

become incapable of further development. At points where the heterocysts thus limit growth the chain eventually

¹ Het'er-o-cyst < Gr. *heteros*, different; *kystis*, a bag.

breaks into short lengths each made up of a comparatively small number of cells. These groups are termed *hormogonia*.¹ While the cell-row is dividing into hormogonia the gelatinous envelope is becoming fluid, and as the hormogonia separate they are observed to take on a swaying, worm-like movement which enables them soon to pass into the surrounding water and travel in various directions. In a little while they come to rest, secrete a new gelatinous envelope, and by repeated fission of the cells develop a new colony. On the approach of adverse conditions, such as those of winter, certain of the cells protect themselves by a dense wall, store up food in the cytoplasm, and become brownish. In this condition they are very resistant of cold and tolerant of drying, and are thus able to survive unharmed under conditions which destroy the other cells. These resistant cells are called *resting spores*. When the other members of the colony perish and the mucilaginous envelope dissolves, these spores are set free; and on the return of favorable conditions they germinate by a swelling of the protoplasm which ruptures an outer dense layer of the wall. Covered then by a thin, inner layer the protoplasm elongates, as shown in Fig. 306, *B, C, D*, and by repeated fission together with a copious secretion of jelly a new "fallen star" colony is started.

Nostoc and *Chroococcus* may be taken as typical of the Class Cyanophyceæ the members of which occur abundantly in salt or in fresh water or on surfaces frequently wet, and are characterized by *having their chlorophyll more or less masked by phycocyanin, and by consisting of single cells or cell-colonies of various form, reproducing only by fission, although the colonies sometimes multiply through hormogonia or resting spores.*

The lower members of the class have about the simplest organization known. They are doubtless as much like the earliest organisms which appeared upon the earth as any creatures now living. It is interesting and perhaps significant, that the algæ previously referred to as thriving in the scalding water of hot springs, belong to this class. From an economic point of view the blue-green algæ have an especial importance as being the chief cause of offensive odors which

¹ Hor''mo-gon'i-um < Gr. *hormos*, a chain; *gonos*, offspring.

develop at certain seasons in the stored water-supply of many cities, often rendering it unfit for use. Through experiments recently performed on a large scale by the United States Department of Agriculture, it has been found that an exceedingly minute percentage of copper sulphate added to the water will kill them and other harmful plants without leaving any traces of itself which are either perceptible or harmful to man or beast in the slightest degree.

174. The green algæ (Class Chlorophyceæ) include many familiar water plants.

They are characterized by *having the chlorophyll ordinarily unmasked by any other pigment, their structure and their methods of reproduction including widely varied types.*

A very simple form, common throughout the world on rocks or tree-trunks which are often wet by rain, is the wall-stain alga (*Pleurococcus*) shown in Fig. 307. Except for the absence of blue pigment it is much like a tint-ball alga. The cell-wall of this alga is ordinary firm cellulose, the nucleus is more distinct than in the tint-balls, and the protoplasm shows further differentiation in the presence of specialized bodies of varied form called *chromatophores*,¹ to which the chlorophyll is confined. Reproduction, as ordinarily observed, is by fission in three directions; and, since the cells often remain attached, more or less globular colonies result. Further development under certain conditions has been reported; but however that may be, the life-history of the plant as commonly seen consists simply of fissions repeated indefinitely.

Somewhat higher in organization are the yellowish green, unicellular, fresh water algæ known as *desmids*, of which *Cosmarium* (Figs. 308-310) is a typical genus. Desmids are of varied and often strikingly beautiful forms, the firm, cellulose wall being sometimes curiously sculptured and frequently developing sharp projections, while the chromatophores take the form of disks, plates or bands symmetrically arranged. Within the chromatophores may be seen transparent spots called *pyrenoids*² in which starch is formed. Many of the genera have the plant-body constricted in the middle, as in *Cosmarium*, forming thus two semicells; and in all cases the halves are symmetrical. This peculiarity modifies in an odd way

¹ Chro'mat-o-phore < Gr. *chroma*, color; *phoros*, bearing.

² Py-re'noid < Gr. *pyrèn*, the stone of a fruit; *eidos*, resemblance.

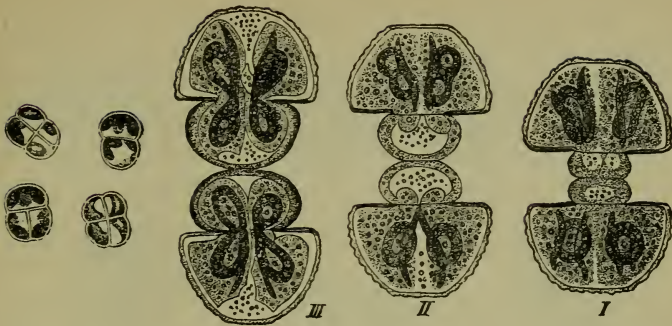


FIG. 307.—Wall-stain Alga (*Pleurococcus vulgaris*, Wall-stain Family, *Pleurococcaceæ*). Plants showing fission in various directions, z_{10}^{z} . (Wille.)—Growing commonly upon moist rocks, bricks, and tree-trunks, forming extensive green-stains, throughout the world.

FIG. 308.—Grape Desmid (*Cosmarium Botrys*, Desmid Family, *Desmidiaceæ*). I–III, stages of fission, z_{10}^{z} . (DeBary.)—Bright green. Common in fresh water.

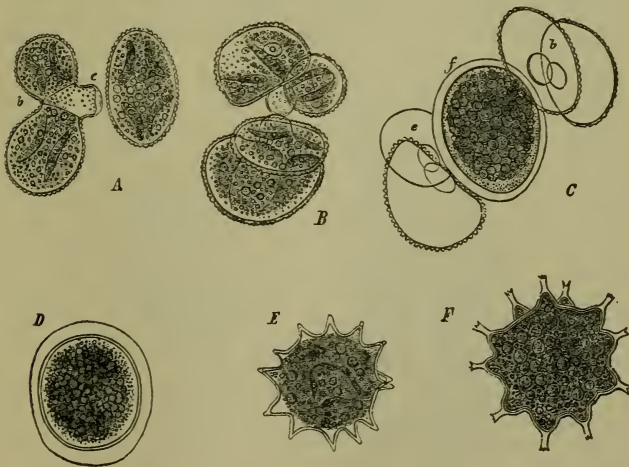


FIG. 309.—Grape Desmid. A, first stage in conjugation; the two halves of the cell-wall (*b*) have been broken apart by the protruding protoplast (*c*). B, later stage; the protoplasts of two plants are coming together. C, final stage; the two protoplasts have fused into one mass to form a zygospore (*f*) leaving the old cell-walls (*e*, *b*) empty. D, E, F, stages in the ripening of the zygospore which surrounds itself with a protective wall from which numerous projections finally arise, z_{10}^{z} (DeBary.)

the process of fission, by which they multiply under ordinary conditions. As shown in Fig. 308, the outer firm layer of the wall, ruptures at the place of constriction, allowing the semicells to separate, while the protoplasm of the isthmus or neck which joins them elongates, being still covered by a thin, elastic, inner layer of cellulose. The nucleus and chromatophores divide, half going to either end. A partition is then formed across the middle of the isthmus, and the new part on either side grows larger and rounder until finally two separate and complete cells are formed each with a new and an old half. Meanwhile chromatophores pass over into this new semicell, and its outer wall becomes thickened and sculptured like the other. In some desmids after fission the cells remain attached forming a row comparable to the chain in *Nostoc*. A striking peculiarity of the free forms like *Cosmarium* is their power of locomotion. While not rapid, the movement is quite perceptible under the microscope. It has been found to be accomplished by protrusions of mucilaginous material, and its direction to be influenced by light. Resting spores are produced in the peculiar manner shown in Fig. 309. Two cells lying side by side, each rupture the outer wall across the middle and the halves separate as for fission, but instead of forming a cross partition the protoplasm of each plant flows out of the old cell-wall and toward the other protoplast. When the two protoplasts come in contact they fuse into a single spherical mass, the two nuclei merge into one, the chromatophores disappear, and the whole contents becomes brownish, while the outer cell-wall or *exospore*¹ thickens and puts forth a number of projections. In this condition the spore is comparatively resistant of cold or dryness. On the return of favorable conditions germinations take place as shown in Fig. 310. The contents swell, rupture the exospore, and emerge, surrounded by the delicate inner wall or *endospore*.² Soon a division of the nucleus takes place followed by division of the protoplast into halves, which become constricted, turn green and form cell-walls much like the uniting pair from which they were derived. Freed from the endospore the newly formed desmids swim about and multiply by fission, during which process the chromatophores soon become distinct and the cell-wall takes on its characteristic sculpturing.

A spore formed as above described by the union of two similar protoplasts is termed a *zygospore*,³ the uniting protoplasts are known as *gametes*,⁴ and the process of their union is called *conjugation*.⁵

Closely related to the desmids are the "pond-scums," algæ which form tangled masses of delicate threads floating near the surface of quiet fresh water. A very common genus is *Spirogyra* (Fig. 311)

¹ Ex'o-spore < Gr. *exo*, outside; *sporos*, spore.

² En'do-spore < Gr. *endon*, within.

³ Zy'go-spore < Gr. *zygon*, yoke.

⁴ Gam'ete < Gr. *gametes*, a spouse.

⁵ Con''ju-ga'tion < L. *con*, together; *jugare*, join or yoke.

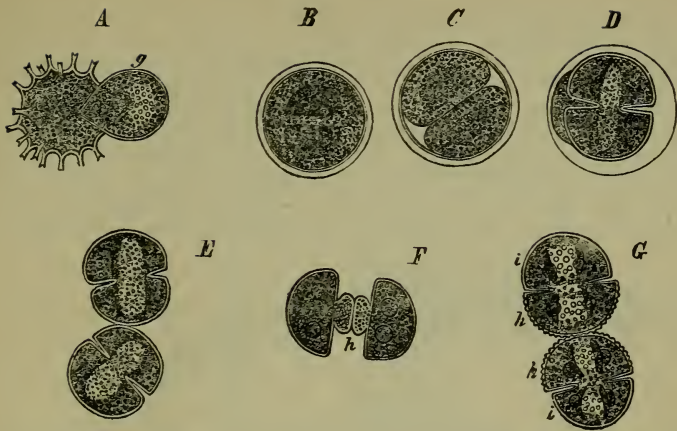


FIG. 310.—Grape Desmid. Germination of zygospore: *A*, protoplast emerging; *B*, protoplast beginning to divide in half; *C*, division nearly complete; *D*, division complete within the thin temporary cell-wall; *E*, the two desmids escaped from the wall; *F*, one of them dividing by fission; *G*, the fission nearly complete, ¹²⁹. (DeBary.)

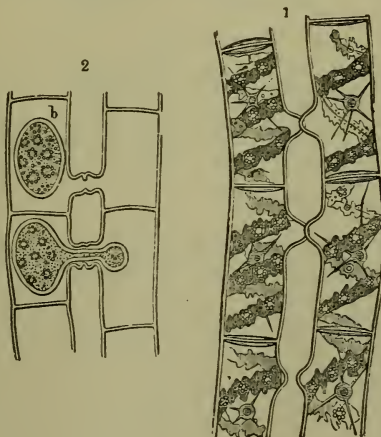


FIG. 311.—Pond-scum (*Spirogyra* sp., Pond-scum Family, *Zygnemaceæ*). 1, segments of two thread-like plants beginning to conjugate by the protrusion of adjacent cell-walls toward each other. 2, later stages resulting in the formation of a zygospore (*b*). Much magnified. (Kerner.)—Pond-scums abound on the surface of ponds, forming masses of bright green color through the summer which turn brownish toward spring when conjugation takes place.

in which the plants are unbranched filaments consisting of a single row of comparatively large cylindrical cells containing spiral, ribbon-like chromatophores, rather prominent pyrenoids, and copious cell-sap. Elongation of the thread results from fission of the cells much as in *Nostoc*; but with *Spirogyra* the more intimate union of adjacent cells gives rise to a multicellular individual rather than to a colony of unicellular plants. Conjugation takes place between cells of separate plants growing near together. Outgrowths from two opposite cells meet, and by absorption of the walls at the point of contact form a tube connecting the cavities. Through this

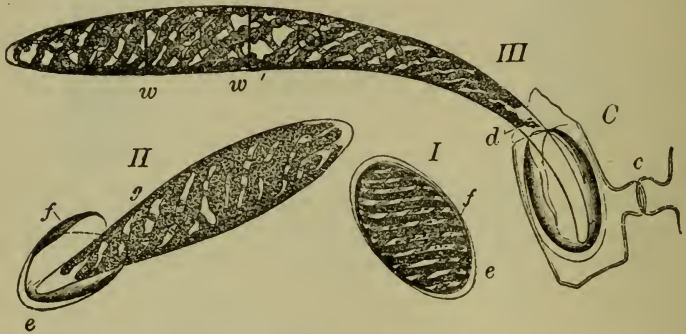


FIG. 312.—Pond-scum. Germination of zygospore. I, resting zygospore; *f*, yellowish-brown layer of the cell-wall; *e*, outer layer of wall. II, the protoplast emerging from the old wall, covered by a thin wall (*g*) of its own. III, young plant beginning to form a thread-like row of cells by elongating and forming cross-partitions (*w*, *w'*); its small end (*d*) still within the old spore-wall, enclosed by the old cell-wall of the original plant whose conjugating-tube (*c*) is still visible. Much magnified. (Pringsheim.)

tube the gamete from one cell passes into the other cell to form a zygospore. Germination takes place in the manner indicated by Fig. 312.

What is here especially noteworthy is that in the conjugation of *Spirogyra* we have a simplest form of sexual reproduction. Whereas in *Cosmarium* the gametes are just alike, in *Spirogyra* the one which passes over might be called male, and the other, female, although before conjugation no difference between them is perceptible.

Somewhat more highly developed in both the vegetative and the reproductive system are the green algæ of the genus *Ulothrix* (Fig. 313) which consist of cylindrical cells forming an unbranched filament fastened by one end to a rock or other firm support. These filaments grow so crowded as to form

a woolly mat which suggests the name wool-weeds as appropriate for the group. A differentiation of the plant-body appears in a specialization of the lowest cell as an organ of attachment. This, therefore, is analogous to a root while the remaining green part has the function of a shoot. But

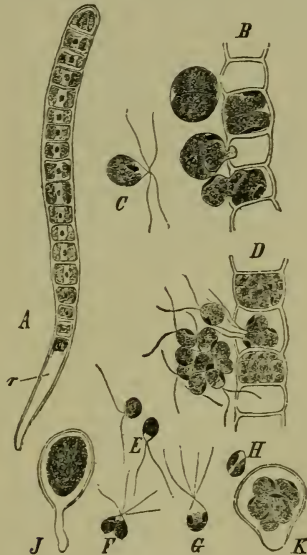


FIG. 313.—Wool-weed (*Ulothrix zonata*, Wool-weed Family, *Ulotrichaceæ*). *A*, young plant with basal cell (*r*) serving as a root-like organ of attachment, $2\frac{1}{2}$ μ . *B*, part of plant with escaping swarm-spores. *C*, single swarm-spore. *D*, formation and escape of gametes. *E*, free-swimming gametes. *F*, gametes conjugating. *G*, conjugation complete. *H*, zygote. *J*, zygospore after a period of rest. *K*, zygospore after division of its protoplast into swarm-spores. *B-K*, $2\frac{1}{2}$ μ . (Dodel-Port.)—Abundant on submerged rocks, especially in fresh water.

the resemblance not being one of homology, it will be most accurate for us to name organs of this kind *pseudo-roots* and *pseudo-shoots* respectively. *Thallus*¹ is a general term for any plant-body in which true roots, true stems, and true leaves do not appear. The pseudo-shoot of a wool-weed elongates by fission of its cells, each of which contains a

¹ Thal'lus < Gr. *thallos*, a young shoot.

single nucleus and a chromatophore in the form of a nearly complete hollow cylinder.

Eventually in some of the cells (*B*) the protoplasm assumes a spheroidal form or may divide into from two to eight smaller masses each provided with a nucleus through division of the original one. These globular masses soon begin to move and presently make their way into the surrounding water through an opening in the old cell-wall. When outside, however, they are still surrounded by a delicate cellulose membrane, but this soon ruptures setting free the naked protoplasts. Each of these (*C*) is now seen to be somewhat pear-shaped, with a colorless pointed end from which come four slender lash-like projections, called *flagella*.¹ The rounded part is grass-green and contains a bright red granule termed the *eye-spot*. As soon as they are free, these naked protoplasts swim about with rapid motion, propelled by their lashing flagella. After a while they come to rest, secrete a cellulose wall, and germinate by fission, the lower one of the two cells first formed becoming the pseudo-root by elongation and attachment to the substratum, while the upper cell develops into a long green multicellular thread by repeated divisions. A naked motile protoplast, by means of which a plant is multiplied non-sexually we call a *swarm-spore*. Ulothrix reproduces also by motile gametes in which may be discerned occasionally a slight inequality in size suggesting the beginnings of difference in sex although for the most part they appear quite alike. These sexual or subsexual gametes arise from the cells of the filament in much the same way as the swarm-spores do, but they are more numerous and smaller, and possess only two flagella (*D*, *E*). They unite sidewise (*F*) with their tips together, thus producing what looks like a swarm-spore (*G*), with its four flagella, but which differs in having two eye-spots. A protoplast resulting from the fusion of two protoplasts, whether they be alike or unlike, is termed a *zygote*.² The zygote of Ulothrix soon absorbs its flagella (*H*), becomes round, and secretes a cellulose wall, thus becoming a resistant zygosporangium ready for a period of rest. The zygosporangium germinates by forming several swarm-spores (*K*) each of which in turn grows into a thallus as already described.

In the sheath algæ (Coleochæte) the thallus (Fig. 314), is in the form of a flat disk or cushion-like mass attached to some support by the lower surface. This disk as in the species figured usually consists of branching filaments which elongate by repeated division of the terminal cell and branch by its frequent forkings. (*B*, *a-g*). In other species the fila-

¹ Fla-gel'lum < L. *a whip*.

² Zy'gote < Gr. *zygotos*, yoked.

ments instead of being distinct grow together into a mass by the coalescence of adjacent cells. Many of the cells produce hair-like outgrowths, and they are all uninucleate.

Any of the cells may form a single swarm-spore like that shown in Fig. 315 *D*, which, as will be noticed, has but two flagella. Such a spore, after attaching itself to some support, divides into a cell-row

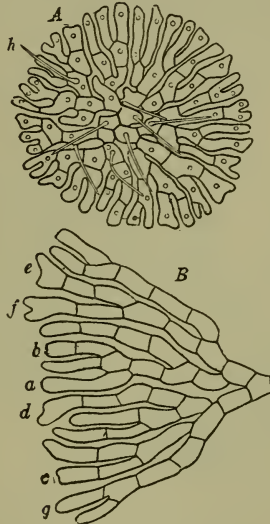


FIG. 314.—Free-branching Sheath-alga (*Coleochaete soluta*, Sheath-alga Family, *Coleochaetaceæ*). *A*, plant showing flat system of branching, and bristle-like outgrowths (*h*), $\frac{1}{4}$ " α . *B*, part of disk, further enlarged; *a-g* show successive stages in the branching of terminal cells. (Pringsheim.)—Thallus forming bright green spots on plants or other submerged objects in fresh water, in Europe and America.

which by further division becomes a mature thallus. Besides this non-sexual method of propagation a well-marked sexual reproduction takes place as follows. The protoplasts of certain small usually terminal cells (*an*, Fig. 315, *A*) become transformed into flagellate bodies like the swarm-spores only smaller (*z*); while other terminal cells (*og*, Fig. 315, *A*) enlarge, become flask-shaped by the formation of a long neck opening at the top, and finally contract the protoplast into a sphere at the base. The motile body as soon as it is set free swims to the flask-cell, enters the opening, forces its way down the neck to the large protoplast, and fuses with it.

The smaller motile protoplast is plainly the male gamete, and the larger, non-motile one, the female. Hence the cells in which they arise may be called respectively the male and the female *gametangia*,¹ the cells in which non-sexual spores appear, being termed *sporangia*.² Union of a male with a female gamete is distinguished as *fertilization*. As a result of this process in *Coleochæte* the fertilized gamete, still remaining within the gametangium, enlarges, and incloses itself in a new cell-wall, thus forming what is called an *oöspore*,³ which becomes further protected by an envelope of branches (*r*, Fig. 315 *B*); for a cell at its base is stimulated to



FIG. 315.—Cushion Sheath-alga (*Coleochæte pulvinata*, Sheath-alga Family, *Coleochætaceæ*). *A*, part of a thallus bearing male (*an*) and female (*og*, *og'*) gametangia; and bristle-like projections sheathed at the base (*h*, *h*); male gametes, *z*, *z*, ^{29a}. *B*, ripe oöspore in its rind (*r*). *C*, oöspore germinating by the formation of swarm-spores (*sch*). *D*, swarm-spores of different ages. *B-D*, ^{24a}. (Pringsheim.)—Found with the other species, forming small cushions.

produce several new cells, which, growing up around the gametangium-base and oöspore produce a sort of rind. Thus protected the oöspore rests through the winter. In spring the protoplast, by division of its nucleus and the formation of partitions, is transformed into a little mass of cells firmly united with one another but quite distinct from the old cells surrounding them. In this little mass we have, in fact, a new plant entirely different from the sexual plant which produced it. It never produces gametes, but from each cell comes a single swarm-spore which under favorable conditions

¹ Gam''e-tan'gi-um < Gr. *angeion*, a vessel.

² Spor-an'gi-um < Gr. *spora*, spore.

³ O'o-spore < Gr. *oon*, an egg.

grows into a sexual plant like the one already described. Thus in the life-history of *Coleochæte* a sexual form producing gametes, alternates with a form of plant which produces only non-sexual spores. That which bears gametes is termed the *gametophyte*,¹ while the merely spore-bearing one is the *sporophyte*.² Each represents a generation; hence the plants whose life-history is thus divided are said to exhibit an *alternation of generations*.

175. The brown algæ (Class Phæophyceæ) are characterized in general by a *brown coloring matter*, *phycophæin*,³ *masking the chlorophyll*. They are almost entirely marine. Besides many comparatively simple forms there are some showing a remarkably high development of the vegetative system.

In their methods of reproduction the brown algæ present rather close parallels to various chlorophyceous types, very rarely, however, exhibiting an alternation of generations.

One of the commonest genera is *Laminaria* (Fig. 316) which includes the familiar leathery "sea-tangles," "kelps," or "Devil's aprons" often cast upon beaches after a storm. The thallus consists of a flat, more or less leaf-like part (*pseudo-leaf*) attached to a stalk (*pseudo-stem*) at the base of which is a hold-fast (*pseudo-root*), often much branched, which clings to stones or other means of anchorage on the bottom. This thallus which may be yards in length consists of an exceedingly large number of cells among which a considerable differentiation may be observed. Thus in the stalk as shown in Fig. 317 we have an outer group of cells forming a sort of rind (*r, r*) which is comparatively tough and thus protective, while at the same time it serves as a food-making part since the cells are rich in chlorophyll. Those inclosed by the rind, (*p, p*) form the chief bulk of the stalk, are pale in color, and serve largely for the storage of food-materials elaborated by the outer cells. In the rind occur numerous cavities (*g, g*) filled with a mucilaginous material. The pseudo-leaf shows a differentiation of cells similar to that of the stalk. For the most part as soon as they are formed the cells lose the power of dividing; but in the region where the pseudo-

¹ Gam'et-o-phyte < Gr. *gametes*, spouse; *phyton*, plant.

² Spor'o-phyte < Gr. *spora*, spore.

³ Phy''co-phæ'in < Gr. *phycos*, seaweed; *phaios*, brown.

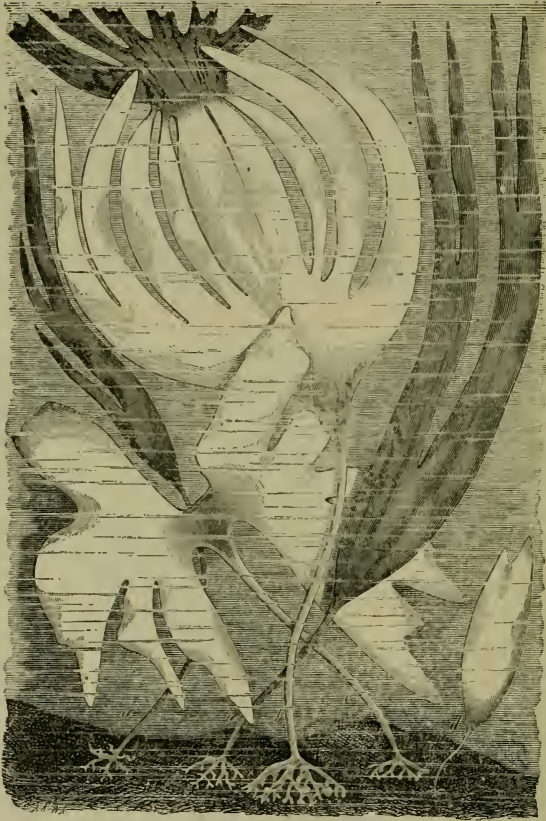


FIG. 316.—Sea-tangles (*Laminaria* spp., Sea-tangle Family, *Laminariaceæ*). Various forms more or less reduced in size; the larger ones often having the stalk over 1 m. long and the expanded part 2 m. (Luerssen.)—These brown, leathery seaweeds are familiar objects along our coasts.

leaf joins the stalk there is a cell-mass which retains this power, and from time to time exhibits it in a striking way; that is to say, it forms a new pseudo-leaf at the base of the old one which it eventually casts off, as indicated in the figure. Any mass of connected cells all of which are similar in origin and character is called a *tissue*. An undifferentiated tissue,

made up of cells still capable of division is termed a *meristem*,¹ or is described as *meristematic*, while a fully differentiated tissue is distinguished as *permanent*.

Laminaria reproduces only by swarm-spores which are formed in sac-like sporangia projecting from the surface of the pseudo-leaf. They are crowded closely, together with a number of curiously shaped protective cells called *paraphyses*.² The swarm-spores have a red eye-spot and two flagella which are attached at the side. There are no gametes.

A somewhat higher development both of the vegetative and reproductive systems is found in the genus *Fucus* (Figs. 318, 319) which includes the common "bladder-wracks" of the sea-shore, so called because of the bladder-like floats (*l*) developed in the thallus. The meristematic tissue is at the tip of the thallus-lobes. A disk-like pseudo-root attaches the thallus to rocks which lie mostly between tides. The pseudo-shoot has forking midribs with flat expansions on either side in which the inflated bladders often appear. There is a rind and an inner, somewhat pith-like tissue much as in *Laminaria*. The tips of certain branches become swollen (*s*, Fig. 318) and produce a number of small cavities (*conceptacles*) each opening by a pore at the surface and lined with numerous paraphyses among which appear either male or female gametangia (Fig. 319, *a*). Within a female gametangium (*b*, *c*) eight large, spherical, non-flagellate gametes arise and are pressed out into the surrounding water by swelling of the paraphyses. The male gametangia, (*d*) expelled at the same time emit numerous flagellate gametes (*g*) which resemble somewhat the swarm-spores of *Laminaria*. They are attracted in large numbers to a female gamete, and, attaching themselves to its surface, often cause the sphere to revolve by the energetic movement of their flagella (*e*). Directly after fertilization the oöspore comes to rest and germinates (*f*), attaching itself to some rock by projections which form the beginnings of a pseudo-root, while the main part above becomes a meristem for the shoot. No swarm-spores are produced and there is no alternation of generations.

176. The red algæ (Class Rhodophyceæ), the largest and one of the most highly developed groups of seaweeds, are characterized by the presence of a red pigment called *phycoerythrin*,³ which very generally masks the chlorophyll completely. The carrageen already studied (page 112) belongs to this class.

¹ Mer'is-tem < Gr. *meristos*, divisible.

² Pa-raph'y-ses < Gr. *para*, besides; *physis*, growth.

³ Phy''co-er'y-thrin < Gr. *erythros*, red.

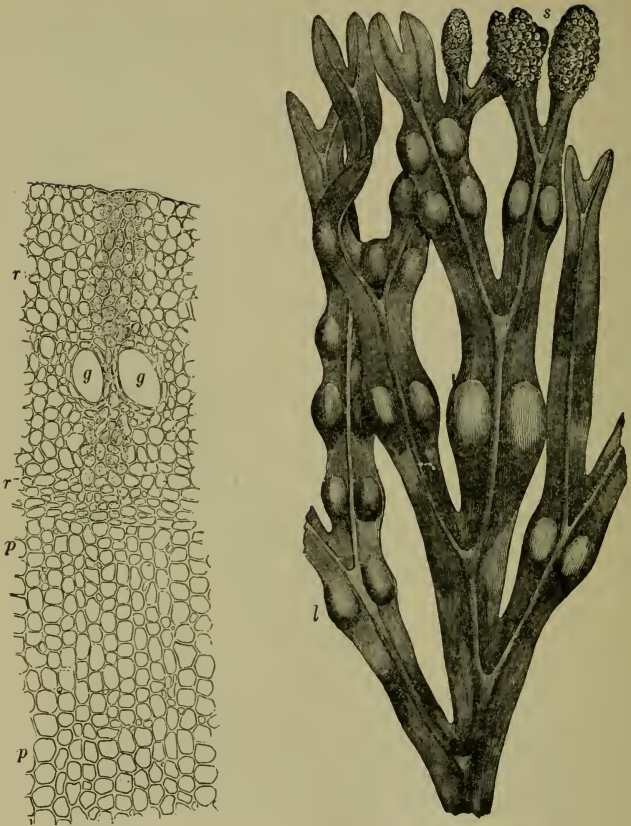


FIG. 317.—Sea-tangle. Transverse section through the outer part of a stalk 2 cm. in diameter, s^2 , showing the darker rind (*r, r*) containing slime-canals (*g, g*); and the lighter interior tissue (*p, p*) which form the greater bulk. (Luerssen.)

FIG. 318.—Bladder-wrack (*Fucus vesiculosus*, Wrack Family, *Fucaceæ*). Branch bearing air-bladders (*l*) and swollen tips (*s*) containing conceptacles. (Luerssen.)—Brown, slimy, tough seaweed, sometimes 1 m. long, growing attached to rocks, etc., between tides along the North Atlantic coast.

A comparatively simple type is the thread-weed (Nemalion, Fig. 320). The thallus is small and with slender branches which grow at the apex but do not show much differentiation among the vegetative cells. Male gametangia (*I, sp*) are developed at the tips

of certain branches, and these emit minute, spherical gametes having no flagella or other means of locomotion. At the tips of other branches female gametes appear, each in the form of a flask-shaped cell with long, slender neck (*I, t*). Fertilization is effected

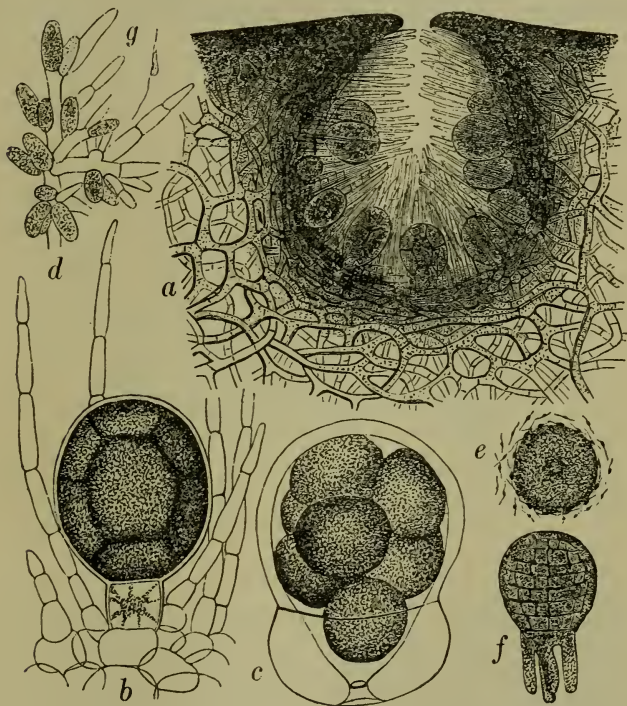


FIG. 319.—Bladder-wrack; *a*, vertical section through a conceptacle (σ^2) showing the female gametangia; *b*, female gametangium beginning to form its eight gametes; *c*, the same, beginning to set free its gametes; *d*, male gametangia (shaded) from which come ciliate gametes like the one (*g*) shown near by; *e*, female gamete surrounded by numerous male gametes which cause it to revolve in the water; *f*, young plant produced directly from the fertilized female gamete. *b-f*, σ^2 , σ^2 , σ^2 . (Thuret.)

by fusion of male gametes with the projecting end of a female gamete to which the little spheres have been brought by currents in the water. After fertilization the basal part (*I-V, c*) gives rise to several branches, each of which finally produces at its tip a spheroidal spore that soon separates, and attaching itself to some support, develops

into a new Nematium plant. Spores which are thus the indirect product of fertilization are called *carpospores*.¹

Sexual reproduction in *Chondrus* (Fig. 118) as also in almost all of the Rhodophyceæ is by means of carpospores. The process is often much more indirect and complicated than in Nematium; and, as is the case with *Chondrus*, the details may be somewhat modified

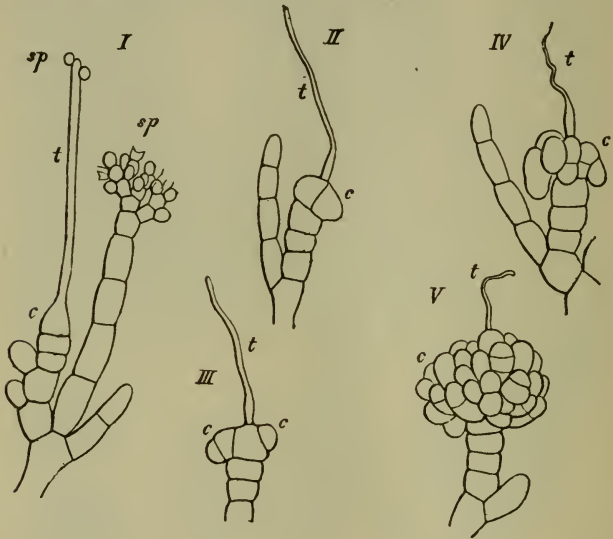


FIG. 320.—Thread-weed (*Nematium multifidum*. Thread-weed Family, *Helminthocladiaceæ*). I, branch bearing male gametangia (*sp*), and a female gametangium with swollen base (*c*) and slender neck (*t*). II, a female branch after fertilization, the neck (*t*) withered, and the base beginning to divide for the formation of branches. III–V, later stages in the formation of branches which finally bear spores. All much magnified. (Thuret and Bornet.)—A brownish-red seaweed with branches 5–20 cm. long, on exposed rocks at low-water mark, North Atlantic coast.

by formation of the carpospores within the thallus, as shown in Fig. 321. Non-sexual reproduction is accomplished very generally throughout the class by non-motile spores, which are produced usually four in a sporangium. The sporangia may be either at the surface or embedded within the thallus as in *Chondrus*.

The thallus in this genus, as with a large part of the class, exhibits a differentiation of cells similar to that already

¹ Carp'o-spore < Gr. *karpos*, fruit.

described in our examples of brown algæ, and many of the red seaweeds rival the brown in elaborate forms of thallus simulating remarkably the shoots of higher plants.

177. The seaweed subdivision, algæ in general. It is believed by evolutionists that life originated in the sea. Among the algæ we generally find that the marine forms are more primitive than their nearest relatives growing in fresh

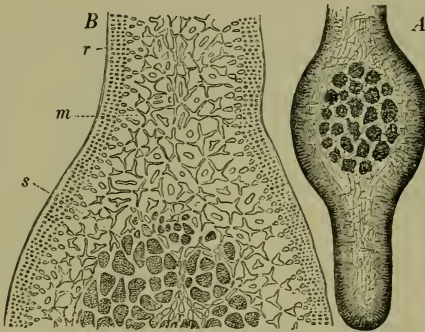


FIG. 321.—Carrageen (see also Fig. 118). A, transverse section through a fruiting branch showing the spore-clusters embedded in the thallus, $\frac{1}{2}$ in. B, same, $\frac{1}{4}$ in., showing rind (*r*), pith-like interior (*m*), and spore-clusters (*s*). (Luerssen.)

water or in the air. Hence, as being at once the most primitive and most typical of the algæ, seaweeds may not inappropriately serve to name the entire group. Over 12,000 species of algæ are known. In spite of the great variety of form in the plant-body and in the life-histories of various algæ, *an alga may generally be recognized as a plant without true roots, stems, or leaves, but containing chlorophyll, although the leaf-green color may be masked by some other pigment.*

It must not be supposed that the pigments which have suggested names for the several classes of algæ are invariably present in these groups, or that mere color is here the basis of classification. The pigments in question happen to be associated very generally with fundamental peculiarities of structure and life-history which give evidence of kinship; hence algæ of the same color may as a rule be regarded as akin and thus the pigments afford a convenient though superficial mark for recognizing related forms.

178. The fission fungi (Class Schizomycetes). *Fungi*, broadly defined, are thallus-plants without chlorophyll. In their structure and life-histories they present often noteworthy parallels to what we have already seen in typical algæ. Thus, closely similar to the Cyanophyceæ are the Fission Fungi, otherwise known as Bacteria. A typical

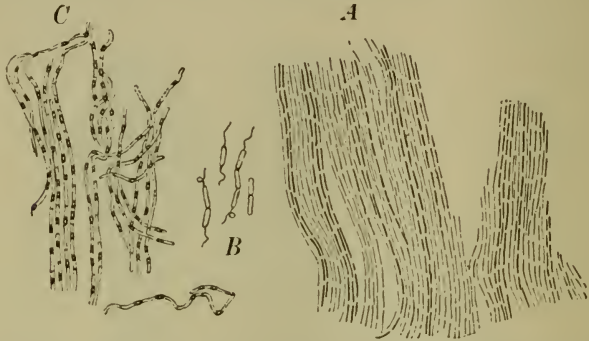


FIG. 322.—Hay bacillus (*Bacillus subtilis*, Rod-germ Family, *Bacteriaceæ*). A, rod-like plants embedded in the film-like gelatinous mass which they produce, ^{sp.}. B, plants swimming freely by means of slender lash-like projections, ^{sp.}. C, plants in the thread condition forming resting spores, ^{sp.}. (Strasburger.)—These plants cause putrefaction in various liquids such as water in which hay has been soaked.

example is the “hay bacillus” (Fig. 322) so-called because it thrives in an infusion of hay. About twenty-four hours after such an infusion is made, the liquid gives off an offensive odor and becomes turbid through the presence of myriads of organisms which under a very high power of the microscope appear as short, colorless rods (B). These are seen to be in rapid motion, but it is only by special staining and very great magnification that the exceedingly delicate lash-like projections which cause the movement can be discerned. The ability of these plants to feed upon the organic substances dissolved in the water about them, renders it unnecessary for them to manufacture food for themselves by the aid of sunlight out of inorganic materials; hence like all fungi they can dispense with chlorophyll, and grow as well, often better, in the dark than in the light. A plant which feeds upon dead

organic material is termed a *saprophyte*,¹ and when the chemical changes induced by its activity are offensive the process is *putrefaction*.²

The motile rods multiply rapidly so long as there is any food available or until the putrid products become so concentrated as to be harmful to the plant. Then the plants rise to the surface of the liquid, lose their swimming organs, form long threads by remaining attached end to end after fission, and at the same time they secrete a gelatinous covering which binds them all together into a rather firm layer or scum (A). While in this stage resistant resting spores are formed in many of the cells, by the protoplast becoming round and secreting a new cell-wall (C). If the liquid is allowed to



FIG. 323.—Milk-souring bacterium (*Bacterium acidilactici*, Rod-germ Family, *Bacteriaceæ*). Plants stained, ²⁹⁹². (Migula).—Causes the souring of milk by converting the milk-sugar into lactic acid.

evaporate and the scum to dry it will become more or less powdery, and slight currents of air may then carry away minute bits containing many of these excessively small spores which no mere drying can harm. Myriads of such spores are floating about in the air around us. When a *Bacillus* spore falls into any putrescible liquid it germinates by elongation of the protoplast and the development of swimming lashes, thus forming a motile rod like that already described.

Very similar to *Bacilli*, both in structure and life-history, are the many forms of the genus *Bacterium* which differs from *Bacillus* mainly in lacking swimming organs. *Bacterium acidilactici* (Fig. 323) causes milk to sour by convert-

¹ Sap'ro-phyte < Gr. *sapros*, rotten.

