L. M. Underwood
11 Nov. 1899

Minnesota Plant Life.

MINNESOTA PLANT LIFE

Compliments of the

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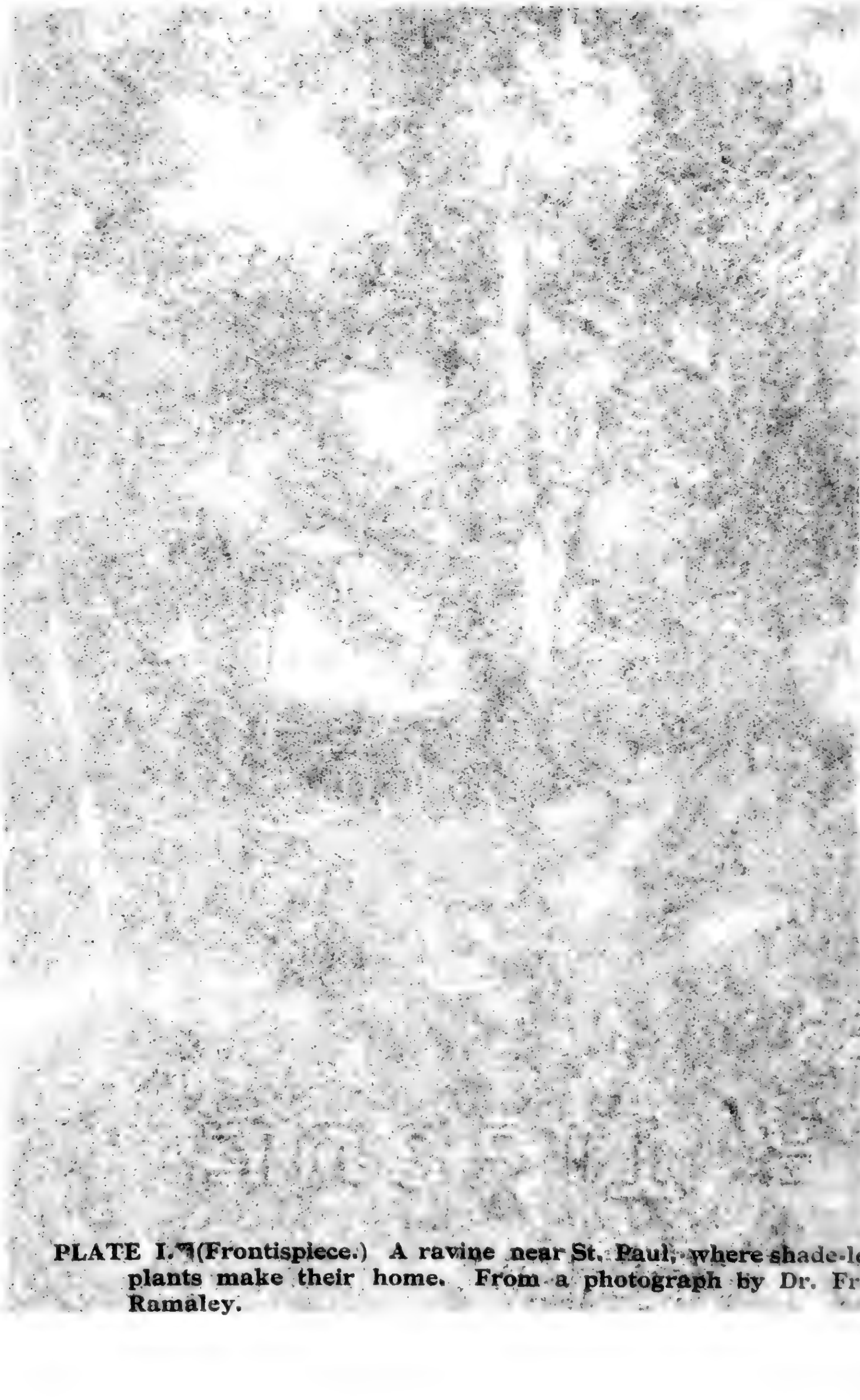

PLATE I. (Frontispiece.) A ravine near St. Paul, where shade-loving plants make their home. From a photograph by Dr. Francis Ramaley.

MINNESOTA PLANT LIFE

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Conway MacMillan

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Report of the [illegible]

Botanical Series

III

Saint Paul, Minnesota.
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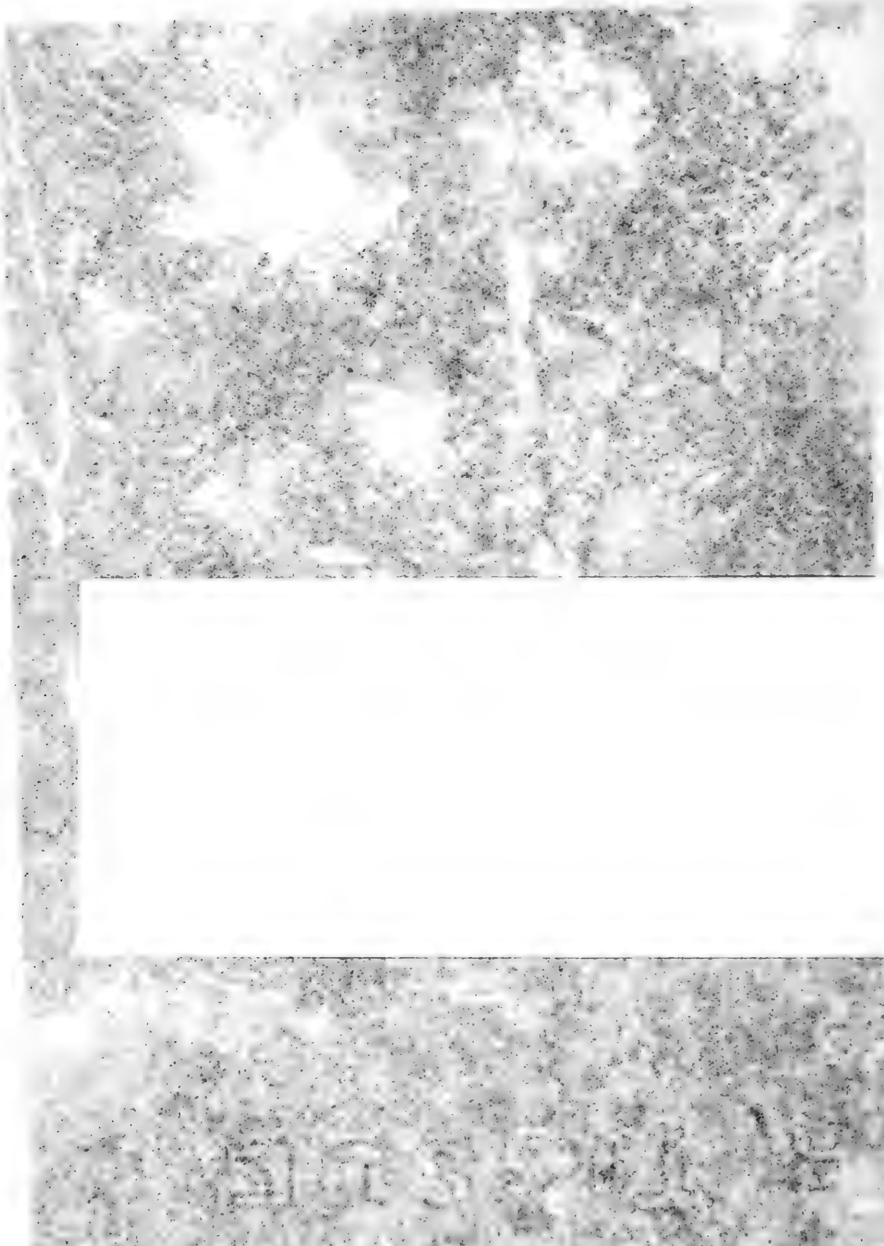

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Preface.

IT has been well said that the main difficulties with the book on popular science are that, if popular, it will not be scientific, and, if scientific, it will not be popular. Yet, notwithstanding the truth thus epigrammatically expressed, I am venturing to put forth *Minnesota Plant Life* as a book certainly meriting the designation of *popular*, in so far as it is addressed to an audience not composed of botanists, and at the same time *scientific*, to the extent at least of choosing for its field one of the two great realms of living things the kingdom of plants.

While to be out of fashion is to be out of the world, I have, nevertheless, resisted the impulse to designate this volume as a suitable text-book for the "secondary schools." On the contrary, such a use of it would be, in my opinion, distinctly unfortunate. It is not written in pedagogical vein, nor does it pre-suppose an acquaintance with teachers and laboratories. It would, however, be disingenuous to deny that the author has a definite educational purpose in view. Since this volume is to be distributed in every county and perhaps in every school district in Minnesota, it should, especially among the young, stimulate an interest in the study of plants. With a minimum of technicalities, sentimentalities, unavoidable inaccuracies or cumbersome details, it seeks to accomplish the following ends:

1. The plant world is presented as an assemblage of living things.

2. The different kinds of plants in Minnesota, from the lowest to the highest, are briefly reviewed in their natural order.

3. Some plant structures and behaviors are elementarily explained, as adaptations to surrounding nature.

4. Certain plant individuals and societies are brought before the reader as having life problems of their own, not as mere material for economic, anatomical or classificatory industry.

In short, I have recognized that there are in Minnesota a number of intelligent men and women, boys and girls, who wish to know more about plants, and in the pages of this book I have sought to bring together what, from my own experience as a student of plants, and as an instructor of the young, seems to me a sufficiently adequate and compact presentation of the subject. Errors of judgment and of fact no doubt exist, as in many works of mere human construction. I hope that they will not prove harmful. In some matters, indeed, the point of view has shifted since certain chapters were in type. For example, experiments recently completed by the United States Department of Agriculture tend to modify the German and Danish explanations of bacterial relation to dairy industries and to the curing of tobacco. Other new facts have been elicited by investigators studying the red and purple coloring substances in plants, so that, if prepared to-day, various chapters would undergo slight alteration. In a subject developing so rapidly as is modern botany, it is difficult to be always absolutely abreast of the current.

A large number of the illustrations in the volume are from photographs of Minnesota vegetation, some of them made by myself, or under my direction, others selected from the collections of friends, acquaintances and dealers. Many figures, too, have been obtained in other ways. I have particularly to thank Dr. N. L. Britton, of the New York Botanic Garden, for the cuts from his splendid *Illustrated Flora of North America,* here credited to Britton and Brown. I am also much indebted to Professor G. F. Atkinson, of Cornell University, for permission to use numerous engravings from his excellent text-book, *Elementary Botany,* and likewise express my thanks to the United States Department of Agriculture, to Professor Francis Ramaley, of the University of Colorado, Mr. C. G. Lloyd, of Cincinnati, the *Botanical Gazette, Meehan's Monthly,* Professor L. H. Bailey, of Cornell University, Professor B. D. Halsted, of Rutgers College, Professors Hall and Appleby and Instructors Mackintosh, Mills and Wheeler, of the University of Minnesota, Professor Bruce Fink, of Fayette College, the late Warren W. Pendergast, and several others, all of whom have assisted me in collecting illustrations. I am also greatly obliged to my father, Dr. Geo. McMillan, for much valuable assistance with the proofs, and to Miss Josephine E. Tilden for the preparation of the index.

I am particularly indebted to President Cyrus Northrop for suggestions and assistance, without which, in all probability, this volume would have been neither prepared nor published.

Among many books that I had occasion to consult during the preparation of manuscript the *Illustrated Flora* of Britton and Brown, Sargent's magnificent *Silva,* Kerner's *Plant Life,* Warming's *Ecology,* Schimper's *Plant Geography,* Lafar's *Technical Mycology* and Upham's *Catalogue of the Minnesota Flora,* deserve especial mention. Yet I should not give the impression that *Minnesota Plant Life* is wholly a product of the study; it is much more the offspring of the woods, the prairies, the rivers and the lakes. In every part of the state, during the past twelve years, I have visited them, and this book, with whatever merits and demerits it may have, received an inspiration from such excursions among the plants themselves.

If, by the distribution of this volume a broader knowledge, a deeper interest, a truer appreciation and a better understanding comes to those in whose hands its pages open, the writer will feel well repaid for the labor of preparation. An intelligent study of nature is one of the foundation stones of useful citizenship.

The University of Minnesota,
October 2, 1899.

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Chapter I.

Plants in their Societies.

Purpose of this book. In the pages of this book I hope to give the reader an idea of the diversified plant life which occupies the air, the soil and the waters of Minnesota. First of all, it must be remembered that plants although passive creatures are quite as truly living beings as are the more active animals. Just as men and women, either themselves or their ancestors, have entered the state from some other region, so also have plants, according to the nature of each, found their way and selected their abodes. It is no easy problem to determine why some family has chosen one village rather than another. This may have been from causes which are too subtle or too remote for analysis, but it is recognized that people have not come to make their homes without some reason which seemed sufficient to them or to their forefathers. So, too, there is always some reason for the appearance at a particular spot of one kind of plant rather than another, and it is possible in a general way to explain the vegetation of the hills and meadows of the state.

Minnesota geography. A glance at the map will show that the State of Minnesota lies between the 43rd and 49th parallels of north latitude and between the 89th and 97th meridians west, and that it is centrally located in the North American continent. Within its domain rises the Mississippi and by this great river the surplus rain-fall of the state is in large measure carried away to the Gulf of Mexico. The northwestern portion, by the Red river and its tributaries, is drained through Lake Winnipeg into Hudson bay, while a few streams flow in the valley of the St. Lawrence to the Atlantic ocean. Minnesota, therefore, is not only geographically but hydrographically central. Hence it might be supposed that its plants would have immigrated equally from all directions. Such, however, is by no means the fact and it is needful to inquire further into the conditions which regulate plant distribution before the true situation can be understood.

Minnesota climate. Connected with the geographical position of the state, and to a very great degree dependent upon it, is that combination of average winds, average temperature, average precipitation of moisture, and average illumination by the sun to which is given the general name of *climate*. Minnesota enjoys what is known as a mid-continental climate, characterized by warmth in the summer and cold in the winter. There are no prevailing winds from year's end to year's end as there are at some places by the sea. The sun never shines with equatorial directness, nor are there ever weeks or months of twilight, or of darkness, as in the regions of the poles. There are no great mountain ranges to cool the clouds as they move across the sky and to force them to yield their moisture in the eternal snows; and during the year there may always be expected an average rain-fall of about twenty-five inches. Through the spring and summer there is always a rise in temperature to stimulate growth, but there is never that fervent, damp heat which favors the rank and luxuriant vegetation of the tropics. Consequently there are to be found in Minnesota, plants adapted to the rhythm of the seasons, to the oblique illumination of the sun, to the average moisture of the air and of the soil, and to the winds which sometimes sweep over the prairies with an almost resistless force.

As an illustration of the adaptation of plants to seasonal rhythm may be mentioned the autumnal habit of most trees in Minnesota of shedding their leaves. Indeed, this is so common a fact of experience that it is scarcely realized to be a definite reaction of the plant to its environment. Yet leaves do not fall merely because the nights are growing cold, but because there is formed at the base of each leaf-stalk a little layer of cork which, when complete, cuts the leaf from the twig as if by a pair of shears. Certainly such is not everywhere a necessary habit, for it is known that in the tropics many trees do not lose their leaves each year, but retain them for varying periods of time until their usefulness is past—a character shared also by some trees of temperate regions. Apparently, then, the habit of rejecting leaves that would be killed by the winter's cold and would become burdensome another summer may be directly connected with the geographical position of the state.

Again, trees with enormous, delicate leaves like those of many palms or bananas, are not found upon the prairies of the Red river, because, clearly, if trees with such thin, large leaves were exposed to the wind they would be blown to pieces and their life would be destroyed. Large delicate-leaved forms are more characteristic of regions where the wind is slight or where it is broken by masses of surrounding vegetation.

Furthermore, in a state so well watered as Minnesota there is no development of those curious desert types which are seen in Arizona, in the Sahara, or in the arid regions of South Africa and Australia; for where it is arid those plants only can grow that by structure and habits are fitted to utilize the relatively small quantities of moisture. The strange columnar cacti of the Gila, standing leafless and rigid—vegetable pillars of the desert—would be out of place wherever the rain-fall permits the production of ordinary leaves and branches. Thus in surveying the vegetation of the world one is impressed with the influence of climate upon the plant population of every district.

The physical history of Minnesota. A knowledge of its geography and climate does not, however, afford all the data for comprehending the vegetation of any region, since it is not alone the climate of to-day, but even more strongly the climate and other conditions of the past, that are reflected in the forms and structures of the plants. Therefore, a knowledge also of the geological history of the state and of its various soils is essential to an understanding of its vegetation. There is strong reason to suppose that about ten thousand years ago much of the surface of North America was covered by a thick sheet of ice which advanced slowly from the north and later as slowly retreated. The period of ice-advance is known to geologists as the glacial period, and throughout Minnesota are to be found the traces of glacial action. The clays, pebbles and bowlders so abundant throughout the state are believed to have been deposited either upon the front of a glacial mass, or underneath, or from the waters caused by its melting. When such a movement of ice took place there must have been a great modification of drainage conditions over all the invaded district. Streams were dammed, hills were levelled, valleys were filled, lake bottoms were hollowed out or covered with confused masses of rocks and clay—ground into powder by the powerful action of the ice, continuing, as it did, through more than a thousand years. It is clear, too, that the ancient vegetation must have been almost wholly swept away by this invasion from the Arctic zone. It is true that plants are sometimes found growing close to the edge of glaciers in the Alps, in Greenland and in Alaska. Sometimes even masses of soil are so borne upon the surface of the glacier that plants of hardy habit may continue their existence there. Yet, with a due regard to these well-known facts, it is not conceivable that for so long a period of rigorous cold the old pre-glacial plant-population of the state could have held its ground. It must be supposed, rather, that as the glacier steadily advanced from the north, year after year plants flung their seeds into air-currents moving southward or attached them to the fur of animals seeking a warmer clime and thus gradually season by season themselves migrated toward the south. Evidently those plants provided with seeds, buoyant, winged, barbed or hooked were best fitted by such contrivances to leave the snows and ice of a thousand years, while the plants with smooth and heavy seeds either migrated more leisurely and more sparingly or were quite extinguished by the cold.

When the glacial period came finally to an end and the ice-sheet moved north beyond the confines of the state, there opened to the immigrants from the south a new Minnesota. Great lakes formed by the waters of the melting ice now lay where before there was land. Rivers were flowing in new directions and were carving for themselves new gorges through the rocks. A fertile soil was deposited upon the hill-sides—not, indeed, a rich leaf-mould, but capable of supporting many kinds of plants. Into this land of promise the southern plants began to come. Winds from the south, animals ranging toward the north and water-fowl in their annual migrations, brought back in some instances no doubt the very same varieties which hundreds of years earlier had fled before the ice, and in others, new kinds born and bred in the south and seeking new homes where they might obtain a foothold for themselves and their descendants. When one contemplates for a moment this epitome of plant-wanderings he is impressed by its similarity to the history of his own race. It is known how peoples have moved from one country to another, not usually *en masse* but individually, quite as did the plants and under very much the same impelling forces. For it is those plants which were able to leave the region of increasing cold that later continued their kind under more favorable circumstances, as it is also the hardy race of men who migrate from the worn out farm, or congested city to some new country in which they may find prosperity and happiness for themselves and for their children.

Laws of plant distribution. There are, then, three paths along which to seek the general laws of plant distribution. First, as regards an area, one must inquire what is its geographical position? second, what is its climate? third, what is its soil and physical history? The answers to these three questions explain in large degree what must be the plant population of that area. With respect to the vegetation of Minnesota the most impressive fact is that it is an immigrant vegetation. It manifests the characters of a new community quite as truly as does the American Republic, in its social and political organization, the characters of a new country. This can be illustrated clearly if one compare the Minnesota forest with the ancient forest of the tropics in India, in Venezuela, or about the sources of the Nile. When one enters the dark solitudes of an equatorial forest his first thought is, from the sounds that reach his ears, that the life of the forest must be above his head. Few animals are seen, almost no insects and scarcely a green leaf or plant upon the forest-floor, but there, rather, are dead and decaying trunks of trees which have fallen and massive columns of trees that are standing, while arching overhead are interlaced branches that intercept the light and make the scene like that in some dim cathedral. But if from a balloon one could look down upon the immemorial crowns he would see spread out beneath him a world alive with birds and insects, brilliant with flowers and rich with the verdure of vines and air-plants. It would be much as if the tree-tops had taken the place of the turf and shrubbery of more northern climes. Many orchids and other plants of that nature would be seen perched upon the branches, dangling their roots into the damp air below; climbing and twining plants would be abundant and especially would there be observed a much greater variety over a particular area than could be expected in temperate regions. This peculiarity of the tropical forest, this exuberant development of tree-top life is a natural result of age. It is because the forest has been standing for countless centuries, unmodified by changes of climate, uninvaded by glacial sheets, that it includes so many different kinds of individuals. For the same reason there have arisen dependencies between different varieties of plants, and some have learned to perch themselves upon the branches of others or have entwined themselves around the stems of their neighbors. Just so, in an old society like that of India or wherever there is not the democracy and equality which exists under a newer social order, is caste developed. People are born to be dependent and it is fore-ordained in the social system that they and their descendants shall not rise above this position.