² Pu'tre-fac'tion < L. *putris*, rotten; *facere*, make.

ing its sugar into lactic acid. Such decomposition, in which the products are not offensive, is distinguished as *fermentation*.¹ Both fermentation and putrefaction are regarded as due to the action of enzymes (comparable to diastase) which are secreted by the active organisms concerned. The tuberculosis bacterium is another species especially noteworthy as it is the germ of "consumption" in man and other animals, producing various forms of the disease according to the part of the body in which it develops. An organism which thus feeds upon the substance of another living thing is called a *parasite*;² the organism which supports it being termed the *host*. Bacteria capable of producing the disease often occur abundantly in the sputum of tuberculous patients, and if this dries small bits are readily detached and blown about. A sufficient number drawn into the lungs or getting into the blood of a susceptible host give rise to the disease. Hence the wisdom of isolating tuberculous patients to avoid contagion, and the importance of enforcing the regulations of Boards of Health against all spitting in public places. Direct sunlight being soon fatal to the plant in all its stages, affords a most valuable means of preventing infection, and often of effecting a cure by killing the parasite.

Nearly all contagious diseases are caused by fission fungi, and to the micro-organisms or "microbes" of this same class are due almost every sort of putrefaction, fermentation, and decay. The discovery of this important truth has given a new significance to cleanliness, and a knowledge of their life-histories and peculiar properties affords a scientific basis for methods of preventing or regulating the activities of these excessively minute, yet exceedingly powerful agents of change. While some forms of bacteria are a menace to health others are useful in important ways as in the manufacture of butter and cheese, in the retting of flax and other fibers, and as improving the soil for many farm-plants.

The various forms assumed by the cells and colonies of fission fungi may all be closely matched by forms of blue

¹ Fer'-men-ta'tion < L. *fervere*, boil, be agitated.

² Par'a-site < Gr. *parasitos*, one who eats at another's table, a hanger on; < *para*, beside; *sitos*, food.

algæ. The fission fungi, therefore, are regarded as descendants of the fission-algæ (as the blue algæ are sometimes called) which have adopted a saprophytic or parasitic mode of life. All plants which contain chlorophyll and, like the algæ, make all their own food by means of sunlight, are termed *holophytes*;¹ while those which feed upon organic materials either as saprophytes or parasites are distinguished as *hysterophytes*.² Doubtless in consequence of their change of habit these hystero-phytic fission-plants have not only altered their relation to sunlight, but have become more or less reduced in size. Certain species of the group are, so far as known, the smallest of living things. *Multiplication solely by fission characterizes the class.*

179. The yeast fungi (Class Saccharomycetes). Alcoholic fermentation, or the conversion of a carbohydrate into alcohol and carbonic acid gas, such as takes place in the manufacture of beer and wine and in the raising of bread, is usually accomplished by means of yeast. This consists of unicellular fungi (Fig. 151, *a-d*). The usual method of reproduction differs from fission in that new cells arise as small protuberances or buds which eventually attain the size of the parent cell. Several resting spores are formed in a single cell (*e, f*) and these germinate by budding (*g, h*). There is reason to believe that yeast-plants represent merely a stage in the life-history of more highly developed fungi, which, however, have the power of perpetuating themselves indefinitely in the simple ways described, much as we have seen to be the case with wall-stain alga. Whatever may prove to be their true relationship to other fungi the species of yeast are conveniently placed provisionally in a class by themselves *composed of unicellular forms, which reproduce only by budding and the formation of spores by internal cell-division.*

180. The pin-mold fungi (Class Zygomycetes). Various fermentations or putrefactions affecting bread, preserves or other food, are often due to so-called "pin-molds" like the *Mucor* shown in Figs. 324, 325, 326. A spore falling

¹ Hol'o-phyte < Gr. *holos*, whole; *phyton*, plant.

² Hys'ter-o-phyte < Gr. *hysteros*, coming after.

upon the surface of some nutrient medium germinates by sending out one or more projections (Figs. 325, 3), and these finding abundant food available elongate and branch indef-

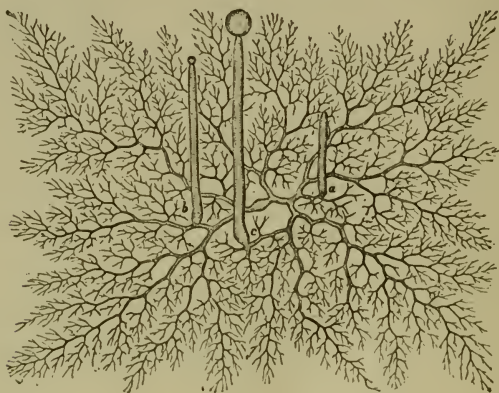


FIG. 324.—Pin-mold (*Mucor Mucedo*, Pin-mold Family, *Mucoraceæ*). Plant showing the much-branched horizontal mycelium from which arise pin-like vertical hyphæ (*a*, *b*, *c*, of different ages) that eventually develop dust-spore-cases at the tip. Somewhat magnified. (Zopf.)

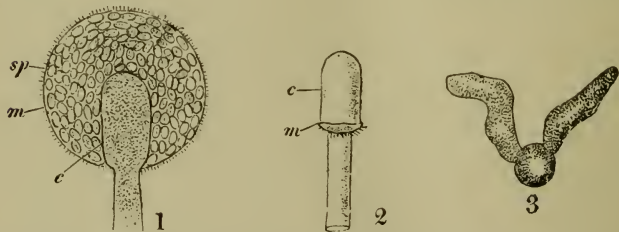


FIG. 325.—Pin-mold. 1, dust-spore-case, viewed as if cut vertically, showing the tip of the vertical hypha (*c*) projecting into the spore-case; the spore-case wall (*m*); and the numerous dust-spores (*sp*), ²/₃. 2, same from which the dust-spores have been shed. 3, germinating dust-spore, ³/₄. (Brefeld.)

initely so long as the conditions are favorable. Soon there may be as complex a system of branches as that in Fig. 324. A fungus thread is termed a *hypha*.¹ The mass of hyphæ forming the vegetative part of a fungal thallus constitutes

¹ Hy'pha < Gr. *hype*, a web.

a *mycelium*.¹ The vegetative hyphæ of *Mucor* form no partitions, hence we may consider the entire horizontal branch-work shown in Fig. 324 as one cell. Its position marks it as

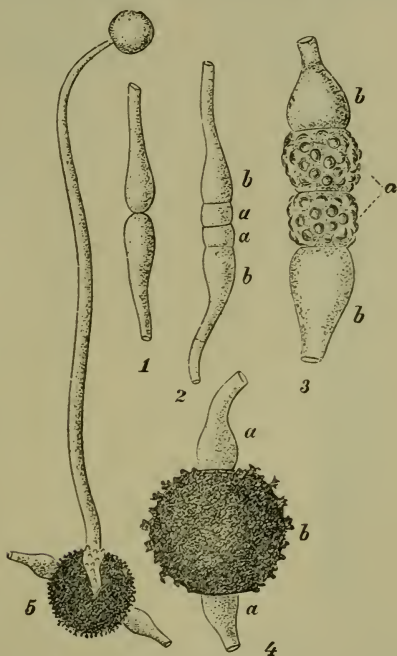


FIG. 326.—Pin-mold. Formation and germination of zygospore. 1, two conjugating branches of the mycelium in contact. 2, separation of the tip of each by cross-partitions, thus forming two "conjugating-cells" (*a, a*) and two "suspensors" (*b, b*). 3, more advanced stage; warty thickenings have begun to form on the conjugating cells, which, however, are still separate. 4, ripe zygospore (*b*) between the suspensors (*a, a*); the conjugating cells now having completely fused. 5, zygospore germinating by producing a vertical hypha with dust-spore case at the tip. 1-4, magnified 225 diameters; 5, about 60 diameters. (Brefeld.)

the pseudo-root of the plant, and for a while it is the only member developed. Pin-shaped vertical hyphæ, which may be called pseudo-stems, arise into the air from the feeding mycelium, and the tip or "head" of each being separated by

¹ My-ce'li-um < Gr. *mykes*, a fungus.

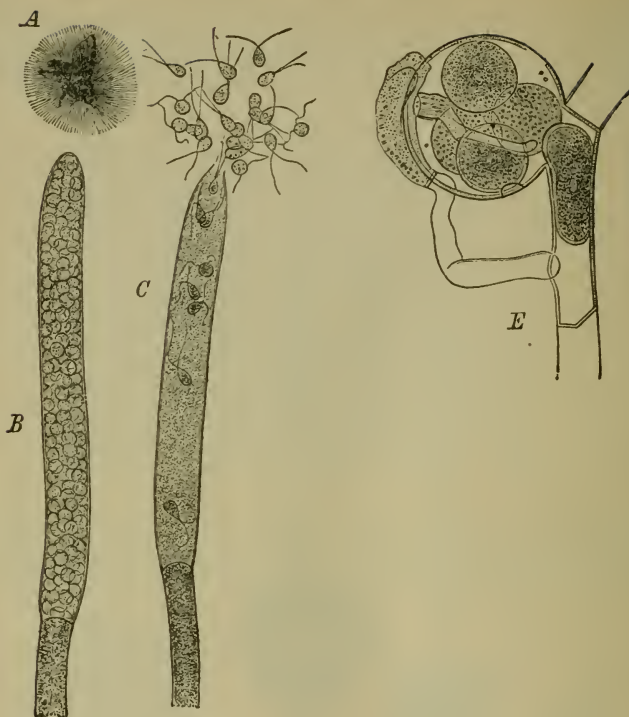


FIG. 327.—Water-mold (*Saprolegnia Thureti*, Water-mold Family, *Saprolegniaceæ*). *A*, dead fly attacked by water-mold, surrounded by radiating hyphæ terminating in swarm-spore-cases, $\frac{1}{2}$. *B*, swarm-spore-case in which the spores are forming, $2\frac{1}{2}$. *C*, same, discharging swarm-spores. *E*, female gametangium containing four female gametes to which comes a projection from the male gametangium that arises as a branch hypha from below the female gametangium, $4\frac{1}{2}$. (Thuret, DeBary.)—Water-molds abound upon dead insects, etc., in water.

a convex partition, swells into a sporangium which becomes filled with a number of spores. These are soon scattered, and are then ready to produce new mycelia in the manner already described. Such non-sexual spores, serving as do swarm-spores for rapid multiplication, float like dust in the air, and may thus be distinguished as *dust-spores*.

Comparatively large and resistant zygospores are formed by the conjugation of special branches as shown in Fig. 326. The zygospore

germinates by forming directly a pseudo-stem which bears a sporangium soon filled with dust-spores. The formation of zygospores at once suggests kinship with algæ like Spirogyra, and it is believed that molds of the type here shown may have evolved from Chlorophyceæ similar to the "pond-scums." *The zygomycetes are fungi which produce zygospores.*

181. The water-mold fungi (Class Oömycetes) are typified by a small group closely resembling algæ because of their aquatic habits. These water-molds, as they are called, are well represented by species of Saprolegnia (Fig. 327) which grow commonly upon dead insects (*A*) or succulent plant-fragments decaying in water; or, in some cases, as parasites upon fish. As with the bread-molds the feeding mycelium is unicellular. Projecting hyphæ form terminal sporangia from which swarm-spores emerge (*B, C*). Female gametangia are formed by swellings on certain hyphæ, the protoplast becoming transformed into one or more spherical gametes (*E*). Meanwhile, male gametangia develop either from the same hypha or from hyphæ near by, as club-shaped organs which grow toward the female gametangium and send a projection through its wall to the gametes within. After fertilization the female gametes become resistant oöspores. These eventually are set free and germinate by sending out a sporangial hypha in which swarm-spores are developed. In some of the water-molds degeneration of the sexual reproductive organs has gone so far that, although male gametangia are developed no fertilization takes place and oöspores form non-sexually. In extreme cases oöspores are formed although no vestige of a male gametangium appears. The life-history of the water-molds is essentially similar to that of other oömycetes which are parasitic upon land-plants. All of these fungi, to judge from their methods of reproduction are more nearly akin to algæ of the type represented by Coleochæte than to any other we have studied, although important differences show that the kinship is rather remote. *Oömycetes are fungi which produce oöspores.*

182. The spore-sac fungi. (Class Ascomycetes) may be illustrated sufficiently for our purpose by the "mildews." These, typified by the "powdery mildew" Erysibe, are parasitic upon the aërial parts of higher land-plants. As shown in Fig. 328 the feeding hyphæ creep over the surface of a leaf, and at short intervals send out projections into the host. These projections by means of which the food is absorbed, are called *haustoria*.¹ Another peculiarity distinguishing these vegetative hyphæ from any previously studied is the presence of frequent cross-partitions. Dust-spores are

¹ Haus-tor'i-um < *L. haustor*, a drinker.

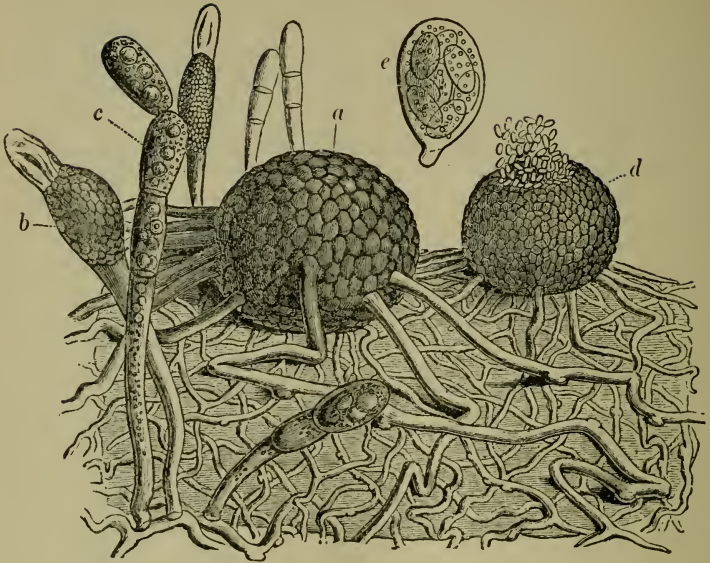


FIG. 328.—Powdery-mildew (*Erysibe communis*, Powdery-mildew Family, *Erysibaceæ*). The surface of a leaf upon which the fungus is parasitic, its horizontal hyphæ spreading over the surface and attaching itself by sucking organs; and giving rise also to vertical hyphæ producing dust-spores (*c*), and to fruiting bodies such as *a*, which contain sac-spore-cases such as *e*. The fruiting bodies *b* and *d* and the hyphæ from which they arise belong to another fungus (*Cincinnatiobolus*) which is parasitic upon the mildew. Magnified about 450 diameters. (Tulasne.)—Powdery-mildews are all too common parasites upon the foliage of flowering plants both cultivated and wild.



FIG. 329.—Powdery-mildew. Horizontal hyphæ (*a*) from which arise "male" (*b*) and "female" (*c*) gametangia; the latter producing sac-spore-cases enclosed within a protective fruit-body (*d*, *e*). (Warming.)

formed at the tips of vertical hyphæ by the separation of individual cells as shown at *c*. Each of the dust-spores thus formed is regarded as representing a degenerate spore-case containing but a single spore. Minute sac-like cases containing eight sac-spores are formed within a spherical envelope from the feeding hyphæ.

What appear to be male and female gametangia arise where two hyphæ cross (Fig. 329, *a, b, c*), the female coming from the lower hypha, the male from the upper. Fertilization has not been observed and all sexuality seems to have been lost in these plants; but from what we have called the female cell there are developed several eight-spored sacs or *asci*,¹ as they are called, while from the supposed male grow up a number of enveloping branches consisting of many short cells so crowded and joined as to make a complete protective envelope.

Fungi related to the mildews and sometimes parasitic upon them, as shown in Fig. 328, *b, d*, produce very minute dust-spores which are crowded within a case resembling the envelope just described. When the sac-spores are set free under favorable conditions they germinate like the dust-spores.

Comparing Erysibe with Coleochæte we find some significant resemblances which make it comparatively easy to suppose that fungi of this sort have descended from such algæ;—the multicellular creeping branches of the thallus becoming multicellular creeping hyphæ; the sporangia, dust-spores; the female gametangium developing into a group of asci, while a neighboring cell, simulating the male gametangium, gives rise to an enveloping rind. These changes are such as might be expected in passing from the aquatic and sun-using mode of life to the aerial and parasitic. *Ascospores* characterize the Class *Ascomycetes*.

183. The spore-base fungi (Class Basidiomycetes) are well represented by the mushrooms, although very many widely diverse forms are included among its other members. The common field mushroom (Figs. 119, 330) vegetates by subterranean hyphæ feeding upon decaying organic matter in the soil. From this mycelium arise, finally, compact masses of hyphæ forming fruit-bodies which soon become differentiated into a vertical stalk and a horizontally expanded

¹ As'cus < Gr. *askos*, bag.

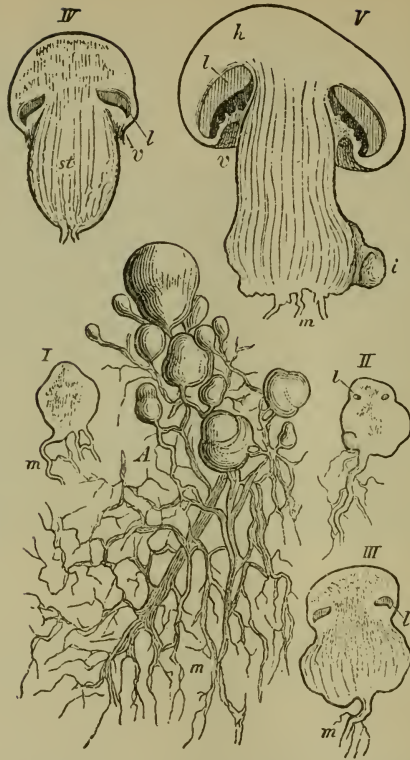


FIG. 330.—Field Mushroom (see also Fig. 119). *A*, mycelium (*m*) producing young fruit-bodies, *i*. *I*, a very young fruit-body cut vertically to show its relation to the mycelium (*m*). *II*, same, a little older, showing the beginnings of gills (*l*). *III*, *IV*, *V*, later stages in which appear the stalk (*st*), the cap (*h*) and the veil (*v*) protecting the gills till they are ripe. (Sachs.)

cap. From the under side of the cap hang numerous thin plates, called "gills," which radiate from the stalk to the margin of the cap. These gills (Fig. 331) bear the spore-producing layer which consists of swollen cell-tips beyond which project club-shaped bodies developing horns, each tipped with a spore. These club-shaped spore-bases are called *basidia*.¹

¹ Ba-sid'i-um < Gr. *basis*, base.

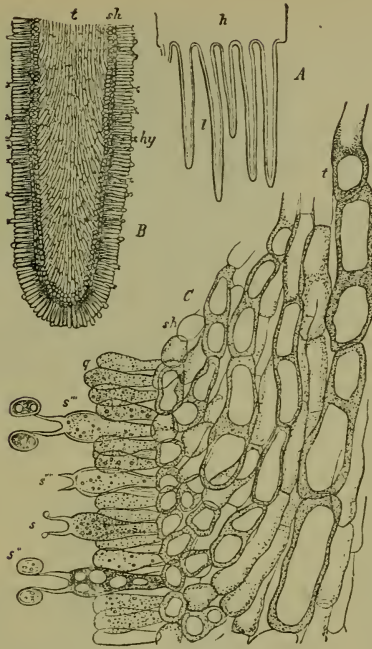


FIG. 331.—Field Mushroom. A, vertical section through part of cap (*h*) at right angles to gills (*l*), slightly enlarged. B, cross-section through a gill, showing the mass of hyphae (*t*) continuous with that of the cap, the spore-bearing layer or hymenium (*hy*), and the layer (*sh*) from which it develops. C, a part of B (^{28a}), showing the development of dust-spores (*s'*–*s'''''*) upon the tip of projections from swollen hypha-tips or basidia, and other swollen tips (paraphyses, *q*) which form a large part of the hymenium but do not produce spores. (Sachs.)

The possession of basidia characterizes the class, in which, moreover, sporangia are entirely lacking and scarcely a trace of any sexual organ has been found.

184. The mushroom division, fungi in general, are most fittingly named after a type which has departed as far as possible from the holophytic condition.

In trying to conceive by what course the higher fungi have evolved, naturalists encounter a peculiar difficulty, for although algæ of some sort are presumably the starting point of all, the hysterozytic mode of life soon obliterates almost every peculiarity characterizing

the vegetative system of the algal ancestor; and as the degeneration proceeds, the reproductive system, whereby kinship is most plainly revealed, loses even the last vestige of sexual organs. Many interesting attempts have been made, however, to correlate the various classes of algæ and fungi, making allowance for the probable extinction of many forms, and for a considerable evolution of fungi as fungi. For further accounts of these evolutionary interpretations the student must be referred to more special works.

The name fungus has been variously restricted by different writers. As here used it is taken in the widest sense as including *all thallophytic hysterophytes*, of which about 40,000 species have been described.

Fungi are of great economic importance, many of the saprophytic forms being, as we have seen, highly beneficial as agents of decay; while, on the other hand, parasitic forms are often exceedingly harmful. Nearly all the diseases of cultivated plants which so seriously affect the pursuit of agriculture are due to fungal parasites. A scientific study of these, however, has led to the discovery of means of defense which have enabled farmers to increase their crops enormously in recent years.

185. The spore-sac lichens (Class Ascolichenes). After long study and careful experimenting in the culture of lichens botanists have reached the strange conclusion that what were at first regarded as individual plants are in reality communities each consisting of a fungus (mostly spore-sac fungi), parasitic upon algæ (commonly colonies of *Pleurococcus*), imprisoned by its mycelium. A lichen spore falling among *Pleurococcus* cells germinates, and the hyphæ attaching themselves to the algæ absorb food materials from them but not generally to an injurious degree. This is shown by the fact that the algæ seem to thrive quite as well as before, dividing repeatedly, while the hyphæ grow luxuriantly into a mycelium which soon envelopes the algæ completely. A well-developed lichen such as "Iceland moss," for example, shows a compound thallus, in which a marked differentiation of parts may be observed (Figs. 161, 332-335). At the middle is a layer of loose cottony mycelium (Fig. 335, *m*) on the borders of which are irregular layers of algal colonies (*g, g*) mingled with the hyphæ, and, covering all, a firm rind (*r, r*)

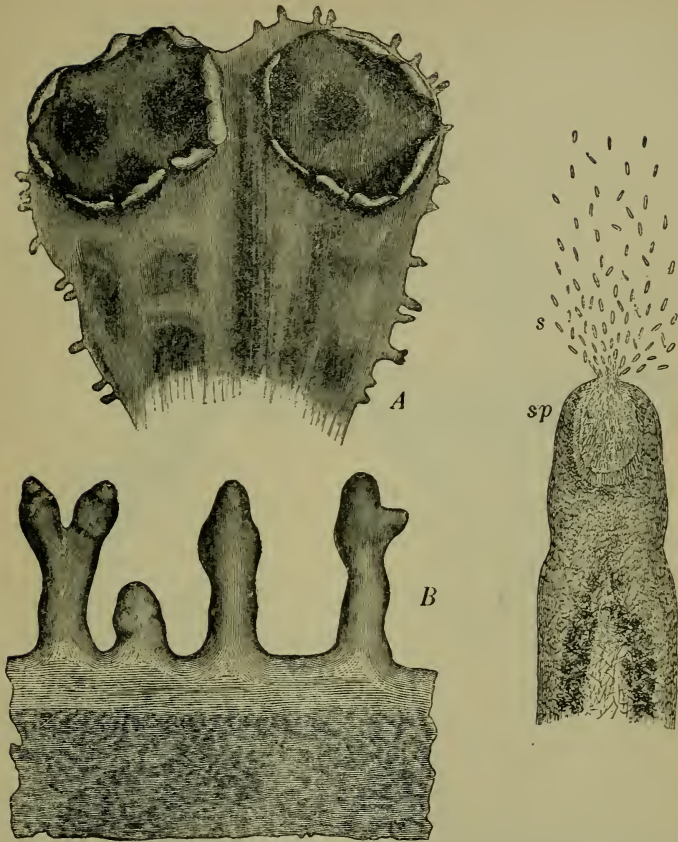


FIG. 332.—Iceland moss (see also Fig. 161). A, tip of thallus-lobe bearing two fruit-patches, called *apothecia*, and along the edge a number of projections, known as *spermagones*, which contain dust-spores, $\frac{1}{2}$. B, edge of thallus bearing four spermagone-projections, $\frac{1}{2}$. (Luerssen.)

FIG. 333.—Iceland moss. A spermagone-projection, cut vertically to show the cavity (*sp*) from which dust-spores are discharged. (Luerssen.)

consisting entirely of hyphæ fused into a uniform tissue. Layers of spore-sacs arise near the tips of the thallus-lobes in *Cetraria*, and numerous projections inclosing dust-spores appear along the margin.

A singular method of reproduction very common among

lichens is by what are called *soredia*,¹ which are little masses of hyphæ surrounding a colony of algæ. Fig. 336, II shows the soredium of a lichen known as beard-moss (Fig. 336, I) nearly related to the "Iceland moss." Soredia arise through luxuriant development of the inner cottony layer at certain points where they rupture the rind, and force their way to the surface from which they eventually separate. Then being carried by the wind to some favorable spot each grows into a new compound thallus. The formation of soredia makes it possible for lichens to gain a foothold where no other living thing could grow. We find them clinging to the rocks of mountain peaks,



FIG. 334.—Iceland moss. Cross-section of apothecium through thallus-lobe, showing the thallus-rind (*r, r*), the cottony interior mass of hyphæ (*m, m*), among which are green algæ, and the layer of spore-sacs and paraphyses which form the hymenium (*h, h*); somewhat diagrammatic, 2^d. (Luerssen.)

or in arctic regions, or deserts. After a land-slide lichens are the first plants to appear upon the newly uncovered rock, thus beginning that slow accumulation of soil which after many centuries permits the growth of higher plants. For this reason lichens have well been called Nature's pioneers. Their wonderful power of living upon the air, with what the winds and rain may bring them, is clearly the result of a mutually beneficial co-operation between the algæ and the fungi composing the thallus. Either alone could not grow where both together thrive. The algæ of course are the food-making members of the little community; while the fungus, living upon the organic materials they provide, affords them protection against too intense sunlight, soaks up the rain and dew and retains it sponge-like for a considerable time; and,

¹ So-re'di-um < Gr. *soros*, a heap.

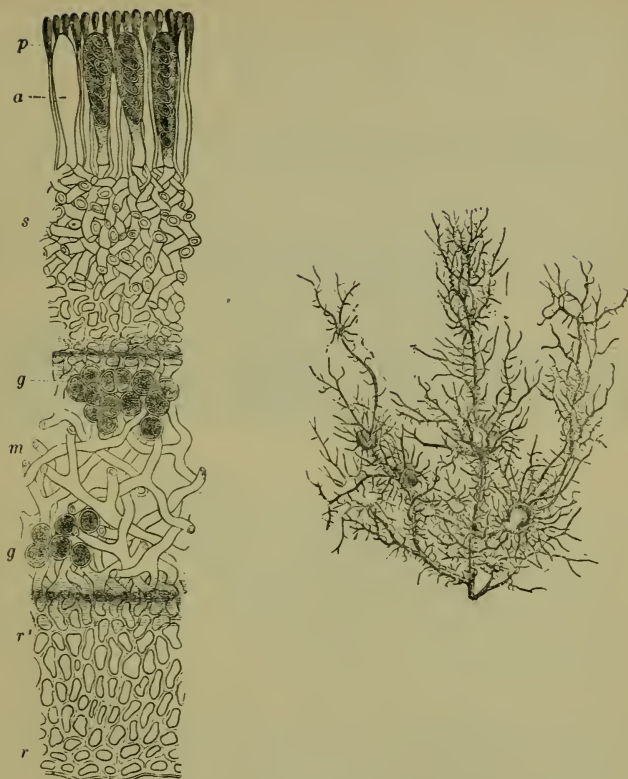


FIG. 335.—Iceland moss. A small part of the apothecium and thallus shown in Fig. 334, magnified 400 diameters; showing the spore-sacs or asci (*a*), the paraphyses (*p*), the compact layer of mycelium (*s*) from which they arise, the algæ (*Pleurococcus*) known as "gonidia" (*g*), the cottony mycelium (*m*), and the compact protective rind (*r*, *r'*). (Luerssen.)

FIG. 336, I.—Beard-lichen (*Usnea barbata*, Beard-lichen Family, *Usneaceæ*). Natural size. Granules often appearing on the surface are soredia. (Baillon.)—Grayish or dull yellowish green throughout; often much longer than shown, with a tough central. Common on trees in various parts of the world.

finally, keeps them supplied with all the carbon dioxide they need as a raw material for their food. Dissimilar organisms living thus together with benefit to both are called

symbionts,¹ and their co-operative mode of life, *symbiosis*.¹ Plants which grow attached to some support from which they derive no nutriment are termed *epiphytes*.² Lichens are aërial epiphytes or "air-plants."

Several aërial forms of Chlorophyceæ besides Pleurococcus, and also a number of Cyanophyceæ including species of Chroococcus and Nostoc, serve as the algal symbiont in various lichens. So little has their structure been modified by the symbiosis, they may almost always be referred to forms found living independently. The fungal symbionts, on the other hand, have become so changed in many ways, that usually much uncertainty attends the effort to find their



FIG. 336, II.—Beard-lichen. *a, b*, a group of eight gonidia among which a hypha is branching. *c*, a soredium consisting of a single gonidium surrounded by hyphæ, viewed as if cut across. *d*, the same in which the single gonidium has multiplied into several. *e*, a soredium which contains but a single gonidium, germinating by developing below in contact with the bark of a tree fine hypha-branches which serve as organs of attachment. *f*, the same, older, showing the multiplication of the gonidia, and the upward growth of the hyphæ to form a thallus. (Schwendener.)

near kin among non-symbiotic fungi. They may always be classified, however, as either Ascomycetes or Basidiomycetes, and it is to the former class that the great majority of lichen fungi belong. Ascolichenes are thus *symbiotic Ascomycetes*.

186. The spore-base lichens (Class Basidiolichenes) include only a few tropical forms of *symbiotic Basidiomycetes* which may be represented by the mushroom-lichen (*Cora pavonia*, Fig. 337). This consists of one of the tougher mushrooms associated with a Chroococcus, or with another bluish alga, and assumes quite different shapes according to which alga is present and according as the algal or the fungal symbiont predominates and so determines the form.

187. The lichen subdivision, lichens in general. Lichens include about 5,000 species, none of which are of

¹ Sym-bi-ont, Sym-bi-o'sis < Gr. *symbiosis*, living together; < *syn*, together; *bios*, life.

² Ep'i-phyte < Gr. *epi*, upon.

much economic importance. They may be defined as *alga-fungal air-plants*. Although made up of plants which belong to different classes of Algæ and Fungi, which therefore on theoretical grounds might require to be assigned each to its own class, lichens are in practice more conveniently treated as compound organisms forming an artificial group by themselves.

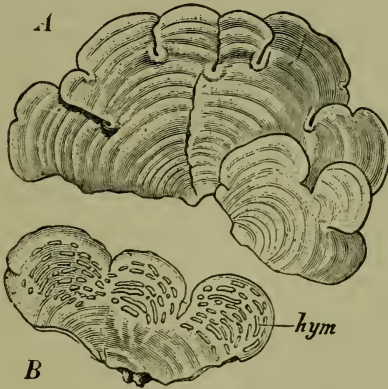


FIG. 337.—Mushroom-lichen (*Cora pavona*, Mushroom-lichen Family, *Coraceæ*). A, top view of fruit-body, natural size. B, under side showing hymenium (*hym*). (Strasburger.)—On trees in the tropics.

Their dual nature, indeed, doubles the difficulty already encountered in trying to associate different types of fungi with their nearest algal kin. It is of course always desirable to express as well as we can our knowledge of resemblances and our views of kinship; but all this may be done effectively by using names like *Ascolichenes* and *Basidiolichenes* (suggestive of relationship between the lichen-fungi and their non-symbiotic kin) and regarding them as forming a series parallel to the series of fungi, much as the fungal series is parallel to the algal.

188. The thallophyte division, lobeworts (Thallophyta) although composed of the humblest members of the vegetable kingdom yet contains, as we have seen, some of man's best friends, and also some of his most harmful enemies, a knowledge of which gained only within recent years has been of incalculable benefit to mankind through improving methods

of agriculture and hygiene. Moreover, a peculiar theoretical interest attaches to thallus-plants from the belief that they include representatives of the forms from which all higher living things have evolved. Since the highest differentiation of the plant-body in thallophytes is for the most part a more or less elaborate lobing, the name lobeworts becomes a significant English equivalent for the group.

In our survey of thallophytic types, several classes were omitted as involving unnecessary complication. Nevertheless, it is hoped that the student has gained some idea of the evolution of thallophytes which may be useful to him in further study. As helping further to a general conception of this multifarious division let us briefly review the main lines of development along which we may reasonably suppose the reproductive and the vegetative system of lobeworts to have been evolved.

With all normal creatures it is as if the controlling purpose of life were the production of well-endowed offspring. Organic evolution seems thus to present a series of attempts to find the best ways of achieving this purpose under all possible conditions of existence.

In the most primitive organisms, typified by *Chroococcus*, there is no differentiation into reproductive and vegetative parts, for the entire individual becomes the offspring by fission. Growth in a way prepares for fission, but it may also be regarded as a preliminary part of the reproductive process. Hence we have here what may be called *vegetative reproduction* in its simplest form. It is a method of propagation admirably adapted to uniformly favorable conditions, such as these little water-plants enjoy; and, so long as favorable conditions prevail, vegetative reproduction is the promptest possible way of taking fullest advantage of them. We therefore see it retained with more or less modification by organisms which have developed other methods as well, as for example in desmids. When the offspring remain attached, as in *Nostoc*, colonies arise, and the colony may propagate vegetatively as if it were an individual by dividing into groups of individuals or hormogonia. If the offspring produced by fission remain not only attached but in intimate organic union, the result is not a colony of unicellular individuals but a multicellular individual composed of subindividual cells. What before was fission has become *cell-division*. Since the growth of multicellular organisms is entirely by cell-division, all growth may be traced back to the preparatory part of reproduction.

We have seen that there is a great difference in the size of vegetable cells, some plants, such as *Mucor*, having the body consist of a single cell of relatively enormous size; and there are certain algæ, less familiar, with a unicellular body very much larger than this. Such extraordinary development of a single cell seems not to have

been a very successful type of structure except in cases where some adventitious means of mechanical support could be depended upon, or, as in *Mucor*, dispensed with because of exceptionally favorable surroundings. But at best the utmost limit of size in a single cell is soon reached, and all large plants and animals consist of innumerable, minute cells. Minuteness of the cell permits as a rule more rapid multiplication, and whether the cells be distinct individuals or the subindividual units of a body-community, minuteness facilitates taking advantage most promptly of all the food available. This principle is strikingly exemplified in bacteria which are at once the smallest organisms known, and the ones capable of most rapid reproduction. Bacteria have been observed to divide at intervals of about a quarter of an hour. At this rate the progeny of one individual would be many millions in a single day. Most plants with a relatively large thallus reproduce vegetatively by setting free minute bits of their protoplasm. Thus most of the aquatic forms, *e. g.*, *Ulothrix*, *Coleochaete*, *Laminaria*, and *Saprolegnia* convert certain of their protoplasts into swarm-spores resembling motile unicellular microbes; while the aerial *Zygomycetes*, *Ascomycetes*, and *Basidiomycetes* produce dust-spores. Both swarm-spores and dust-spores besides being quickly formed and readily set free, have the further advantage from their minuteness of being easily and widely dispersed by currents of water or air, just as was the case with the two halves of the ancestral fission-plants. The larger thallophytes throughout their evolution have thus retained, in their formation of minute non-sexual spores, the most primitive method of reproduction, while vegetating by a single enlarged cell or by a multicellular thallus.

An obvious limitation of this primitive, rapid method of reproduction lies in the fact that it depends upon a continuance of favorable conditions for its success in perpetuating the species, whereas in nature such conditions are often suspended through periods of adversity. A very simple organism like *Chroococcus* living under fairly uniform conditions can bide its time through seasons of cold and drought and resume its very moderate activity when warmth and moisture return. But the chances of injury are decreased and the power of taking prompt advantage of every favorable opportunity to grow, retained, if at the approach of winter, for example, the tender protoplasts harden by getting rid of superfluous water, become invested by a thicker, firmer wall, and store up what food they can instead of spending it all in immediate growth and reproduction. A resting spore such as that of *Nostoc* thus provides for the future.

An improvement upon this simplest type of resting spore is the zygospore in which two protoplasts co-operate to form a single, relatively large cell, well protected and richly stored with food for use at the time of germination. Even in the most primitive cases of co-operative provision for the welfare of offspring, a far-reaching

advantage probably results from the union of different protoplasts. Much research in recent times warrants the belief that the offspring of two parents is benefited by the interaction of the slightly different powers inherited from either side. Invigoration of the offspring and increased adaptability are often plainly shown. Within specific limits, the beneficial effect of a *cross*, as the union of gametes from different individuals is called, has been found to be greater as the parents are less alike or have lived under more dissimilar conditions. Hence plants which can co-operate in the production of offspring while living somewhat apart, make the most successful parents. Traveling gametes, as in *Ulothrix*, enable them to do this. But in order to travel well a gamete must be comparatively small, and when this is true of both gametes as in *Ulothrix*, the resulting zygote cannot be large or very well provided with food, and is therefore at a disadvantage in becoming a resting zygospore. Here then is an opportunity for a useful division of labor in co-operative reproduction. Let one of the gametes remain small for traveling, and let the other become as large and as well stored with food as possible, then the result of their union will be a cross-fertilized zygote of superior capabilities. The fact that the most highly developed groups of algæ, notably the higher Chlorophyceæ and the Rhodophyceæ, have adopted this expedient indicates that the experiment has been a great success among thallophytes wherever it could be fairly tried. Along with the possibility of cross-fertilization is apt to go also the possibility of union between gametes from the same individual. This is distinguished as *close-fertilization*. It is better than no fertilization at all, but seems scarcely more beneficial to offspring than non-sexual reproduction.

Where both gametes are set free, about the best that can be done is the formation of such zygotes as we find in *Fucus*, where the offspring receives no further care after fertilization has taken place. When, on the other hand, as in *Coleochæte*, only the male gamete is set free, the female plant gains the opportunity to act as a nurse to its offspring, giving it additional protection and sometimes food after fertilization until it is well able to take care of itself. This nursing may so affect the development of the offspring that it becomes strikingly different from the form which bears it; then we have an alternation of generations. It is in this new development, which represents the highest achievement of thallophytes in their care of offspring, that we shall find potentialities of the utmost importance for the further development of plants.

Fungi, especially non-aquatic forms, have generally degenerated so far as to lose any power of fertilization they may once have had. This may be because in the more or less isolated situations they usually occupy, co-operative reproduction seldom is possible; and another important reason may be that their dependence upon ready made food throughout life makes invigoration and nursing

of offspring less important for the welfare of the species than rapid and prolific multiplication.

189. The liverworts or hepatics (Class Hepaticæ) take their name from a fancied resemblance of the broad-lobed thallus of certain lower forms to the lobed liver of an animal.

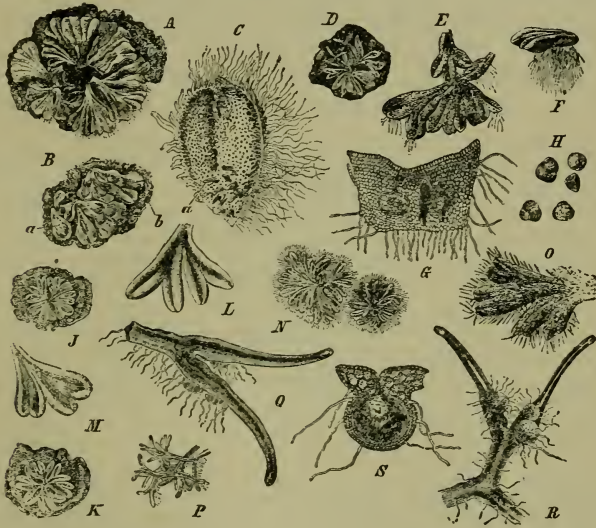


FIG. 338.—Crystalworts (*Riccia* spp., Crystalwort Family, *Ricciaceæ*). A-C, *R. bischoffii*; A, B, clumps of the plant growing on mud, ($\frac{2}{3}$) a, male plant; b, female plant. C, male plant, enlarged, showing the male gametangia or antheridia (a). D-H, *R. minima*. D, plants ($\frac{2}{3}$). E, fruiting plant enlarged, top view. F, a lobe, side view. G, a fruiting lobe, cut vertically through the young "fruit" or sporophyte, still more enlarged. H, spore-groups and spores. J-M, *R. glauca*. J, K, plants ($\frac{2}{3}$). L, M, lobes, enlarged. N, O, *R. ciliata*. N, two plants ($\frac{2}{3}$). O, lobes, enlarged. P-S, *R. canaliculata*. P, plant ($\frac{2}{3}$). Q, fruiting lobes, enlarged, top view. R, same, under side. S, lobe cut vertically through the sporophyte. (Bischoff.)—Plants growing in moist places.