In the forests of Minnesota all is very different. When one enters the pine-woods of the north, or the elm and maple-woods of the south, he is not impressed with the silence and solitude of the forest-floor, nor does he discover that the tree-tops have become a special soil for the development of peculiar plants. Perching plants are rare; vines and lianas do not form so large a proportion of the total population. There is nearly always a well-developed underbrush, and many sorts of little heaths, asters, gentians and golden-rods display their flowers and ripen their fruits under the shadow of the trees. They are not compelled by the umbrageous growth of larger plants to climb the trunks or hang themselves upon the topmost branches in order to obtain their share of sunlight and of rain. Nor is the number of kinds in an acre nearly so great as in the tropics, for there has not yet ensued that long period of competition which, in the tropical forest, has reduced what might once have been social clumps of trees to the lone survivors of to-day.

Forest and prairie. There are two principal vegetation-regions in Minnesota, the forest and the prairie. The forest occupies the northern portion of the state extending south to the valley of the Minnesota river. The prairie comprises the southern portion of the state and a strip along the western boundary in the valley of the Red river of the North. These two regions, so different in their appearance, are inhabited by plants which are not altogether dissimilar to each other. Most of the plants at home on the prairie are not entirely absent from the forest, while the greater number of forest plants may be encountered, possibly not so abundantly, but at least casually, on the prairie. The difference between the two regions does

FIG. 1.—In the forest district. Growth of white pines and spruces upon a rocky island. Steamboat channel, Lake of the Woods. After photograph by the author.

not lie in differences in the *kinds* of plants so much as it does in the different character of the *dominant* plants. Among the pines and spruces of the forest occur many of the grasses, vetches and asters of the prairie. Along the borders of prairie sloughs and streams there will be growing the same varieties of arrow-heads, milkweeds and willow-herbs that form a characteristic vegetation in similar places in the forest. But the dominant plants of the forest are trees, lifting up their erect, perennial stems, struggling with each other for light and air and giving to the whole formation an upright effect, while the prairies are dominated by grasses with prostrate underground stems woven together into a solid and matted turf, thrusting into the air only their side-branches and thus giving to the whole a flat and level character. It is not very well known precisely why the prairie type of vegetation has established itself over such large areas of the world. Some have attributed it to fires, others have thought that climate and soil are responsible for the difference between prairie and forest. Perhaps all that need be said is that there are these two principal methods of developing plant-stems. When the dominant plants of an area are such as have acquired the habit of trying to avoid each other's shade by elongation of their stems, that region is a forest. When, on the other hand, an area is occupied by plants that have learned to elbow each other beneath the surface of the soil, that region is a prairie. It is a mistake to suppose that the lofty tree is in every sense stronger than the modest grass, for the two have simply devised different means of accomplishing the same result. A prime necessity of most plants is sunlight, since without it they are unable to construct their food from the gases of the atmosphere and the water of their sap. Therefore, they must have light, and to obtain it they adopt instinctively the methods of growth which will enable them to do their own life-work regardless of their neighbors. The pine tree may be described as a plant which for ages has been solving the problem of better illumination by a progressive increase in height. The grass, by copious ramification of a protected underground stem upon which lateral leaf-bearing branches are produced, in its way strives to obtain illumination, nutriment and persistence.

Another difference which exists between the forest and prairie of Minnesota is in the direction from which the plants have come. The forest is, in large part, composed, so far as its dominant plants are concerned, of northern forms, while the prairie is inhabited rather by immigrants from the south. So on a map illustrating plant distribution in the northern hemisphere it will be found that the prairies in Europe, in Asia and in America lie south of a forest belt. It is true that in the tropics around the world a forest region exists, broken only by deserts like those of the Sahara, or northern Australia; but in regions beyond the tropics it would seem that in both hemispheres there are intermediate forest zones between the prairies of temperate regions and the tundras about the poles.

Minnesota is situated between the forest and prairie regions of the North American continent and includes a representation of each. A careful study of the populations in these regions will show that each is striving to extend itself; thus wherever a stream flows from the forests of the north down through the prairies of the south, forest plants advance along the banks and reach more southern latitudes. In Minnesota the pine trees that in the north form so characteristic a growth are found in isolated patches, fewer in numbers, down the Mississippi—even

FIG. 2.—Prairie scene on the Coteau. Sunflowers line the roadway on either side. After photograph by Mr. R. S. MacIntosh.

beyond the confines of the state, for the white pine exists upon the Mississippi bluffs in Iowa. Similarly, along the open which a river produces, there is chance for southern winds to distribute the seeds of prairie plants, and characteristic vegetation of the prairie, such as sunflowers and golden-rods, has pushed its way up into the forest, leaving the larger streams along their tributaries, and finding a path even into depths of the pine-woods where the soil is favorable. It would be a great mistake to count plants quiet, unenterprising creatures, not alert to make use of every opportunity for growth and development. The forest must rather be regarded as composed of plants eager to compete with those of the prairie upon their own ground, and equally must the prairie plants be regarded as ambitious on their part to try conclusions with those of the forest, if they obtain an opportunity to penetrate between the interstices of the more northern erect formation.

Plant populations, then, in the two great vegetation regions of the state, are in a state of *tension*, and the line between them is necessarily slowly shifting and irregular. Some little change in the topography, some slight modification of the drainage, the drying up of a lake or the erosion of a deeper gorge by a stream, may give an opportunity for one formation or the other to extend its limits at the expense of its neighbor. This general state of tension exists not only between the forest and the

Fig. 3.—Roadside vegetation. Grasses and pulses. An elm tree in background. Cedar lake. After photograph by Williams.

prairie, but also between plants on the tops of hills and those at the base, between plants in the center of swamps and those at the circumference, or between plants at the edge of a lake or stream and those farther inland.

Plant zones. The result of such competition is seen in the pretty general appearance of plant zones wherever the topography permits them to be developed. A simple and well-known example of this tendency of plants to grow in zones or lines may be seen along any road, path, ditch or trail in the state. It is well known that certain kinds of plants particularly select the road-side as a favorite place for growth. Such are usually robust, enterprising plants of modern structure, and the pick of the whole world for growing ability—for nowhere is there so great a proportion of what are called *weeds* and introduced plants as beside a road. There one finds the knot-grasses, rag-weeds, thistles, cockscomb-grasses and other imported species, many of them belonging to types which by sheer vegetable enterprise and ability have found their way with man around the whole northern hemisphere, and some of them are common even to Australia and Africa as well. As might be expected

FIG. 4.—Spruces forming a zone around a peat-bog. Farther back are tamaracks and pines. The shrub in the foreground is the bog-willow, while the flowers are those of an orchid,—*Pogonia*. Near Grand Rapids. After photograph by Mr. Warren Pendergast.

from their distribution along paths or other works made by man, they have been assisted in their wanderings by human agencies rather than by the ministrations of the winds, the water-fowl or the beasts of the field. Such plants appear also in door-yards, in neglected meadows, in pastures, along railway lines and in short wherever man has gone.

Another kind of zonal distribution, not influenced by human agencies, may be seen around the lakes of the state, especially where beaches have been formed. Here special beach-rows of plants will be found, consisting among others of certain sand-loving grasses, cockleburrs, pinks and fumitories, and clearly distinct from the plants farther back upon the shore. Nor will these plants develop so vigorously under any other conditions. Again in the swamp region of the north, where a peat-bog is slowly filling with moss and encroaching upon the forest, beautiful illustrations of this zonal arrangement can be observed with the tamarack and spruce trees becoming gradually smaller and smaller toward the center of the bog. In meadows, too,

FIG. 5.—Zones of aquatic vegetation. In the center pond-lilies; at the edge smartweed; farther back cat-tails, blue flags, sweet flags, and sedges; still farther back soft turf with grass, moss, sedge and milkweed. After photograph by Williams.

formed by the drying-up of lakes, are sometimes found encroachments of the meadow plants upon such knolls as were originally islands surrounded by water. The meadow, as it were, washes up upon the knoll and upon the banks of the old lake, so that mingled with the dogwoods, willows and other shrubs of the knoll or bank one will observe the grasses and sedges of the meadow.

Zonal distribution is a characteristic arrangement not only of land, but also of water plants, and as one pushes his canoe from the shore of a Minnesota lake he will doubtless find that he passes over distinct zones of aquatic vegetation. First, there will be the sedges at the water's edge, then the reed-grasses, or wild rice in a little deeper water, then the bulrushes with their cylindrical, leafless stems rising from submerged rootstocks below, and exposing as small a surface as possible to the action of the surf. Next will come the pond-lilies and water-lilies, the water-shields, and sometimes the lotus with its circular leaves rising from or floating upon the water and presenting everywhere their arched margins to the waves. Then come the pond-weeds and milfoils with their stems and submerged leaves ascending through the water but not reaching the surface, and finally the bass-weeds with their lime-encrusted stems and leaves lying upon the bottom at a depth of from ten to fifteen feet. Whether one climbs a hill, rows out into a lake, walks from the margin of a stream back to the prairie or the woods; whether one steps from his house and across the road into a field, or strolls from a meadow up to a wooded bank, he will find that he is traversing zones of vegetation. The occasion for such a distribution of plants in zones is to be sought generally in the topography of the region, and where there is great irregularity in the topography there is irregularity in the zones, while sometimes over a level no zones appear. Sometimes, also, where the topography is favorable to the development of plant zones special conditions of distribution serve to obliterate them or prevent their occurrence.

The same general causes which tend to separate the forest from the prairie, defining their limits, are seen to mark also the boundary between one portion of the forest and another. Just as the great prairie group of plants strives as a whole to encroach upon the forest, so the plants at the base of a knoll strive to climb it and establish themselves over its surface, and meanwhile quite as vigorously the plants on the knoll attempt to make their way into the gullies and sloughs. The plant on drier soil may be regarded as always endeavoring to accommodate itself to moister soil, and that on moist soil as always struggling to gain a foothold where the moisture is not so great. So there are often seen at the margin of ponds the pond-lilies emerging as far as they are able upon the mud, exerting themselves to the full limit of their structural qualities to maintain a terrestrial life, and in the same pond may be found land-plants pushing down to the very water's edge or beyond it until they can go no farther because of the limitations of their structure.

The tension between the forest and prairie, because it extends so widely, may be called a continental tension. The other tensions, between knolls and ravines, between banks and meadows, between beaches and pond edges, may be called minor tensions, but the law of the two cannot be very different. Indeed, there may be gained a fair idea of the fundamental difference between prairie and forest by observation of an area so limited as a road-

FIG. 6.—Island in the Mississippi above St. Paul. The center is occupied by elms while the rim is fringed with willows. An example of a "minor tension." After photograph by Professor W. R. Appleby.

side or path. The principal difference between the two is the duration of the causes at work. Between the prairie and the forest the tension has been in existence possibly for thousands of years, while between the knoll and the ravine possibly for but a few decades or centuries. As a result there have come to exist in the old warring formations structural peculiarities characteristic of each, so that, to the eye of the observer, they present very different appearances. Where the struggle is of more recent origin and of more limited extent the differences are not so great and, therefore, not so evident.

Forests of Minnesota and of the world. We cannot well consider forest as it exists in Minnesota apart from the general forest which covers the northern part of the continent. From the plant's point of view, Minnesota is not a province, for, to the plant, political boundaries as established by man, have slight significance. Nor does the prairie, which occupies the southern part of the state, exist as a special Minnesota prairie. Rather is it the northeastern extension of the great plains which occupy the whole central area of the continent from the foothills of the Rockies back to the forests of Kentucky, Tennessee, Indiana and Wisconsin. The question then arises how did the forests come to consist of the plants which dominate them, and how did the prairie come to have its particular inhabitants rather than others?

If a census be taken of all the kinds of plants in the forests of North America and be compared with a similar census taken in the forests of Europe and Siberia there will be perceived a great similarity between the plants of the two regions. But if in like manner the plants of the prairies of the United States be compared with those growing upon the steppes of Russia and Siberia it will be discovered that the similarity is not by any means so great. A very much larger number of plants are common to the forest districts of Europe, Asia and North America than are common to the steppes and prairies of the two hemispheres. Yet, in this latter instance, there are many groups which are similar and not a few identical species. Suppose, further, that the forests of the northern hemsiphere, of which the Minnesota forest is but a portion, be compared with the deciduous forests of the southern hemisphere, including those of the Transvaal Republic, Chili and the Argentine, New Zealand and Tasmania, it would be noticed that almost no common species, and but few common groups of species can be found. Or if the pampas of the Argentine be compared with the prairies of the United States, again would it be discovered that the common species are exceedingly scarce.

It would seem, then, that the greatest differences which exist between plant populations of the world are between those of the north temperate and the south temperate regions. The occasion of this will be understood if it be remembered for a moment what are the opportunities for the expansion of plant-life in the tropics and under the equator. There for countless thousands of years plants have been developing and competing with one another amid favorable conditions of temperature, moisture and illumination. The equatorial region of the world is at once the cradle and the crucible of plant-life. In that tremendous struggle for existence many of the modern improvements and refinements in plant structure began to originate. During the centuries, forms unfavorable were eliminated and destroyed, leaving the stronger in a condition to migrate north or south as rapidly as they accommodated themselves to the increasing obliqueness of the sun. Evidently, then, the greatest differences should be expected not between the plants of North America and Europe, both of them tenanted by north-bound immigrants from the equatorial region, nor even between the north temperate regions and the tropics, since the plants in the former are but the traveled relatives of those at home in the latter region. But the greatest difference should be expected to exist, as it does, between those plants which have left the tropics and have slowly made their way, changing their form and habits as they wandered, some to the far north and others to the south.

North American flora. If the North American continent were quite flat, without differences in elevation above the sea, and were connected with the tropics by a continuous stretch of land, it could be imagined that the forest region might have extended directly across the northern half of the continent. It is, however, not such a level plain, for two great mountain ranges run from north to south and the continent is connected with the tropics by a narrow isthmus, so that there are factors which prevent an even division of forest and prairie. Mountain ranges extending from north to south are not, as mountain ranges extending from east to west would be, barriers against plant distribution from the tropics toward the poles. This is the reason why North America has what the botanists call a "richer flora" than Europe and Asia. In the Old World the principal mountain ranges, such as the Pyrenees, the Alps, the Appenines, the Carpathians, the Caucasus and the Himalayas are transverse, extending in a generally east-and-west direction. For this reason when the glacial period came on, unfortunate European or Asiatic plants as they migrated south, found themselves compelled to climb some mountain range in order to make their escape to the temperate climate beyond the influence of the ice, and under these conditions most of them must have perished as wretchedly as did so many of the troops of Hannibal when they crossed the Alps. Moreover, when the glacial period came to an end in Europe and Asia it was difficult for plants to return over the mountain-passes, and as a result, these continents are tenanted by a less diversified vegetation than that of North America.

The longitudinal mountain ranges of the New World have rather aided the movements of plants than hindered them, for they have assisted northern plants to find their way along high altitudes to constantly lower latitudes, while at the various stages of their journey such plants have enjoyed the opportunity of climbing down the mountain sides and out upon the plains, if they were able to accommodate themselves to the higher temperature. This movement has taken place not only on the western side of the continent, but also along the Alleghenies. Yet owing to the greater height of the western range it is found that northern genera of plants like some of the roses and willows have developed more abundantly toward the southwest than toward the southeast, simply because they have followed an easier path along the cool high ridges of the Rockies than along the warmer, lower Appalachian range. By these two mountain ranges, lying one to the east and the other to the west of Minnesota, some slight influence has no doubt been exerted upon plant migration, both in the prairie and in the forest region of the state. But this effect must have been stronger in the prairie region; for the forest plants from the east and north could enter as easily from the north and would not need to depend upon any lateral movement. From the west, however, where the plains rise gently to the mountains, many plants which had found an asylum on the sides of peaks and escarpments must have, in the last ten thousand years, slowly crept down into the plains and there developed habits and structures which persist to this day.

Chapter II.

Plant Wanderings and Migrations.

Habits of birds and animals. The habits of birds and animals are of much importance in any study of plant distribution; for the plant, but rarely provided with independent methods of locomotion, is forced to depend upon other agencies for dissemination. To the waterfowl especially, with their well-

Fig. 7.—Lake border vegetation of cat-tails, grasses, reeds and sedges, Lake of the Isles. After photograph by Williams.

known habit of flying south in the autumn and north in the spring, do many plants owe the widening of their range. Their seeds are ripened and fall upon the mud at the border of some lake or pond where they are picked up on the feet or plumage of migrant birds and are carried hundreds of miles north or south of the point where they were produced. That is one reason why throughout Minnesota the lake-shore vegetation is so homogeneous. Every bay is visited at some time during the year by wild fowl and in the mud on their feet they carry about the seeds of a variety of plants. It is therefore, those water-edge plants which have seeds not too large to be thus transported that are the more widely distributed. Especially if the seed is of a kind attractive to the bird is it likely to be removed. Thus ducks, though they eat hundreds of thousands of young wild-rice plants encased in their seed-coats, nevertheless from their very habit of using these plants for food distribute them more widely than if they were not thus agreeable to their taste.

Migrating animals, like the bison which once roamed in enormous herds over the whole prairie region, must have picked up in their fur, as they wallowed in the sand or on the banks of streams, countless seeds of a great variety of plants and carried them to all parts of their range. In this way, plants having seeds provided with attachment-prongs, like the tick-trefoils, beggars'-lice, burdocks and cockleburrs must have obtained through the agency of animals far greater opportunities for travel than were enjoyed by species the seeds or fruits of which were hard and smooth.

The fancy of animals and birds for certain sleeping places has also influenced plant distribution, and their habits of wandering in the woods and by the water have been utilized by certain kinds of plants, and some remarkable adaptations exist, such as the curious explosive seed-pods of the touch-me-not. This common plant, when brushed against, explodes its fruits, throwing out the seeds where they may be caught in the fur of a passing animal and carried away. Certain exotic gourd-plants too, have explosive fruits which when agitated by a slight touch shoot out the seeds and these, provided with a viscid membrane, readily adhere to the passing bird or animal. Other plants have their seeds enclosed in edible areas, as for example the gooseberries, currants, apples, peaches, raspberries, junipers and a host of others. In such fruits the seeds are themselves protected by hard coats which resist the digestive processes of the animal or bird and they can thus pass through its body without injury. Sometimes the instincts of animals benefit the plant, as when a squirrel carries off an acorn and buries it from some dim notion of secretiveness or possibly of providence. On account of the rhythm of the seasons in Minnesota the principal migrations of birds and land animals have not been from east to west but from north to south, and the principal tension-line runs in general from east to west.

Insects and worms. A few seeds are peculiarly modified for insect distribution, as for example, those of some spurges and other small plants, which have little crests or grooves just fitted to receive the jaws of ants, thus making them easily portable by these busy toilers. Others are assisted in their distribution by burrowing worms, but this always within narrow limits.

Inanimate agencies. Allusion has already been made to the inanimate agencies which are employed by plants as aids in distribution. Among these are currents of wind, currents of water and in a slight degree translocations of soil. The latter, best observed in mountainous regions where avalanches exert a considerable influence, is of slight importance in Minnesota, though upon the hillsides and cliffs along some of the northern lakes, this method of distribution exists.

Wind currents. In plant distribution the most important inanimate agency is doubtless the wind. The alertness with which plants make use of it in seed-dissemination is well exemplified by the new population which appears after a fire and covers burnt places in the forest. When the pines or spruces are destroyed by fire it is a fact of common observation that poplars, maples, elms, willow-herbs, milkweeds and other light-seeded plants spring up. The well-known fire-weed with its purple panicle of flowers ripens seeds that are provided with tufts of delicate hairs, and when thrown out of the pods in which they are produced the wind may catch them and whirl them away over the tree-tops for many miles. The poplars, too, and cottonwoods are famous for their winged seeds and succeed in entering promptly a burnt tract, so that within a year or two they have established themselves while there are yet to be found probably none of the heavy-seeded plants, like hickories, walnuts and oaks, and but few of the plants with adhesive seeds or pulp-inclosed seeds fitted for animal distribution. It is not the seeds alone but often the fruits of plants which are transported by the wind, as for example, the maple-fruits, the elm-fruits and the fruits of a great variety of dandelion-like and sunflower-like plants. Sometimes the whole plant is distributed by the wind and examples of this are especially striking upon the prairie where the wind has free sweep. Thus, tumbling plants like the Russian thistle, the tumbling mustard and the tumbling grass, when their fruits are ripe separate all or the greater part of the stem from its attachment and curve their branches so that the whole takes the shape of a ball rolling freely for miles over the level prairies before the wind. Sometimes the wind acts indirectly in the distribution of plants, as for instance, when a portion of the boggy shore of some lake breaks loose and is blown away to be anchored possibly under new conditions across the lake.

Water currents. Though the agency of currents of water in transporting seeds is scarcely so universally employed as that of the wind, it should not be overlooked. This agency is particularly important for heavy-seeded plants as their seeds are often borne along a stream in its currents and eddies to find a lodgment possibly miles below the point where they were introduced. Other seeds, to facilitate their floating, are provided with buoyant apparatus which adapts them also for wind distribution.