There are about 3,000 species in the group. The most primitive liverworts belong to the group known as crystalworts, occurring in all parts of the world and including many species. Some of these grow floating on the surface of still, fresh water and finally come to lie upon the mud when the water subsides in dry seasons. Other forms grow

more upon moist earth or rocks; in these the thallus shows the broad liver-like lobing especially well, and often appears as a flat rosette (Fig. 338, *A, B*). The more aquatic forms have narrow, much-branched, ribbon-like lobes (*P, Q, R*), and bear a striking resemblance to such algæ as carrageen, while the forms with disk-like thallus (*J, K*), are closely similar to forms of sheath-algæ. In both crystalworts and sheath-algæ a lobe elongates by the continued division of a single terminal cell, which by its occasional forking gives rise to similar branches. Compare Fig. 314 with Fig. 338, *P*.

One consequence of this continuous terminal growth and branching is that when the older parts die and decay the newer parts are distinct plants which have thus arisen by a sort of vegetative reproduction. No swarm-spores are produced, but the thallus often propagates non-sexually by single mature cells in various parts of the thallus dividing like a terminal cell and so producing a tiny bud or *brood-body* which, separating, becomes a distinct plant. The main structural difference between the alga and the liverwort-thallus is a somewhat more advanced differentiation of the latter. As the cells of *Riccia* grow older they may give rise on the lower surface to filamentous pseudo-roots and sometimes scale-like or tongue-like pseudo-leaves, while at the upper surface they may form a firm protective layer. Gametangia arise on the upper surface as in *Coleochæte* but soon become immersed in the thallus through the growth of surrounding cells. Although strictly homologous with the gametangia of *Coleochæte* those of the liverwort are somewhat more elaborate in structure. The male gametangium (Fig. 339, *A-D*) includes a number of cells producing motile gametes each having two flagella like the male gametes of *Coleochæte* and differing from them chiefly in having a more slender body. The female gametangium (*E, a''*) is a flask-shaped multicellular organ containing a single female gamete. A female gametangium thus constructed is distinguished as an *archegonium*,¹ the female gamete being called an *egg-cell*. In some cases both male and female gametangia are borne on the same thallus, that is to say, the thallus is *bisexual*; while in other cases, a thallus has but one kind of gametangium, making it thus *unisexual*. In the bisexual plants close-fertilization can doubtless occur; while in the unisexual, only cross-fertilization is possible. Fertilization is effected by a single male gamete, which because of its slender form is able to make its way down the projecting neck of the archegonium to the egg-cell. The zygote becomes surrounded by a cellulose wall, and through repeated division forms a spherical mass of cells which at first are all much alike. This mass is a rudimentary sporophyte or *embryo*. The inner

¹ Ar-che-go'ni-um < Gr. *arche*, first; *gonos*, generation.

cells each divide into four spores, while the outer cells become somewhat thickened to form a protective case or *capsule* (Fig. 338 Q, R, S). At the same time the basal part of the archegonium grows apace and may become so thickened as to give additional protection to the spores over the winter. When thus developed it is termed a *calyptra*.¹ The spores are set free in spring by the breaking down of the coverings about them, and they germinate by producing a row of cells of which the apical one finally develops a thallus like that already described. We have thus in *Riccia* quite as evident an alternation of generations as we found in *Coleochæte*, both the gametophyte and the sporophyte being somewhat more highly developed.

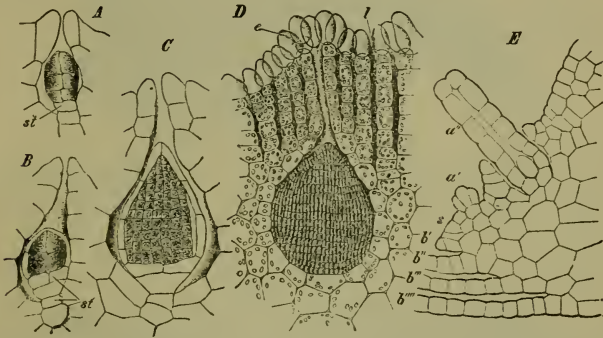


FIG. 339.—Crystalworts. A–C, *Riccia glauca* (²⁶⁰): A, young antheridium; *st*, stalk. B, same, older. C, same, still older, showing the many cells, in which motile gametes (*spermatozoids*) are produced. D, ripe antheridium of *R. minima* (²¹²); *e*, outer cells of thallus; *l*, air-spaces. E, *R. ciliata* (²⁹⁰), growing-tip cut vertically to show the terminal cell (*s*) which by its successive divisions produces all the rest of the plant, the pseudo-leaves (*b'–b'''*) which project from the lower surface of the thallus and hold water for it, and archegonia, very young (*a'*) and full grown (*a''*), ready for fertilization. (Waldner, Kny.)

Both generations are still more highly developed in the umbrella-liverwort (*Marchantia*, Figs. 340–342), a common species growing on the earth in moist localities. The spores germinate much as in *Riccia*, but the thalli are always bisexual. At first, however, both forms are essentially alike and resemble a brood-lobed *Riccia*. From the under side arise numerous unicellular pseudo-roots and many scale-like pseudo-leaves. On the upper surface are often formed numerous brood-bodies of the form shown in Fig. 342, which are produced at the bottom of little cups the whole suggesting a miniature nest full of eggs. By this peculiar form of vegetative reproduction the gametophyte is rapidly multiplied; for as soon as a brood-

¹ *Ca-lyp'tra* < Gr. *kalyptra*, a veil.



FIG. 340, I.—Umbrella-liverwort (*Marchantia polymorpha*, Umbrella-liverwort Family, *Marchantiaceæ*). Male plant bearing antheridia-carriers (*antheridiophores*) ? (Atkinson.)—The plant is common on moist earth, rocks, etc., throughout the world.

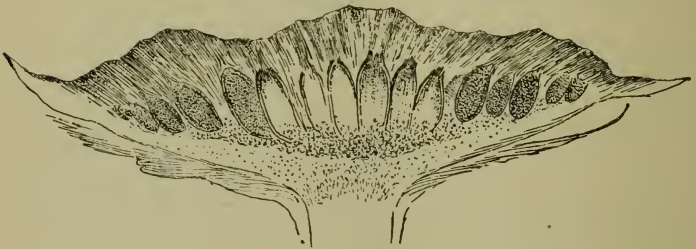


FIG. 340, II.—Umbrella-liverwort. Top of antheridiophore (?), cut vertically to show the cavities containing antheridia. (Atkinson.)

body is carried away by some current of rain water and comes to rest in a favorable spot it sends out pseudo-roots from whichever surface happens to be undermost, and begins to grow into a new thallus. After a while organs distinctive of the sex appear near the growing end, and curving upward become differentiated into a cylindrical stalk and an expanded top. In male plants (Fig. 340 I-IV) this top is a lobed disk on the upper side of which are pits, each containing a multicellular gametangium, from which come slender motile gametes like those of *Riccia* already described. Archegonia arise also on the top of what is at first a somewhat similar

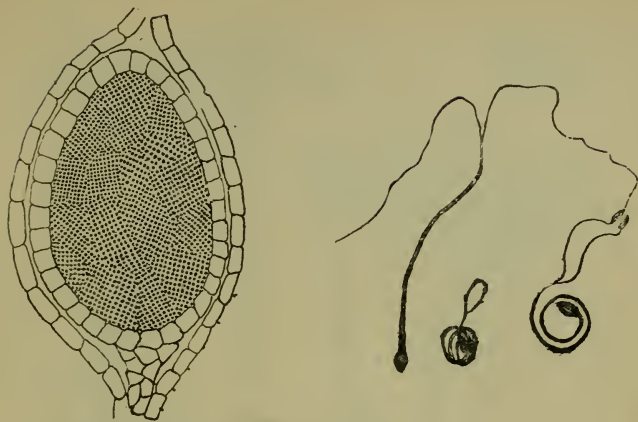


FIG. 340, III.—Umbrella-liverwort. Antheridium (σ^9) showing the numerous cells within which produce spermatozooids. (Atkinson.)

FIG. 340, IV.—Umbrella-liverwort. Spermatozooids, highly magnified. (Atkinson.)

expansion (Fig. 341, I-V), but they come finally to lie underneath through the folding downward of the edges of the lobes. The female gametangia are thus protected by their position, and besides this they are covered by a hanging curtain (Fig. 341, V, p). When the plants are wet with rain or dew the flagellate male gametes are set free and swim or crawl from their elevated home down the stalk and to a female plant; then they climb up its stalk (doubtless aided by numerous hairs thereon) to the archegonia. The fertilized egg-cell gives rise to a spheroidal embryo which develops into a sporophyte resembling that of *Riccia* for a while but finally, by growth of the basal region of the capsule, producing a foot-stalk whose elongation pushes the sporangium through the top of the calyptra (Fig. 341, III). Meanwhile, elongated cells, called *elaters*¹ (Fig. 341, IV), having elastic, spirally thickened walls are being formed among the spores; and when finally the capsule bursts open these elaters, by mechanical movements due to drying, eject the spores and so help to scatter them. The sporophyte is fed entirely by the gametophyte and lives as a parasite, the *foot* or lower end of the stalk serving as an haustorium.

Especial interest attaches to the genus *Anthoceros* (often called horned liverworts from the form of the sporophyte), because these humble plants have preserved structures which help us to understand how all the higher plants may have originated. The game-

¹ E-la'ter < Gr. *elater*, a driver.



FIG. 341, I.—Umbrella-liverwort. Female plant (♀), bearing archegonia-carriers (*archegoniophores*). (Atkinson.)

tophyte develops from a spore in much the same way as happens with the other liverworts described. Even more than in *Riccia* it is like the thallus of *Coleochaete*, notably in possessing but a single chromatophore in each cell, and in having no trace of pseudo-leaves (Fig. 343). The gametangia are completely embedded in the thallus (Fig. 344). The embryo (*E*) develops a somewhat expanded foot which serves to hold the slender sporophyte in an upright position, and functions also as an organ of absorption. As the sporophyte continues to grow, however, it is plain that scarcely more than inorganic materials are taken in; for very soon, above the foot appears an elongating zone of tissue containing much chlorophyll; and this enables the sporophyte to photosynthesize and so, unlike our other liverworts, to be almost self-supporting. If an *Antheroceros* sporophyte should ever develop a root it would no longer need to be even a partial parasite, as now, but could lead an entirely independent existence. The elongating region connecting the capsule and the foot is morphologically a shoot, and thus we have in this little plant the beginnings of a differentiation into three members—sporangium, foot, and shoot. At the center of the shoot and



FIG. 341, II.—Umbrella-liverwort. Archegoniophores (♂) bearing ripe "fruit" (sporophytes), the spore-cases of which are seen projecting beyond the curtains which protected them while young. Two of the spore-cases have burst showing the projecting elaters. (Atkinson.)

extending into the capsule is a column of somewhat elongated cells, which is called the *columella*¹ (Fig. 345, c, c). *Breathing-pores* at the surface permit aëration of the inner cells.

Hepaticæ are plants producing archegonia upon a mostly prostrate and thallic gametophyte which may be variously lobed or branched and often resembles a flattened leafy moss, but which generally has well-contrasted upper and lower surfaces; and there is a sporangium generally dehiscing longitudinally and discharging its spores by means of intermingled thread-like elaters. There are about 3,000 species.

190. The true mosses (Class Musci). The name "moss" is popularly given to any small, matted plant of soft texture

¹ Col-u-mel'la < L. diminutive of *columna*, a pillar.

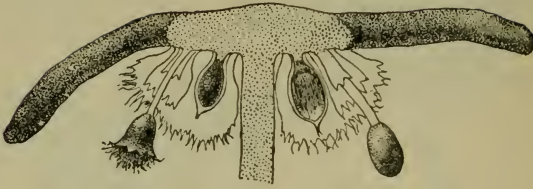


FIG. 341, III.—Umbrella-liverwort. Top of archigoniophore (♂) cut vertically to show the stalked sporophytes of different ages: the two inner ones are still within the enlarged wall of the archegonium; the right-hand one has protruded on its stalk leaving the archegonial wall as a sheath (*calyptra*) at the base of its stalk; while the left-hand one has burst open and is shedding its spores and elaters. (Atkinson.)

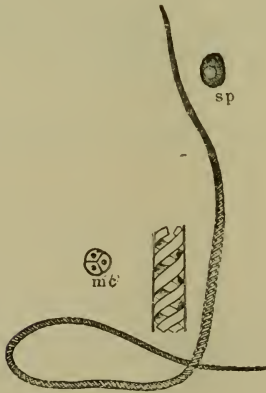


FIG. 341, IV.—Umbrella-liverwort. mc, cluster of young spores; sp, spore. An elater. A piece of the same, showing the elastic spring-like spiral thickening within. All highly magnified. (Atkinson.)

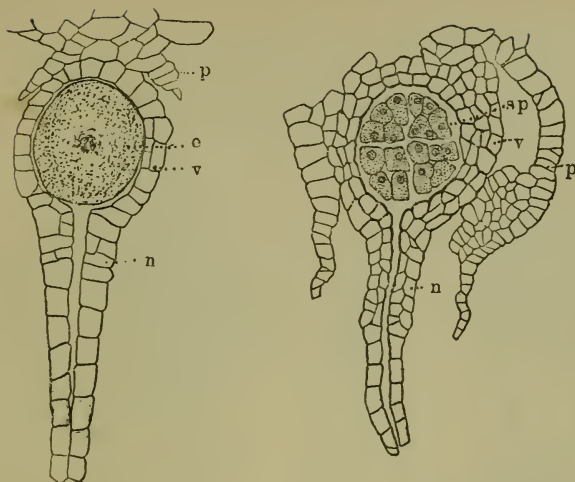


FIG. 341, V.—Umbrella-liverwort. Archegonium (at the left) containing an egg-cell (e); and (at the right) the same, later, containing a young sporophyte (sp). ³⁹⁹ The neck (n) of the archegonium, and its base (v), are shown in both; as also the protective curtain (p). (Atkinson.)

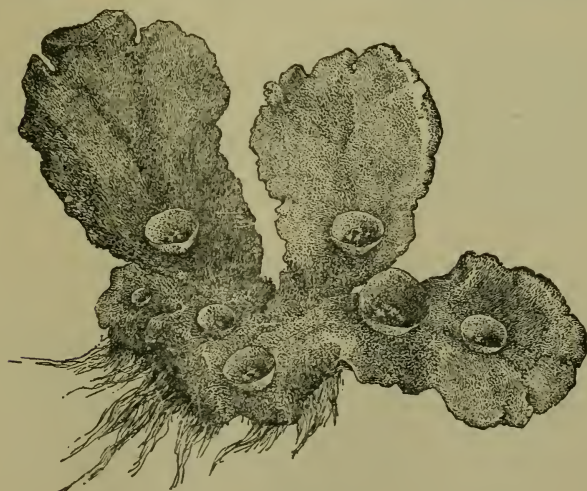


FIG. 342.—Umbrella-liverwort. Thallus (♂) showing on the top seven brood-cups containing minute brood-bodies; and below numerous pseudo-roots. (Atkinson.)

whether it be a seaweed, a lichen, a liverwort, or one of the higher plants. In strictest botanical use it belongs only to about 5,000 species of small green plants which have pseudo-leaves usually arranged spirally on a pseudo-stem, and produce spores in urn-like cases opening mostly by a lid.

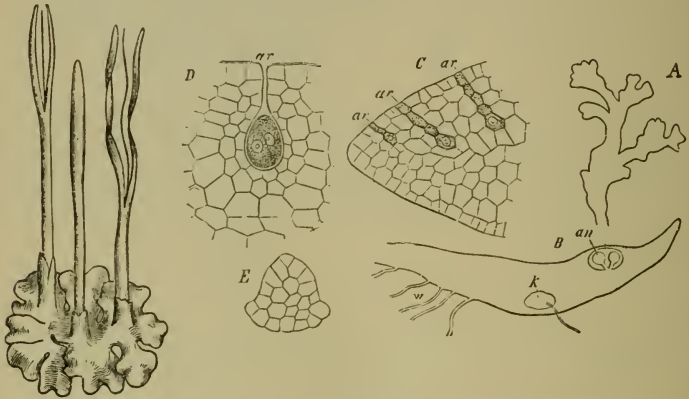


FIG. 343.—Horned-liverwort (*Anthoceros laevis*, Horned-liverwort Family, *Anthocerotaceæ*). Plant (\hat{i}) with three "fruits" (sporophytes). (Luerssen.)—Rather common in moist soil.

FIG. 344.—Horned-liverwort. A, branched thallus. B, thallus (\hat{z}) cut vertically to show the antheridia (*an*), the pseudo-roots (*w*), and a colony of *Nostoc* (*k*) which sometimes lives in the interior of this plant. C, vertical section through tip of thallus (\hat{z}^0) showing beginnings of archegonia (*ar*). D, section through older part of thallus (\hat{z}^0), showing a fertilized archegonium in which the egg-cell has begun to divide. E, embryo of sporophyte showing shoot-part above and foot below. (Hofmeister.)

True mosses resemble liverworts except in having a *mostly erect gametophyte with pseudo-leaves spirally disposed about a pseudo-stem which supports a sporangium dehiscing by a lid and lacking elaters*. These peculiarities are shown in the peat moss (*Sphagnum*, Figs. 227, 346–349) and the cord moss (*Funaria*, Figs. 350–356).

The spores of *Sphagnum* (Fig. 346) germinate in water by sending out a branched thread which resembles a filamentous alga. Sooner or later this thread gives rise at several points to apical cells each of which by its frequent oblique divisions produces a pseudo-stem with pseudo-leaves. If, however, the spore falls upon moist earth, its germination is more like such a liverwort as *Anthoceros* or *Marchantia*, for the initial thread soon develops into a flat-lobed thallus, producing slender pseudo-roots below, and vertical

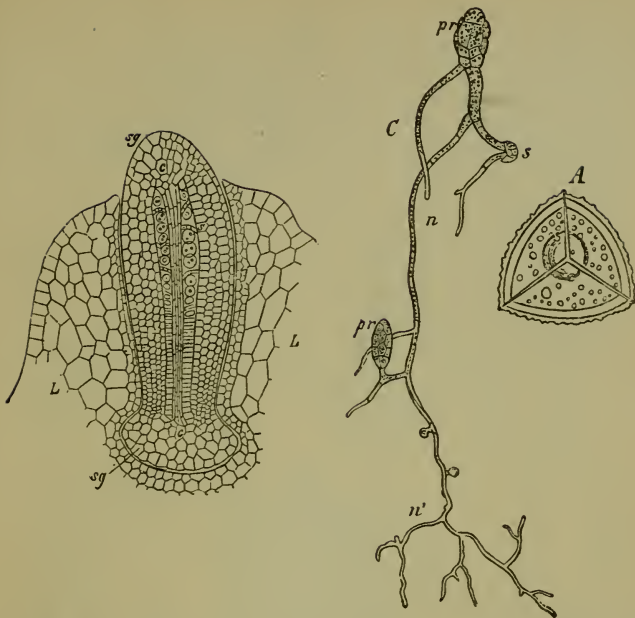


FIG. 345.—Horned-liverwort. Young sporophyte (sg, sg) showing the beginnings of a columella (c, c) and spores (s). L, L, calyptra, 1st. (Hofmeister.)

FIG. 346.—Peat moss (*Sphagnum acutifolium*, Peat moss Family, *Sphagnaceæ*). A, spore, highly magnified. C, spore (s) germinating in water producing a green branched thread or protonema (n, n') from which buds (pr, pr) arise and produce gametophytes. (Schimper.)—Plant common in bogs.

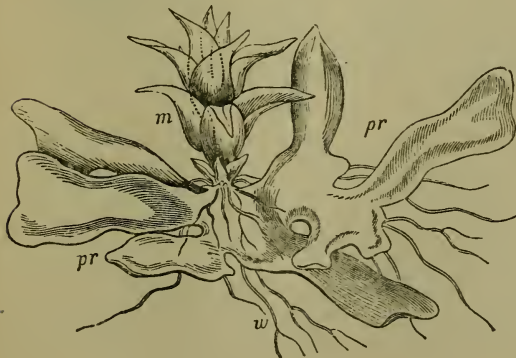


FIG. 347.—Peat moss. Flat protonema (pr, pr) produced on moist earth, giving rise to a gametophyte (m) and pseudo-roots (w), 1st. (Schimper.)

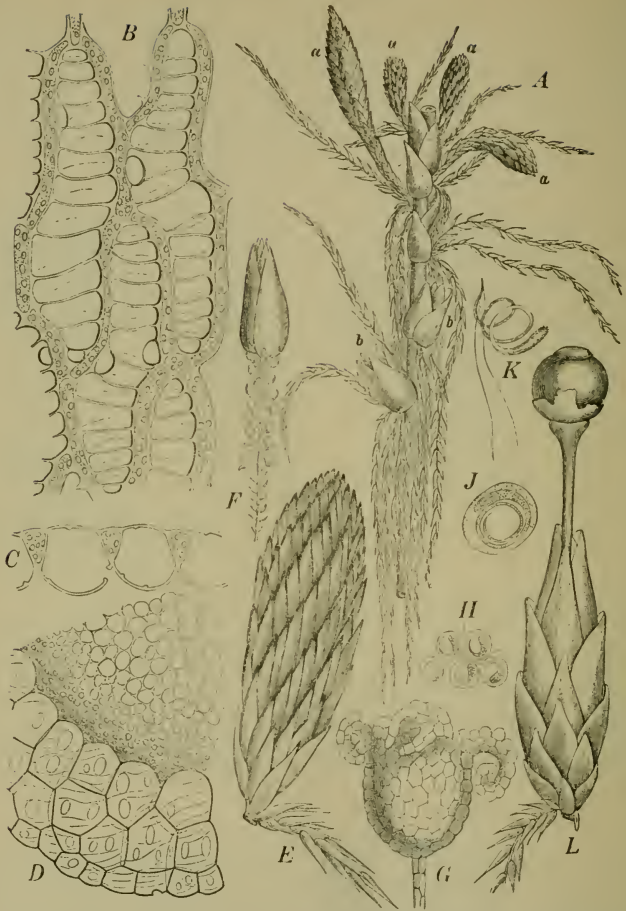


FIG. 348.—Peat mosses. *A*, part of a gametophyte, enlarged, showing male branches (*a, a, a, a*) and female branches (*b, b*). *B*, part of a leaf (*S. cymbifolium*), $300\times$, showing the net-work of green cells surrounding the large ones which fill with water or air. *C*, vertical section through a small piece of leaf (*S. cuspidatum*) showing the small and the large perforated cells, $200\times$. *D*, cross-section through outer part of stem (*S. cymbifolium*) highly magnified. *E*, male branch of *S. acutifolium*, with a vegetative branch at the base, $37\times$. *F*, same, with many pseudo-leaves removed to show the male gametangia (*antheridia*), $31\times$. *G*, an opened and empty antheridium, $260\times$. *H*, five cells containing young spermatozoids, $450\times$. *J*, such a cell nearly ripe, $300\times$. *K*, spermatozoid, $300\times$. *L*, ripe "fruit" (sporophyte) with remains of the archegonium at its base borne on a stalk continuing the axis of the pseudo-stem which bears pseudo-leaves at its base; magnified. (Schimper.)

moss-branches above (Fig. 347). In either case these vertical pseudo-leafy shoots are homologous with the ascending branches of *Marchantia*; but as seen in Fig. 348 they are much more elaborately constructed. At the surface of the stem are developed usually several layers of large cells with very thin walls which are kept from collapsing by ridge-like thickenings, and communicate with one another and with the exterior by pores (*D*) of considerable size. These cells soon lose their protoplasm and then form a sponge-like

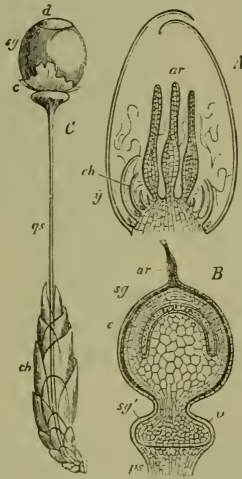


FIG. 349.—Peat mosses. *A*, tip of female branch of *S. acutifolium*, cut vertically to show the archegonia (*ar*), protective leaves (*ch*) still young, and older ones (*y*) acting like bud-scales. *B*, young "fruit," cut vertically to show the sporophyte of which the foot (*sg'*) is fixed in the head (*v*) of the stalk or *pseudopodium* (*ps*), and the spore-case (*sg*) is still enveloped by the calyptra (*c*) bearing above the old neck (*ar*) of the archegonium. *C*, ripe sporophyte of *S. squarrosum*, showing its lid (*d*) and spore-case (*sg*) emerged from the torn calyptra (*c*) and borne upon a pseudopodium pushing it beyond the formerly protecting pseudo-leaves (*ch*). All magnified. (Schimper.)

or wick-like envelope which draws water from below by capillarity, and stores it ready for use. The pseudo-stem is strengthened by a uniform thickening of the walls of an inner cylinder of cells. The pseudo-leaves are made up chiefly of large, thin-walled cells (*B*) like the outer cells of the pseudo-stem, similarly reinforced by ridges and similarly perforated. They supply water to a net-work of small cells containing numerous chromatophores in which the work of photosynthesis is carried on. Vegetative reproduction so far as known takes place only through the separation of branches

by decay of the older part. Male gametangia (*F*) are borne on the side of special branches which may be recognized as having their leaves more crowded and often reddish (*A* and *E*). The numerous male gametes (*K*) are more elongated and more spiral than those of *Marchantia*, but are otherwise similar. Archegonia are produced at the tip of short branches surrounded by comparatively large leaves (Fig. 349, *A*). After the female gamete has been fertilized, the axis of the branch elongates into a stalk bearing at its tip the enlarging sporophyte enveloped in the calyptra (*B*, *C*). The sporophyte is differentiated into a short, thick foot (*sg'*) and a capsule in which there is a central mass of large air-filled cells surmounted by

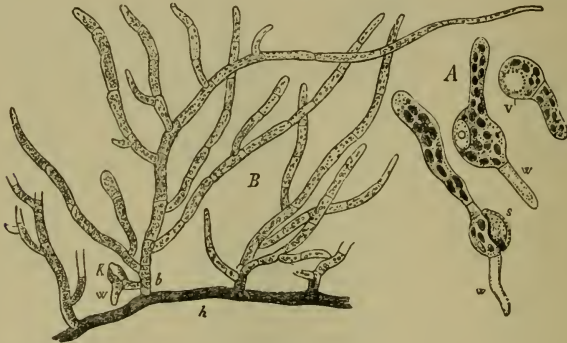


FIG. 350.—Cord-moss (*Funaria hygrometrica*, Cord-moss Family, *Funariaceae*). *A*, germinating spore ($4\frac{1}{2}$) showing a sap-filled cavity or vacuole (*v*) a pseudo-root (*w*, *w*), and the old outer spore-wall (*s*). *B*, further development of the thread (protonema) which comes from the spore, showing the main thread (*h*) and side branches from one of which (*b*) is growing a bud (*K*) destined to form a pseudo-stem and pseudo-leaves, and already sending out a pseudo-root (*w*), $7\frac{1}{2}$. (Sachs.)

a hollow dome-like mass of spores, and the whole inclosed in a firm wall of small, hardened cells. A horizontal ring of these becomes finally so brittle as to render the top of the capsule separable like a lid (*C*, *d*). As the capsule enlarges, the calyptra (*c*) is ruptured, and as the spore-case dries its form changes perceptibly from spherical to subcylindrical but without elongation. The result is that the inner air-filled cells below the spore-mass are so much compressed, that a degree of tension is soon reached sufficient to blow off the lid with a perceptible report and scatter the spores to a distance of several inches. Elaters are thus unnecessary.

In *Funaria* (Figs. 350–356) the spores when germinating (Fig. 350) produce a much-branched thread which makes a bright green, felt-like layer on moist earth. From this thread at many places arise directly vertical pseudo-shoots each consisting of an axis bearing

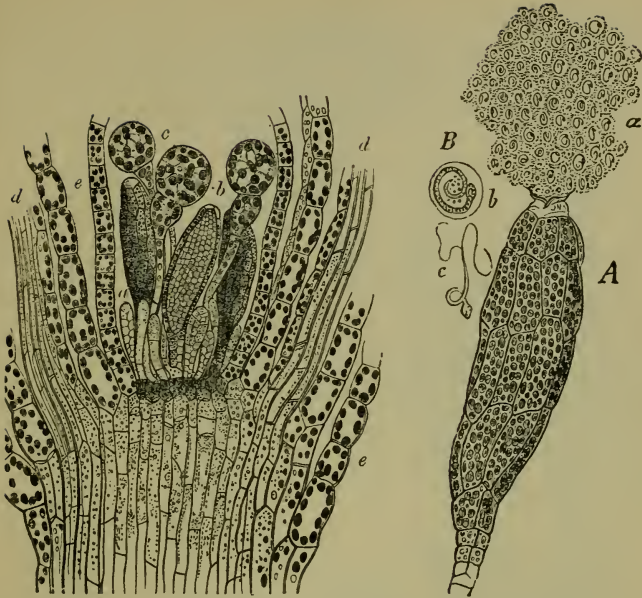


FIG. 351.—Cord-moss. Tip of a male gametophyte cut vertically to show the male gametangia (antheridia) of various ages from young (*a*) to almost full-grown (*b*); also paraphyse (*c*), protective pseudo-leaves (*d*) and foliage pseudo-leaves (*e*), ²⁰⁰/₁. (Sachs.)

FIG. 352.—Cord-moss. *A*, antheridium discharging its spermatozoids (*a*), ²⁵⁰/₁. *B*, *b*, spermatozoid not yet escaped from its cell-wall; *c*, the same swimming freely, ²⁵⁰/₁. (Sachs.)

delicate pseudo-roots from the lower part, pseudo-leaves arranged spirally along the sides, and at the tip either male or female gametangia (Figs. 351–353). The gametophyte in *Funaria* is thus of somewhat simpler constitution than in *Sphagnum*. The cellular structure also shows less differentiation. On the other hand, the sporophyte is more complex. As shown in Figs. 354, 355 the foot becomes a long stalk, and the capsule develops several different tissues. The calyptra ruptures transversely at the base and is carried up on the capsule as a hood which falls off after the capsule is mature. A cylindrical spore-layer surrounds an inner mass of cells and certain inner cells of the lid break so as to leave behind on the capsule after dehiscence a fringe of teeth, called the *peristome*.¹ Its function is to protect the spores and keep them from being blown out by a light breeze which would carry them only a short distance.

¹ Per'i-stome < Gr. *peri*, around; *stoma*, mouth.

In dry weather, after calyptra and lid have fallen, a strong wind will shake the capsule on its slender elastic foot-stalk, and scatter the spores out between the teeth. The most remarkable difference between the sporophytes of *Funaria* and *Sphagnum* is that the former like that of *Anthoceros* contains chlorophyll and is thus able

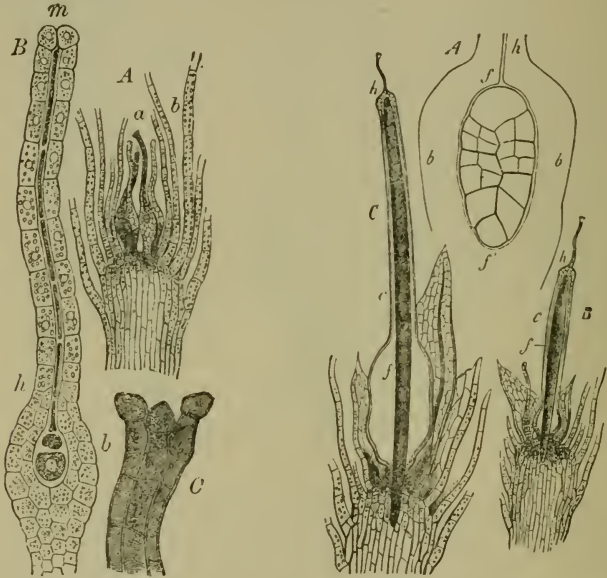


FIG. 353.—Cord-moss. *A*, tip of a female gametophyte cut vertically to show the female gametangia (archegonia) surrounded by pseudo-leaves (*b*), $\frac{50}{1}$. *B*, an archegonium showing the swollen lower part (*b*) containing an unfertilized egg-cell, the neck (*h*) with its orifice (*m*) still closed and the axial row of cells being converted into mucilage, $\frac{400}{1}$. *C*, orifice of an archegonium after fertilization, with its cell-walls colored dark red, $\frac{500}{1}$. (Sachs.)

FIG. 354.—Cord-moss. *A*, embryo of sporophyte (*f, f'*) still within the archegonium (*b, b*), cut vertically, *h*, being the neck, $\frac{271}{1}$. *B, C*, more advanced stages in the development of the sporophyte (*f*) covered by the old archegonium or calyptra (*c*) upon which the neck (*h*) still remains, $\frac{200}{1}$. (Sachs.)

to manufacture a large part of its own food while the latter is like the sporophytes of *Riccia* and *Marchantia* in being entirely parasitic upon the gametophyte. Inorganic materials absorbed by the slender pseudo-roots of the gametophyte are supplied to the foot of the stalk and thence conducted to the photosynthetic tissue of the capsule. Conduction takes place mainly through a *central*

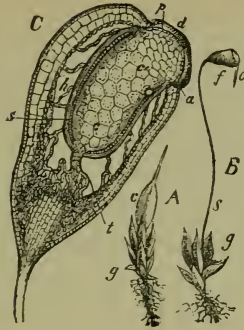


FIG. 355.—Cord-moss. A, female gametophyte bearing pseudo-leaves (*g*) and a calyptra (*c*) still protecting a young sporophyte, 1. B, same, at a later stage when the calyptra (*c*) has been carried up as a hood on top of the spore-case (*f*) by the elongation of the stalk (*s*) of the sporophyte, 1. C, spore-case or capsule, enlarged and cut vertically to show the lid (*d*), a connecting row of cells, the *annulus* (*a*), a row of projections, the *peristome* (*p*) covering the mouth, a central mass of cells, the *columella* (*c, c*), air spaces (*h*), and the layer of spores (*s*), 2. (Sachs.)

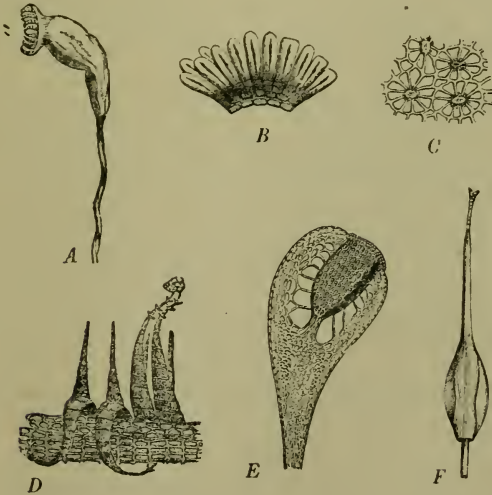


FIG. 356.—Cord-moss. A, spore-case, showing peristome and twisted stalk. B, cells of the annulus. C, breathing-pores (*stomata*). D, teeth of the peristome. E, spore-case cut vertically, F, young spore-case still covered by the calyptra. Various magnifications. (Baillon.)—Common on waste or barren soil.

cylinder which consists of cells elongated in the direction of the axis and with pointed ends which interlock. Such a tissue is termed *prosenchyma*¹ in contrast with *parenchyma*² which is composed of cells not much elongated, and without pointed ends, as is the case with nearly all the tissues we have so far studied. At the surface of the sporophyte is a protective layer of cells, distinguished as the *epidermis*;³ the looser, mostly green tissue which lies between the epidermis and the central cylinder being termed the *cortex*.⁴ In the epidermis near the base of the capsule occur peculiar openings called *stomata*⁵ communicating with the internal air-spaces of the cortex. Each opening is guarded by two special cells which might be likened to lips. It is by means of these breathing pores that the interior tissues are aerated. Whereas in the sporophyte of *Sphagnum* we have a very simple sporangium from which there is differentiated a small foot and the merest hint of a short connecting stem; in *Funaria* we find a long slender stalk, homologous with the foot, bearing a capsule made up of the sporangium partly inclosed by an urn-like mass of tissue which we may call the shoot. *Funaria* represents about as high development of the sporophyte as moss plants have ever attained.

191. The bryophyte division, mossworts (Bryophyta) comprises only the two classes liverworts (*Hepaticæ*) and true mosses (*Musci*) which in general are often called mossworts.

Mossworts show us possibly how green earth-plants first stood upright. The occasion for their vertical development may have arisen when certain flat algæ more or less like *Coleochæte*, became stranded and had to form spore-cases as best they could before the mud completely dried. If some of them were able to make a small globular capsule this might be fed entirely by the thallus, but being immersed within it could not ordinarily scatter the spores very far. Their descendants perhaps give us *Riccia*. Others we may suppose, hit upon the plan of elongating the capsule upward, giving it some chlorophyll to utilize the sunshine, and thus enable it to make more spores and scatter them farther—all with much less dependence upon the slender resources of the little nurse. The result would be a liverwort of the *Anthoceros* type which solves the problem of uplifting its spores in the simplest way. Various more or less com-

¹ Pros-en'chy-ma < Gr. *pros*, before; *en*, in; *cheo*, pour.

² Par-en'chy-ma < Gr. *para*, beside. A term applied by the earlier anatomists to the main tissue of such organs as the lungs which they supposed was formed of material poured in beside the vessels and nerves that had been "poured in" before.

³ Ep-i-der'mis < Gr. *epi*, upon, *i. e.*, outer; *derma*, skin.

⁴ Cor'tex < L. *cortex*, rind or bark.

⁵ Sto'ma < Gr. *stoma*, a mouth.

plicated expedients were adopted by plants akin, and the outcome is seen in such liverworts as *Marchantia* where small capsules are made to hang from the branches of vertical thallus-lobes, or in mosses like *Sphagnum* where a similar though erect capsule is borne on an even more elaborately developed vertical branch of the nurse-plant, which may live for many years. The most complicated ways of securing elevation are found in the mosses typified by *Funaria*, where both the nurse-plant and the spore-plant develop vertically as far as they can—the latter, as it were, standing upon the shoulders of the former—and by photosynthesis making food for the spores. But the utmost height attained by these methods is only a few inches; the foundation is weak. Growth which has to be accomplished during a short season of moisture or by improving brief periods of wet weather, must naturally for the most part be limited to rather soft tissue and small organs. Mosses often grow crowded together like *Sphagnum* and thereby give mutual support and store a supply of water for use in common; but although axes of considerable height may be built in this way, the offspring is not much benefited, for the crowded tops of the axes form virtually a new surface above which is the only height effective for scattering the spores. It is plain that effectiveness is not always favored by complexity.

The view suggested above that mossworts have evolved directly from algae akin to *Coleochæte*, although regarded as probable by many botanists, receives no support from the study of fossil plants; and is by no means the only view consistent with what is known of the plants of to-day. Thus, it is quite possible that our mossworts may be the more or less simplified descendants of larger plants widely different from any we know, which themselves were descended from seaweeds very unlike *Coleochæte* and of which we have now no trace. Not a few facts point to this conclusion; but the truth is we are much at a loss as to what to believe regarding the origin of mossworts, and the question seems likely to remain long a puzzle. Meanwhile, the hypothesis of direct algal origin may help us to imagine something of the nature of the problems which had to be faced by the earliest land-plants, whatever these plants may have been; and may suggest, at least by analogy, something of the means that may have proved most effective.

When we remember that Bryophytes have had to depend almost entirely upon superficial moisture it is not a little remarkable how much they have been able to accomplish for the welfare of their offspring. In spite of serious difficulties attending the use on land of reproductive arrangements adapted to aquatic life, these little plants very commonly achieve the benefits of cross-fertilization, and of a considerable period of nursing for their young. All this is made possible by the formation of archegonia which not only protect the protoplast of the egg, but by further development shield the young spore-plant all through its time of special tenderness.

Finally, in a considerable variety of ways means are provided for scattering the spores as far as possible and under the most favorable conditions for giving the new plants a good fair start.

Bryophyta are distinguished by having archegonia on lobed or pseudo-leafy gametophytes which bear sporophytes lacking true roots, stems, and leaves.

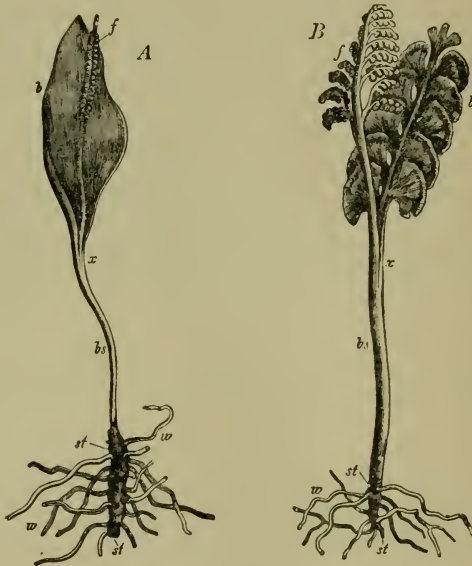


FIG. 357.—Adder-tongue, *A*, and grape-fern, *B* (*Ophioglossum vulgatum* and *Botrychium Lunaria*, Adder-tongue Family, *Ophioglossaceæ*). Sporophytes showing roots (*w*), stem (*st*), leaf-stalk (*bs*), point (*x*) at which leaves branch to form a foliage-blade (*b*) and a spore-bearing division (*f*). Two-thirds natural size. (Sachs).—Not very common but widely distributed in mostly open ground.

192. The ferns (Class Filicinæ). Our most primitive ferns are represented by adder-tongues (*Ophioglossum*) and grape-ferns (*Botrychium*, Fig. 357).

Unfortunately their life-histories are not yet fully known owing to peculiar difficulties in tracing the germination of the spores. The gametophyte is subterranean (Fig. 358) and at least when mature it is saprophytic. Except for its lack of chlorophyll it is not a little like the gametophyte of *Riccia*. The gametophyte of

certain ferns closely related to the above more nearly resembles that of *Anthoceros*, and is holophytic, as we may suppose to have been the case with the original fern-ancestor. When we compare the sporophytes of an adder-tongue and a horned liverwort, however, so many striking differences appear, that it may at first seem hopeless to think of homologizing the parts. Indeed, we have in ferns true leaves, stems, and roots, no trace of which appear in any liverwort. But we have sporangia in both, and in the growing zone of *Anthoceros* we have a cylindrical meristematic organ suggesting possibilities of much further differentiation. If the sporangium of



FIG. 358.—Grape-fern. *A*, gametophyte (prothallus) cut vertically to show the antheridia (*an*), the archegonia (*ac*), and the pseudo-roots (*w*), ^{5p}. *B*, lower part of a young sporophyte dug up in September, cut vertically to show the stem (*st*) and leaves (*b*, *b'*, *b''*), ^{2p}. (Hofmeister.)

FIG. 359.—Adder-tongue. Upper part of spore-bearing division of leaf (¹), cut vertically to show the tip (*s*), the spore-cavities (*sp*), the places (*r*) where a slit is formed to free the spores, and the woody strands or fibro-vascular bundles (*g*) which strengthen and conduct sap. (Sachs.)

Anthoceros were enlarged and instead of elaters produced sterile tissue between groups of spores forming two rows on either side of the columella, the resulting organ would be a flat spike of sporangia like that of *Ophioglossum* (Fig. 359). What may have happened is that in very ancient times, before the age when coal plants flourished, a liverwort something like an *Anthoceros* did evolve a root from the lower end of its growing zone, which made possible an expansion of the green tissue above, while this in turn helped to bring about the formation of two rows of globular sporangia making a flat cluster as already described. Such an expanded member

bearing sporangia would be a spore-sac-leaf, while the cylindrical elongating zone from which it arose would now be a true stem. Here would be about as simple a fern as we can imagine; but it would have all the essential features, and it is not inconceivable that higher forms might have been evolved from it. Suppose, for instance, that the sac-leaf member forked into two branches, and let one of them be expanded so as to secure as much sunlight as possible and be devoted exclusively to photosynthesis, while the other branch instead of doing much food-making was narrower and developed as many spores as possible from food that the expanded branch furnished. Suppose further that the stem lived on from year to year, sending new roots into the earth and new leaves into the air, then our plant would have become like an adder-tongue fern.

The striking differences between liverworts and ferns of any kind have so impressed not a few botanists as to have made them doubt the likelihood of ferns having originated in the manner above suggested; and this doubt has gained strength from the fact that the most ancient fossil ferns are of highly complex organization, being often tree-like in form, and so even less like liverworts than the presumably degenerate ferns with which we are most familiar to-day. Moreover, if modern liverworts are also to be regarded as degenerate plants—a view, as we have seen, for which there is some evidence—the gap which separates them from ferns is even wider. It may well be true that ferns evolved directly from seaweeds in which a clearly marked alternation of generations had developed as in certain rather highly organized red algæ living to-day. On this supposition, however, we are still left with the difficulty of imagining the stages through which a seaweed could pass in fitting itself for life on land as a tree. Here fossils cannot help us, for we have none at all intermediate between seaweeds and ferns. Since, however, there are undoubted fundamental resemblances between a *Coleochæte*, an *Anthoceros*, and an *Ophio-glossum*, these may offer at least a possible clue as to how the great changes in question may have taken place.

Grape-ferns would be readily derivable from adder-tongues by further branching of the two leaf branches, which in the fertile or sporangial segment might result in each sporangium being borne on a little stalk or branchlet of its own. We may well imagine that wonderful possibilities of development lay before such a type as this as soon as it established itself on the edges of swamps or on land where food and moisture abounded. It could then afford to delay the production of spores until it had built a thick, tall stem, by means of leaves made larger and larger year after year and devoted entirely to making food so that a surplus might be stored in the stem. Finally, a very large number of sporangia might be produced upon much-branched spore-sac-leaves; and these, held high in the air, could scatter their spores most effectively.

We know that during the coal age many tree-ferns like the *Pecopteris* shown in Fig. 277 (page 299), apparently near of kin to the adder-tongues, produced stout trunks bearing a crown of ample leaves nearly twenty meters above the ground.



FIG. 360.—Tree-Ferns and Herbaceous Ferns. (Baillon.)

At the present day tree-ferns such as the one shown in Fig. 360 abound in moist, warm regions, although the ferns most common in northern lands are more like the smaller ones shown in the same illustration. Thus it would appear that a certain amount of degeneration has attended the adaptation of ferns to the more stringent conditions of cold

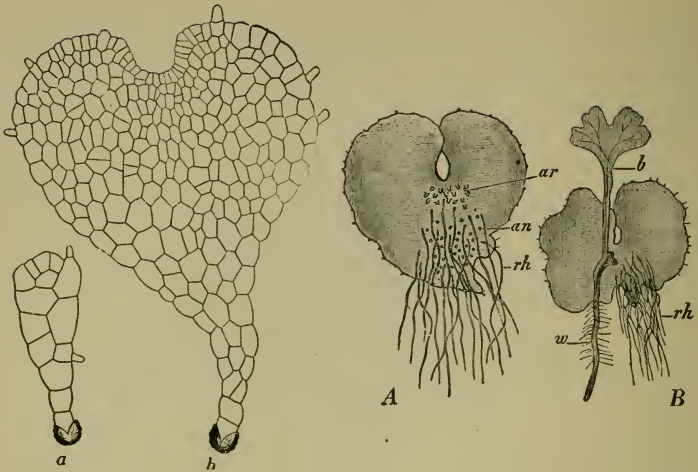


FIG. 361.—Male-fern (see also Fig. 170). *a, b*, germination of spores showing formation of young gametophytes (prothallia), $\frac{6}{1}$. (Luerssen.)

FIG. 362.—Male-fern. *A*, prothallus, lower side, showing archegonia (*ar*), antheridia (*an*), and pseudo-roots (*rh*), $\frac{1}{1}$. *B*, same, after production of young sporophyte, showing first leaf (*b*) and first root (*w*). (Schenck.)

or dry climates. One of our best developed northern ferns is the *Aspidium* already studied (Fig. 170, page 179).

As shown in Figs. 361, 362, the spore in germinating produces first a row of cells, the terminal one of which soon divides in such a way as to produce a flat, heart-shaped thallus, which is rich in chlorophyll and sends out from the under side of the older part a number of pseudo-roots. By means of these the rear end is firmly attached to the earth while the lobed end slightly ascends. Finally on the lower surface appear archegonia near the tip, and male gametangia toward the base. The latter and their motile gametes are of the form shown in Fig. 363. The gametes, it will be noticed, are somewhat more highly developed than any found among the Bryophyta. That is to say, the spiral is larger and the flagella are more numerous. The archegonia, which are like the one shown in Fig. 364, differ but little from the others already studied. After fertilization the egg-cell divides into four (Fig. 365, *A*). The uppermost of these, by its further growth and division produces the foot (*f*) the function of which is to act temporarily as an haustorium for the embryo-sporophyte, and to push it out of the gametophyte and on to the earth. One of the lateral cells develops into the first root (*w*) while the opposite one becomes the growing point of the stem, and

the lowest cell gives rise to the first leaf. A later stage in the development of these parts is shown in Fig. 365, *B*. Covering the growing tip of the root, somewhat as a thimble covers a finger tip, is a protective organ termed the *root-cap*. Such a thimble-like covering continually renewed by the meristem which it protects is characteristic of true roots. Root-hairs for absorption are soon developed. The leaf (Figs. 365, *B*, 362, *B*) soon differentiates into petiole and blade, and curves so as to drag the tender leaf-tip up out of the ground. An extreme curving of this nature performed by every

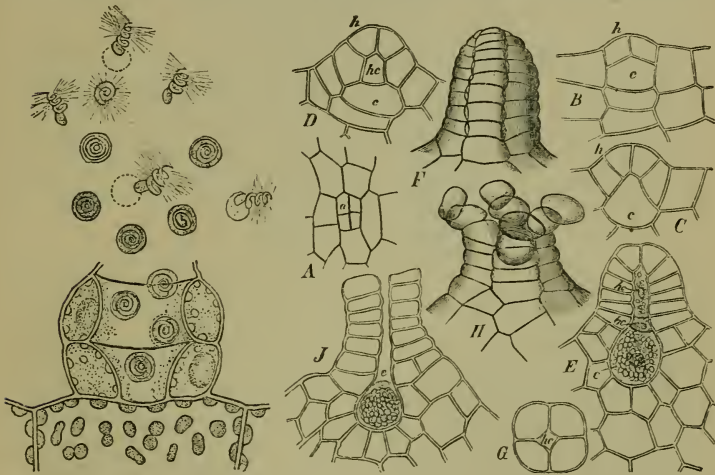


FIG. 363.—Fern Antheridium (*Pteris* sp., Polypody Family, *Polypodiaceæ*), $3\frac{1}{2}\mu$. (Luerssen.)

FIG. 364.—Fern Archegonium (*Osmunda* sp., Royal-fern Family, *Osmunda-cææ*). *A*, first stage viewed from above, $2\frac{1}{2}\mu$. *B*, same, cut vertically to show the central cell (*c*) from which the egg is formed, and the cells (*h*) which give rise to the neck, $1\frac{1}{2}\mu$. *C-E*, older stages, showing canal cells (*hc*, *bc*). *F*, neck with mouth closed. *G*, same, top view. *H*, same, mouth open. *J*, same as *E* but with egg-cell (*e*) ready for fertilization. (Luerssen.)

branch of the developing leaves gives us the familiar crozier-like veneration characteristic of ferns. In the axis of the stem soon appears a central cylinder of prosenchyma which developing also in the root and the leaf serves as a channel for conducting solutions absorbed by the root to the green food-making parts of the leaf, and likewise dissolved nutrients from the leaves to the stem and the root where they may be used in growth or stored as a reserve. As the stem grows larger, and leaves and roots become more numerous, its central cylinder becomes a hollow cylindrical net-work of broad flat meshes (Fig. 366), giving off slender branches to the

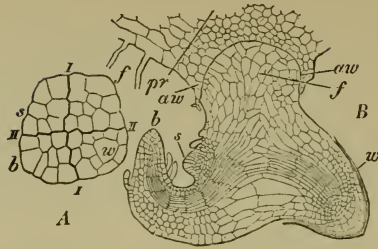


FIG. 365.—Fern Embryo (*Pteris* sp.). *A*, embryo removed from archegonium and cut vertically to show the first dividing wall (I, I) and the walls at right angles to this (II, II) whereby the fertilized egg-cell was divided into quadrants of which one (*f*) by further cell-division and growth becomes the foot, another (*s*) the stem, another (*b*) the first leaf, and another (*w*) the root. *B*, embryo still further developed but still attached to the prothallus (*pr*), cut vertically to show the foot (*f*) embedded in the archegonium (*aw*), the root (*w*) with its tip protected by a root-cap, the stem (*s*) and the incurved leaf (*b*). Magnified. (Hofmeister.)

leaves and roots. When a leaf falls off it leaves a scar upon which one may see clearly traces of these slender branches which went into the petiole.

In the trunk of a tree-fern (Fig. 367) the prosenchyma is particularly well-developed and shows plainly a differentiation of tissues which is characteristic of all plants higher than bryophytes. Each strand is here found to contain thick-walled woody fibers (*FB*) and larger cells (*VS*) called *vessels* which have thin walls variously strengthened by ridges. These vessels correspond to the "pores" found in the wood of oak and other trees we have already studied. Such strands are called *fibrovascular*¹ *bundles*, and the plants or parts containing them are said to be *vascular*. The ultimate branches of the framework of a leaf are often nothing but single vessels. Besides the woody and the vascular tissues, which serve mainly for conducting fluids, ferns and higher plants often develop strands or layers of hardened, thick-walled cells whose function is mainly to give strength or afford protection. Such tissue is termed *sclerenchyma*² in general, or sclerotic parenchyma or prosenchyma in particular. An outer layer of the cortex as at (*FL*) often becomes sclerotic and thus contributes much additional strength to a columnar organ. The parenchyma of a fern-stem serves very largely for the storage of reserve food in the form of starch. From the epidermis of various parts may arise hair-like or scale-like outgrowths which serve mainly to protect organs that are very young or especially need to be covered. Whereas in multicellular plants

¹ Fi'bro-vas'cu-lar < L. *fibra*, a fiber; *vasculum*, a small vessel.

² Scler-en'chy-ma < Gr. *skleros*, hard.



FIG. 366.—Fern Stems (*Aspidium* spp.). *A*, underground stem (*rhizome*) of *A. Filix-mas* with rind removed to show the net-work of fibrovascular bundles. *B*, one mesh of this net-work enlarged to show the branches which enter a leaf to form its framework. *C*, cross-section of a rhizome (*A. coriaceum*) slightly enlarged to show the cylindrical fibrovascular system formed of two main strands, the upper (*o*) smaller than the lower (*u*), and the finer branches of these which enter the leaves. *D*, the fibrovascular cylinder of the same, removed and laid out flat after splitting the lower strand (*u*, *u*) in halves, leaving the upper strand (*o*) in the middle unbroken, as also the finer strands (*b*, *b*, *b*, *b*) which enter leaves and roots, and the larger strands (*x*, *x*, *x*, *x*, *x*) which enter branches of the stem. (Sachs, Mettenius.)

of simpler structure it was sufficient to distinguish merely different tissues, in the higher plants the differentiation has progressed so far that *tissue systems* must be recognized. Thus we have a *tegu-*
mentary system consisting of the epidermis and its outgrowths, a *vascular system* comprising the vascular bundles, and a *fundamental system* consisting mainly of parenchyma and including meristem, the green cells accessible to light, and the pith-like internal parts in which food is stored.

The stem of an *Aspidium* (Fig. 170) as of nearly all our native ferns, remains mostly underground as a more or less horizontal rhizome. A considerable amount of starch stored over the winter in the fundamental tissues of this perennial organ, accounts for the rapid unfolding of the leaves in spring. Some of the leaves are entirely vegetative; other leaves bear numerous minute sporangia in clusters upon the back, each cluster being covered by a shield-like out-growth (Figs. 170, 3-5). A peculiar part of the sporangium is a ring of thickened cells running along the back (6*c*), which when

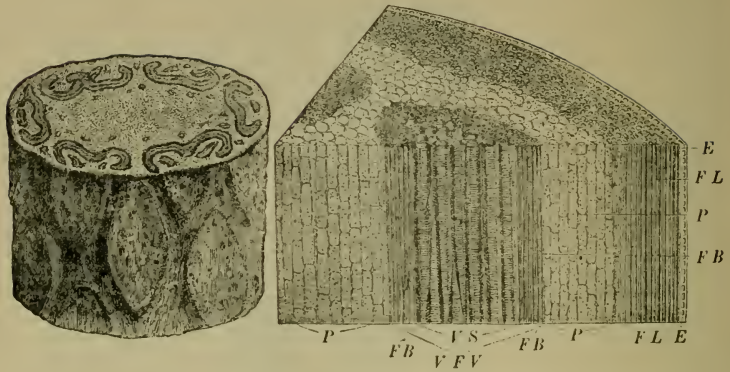


FIG. 367.—Tree-Fern. Section of trunk. A wedge cut from the same, magnified to show the pith (*P*), a fibrovascular bundle (*V F V*) with its sclerenchyma (*F B*) and vessels (*V S*), and the rind (*F L*) and epidermis (*E*). (Baillon.)



FIG. 368.—Fern Brood-bud (*Aspidium Filix-mas*) on base of leaf-stalk, ♀. (Luerssen.)



FIG. 369.—Scouring-rush (*Equisetum arvense*, Scouring-rush Family, *Equisetaceæ*). 1, spore-bearing shoot with erect branches ending in cone-like clusters (*a*) of *sporophylls* or sporangia-bearing leaves. 2, vegetative shoot, with underground stem bearing tubers (*a*) gorged with food. 3, a sporophyll with sporangia, enlarged. 4, same, showing sporangia split open after discharging the spores. 5, 6, 7, spores with "elaters" wrapping closely, or more or less spread. (Wossido.)—Common in moist places.

ripe suddenly straightens, so as to rupture the thin wall in front and eject the spores. Sporangia of this type although differing in many ways from those of the adder-tongue and its kin, are doubtless homologous with them, for students of ferns find a very complete series of intermediate forms connecting the extremes. Vegetative

reproduction is sometimes accomplished in ferns by the formation on various parts of buds which fall to the ground and take root (see Fig. 368).

Filicinae in general agree with the ferns described in being *archegoniate, vascular plants, forming true roots and stems, and having alternate leaves upon which are borne sporangia that discharge their spores without elaters*. The number of species is reckoned at about 3,000.

193. The scouring-rushes (Class Equisetinæ) are represented in modern times only by comparatively small plants of the genus *Equisetum* (Fig. 369)—about 25 species—which, however, are closely related to numerous gigantic rush-like coal plants, typified by the genus *Calamites* (Fig. 277, 2).

In *Equisetum* cross-fertilization is accomplished by having male and female gametophytes which, as shown in Figs. 370, 371, differ considerably from one another, the female being much the larger and suggesting somewhat by its pseudo-leaves the nurse-plant of a moss. The sporophyte differs remarkably from that of any fern in the comparatively great development of the stem. This is hollow except at the nodes, and performs nearly all the work of photosynthesis.

The roots do not differ essentially from those of ferns, but the foliage leaves are reduced to toothed sheaths serving chiefly to protect the tender regions of the stem. The fibrovascular bundles of the stem are arranged in a ring, and in some forms (mostly extinct) a cambium like that of higher plants is developed which gives rise to successive rings of tissue. Such additional material by which increase in thickness is accomplished takes the name of *secondary tissue*, to distinguish it from the *primary tissue* formed by the primary meristem. The epidermis is often so filled with silica or flint, as to render the plants useful for scouring metal, and this accounts for the popular name. Certain subterranean branches of the rhizoma (*a*, Fig. 369) may have their fundamental tissue gorged with reserve food, and thus form tubers which feed new growth in spring, and may sometimes serve as a means of vegetative reproduction. Among the vertical branches there is often a differentiation into the purely vegetative and the purely reproductive. The latter terminate



FIG. 370.—Scouring-rush. A, male gametophyte or prothallus (σ^8) showing antheridia (a, a). B-E, spermatozoids of various ages, much more highly magnified. (Hofmeister, Schacht.)

FIG. 371.—Scouring-rush. Female gametophyte or prothallus (σ^8) showing archegonia (a, a, a) and pseudo-roots (h). (Hofmeister.)

in a cone-like aggregation of whorled sac-leaves. Each of these has a stalk ending in a shield-shaped expansion, six-sided from pressure. Behind each angle of the shield is a large sporangium dehiscing by a longitudinal slit (3, 4). The spores are peculiar in having four slender arms which close tightly about the spore when moist, and spread apart in drying, thus serving to eject the spores. They are therefore called elaters (5, 6, 7).

The massive, much-lobed gametophyte bearing gametangia above, and the comparatively large sessile sporangia of the scouring-rushes, indicate a closer kinship with the adder-tongues than with the true ferns, and suggest that the Equisetinæ may have evolved from Hepaticæ somewhat more moss-like perhaps than Anthoceros. They may be characterized as *plants similar to ferns except in having*

relatively much greater stem-development, and in having the leaf-members whorled, the sac-leaves in cones, and the spores with elaters.

194. The club-mosses (Class *Lycopodinæ*) are well typified by *Lycopodium* (Fig. 166) which is popularly regarded as a kind of "moss" because of the general resemblance of the leaves and stems, in form and proportionate development, to the pseudo-leaves and pseudo-stems of many true mosses.

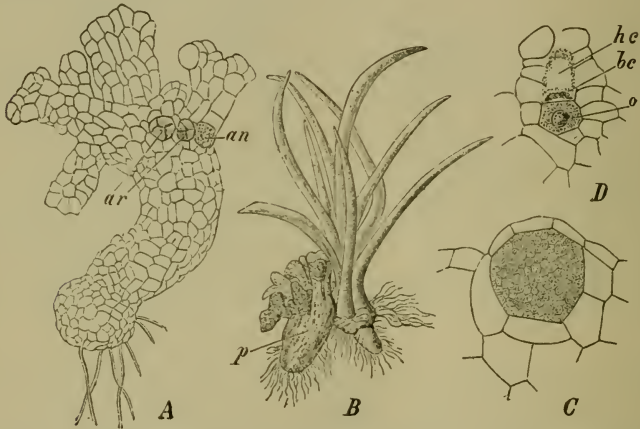


FIG. 372.—Club-moss (*Lycopodium* sp., see Fig. 166.) A, gametophyte (♂♂), showing archegonia (*ar*) and antheridia (*an*). B, old gametophyte (*p*) nursing a young sporophyte, ♀ . C, antheridium (♂♂) almost ready to discharge its spermatazoids. D, archegonium, cut vertically to show the egg-cells (*o*), the upper canal-cells dissolved into mucilage (*hc*), and the lower canal-cell (*bc*), ♀♀ . (Treub.)

The gametophyte (Fig. 372) is bisexual and massive, as in the adder-tongues, and mostly saprophytic; and the embryo resembles that of a fern in having but a single cotyledon. Its development is essentially like that of the next type to be described.

The stem often forks but shows no secondary thickening. The leaves are unbranched, and in some species are all much alike, while in other cases the sac-leaves are smaller than the foliage leaves, are crowded into cones, and serve chiefly as protective scales for the sporangia. Each sac-leaf bears but a single spore-case on its upper surface near the base. There are no elaters.

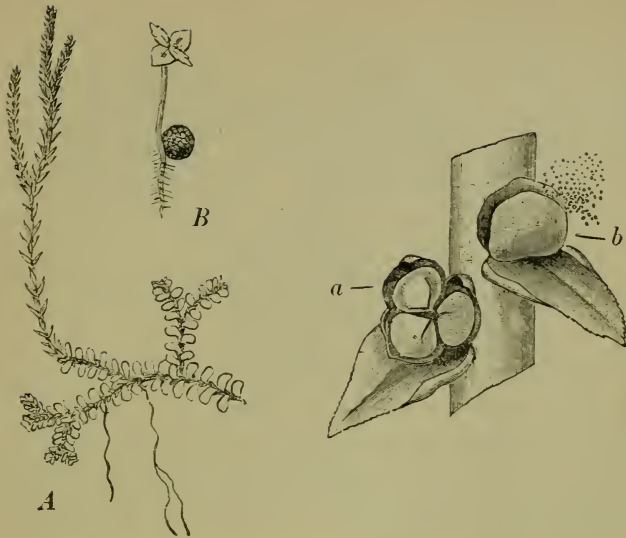


FIG. 373.—Mountain *Selaginella* (*Selaginella helvetici*, *Selaginella* Family, *Selaginellaceæ*). A, sporophyte, $\frac{1}{2}$. B, young sporophyte growing from macrospore. (Bischoff.)—Native home, Eurasian mountains.

FIG. 374.—Mountain *Selaginella*. Part of cone, showing a macrosporangium (a) containing three macrospores, and a microsporangium (b) discharging numerous microspores, $\frac{1}{2}$. (Schenk.)

Another large group is *Selaginella* (Fig. 373) the sporophytes of which often resemble those of the club-mosses so closely that they were at first included in the same genus, and many forms in cultivation are still called by florists, lycopodiums. A most significant though inconspicuous difference is that *Selaginella* has two kinds of spores—minute ones, called *microspores*,¹ which are very numerous in anther-like sacs termed *microsporangia* (b, Fig. 374); and *macrospores*² (a) which are so large that four fill a *macrosporangium*. Both kinds of sporangia are borne singly on the stem just above or in the axils of upper leaves, in the same branch or cone.

¹ Mi'cro-spore < Gr. *mikros*, small.

² Mac'ro-spore < Gr. *makros*, large.

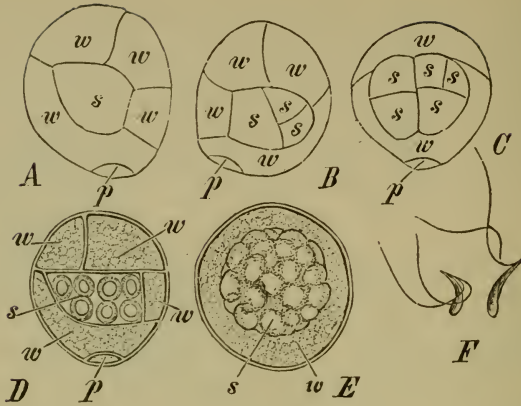


FIG. 375.—Selaginellas. Germination of microspores. *A-E*, different views of the spore showing the prothallus-cell (*p*), cells of the antheridium-wall (*w*), and the cell producing spermatozooids (*s*), z_1^2 . In *E* the cell-walls have dissolved previous to discharging the spermatozooids. *F*, spermatozooids, z_1^2 . (Belajeff.)

The spores begin to germinate while still within the sporangium. The contents of each microspore divides into several cells (Fig. 375, *A-D*) one of which (*p*) represents the vegetative part of a male gametophyte, the others constituting a male gametangium, in the center of which is formed a cluster of elongated gametes closely resembling the male gametes of a liverwort. After leaving the sporangium the microspores liberate their motile gametes by rupture of the wall. The large cell which constitutes the macros pore is rich in reserve food and begins to germinate by dividing into a number of small cells within the wall. Soon the macros pores are set free from the sporangium, and continue to germinate by forming a few archegonia on the upper side, which eventually protrudes from the ruptured spore-wall shown in Fig. 376. After fertilization, the egg-cell divides into an upper and a lower half, the lower half growing into an embryo, while the upper half develops into a peculiar organ called the *suspensor* (*et*). This by its elongation pushes the embryo, foot foremost, into the mass of vegetative cells upon which it feeds. The root and the shoot of the young embryo (Fig. 377) finally protrude from the macros pore, the foot (*f*) still remaining within as an organ of absorption in contact with the food supply. There are two cotyledons, which, containing chlorophyll, soon begin to make food for the plantlet, and aided by the developing leaves of the plumule, finally render the young plant self-supporting. From the upper side of each cotyledon (and often on later leaves) a flat

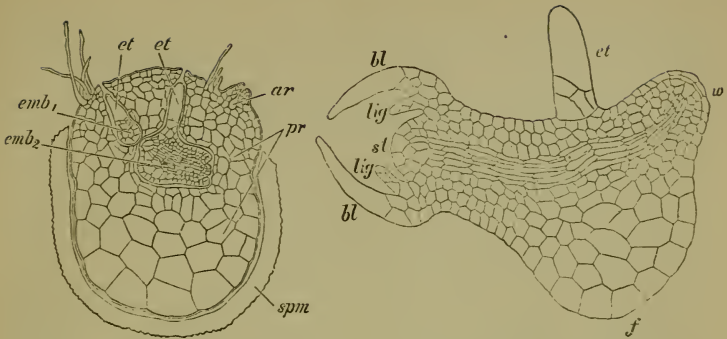


FIG. 376.—Martin's *Selaginella* (*Selaginella Martensii*, Selaginella Family, *Selaginellaceæ*). Germination of macrospore (2^a), cut vertically, showing the female gametophyte protruding from the ruptured spore-wall (*spm*) and exposing an unfertilized archegonium (*ar*), but still enclosing two embryos (*emb*¹, *emb*²) which have been pushed down into the nutritive prothallus (*pr*) by their suspensors (*et*, *et*). (Pfeffer.)—Native home, Mexico; much cultivated.

FIG. 377.—Martin's *Selaginella*. Embryo (4^a), cut vertically to show its suspensor (*et*), root (*w*), leaves (*bl*, *bl*), ligules (*lig*, *lig*), and tip of stem (*st*). (Pfeffer.)

projection (*lig*) termed a *ligule*,¹ arises, which, by secreting mucilage, serves to keep the tender terminal organs from drying.

The formation of macrospores that begin to germinate while still within the sporangium, marks a most important advance in the care of offspring; for by this means not only are the chances of cross-fertilization increased, but the embryo is afforded more protection, and the young plantlet can be provided with a larger quantity of promptly available food while preparing for independent life. Just one step further is needed as we shall see, to attain the high development of parental care achieved by seed-plants. A similar differentiation of the spores and sporangia into male and female is found also in certain types of Filicinæ, and in extinct Equisetinæ.

As with scouring-rushes and ferns, so with the club-moss class, the modern species but feebly represent their kin of the coal age. These include giant lycopods such as *Lepidodendron* (Fig. 278, page 301) and *Sigillaria* (Fig. 277, page 299) with much-branched trunks ten meters or more in height and often a meter in thickness, bearing cones as large as those of a pine tree, and forming extensive forests.

¹ Lig'ule < *L. ligula*, a little tongue.

The Lycopodinæ, which comprise in a very few genera about 600 species, *occupy an intermediate place between Filicinæ and Equisetinæ in the relative size of their leaves and in their arrangement which may be either alternate or whorled; but, while having the sac-leaves or sacs often in terminal cones, the sporangia are always solitary and never on the under side of a leaf; and there are no elaters.*

195. The pteridophyte division, fernworts (Pteridophyta) is made up of the three classes above named. Ferns being especially typical of them all, the plants of this division are conveniently designated as fernworts.

While, as we have seen, mossworts were perhaps the first green plants out of water to succeed in standing upright, it is among fernworts that we first find vertical growth producing lofty trunks. Spores formed near the top of such a trunk are plainly given an immense advantage since they may be dispersed over an extensive area. This highly beneficial provision for the welfare of offspring was made possible by the development of roots able to absorb subterranean moisture, and of leaves that could utilize it in connection with the air and sunlight. A protective function with reference to the sporangia or to tender parts of the stem was easily assumed by these lateral appendages, and in some cases became their chief or only office, as happened with the sheathing whorls of Equisetum or the cone-scales of Selaginella. Various differentiations of the stem-parts, gave rise to more or less branched ascending axes, either independent or climbing, or to more or less horizontal, often subterranean stems in which the capacity for storing food was often especially developed, and from which vertical branches or vertical leaves arose during seasons favorable for growth. For the bearing of spore-sacs either leaf-parts or stem-parts were available; and sometimes the one, sometimes the other was used. Nurse-plants were depended upon to foster the embryo and prepare it for independent, vigorous life; and the nurse itself was so well provided with reserve food that it could afford to dispense with food-making organs of its own to a considerable extent. It is thus perhaps of evolutionary significance that the gametophyte of fernworts is commonly much simpler in form and of less vegetative importance in the life-history of the plant than is the case in mossworts. An extreme of specialization in the reproductive function of the gametophyte is found in those fernworts which have male and female spores, the latter having in general such a large amount of reserve food that the nurse-plant does not need to make any for itself and scarcely protrudes beyond the spore, while the former having no embryo to nurse reduces its vegetative part to a single cell. Such gametophytes are virtually hysterozytic, and it is interesting to observe that types which do not produce macrospores but are

closely akin to those which do, have more or less hysterozytic nurse-plants.

In endeavoring to trace the evolution of fernworts we continually encounter the question as to whether a given type or organ of relatively simple form is best regarded as primitive or degenerate. The evidence available is often conflicting and has led different botanists to very diverse conclusions regarding the kinship and evolution of the different groups. Another stumbling block has been the difficulty of distinguishing between the resemblances that arise from similar adaptation to the same environment though in different lines of descent, and those resemblances which are due to inheritance even under different environments. It is now generally admitted, however, that the fernworts of the coal period attained much higher development than any which have survived, and that several important features, such as the development of macrospores, have evolved independently in each of the three classes. We have thus good reason to suppose that the progressive evolution of the Pteridophyta was mainly accomplished in geological ages long past, that this progress took place along the three main lines represented by our modern ferns, scouring-rushes, and lycopods, and that these fernworts of to-day are the more or less degenerate descendants of giant plants like those preserved in coal.

When we take the adder-tongue fern as possibly representing the sort of plant which first evolved from a liverwort like *Anthoceros*, we must accordingly make allowance for considerable modification of detail due to special adaptations in the course of ages and to more or less degeneration. We cannot say much more than that our supposed ancestor of the ferns presumably had rows of large sporangia along the edges of the blade-like expansion of a growing axis which put forth, below, cylindrical projections for absorbing water. From such an ancestor, ferns, scouring-rushes, and club-mosses may perhaps be supposed to have evolved, one or another according as the stem-parts or leaf-parts reached greater or less, or about equal development, and the spore-sacs were multiplied or reduced in number and diminished

or increased in size or otherwise modified to provide for the welfare of offspring.

But however well these plants might succeed in utilizing underground moisture they could never take fullest advantage of the opportunities offered for life upon the land so long as they were dependent upon surface water to secure fertilization; and every fernwort still retains traces of its aquatic ancestry in the male gametes which must swim to accomplish their purpose. Thus fernworts like mossworts are truly land-plants only during part of their life, although the former have attained a prodigious development upon land.

Pteridophyta agree with Bryophyta in having archegonia, but are distinguished among cryptogams by developing true roots, stems, and leaves, in which a vascular system is developed.

196. Cryptogams and phenogams. The highest development of plant life is associated with the production of seeds, which afford the best possible provision for the welfare of offspring.

There is abundant evidence to show that the earliest seed-plants differed but little from certain fernworts that had developed macrosporangia containing single macrospores. The first step toward converting such a macrosporangium into a seed might easily be taken if the macrospores remained attached to the plant until the archegonia were exposed, while the microspores, set free, were carried by wind to the attached gametophyte there to germinate and effect fertilization. The final step would come, when, after fertilization of an egg-cell thus doubly protected by nurse-plant and spore-sac, the nurse-plant itself should be further protected by continued growth of the surrounding parts and should be fed by the parent while it was in turn feeding the embryo. An embryo thus fed through a connection maintained with the parent plant, and protected by a sporangium wall which finally becomes detached from the parent for dispersal, is a *seed*; the macrosporangium with its inclosed macrospore and female gametophyte is an *ovule*; the microsporangia are *anthers*; and the microspores, *pollen grains*. When such highly differentiated spore-sacs are borne upon leaves we have sac-leaves which we call either *carpels* or *stamens*.

Pines and other gymnospermous plants (Figs. 258, 259, 260, 263) as we have seen, bear ament-like clusters of stamens or carpels each cluster forming what we may regard as a separate flower. A Selaginella which had certain cones producing microspores exclusively would thus be homologous with a staminate flower of *Pinus*, while an exclusively macrosporic cone would correspond to a pistillate flower. The morphology of the stamens and their parts in

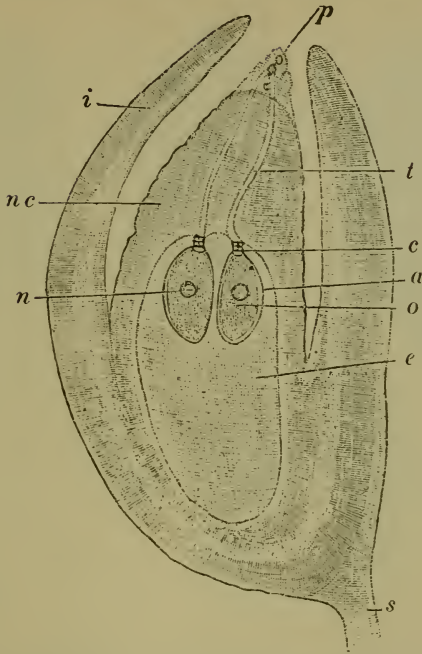


FIG. 378.—Norway Spruce. Ovule cut vertically and enlarged to show the embryo-sac (*e*) filled by the prothallus or *endosperm* and two archegonia (*a*), each with its neck (*c*) and swollen part (*o*) which contains an egg-cell with a nucleus (*n*); the *nucellus* (*nc*) surrounded by the *integuments* (*i*); pollen-grains (*p*) from which come pollen-tubes (*t*) extending to the archegonia; and a part of the seed-wing (*s*). (Strasburger.)

Pinus and related genera will doubtless be sufficiently clear without further explanation, but the carpels and ovules call for more detailed examination. Each carpel, as we have seen, bears two ovules on its upper side near the base (Fig. 258, 8). When cut in half vertically such an ovule exhibits the parts shown in Fig. 378. A single macrospore organically connected with the surrounding tissue constitutes what is termed the *embryo-sac* (*e*). The rest of the ovule represents the *macrosporangium*, which is divided into a central part, the *nucellus*¹ (*nc*) in which the embryo-sac is embedded, and an outer layer, called the *integument* (*i*), which covers the nucellus except at the *micropyle*. Microspores, *i. e.*, pollen grains, intrusted to the wind, are carried to the pistillate flowers. Caught by a

¹ Nu-cel'lus < *L. nucella*, a little nut.

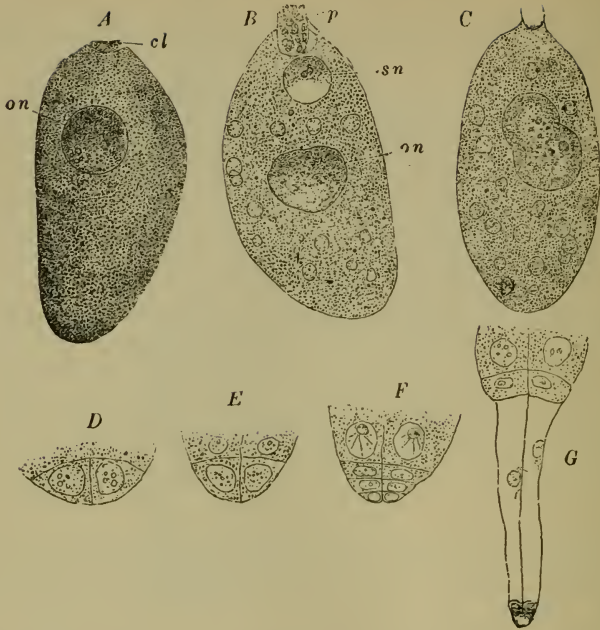


FIG. 379.—Norway Spruce. Fertilization of egg-cell. *A*, ripe egg-cell with nucleus (*on*) and lower neck-cell (*cl*), $\frac{1}{2}$. *B*, same, later, the tip of a pollen-tube (*p*) having entered the egg-cell and discharged into it the male nucleus (*sn*) which approaches the female nucleus (*on*). *C*, same, later, the two nuclei having become fused into one, which soon divides into four nuclei that move to the lower end of the egg-cell. *D*, lower end of the egg-cell showing two of the four nuclei which have moved into it. *E*, same after division of the four nuclei into eight. *F*, same after further division has produced four tiers of nuclei, all but the uppermost four being enclosed in cell-walls. *G*, same, after the middle tier of cells has elongated to form a suspensor which has pushed the lower tiers of cell into the prothallus (or endosperm) where they give rise, by repeated cell-division, to an embryo which is fed by the endosperm. The nutritious materials left over in the endosperm when the ovule has become a seed constitutes the seed-food which supports the young plantlet during germination. (Strasburger.)

spreading carpel, they come finally to the micropyle where the integument is often prolonged in such a way as to lead them directly to the tip of the nucellus. Here they germinate by forming a few cells, some of which, remaining within the spore, represent the vegetative part of the male gametophyte; while others, the male gametes, form a hypha-like tube which penetrates the soft tissue of the nucellus and feeds upon it like a fungus. Meanwhile the macrosore

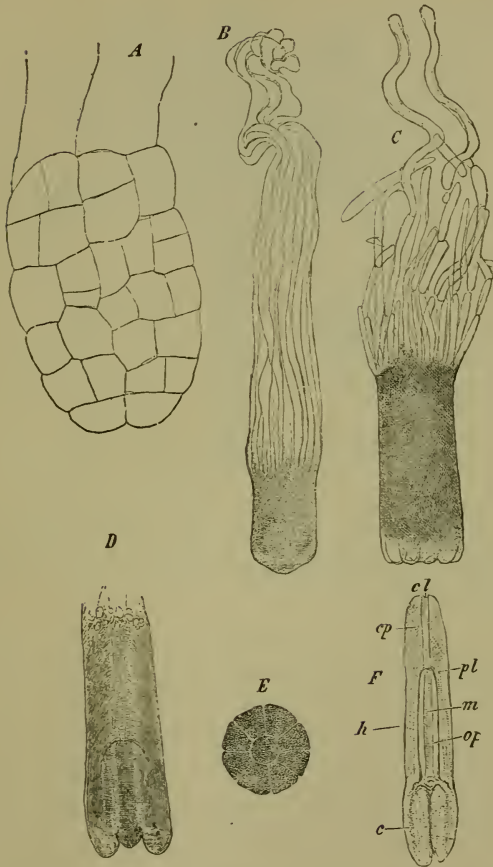


FIG. 380.—Norway Spruce. Growth of embryo. *A*, early stage, 17^d. *B*, later stage, 23^d. *C*, half-ripe embryo, showing below the protrusions from which the cotyledons are formed, 23^d. *D*, same, cut vertically. *E*, same, end view, showing the eight rudimentary cotyledons surrounding the stem-tip. *F*, embryo, fully formed (1), cut vertically to show the seed-leaves or cotyledons (*c*), the seed-stem (*h*), the beginning of the root (*pl*), root-cap (*cp*), fibrovascular cylinder of root (*cl*), pith of stem (*m*), and rudimentary fibrovascular strands (*op*) surrounding it. (Strasburger.)