Man. One very important agent in plant distribution remains to be considered, namely, man. Unlike the birds and animals, man in his migrations is not so strongly regulated by the changing rhythm of the seasons. On the contrary the principal lines of migration of men since the advent of Caucasians upon the continent have been from east to west, rather than from north to south. Roads and trails have been beaten across the plains and through the forests; railway lines have been built, binding distant portions of the country together, and to connect with them steamships cross the seas. Freights are carried from one hemisphere to another, and along with that for which there are invoices and bills of lading comes often a consignment of seeds of fruits, unrecorded yet none the less important. In this manner some harmful weeds as well as some useful forage-plants have reached the fields of Minnesota. With the immigration of men and women from Russia has come the Russian thistle; from France and England the cockles of the wheat; from Italy some mustards; indeed, from all the countries of Europe plants have found their way in company with man. Some of them are later immigrants than others. Those which crossed with the pilgrim fathers are now as much at home as those to the manner born. Others, the advent of which dates from yesterday, have not yet shown all their capabilities, and doubtless even now the dangerous new weeds of the next decade are some of them precariously existing as little colonies upon ballast-heaps or along the lines of eastern or western railways.

Associations between migrating plants. When plants travel they do not always travel alone, but in company as man does, who when he migrates brings with him his horses, oxen, sheep, fowls, dogs, and other domestic animals which have become attached to him. So the plant when it migrates often takes with it other plants. Thus where the maples go, there go also those curious fungi that grow upon the leaves, looking like little drops of tar. With the willow as it is uprooted and floats down a stream, perhaps finding a foothold for its twigs somewhere below, go the lichens and mosses upon its bark.

There is something about the proximity of certain kinds of plants which is very agreeable to other varieties, so that generally with pine trees one finds wintergreens associated, and with peat-mosses, cranberries. The latter are not associations like the associations between the maple and the fungus upon its leaves, but are rather indications of kindred tastes in habitations. The establishment of one kind of plant over an area may be the natural and, perhaps, the necessary pre-requisite for the development of another plant which has formed the habit of attaching its fortunes to those of the first one in the field. Plants, also, by their position and attitudes strongly influence the distribution of other plants. If plants, which are accustomed to depend upon winged seeds for their distribution, find themselves gradually enclosed by the foliage of strong-growing neighbors it will be difficult, perhaps, for them to extend farther the range of their seeds. Or, possibly, the berries which were attractive during a season when neighboring plants were not in fruit may not be so attractive another year when the adjacent forms are ripening their own larger, more highly colored, more highly scented or sweeter fruit.

Where the story of plant migration is recorded. It is impossible to mention except in a more extended account the many and various ways in which plants influence the distribution of each other or receive influence from outside sources, but enough has been said to indicate the general laws under which the State of Minnesota has received the plants which now inhabit its territory. They have come from all points of the compass, from all parts of the world, bringing with them habits acquired through countless generations of struggle and adaptation. To the enlightened eye, the form of a plant tells a story of its life and of the experiences it must have undergone to develop one type of structure rather than another. Just as in the formidable defensive armor of an extinct armadillo may be read somewhat of the story of its struggle with its enemies, so in the three hundred feet of solid trunk and in the massive girth of a living Big-tree in the Sierras one may read the story of its struggle in the ancient forests when its allies and competitors were perhaps more numerous and more vigorous in their aspiration for light than are the neighbors of to-day.

In the Minnesota valley, not far from New Ulm, there are found upon rocks exposed in the river-bed by the erosion of the waters, some specimens of the little prickly-pear cactus, a desert plant which has found its way from the plains of Arizona and New Mexico. By all its characters it indicates how it must have been trained in a school of life different from that in which the plants around it receive their education. Its solid, leafless, flattened stem with a resistent rind is fitted to withstand the evaporation of moisture—a character much needed in the desert, but less necessary in the valley of the Minnesota. Its strong root system extending out a yard or more on every side was indispensible to collect what little moisture there might have been in the arid soil of the southwestern desert; with a smaller root system it could do very well in its northern home. The sharp thorns and spines with which it is covered were a necessary protective armor where vegetation was sparse and grazing animals hungry; without this armor it could live very well on the hills of New Ulm, for there dwell other plants without armor nor do the herds destroy them. Such a plant, evidently a wanderer from another land, is like a man of mediæval times who should be reincarnated in a modern society and should insist upon wearing the coat of mail and carrying the rapier which were necessary in another age, but would be recognized as altogether out of place in the life of the present day.

The pine trees, with their needle-shaped leaves fitted to transpire water but slowly and with their strong branches able to carry the weight of the snow which is piled upon them in their northern home, when they find their way down the river to the comparatively genial climate of Iowa cannot at once abandon the structures which they developed under the stern necessity imposed by the severer climate of their native land. The mat-plant, such as a purslane or carpet-weed, adapted to life on a flat plane where it is not shaded by surrounding plants but spreads out all its prostrate branches in a discoid body, cannot erect itself into the slender wand of the aster, taught to assume this shape by centuries of existence in the underbrush above which it had to lift its leaves that they might catch the sun. The aspiring spruce telling in its form a story of other spruce trees close beside it crowding each other as they all reached upward for the light, if it is planted in one's dooryard with nothing near to shade it cannot abandon the character which it developed of old. Plants when they migrate from place to place must take with them those structures and habits which are fitted best to the whole history of their species. In their migrations they select places which resemble as closely as possible those to which they are accustomed. They allow themselves a certain freedom just as men do, but even as regards men it is well-known that they prefer to migrate along the same parallel of latitude, so that the inhabitants of Minnesota have come rather from the forests of New England and New York, from Canada, from Scotland, and from Scandinavia, than from the highlands of Mexico, from Italy, Africa, or Brazil.

Struggles of migrating plants. It must be apparent from all that has been said that the laws governing the migration of plants are substantially the same as those that govern the migration of other living beings. It is an instinct with all living creatures to maintain their own existence as long as they can and to do this they wrest from others, weaker or less fortunate, the right to food and sunshine which they in their turn demand of nature. It is even so with men; the dervishes of the Soudan must give way before civilized England. Thus also must the feeble plants of a meadow's edge yield before the onslaught of trained roadside plants, brought in from other parts of the world and fitted to cope with the conditions of existence in a stronger and better way. As one looks at a placid meadow, its grasses bending in the breeze, he should remember that underneath the calm serenity of the scene there is a bitter struggle, a relentless internecine warfare between the plants that are already in the meadow and those that are striving to enter from without.

Comparison of plants with animals. Next to and even stronger than the instinct to exist is the instinct to *persist*, and plants sacrifice their own lives for their offspring just as readily in their sphere of life as will a human mother give up her life for her child. In dealing with plants the mind must be rid of the mistaken notion that they are dull, stupid things which stay where they are set without ability to better themselves and their offspring. On the contrary the plant should be regarded as a living organism with definite necessities and definite instincts. Plants are quite as much alive as animals, and, indeed, they are greater ground-gainers on the surface of the earth than animals are, for if all the plants of the world should be weighed in one scale pan of a gigantic balance with all the animals in the other it would be seen that as organizers of dead matter into living substance the plants far outrank the animals. In dynamic force, in the ability to apply energy in some definite direction, the animal is indeed superior, but in those purely constructive vital powers no organisms are so skillfully adapted and so perfectly organized as the plants. They are not altogether of a lower type of life than animals, for they do their work in the world after their fashion, and that is all that animals can do. They are rather to be viewed as other kinds of living things, and are to be regarded not as merely subservient to the needs of animals, not solely as a food-supply for grazing cattle or roving birds, but of interest for their own sake and possessing an individuality to be respected.

Chapter III.

Slime-Moulds and Blue-green Algae.

Number of plants in the world. In the whole world there are now living about 300,000 different kinds of plants, and it is possible that nearly as large a number of forms are extinct. The relics of past plant life in Minnesota are not very abundant, but in the older rocks there are a few fossil sea-weeds deposited on the mud flats of an ancient ocean which covered the region now occupied by the land, and in the red sandstone which occurs in the Minnesota valley in limited quantities, there have been found imprints of leaves belonging to by-gone genera. For example, in those days palm trees flourished in the state and have left their replicas along with the remains of red-woods, big-trees, cycads, magnolias, tulip-trees and other varieties. which are not now found within hundreds of miles of Minnesota. From old peat deposits and from soil masses lying under the glacial clays, fragments of charred wood and vegetable debris are sometimes exhumed. Such fossils often show that the distribution of plants before the glacial period was quite different from that of to-day.

Number and sorts of plants in Minnesota. At the present time, of the 300,000 living species of plants, about 7,500 are probably to be found growing without cultivation in Minnesota. The figures are in the nature of an estimate, for by no means so considerable a number has yet been discovered. But it must be remembered that the larger proportion of these plants are not the conspicuous objects which are usually in mind when the word "plant" is used, but are rather the insignificant microscopic forms, difficult to discover and often of such slight difference from each other that they would be recognized as distinct varieties only by the most trained observers.

An estimate of the distribution of these 7,500 species of Minnesota plants among the different groups is approximately as follows: slime-moulds 150; bacteria and algae 1,000; fungi and lichens 3,250; liverworts and mosses 500; ferns and flowering plants 2,600. It is evident then, that most plants of the state belong to the lower orders of vegetation.

There may now be given a general account of the Minnesota vegetation, avoiding the use of technical terms and describing where it is possible certain common forms of each group, so that the reader may have within small compass a comprehensive view of the classes just named, as they are represented in the state.

Slime-moulds. The plants (or more probably animals) known as slime-moulds constitute a very peculiar group of organisms. It is by no means certain that they are plants at all, although they have some vegetable characters. In other respects they resemble the lower animals, and botanists and zoölogists have often debated to which of the two great realms of life they really belong. One of them, which is known to occur in Minnesota, may possibly have come under the observation of some of the readers of this book. The roots of cabbages and turnips, when pulled from the ground, are sometimes found to be covered with a curious irregular growth of little spherical tubers, about the size of hazel nuts,—sometimes larger, though often very much smaller. The occasion of the appearance of such tubers is the development of singular little slime-moulds too small to be seen by the naked eye but sufficiently active to cause gall-like swellings in the tissues of the root. Because of the ruptured appearance which the root has when affected by these tiny organisms, the whole structure, root and slime-mould, is known as a *root-hernia* or as *club-root.*

Most slime-moulds do not, however, live thus as parasites on other plants, but are found on decaying leaves, rotten twigs, fallen logs and other debris of the forest-floor in shaded places. They sometimes grow up from a mucilaginous base, forming little brown, cylindrical plumes, not more than half an inch in height and clustered together, a score or more, in a group. The brown plumes are found upon careful examination to be delicately woven masses of threads, between which is a fine brown dust which can be shaken out upon the hand or upon a piece of paper. This brown dust, under the microscope, is seen to consist of innumerable tiny spheres, the *spores* of the plant. If the spores be placed in water, after a time their shells break and out of each comes a little mis-shapen drop of jelly-like substance, which oozes away with a slow and viscid movement. If several of these tiny bits of jelly find themselves close together—perhaps after a rain upon the bark of some rotten log—they crawl towards each other and fuse into a common patch. The patch then moves imperceptibly over the wood, increasing in size as it extracts nourishment from the decayed material. Sometimes the jelly-masses grow to the size of a man's hand. A common sort is found in tan yards and often upon railway ties resembling very much a piece of ordinary thin jelly and generally covered with a sulphur-colored powder. After the jelly-mass has increased in size to a certain point it breaks up into little clusters which afterwards develop fruit-bodies more or less like the brown plumes spoken of above.