(or embryo-sac) has been developing some very simple archegonia (*a*), consisting only of a large egg-cell (*o*), and one or more very small cells (*c*) representing the neck. See also Fig. 379, *A*. Presently the tip of a pollen-tube bearing the male nucleus reaches the egg-cell and discharges its nucleus into the female protoplast (Fig. 379 *B*). The male and the female nucleus fuse into one (*C*) and move to the opposite end of the egg-cell, there to form a group of small cells from which one or more embryos arise, but only one develops, in each seed. As in *Selaginella*, certain cells form a suspensor which pushes the developing embryo into the storage tissue of the gametophyte. But in the pine and spruce this vegetative part of the nurse-plant, because of its long connection with the parent, is able to draw into itself a continued supply of nutritive material. Part of this nourishes the embryo till it develops root, stem, and leaves, while a surplus is stored around it as seed-food for the use of the plantlet when it has left the parent, and is ready to germinate (Figs. 379, 380). Not only is abundant food thus supplied to and for the embryo, but the sporangium wall (nucellus and integument) and the sac-leaf (cone-scale or carpel) are so well nourished after fertilization has taken place, that they grow enormously and become much hardened as organs of protection. The ripened ovule thus becomes a seed, and finally, as already described, separates from the parent and is aided in its aerial voyage to a home for life, by a wing derived from the carpel. The young sporophyte has simply to grow after the manner of its kind to become a tree and produce gametophytes which shall coöperate in the formation of highly favored offspring.

In view of the many resemblances between *Pinaceæ* and *Lycopodiaceæ* it has been thought that plants closely related to the club-moss trees of the coal-period may have been the ancestors of both of these cone bearing groups. It should be said, however, that the remains of extinct gymnosperms represented by *Cordaites* (Fig. 277, 5) contemporaneous with *Lepidodendron*, show resemblances to the ancient ferns which indicate that the ancestor of the conifers was more fern-like than might appear merely from a comparison of modern types.

Cycas (Fig. 381) shows even closer affinity with ferns, as for instance, in the ample branched foliage-leaves which unroll as they develop, and the numerous sporangia borne upon a sac-leaf. In general the life-history is similar to that of *Pinus*, pollen spores being carried by the wind to a little chamber at the tip of a naked ovule to fertilize an egg-cell; but in this case the microspore upon germinating produces in the pollen-tube two motile gametes pro-

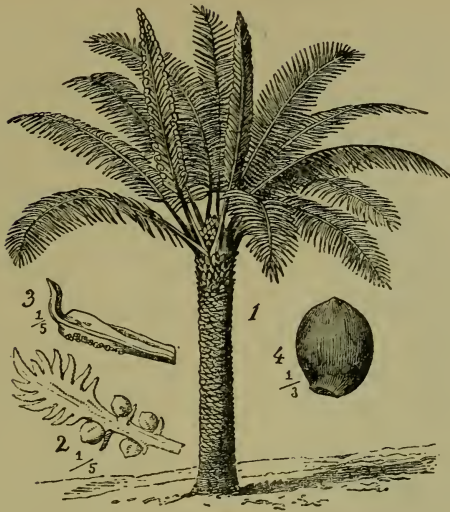


FIG. 381.—Japanese Cycad (*Cycas revoluta*, Cycad Family, *Cycadaceæ*). 1, seed-bearing plant. 2, macrosporangial leaf or carpel showing the naked ovules (macrosporangia) near its base. 3, microsporangial leaf, or stamen, showing the numerous microsporangia (anthers) on its lower face. (Wossidlo.)—Tree growing about 3 m. tall; fruit densely hairy. Native home, Japan; commonly cultivated as “sago-palm.”

vided with numerous swimming-hairs. One of these fertilizes the egg-cell. After fertilization a seed is formed, an abundance of extra food being stored about the single embryo. The sporophyte as it develops becomes, as we have seen, singularly like a tree-fern and at the same time so closely resembles a *Metroxylon* as to be called by florists a “sago-palm.” While we must of course regard this outward resemblance as more or less superficial, it gains significance from the presence of much deeper resemblances which have led botanists to regard the Cycad-type as a connecting link between the fern and the angiosperm.

As already shown, the main difference between a gymnosperm and an angiosperm is that the latter incases its macrosporangia in carpellary leaves. Fertilization is accomplished, however, as before by means of a pollen-tube, which, starting from the stigma, has simply a longer road to travel before its tip reaches the egg-cell. Moisture to enable the microspore to germinate is afforded by a stigma, while food for the tubular cell is supplied by the tissues along its route. The parts concerned in angiospermic fertilization are shown in Fig. 382. When germinating, the pollen-cell produces two nuclei, one of which represents the vegetative part of the male

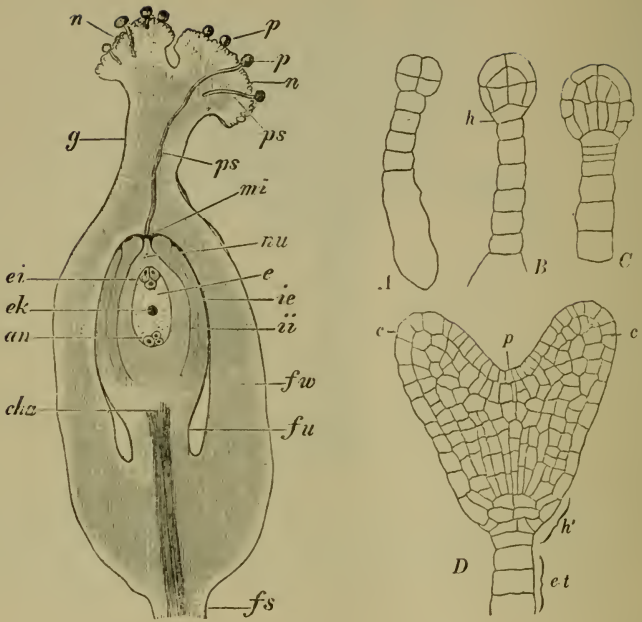


FIG. 382.—Climbing Buckwheat (*Polygonum Convolvulus*, Buckwheat Family, *Polygonaceæ*). Pistil ($\frac{2}{3}$) during fertilization, cut vertically to show stalk-like base (*fs*) of ovary; stalk of ovule (*fu*); end of stalk (*chz*); the nucellus (*nu*), the micropyle, or opening to the nucellus (*mi*); the inner integument (*ii*); the outer integument (*ie*); the embryo-sac (*e*); nucleus of the embryo-sac (*ek*); the egg-apparatus (*ei*) consisting of three cells, the lower one being the egg-cell and the two others companion cells which are thought to represent rudimentary archegonia; prothallial cells (*an*); style (*g*); stigma (*n*); pollen grains (*p*); and pollen-tubes (*ps*). A pollen grain falling upon the stigma produces a tube which grows down through the style, enters the micropyle, and penetrates to the egg-cell; here it discharges its (male) nucleus which fuses with the nucleus of the egg-cell and from this union an embryo arises. (Strasburger.)—The plant is an annual vine resembling buckwheat but with greenish flowers; native to Europe but a common weed in America.

FIG. 383.—Shepherd's Purse (*Capsella Bursa-pastoris*, Mustard Family, *Cruciferae*). Development of the embryo. A-D, successive stages, much magnified, showing the suspensor (*et*), lower end of embryo (*h*), cotyledons (*c*), and the stem-tip (*p*) from which the plumule arises. (Hanstein.)—The plant is annual, about 50 cm. tall, with small white flowers and dry fruit; native of Europe; common as a weed in America.

gametophyte, while the other is the essential part of a gamete. Here then is a gametophyte reduced to the simplest terms. The female gametophyte formed within the embryo-sac consists of a few cells forming two groups which lie at opposite ends of the macrospore. Those at the micropylar end (*ei*) include an egg-cell which is thus advantageously situated for fertilization by the pollen-tube entering the micropyle. The growth of the embryo from the fertilized egg-cell involves, as shown in Fig. 383, the formation of a suspensor (*et*) which pushes the developing germ well into the mass of food. In this example the embryo comes to fill the sporangium completely while still attached to the parent, thus forming an exalbuminous seed, in which radicle, caulicle, and cotyledons are well developed.

While it is not altogether clear how closed ovaries evolved from open carpels, the change may well have taken place as a result of the peculiar inrolling of the young leaf-lobes which primitive gymnosperms are supposed to have inherited from ferns. If ovules should form on such lobes while still inrolled, and the lobes should coalesce, the carpel would be angiospermic. However it happened, many highly important consequences of this advance are apparent. Most obvious is the greater protection of the offspring during the period of their dependence.

There is also an enormous gain in possibilities for securing an advantageous cross. Thus a moist, projecting stigma becomes a target more likely to be hit by wind-carried pollen grains and more likely to insure their prompt germination, than the micropyle of a naked ovule. Expansion or branching of the stigma, such as we find to be characteristic of wind-pollinated angiosperms, shows how well this new organ lends itself to increasing the chances of pollination and at the same time favors economy in the amount of pollen produced. See Figs. 2-15, 27, 36, 74 *B, C*, 109 *C, D*, 124 *B*, 153, 159, 165 *II*, 171 *II*, 243, 248, 254, 256 *B*, 257, 267 *D*, etc. A still further advance in these directions came when insects and other animals were attracted to the flowers, and their services thus secured as carriers of pollen. The attractive odors, bright colors, and alluring sweets, together with the marvelous arrangements of the various floral organs, present modifications of endless variety and offer one of the most fascinating fields in the whole range of botanical study. See Figs. 22, 39 *II*, 48, 57, 59 77, 80, 91-100, 106, 133, 139, 145, 148, 156, 163, 164, 168 *II*, 172, 178, 187, 188, 189, 192, 217, 251, 275, 276, 282-293, 299, etc.

This elaborate modification of stem-parts and leaf-parts cooperating with pollen-sacs and ovules to form what we call a flower brings with it the further possibility of utilizing these accessory organs,



Fig. 384.—Diagrams illustrating the supposed evolution of flowering plants through various stages from algae. The heavy, branching line above stands for the ancestral line of the angiosperms, from which have come off also those main branches of more primitive plants that have representatives now living. Order of time is shown by distance above the base; increasing complexity of structure by distance toward the right. Below each branch is a diagram outlining the life-history of a typical example of the group named above it. In these diagrams by following the dotted lines in the directions indicated by the arrow-points, the successive stages of each life-cycle will be passed through in their natural order. Each cycle begins below with a single cell, and is complete when a similar initial cell is produced. In the different types corresponding stages of development are placed at about the same height, so as to come in nearly the same horizontal line, thus illustrating the theory of "recapitulation of phylogeny by ontogeny." It should be noted that the view here suggested does *not* imply that any living form has descended from remote ancestors closely similar to any form now living. On the contrary, it aims to express the idea that modern angiosperms evolved from *extinct* ancestors of modern cycads. (very different from either living cycads or angiosperms) and that these common ancestors of the cycads and angiosperms were descended from *extinct* ancestors which gave rise also to modern ferns (although they themselves were doubtless very unlike any ferns of to-day); and so on back to the earliest forms of life. As we try to trace the line back beyond the ancestral ferns our conclusions must be more and more uncertain for lack of fossil remains to compare with living structures. (Original.)

or certain parts of them, to further protect the embryo and provide for its surer and wider dispersal. Hence arise protective shells (Figs. 23-36) and various aids to dissemination, including wing-like or plume-like appendages (Figs. 55, 59, 76, 159, 197, 215, 248, etc.), for catching the wind; elastic springs for propelling the seeds to a distance (Figs. 164, 165), and succulent parts (Figs. 88-110) which being attractive food, lead animals to swallow indigestible seeds and transport them often to enormous distances. Thus, it is in plants which form seeds within a case that we find the most perfect provision for the welfare of offspring; and it is doubtless because of this provision that angiosperms are the dominating plants of to-day.

In concluding our survey of vegetable evolution it may help us to a just perspective if we briefly review the main steps which the ancestors of angiosperms appear to have taken in their long upward journey. The accompanying diagrams (Fig. 384) will serve to recall the chief facts and conclusions already presented regarding the phylogeny of these highest plants, and also the ontogeny of modern types representing the supposed links in the series. In accordance with the "law of recapitulation" (see page 435) we find that the younger the stages the more they are alike, and that immature stages of the higher types correspond to mature stages of lower types, the youngest stage of each being a single cell like the supposed ancestor of all. This reproduces simply by fission, a process which is retained by all higher forms as growth by cell-division resulting in cell-rows, cell-plates, or cell-masses variously differentiated into tissues and ultimately, tissue-systems. Vegetative reproduction occurs also in these higher forms through the occasional separation of cells or cell-groups capable of independent life. Sexual reproduction appears with the fusion of two protoplasts to form one which afterward increases by division. In the aquatic forms the fusing protoplasts soon became motile and this motility is long retained in the male by their descendants while adapting themselves to a terrestrial life, and disappears finally when this is fully attained. The single protoplast resulting from the fusion of two gives a second unicellular beginning and thus the life-history of an individual becomes divided into a sexual and a non-sexual stage or generation. When the female protoplast remains attached to a plant in the sexual stage until after fertilization there results an egg-cell which becomes a non-sexual embryo if the connection be maintained so that the sexual generation may nurse the non-sexual. This new beginning, nursed by the more primitive stage, affords, it would seem, a good opportunity for the transition from life in water to life on land. Then, too, the nursing, when not excessive, both permits and encourages the highest development of the non-sexual generation. Finally, it nurses the nurse, and thus through ample provision for both nurse and nursling produces a seed well cared for in every way. This is the greatest achievement of the vegetable kingdom.

CHAPTER XIII

THE PLANT'S PLACE IN NATURE

197. The three kingdoms. It has long been the general opinion that all natural objects fall readily into three main groups or kingdoms—the mineral, the vegetable, and the animal. Over a century ago the characteristics of each kingdom as understood at the time, were given by Linnæus in his famous aphorism: “Minerals grow; plants grow and live; animals grow, live, and feel.”¹ This threefold division is still recognized as convenient, and the distinctions given are admitted as valid to a considerable extent; but that a mineral grows in essentially the same way as a plant, and that a plant lacks any quality that is found in all animals, would not generally be admitted by the naturalists of to-day. In order to understand modern views regarding the plant's place in Nature we need to consider what is meant by growing, living, and feeling.

By “growth” Linnæus seems to have meant merely increase in size. Yet is not the enlargement of a seaweed or a fish essentially different from the so-called growth of a salt crystal in concentrated brine? The crystal gets larger simply by additions upon the outside, while the living body increases in size by the incorporation within itself of substances derived from without. Moreover, the crystal as it enlarges remains substantially the same throughout, and all the parts behave alike. In a growing body on the contrary there is a progressive differentiation of parts and functions. Hence we cannot say that a mineral grows in the same sense that an organism grows.

But does not Linnæus express the differences above in-

¹ *Lapides crescunt; vegetabilia crescunt et vivunt; animalia crescunt, vivunt et sentiunt.*

sisted upon by saying that organisms are alive? Doubtless he meant to do so; yet what did he mean by life without any trace of feeling? What sort of feeling can a sponge or a jelly-fish have that we must deny to a climbing-plant, or to a swimming-plant that moves toward the light? Our only evidence that the animal feels is that it responds by movements to certain stimuli. When we watch plants carefully we find that they also respond to similar stimuli. Thus we are left without any distinction between plants and animals; and since what "feeling" stands for in animals is found in plants as well, it would seem that this same "feeling" might be what best distinguishes living from lifeless bodies, and so underlies the various manifestations of life. According to a view which we must examine more at length it is because of their purposeful activities that animals and plants are called *living*, and because of their coördinated parts, *organic*. All other bodies are then appropriately termed *lifeless* or *inorganic*. This modern view of Nature implies a revised classification which may be conveniently presented in the following tabular form.

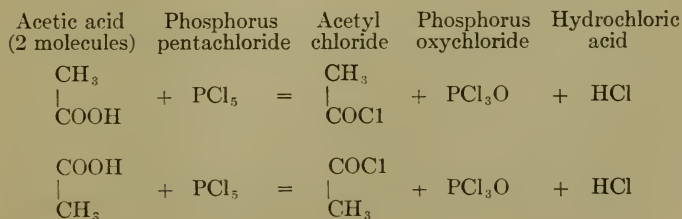
Nature	{	Inorganic Realm or Mineral Kingdom.
.	{	Organic Realm {
		Vegetable Kingdom.
		Animal Kingdom.

198. **The inorganic realm**, it must be admitted, presents many points of fundamental similarity with the organic. Thus volume, mass, resistance, form, and all such physical properties are common to both realms. Furthermore, all the chemical elements found in animals or plants occur also in minerals, and often in the same combinations. Indeed many of the so-called "organic compounds" once supposed to be formed only within living bodies are now made in chemical laboratories by purely artificial means. Oil of wintergreen, indigo, and madder-red are examples we have already had occasion to notice. Many others might be added, including certain sugars.

It has been urged that some day it may be possible to manufacture protoplasm artificially, and so break down the distinction now made

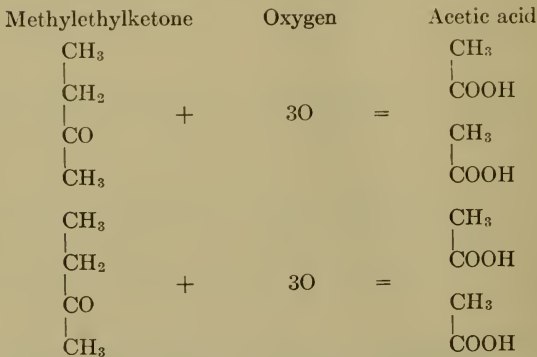
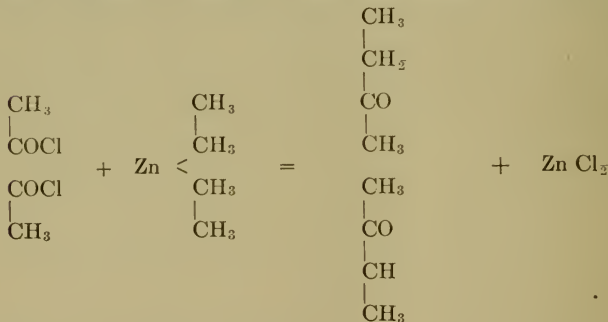
between living and lifeless things. Certain naturalists go so far as to insist that even to-day no fundamental difference can be found that will absolutely distinguish all organisms from all minerals. They say that life consists merely of the activities of protoplasm, that these are determined solely by the combined properties of the several chemical elements of which protoplasm is composed, and that already it is possible to match every one of the fundamental properties of protoplasm by an artificial process. For example, if a crystal of copper sulphate be thrown into a solution of potassium ferrocyanide there is formed at once, by precipitation around the crystal, a membrane resembling a cell-wall, which presents every appearance of growing as a consequence of pressure from within and fresh precipitation wherever the two solutions come in contact. The artificial cell thus produced may attain considerable size and branch in various ways. Another striking experiment consists in putting a few grams of mercury into a flat-bottomed dish containing a 10% solution of nitric acid in water, and then placing a crystal of bichromate of potash on the bottom about an inch away from the mercury. As the potash salt dissolves it becomes surrounded by a reddish cloud which finally reaches the mercury. Then suddenly the mercury becomes agitated, moves toward the crystal, and envelopes it, very much as certain of the lower animals seize and swallow their prey. Finally, an experiment held to be of profound significance as showing in a mineral substance the very essence of growth and reproduction attended by anabolic and catabolic reactions, consists in adding to a certain quantity of acetic acid, chemically equivalent amounts, successively, of phosphorous pentachloride, zinc ethyl, and oxygen. As a result there is formed double the original amount of acetic acid plus several substances which correspond to the by-products of organic metabolism.¹ Here, then, we have what is regarded as the life-history of a molecule, which, so long as it is fed, grows and reproduces as if by fission and excretes much as a bacterium would do.

¹ For the benefit of students familiar with organic chemistry the transformations above referred to may be expressed by the following equations copied from *Les Problèmes de la Vie*, by E. Giglio-Tos. Part I, 1900, pp. 20, 21.



What is the utmost that may be inferred from such experiments? Have lifeless things really been made to act as if they were alive? It is plain that all we have here are simply imitations of isolated vital processes, and *not* such a coördination of activities as characterizes a living being. Living protoplasm does not *merely* feed, or grow, or reproduce, or respond to stimuli: it does all these things at once, and more; and its activities are so coördinated as to accomplish definite ends. Nothing which can do all that protoplasm does has ever been manufactured. Supposing it were possible, however, to effect a combination of elements which would imitate all the physical and chemical activities of protoplasm, and all at once; what would that mean? We could be sure that such artificial protoplasts would always do the same thing under the same conditions, and that corresponding parts would always act exactly alike.

Acetyl chloride Zinc ethyl Methyleneethylketone Zinc chloride



Thus for every *two* molecules of acetic acid *four* are finally produced.

But this is precisely what seems not to happen with living protoplasts. No two living things are ever expected to act in the same way in all respects. Furthermore, the theory of evolution as we have seen, assumes that the halves of a cell divided by fission have individual differences such as we should have no reason to expect in the artificial protoplasts of a single batch. We may well believe that something quite essential to life will always elude the efforts of any man to create a living thing. Nothing that has been done gives any assurance of the possibility of realizing such a dream.

It used to be supposed that the transformation of a lifeless into a living thing might be scientifically demonstrated to occur in the appearance of bacteria in a putrescible substance. The supposed transformation was called *spontaneous generation*, a term also applied to an older notion widely held that many of the lower forms of life arose spontaneously from dead matter, as maggots in cheese or pond-scum on a stagnant pool. What gave rise to the belief that bacteria were spontaneously generated was that sometimes after a broth had been boiled in a flask and all air excluded, bacteria did appear within a few days. Investigation showed, however, that in these cases spores were present which were able to resist an amount of heat fatal to the plants in their actively dividing condition; and one had only to repeat the boiling till all the plants were killed in order to obtain a broth which could be kept indefinitely. Science was thus left without any proof of spontaneous generation, and it must now be said that so far as we know every organism has had a living parent or parents. The aphorism "All life comes from former life" still remains undisproved.

Those who doubt that there is any essential difference between living and lifeless things may still urge in favor of their view that certain plants are to all appearance practically lifeless during their so-called resting period; and if that be true we have a lifeless thing coming to life simply as a consequence of a change in temperature. So also, many simple organisms when frozen lose all trace of life except that they live as before, when they are thawed out. They may be submitted to a temperature of 250° below zero centigrade for any length of time and will resume their activities when warm. Or, they may be dried so as to show no more sign of life than so much inorganic dust, and then be revived by moisture. Thus when there is too much or too little heat, or not enough water present to permit signs of life, an organism may be as inactive as a crystal and indistinguishable from a lifeless thing except in so far as under favorable condi-

tions it again becomes active. We should remember, however, that even granting in such cases the appearance of life in a body which before was lifeless, it was a reappearance; and this previous life again confronts us with the original problem. We still must ask, Is there not some profound difference between a body in which life reappears and one in which life never has appeared?

To this question the doubter may reply: "Let us go back then to the first of living things. Evolutionists suppose this to have come from something that had never been alive before. Does not the change here assumed imply that the inorganic realm merges so gradually into the organic that some organisms differ no more from some minerals than one organism or one mineral does from another?" Not at all. It does not follow just because one thing is transformed into another that the new may not be profoundly different from the old. An evolutionist, therefore, is free to believe that when the first living creature appeared upon the earth, a form of existence essentially different from any that had been here before, came into the world. We may suppose that as the earth was cooling from its molten state there were formed according to chemical and physical laws acting under conditions not since repeated, aggregations of compounds like those now found only in the organic realm; and that as soon as the temperature became favorable these aggregations became alive, exhibiting the activities of a living thing much as a revived creature would do. In saying this, however, we have admitted only that life may have appeared as soon as the conditions required for its manifestation were present. We have not implied that life is a product of the chemical and physical properties of matter, however necessary certain material conditions are to the manifestation of life in an organism. It may be freely admitted that chemically and physically considered certain lifeless bodies are indistinguishable from certain living ones; that indeed one and the same body may pass from one condition to the other without change of properties, and that when alive all the activities of its parts are describable in chemical and physical terms. All this would necessarily

be true if the life principle were an immaterial something which could find expression in an organism only through material bodies presenting favorable properties under favorable conditions; and if life be *not* inherent in matter we should expect that all attempts to find any difference between the matter with which life is associated and that which is lifeless, would fail, as they have done.

It may be urged against the supposition of life having entered into lifeless compounds as a controlling force in the beginning that this virtually concedes the possibility of lifeless bodies becoming alive, and merely substitutes a wholly mysterious idea for a chemical conception of the process. It is conceded that an evolutionist who assumes a first living thing to have been produced in some way can hardly escape supposing this living thing to have become alive; but neither does he escape facing a mystery whether he tries to think about it in chemical terms or not. Scientific thinkers try to avoid unnecessary assumptions. Why then should we assume that there ever was a first living thing? There can be no more need of so doing than of trying to imagine a time when the universe began to exist. Parts of the universe may always have been alive. Yet granting this possibility, it may be argued that since no life could have existed upon the earth when it was a molten sphere we have still to account for the presence of life upon it to-day. The answer of modern astronomers to the question as to how our earth came to be inhabited is afforded by the theory of *panspermia*.¹ This theory supposes that innumerable living spores are traveling through the celestial spaces impelled by the radiation pressure of light. It has been found by experiment that minute particles allowed to fall in a vacuum are driven from their downward course by a beam of light; and it has been calculated that spherical spores 0.00016 mm. in diameter—such as we have good reason for believing to exist although too small to be seen through ordinary microscopes—would be moved readily by the pressure of sunlight if they should once pass out of our atmosphere. Air currents would carry such bodies to a height of about 60 miles where, if electrified by a radiating auroral discharge they would be carried beyond our atmosphere and beyond the effective pull of gravity. The light pressure could then propel them to the orbit of Mars in about twenty days, and beyond our solar system in little more than a year. Thousands of years might be required for them to reach other solar systems; but meanwhile the extreme cold, dryness, and other conditions prevailing in space would be favorable to their remaining alive and resting indefinitely. Within a solar system particles of dust are being attracted towards the sun. If a traveling spore should meet one of these dust particles it might be

¹ Pan-sper' mi-a < Gr. *pan*, universal; *sperma*, seed or living germ.

carried into the atmosphere of a planet, and without harm come to rest upon its surface there to germinate if the conditions proved to be favorable. It would thus appear that we have abundant scientific warrant for supposing that the first living things upon our earth were resting spores which came through vast spaces from some other planet; and that our simplest forms of life are being distributed similarly throughout the universe, just as similar living germs have been carried from planet to planet during endless ages for which it would be idle to seek a beginning. Life having always existed does not need to be accounted for in terms of physics and chemistry.¹

If not in physical or chemical terms, how then can we define that which distinguishes all living from all lifeless things? Some naturalists have seemed to think that this question could best be answered by trying to interpret the more complex manifestations of life in the higher organisms through a study of the simpler manifestations of the lower forms: but this means trying to explain the life of which we know most by that of which we know least. A method just the reverse is surely more promising. When I ask myself what it is that makes me alive, my answer is: Not any particular arrangement or movement of material particles of a certain sort, but rather an immaterial something which to some extent can control the arrangements and movements of such particles in accordance with purposes peculiarly my own. My body is alive only so long as it affords opportunity for the exercise of my *will*. It is my power of choice that makes me alive. What I choose gives me my character. My life and my individuality come from my power to choose and the way I use it.

If you should ask me how I suppose an immaterial existence can exert an influence upon what is material, I must answer that I have no more idea than I have how mind can affect mind or matter affect matter. The real nature of either is doubtless very imperfectly expressed by any scientific definitions of them that were ever offered; but I do not need to know the ultimate truth about them in order to feel justified in believing that somehow in every living creature the free will of something mental gets expressed through something material,

¹ For a fuller account of the theory of panspermia the student may profitably consult *Worlds in the Making* by Svante Arrhenius, 1908, from which the calculations given above have been taken.

whatever mind or matter may be and however they may interact. If I am right in my belief, then it follows that this power of choice which we have already seen reason to regard as the fundamental factor in organic evolution, is indeed the very essence of life. On this view an organism is recognized as alive when it shows signs of control from within, manifested by activities regarded as purposeful, and in so far peculiar to itself as to defy exact foretelling. It has been well said that no arguments can ever force a person to believe that even he himself has a free will; for, if it were true that he had a free will he must always be free to choose the other alternative. The reader will understand, therefore, in what follows that as a believer in free will I wish merely to show some of the consequences of this belief to anyone who is disposed to share it with me. Those who agree with me will feel free to believe in the workings of will throughout the universe. They will conceive of the difference between a lifeless and a living thing as simply this: the lifeless thing *must* do whatever it does, while the living thing *may* do this or that. From this it follows that to us and to all other living things belongs in various measure a power of preference.¹ The range of this power in us though limited by a Power beyond ourselves increases according as it is used. And shall we not say that the Power which limits while it permits the exercise of our separate wills is reflected in what we call the inorganic realm?

199. The organic realm. A typical living organism may be conceived of as a self-building boat formed of materials taken from the inorganic stream in which it floats, but controlled by an indwelling, immaterial power capable of steer-

¹ If the reader has studied philosophy he is doubtless aware that certain thinkers who concede a power of choice to all living things refuse to limit this power to the organic realm, but hold that a certain measure of conscious freedom is permitted to every particle of matter. They favor this view as enabling them to unify their conception of the universe, and at the same time to recognize the immanence of God throughout. The unification which is gained, however, by saying that all things are alive, deprives Life of any special meaning. For if nothing is really lifeless, being alive means no more than simply existing. Whatever truth there may be in saying that all Nature is somehow alive seems to me to be implied in the view outlined above.

ing as it chooses. The materials of such a living boat as we have imagined would be continually dissolving into the stream; while, at the same time, fresh inorganic material, admitted by the indwelling power, would be building the structure anew. So long as these materials formed part of the boat or showed signs of having once belonged to its organized structure, we should call them *organic*; and we should apply the same term to any compounds possessing the same properties. So long as the materials were arranged in a way to permit the indwelling chooser to act through them directly, they would constitute *living substance*. Until thus controlled they would be simply *lifeless substances*; after they had passed from this control they would be *dead*. Before they had been organized and after they had ceased to bear the marks of organization we should call them *inorganic*.

The materials of which these wonderful boats are made consist chiefly, as we have seen, of the elements carbon, hydrogen, oxygen, and nitrogen. It is perhaps significant that each of the four is preëminent for certain properties which are in marked contrast with what characterizes one or more of the others. Carbon, in a sense, is the most solid of all known substances. It requires the highest temperature to melt it, and in its diamond condition exceeds all other materials in hardness. It is remarkable for the different ways it can combine, and as entering into more compounds than all the other elements taken together. Hydrogen, on the other hand, is of all common elements the most fluid. It requires the utmost cold to freeze it and remains gaseous under the highest pressure. It is remarkable for the ease with which it may be made to pass from one compound to another. Oxygen, also a gas at ordinary temperatures, is preëminent for the stability of its compounds, and for the activity it shows in combining; while nitrogen, similarly gaseous, is in marked contrast as being most difficult to combine and most unstable in combination. We have here, then, three of the most fluid of substances, gaseous at all life-temperatures, combined with the most solid substance known; and among the four we find the readiest combiner, and the most inert; the easiest to displace, and the

most firmly grappling; the stablest, and the most unstable, of all common elements. From the interplay of such opposites extraordinary resultants should appear.

If localized wills are to gain progressive expression through masses of matter we should expect that the materials used would have both mobility and fixity. That is to say, we should look for a constant flow of particles, and at the same time relative permanence in the arrangements into which they temporarily enter; for only thus could change be added to change. Furthermore, if such a will were to be free to oppose outside influences as well as to yield to them promptly, the material through which it responded should have unusual stability associated with an instability resembling that of explosive compounds. Accordingly, since the properties of a compound result from the properties of its constituent elements more or less modified by mutual influence, it may not be altogether fanciful to suppose that the solidity of carbon, the fluidity of hydrogen, the stability of oxygen, and the instability of nitrogen may be especially significant as properties which in combination largely account for the almost paradoxical properties of living substance which is characterized by permanence with constant change, and sensitiveness with resistance; and having withal such an exceeding delicacy of balance that an infinitesimal force is sufficient to release energy in one direction rather than another.

Of course a complete explanation of the chemico-physical properties of this living substance, if ever attainable, must be vastly more complex than might appear from the vague suggestions given above as to possible connections between a few important facts. The purpose of these hints is merely to indicate how increasing knowledge of matter may help us to understand the conditions under which life is possible, and so be of profit in our dealings with the world in which we live. It seems only reasonable to assume that the properties inherent in the materials of which all living bodies are composed should make possible and largely determine the activities they all exhibit.

Whatever may be the explanation of the fundamental properties of protoplasm, they are indeed, marvelous to

contemplate. Our simile of the living boats would need to be much elaborated before it could well portray the bewildering complexities of action and interaction which go on within the simplest organisms. We said that the materials of each organic craft were being continually lost and continually replaced. But we must remember that often more is added than is lost; then the organism grows. It should be said also that so long as inner impulses control the arrangement of the fresh material, and thus partly determine the character of the growing structure, the arrangements formed usually show progressive fixity, each arrangement determining somewhat the arrangements which follow and rendering them less susceptible of change. Hence, old age with its decreasing mobility and final death is an incidental result of the progressive fixity which makes structure and habit possible. Yet under certain conditions, as we have seen, protoplasm passes into a fixed condition, to all appearance like that of death, but from which it may revive with youth renewed. A similar renewal of mobility distinguishes reproduction from mere growth, and offsets death in the economy of nature. Our living boats, then, grow old, and may die; or, they may become inactive and afterward resume activity with youthful vigor. When they have grown large enough they form out of themselves new boats, similarly invigorated and similarly relieved from the hamperings of old habits or fixed arrangements;—but not entirely, for each is built upon much the same lines as its parent, and in its own building can only modify the design. Yet what wonders may result from an ever so slight power of modification bearing the slightest impress of a choice! This part may be modified in one way, that in another: and morphological differentiation with physiological division of labor may ensue. What one brief life cannot accomplish, another may; individuality, heredity, adaptation, organic evolution—all are here implied. Such are the powers and potentialities of a mass of living jelly.

Our imagined boats each built and captained by a choosing power are meant to represent living things in general. All plants and all animals, as we have seen, differ from all minerals in having differentiated organs adapted to the needs

imposed by the conditions under which they live; and in detaching certain portions of their substance, such as seeds or eggs, capable of developing from infancy to old age by taking in as food suitable materials, transforming them, then building them into their bodies, and finally after utilization, eliminating them as waste products. Such being the characteristics of all living things we should hardly expect any well-marked peculiarities by which all animals can be distinguished from all plants. In fact there is not a single point of difference available for separating sharply the animal from the vegetable kingdom. The Linnæan criterion of feeling we have already found to fail when applied to primitive types. So also the popular criterion of motion or locomotion must be rejected by anyone acquainted with the lower forms of life, which include not only motile plants but fixed animals; and we have only to remember the absence of chlorophyll from many plants to realize that even this highly characteristic vegetable substance does not afford an adequate mark of distinction between the two kingdoms. Not a few organisms behave like plants at one stage, and like animals at another. A considerable number of these vegeto-animal organisms have been claimed alike by botanists and zoölogists. The uncertainty in classifying such forms has led to the suggestion that a third organic kingdom, intermediate between the animal and the vegetable, be recognized to include all the kinds in dispute. This suggestion has not met with much favor among naturalists, for instead of lessening the practical difficulties of the case it would really double them by giving us two uncertain boundary lines instead of one. Our best way surely is to meet the difficulty by trying to define as strictly as possible what may be conveniently meant by animal and plant, remembering that whatever definition we frame is sure to be arbitrary.

We know that the great majority of plants organize inorganic material, while the great majority of animals, if not all, have no such power and so must depend upon plants for their food. The raw materials which plants build up into food have only to be absorbed in solution from the water, soil, or air in which they live. The elaborated food of animals,

on the other hand, is generally solid and so requires to be dissolved in a digestive cavity within the body before absorption is possible. Plants which can make their own food from materials always at hand have no such need for traveling about in search of food as most animals have; and while food-seeking calls for the special sensitiveness which Linnæus termed feeling, food-making involves only such manifestations of irritability as might easily escape his notice. A typical plant is thus a sedentary food-maker, a typical animal being a roving eater. It is only when plants lose more or less their power of making food, and animals their power of locomotion that doubt arises as to their kingdom, and then the question has to be decided not so much by rules and definitions, as by evidences of their kinship to undoubted examples of vegetable or animal life.

A Bacterium, for example, is classed as a plant because of resemblances to a Nostoc which outweigh its animal-like motility and dependence upon organic food. If a Bacterium should develop a digestive cavity for the reception of its food we should say it had become an animal.

The most fundamental difference between plants and animals appears thus to lie in the ways they prefer to get their food—the vegetable way being to make the best of what comes to it, the animal choosing rather to capture what plants have made. Returning to our simile of the boats it might be said that the vegetable craft choose to anchor in a stream of materials which they organize into food, while the animal craft navigate the stream and repair their losses entirely from other vessels. A modern revision of the aphorism of Linnæus, still, however, confessedly inaccurate, might read:—minerals crystallize; plants organize or reorganize materials which they absorb; animals reorganize food which they have swallowed.

200. Plants in general. The foregoing reflections upon the way natural objects are related to one another are intended especially to emphasize the pivotal place which plants hold in the economy of nature. It is now believed that the wide and rich possibilities of earthly life could not have been gained or maintained without plants. Plants were

presumably the first things to manifest individualized powers of choice upon our planet; and plants have so chosen that animals have been born and enabled to realize the highest opportunities of life. Hence, because some plants have chosen as they did, we are now able to choose as we do.

One of the earliest results of plant choice was doubtless the fixed mode of life; and with this we may connect the building of a protective cellulose covering and framework readily permeable by fluid raw-food materials. The firmness of this framework, combined with its power of conducting fluids, permitted eventually the building, even upon land, of enormous structures hundreds of feet in height. Fixity, together with their powers of absorption, have thus enabled plants to attain in some cases the longest life and the greatest size of any organisms. Preferring to be home-keepers rather than hunters their more tranquil lives have given neither opportunity nor occasion for such specializations of sensitiveness as are involved in the rapid and highly complex responses of animals. Hence it is that their modes of life appear so different from ours although but modified manifestations of the same fundamental, vital power.

It is just because of the contrasts between vegetable and human life that plants are able to serve our needs in so many ways. They feed us because they have retained the power of food-making which our line of life has lost. They shelter us because they have learned how to form in wood a constructive material better than any we or our ancestors could ever make. They clothe us because the cellulose fibers of their bodies make a better covering than the hairs our bodies have retained. They warm us and work for us because they can store up sunshine, as we cannot. They help to make us well partly because their waste-products are so different from ours. They excite our admiration by doing to perfection so many things we cannot do at all. They harm us only when we have not learned to know them and to behave toward them as we should. There are thus abundant reasons why mankind should study the economic properties of plants as fully as possible. We may be sure there will always be much to learn regarding the relations of plants to human

welfare, and that all we shall learn about this or any other aspect of their lives may serve to enrich our own. Thus, an inexhaustible interest as well as an increasing command over the resources of our world is the reward of our endeavor.

An even deeper interest than belongs to any idea of use or harm is also sure to be aroused by watching the behavior of these our fellow-creatures that are so different from us in almost every way. For, again, these very differences give them an endless fascination as objects of study; and, finally, it is just these differences which enable us to distinguish the incidental from the essential powers of life. In these organisms we see individualized wills expressed under conditions as different as possible from those which permit the action of our own power of choice. We cannot hope to fathom the mysteries to which the humblest plant may lead us; we can only say with the poet Tennyson—

“Flower in the crannied wall,
I pluck you out of the crannies,
Hold you here, root and all, in my hand,
Little flower—but *if* I could understand
What you are, root and all, and all in all,
I should know what God and man is.”

INDEX

All numbers refer to pages, heavy type indicating illustrations.

- Abnormalities, 436
Absinthe, 159
Absorbent cotton, 228
Acacia Senegal, Gum Arabic Tree
Accommodation versus competition, 454
Acer Saccharum, Sugar-maple
Aceraceæ, Maple Family
Acetic Acid, 156
Achene, 351, 386
Aconite, 182, 189, 190
Aconitine, 190
Aconitum Napellus, Monkshood
Acorn, morphology, 375
Acorus Calamus, Sweet-flag
Acquired adaptations, 441, 443; characters, 443, 445
Acquirement, permitted by natural selection, 450; versus selection, 452
Acrid juice, 357
Actæa spicata, Baneberry
Adaptation, 428, 572
Adaptations, 431; acquired, 441, 443; characteristic, 442; individual, 442; origin of, 442; selected, 446; sudden, 457, 459
Adder-tongue, **532, 533, 558**
Adder-tongue Family: adder-tongue, **532, 533, 558**; grape-fern, **532, 533**.
Adhere, 365
Adhesion of organs, 365
Aëration, 530
Æstivation, 349; convolute, 369; imbricate, 349, 354; open, 371; plicate, 381; plicate-convolute, 381; valvate, 349, 354
Agaricaceæ, Gill-mushroom Family
Agaricus campestris, Field Mushroom
Agriculture, primitive centers, 122, **123**
Air-cushions, 284
Air-plant, 508
Albumen, 316, 351, 352
Albuminous seeds, 355
Alcohol, 156
Alcoholic beverages, 156
Alcoholic fermentation, 495
Alga Subdivision, 395, 396
Algæ, Seaweed Subdivision
Algæ, as gonidia, 509; in general, 491; of hot springs, 475
Algo-fungal air-plants, 509
Alkaloids, 150, 177, 181
Allium Cepa, Onion
Allspice, 128, **130, 177**; oil, 130, 297
Almond, 35, **42, 120, 124, 167, 363**; kernel, 114; oil, 296; philopena, 365
Alpine Rose, **378**
Alternate, floral organs, 350, 354; leaves, 342, 352
Alternation, of floral organs, 350; of generations, 485, 512
Althæa officinalis, Marshmallow
Amadou, 239, **241**
Amanita muscaria, Fly-amanita
phalloides, Death-cup
Amarantaceæ, Amaranth Family
Amaranth Family, 378
Amaryllidaceæ, Amaryllis Family
Amaryllis Family, 397
Amber, 288
Amentaceous inflorescence, 373
Aments, 373
American, aspen, **264**; food-plants, 124; elm, **259**; laurels, 416, 417; sycamore, **267, 268**; wood-anemony, 205
Ammonia, 33

All numbers refer to pages, heavy type indicating illustrations.

- Anabolism, 84
 Anabolism imitated, 563
Anacardiaceæ, Sumac Family
 Analogous organs, 321, 326
 Analogues, 321, 322, 326
 Analogy, 326
Ananas sativas, Pineapple
 Anotropous ovules, 346, 355
 Ancestral forms vague, 441
 Ancient food-plants, 124
 Andrœcium (*see also* stamens), 346, 347
Andropogon halepensis, Johnson Grass
 Sorghum, Broom-corn
Anemone quinquefolia, American Wood-anemony
 nemerosa, Wood-anemony
 Pulsatilla, Pasque-flower
 Anemony, 328-356, **341**, 404, 405
Angiospermæ, (Case-seed Class), 8
 Angiospermous gynœcium, 392
 Angiosperms, 397; as dominating plants, 560; evolution of, **538**
 Aniline dyes, 290
 Animal, fibers, 223; kingdom, 561, 562
 Animals and plants defined, 573, 574
 Animals evolved from plants, 466
 Anise, 137, **142**, 170, 370, 412, 413
 Annual herbs, 333; rings, **253**
 Annuals, 352
 Annulus, **529**
 Anther, 12, **14**, 319, 550
 Antheridia, **515**, **516**, **517**, **527**, **537**
 Antheridia-carriers, **516**
 Antheridiophores, **516**
 Anthers dehiscing by longitudinal slits, 354, 355; by uplifted valves, 360; poricidal, 379; syngenesious, 384
Anthoceros lævis, Horned-liverwort
Anthocerotaceæ, Horned-liverwort Family
 Antiseptics, 177
 Apetalous flowers, 349
 Aphorism of Linnæus, 561; revised, 574
Apium graveolens, Celery
Apocynaceæ, Dogbane Family
 Apothecium, **505**
 Appendages for dissemination, 560
 Apple, **86**, **87**, 88, 121, 124, 363, 408, 409; pulp, 114; wood, 269
 Aquatic ancestry of fernworts, 550
Aquifoliaceæ, Holly Family
Aquilegia vulgaris, Columbine
 Arabin, 163, 164
 Arabinose, 164
Araceæ, Arum Family
Arachis hypogœa, Peanut
Arales, Arum Order
Araliaceæ, Ginseng Family
 Archegonia-carriers, **518**
 Archegonia, rudimentary, **556**
 Archegoniophores, **518**
 Archegonium, 514, **528**, **537**, **551**
Archichlamydeæ, Crowfoot Series
 Archichlamydeous flower, 378
 Aril, **213**, 393
 Arrhenius, Svante, 568
 Arrow-poison, 189
Artemisia Absinthium, Wormwood
 Artichoke, Jerusalem, 43, **61**, **62**, 120, 125, 385, 420, 421
 Articles of dress, 284
 Artificial, cell, 563; feeding, 563; lightning, 168; limbs, 245; 280; selection, 446, 447, 455; silk, 224, 228; systems, 307
 Arum Family, 389, 397, 422, 423: sweet-flag, **174**
 Arum Order, 389, 397, 422, 423
 Asafetida, 170, 172, 173, **175**, 287, 370, 412, 413
Ascolichenes, Spore-sac Lichens
Ascomycetes, Spore-sac Fungi
 Ascospore, 501
 Ascus, 501
 Ash, in coal, 300; in foods, 114; in grains, 30; in peat, 300; in wood, 298, 300
 Ash, splinters, 241; white, **259**; wood, 562, 259
 Asparagus, 55, **64**, 65, 114, 120, 124, 390, 424, 425
Asparagus officinalis, Asparagus
 Aspen, American, **264**
Aspidium Filix-mas, Male-fern
Astragalus gummifer, Tragacanth Shrub
 Astringents, 154, 166

All numbers refer to pages, heavy type indicating illustrations.

- Atavism, 436
Atropa Belladonna, Belladonna
 Atropine, 182, 186
 Attar of roses, 150
 Authority, 7
Avena sativa, Oats
 Awn, **13**
 Awnings, 223
 Ax handles, 286
 Axil, 319
 Axile placenta, 355
- Bacillus subtilis*, Hay Bacillus
 Bacteria, 492, 511
Bacteriaceæ, Rod-germ Family
 Bacterium, 574
Bacterium aceti, Vinegar Ferment
acidii lactici, Milk-souring Bacterium
 Bagging, 230, 232
 Balls, 245, 277
 Bamboo, 232, 235, **239**, 274, 291, 387, 420, 421
Bambusa vulgaris, Bamboo
 Banana, 88, **98**, **99**, 121, 124; pulp, 114
 Banana Family, 397: banana, **98**, **99**; Manila hemp plant, **233**
 Banana Order, 597
 Baneberry, 328-356, **334**, **335**, 404, 405
 Barberry Family, 398
 Bark, 252; origin, **254**
 Barley, 11, 15, 25, 120, 124, 126, 156, 235, 387, 420, 421; common, **21**; kernel, 114; range, 26; six-rowed, **22**; two-rowed, **22**
 Barrels, 263
 Base-ball bats, 245
Basidiolichenes, Spore-base Lichens
Basidiomycetes, Spore-base Fungi
 Basidium, 502, **503**
 Basketry, 223, 235
 Baskets, 241
 Basswood, 263
 Bast fibers, 224, 228
 Bats, 245
 Bayberry Family, 398
 Bayberry Order, 398
 Bay, Bull, **262**
- Bean, 40, 270, 365, 408, 409; kidney, **49**; Lima, **51**
 Beard-lichen Family: beard-lichen, **507**, **508**
 Beard, of grasses, 13
 Bee plants, 303
 Beech, 414, 415; European, **268**; wood, **257**, 268
 Beech Family, 374, 398, 414, 415; chestnut, **37**; cork oak, **277**, **278**; English oak, **258**; European beech, 268; red oak, **257**
 Beech Order, 376, 398, 414, 415
 Beer, 156, 495
 Beet, 43, **52**, **53**, 120, 124
 Beet-sugar, 102
 Beggar sores, 217
 Beginnings, many, 433
 Belladonna, 186, **187**, 208, 382, 416, 417
 Bellflower, 384, 418, 419; creeping, **381**
 Bellflower Family, 384, 401, 420, 421; creeping bellflower, **381**; Indian tobacco, **201**
 Bellflower Order, 386, 401, 420, 421
 Bellflower Series, 386, 397
 Belts, 223
 Bent embryo, 363
Berberidaceæ, Barberry Family
 Berry, 351
 Berry-like fruit, 392
Bertholletia excelsa, Brazil-nut
Beta vulgaris, Beet
Betula alba, White Birch
Betulaceæ, Birch Family
 Beverage plants, 128
 Biennial, **52**, 333
Bignoniaceæ, Bignonia Family
 Bignonia Family, 401
 Bilabiate calyx, 366
 Billiard cues, 245
 Binomial nomenclature, 4
 Binders' boards, 224
 Biological botany, 10
 Birch, 373, 412, 413; oil of, 297; white, **265**; wood, **257**, **263**
 Birch Family, 373, 398, 414, 415; filbert, **36**; white birch, **265**
 Bird's eye maple, 263
 Bisexual thallus, 514

All numbers refer to pages, heavy type indicating illustrations.

- Bitter Cassava, 104, **110**, **111**, 121, 124
 Bittersweet, **209**, 212
 Black, dye, 294; mustard, **133**, 134; nightshade, **208**, 212; pepper, 128, **131**, 136, 177; pepper oil, 130; pigments, 294; walnut, **260**, 376
 Bladderwort Family, 401
 Bladder-wracks, 487, **488**, **489**
 Blade, 336, 537
 Blanc-mange, Irish moss, 107
 Blossom, 343
 Blue Algæ, 470, 492, 508
 Bluebell type of flowers, 435
 Boats, portable, 284
 Body of ovule, 346
 Bone substitute, 276
 Boot-soles, 287
 Borage Family, 401
Boraginaceæ, Borage Family
 Borecole, Garden Kale
 Botanical pictures, 312; questions, 1
 Botany, as a study of names, 314; beginnings, 1; departments of, 8; science of, 1; systematic, 314, 315
Botrychium Lunaria, Grape-fern
 Botryose inflorescence, 344, 345, 352
 Bottle-gourd, **275**, 383, 418, 419
 Bowling-alleys, 245
 Boxes, 243, 263, 268, 270
 Brace root, **23**, **299**
 Bract, **13**, 343, 352, 354
 Bractlet, 343, 352, 354
 Braiding, 223
 Branch, 428
 Brandy, 159
Brassica campestris, Turnip
nigra, Black Mustard
oleracea, var. *acephala*, Garden Kale and Tree-cabbage
oleracea, var. *Botrytis*, Cauliflower
oleracea, var. *capitata*, Common Cabbage
oleracea, var. *gemmifera*, Brussels Sprouts
oleracea, var. *gongylodes*, Kohlrabi
oleracea, var. *sabauda*, Savoy Cabbage
oleracea, var. *sylvestris*, Wild Kale
 Brazilian Rubber-tree, **281**
 Brazil-nut, 35, **44**, 120, 125, 282; kernel, 114; shells, 282
 Brazil-nut Family, 400
 Bread raising, 495
 Breathing-pores, 519, **529**
 Breeding, 430
 Bridges, 270
Bromeliaceæ, Pineapple Family
 Brood-body, 514, **521**
 Brood-bud, **540**, 542
 Brood-cup, **521**
 Broom-corn, 232, 235, **236**, 387, 420, 421
 Brooms, 223, 235
 Brown Algæ, 485
 Brushes, 223; whisk, 235
 Brussels sprouts, 55, **69**
Bryophyta, Bryophyte Division
 Bryophyte Division, 530
 Bryophytes, 395, 396
 Buckthorn Family, 399
 Buckthorn Order, 399
 Buckwheat, 11, **29**, 120, 125, 126, 372, 412, 413; climbing, **556**; kernel, 114
 Buckwheat Family, 372, 398, 412, 413; buckwheat, **29**; climbing buckwheat, **556**; garden rhubarb, **104**; medicinal rhubarb, **170**
 Buckwheat Order, 372, 398, 412, 413
 Budding, reproduction by, 495
 Buds; 319, **320**; reproduction by, **540**, 542
 Buffers, 280
 Building, 222, 263
 Buildings, 242
 Bulb, 43; solid, 336
 Bull Bay, **262**
 Burlap, 223, 230
 Burr of chestnut, **38**, 375
 Butter bacteria, 494
 Buttercup, **216**, 443; at the seashore, 462; evolution of aquatic form, 467; pigmy, 444
 Buttercups, 217, 328-356

- All numbers refer to pages, heavy type indicating illustrations.
- Butternut, 35, **40**, 120, 125, 376;
wood, 261
- Button-molds, 244
- Buttons, 277
- Buttonwood, **267**, 268
- Cabbage, 55, 120, 124, **274**, 406,
407; common, **69**; leaves, 114
- Cabbages, etc., 362
- Cabinet woods, 266, 268, 274
- Cabinet work, 259, 261, 266, 270
- Cables, 223, 235
- Cacao, 103, **107**, **108**, 121, 124,
150
- Cacao-butter, 167
- Cactus Family, 400
- Cactus Order, 400
- Caffeine, 150, 153, 154
- Calamites ramosus*, Giant Scour-
ing Rush
- Calamus, 170
- Calamus spp.*, Rattans
- Calisaya-tree, **188**
- Calking, 223
- Calories in foods, 114
- Calory, 116
- Caltha palustris*, Marsh-marigold
- Calycanthaceæ*, Strawberry-shrub
Family
- Calyptra, 515, **520**, 526, 528, **529**
- Calyx, **29**; bilabiate, 366; gam-
osepalous, 366
- Cambium, 252, **254**, 542
- Campanula rapunculoides*, Creep-
ing Bellflower
- Campanulaceæ*, Bellflower Family
- Campanulales*, Bellflower Order
- Camphor, 177, 228, 360
- Camphors, 177
- Campylotropous ovule, 363
- Canal-cells, **544**
- Candles, 288
- Canes, 245, 268, 274
- Cane seats, 235
- Cane-sugar, 101, 102
- Cannabis sativa*, Indian Hemp
- Canning, 157
- Canoes, paper, 224
- Cantaloup, Muskmelon
- Canvas, 230
- Caoutchouc, 280, 281
- Caper-bush, **145**, **146**
- Caper Family, 398: caper-bush,
145, **146**
- Capers, 137
- Caper Spurge, **216**, 217
- Capitate inflorescence, 373
- Capparidaceæ*, Caper Family
- Capparis spinosa*, Caper-bush
- Cap of mushroom, **502**
- Caprifoliaceæ*, Honeysuckle Fam-
ily
- Caps, 239
- Capsella Bursa-pastoris*, Shep-
herd's Purse
- Capsicum annuum*, Red Pepper
- Capsule, 351, 515; enveloped
loculicidal, 379; loculicidal, 368;
marginicidally septifragal, 382;
poricidal, 362; septicidal, 379;
septifragal, 382
- Caraway, 137, **142**, 170, 297, 370,
410, 411
- Carbohydrates, 31, 74, 114, 115
- Carbon, 570
- Carbonaceous foods, 115
- Carbon dioxid, 68
- Carbon filaments, 228
- Carbonic acid gas, 68
- Carboniferous period, 299
- Cardamoms, 137, **141**, 170
- Cardol, 218
- Carpel, 346, 352, 550, 551
- Carpellary leaves, 352, 555
- Carpentry, 242, 256, 271
- Carpets, 230
- Carpospore, 490
- Carrageen, 105, **112**, 121, 125, 163,
165, 395, 487, **491**
- Carrageen Family: carrageen, **112**,
491
- Carrriages, 259, 260, 263
- Carrot, 43, **55**, **56**, **57**, 120, 124,
219, 370, 412, 413; wild, 430
- Cars, 256, 259
- Carum Carui*, Caraway
- Carving, 242, 257, 263, 269, 280
- Car-wheels, paper, 224
- Carya alba*, Hickory, Shagbark
- Carya olivæformis*, Pecan
- Caryophyllaceæ*, Pink Family
- Caryopsis, 388
- Case-seed Class, 8, 391, 397
- Case-seedworts, Case-seed Class

All numbers refer to pages, heavy type indicating illustrations.

- Casks, 243
 Cassava, Bitter, 104, **110**, **111**, 124
Castanea sativa, Chestnut
 Castile soap, 296
 Castor-oil, 167
 Castor-oil plant, **172**, **173**, 213
 Catabolism, 85; imitated, 563
 Catkins, 373
 Caulicle, 317, **318**, **319**, 557
 Cauliflower, 55, **70**
 Cedar, Red, **273**, 392; oil of, 297; wood, 270
 Celery, 55, **75**, 114, 121, 124, 137, 370, 412, 413
 Cell, 473, 560; artificial, 563
 Cell-contents, 473
 Cell-division, 510
 Cell-masses, 560
 Cell-multiplication, rapidity of, 511
 Cell-plates, 560
 Cell-rows, 560
 Cells, mostly minute, 511; of large size, 510
 Cellular cryptogams, 396
 Celluloid, 224, 228
 Cellulose, 32, 276, 472; products, 223, 224
 Cellulose covering, protective and permeable, 575
 Cell-wall, 473
 Cement for leather, 287
 Cements, 288
 Central cylinder, 528
Cerealía munera, 11
 Cereals, 11-34 (*see also* Grains); the principal, 15; value of, 30
 Ceres, 11
Cetraria islandica, Iceland Moss
 Chaff, 11
 Chain, family, 355
 Chairs, 223
 Chair seats, 241
 Characteristic adaptations, 442
 Characters, acquired, 443
 Charcoal, 298, 300
 Chart, Food, **114**
 Checkerberry, 203
 Checkers, 245
 Cheese bacteria, 494
 Chemical botany, 9; composition of foods, 114
 Chemico-physical properties of living protoplasm, 571
Chenopodiaceæ, Goosefoot Family
Chenopodiales, Goosefoot Order
Chermes abietis, Spruce Aphid
 Cherry, 88, **90**, 121, 209, 364, 408, 409; poisoning by leaves, 203; poisoning by stones, 205; wild black, **260**; wood, 263
 Chessmen, 245
 Chestnut, 35, **37**, **38**, 120, 124, 294, 374, 414, 415; kernel, 114; wood, 257
 Chests, 260
 Chili Pepper, **132**
 China-tree Family, 399
 Chip, 241
Chlorophyceæ, Green Algæ
 Chlorophyll, 67, 74, 471, 476, 485, 487, 573
 Chocolate, 102, 154
 Choice, in plants and animals, 463; power of, 568; the pivotal factor in evolution, 469
Chondrus crispus, Carrageen
 Choosing the better way, 468, 469
 Choripetalous corolla, 379
 Christmas Holly, **212**; Rose, **330**, **331**, 328-356, 404, 405
 Chromatophore, 476
Chroöcoccaceæ, Tint-ball Family
Chroöcoccus turgidus, Tint-ball Alga
Cicuta maculata, Water Hemlock
Cinchona Calisaya, Calisaya-tree
Cinninnobolus, **500**
Cinnamomum Camphora, Laurel-camphor Tree
zeylanicum, Cinnamon
 Cinnamon, 128, **135**, 177, 360, 406, 407
Cistaceæ, Rock-rose Family
Citrullus vulgaris, Watermelon
Citrus Aurantium, Orange
medica, var. *Limonum*, Lemon
 Class, 8, 428
 Classes, Linnæan, 308
 Classification, 305; by size, 306; by uses, 306; early attempts, 306; expressing kinship, 433
 Cleanliness, 494

All numbers refer to pages, heavy type indicating illustrations.

- Clematis, 404, 405; erect silky, **337**, 328-356; evolution of, 444, 445, 449, 457; mountain, **335**, 328-356; vine-bower, **336**, 328-356
- Clematis alpina*, Mountain Clematis
- Vitalba*, Vine-bower Clematis
- Climbing Buckwheat, **556**
- Climbing-ferns, **299**
- Climbing habit, evolution of, 455
- Close-fertilization, 512
- Clothes-pins, 259
- Cloves, 128, **129**, 177
- Cloves, oil of, 129, 130
- Club-moss, 167, **174**, 326, 394, **544**
- Club-mosses, 544; giant, **299**, **301**
- Club-moss Family, 554: club-moss, **174**
- Coal, 298, 300, 549; age, 547
- Coalescence of floral organs, 354
- Coalescent floral organs, 350
- Coal plants, **299**, 432
- Coal-tar, 290
- Coca, 182, **185**, 186, **187**
- Coca Family, **399**: coca, **185**, **187**
- Cocoa, 102
- Cocoa-butter, 296
- Coconut, *see* Coconut
- Coconut, 35, **46**, **47**, 120, 124, 296, 388, 422, 423; dipper, 276; kernel, 114; oil, 296, 297; palm, **46**, **47**, 235, 274
- Cocos nucifera*, Coconut
- Coffea arabica*, Coffee
- Coffee, 150, **153**, **154**, **155**; aroma, 154
- Coffee-sacks, 230
- Cogs, 245
- Cohesion figures, 129, 130
- Coir, 232, 235
- Coke, 298, 300
- Coleochaetaceae*, Sheath-alga Family
- Coleochaete soluta*, Free-branching Sheath-alga
- Collodion, 224, 228
- Colonies, 510
- Colophony; 288
- Coloring matters, 222, 290
- Colors of flowers, 557
- Columbine, 328-332, **333**, 334-356, 404, 405
- Columbus, Christopher, 283
- Columella, 519, **529**
- Column, **149**
- Combs, 284
- Commelinaceae*, Spiderwort Family
- Common, cabbage, **69**; cherry, 121, 124; currant, **94**; field mushroom, 107; pea, 126
- Companion-cells, **556**
- Compass plant, **73**
- Complete flower, **42**, 349
- Compositae*, Composites
- Composites, 311
- Compound cyme, 344; flower, 385; inflorescence, 345, 352; leaf compared with leafy shoot, 342; leaves, 339, 352; pistil, 347
- Concave torus, 355
- Conceptacle, 487
- Condiments, 128; miscellaneous, 137
- Conduction, 528
- Cone-like fruit, 374
- Cone of scouring-rushes, 543
- Cones, 547
- Cone-scales, 548
- Conflicts destroy or test, 468
- Coniferae*, Conifers and Pine Order
- Coniferales*, Pine Order
- Conifers, 311; evolution of, 554
- Conium maculatum*, Poison Hemlock
- Conjugating-cells, **497**
- Conjugation, 478
- Connecting links, 402, 440, 449, 456
- Consumption, 494
- Contrast of vegetable with human life, 575
- Convallaria majalis*, Lily-of-the-valley
- Convex torus, 355
- Convolute aestivation, 369
- Convolvulaceae*, Morning-glory Family
- Cooking, 297
- Cooperage, 243, 258, 259, 260, 261, 268, 270
- Co-operative provision for offspring, 511
- Copal, 288, 290, 296
- Copal-tree, Zanzibar, 366, 408, 409

All numbers refer to pages, heavy type indicating illustrations.

- Copper sulphate for killing algæ, 476
- Cora pavonia*, Mushroom-lichen
- Corchorus capsularis*, Podded Jute
- olitorius*, Pot-herb Jute
- Cordage, 223, 230, 232, 235
- Cord-moss, 522, **526**, **527**, **528**, **529**
- Cord-moss . Family: cord-moss, **526-529**
- Cords, 223
- Cordaites*, 299, 554
- Core of pome, 365
- Coriander, 137, **143**, **144**, 370
412, 413; oil of, 297
- Coriandrum sativum*, Coriander
- Cork, 222, 279; mother, **278**, 279;
oak, **277**, **278**
- Corn, 336
- Cornaceæ*, Dogwood Family
- Corn, Indian (*see* Maize)
- Corolla, **43**; choripetalous, 379;
gamopetalous, 379; labiate, 383;
papilionaceous, 366; strap-
shaped, 385
- Corolla, parts of, keel, 366; stand-
ard, 366; wings, 366
- Correlated characters, 451
- Cortex, 530, 538
- Corylus Avellana*, Filbert
- Corymb, 345
- Corymbose inflorescence, 345, 352
- Cosmarium Botrys*, Grape Des-
mid
- Costate, 341
- Cotton, 224, **225**, **226**, **227**, 369,
410, 411; absorbent, 228; bag-
ging, 230; batting, 228
- Cotton-seed oil, 100, 296, 297
- Cotyledon, **46**, **48**, 317, **318**, 319,
546, 557
- Courbaril-tree, **289**, 290, 366, 408,
409
- Coverings, waterproof, 284
- Crassulaceæ*, Orpine Family
- Crates, 243, 263, 270
- Creation, special, 429
- Creationism, 429
- Creator as architect, 431
- Creeping Bellflower, **381**
- Cremocarp, 371
- Creosote, 300
- Cricket-bats, 245
- Crocus sativus*, Saffron Crocus
- Croquet-mallets, etc., 245
- Cross-fertilization, 512, 557
- Cross-partitions in hyphæ, 499
- Crowfoot, 217, 328-356, 404, 405;
white water, **467**
- Crowfoot Family, 328, 330, 358,
360, 398, 404, 405: baneberry,
334, **335**; Christmas rose, **380**,
331; columbine, **333**, **334**; ditch
crowfoot, **216**; erect silky clem-
atis, **337**; marsh-marigold, 198;
monkshood, **191**; mouse-tail,
330, **331**, **332**; mountain clem-
atis, **335**; pasque-flower, **338**;
peony, **329**; pigmy buttercup,
444; seaside crowfoot, **463**; tall
buttercup, **216**; vine-bower
clematis, **336**; white water crow-
foot, **467**; wood-anemony, **205**
- Crowfoot Order, 361, 398, 406, 407
- Crowfoot Series, 377, 386, 397
- Crowfoot type of flower, 435
- Crown-tuber, 43
- Crozier-like vernation, 537
- Cruciferaæ*, Mustard Family
- Crude rubber, 283
- Crutches, 245
- Cryptogamia*, Cryptogams
- Cryptogams, 308; cellular, 396;
vascular, 396
- Cryptogams and Phenogams, 550
- Crystalwort Family: crystalworts,
513, **515**
- Crystalworts, **513**, **515**
- Cucumber, **82**, **83**, 121, 124, 383,
418, 419; fruit, 114; sponge, 383
- Cucumis Melo*, Muskmelon
- sativus*, Cucumber
- Cucurbita maxima*, Hubbard
Squash and Turban Squash
- moschata*, Winter Crook-neck
squash
- Pepo*, Pumpkin, Long White
Squash, Summer Crook-neck
Squash, and Scallop Squash
- Cucurbitales*, Gourd Order
- Cucurbitaceæ*, Gourd Family
- Culture-period and native, home,
123, 125; of food-plants, 120
- Cupule, 375

All numbers refer to pages, heavy type indicating illustrations.

- Curly maple, 263
 Currant, 88, **94**, 121, 125
Cyamophyceæ, Blue Algæ
 Cycad, **558**; Japanese, **555**
Cycadaceæ, Cycad Family
Cycadales, Cycad Order
 Cycad Family: 397; Japanese cycad, **555**
 Cycad Order, 397
 Cycads, 554; evolution of, **558**
Cycas revoluta, Japanese Cycad
 Cycles of life, 470
Cydonia vulgaris, Quince
 Cyme, 344
 Cymose inflorescence, 343, 344, 345, 352
Cyperaceæ, Sedge Family
Cyripedium hirsutum, Showy Ladies' Slipper
parviflorum, Yellow Ladies' Slipper
 Cytoplasm, 473
- Daily ration, 117, 118
 Dandelions, 442, **443**
 Daphne, **205**, 209
Daphne Mezereum, Daphne
 Darwin, Charles, 446
 Darwinism, 446, 453, 456, 457; objections to, 452
 Date, 88, **100**, **101**, 114, 121, 124, 388, 422, 423
 Date-palm, 274
Datura Stramonium, Jimson-weed
Daucus Carota, Carrot
 Dead substances, 570
 Death, **572**
 Death-cup, 214, **215**
 De Candolle, Augustin Pyrame, 316
 Decay, 494, 504
 Decomound leaves, 339, 352
 Decoration, 223
 Definite variations, 448
 Degeneration, 468, 512; in ferns, 535
 Dehiscence of anthers, 354; by longitudinal slits, 355; by pores, 379; by uplifted valves, 360
 Dehiscence of fruits, 351; dorsal, 359; loculicidal, 368; marginicidally septifragal, 382; poricidal, 362; septicidal, 379; septifragal, 382; ventral, 351
 Dentists' absorbent, 239
 Departments of botany, 8
 Description, early attempts, 312; Linnæan ideal, 314; in "ordinary English," 312; technical, 312
 Desert plants, 454
Desmidiaceæ, Desmid Family
 Desmid Family: grape desmid, **477**
 Desmids, 476
 Determinate inflorescence, 343, 352
 Devil's Aprons, 485
 Diadelphous stamens, 366
 Diastase, 32
 Dicots, 397
 Dicotyledonous embryo, 386
 Dicotyl Subclass, 397
 Dietary standards, 117
 Diet, mixed, 118; well-balanced, 118
 Difference between animals and plants, 573
Digitalis purpurea, Foxglove
 Dioecious inflorescence, 360
 Dippers, 276
 Diseases due to fungi, 504
 Disk, **61**
 Dispersal of seeds, 560; of spores, 511, 532
 Dissemination, 560; organs of, 322
 Distillation, 128
 Distilled beverages, 159
 Distinct floral organs, 350, 354
 Ditch Crowfoot, **216**, 328-356
 Divided leaves, 339
 Diving-dresses, 284
 Division, 8
 Division of labor, 321
 Divisions of vegetable kingdom, 394, 396
 Dogbane Family, 401; oleander, **206**, **207**
 Dogwood Family, 400
 Domesticated varieties, 430
 Domestication, 446
 Domestic utensils, 243
 Door-mats, 235
 Dorsal dehiscence of pericarp, 359; placenta, 346
 Double flowers, 347

- All numbers refer to pages, heavy type indicating illustrations.
- Drawing-paper, 224
 Drawers, 263, 268
 Drugs, 163; poisonous, 176
 Drupaceous, fruit, 365; nut, 376
 Dupe, 364
 Dry, cooperage, 243; fruits, 351; pericarp, 351, 355
 Drying oils, 295
 Duck, 230
 Dugout canoe, 247
 Dust-spore, **496**, 498, 505, 511
 Dust-spore-case, **496**
 Dyeing, 222
 Dyers' Indigo Shrub, 292, **293**
 Dyestuffs, 290
- Early attempts at classifying, 306; at describing, 312
 Ear of grain, 11
 Earth-vegetables, 35, 41
Ebenales, Ebony Order
 Ebony Order, 401
 Ebracteate inflorescence, 362
 Ecological botany, 10
 Economic, botany, 9, 304; importance of fungi, 504; properties of plants, 575
 Economics of co-operation, 468
 Egg-apparatus, **556**
 Egg-cell, 514, **521**, **551**, **552**, **556**, 557, 560
 Egg-plant, **85**, 121, 124, 382
 Egg sac members, 352
 Egg-sacs, 325, 326
 Egg-spore Algæ, Evolution of, **558**
 Elastic, bands, 284; gums, 222, 280, 287; springs for dissemination, 560; webbing, 283
 Elater, 517, **520**, 526, **541**, 543
 Elder, 196, **197**, 202, 208
 Electric apparatus, 288
Elettaria cardamomum, Cardamoms
 Elm, **259**; American, **259**; bark, 163; English, **166**; wood, **256**, 259
 Elm Family: 398; American elm, **259**; English elm, **167**
 Elm-leaved Linden, **264**
 Embryo, **29**, **48**, 316, 317, **318**, 351, 352, 514, **553**, **556**; bent, 363; curved, 362; dicotyledonous, 386; monocotyledonous, 388; uncoiled, 355; of fern, **538**
 Embryo, parts of; cotyledon, **46**, **48**; plumule, **48**; radicle, **48**; scutellum, 388; seed-bud, **48**; seed-leaf, **46**, **48**; seed-root, **48**
 Embryos, **547**
 Embryo-sac, **551**, **556**
 Endogenous stems, 387
 Endosperm, **551**
 Endospore, 478
 Energy, in food, 114; measures of, 115; of vegetable foods, 116
 Engler and Prantl's classification, 394
 English, elm, 165, **167**; oak, **258**; walnut, 261, 296
 Environment, 431
 Enzyme, 32, 494
 Epidermis, **254**, 530, 538, **540**, 542
 Epicalyx, 364
 Epigynous flower, 365
 Epiphyte, 508
Equisetacea, Scouring-rush Family
Equisetina, Scouring-rushes
Equisetum arvense, Scouring-rush
 Erasers, 284
 Erect Silky Clematis, 328-336, **337**, 338-356
Ericacea, Heath Family
 Ericales, Heath Order
Erysibe communis, Powdery-mildew
Erythroxyloacea, Coca Family
Erythroylon Coca, Coca
 Essence of life, 568, 569
 Essences, 128, 146
 Essential organs of flower, 13, **43**, 319
 Ethers, 159
Euphorbiacea, Spurge Family
Euphorbia Lathyris, Caper Spurge
marginata, Snow-on-the-mountain
 European, beech, **268**; grape, 88, **93**, 121, 124; larch, **271**; raspberry, **91**
 Evening-primrose, 457
 Evening-primrose Family, 400
 Evolution, 433; by choice, 461, 464; in general, 464; of clematis,

All numbers refer to pages, heavy type indicating illustrations.

- 444, 445, 449, 452, 457; of crow-foot family, 437, 438; of fern-worts, 548, 549; of flowering plants, **559**, 560; of human society, 468; of mankind, 468, 469; of mossworts, 531; of ovaries, 557; of plants, 560; of scouring-rushes, 543; of seed-plants, **558**, 559, 560; of thallophytes, 510; of the universe, 464; of vegetable kingdom, 466
- Exalbuminous seed, 363, 557
- Excelsior, 241
- Exogenous stems, 387
- Exospore, 478
- Exstipulate leaf, 359
- Extinct, branches, 449; types, 467
- Extinction, 467, 468
- Eye-spot, 482
- Fabrics, 223
- Factors of change, 468
- Fagaceæ*, Beech Family
- Fagales*, Beech Order
- Fagopyrum esculentum*, Buck-wheat
- Fagus sylvatica*, European Beech
- Fallen Stars, 473, **474**
- Family, 7, 403; chain, 355; tree, 436, **437**
- Famine, effect of, 463
- Fans, palm-leaf, 388
- Farm implements, 256
- Fat, 34; in foods, 114
- Fats, 74, 114, 115
- Feeding, imitation of, 563
- Feeling, 573; in plants and animals, 562
- Fence rails, 258
- Fences, 245, 260
- Fennel-flower, 328-**332**, 333-**341**, 342-356, 404, 405
- Fermentation, 156, 494
- Fermented beverages, 156
- Fern prothallium, **536**
- Ferns, 308, 311, 532; climbing, **299**; evolution of, **558**; fossil, 534; herbaceous, **535**
- Fernworts, 394, 396, 548
- Fertility of hybrids a test of species, 430
- Fertilization, 484, **552**; in angio-sperms, 555, **556**; in gymnosperms, 551-555
- Ferula assa-fetida*, Asafetida Plant
- Fiber-plants, 224
- Fibers, 222, 224; animal, mineral, and vegetable, 223
- Fibrils, 250
- Fibrovascular bundles, 394, **533**, 538, **539**, **540**
- Ficus carica*, Fig
- elastica*, India Rubber-tree
- Field Mushroom, **113**, 121, 125, 395, 501, **502**, **503**
- Fig, 88, **102**, 121, 124
- Figwort Family, 382, 401, 416, 417; foxglove, **204**
- Filament, 12, **14**, 319
- Filbert, 35, **36**, 120, 124, 373; kernel, 114
- Filices*, Ferns
- Filicinaæ*, Ferns
- Filling, 223
- Finishing lumbers, 263
- Fireworks, 168
- First of living things, 466, 566, 567
- Fission, 473, 560
- Fission-algæ, **558**
- Fission fungi, 492; descendants of fission-algæ, 495
- Fishing-rods, 274
- Fish-lines, 223
- Fixed mode of life in plants, 575
- Fixed oil, 34; of black mustard, 134; of white mustard, 134
- Fixed oils, 128, 166, 295
- Fixity, in animals, 573; of species, 429, 430
- Flagellum, 482
- Flavoring plants, 128
- Flax, 224, **229**, **231**, 345, 435; as a type, 316; bud, 319, **320**; germination, 317, **318**; plant, **229**, 230, **231**, 334
- Flax Family, 399; flax, **229**, **231**
- Flaxseed, 163, 164, 295, **318**
- Fleshy, fruits, 351; pericarp, 351, 355; torus, 364
- Flint in epidermis, 542
- Floats, 279, 280
- Floor covering, 280
- Flooring, 263, 270

All numbers refer to pages, heavy type indicating illustrations.

- Floral envelops, 319
 Floral organs, adhesion of, 365; arrangements for pollination, 557
 Floral organs, alternate, 350, 354; coalescent, 350; distinct, 350, 354; epigynous, 365; free, 350, 354; hypogynous, 350; insertion of, 349; opposite, 368; partially coalescent, 354; perigynous, 350
 Florets, **380**
 Flower, 319, 557
 Flower-cluster, 343
 Flower in the crannied wall, 576
 Flower, parts of: androecium, 346; anther, 12, **14**; calyx, **29**; carpel, 346; corolla, 43; epicalyx, 364; essential organs, 13, **43**; filament, 12, **14**; funicle, 346; gynœcium, 346; keel, **48**; micro-pyle, 346; nectar, 29; nectar-gland, **29**; nectar-leaves, 348; ovary, 12, **14**, 345; ovule, 12, **14**, 346; pappus, 386; perianth, **43**; petal, **42**, 348; pistil, 11, **14**, 345; placenta, 346; raphe, 346; receptacle, 349, 385; sepal, **29**; silk, **24**; stamen, **12**, **14**; staminodes, 348; standard, **48**; stigma, 12, **14**, 345; style, 12, **14**, 345; torus, 349, 350; wings, **48**
 Flowering plants, 393, 396, 397; evolution of, **559**
 Flowers, attractions of, 557
 Flowers, apetalous, 349; archichlamydeous, 378; axillary, 345; clustered, 352; complete, **42**, 349; compound, 385; double, 347; epigynous, 365; imperfect, 13, 347; irregular, 349, 354; metachlamydeous, 386; neutral, 371; perfect, 13, 347, 353; pistillate, 347; polygamous, 347; regular, 354; resupinate, 391; rudimentary, 13, 14; solitary, 345; solitary axillary, 352; solitary terminal, 352; staminate, 347
 Fluctuating variations, 448, 455
 Flux, 288
 Fly-amanita, **215**, 217
 Fly-poison, 217
 Fodder, 303
 Foliage, as a sunbeam-trap, 302; main work of, 85
 Foliage-plants, 303
 Follicle, 351
Fomes fomentarius, Amadou
 Food, 128; as fuel and building material, 114; chart, **114**; favorite combinations, 119
 Food-adjuncts, 128, 159, 302
 Food-making, 74
 Food-plants, 122; classes of, 35; native home and culture period, 120, 121
 Food-products, miscellaneous, 91
 Foods, 302; vegetable, 113; vegetable versus animal, 119
 Foot of sporophyte, 517, **538**
 Footstalk, 336
 Forests, effect on water-supply, 304
 Form blocks, 263
 Formative material, **254**, **320**
 Formulas, plant, 352; of seed-plants, 404-427
 Fossil, botany, 10; club-moss, **301**; ferns, 534; scale-tree, **301**
 Fossils, 432
 Fountain pens, 284
 Foxglove, **204**, 208, 382, 416, 417
 Fox-grape, 125
Fragaria spp., Strawberry
Fraxinus americana, White Ash
 Free-branching Sheath-alga, **483**
 Free floral organs, 350, 354
 Free will, 568, 569
 French Rose, **150**
 Fruit, 12, 319, 350; cone-like, 374; dehiscent, 351; drupaceous, 365; dry, 351; fleshy, 351; indehiscent, 351
 Fruit-body, **500**, 501, **502**
 Fruit, parts of: aril, **213**, 393; burr, **38**; chaff, 11; grain, 12; husk, 11, 12; kernel, 11; pericarp, 351; pit, **89**; seed, 350; stone, **89**, 364; suture, 351
 Fruits, 35, 88: achene, 351, 386; berry, 351; berry-like, 392; capsule, 351; caryopsis, 388; cremocarp, 371; cupule, 375; drupa-

All numbers refer to pages, heavy type indicating illustrations.