Another kind of slime-mould crawls up the stems of various plants in meadows and deposits itself upon the leaves in little foam-patches looking very much like drops of spittle. There are some insects which make similar spittle-masses on leaves and an expert investigation is necessary to determine whether such objects are insect products or the plant bodies of slime-moulds.

Some slime-moulds have the power of incrusting their tiny fruit-bodies with lime which they extract from their soil or from rain-water that falls upon them. Such forms are often observed in Minnesota upon dead wood, or fallen leaves, generally in moist shady places in the deep forest. Sometimes the fruit-bodies are almost round, resembling the familiar pills of the homeopathist. In other species they are worm-like, coiled like loose snail-shells, but very much smaller, yet not so small that they cannot easily be discovered if searched for in the places that they have chosen. A few slime-moulds will be encountered among mosses, forming little brown scurfs upon the moss tuft or displaying themselves as yellowish patches around the bases of the leaves. None of these plants have any economic importance. The most conspicuous one in Minnesota occurs upon dead logs as pink, hemispherical bodies, about the size of the end of one's finger. Usually these fruit-bodies are seen in clusters of a dozen or more. If one of them is cut into it will be discovered that the interior consists of a brown moist powder, which when dry blows away in an impalpable dust. In a single fruit-body such as one of these, millions of spores originate which, washed away by the rains or blown about through the atmosphere, may fall upon suitable decaying substances, open and liberate each its tiny bit of living jelly that by itself or with the assistance of others gradually builds up a new plant-body.

Algae. The plants known as algae secure their best development in the sea, where under the name of sea-weeds they are universally known and many of them admired for their beauty of color and gracefulness of form. Of the algae there are five principal groups; 1, bacteria; 2, blue-green algae; 3, bright-green algae; 4, brown algae; 5, red algae. The red algae and brown algae are chiefly marine, although a few varieties of at least the red group are found in the fresh waters of Minnesota. Most of the algae in fresh waters belong to the blue-green or bright-green groups, while those lowly and most extraordinary of plants, the bacteria, are of such various occurrence in soil, water, air, and the bodies of other organisms that I shall consider them in a special chapter.

Blue-green algae. The plants of this group may generally be recognized by their bluish-green color, approaching sometimes the hue of verdigris and never the pure grass-green which distinguishes the bright-green group. One of the most common of them is the so-called "water flower" which in summer develops in such vast quantities in the lakes of Minnesota. The tiny, bluish, jelly-ball of the water-flower, ordinarily not larger than a pin-head, if examined closely will be found to have a bubble of gas at the centre, by means of which it floats. If this bubble is analyzed by chemical methods it will be ascertained to be more highly oxygenized than the atmosphere. It is produced by the growth-activities of the plant and incidentally serves the important purpose of keeping it near the surface of the water where it may obtain the light. At Lake of the Woods I have seen these plants in such enormous numbers that the water looked more like green paint than lake-water and at Lake Minnetonka the cottagers often complain of the abundance of the water-flower and inquire for methods of exterminating it. There is, however, no practicable way of destroying it, for if the water should be poisoned enough to kill the water-flower other living things, pond-lilies, bulrushes and bass would also disappear.

Structure of the water-flower. A microscopic examination of the water-flower will show that each tiny jelly-ball consists of a number of delicate algal threads intertwined and imbedded in a common mass of jelly which they secrete. When a jelly-ball becomes sufficiently large it commonly breaks in two and the pieces continue growing as before. If the jelly be dissolved hundreds of tiny coiled threads escape from it and multiply, developing hundreds of new jelly-balls. In the autumn these little creatures drop to the bottom of the lake, or remain in a dormant condition frozen in the ice until the warmth of another season stimulates them into renewed activities.

Larger jelly-balls, in appearance very much like green plums, but with the characteristic bubble of gas at the centre are often found floating in ponds. These belong to another species of blue-green algae but they are closely related to the water-flower and their structure and life-habits are not essentially different. Still another variety of blue-green algae is common as little hemispherical lumps an eighth of an inch in diameter attached upon the stems of bulrushes, just beneath the surface of the water. Still other kinds form tufts and stringy masses several inches in length floating near the surface of stagnant pools. A curious form which has lost the blue-green color, and may be classed also as a bacterium, is sometimes found growing in the outlets of springs, where it resembles a mass of iron rust dissolved in water. The red color is not a deception for it is actually due to iron oxide extracted from the water by the microscopic filaments of the plant.

Rock-forming algae. Some of the blue-green algae have the power of encrusting themselves with lime, and in watering-troughs and tanks there sometimes occurs a calcareous formation reminding one of the deposit in old tea-kettles. Such a crust is true limestone extracted from the water by the chemical activities of the algae. Upon a large scale the blue-green algae play their part in the formation of rock. The best place in

America and, indeed, in the world, to observe their action is at the Yellowstone National Park, where great masses of traver-

FIG. 8.—Portion of a board which had been standing in the tank shown in fig. 10. It is encrusted with lime stone deposited by a colony of blue-green algae. After photograph by Miss Josephine E. Tilden. From the *Botanical Gazette*.

tine and sinter are formed, covering acres around the hot springs in which the blue-green rock-forming algae find a congenial home. Travertine is a kind of limestone; sinter is a kind of silica or sand rock and it therefore appears that not only can some blue-green algae extract lime salts from the water, but other varieties can form quartz as well. No doubt very much of the limestone and even of the granite that occurs in ledges over the continent was begun in ancient warm seas by the action of organisms similar to the blue-green algae, while at the Yellowstone Park, or upon a smaller scale in one's watering trough, the same rock-forming processes are still going on.

Skin-algae. Still another variety of blue-green alga produces broadly expanded membranes, or skins, along the bottom of springs, and on pebbles in streams or lakes. In general the plants of this group may be recognized by their color and they are among the lowest of the algae.

Chapter IV.

Bright-green Algae.

By far the greater number of Minnesota algae belong to this group.

Pond-scums. Probably the most easily recognized is the familiar pond-scum, which is by many people regarded with aversion and is supposed to be in some mysterious way connected with the presence of frogs. If the slimy bright-green scum be lifted from the pool, taken upon the fingers and closely examined, it will be seen to consist of long delicate unbranched hairs, not much thicker than a spider's web. As it dries in the hand it curls and shrivels, but under the microscope the hairs are beautiful objects. They are jointed and in each joint lie coiled one or more green bands, like ribbons in a glass jar. By means of the green bands the plant can construct starch out of the carbonic-acid gas in the bubbles of air scattered near it through the water, using also the water itself in the process. By the breaking of the threads between their joints the plant abundantly propagates itself throughout the summer.

When autumn arrives a very remarkable breeding-habit comes into play. Two of the pond-scum threads extend themselves close together in the patch and from the joints of each, little protuberances arise which become blended into tunnels, uniting ordinarily the joints of one filament to the neighboring joints of an adjacent filament. Through such tunnels the entire living contents of one joint creep over and combine with the living contents of a neighboring joint. The fused-body then contracts like a sponge, expressing much of its sap and secreting about itself a firm clear membrane. After such a process, repeated throughout the patch of algae, the walls of the old joints may slowly break or dissolve, and the hundreds or thousands of oval fused-bodies, inclosed in their special membranes drop to the bottom of the pool, where they lie dormant until the following spring. Then each membrane dissolves or breaks and the fused-body extends itself into a new pond-scum thread, becoming jointed as it grows and elaborating in each of the joints the green ribbons by means of which it produces its food from water and carbonic-acid gas just as did its parents the preceding season. By the breaking in pieces of this filament in the way that has been described and by the subsequent growth of the pieces a large patch of scum, enough to cover the surface of a small pool, will be produced before the summer is at an end.

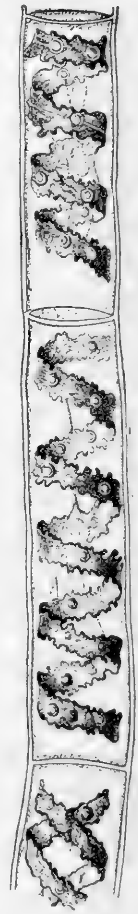


Fig. 9. — Portion of a pond-scum thread, showing how it is made up of transparent-walled cells with a coiled green ribbon in each, much magnified. After Atkinson.

Desmids. Related to the pond-scum are a large number of tiny crescent-shaped and star-shaped plants called desmids. These are often particularly well-developed in the water of peat-bogs, so that if one goes to the nearest tamarack swamp and brings away a tumbler full of water which he has squeezed out from among the peat-mosses, and sets the tumbler in the window, within a few hours a green film of desmids will be likely to form upon the side of the glass turned toward the light. Like the pond-scums these little plants have their breeding habits and like them they are able to maintain and distribute themselves throughout the water of their pool. If in the autumn, the pool becomes dry, the little eggs of the desmids lying among the particles of soil may be caught up by the wind and carried to distant pools where they continue developing as before.

Rolling algae. Not uncommon in Minnesota is another bright-green alga which appears in quantity in pools as green globules somewhat smaller than pinheads. If placed in a saucer of water and observed closely one of these green globules will be seen to roll over and over in the water and make its way from one side of the saucer to the other. It does this because its surface is covered with tiny contractile threads, which lash about in the liquid like so many little whipcords and roll the whole ball from one point to another as the needs of the plant may determine. Because of its rolling habit this little plant is called *Volvox*, or the rolling alga.