- aceous nut, 376; drupe, 364;
fleshy torus, 364; follicle, 351;
hip, 364; legume, 367; nut, 374;
nutlet, 364; pepo, 384; pome,
365; samara, 358; schizocarp,
370; silique, 363; stone-fruit,
364
- Fruit-vegetables, 35, 85
- Fucaceæ*, Wrack Family
- Fucus vesiculosus*, Bladder-wrack
- Fuels, 222, 279, 297
- Fuel value of foods, 114
- Funariaceæ*, Cord-moss Family
- Funaria hygrometrica*, Cord-moss
- Function, 321
- Fundamental system, 539
- Fungal diseases, 504
- Fungi, 589 (see also Mushroom
Subdivision)
- Fungi, in general, 503; parasitic
upon parasitic fungi, 501
- Fungus Subdivision, 395, 396
- Funicle, 346
- Furniture, 243, 257, 259, 263, 276
- Gamboge, 290, 291
- Gamboge Family, 400
- Gamboge-tree, Siamese, 290, **291**
- Gametangium, 484
- Gamete, 478, 512
- Gametophyte, 485, 514, 515
- Gamopetalous corolla, 379
- Gamosepalous calyx, 366
- Gaps, 449; limiting groups, 440
- Garcinia Hanburyi*, Siamese gam-
boge-tree
- Garden, currant, 125; kale, 55, **68**;
rhubarb, 91, **104**, 121
- Garments, paper, 224; waterproof;
284
- Gas, illuminating, 298
- Gaultheria procumbens*, Winter-
green
- Gelatinous, substances, 163; ma-
terial, 472
- Genus, 6, 428
- Gentianaceæ*, Gentian Family
- Gentianales*, Gentian Order
- Gentian Family, 401
- Gentian Order, 401
- Geographical botany, 10
- Geraniaceæ*, Geranium Family
- Geraniales*, Geranium Order
- Geranium Family, 399
- Geranium Order, 399
- Germ, 316, 352
- Germs carried from plant to plant,
568
- Germination of flax, 317, **318**
- Giant, club-mosses or lycopods,
299, **301**, 547; scouring rush, **299**
- Gigartinaceæ*, Carrageen Family
- Giglio-Tos, E., 563
- Gill-mushroom Family: death-cup,
215; field mushroom, **113**; fly-
amanita, **215**
- Gills of mushroom, **502**, **503**
- Gin, 159
- Gin, cotton, 228
- Ginger, 128, 134, **136**, 170; oil, 130
- Ginger Family, 397: cardamoms,
141; ginger, **136**
- Ginkgoaceæ*, Ginkgo Family
- Ginkgo Family, 397
- Ginkgo Order, 397
- Ginkgoales*, Ginkgo Order
- Ginseng Family, 400
- Girths, 223
- Glabrous, 343
- Gliadin, 33, 34
- Glucose, 31, 102
- Glucosides, 292
- Glumaceous perianth, 390
- Glumes, 387
- Glumifloræ*, Grass Order
- Gluten, 33
- Glutin, 33
- Glycerides, 296
- Glycerin, 296
- Glycyrrhiza globra*, Licorice
- God, immanence of, 569
- Goethe's theory of flowers, 325
- Golf, balls, 287; clubs, 245
- Gonidium, **507**
- Goodyear, Charles, 283
- Goosefoot Family: beet, **52**, **53**;
spinach, **71**, **72**
- Goosefoot Order, 398
- Gossypium barbadense*, Sea-island
Cotton; *herbaceum*, Upland Cot-
ton
- Gourd, 121, **275**, 276
- Gourd Family, 383, 398, 401,
418, 419: bottle-gourd, **275**;

All numbers refer to pages, heavy type indicating illustrations.

- cucumber, **82**, **83**; hubbard squash, **81**; long white squash, **79**; muskmelon, **95**; pumpkin, **76**, **77**, **78**; scallop squash, **80**; summer crook-neck squash, **79**; turban squash, **81**; vegetable sponge, **240**; watermelon, **96**; winter crook-neck squash, **81**, **82**
- Gourd Order, 401
- Grains (*see also* Cereals) 11, 12; earliest use, 20; in ancient times, 17
- Gramina*, Grasses
- Graminales*, Grass Order
- Gramineæ*, Grass Family
- Grape, European, 88, 121, 124; northern fox, 88, 93, 125; pulp, 114; sugar, 31
- Grape Desmid, **477**, 479
- Grape Family, 399; grapes, **93**
- Grape-fern, **532**, **533**
- Grapes, 88, **93**, 121, 157
- Grasses, 11, 311
- Grass Family, 387, 397, 422, 423: bamboo, **239**; barley, common, **21**; barley, six-rowed, **22**; Barley, two-rowed, **22**; broom-corn, **236**; maize, **23**, **24**; oat, **12**, **13**, **14**; rice, **16**, **17**; rye, **18**; sugarcane, **106**; wheat, **19**, **20**
- Grass Order, 388, 397, 422, 423
- Gravitation and evolution, 441
- Greek origin of terms, 313
- Green Algæ, 476, 508
- Growing-points, **254**
- Growth, 561, 572; a slow behavior, 442
- Guitars, 245, 270
- Gum, 32, 287
- Gum arabic, 163, **164**
- Gum Arabic Tree, 163, **163**, 366, 408, 409
- Gum-resins, 287
- Gum tragacanth, 164
- Guncotton, 224, 228
- Gunny bagging, 223
- Gunpowder, 300
- Gun-stocks, 261, 245
- Gutta-percha, 280, 285
- Gymnosperma*, Naked-seed Class
- Gymnospermous gynoecium, 392
- Gymnosperms, 397, 550
- Gynoecium, 346; angiospermous, 392; gymnospermous, 392; naked-seeded, 392
- Habit of plant, 359
- Habits, 572
- Hæmatein, 292
- Hæmatoxylin, 292
- Hæmatoxylin campecheanum*, Log-wood-tree
- Hair-like outgrowths, 538
- Half-inferior ovary, 350
- Hamamelidaceæ*, Witch-hazel Family
- Hamamelis virginica*, Witch-hazel
- Hames, 244
- Hammocks, 223
- Hampers, 223
- Handles, 245, 280, 284
- Hard, pine, 270; rubber, 284; soap, 296
- Harmful plants, 302
- Harness, 244, 259, 260
- Hashish, 181
- Hat linings, 280
- Hats, 223, 238; chip, 241; straw, 235
- Haustorium, 499
- Hay Bacillus, **492**
- Hazel, 373, 412, 413
- Hazelnut, **36**
- Head, 373; of grain, 11
- Heart-wood, 246
- Heath Family, 378, 401, 416, 417: mountain laurel, **202**; sheep laurel, **202**; wintergreen, **148**
- Heath Order, 379, 401, 416, 417
- Heating, 297
- Helianthus tuberosus*, Jerusalem Artichoke
- Heliopsis scabra*, Oxeye
- Helleborus niger*, Christmas Rose
- Helminthocladiaceæ*, Thread-weed Family
- Hemlock, **273**, 294, 392, 426, 427; poison, **194**, **195**, 209, 370; water, **193**, 370; wood, 271
- Hemp, 224, 230
- Hemp, Indian, **193**
- Hemp, Manila, 232, **233**
- Hepaticæ*, Liverworts

All numbers refer to pages, heavy type indicating illustrations.

- Hepatics, 513
 Herb, 330
 Herbaceous, 333
 Herbaceous Ferns, **535**
 Herbage-vegetables, 35, 53
 Herbs, 306
 Heredity, 572
 Heterocyst, 474
Hevea guyanensis, Brazilian Rubber-tree
 Hickory, 376, 414, 415; nut, 35, 120, 125; shagbark, **41**; splints, 241; wood, 260
 Higher dicots, 397, 401
 Hip, 364
Hippocastanaceæ, Horse-chestnut Family
 Hockey-sticks, 245
 Holly, **212**
 Holly Family, 399: Christmas holly, **212**
 Holophyte, 495
 Homologies, 326, 327
 Homologous parts, 326
 Homologues, 326, **327**
 Homology, 326
 Honey, 303
 Honeysuckle Family, 401: elder **197**
 Hoops, 259
 Hops, 156, **157**, 170
Hordeum sativum, var. *distichon*, Barley, Two-rowed; var. *hexastichon*, Barley, Six-rowed; var. *vulgare*, Barley, Common
 Hormogonia, 475, 510
 Horned-liverwort, 517, **522**, **523**, **558**
 Horned-liverwort Family: horned-liverwort, **522**, **523**, **558**
 Horn substitute, 284
 Horsechestnut Family, 399
 Horseradish, 137, 141, **144**, 177, 362
 Horticultural hybrids, 430
 Hose, 284
 Host, **211**, 494
 Hot springs containing algæ, 475
 House-furnishing, 223
 Hubbard Squash, **81**
 Hubs, 259, 263
 Human life contrasted with plant life, 575
 Human welfare dependent upon a knowledge of plants, 575
Humulus Lupulus, Hops
 Husk, 11, 235
 Hybrids, 430
 Hydrocarbon, 284; oxidized, 285, 287
 Hydrogen, 570
Hymenæa Courbaril, Courbaril-tree
 Hymenium, **503**
 Hypha, 496
 Hypogenous floral organs, 350, 355
 Hysterophyte, 495
 Ice age, 432
 Iceland Moss, 163, 165, **169**, 395, 504, **505**, **506**, **507**
 Ignorance not to be argued from, 453
Ilex Aquifolium, Christmas Holly
Illicium anisatum, Star Anise
 Illuminating gas, 298, 301
 Illuminants, 295, 297
 Imbricate æstivation, 349, 354
 Imitation of feeding, 563; of vital processes, 564
 Immanence of God, 569
 Imperfect flowers, 13, 347
 Implements, 245, 259, 260, 263
 Incandescent lamp filaments, 228
 Indehiscent fruits, 351
 Indeterminate inflorescence, 344, 352
 India ink, 294
 Indian, corn (*see* Maize); hemp, **180**, **181**; poke, **199**, 390, 424, 425; tobacco, **201**, 202, 384, 418, 419
 India-rubber, 283
 India-rubber tree, **282**
 Indican, 292
 Indigestible seeds for dissemination, 560
 Indigo, 290, 291, 562; blue, 292; white, 292
Indigofera tinctoria, Dyer's Indigo Shrub
 Indigo Shrub, Dyer's, 292, **293**, 366, 408, 409

- All numbers refer to pages, heavy type indicating illustrations.
- Individual adaptations, 442; differences, 565
- Individuality, 572
- Induced variations, 448
- Indusium, 179
- Industrial implements, 245; plants, 222
- Inferior ovary, 350, 365, **380**
- Infertile hybrids, 430
- Inflorescence, 343, 352; amentaceous, 373; botryose, 344, 345, 352; capitate, 373; compound, 344, 345, 352; corymbose, 345, 352; cymose, 343, 345, 352; determinate, 343, 352; diœcious, 360; ebracteate, 362; indeterminate, 344, 352; monœcious, 374; paniculate, 345, 352; polygamous, 354; racemose, 345, 352; simple, 352; spicate, 373
- Inflorescence, parts of: awn, **13**; beard, **13**; bract, **13**, 354; bractlet, 354; chaff, 11; disk, **61**; glume, 387; husk, 11; involucl, 344; involucre, **61**, 344, 354; lodicule, 13; rachis, **14**, 344; receptacle, **61**; spathe, 388; spikelet, **13**
- Inflorescences, ament, 373; catkin, 373; cyme, 344; ear of grain, 11; head, 373; head of grain, 11; panicle, 345; raceme, 344; spadix, 388; spike, 373; umbel, 370; umbellule, 370
- Inheritance of acquired characters, 446; of acquirements, 443
- Ink, 290; India, 294; printing, 294, 295; writing, 294
- Inorganic, realm, 562; substances, 321, 570
- Insect-pollination, 557
- Insects attracted by sweets, 557
- Insertion, 349
- Insoles, 280
- Insulating material, 287
- Insulators, 284
- Integuments of ovule, **551**, **556**
- Intensity of the struggle for existence, 453
- Interior finish, 257, 259, 261, 263, 268, 270
- Internode, 317, 318
- Interval cell-division, 495
- Involucl, 344
- Involucre, **61**, 344, 354
- Ipomœa Batatas*, Sweet Potato
- Iridaceæ*, Iris Family
- Iris Family, 390, 397, 424, 425: saffron crocus, **176**
- Irish moss, 105, **112**, 163, 165, **491**
- Iron and steel versus wood, 248
- Irregular flowers, 349, 354
- Ivory, Vegetable, **275**, **276**, 388
- Ivy, Poison, **218**, 219
- Jambosa Caryophyllus*, Clove
- Japanese Cycad, **555**
- Jerusalem Artichoke, 43, **61**, **62**, 120, 125, 385, 420, 421
- Jimson-weed, 199, **200**, 208, 210, 382, 416, 417
- Johnson Grass, **236**
- Joinery, 242, 260, 266
- Juglandaceæ*, Walnut Family
- Juglanales*, Walnut Order
- Juglans cinerea*, Butternut
- nigra*, Black Walnut
- regia*, Walnut
- Juice, acrid, 357; milky, 361; poisonous, 357
- Juncus effusus*, Rush
- Juniper, **158**, 159, 392, 426, 427
- Juniperus communis*, Juniper
- virginiana*, Red Cedar
- Jussieu, Antoine Laurent de, 311, 328; Bernard de, 311
- Jute, 224, 230, **232**, 367, 410, 411
- Kale, 55, 120; garden, **68**; wild, **66**, **67**
- Kaleidoscope analogy, 461
- Kalmia latifolia*, Mountain Laurel
- Keel, **48**, 366
- Keels, 263
- Kelps, 485
- Kidney Bean, **49**, **50**, 85, 114, 120, 124
- Kilogrammeter, 116
- Kingdom, 8, 428
- Kingdoms, The Three, 561
- King of dyestuffs, 291
- Kinship, 403, 428
- Knitting, 223

All numbers refer to pages, heavy type indicating illustrations.

- Knobs, 269, 277
 Kohlrabi, 55, **69**
- Labiata*, Mint Family
 Labiate, corolla, 383
 Lace, 223, 230
 Lacquer, 291
Lactuca saliva, Lettuce
scariola, Wild Lettuce
 Ladies' slippers, 218, 219, **220**, 391, 424, 425
Lagenaria vulgaris, Bottle-gourd
 Lamarckism, 445, 453, 456, 457
 Lamarck, Jean Baptiste, 445
Laminariaceæ, Sea-tangle Family
Laminaria spp., Sea-tangles
 Lampblack, 290, 294
 Larch, 294, 392, 424, 425; European, **271**; wood, 270
Larix decidua, European Larch
 Latin terms, 313
Lauraceæ, Laurel Family
 Laurel Camphor, 177, 228
 Laurel-camphor Tree, **178**
 Laurel Family, 360, 398, 406, 407: cinnamon, **135**; laurel-camphor tree, **178**; sassafras, **168**
 Laurel, American, 416, 417; mountain, **203**, 379; sheep, **202**, 379
 Laurels, 208
 Laurinol, 177
 Law of recapitulation, 435, 560
 Lead-pencils, 270
 Leaf, 324, 336, **538**
 Leaf-buds, 323
 Leaflets, 339, 342, 352
 Leaf-member, 326, **327**, 348
 Leaf-part, 323, 325
 Leaf, parts of, ligule, **16**; rain-guard, **16**; ocrea, 372; stipule, 358
 Leaf-stalk, 336
 Leafy shoot compared with compound leaf, 342
 Leather, 295
 Leather-finishing, 294
 Leaves, 352, 533; alternate, 342, 352; carpellary, 352; compound, 342, 352; decompound, 352; exstipulate, 359; ocreate, 372; of the flower, 324; opposite, 342, 352; palmate, 352; parallel-veined, 387; pinnate, 352; primary, **318**, 319; rosette, 342; secondary, **318**, 319; sessile, simple, 342; stipulate, 358; ternate, 352; verticillate, 342; whorled, 342
 Legume, 367
Leguminosæ, Pulse Family
 Lemon, 88, **97**, 121, 124, 146, 170
 Lemonade, 150
Lentibulaceæ, Bladderwort Family
Lepidodendraceæ, Scale-tree Family
Lepidodendron (see also Giant Club-mosses, and Scale-tree), 547, 554
 Lettuce, 55, **72**, **73**, **74**, 121, 124, 385, 420, 421; leaves, 114; wild, **73**
 Lichen, 165
Lichenes, Lichen Subdivision
 Lichenin, 165
 Lichens, 504
 Lichens as Nature's pioneers, 506
 Lichen-starch, 165
 Lichen Subdivision, 395, 396, 508
 Licorice, 163, 166, **169**, 366, 410, 411
 Lid of capsule, 526
 Life, always existed, 568; essence of, 568, 569; test of, 568, 569
 Life-cycles, **559**
 Life-histories, 470
 Life-history of a molecule, 563
 Lifeless substances, 570
 Lifeless things versus living things, 569
 Life-preservers, 280, 284
 Lignin, 247
 Ligule, **16**, **547**
 Likeness a measure of kinship, 433
Liliaceæ, Lily Family
Liliales, Lily Order
Liliifloræ, Lily Order
 Lily Family, 390, 397, 424, 425: asparagus, **64**, **65**; Indian poke, **199**; lily-of-the-valley, **204**; onion, **63**, **64**
 Lily-of-the-valley, **204**, 208, 390, 424, 425
 Lily Order, 390, 397, 424, 425
 Lima bean, **51**, 120, 124

All numbers refer to pages, heavy type indicating illustrations.

- Lime in grains, 31
Linaceæ, Flax Family
 Linden, 263, 367, 410, 411
 Linden, 362, 367, 410, 411; elm-leaved, **264**
 Linden Family, 367, 399, 410, 411; elm-leaved linden, **264**; jutes, **232**
 Linen, 230
 Linnæan, reform in terminology, 313; Society, 446; system, 308
 Linnæus, 3, 308, 311, 312, 313; aphorism of, 561; revised, 574
 Linoleic acid, 296
 Linolein, 296
 Linseed-oil, 280, 295, 296
Linum usitatissimum, Flax
 Liqueurs, 159
 Liquors, 159
Liriodendron Tulipifera, Tulip White-wood
 Liverworts, 513, 530; evolution of, **558**
 Living beings, 562
 Living substance, 570
 Living versus lifeless things, 563
Lobelia inflata, Indian Tobacco
 Lobewort Division, 395, 396
 Lobeworts, 509, 510
 Locomotion of desmids, 478
 Loculicidal dehiscence of capsule, 368
 Locust, 196, **197**, 208, 366, 408, 409; wood, 259; yellow, 259
 Lodicule, **13**
Loganiaceæ, Logania Family
 Logania Family: nux vomica, **189**, **190**
 Logwood, 290, 292
 Logwood-tree, **294**, 366, 408, 409
 Long life of plants, 575
 Long White Squash, **79**
Loranthaceæ, Mistletoe Family
 Lower dicots, 397, 398, 399, 400
 Lubricants, 295, 297
Luffa ægyptiaca, Vegetable Sponge
Lycopodiaceæ, Club-moss Family
Lycopodinaæ, Club-mosses
 Lycopodium, 167
Lycopodium sp., Club-moss
 Lycopods, Giant, 547
 Macaroni, 33
 Mace, 128, **134**
 Machinery, 257, 260, 263
 Machines, 245, 259
 Macrosporangium, **545**
 Macrospore, **545**, **547**
 Madder Family, 401: calisaya-tree, **188**; coffee, **153**, **154**, **155**
 Madder Order, 401
 Madder-red, 562
 Magnesia in grains, 31
 Magnolia, 358, **262**, 406, 407; wood, 263
Magnoliaceæ, Magnolia Family
 Magnolia Family, 358, 398, 406, 407: magnolia, **262**; star anise, **143**; tulip whitewood, **261**
Magnolia grandiflora, Magnolia
 Mahogany, **266**
 Maize, 11, 15, **23**, **24**, 25, 28, 120, 122, 126, 159, 232, 235, 387, 420, 421; kernel, 114; range, **28**
 Malaria, 188
 Male-fern, **179**, 180, 394, **536**, **539**, **540**
 Male protoplasts, motile, 560
 Mallet-heads, 269
 Mallow Family, 369, 399, 410, 411: marshmallow, **166**; sea-island cotton, **227**; upland cotton, **225**
 Mallow Order, 376, 399, 410, 411
 Malt, 156; liquors, 156; sugar, **32**
 Malting, 32
 Maltose, 32
Malvaceæ, Mallow Family
Malvales, Mallow Order
Manihot utilissima, Bitter Cassava
 Manila, 224, 232; hemp, 232; paper, 232
 Manila Hemp Plant, **233**
 Maple, **261**; stem, **254**; sugar, 101; wood, 263
 Maple Family, 399: sugar-maple, **261**
Marchantia polymorpha, Umbrella Liverwort
 Marginicidally septifragal dehiscence, 382
Mariopteris, Climbing Ferns
 Marjoram, 418, 419; oil of, 297; sweet, 137, **140**, 383
 Market baskets, 241

All numbers refer to pages, heavy type indicating illustrations.

- Marshmallow, 163, 164, **166**, 369, 410, 411
 Marsh-marigold, **198**, 199, 208, 328-356, 404, 405, 558
 Mastery through choosing the better way, 468
 Masts, 270
 Matches, 245
 Mats, 232, 235, 239
 Matting, 223, 235; straw, 235
 Mattress filling, 235
 Meadow Rue, **339**, 328-356
 Mechanical causes in evolution, 453
 Mechanical equivalent of heat, 116
 Medicinal plants, 162, 163; plasters, 288; rhubarb, **170**
 Medicines, 162
 Mediterranean food-plants, 124
Megaphyton, Tree-ferns
Meliaceæ, Melia Family
 Melia Family: mahogany, **266**
 Members, 323, 324, 326; of flowering plant, **327**
Menispermaceæ, Moonseed Family
Mentha piperita, Peppermint; *spicata*, Spearmint
 Menthol, 178
 Meristem, 487
 Meristematic tissue, 487
 Metabolism, 84
Metachlamydeæ, Bellflower Series
 Metachlamydeous flowers, 386
 Metallurgy, 300
 Metal polishing, 542
Metroxylon læve, Smooth Sago Palm
Metroxylon Rumphii, Prickly Sago Palm
 Mezereum Family, 400: daphne, **205**
 Microbes, 494
 Micro-organisms, 494
 Micropyle, 346, 552, **556**
Microspermaæ, Orchid Order
 Microsporangium, **545**
 Microspore, **545**, **546**
 Migrations, 468
 Mildews, 499
 Milk-souring Bacterium, **493**
 Milkweed Family, 401
 Milky juice, 361
 Mineral fibers, 223; kingdom, 561, 562; substances, 321
 Mineral matter in grains, 31
 Mine timbering, 245
 Mint, 418, 419
 Mint Family, 383, 401, 418, 419: peppermint, **147**, 148; sage, **138**; spearmint, **139**; summer savory, **139**; sweet marjoram, **140**; thyme, **139**
 Miscellaneous condiments, 137; food-plants, 35; food-products, 91
 Misconceptions of evolution, 439, 440
 Mistletoe, **210**, **211**, 212
 Mistletoe Family, 398: mistletoe, **210**, **211**
 Mixed diet, 118
 Mixed fibers, 225, 231
 Models, 280
 Modern food-plants, 124
 Molasses, 101
 Molded ornaments, 287
 Monadelphous stamens, 366
 Monkshood, 189, **191**, 196, 208, 328-356, 404, 405
 Monocots, 377
Monocotyledones, Monocotyl Subclass
 Monocotyledonous, 388
 Monocotyl Subclass, 391, 397
 Monœcious, 374
 Montgomerie, Dr. W., 286
 Moonseed Family, 398
Moraceæ, Mulberry Family
 Mordant, 294, 295
 Morning-glory Family, 379, 401, 416, 417: sweet potato, **58**, **59**
 Morphine, 182
 Morphological, botany, 10; differentiation, 322, 572; units, 323
 Moss, 395, 519, 544; Iceland, 395; Irish, 105; Peat, 394
 Mosses, 308
 Mosswort Division, 395, 396
 Mossworts, 530
 Mother of vinegar, 155
 Motile gametes in cycads, 554; protoplasts, 560
 Motion in plants, 573

All numbers refer to pages, heavy type indicating illustrations.

- Mountain, clematis, **335**, 328-356;
 laurel, **202**, 379; selaginella, **545**
 Mouse-tail, **330**, **331**, **332**, 328-
 340, 356, 404, 405
 Mucilaginous material, 485; sub-
 stances, 163
Mucoraceæ, Pin-mold Family
Mucor Mucedo, Pin-mold
 Mulberry Family, 378: fig, **102**;
 hops, **157**; Indian hemp, **180**,
181; India rubber-tree, **282**
Musaceæ, Banana Family
Musa sapientum, Banana; *textilis*,
233, Manila Hemp Plant
Musci, True Mosses
 Mushroom, 125; field, 107, **113**,
 395
 Mushroom Division, 503
 Mushroom Subdivision, 395, 396
 Mushroom-lichen, 508, **509**
 Mushroom-lichen Family: mush-
 room-lichen, **509**
 Mushrooms, 111, 308, 501; poi-
 sonous, 213
 Musical instruments, 245, 263
 Muskmelon, 88, **96**, 121, 124, 283
 Must, 155
 Mustard, 128, **133**, 177; oil of,
 133; volatile oil of, 173
 Mustard Family, 362, 398, 406,
 407; black mustard, **133**; Brus-
 sels sprouts, **69**; cauliflower, **70**;
 common cabbage, **69**; garden
 kale, **68**; horseradish, **144**; kohlr-
 rabi, **69**; radish, **55**; Savoy cab-
 bage, **69**; shepherd's purse, **556**;
 tree-cabbage, **274**; watercress,
70, **71**; white mustard, **133**; wild
 kale, **66**, **67**
 Mustards, 362
 Mutant, 458
 Mutation, 458
 Mutationism, 458
 Mutations like special creations,
 460
 Mutual help, 469; support, 531
 Mycelium, 497, **496**
Myosurus minimus, Mouse-tail
Myricaceæ, Bayberry Family
Myricales, Bayberry Order
Myristica fragrans, Nutmeg
Myristicaceæ, Nutmeg Family
Myrtaceæ, Myrtle Family
Myrtales, Myrtle Order
 Myrtle Family, 400: allspice, **130**;
 Brazil-nut, **44**; clove, **129**
 Myrtle Order, 400
 Mystery of life, 567
 Naked-seed class, 393, 397
 Naked-seeded gynœcium, 392
 Natural objects not diagrammatic,
 327
 Natural orders, 310, 311
 Names of plants, early, 3
 Napkins, paper, 224
Nasturtium Armoracia, Horse-
 radish
officinale, Watercress
 Native home and culture-period,
 123
 Native homes of food-plants, 120,
 121
 Natural, classification, 308; selec-
 tion, 447, 460; system, 310, 311,
 328, 433
 Nature, 562
 Nebula hypothesis, 464, 465
 Neck of archegonium, **521**, **528**,
551
 Nectar, 29, 346; in flowers, 557
 Nectar-gland, **29**
 Nectar-leaves, 348
Nemalion multifidum, Thread-
 weed
 Neo-Darwinism, 448, 449
 Neo-Lamarckism, 445, 449
Nerium Oleander, Oleander
 Nervation, 337
 Net floats, 280
 Nets, 223
 Netted-veined, 337
 Netting, 223
 Nettle Family, 398
 Nettle Order, 398
 Neutral flower, 371
Nicotiana rustica, Turkish To-
 bacco
Tobacum, Virginia Tobacco
 Nicotine, 184
Nigella spp., Fennel-flowers
 Nightshade, black, **208**
 Nightshade Family, 382, 401, 416,
 417: belladonna, **187**; bitter-

All numbers refer to pages, heavy type indicating illustrations.

- sweet, **209**; black nightshade, **208**; egg plant, **85**; jimson-weed, **200**; red pepper, **131, 132**; tobaccos, **184**; tomato, **83, 84**; white potato, **59, 60**
- Nine-pins, 245
- Nitrocellulose, 228
- Nitrogen, 570; need of, 115
- Nitrogenous food, 114
- Node, **23, 317, 318**
- Nomenclature, 314; binomial, 4
- Non-alcoholic beverages, 150
- Non-motile spores, 490
- Non-nitrogenous foods, 115
- Non-nutrients, 31
- Non-sexual, generation; 560; reproduction, 480, 483, 512; spores, 511
- Northern Fox-grape, 88, **93, 125**
- Norway Spruce, **272, 551, 552, 553**
- Nostoc, **522, 574**
- Nostoc spp.*, Fallen Stars
- Nucellus, **551, 556**
- Nucleus, 473
- Nurse-plants, 512, 548, 560
- Nursing by mosswort gametophyte, 531
- Nut, 374; drupaceous, 376
- Nutlets, 364
- Nutmeg, 128, **134, 177**; oil of, 130, 297
- Nutmeg Family, 398: nutmeg, **134**
- Nut-oils, 101, 296
- Nutrients, 31
- Nutrition, organs of, 321
- Nuts, 35
- Nux vomica, 188, **189, 190**
- Nymphaea*, Water-lily Family.
- Oak, 294, 414, 415; cork, **277, 278**; English, **258**; red, 257
- Oaks, 374
- Oak wood, **256**
- Oakum, 231
- Oars, 259
- Oats, 11, **12, 13, 14, 15, 25, 120, 124, 126, 235, 387, 420, 421**; kernel, 114; range, **27**
- Ocrea, 372
- Ocreate stipules, 372
- Odors of flowers, 557
- Œcology, 10
- Enothera spp.*, Evening Primrose
- Enothraceæ*, Evening Primrose Family
- Offensive odors caused by blue algæ, 475
- Offspring, of two parents, 512; well-endowed, 510
- Oil finish, 296
- Oil, of almond, 167; of cacao, 167; of cloves, 129, 130; of mustard, 173; of nutmeg, 130; of saffron, 175; of turpentine, 288, 296; of wintergreen, 147
- Oil reservoirs, 360
- Oil-cloth, 230
- Oils, 222, 295; drying, 295; fixed, 34, 128; non-drying, 297; volatile, 128
- Ointments, 288
- Old age, 571
- Oleaceæ*, Olive Family
- Olea europea*, Olive
- Oleander, **206, 207, 209**
- Oleic acid, 296
- Olein, 296
- Oleoresins, 287
- Olive, 100, **105, 124, 167, 296**; oil, 101, 167, 296, 297; wood, 269
- Olive Family, 401: olive, **105**; white ash, **259**
- Once-compound, 339
- Onion, 43, **63, 64, 120, 124, 146, 390, 424, 425**; bulb, 114
- Ontogeny, 435, 560
- Oömycetes*, Water-mold Fungi
- Oöspore, 484
- Open æstivation, 371
- Ophioglossum vulgatum*, Adder-tongue
- Opium, 182
- Opium Poppy, **182, 183, 296, 361**
- Opposite, floral organs, 368; leaves, 342, 352
- Opuntiales*, Cactus Order
- Orange, 88, **97, 121, 124**; pulp, 114; wood, 266
- Orange-flower oil, 297
- Orange-peel oil, 297
- Orchidaceæ*, Orchid Family
- Orchidales*, Orchid Order
- Orchideæ*, Orchids
- Orchid Family, 391, 397, 424, 425:

All numbers refer to pages, heavy type indicating illustrations.

- showy ladies' slipper, **220**; yellow ladies' slipper, **220**; vanilla, **149**
- Orchid Order, 391, 397, 424, 425
- Orchids, 218, 219, 311
- Order, 8, 428
- Orderly progress, 469
- Orders, Linnæan, 309; natural, 310, 311
- Ordinary English in describing, 312
- Organic, compounds, 562; evolution, 431, 572; materials, 570; realm, 562, 569; substances, 321
- Organisms, 321, 562; as self-building boats, 569
- Organs, 321; adhesion of, 365; analogous, 321
- Oriental food-plants, 124
- Origanum Majorana*, Sweet Marjorum
- Origin, of adaptations, 442; of life, 566; of life in the sea, 491; of species, 441
- Origins, the problem of, 428
- Ornamental, flowers, 303; woods, 268, 269
- Ornaments, 268, 276
- Orpine Family, 399
- Orthotropous ovule, 372
- Oryza sativa*, Rice
- Osiers, 241
- Osmunda, **537**
- Osmundaceæ*, Royal-fern Family
- Ovaries, inferior, 350, 365, **380**; half-inferior, 350; superior, 350
- Ovary, 12, **14**, 319, 345, **556**
- Overproduction of offspring, 447
- Overshoes, 283
- Overstimulation, 159, 160
- Ovulatory cavity, 345; divided by partition, 363
- Ovule, 12, **14**, 319, 325, 352, 550, **551**; parts of, 346
- Ovules, anatropous, 346, 355; campylotropous, 363; orthotropous, 372
- Oxalidaceæ*, Oxalis Family
- Oxalis Family, 399
- Oxeye, **380**, 435
- Oxidized hydrocarbons, 285, 287
- Oxygen, 570; in grains, 31
- Packing, 223, 235, 279, 280
- Packing material, 239
- Pæonia officinalis*, Peony
- Pails, 243; paper, 224
- Painting, 222, 296
- Paints, 295
- Palaquium Gutta*, Taban-tree
- Palmaceæ*, Palm Family
- Palma*, Palms
- Palmales*, Palm Order
- Palm, oils, 296, 297, 389, 397, 422, 423; sago, 388; seeds, 282; stem, **255**
- Palm Family, 388, 397, 422, 423: coconut, **46**, **47**; date, **100**, **101**; rattans, **237**, **238**; sago palms, **109**, **110**; vegetable ivory, **275**, **276**
- Palm Order, 389, 397, 422, 423
- Palmatic acid, 296
- Palmatin, 296, 297
- Palmate nervation, 340, 352
- Palmately compound, 340; divided, 340; ribbed, 337
- Palm-leaf fans, 388
- Palms, 311, 389
- Paneling, 263
- Paniculate inflorescence, 345, 352
- Panspermia, 567
- Papaveraceæ*, Poppy Family
- Papaverales*, Poppy Order
- Papaver somniferum*, Opium Poppy
- Paper, 223, 224, 228, 230, 235, 241; boxes, 224; canoes, 224; car-wheels, 224; making of, 222; manila, 232; napkins, 224; pails, 224
- Papier-maché, 224
- Papilionaceous corolla, 366
- Pappus, 386
- Parallel-veined leaves, 387
- Paraphyses, 487, **503**
- Parasite, 303, 494
- Parasitic fungi, 504
- Parchment, vegetable, 230
- Parenchyma, 530
- Parietal placenta, 362
- Parmeliaceæ*, Shield-lichen Family
- Parsley, 137, **140**, 370, 410, 411
- Parsley Family, 370, 400, 412, 413: anise, **142**; asafetida plant, **175**; caraway, **142**; carrot, **55**, **56**, **57**;

All numbers refer to pages, heavy type indicating illustrations.

- celery, **75**; coriander, **143**, **144**;
parsley, **140**; parsnip, **57**; poison
hemlock, **194**, **195**; water hem-
lock, **193**
Parsley Order, 371, 400, 412, 413
Parsnip, 43, **57**, 120, 124, 219, 370,
412, 413; root, 114
Partition in ovary, 363
Parts of a seed-plant, 316
Pasque-flower, **338**, **341**, 328-356
Pasteboard, 235
Pastinaca sativa, Parsnip
Pasture plants, 303
Patterns, 270
Pea, 40, **48**, 120, 124, 365, 408, 409
Peace and progress, 468
Peach, 88, **89**, 121, 124, 364
Peanut, 35, **45**, 120, 124, 365, 410,
411; kernel, 114; oil, 100, 296,
297
Pear, **87**, 88, 121, 124, 363
Peat, 298; ash, 300; bogs, 298;
moss, 239, **242**, 298, 394, 522,
523, **524**, **525**
Peat-moss Family: peat-moss, **242**,
523-525
Pecan, 35, **40**, 376; nut, 120, 125
Pecopteris, 535
Pecopteris, Tree-ferns
Pedate, 340
Pedicel, 344
Peduncle, 343
Pentadelphous stamens, 368
Peony, **329**, 328-356, 404, 405
Pepo, 384
Pepper, black, 128, **131**; red, 128,
131, **132**, 382, 416, 417
Pepper Family, 398: black pepper,
131
Peppermint, 146, **147**; **148**, 177,
383; camphor, 178; oil, 297
Pepper Order, 398
Perennial, **58**, 331, 332; herbs, 352
Perfect flowers, 13, 347, 354
Perforated cells, **524**
Perfumery, 295, 297
Perianth, **43**, 319; glumaceous,
390; petaloid, 390
Pericarp, 351, 352, dehiscent dor-
sally, 359; dry, 355; fleshy, 355;
winged, 359
Permanent tissue, 487
Perigynous floral organs, 350, 355
Peristome, 527, **529**
Persistence, 466, 468
Petal, **42**, 319, 348, 352
Petaloid perianth, 390; sepals, 348
Petiole, 336, 537
Petiolute, 339
Petroselinum hortense, Parsley
Phanerogamia, Phenogams
Phænogamia, Phenogams
Phærophyceæ, Brown Algæ
Phaseolus lunatus, Lima Bean
vulgaris, Kidney Bean
Phenogamia, Phenogams
Phenogams, 309, 393, 396, 397
Phenogams and cryptogams, 550
Philopena almonds, 365
Phlox Order, 383, 401, 418, 419
Phœnix dactylifera, Date
Phosphorus in grains, 31
Photographer's trays, 284
Photosynthesis, 85
Phycocyanin, 471
Phycocerythrin, 487
Phycophæin, 485
Phylogeny, 435, 560
Physical basis of life, 471
Physiological botany, 10; division
of labor, 319, 321, 572
Phytelephas microcarpa, Vegetable
Ivory
Phytolacca decandra, Pokeweed
Pianos, 245, 263
Picea excelsa, Norway spruce
Pictures, botanical, 312
Pie-plant, 91
Pigments, 290, 291
Pigmy Buttercup, **444**
Piling, 245, 257
Pimento officinalis, Allspice
Pimento walks, 130
Pimpinella Anisum, Anise
Piña, 234
Pinaceæ, Pine Family
Pine, 241, **253**, 392, 424, 425;
Scotch, **269**; wood, **250**, **251**,
270
Pine Family, 392, 397, 426, 427,
554: European larch, **271**; hem-
lock, **273**; juniper, **158**; Norway
spruce, **272**; red cedar, **273**; red-
wood, **273**; Scotch pine, **269**

All numbers refer to pages, heavy type indicating illustrations.

- Pine grove illustrating mutual accommodation, 453, 454
 Pine Order, 393, 397, 426, 427
 Pines, 550
 Pineapple, 88, **103**, 121, 124, 233; fiber, 232; gall, **272**
 Pineapple-cloth, 234
 Pineapple Family, 397: pineapple, 103; southern moss, **234**
 Pin-mold, 495, **496**, **497**
 Pin-mold Family: pin-mold, **496**, **497**
 Pin-mold Fungi, 495
 Pink Family, 398
 Pinnate, 341; nervation, 352
 Pinnately, compound, 341; nerved, 341
Pinus sylvestris, Scotch Pine
Piperaceæ, Pepper Family
Piperales, Pepper Order
Piper nigrum, Black Pepper
 Piping, 287
 Pistil, 11, **14**, 308, 319, 345; compound, 347; simple, 347
 Pistillate flowers, 347
 Pistil, parts of, ovary, 345; ovule, 346; placenta, 346; stigma, 345; style, 345
Pisum sativum, Pea
 Pith, 250, **254**
 Pith-rays, 250, **253**, **254**
 Pivotal place of plants in economy of nature, 574
 Placenta, 346; axile, 355; dorsal, 346; parietal, 362; ventral, 346
 Plaiting, 223, 235
 Planetesimal hypothesis, 465
 Plane-tree, **267**, 268
 Plane-tree Family, 399: American sycamore, **267**
 Planks, 270
Plantaginaceæ, Plantain Family
Plantaginales, Plantain Order
 Plantain Family, 401
 Plantain Order, 401
 Plant, formulas, 352; groups, 358; names, early, 3
 Plant life and human life, 575
 Plants, annual, 11; biennial, **52**; compass, 73; diœcious, 360; habit of, 359; monœcious, 374; ocreate, 372; perennial, **58**; polygamous, 347; shrub, 36; tree, 36; glabrous, 343; pubescent, 343
 Plants and animals defined, 573, 574
 Plants, how named, 2; in general, 574; our dependence upon, 1; needs of, 2
 Plant's place in Nature, 561
 Plants poisonous, to eat, 192; to handle, 217
 Plant segment, 324
Platanaceæ, Plane-tree Family
Platanus occidentalis, American Sycamore
Pleurococcaceæ, Wall-stain Algae
Pleurooccus vulgaris, Wall-stain Alga
 Plicate æstivation, 381
 Plicate-convolute æstivation, 381
 Plum, 88, **90**, 121, 124, 364; wood, **357**, 263
 Plumule, **48**, 317, **318**, 319, 546, **556**
 Podded Jute, **232**
 Poison, Dogwood, *see* Poison-sumac; Hemlock, **194**, **195**, 209, 370, 410, 411
 Poison-ivy, 217, **218**, 219
 Poison-oak, *see* Poison-ivy
 Poisonous bark, 196; drugs, 176; flowers, 205, 208; fruits and seeds, 209; herbage, 199; honey, 205, 207, 208; mushrooms, 111, 213; juice, 357; plants, 112, 162, 163, 192, 219; substances, 302; underground parts, 192; volatile oils, 177
 Poisons, 162; as by-products, 192
 Poison-sumac, 217, **220**
 Poke, Indian, 390, 424, 425
 Pokeweed, **195**, **196**, 208, 209
 Pokeweed Family, 398: pokeweed, **195**, **196**
Polemoniales, Phlox Order
 Poles, 245, 270
 Pollen, 12, **14**, 319; grain, 550, **551**, **556**
 Pollen-sacs, 325, 326
 Pollen-tube, **551**, 555, **556**
 Pollination, 557
 Polygamous flowers, 347, 354

All numbers refer to pages, heavy type indicating illustrations.

- Polygonaceæ*, Buckwheat Family
Polygonales, Buckwheat Order
Polygonum Convolvulus, Climbing Buckwheat
Polypodiaceæ, Polypody Family
 Polypody Family: male-fern, **179**; pteris, **537**
Polyporaceæ, Pore-mushroom Family
 Pome, 365
 Pond-scum, 478, **479**, **480**, 499, **558**
 Pond-scum Family: pond-scum, **479**, **480**
 Poplar, 241, 263, **264**, 377, 414, 415; wood, 263
 Poppy, 208, 406, 407
 Poppy Family, 361, 398, 406, 407: opium poppy, **182**, **183**
 Poppy-oil, 296
 Poppy, Opium, *see* Opium Poppy
 Poppy Order, 363, 398, 408, 409
Populus tremuloides, Poplar
 Porcupine-wood, 272
 Pore-mushroom Family: amadou, **241**
 Pores of wood, 252, 538
 Poricidal dehiscence, 362; of anthers, 379
 Portable boats, 284
Portulacaceæ, Portulaca Family
 Posts, 258, 270
 Potash in grains, 31
 Potassium, 74
 Potato berries, poisonous, 210
 Potato, sweet, 43, **58**, **59**, 379, 416, 417; white, 43, **59**, **60**, 210, 382, 416, 417
 Potentialities of protoplasm, 572
 Pot-herb Jute, **232**
 Pot-herbs, 55
 Powdery mildew, 499, **500**
 Powdery-mildew Family: powdery mildew, **500**
 Preference, power of, 569
 Prehistoric food-plants, 124
 Prickly Sago Palm, **109**, **110**
 Primary leaves, **318**, 319; tissue, 542
 Primitive centers of agriculture, 122, **123**
 Primitive man, 302
 Primitive versus degenerate forms, 549
 Primrose Family, 401
 Primrose Order, 401
Primulaceæ, Primrose Family
Primulales, Primrose Order
 Progress of the Vegetable Kingdom, 389
Principes, Palm Order
 Printing-ink, 294, 295
 Printing-paper, 224
 Progress and peace, 468; in evolution, 466; made in spite of competition, 468
 Progressive fixity of growing structures, 571
 Prolific multiplication, 512
 Prosenchyma, 530
 Protection, organs of, 321, 538
 Proteid, 33, 74, 114, 115, 471
 Protein in foods, 114 (*see also* Proteid)
 Prothallial cells, **556**
 Prothallus, **533**, **536**, **551**
 Prothallus-cell, **546**
 Protonema, **523**, **526**
 Protoplasm, 471; artificial, 562; fundamental properties of, 571; potentialities of, 572
 Protoplast, 473
 Protoplasts, artificial, 564; fusion of, 560
Prunus Amygdalus, Almond
Cerasus, Sour Cherry
domestica, Plum
Persica, Peach
serotina, Wild Black Cherry
 Prussic acid in cherry leaves, 204; in cherry stones, 205
 Pseudo-fibers, 225, 239
 Pseudopodium, **525**
 Pseudo-root, 481, **521**, **536**
 Pseudo-shoot, 481
 Pseudo-woods, 256, 272
Pteridophyta, Pteridophyte Division
 Pteridophyte Division, 548
 Pteridophytes, 394, 396
Pteris, **537**
 Pubescent, 343
 Pulse, 35, 40
 Pulse Family, 365, 398, 399, 410,

All numbers refer to pages, heavy type indicating illustrations.

- 411: courbaril-tree, **289**; dyer's indigo-shrub, **293**; gum arabic tree, **164**; kidney bean, **49, 50**; Lima bean, **51**; locust, **197**; logwood-tree, **294**; pea, **48**; peanut, **45**; tragacanth shrub, **165**; Zanzibar copal-tree, **289**
 Pumpkin, **76, 77, 78, 85, 114, 121, 124, 383**
 Purifiers of air and water, 304
 Pussies, 373
 Putrefaction, 493
 Pyrenoid, 476
 Pyrography, 263
Pyrus communis, Pear
 Malus, Apple
 Quarter-sawed timber, 250, 257, 268
Quercus pedunculata, English Oak
 rubra, Red Oak
 Suber, Cork Oak
 Quince, **88, 121, 124, 363, 408, 409**;
 seed, 163, 164
 Quinine, 182, 186
 Raceme, 344, 345
 Racemose inflorescence, 345, 352
 Rachis of inflorescence, **14, 344**
 Radicle, **48, 317, 318, 319, 557**
 Radish, **43, 55, 120, 124, 146, 362, 406, 407**
 Railway ties, 257, 258, 270
 Rain-guard, **16**
Ranales, Crowfoot Order
 Rancid oil, 296
Ranunculaceæ, Crowfoot Family
Ranunculaceæ, family tree, 437
Ranunculales, Crowfoot Order
Ranunculus acris, Tall Buttercup
 aquatilis, White Water Crow-foot
 Cymbalaria, Seaside Crowfoot
 pygmæus, Pigmy Buttercup
 sceleratus, Ditch Crowfoot
 Rape, 362
 Rape-oil, 297
Raphanus sativus, Radish
 Raphe, 346
 Rapid multiplication of cells, 511
 Raspberry, **88, 91, 121, 125, 364, 408, 409**
 Rations, 115, 117
 Rattan, 232, 235, **237, 238, 388, 422, 423**
 Raw products, 302
 Ray-floret, **380**
 Reappearance of life, 566
 Recapitulation, law of, 435, 560
 Recapitulation or phylogeny by ontogeny, **559**
 Recent food-plants, 125
 Receptacle, **61, 349, 385**
 Recreational appliances, 245
 Red, algæ, 487; cedar, **273, 392**;
 cedar oil, 297; cedar wood, 270;
 oak, **257**; pepper, 128, **131, 132, 136, 382, 416, 417**
 Redwood, 270, **273, 392, 426, 427**
 Reed, 235
 Refuse in foods, 114
 Regular flowers, 349, 359
 Reproduction, 572; by budding, 495; by fission, 476; organs of, 321; sexual, 480; vegetative, 510
 Reproductive system, 322, 343
 Reservoirs of volatile oil, 359
 Resin, 288
 Resin-ducts, 252, **253**
 Resinous electricity, 288
 Resins, 177, 178, 222, 285, 287
 Resting spores, 475, 568
 Resupinate flower, 391
 Retting flax, 230
 Reversion, 436
Rhamnaceæ, Buckthorn Family
Rhamnales, Buckthorn Order
Rheum officinale, Medicinal Rhubarb
 Rhaponticum, Garden Rhubarb
 Rhizome, 336, 539
Rhodophyceæ, Red Alga
Rhædales, Poppy Order
 Rhubarb, 125, 412, 413, 372; garden, **91, 104, 121**; medicinal, 166, **170**
Rhus Toxicodendron, Poison-ivy
 Vernix, Poison-sumac
Ribes rubrum, Common Currant
 Ribs, 337
Riccia spp., Crystalworts
Ricciaceæ, Crystalworts
 Rice, 11, 15, **16, 17, 25, 120, 122,**

All numbers refer to pages, heavy type indicating illustrations.

- 124, 126, 235, 387, 420, 421; kernel, 114; range, **28**
- Ricinus communis*, Castor-oil Plant
- Rigging, 235
- Rind, 485, **540**
- Road materials, 244
- Robinia Pseudacacia*, Locust
- Rock-rose Family, 400
- Rod-germ Family: hay bacillus, **492**; milk-souring bacterium, **493**; vinegar ferment, **155**
- Root, 323, 324, 533, **538**
- Root-cap, 537, **538**
- Root-hairs, 317, **318**, 319
- Root-member, 326, **327**
- Roots, brace, **23**
- Rootstock, 336
- Root-tuber, 43
- Ropes, 223, 230
- Rosa alpina*, Alpine Rose
- gallica*, French Rose
- spinosissima*, Scotch Rose
- Rosaceæ*, Rose Family
- Rosales*, Rose Order
- Rose, 146, 408, 409, 432, 435; alpine, 378; French, **150**; Scotch, **151**
- Rose Family, 363, 399, 408, 409: almond, **42**; alpine rose, **378**; apple, **86**, **87**; peach, **89**; pear, **87**; plum, **90**; quince, **88**; raspberry, **91**; roses, **150**, **151**; sour cherry, **90**; strawberry, **92**; wild black cherry, **260**
- Rose Order, 367, 399, 410, 411
- Roses, 364; an "unpruned" group, 440
- Rosette, 342
- Rosin, 288, 294
- Royal-fern Family: osmunda, **537**
- Rubber, 280; balls, 284, crude, 283
- Rubber-tree, Brazilian, **281**; India, **282**
- Rubber tubing, 284; type, 284
- Rubbery materials, 287
- Rubiaceæ*, Madder Family
- Rubiales*, Madder Order
- Rubus idæus*, European Raspberry
- strigosus*, Wild Red Raspberry
- Rudimentary flowers, 13, **14**; organs, 436; ovules, 352
- Rue Family, 399: lemon, **97**; orange, **97**
- Rue, Meadow, **339**, 328-356
- Rules for telling a toadstool, 214
- Rum, 159
- Runners, **92**
- Rush, 232, **234**, 235, 390, 422, 423
- Rush Family, 390, 397, 422, 423: rush, **234**
- Russia leather, 297
- Rustic work, 279
- Rutaceæ*, Rue Family
- Rye, 11, 15, **18**, 25, **27**, 114, 120, 124, 126, 159, 235, 387, 420, 421
- Saccharomyces cerevisiæ*, Yeast
- Saccharomycetaceæ*, Yeast Family
- Saccharomycetes*, Yeast Fungi
- Saccharum officinarum*, Sugar-cane
- Sac-leaves, 550
- Sac-member, 326, **327**
- Saddles, 244
- Saffron, 170, 175, **176**, 390, 424, 425
- Saffron Crocus, 175, **176**
- Sage, 137, **138**, 170, 383, 418, 419
- Sago, 104, 125, 422, 423
- "Sago-palm," 555
- Sago palm, prickly, **109**, **110**; smooth, **109**; spineless, 104
- Sago-palms, 121, 388
- Sail-cloth, 230, 232
- Sails, 223
- Salads, 55
- Salicaceæ*, Willow Family
- Salicales*, Willow Order
- Salix sp.*, Willow
- Salvia officinalis*, Sage
- Samara, 358
- Sambucus canadensis*, Elder
- Sandalwood Order, 398
- Sand-binders, 303
- Santalales*, Sandalwood Order
- Sapindales*, Soap-berry Order
- Sapodilla Family, 401: taban-tree, **286**
- Sapotaceæ*, Sapodilla Family
- Saprolegniaceæ*, Water-mold Family
- Saprolegnia Thurcti*, Water-mold

All numbers refer to pages, heavy type indicating illustrations.

- Saprophyte, 493
 Sap-wood, 246
 Sassafras, 165, **168**, 360, 406, 407;
 oil of, 297; pith, 163; wood, 260
Sassafras officinale, Sassafras
Satureia hortensis, Summer Savory
 Savory, 418, 419; herbs, 128, 137;
 seeds, 128, 137; summer, 137,
 383
 Savoy cabbage, **69**
Saxifragaceæ, Saxifrage Family
 Saxifrage Family, 399: currant,
94
 Scale-like outgrowths, 538
 Scale-tree, **299**, **301**
 Scale-tree Family: scale-tree, **299**,
301
 Scallop Squash, **80**
 Schizocarp, 370
Schizomycetes, Fission Fungi
Scitaminales, Banana Order
 Sclerenchyma, 538, **540**
 Sclerotic tissues, 538
 Scotch Pine, **269**; rose, **151**
 Scouring-rush, **541**, 542, **543**;
 giant, **299**
 Scouring-rush Family: scouring-
 rush, **541**, **543**
 Screens, 223
Scrophulariaceæ, Figwort Family
 Scutellum, 388
 Sea Island Cotton, 225, 226, **227**
 Sealing-wax, 288
 Seaside Buttercup, evolution of,
 462
 Seaside Crowfoot, **463**
 Sea-tangle Family: sea-tangles,
486, **488**
 Sea-tangles, 485, **486**, **488**
 Seaweed Division, 491
 Seaweed Subdivision, 395, 396
 Seaweeds, 308
Secale cereale, Rye
 Secondary, inflorescence, 352;
 leaves, **318**, 319; tissue, 542
 Sedge Family, 397
 Seed, 350, 351, 550; albuminous,
 355; exalbuminous, 363, 557; of
 flax, 317, **318**
 Seed-bud, **48**, 317, **318**
 Seed-coat, 316, 317, **318**
 Seed-food, **29**, 316, 317, 318
 Seed-leaves, **46**, **48**, 317, **318**
 Seedling, development, 317; of
 flax, **318**, 319
 Seed-oils, 101
 Seed-plant Division, 393, 396, 397
 Seed-plants, 393, 396, 397
 Seed-root, **48**, 317, **318**
 Seeds, 352; make best provision
 for offspring, 550; parts of,
29, **49**, 316, 352; the greatest
 achievement of the vegetable
 kingdom, 560
 Seed-stem, 317, **318**
 Seed-wing, **551**
 Seedwort Division, 394, 396
 Seedworts, 393, 394, 396, 397
 Selaginella, 550
Selaginellaceæ, Selaginella Family
 Selaginella Family: selaginellas,
545-547
Selaginella spp., Selaginellas
 Selaginellas, **545-547**
 Selected adaptations, 446, 452
 Selection, artificial, 127, 446, 447;
 natural, 447, 448; subordinate
 rôle of, 460
 Self-control inherent in every or-
 ganism, 464
 Self-movement, 461
 Sepal, **29**, 319, 352
 Septicidal dehiscence of capsule,
 379
 Septic organisms, 177
Sequoia sempervirens, Redwood
 Service versus competition, 468
 Sessile, 342
 Sewing-thread, 223
 Sexual, generation, 560; reproduc-
 tion, 480
 Sexuality lost in certain fungi, 501
 Shade trees, 303
 Shagbark Hickory, **41**
 Sheath, 337
 Sheath-algæ, 482, **483**, **484**, 514,
558; compared with spore-sac
 fungi, 501
 Sheath-alga Family: cushion
 sheath-alga, **484**; free-branching
 sheath-alga, **483**
 Sheep Laurel, **202**, 379
 Shelf fungus, 239
 Shell substitute, 284

All numbers refer to pages, heavy type indicating illustrations.

- Shepherd's Purse, **556**
 Shield-lichen Family: Iceland moss, **169**
 Shingles, 270
 Shipbuilding, 256, 270
 Ships, 259
 Ships' knees, 270
 Shoe-last, 263
 Shoemaker's wax, 288
 Shoe-pegs, 245, 263
 Shoe-soles, 287
 Shoes, 282; wooden, 263
 Shoot, 323
 Shoot-segment, 323
 Shoots, kinds of: runners, **92**; spur, **271**
 Showbill type, 263
 Show Ladies' Slipper, **220**
 Shrub, 36, 306, 333
 Siamese Gamboge-tree, 290, **291**
 Sigillaria, 547
Sigillaria, Giant Club-mosses
 Silica in epidermis, 542; in grains, 31
 Silique, 363
 Silk, artificial, 224, 228; of maize, **24**
 Silk-cotton Family: cocoa, **107**, **108**; Sterculia Family, 399
 Silkworm food, 303
 Simple inflorescence, 352; leaves, 339, 342; pistil, 347
Sinapis alba, White Mustard
 Sinker, **211**
 Size of plants, enormous, 575
 Skiffs, 260
 Slippery Elm, 165
 Smokeless fuel, 300, 301; powder, 224
 Smooth Sago Palm, **109**
 Snow-on-the-mountain, **203**, 207, 217
 Snuff, 185
 Soap, yellow, 288
 Soap-berry Order, 399
 Soaps, 288, 295, 296
 Socrates, poisoning of, 194
 Soda in grains, 31
 Soda water mixtures, 150
 Soft pine, 270; soap, 296
 Soil bacteria, 494
 Soil-binders, 303
 Soil-building by lichens, 506
 Soil-makers, 304
Solanaceæ, Nightshade Family
Solanum Dulcamara, Bittersweet
Lycopersicum, Tomato
Melongena, Egg Plant
nigrum, Black Nightshade
tuberosum, White Potato
 Solar system, 464
 Soldering flux, 288
 Soles, 280
 Solid bulb, 336
 Solitary flowers, 345, 352
 Solvents, 296
 Soredium, 506, **508**
 Sorghums, **236**
 Sorus, **179**
 Sounding-boards, 270
 Sour Cherry, **90**
 Southern Moss, 232, **234**
 Souvenirs, 268
 Spadix, 388
 Spars, 243, 270
 Spathe, 388
Spathifloræ, Arum Order
 Speaking tubes, 287
 Spearmint, 137, **139**, 170, 177, 338; oil, 297
 Special creation, 429
 Species, 4, 428; as units of, classification, 431; destruction of 432; fixity of, 429, 430; limits of, 431; origin of, 441
 Spermatophyte, **505**
 Spermatophyta, 8
Spermatophyta, Seed-plant Division
 Spermatophytes, 393, 394, 396, 397
 Spermatozoid, **515**, **517**, **527**
Sphagnaceæ, Peat-moss Family
Sphagnum spp. Peat Moss
Sphenophyllum cuneifolium, Wedge-leaf
Sphenopteris, Climbing-ferns
 Spicate inflorescence, 373
 Spices, 128, 302; danger of, 130, 133; history of, 137
 Spiderwort Family, 397
 Spike, 373
 Spikelet, **13**

All numbers refer to pages, heavy type indicating illustrations.

- Spinach, 55, **71**, **72**, 120, 124;
leaves, 114
Spinacia oleracea, Spinach
Spindles, 245
Spineless Sago-palm, 104
Spinning, 222
Spirits of turpentine, 288, 296
Spiritous liquors, 159
Spirogyra sp., Pond-scum
Spitting, danger from, 494
Splint, 241
Splints, surgical, 245
Sponge Cucumber, 238, 383, 418,
419
Spontaneous generation, 565; va-
riations, 449
Spools, 245, 263
Sporangium, 484, 541
Spore, 167
Spore-base, Fungi, 501; Lichens,
508
Spore-case, **529**
Spore-layer, **529**
Spores, 511
Spore-sac Fungi, 499, 504
Spore-sac-leaf, 534
Spore-sac Lichens, 504
Spore-sacs, 550
Sporophyll, **541**
Sporophyte, 485, 514, 515
Spring wood, 251, **253**
Spruce, 241, 292, 294, 424, 425,
551, **552**, **553**; aphis, 272; Nor-
way, **272**; wood, 270
Spunk, 239
Spur, **271**
Spurge Family, 399: bitter cas-
sava, **110**, **111**; Brazilian rubber-
tree, **281**; caper spurge, **216**;
castor-oil plant, **172**, **173**; snow-
on-the-mountain, **203**
Sputum, danger from, 494
Squash, 85, 121, 124, 383, 418,
419; hubbard, **81**; long white,
79; scallop, **80**; summer crook-
neck, **79**
Staff, 232
Stamens, 12, **14**, 309, 319, 352,
550; diadelphous, 366; mona-
delphous, 366; pentadelphous,
368; syngenesious, 384
Staminate flowers, 347
Staminodes, **340**, **341**, 348, 352
Standard, **48**, 366
Star Anise, 137, **143**, 358, 406, 407
Starch, 31; conversion into sugar,
32
Staves, 259
Stem, 324, **538**; of fern, **540**
Stem-member, 326, **327**
Stem-part, 323, 325
Stems, 387, 533
Stem-tip, **320**, **556**
Stem-tuber, 43
Sterculiaceae, Silk-cotton Family
Sterculia Family, 399
Stiffening, 223, 232
Stigma, 12, **14**, 319, 345, 555, **556**;
enlargement of, 557
Stimulants, 156, 160, 161
Stimulating beverages, 161
Stimulation, 159
Stimuli, response to, 562
Stipulate leaf, 358, 359
Stipule, 358, 359
Stipules, ocreate, 372
Stirrups, 244
Stomata, **529**, 530
Stone-fruit, 364
Stone of drupes, 365
Stoppers, 280
Storage of food-materials, 485, 538
Strap-shaped corolla, 379, **380**, **381**,
385
Straw, 232, 235; hats, 223; mat-
ting, 235
Strawberry, 88, **92**, 121, 125, 364,
408, 409
Strawberry-shrub Family, 398
String-beans, 85
Structure, 572
Struggle for existence, 447, 454
Struggles for supremacy often
destroy what is best, 468
Strychnine, 182, 188
Strychnos Nux-vomica, Nux Vom-
ica
Stuffing for saddles, 238
Sturtevant, Dr. E. L., 456
Style, 12, **14**, 319, 345
Suberin, 279
Subtend, 342
Succulent parts for dissemination,
560

All numbers refer to pages, heavy type indicating illustrations.

- Sudden adaptations, 457, 459; variations, 456
- Sugar, 32, 101
- Sugar-beet, 101
- Sugar-cane, 101, **106**, 121, 124, 387, 420, 421; stalks, 298
- Sugar-maple, 101, **261**, 263
- Sugars, 562
- Sulphur in grains, 31
- Sumac Family: poison-ivy, **218**; poison-sumac, **220**
- Summer, crook-neck squash, **79**; savory, 137, **139**, 383; wood, 251, **553**
- Sunflower, 420, 421
- Sunflower Family, 385, 401, 420, 421: dandelion, **443**; Jerusalem artichoke, **61**, **62**; lettuce, **72**, **73**, **74**; oxeeye, **380**; wormwood, **160**
- Superior ovary, 350
- Support, organs of, 321
- Surface fibers, 224, 225
- Surgeon's plaster, 284
- Surgical appliances, 245, 284, 287; instruments, 284
- Survival of the fittest, 447, 448
- Suspensor, **497**, 546, **547**, **552**, **556**, 557
- Suture, 351
- Swamp-drainers, 303
- Swarm-spore, 482, 511
- Swarm-spore algæ, evolution of, **558**
- Sweating of cocoa, 103
- Sweet, corn, sugar in, 32; flag, 170, **174**, 389, 422, 423; marjoram, 137, **140**, 383; potato, 43, **58**, **59**, 120, 124, 379, 416, 417; potato root, 114
- Swietenia Mahogoni*, Mahogany
- Sword hilts, 286
- Sycamore, American, **267**, 268; wood, 268
- Symbiont, 508
- Symbiosis, 508
- Syngenesious anthers, 384
- Synopsis of Seedworts, 397
- Syringodendron*, Giant Club-mosses
- System, Linnæan, 308; natural, 310, 311, 328
- Systematic, botany, 9, 304, 305, 314, 315; classification, 305
- Systems, artificial, 307
- Taban-tree, 285, **286**
- Table mats, 239
- Tall Buttercup or Crowfoot, **216**, **241**, 328-356
- Tan-bark, 290, 294
- Tanks, 243
- Tanning, 222, 295
- Tannins, 154, 166, 222, 294
- Tape, 223
- Tape-worms, 180
- Tapioca, 104
- Taraxicum officinale*, Dandelion
- Taxaceæ*, Yew Family
- Taxus baccata*, Yew
- Tea, 150, **152**; aroma, 154
- Tea Family, 400: tea, **152**
- Tea-tasters, 154
- Technical, description, 312; terms, 312
- Tegumentary system, 539
- Telegraph-poles, 270
- Telephones, 284
- Temperatures required by life, 466
- Terminal flower, 343
- Terminology, 314; Linnæan, reform in, 313
- Terms, technical, 312
- Ternate nervation, 352
- Tennis-rackets, 245
- Test of life, 568, 569
- Thalictrum flavum*, Meadow Rue
- Thallophyta*, Thallophyte Division
- Thallophyte Division, 509
- Thallophytes, 395, 396
- Thallus, 481
- Thatch, 223, 235
- Theaceæ*, Tea Family
- Thea Sinensis*, Tea
- Theine, 150
- Theobroma Cocoa*, Cocoa
- Theobromine, 150, 154, 181
- Third organic kingdom, 573
- Thread, 223
- Thread-weed, 488, **490**
- Thread-weed Family: thread-weed, **490**
- Thyme, 137, **139**, 177, 383, 418, 419; oil of, 297

All numbers refer to pages, heavy type indicating illustrations.

- Thymelæaceæ*, Mezereum Family
Thymus vulgaris, Thyme
Tilia ulmifolia, Elm-leaved Linden
Tiliaceæ, Linden Family
Tillandsia usneoides, Southern Moss
 Timber, 257; pins, 260
 Tinning, 157
 Tint-ball Alga, **471**, **558**
 Tint-ball Family: tint-ball alga, **471**
 Tires, 284
 Tissue, 486, 560; systems, 539, 560
 Tissues, meristematic, 487; permanent, 487
 Toadstools, 111, 213
 Tobacco, 182, **184**, 208, 382, 416, 417; Indian, **201**, 384, 418, 419
 Toilet soaps, 296
 Tomato, **83**, **84**, 85, 121, 124, 382; fruit, 114
 Tool-handles, 259, 260, 269
 Toothpicks, 245, 268
 Torches, 282
 Torus, 349, 350, 352; concave, 355; convex, 355; epigynous, 365; fleshy, 364; hollow, **380**
 Toys, 245, 259, 263, 270, 284
Trachylobium Hornemannianum, Zanzibar Copal-tree
 Tragacanth, 163
 Tragacanth Shrub, 164, **165**, 366, 410, 411
 Tragacanthin, 164
 Traveling gametes, 512
 Tree, 36; of life, 434
 Tree-cabbage, **274**
 Tree-ferns, **299**, **535**, 538, **540**
 Treenails, 259
 Trees, 306, 333
 Trestlework, 245
 Trianon botanic garden, 311
Triticum sativum, Wheat
 True, gums, 287; mosses, 519, 530; woods, 256
 Trunk of fern, **540**
 Trunks, 263
 Truth, supreme test of, 429
Tsuga canadensis, Hemlock
 Tuberculosis bacterium, 494
 Tuber, 43, **541**, 542
Tubiflora, Phlox Order
 Tubs, 243
 Tubular floret, **380**
 Tulip-tree, **261**, 358, 406, 407
 Tulip Whitewood, **261**, 263
 Turban Squash, **81**
 Turkish Tobacco, **184**
 Turnery, 242, 257, 259, 263, 268, 269, 277, 280
 Turnip, 43, **54**, 120, 124, 362; root, 114
 Turpentine, 287, 288, 296
 Turps, 296
 Twice-compound, 339
 Twine, 223, 230
 Type, plants, 316; rubber, 284; wooden, 263
Ulmaceæ, Elm Family
Ulmus americana, American Elm
canpestris, English Elm
Ulodendron, Giant Club-mosses
Ulothrix zonata, Wool-weed
Ulotrichaceæ, Wool-weed Family
 Umbel, 370
Umbellales, Parsley Order
Umbellifera, Parsley Family
Umbelliflora, Parsley Order
 Umbellule, 370
 Umbrella handles, 245, 274, 276
 Umbrella liverwort, 515, **516**, **517**, **518**, **519**, **520**, **521**
 Uncoiled embryo, 355
 Universality of life, 569
 Upholstery stuffing, 235
 Upland Cotton, **225**, **226**
 Upright posture of land-plants, 530
Urticaceæ, Nettle Family
Urticales, Nettle Order
 Useful bacteria, 494; plants, 302
 Useless organs, 436
Usnea barbata, Beard-lichen
Usneaceæ, Beard-lichen Family
 Valvate æstivation, 349, 354
 Vanilla, 146, **149**, 391, 424, 425
Vanilla planifolia, Vanilla
 Vanillin, 146
 Variation, 448, 449; under domestication, 456
 Varieties, 5, 428; cultivated, 6; do-

- All numbers refer to pages, heavy type indicating illustrations.
- mesticated, 430; multiplication of, 126; origin of, 126
 Various plant groups, 358
 Varnishes, 288, 290, 294, 296
 Vascular cryptogams, 396; parts, 538; plants, 396; system, 539
Vegetabilia, Vegetable Kingdom
 Vegetable, ecology, 10; fibers, 223; foods, 113; ivory, **275**, **276**; 388, 422, 423; morphology, 10; parchment, 230; physiology, 10; sponge, 232, 238, **240**; versus animal foods, 119; wool, 228
 Vegetable Kingdom, 8, 394, 396, 561, 562; culminating in seed-plants, 560; evolution of, 466
 Vegetative, cone, 323; organs of crowfoot family, 330; reproduction, 510, 560; system, 322
 Vegeto-animal organisms, 573
 Vehicles, 244; for pigments, 295
 Veins, 337
 Veinlets, 337
 Venation, 337
 Ventral placenta, 346; suture, 351
Veratrum vivide, Indian Poke
Verbenaceæ, Verbena Family
 Verbena Family, 401
 Vernation, 349; crozier-like, 537
 Vertical hypha, **496**, 497
 Verticil, 342
 Vessels, 243, 538, **540**; in wood, 252
 Vestiges, 436
 Vestigial characters, 452
 Vine, 333
 Vine-bower Clematis, **336**, 328-356
 Vinegar ferment, **155**
Violaceæ, Violet Family
Violales, Violet Order
 Violet Family, 400
 Violet Order, 400
 Violins, 245, 270
 Virgin cork, **278**, 279
 Virginia Tobacco, **184**
Viscum album, Mistletoe
Vitaceæ, Grape Family
 Vital processes, imitations of, 563, 564
Vitis spp., Grapes
 Volatile oil reservoirs, 359, 360
 Volatile oils, 128, 159, 160, 170, 177, 295, 296, 297; poisonous, 177
 Volition in plants and animals, 464
 Vries, Hugo de, 457
 Vulcanization, 284
 Wagons, 256, 259, 260, 263
 Wallace, Alfred Russel, 446
 Walnut, 35, **39**, 120, 124, 376, 414, 415; black, **260**; English, 296; kernel, 114; white, 261; wood, **256**, 260
 Walnut Family, 376, 398: black walnut, **260**; butternut, **40**; hickory, **41**; pecan, **40**; walnut, **39**
 Walnut Order, 376, 398, 414, 415
 Wall-stain Alga, 476, **477**, 504
 Wall-stain Family: wall-stain alga, **477**
 Waste products, 573
 Water, Hemlock, **193**, 370, 412, 413; in foods, 114; in grains, 30
 Water-bottles, 284
 Water-craft, 243
 Watercress, 55, **70**, **71**, 362, 406, 407
 Water-lily Family, 398
 Watermelon, 88, **96**, 121, 124, 383, 418, 419; pulp, 114
 Water-mold, **498**
 Water-mold Family: water-mold, **498**
 Water-mold Fungi, 499
 Waterproof, coverings, 284; garments, 283, 284; material, 287
 Water-supply, effect of forests on, 304
 Water-vessels, 282
 Wax, 303
 Wax-beans, 85
 Weapons, 245
 Weaving, 222, 223
 Webbing, 223, 230
 Wedge-leaf, **299**
 Weeds, 303
 Wearing apparel, 223
 Well-endowed offspring, 510
 Wet cooperage, 243, 257
 Wheat, 11, 15, **19**, **20**, 28, 120, 122, 124, 126, 159, 235, 387,

- All numbers refer to pages, heavy type indicating illustrations.
- 420, 421; gum, 31; kernel, 114; range, **26**; straw, 298
- Whisk brushes, 235
- Whisks, 223
- Whisky, 159
- White, ash, **259**; birch, **265**; birch oil, 297; cooperage, 243, 270; mustard, **133**; oak wood, **256**; pine, 241, 270; pine wood, **250**, **251**; potato, 43, **59**, **60**, 120, 124, 210, 382, 416, 417; potato tuber, 114; walnut, 261; water crowfoot, **467**
- Whitewood, 263; Tulip, **261**
- Whorl, 342
- Whorled leaves, 342
- Wicks, 228; wickerwork, 223, 235, 241
- Wild, black cherry, 203, **260**, 263; carrot, 430; cotton, 227; kale, **66**, **67**; lettuce, **73**; red raspberry, 91
- Will, 568; in plants, 462
- Willow, 241, **243**, **244**, 294, 377, 414, 475
- Willow Family, 377, 398, 414, 415; poplar, **264**; willow, **243**, **244**
- Willow Order, 377, 398, 416, 417
- Wind-balls, 283
- Wind-breaks, 303
- Wind-carried pollen, 557
- Wind-flower, 328-356
- Wind-pollination, 557
- Wine, 156, 157, 243, 495
- Winged pericarp, 359
- Wings, **48**, 366
- Winter Crook-neck Squash, **81**, **82**
- Wintergreen, 146, **148**, 177, 203, 297, 378, 379, 416, 417; oil of, 562
- Witch-hazel, 166, **171**
- Witch-hazel Family: witch-hazel, **171**
- Wood, 241, 298; ash, 298; origin, **254**; pulp, 241; structure, 249
- Wood-alcohol, 300
- Wood-anemony, **205**, 209, 328-356
- Wood-anemony, American (*see* American Wood-anemony)
- Wooden shoes, 263
- Woodenware, 263
- Woods, 222; true, 256
- Wood-working trades, 242
- Woody, fibers, 225, 240, 538; plants, 333, 352
- Wool, vegetable, 228
- Wool-weed, 480, **481**, **558**
- Wool-weed Family: wool-weed, **481**
- World-making an evolution, 464
- Wormwood, 159, **160**, 385, 420, 421
- Wrack Family: bladder-wrack, **488**, **489**
- Wrapping for bottles, 280
- Writing-inks, 294
- Writing-paper, 224
- Xyridales*, Yellow-eyed Grass Order
- Yarn, 223
- Yeast, **155**
- Yeast Family: yeast, **155**
- Yeast Fungi, 495
- Yellow Ladies' Slipper, **220**; *Y. Locust*, 259
- Yellow-eyed Grass Order, 397
- Yew, 212, **213**, 392, 393, 426, 427
- Yew Family, 392, 397, 426, 427: yew, **213**
- Yokes, 244, 263
- Yoke-spore algæ, evolution of, **558**
- Zanzibar Copal-tree, **289**, 290, 366
- Zea Mays*, Maize
- Zingiber officinale*, Ginger
- Zygomycetes*, Pin-mold Fungi
- Zygospore, 478, 497, 511
- Zygote, 482, 512

2, 461, ~~146~~, ~~187~~, ~~186~~, ~~189~~

Sied. 281, - Malaya - Costa

~~Red 299~~ - 311

THE METRIC SYSTEM.

UNITS.

THE MOST COMMONLY USED DIVISIONS AND MULTIPLES.

THE METER, for LENGTH.....	{	<p><i>Centimeter</i> (cm), 1/100 meter; <i>Millimeter</i> (mm), 1/1000 meter; <i>Micron</i> (μ), 1/1000 millimeter. The micron is the unit in micrometry.</p> <p><i>Kilometer</i>, 1000 meters; used in measuring roads and other long distances.</p>
THE GRAM, for WEIGHT.....	{	<p><i>Milligram</i> (mg), 1/1000 gram.</p> <p><i>Kilogram</i>, 1000 grams, used for ordinary masses, like groceries, etc.</p>
THE LITER, for CAPACITY....	{	<p><i>Cubic Centimeter</i> (cc), 1/1000 liter. This is more common than the correct form, Milliliter.</p>

Divisions of the units are indicated by Latin prefixes: *deci*, 1/10; *centi*, 1/100; *milli*, 1/1000.

Multiples are designated by Greek prefixes: *deka*, 10 times; *hecto*, 100 times; *kilo*, 1000 times; *myria*, 10,000 times.

TABLE OF METRIC AND ENGLISH MEASURES.

METER = 100 centimeters, 1000 millimeters, 1,000,000 microns, 39.3704 inches.

Millimeter (mm) = 1000 microns, 1/10 millimeter, 1/1000 meter, 1/25 inch, approximately.

MICRON (μ) (unit of measure in micrometry) = 1/1000 mm, 1/1000000 meter (0.000039 inch), 1/25000 inch, approximately.

Inch (in.) = 25.399772 mm (25.4 mm, approx.).

LITER = 1000 milliliters or 1000 cubic centimeters, 1 quart (approx.).

Cubic centimeter (cc or cctm) = 1/1000 liter.

Fluid ounce (8 fluidrachms) = 29.578 cc (30 cc, approx.).

GRAM = 15.432 grains.

Kilogram (kilo) = 2.204 avoirdupois pounds (2½ pounds, approx.).

Ounce Avoirdupois (437½ grains) = 28.349 grams } (30 grams, approx.).

Ounce Troy or Apothecaries' (480 grains) = 31.103 grams }

TEMPERATURE.

To change Centigrade to Fahrenheit: $(C. \times \frac{9}{5}) + 32 = F.$ For example, to find the equivalent of 10° Centigrade, $C. = 10^\circ$, $(10^\circ \times \frac{9}{5}) + 32 = 50^\circ F.$

To change Fahrenheit to Centigrade: $(F. - 32^\circ) \times \frac{5}{9} = C.$ For example, to reduce 50° Fahrenheit to Centigrade, $F. = 50^\circ$, and $(50^\circ - 32^\circ) \times \frac{5}{9} = 10^\circ C.$; or -40° Fahrenheit to Centigrade, $F. = -40^\circ$, $(-40^\circ - 32^\circ) \times \frac{5}{9} = -72^\circ$, whence $-72^\circ \times \frac{5}{9} = -40^\circ C.$

—From "The Microscope" (by S. H. Gage) by permission.

NORMAN TAYLOR
BROOKLYN BOTANIC GARDEN
BROOKLYN, N. Y.



MEASURES OF TEMPERATURE

3 5185 00108 1262

Centigrade	Fahrenheit	Centigrade	Fahrenheit
+100	+212	+16	+60.8
90	194	15	59
80	176	14	57.2
70	158	13	55.4
60	140	12	53.6
50	122	11	51.8
49	120.2	10	50
48	118.4	9	48.2
47	116.6	8	46.4
46	114.8	7	44.6
45	113	6	42.8
44	111.2	5	41
43	109.4	4	39.2
42	107.6	3	37.4
41	105.8	2	35.6
40	104	+1	+33.8
39	102.2	0	+32
38	100.4	-1	+30.2
37	98.6	2	28.4
36	96.8	3	26.6
35	95	4	24.8
34	93.2	5	23
33	91.4	6	21.2
32	89.6	7	19.4
31	87.8	8	17.6
30	86	9	15.8
29	84.2	10	14
28	82.4	11	12.2
27	80.6	12	10.4
26	78.8	13	8.6
25	77	14	6.8
24	75.2	15	5
23	73.4	16	3.2
22	71.6	17	1.4
21	69.8	18	- 0.4
20	68	19	2.2
19	66.2	20	4
18	64.4	30	22
17	62.6	-40	-40