Flower-pot algae. Somewhat related to the *Volvox*, but by no means so interesting an object, is the bright-green alga which forms a scurf on flower-pots in green-houses, upon curbstones near hydrants, upon the foundation stones of houses standing upon damp places, upon damp soil, and often upon fallen trees in the deep forest. A microscopic examination of the green

FIG. 10. Patches of pond-scum floating in a tank. A lime-encrusting alga grows on the boards up to high-water mark. Near Minneapolis. After photograph by Mr. R. W. Squires.

scurf on a flower-pot would show that it is made up of countless very tiny green spheres, fifty of which could be laid side by side across the dot over a lower case "i" on this page. The way in which these little plants multiply is as follows: While they are finding food in plenty in the moisture about them, the contents of each of the spheres will be seen to divide into two, four or eight smaller balls. The membrane of the old sphere then dissolves and the little balls tumble out and grow to the size of the one which produced them. This process is rapidly repeated and in a few days such a geometric progression will bring into existence an enormous number. A variation of the process sometimes occurs when there is an unusual abundance of moisture, as after a heavy rain. Each of the little balls formed under these circumstances is provided with a pair of extremely delicate lashes by means of which it propels itself through the water with a curious rotating and wabbling movement, something like that of a rifle-ball, only, of course, very much slower. It takes some moments to travel an inch, yet, on account of the very small size of the plant, its movements viewed under a microscope seem fairly agile.

Red snow. The famous red-snow plant, which is found upon mountain heights in the Alps, in Bolivia, or in the Selkirks, is a relative of the green-slime so common upon flower-pots in the Minnesota conservatories. The color of the red-snow plant is adapted, no doubt, to the cold region which it has chosen for growth, and, in general, red coloring substances in plants have been described as *warming-up colors*—thus the autumn leaves turn red not because they are dying but for very much the same reason that men wear overcoats and woolens. Redness may be regarded as one of the plant's ways of protecting itself against a low or falling temperature.

Water-nets. Among the bright-green algae a conspicuous but not extremely common form in Minnesota is the water-net. This plant grows in quiet pools and resembles very much a piece of green mosquito-bar rolled up in an irregular cylinder, three or four inches long, and an inch or more in diameter. Each side of a mesh in the net is a joint or cell of the plant, and in each cell the living contents have the power of arranging themselves into a tiny net. When the wall of an old cell dissolves the tiny net begins to grow, enlarging all of its mesh-sides equally, until it has become as large as its parent. Besides this propagative process the water-net has the power of breeding somewhat as does the pond-scum, and produces curious little microscopic jackstone-shaped fused-bodies which remain dormant at the bottom of pools during the winter months. A great variety of bright-green algae are found growing upon pebbles, upon the stems of submerged vegetation and upon twigs or branches which have fallen into the water. Their characters are all more or less similar to those which have been already described.

Leaf-dwelling algae. One remarkable alga, very rare in Minnesota, is found in a peculiar habitat. On the leaves of the jack-in-the-pulpit there may occasionally be noticed watery blisters, in which, under the epidermis of the leaf, slender green threads branch and grow, giving a pale green tint to the central portion of the blister. Here is an example of a parasitic alga, forms similar to which are more frequent upon leaves in tropical forests than in temperate regions.

Sphere-algae. Another bright green alga which appears to be uncommon in Minnesota, but sometimes forms floating tufts of slender green threads in the waters of overflowed meadows, is remarkable for its production of true eggs and spermatozoids. As in the pond-scum, each thread of the body is an unbranched row of joints or cells all of which are shaped like long glass cylinders closed at each end. In some of these cells the living contents break up into a dozen or more spherical green eggs, which lie close against the wall of the mother-cell and, by ferments which they secrete, make little punctures. Other cells of the filament convert their contents into thousands of motile spermatozoids which dart about in the cell-cavity in a complicated dance which finally results in some of them perforating the wall, and through the apertures all escape into the water. After swimming about for a time many of them find their way through the pin-holes which the eggs had made in the walls of their mother-cells. They enter the egg-mother-cells and one of them buries itself in the substance of each egg. When the eggs in a tube have been thus fecundated each encloses itself in a spiny membrane, assumes an orange color, and after the wall of the mother cell has broken or dissolved each fused-body escapes into the water and divides internally into a little group of *spores*. The spores in turn escape and develop new filaments of the alga. This alga is called the sphere-alga on account of the tubes full of spherical eggs which characterize it.

Green felts. Among the other algae of this group should be mentioned the green-felts which form plush-like masses in springs and ditches. They are remarkable for the unjointed character of their filaments and their breeding habits remind one in some respects of the sphere-alga, for they form true eggs and spermatozoids.

Bass-weeds. Of all the algae of Minnesota, the largest and most conspicuous are the bass-weeds. These plants are familiar to fishermen because tufts of them are commonly entangled by trolling-hooks which have been dragging along the bottom outside the bulrushes. The bass-weeds have stems the thickness of a knitting needle, with distinct nodes and internodes. Upon the nodes whorls of branches are produced and upon the branches subsidiary leaflets. The whole plant, in the more common form, is encrusted with a limestone deposit, which gives it a brittle and stony feeling to the touch. Hence these plants are also called *stone-worts.* Many of them have the habit of forming diminutive bulbs which separate and serve to propagate the plant, and they also produce near the bases of their leaflets very definite oval, brown eggs, not much larger than a pin-point and inclosed in a little spirally twisted jacket of cells leaving an opening at the top through which the spermatozoids can enter. The spermatozoids are derived from curious little spherical organs of a reddish color, and each spermary, not larger than a small pin-head, forms as many as 30,000 actively moving spermatozoids, thousands of which are destined to be lost in the water, but enough are produced so that the eggs are reasonably certain of fecundation and may then, after a dormant period which extends over the winter months, develop into new bass-weed plants. During the cold weather the eggs and many of the propagative bulbils lie safely at the bottom of the lake too deep to be injured by the frosts.

Some varieties of bass-weeds, slenderer than the others, are not provided with the limestone sheath which characterizes the more common form, but may be recognized by their general similarity of structure. When taken out of the water they are limp, though not slimy like the pond-scums. Bass-weeds form an extremely abundant vegetation, generally distributing themselves in the deeper waters of a lake, outside the zone of pondweeds, or of bulrushes. Sometimes they are very common in shallow waters, and I have seen them in Glenwood lake, and in some of the northern lakes of Minnesota, growing vigorously in water only a few inches deep.

Chapter V.

Brown Algae and Red Algae.

Brown algae. Almost all of the true brown algae are marine and they are remarkable as comprising the longest plants in the world. It is a popular impression that the big-trees of California, the Eucalypti of Australia and the Rotang palms of Java and the Orient are the longest-stemmed plants in existence. This, however, is a mistake for some of the gigantic seaweeds of the Antartic ocean extend their stems for over a thousand feet, making them nearly three times as long as the trunk of the tallest big-tree in Calaveras county, California. Such huge brown algae are not unknown along the sea-coast of the United States, and the giant kelp of Puget sound sometimes reaches a length of more than three hundred feet. By means of its long cable-like axis, it attaches itself to the rocks and floats its immense leaves many fathoms out upon the surface of the sea. Other brown sea-weeds develop enormous strap-shaped leaves in tufts, attached by hold-fasts to the rocks. Some of them have their leaves perforated with numerous holes, an adaptation to prevent them from being torn by the waves. In the fresh waters of Minnesota no such forms as these are to be found and the most abundant ones are doubtfully to be classed as brown algae at all, but from their brownish or olive-green color they may here be considered as if certainly members of the group.

Diatoms. In the early spring, in rivers, one often finds olive-green membranous masses as large as one's closed fist floating idly at the water's edge. An examination of them would show that they consist of great numbers of microscopic boat-shaped bodies, with clear glassy walls and olive-green or brown contents. Such algae are known as diatoms. They sometimes occur in great fossil deposits, and in this condition are much prized for polishing powder. The walls of the diatom cells have the power of depositing in their interstices, silica, and it is this which gives the polishing quality to the fossil powder.

Some diatoms are provided with slender gelatinous stalks, by means of which they attach themselves to objects under the surface of the water, but many of them are free-swimming organisms. The exact mechanism by which they swim has long been a puzzle to students of the group, for they are not, like the swimming cells of the green-slime which grows on flower-pots, provided with conspicuous lashes by means of which they roll themselves through the water. Most of them seem to have, however, extremely small apertures in their walls through which the living substance probably protrudes itself and sets up an agitation in the water, so that the tiny boat moves mysteriously across the field of view of the microscope like some infinitesimal electric launch.

Red algae. This group like the brown algae is essentially marine and but few forms are found in the fresh waters of Minnesota. In rapidly flowing streams or under cataracts certain kinds display their red bodies, appearing as delicate plumes a few inches in length or as little pink or purple plates an eighth of an inch or less in diameter. Their structure is more complicated than that of any of the algae which have been considered. They are supplied with egg-cells from which long cylindrical protuberances are developed. The spermatozoids, unlike those of the sphere algae, have no swimming lashes and are, therefore, carried to the protuberances of the eggs by currents of water, or by the ministration of aquatic insects, recalling in this latter adaptation the extraordinary relation which exists between insects and flowers. When, however, a little spherical spermatozoid comes in contact with the slender cylinder developed on the egg-cell, it adheres and fuses and, as a result of its stimulation, from the egg are thrust out branches which finally develop spores, and thus the plant persists from one generation to another.

Some kinds of red algae are so faintly red that they would be mistaken for brown algae, if color alone determined the classification. Such are certain rather stiff, wire-like plants, sparingly branched and preferring for the most part the same rapid foaming water which the easily recognizable varieties select as an habitation. Yet on account of their various structural peculiarities botanists assign them to the group of red algae.

General remarks about algae. The account that has been given is very elementary and the reader must remember that it covers perhaps as many as a thousand varieties, most of which, are species of bright-green algae and diatoms. None of the fresh-water algae has any great economic importance. Some sea-weeds are employed in the manufacture of iodine, others, especially the kelps, as fertilizing material for farms near the sea-shore. The "Irish moss," as it is called, is a red alga and is used for food; when cooked it is a kind of blanc-mange. In China several other kinds of sea-weed are regarded as edible. The Indian fishermen in Alaska use the stem of the giant kelp as siphons and for fishing lines. In Minnesota the algae are sometimes rather noxious than useful. Blue-green algae in decaying masses are known to give to the water a characteristic pig-pen odor which is very offensive. It is at times a difficult problem to prevent them from vitiating aqueducts and reservoirs, and cattle are reported to have been poisoned by drinking water which contained their rotting remains. It is, therefore, not the water which contains the bright grass-green pond-scums that is so objectionable, though on account of the slimy character of these plants they are more repugnant to most people than the verdigris-colored water-flower. Cattle should not be allowed to drink from pools in which the algal vegetation is of a blue-green shade, but no injury is likely to result if the scums are bright-green.

In past time it should be remembered that certain lime-secreting-algae and silica-secreting algae have no doubt done their part in creating the building-stones of the state. Even the quartzites and the granites may be the modified sinter deposits from some hot-water algal vegetation of former ages. In the sea, to-day, countless millions of algae are busy building coral-reefs similar to those produced by the coral polyp, while nearer home, in Lake Michigan, limestone pebbles have been found to be produced by the concretionary growth of lime-secreting algae. I have not yet found any of these algal pebbles in the lakes of Minnesota, but it is probable that they occur. If any one should chance to find calcareous pebbles the size of an egg, which upon being broken have a moist bluish-green interior or are hollow, he will doubtless have discovered a growth of rock-forming algae.

Algae the oldest kinds of plants. The great group of algae is of peculiar interest to students of nature because it includes the oldest types of plants living upon the earth. There is reason to suppose that life originated in the sea, and that all the terrestrial forms are descendants of those which in distant epochs learned to leave the ocean and establish themselves upon the land. One reason for supposing this is that in distant periods of the earth's history there was very little land in existence, and almost the whole surface of the globe was covered by the waters of the ocean. No doubt, at first, before the ocean had cooled, when the world was still young, warm-water algae, among which the rock builders are so prominent, came into being and began their work perhaps among the very first living creatures of all the hosts that now exist. Some varieties of land-plants at present, as for example the mosses and liverworts, show clearly in their structure their relationship to the algae, and serve as connecting links between the great primal flora of the ocean and the modern flora of the land. The algae, then, are the forms from which all other plants are supposed to have originated. The history of life upon the earth is one of constant improvement, and as land appeared improved forms of algae tenanted it, and may have given rise to all the myriad higher species of forest and prairie as they are now exhibited over the continents of the world. And finally there are very many excellent reasons for regarding the continents themselves to have arisen largely through the activities of living organisms—a process that may be observed continuing even in these days if one should visit the coral-islands of the south seas, those enchanted atolls of the Pacific.

Chapter VI.

The Lower Sorts of Fungi.

Number of fungi in Minnesota. While there are nearly 200,000 known species of flowering plants in existence, there have been described only about 50,000 species of fungi. Yet in Minnesota, while there are but 2,500 or 2,600 flowering-plants growing without cultivation there are probably not less than 3,000 fungi, so that the state furnishes a field for the development of a greater comparative proportion of fungi than of flowering plants. Like the mosses and liverworts, the fungi are believed to have arisen from primitive algal types and students recognize two principal series. The lower series known as the *algal fungi*, the structure of which is more directly suggestive of algae, is much poorer in forms than the higher series of *true fungi* in which all the peculiar fungal structures and characters have had an opportunity to be unfolded.

Black moulds. Of the algal fungi a very widely distributed group is that of the moulds. Among these the black mould is omnipresent, and easily cultivated. If a slice of bread be dipped in water, placed in a saucer, a tumbler inverted over it and then set in a warm place, perhaps behind the kitchen stove, in a few days the tumbler will be filled with a white cloud of fungus threads and presently little black, spherical spore-cases will arise at various points on the fungus network. The white threads are the vegetative plant-body of the mould; the black knobs (white when young), smaller than a pin-head, are the fruit-bodies. The black color of each fruit-body is occasioned by the presence, in a swollen cell, of some hundreds of little black spores, which have developed by the division of the living contents of their mother-cell or spore-case. When the spore-cases are broken and the living powder is disseminated, it is caught in air currents and is held suspended in the atmosphere to such an extent that in the dust of the air in every living room in Minnesota, hundreds of such spores are already floating. It is necessary, therefore, only to dip the slice of bread in water and set it aside, for the spores which have fallen upon it in the process to begin their development. It would be a mistake to suppose that moulds originate spontaneously. A mould plant can no more come into existence without the coöperation of some mould-spore than could an oak-tree without the assistance of an acorn. It is because of the presence almost everywhere of incalculable numbers of mould spores floating invisibly in the atmosphere that this seeming spontaneity of development impresses one. There are, however, many places where bread will not quickly mould if set out in a saucer, for example, if carried to some high mountain top where the air is pure and free from spores, or if exposed in a chamber which has been purified and sterilized by a spray of carbolic acid.

The black moulds have a breeding habit reminding one of the pond-scums. Two of the white threads close together or touching each other, may develop little side branches the ends of which blend and gradually convert themselves into a black fused-body with very much the character of a fecundated egg and capable of growing into a new mould thread.

Other kinds of moulds. There are several other varieties of moulds belonging to this group of algal-fungi, but the well-known blue-moulds, or green-moulds, with their verdigris colored fruit-bodies are classified in a higher group. Some of the moulds have curious habits. One, called the pill-throwing mould, produces a mass of spores upon the end of a filament, then underneath this mass there develops a swollen cell in which pressure is exerted, so that after a time the mass of spores is shot off into the air by the explosive mechanism of the stalk-cell.

Moulds on moulds. Still another mould has the peculiarity of attaching itself to the vegetative body of the black mould. It lives as a kind of mould-louse, extracting its nutriment from the body of the larger and more vigorous black mould. A plant which thus fastens itself upon another living creature and absorbs nutriment from it to the injury of the host is called a parasite.

Fly-cholera fungi. Related to the moulds are the singular fly-cholera fungi. Many persons will have noticed sticking to the window-panes in autumn the dead bodies of flies surrounded for some distance by a faint yellowish film upon the glass. This film consists of spores of the fly-cholera fungus which have been shot into the air by a mechanism similar to that described for the pill-throwing mould. The vegetative body of the fly-fungus lives within the body of the fly where, growing luxuriantly, it interferes with the life-processes of the insect, kills it, and converts a large portion of its body into food for its own use. Other flies approaching the infected individual are peppered with the tiny spores of the fungus, or they receive the contagion while walking upon an infected window pane or in a spore-strewn corner. In this way every autumn unnumbered millions of flies are killed. A closely related cholera-fungus attacks the Rocky mountain locust and is of great economic importance because it keeps this dangerous insect in check. Still other varieties attack other insects, but these two will serve as examples.

Cell-parasites. There are a large number of microscopic algal-fungi of very curious behavior. Some of them find their way into the skin-cells of flowering plants and there live as parasites, while others insinuate themselves into the eggs of algae and devour them. Some of them are found in the soft substance of swamp plants; some may be discovered in pond-scum filaments where they consume the cell-contents; some find their way into desmid cells and destroy them; some enter the pollen-grains of flowering-plants, notably of the pines, and feed upon the living contents. They invade the diatoms and various algae; they infect the spongy tissues of the peat-mosses; they penetrate the wall of fish-mould eggs and by their omnivorous habits impress it upon us that no organism is too small or inconspicuous to escape its enemies.

Fish-moulds. Related to the fungi which sometimes injure their eggs are those surprising organisms, the fish-moulds, that are often found forming gray fur coats on the bodies of dead minnows or dead frogs. They are especially unwelcome in fish hatcheries where they attack the eggs of the fish and destroy them. Some varieties are found upon the dead bodies of aquatic insects and others grow upon decaying substances when submerged in the water, although the majority are parasitic upon living plants or animals, or make the dead bodies of these their habitat. The life of a fish-mould differs from that of the black mould in some important particulars from its being an aquatic organism. Its spores are not mere passive spheres of microscopic size like those of the black mould, but are provided with swimming lashes, so that they may propel themselves through the water in search of other fish or insects upon the bodies of which they may be fortunate enough to obtain a lodgment. One fungus related to the fish-moulds, not yet discovered in Minnesota, but possibly occurring somewhere within the state, is noteworthy in botanical annals as being the only fungus known to produce motile spermatozoids like those of the algae and, as will be seen later, of the ferns and mosses.

Mildews. Closely related to the fish-moulds are the mildews. These are fungi which live as parasites upon land plants. A striking example of the group is the mildew of mustards, which occasions a rotting of the stems and leaves in the shepherd's-purse. Another causes a rotting of potato tops and is one of the most serious diseases of the potato with which cultivators have to contend. Still another which occurs in Minnesota is the mildew of the grape-vines, inducing the leaves to wither and decay. The lives of mildews are in many respects similar to those of the fish-moulds, but with certain differences owing to their non-aquatic habits. For example, the mildew of the vine when it attacks the leaves goes about the task somewhat in this fashion. From the air, into which from other mildewed leaves the spores have been projected, certain spores come to fall upon the surface of a healthy leaf. They lie upon the skin of the leaf and extend little infecting tubes which crawl around upon the surface of the leaf until they find one of the air-pores with which the leaf is provided for respiratory and vapor-excretory purposes of its own. Into such apertures the fungus insinuates itself, and as its infection-tube crawls beneath the skin of the leaf among the soft cells filled with leaf-green and starch, it finds there plenty of food material. Into each cell it drives a little sucking organ and extracts the nutritive substances and converts them into its own body. Going thus from cell to cell it finally saps the life of so many of them that the usefulness of the leaf is destroyed, and thus the vigor of the whole vine is definitely impaired. When the mildew has accumulated in this manner sufficient nutriment for its needs it puts forth a branch which grows out through one of the air-pores of the leaf and here, in the open air, spore cells are formed. These are separated from the branch which produced them and are carried away by wind-currents to other vine leaves. Moreover the mildew within the tissues of the leaf breeds after its fashion, forming little spherical eggs which after they have been fecundated divide up internally into a considerable number of tiny motile bodies, provided with lashes, so that, when the rotting mass of the leaf has broken down after some rain, these motile cells can be washed out and swim to fresh parts of the leaf or fall with the rain drops to other leaves upon the same plant. Such egg-cells of the mildew serve to bridge over the winter season, and it is, therefore, important, if potatoes, vines, or lettuce should be in the habit of mildewing, that all dead leaves in the autumn should be burned. This diminishes for the following season the danger from fresh infection.

Chapter VII.

Smuts and Rusts.

Higher fungi. The plants already described may suffice as examples of the algal fungi. The higher or "true" fungi constitute a very large group of various forms, some of which are parasitic, attaching themselves to the bodies of plants or of animals, while others live upon decaying organic matter. No fungus has leaf-green and consequently no fungus can manufacture starch out of carbonic-acid-gas and water, but its nutrition is rather animal-like, in that there must be provided more complex food-substances. A fungus cannot live on a diet principally of air, salts and water as do the algæ, mosses, ferns and most flowering plants.

Smuts. Among the higher fungi the smuts are a well-known group. Every one is familiar with the smut of Indian corn which occasions the appearance of great distorted kernels, many times as large as the ordinary ones, composed almost entirely of smut threads and a very copious black mass of smut spores. Other kinds of smut are found upon oats, upon wheat, upon millet-grass, upon sedges, and upon sand-burrs. Generally the smut spore-masses develop themselves in the seed-areas of plants, and substitute for the seed their own fruit-bodies. Hence the smut fruit-body in the Indian corn takes the form of a greatly enlarged corn kernel and the stinking smut of wheat fills the wheat grain with a mass of spores, allowing the wheat to produce only the shell of the fruit while the interior is a solid mass of smut. Sometimes a whole flower-cluster is infected as in the sand-burr smut. In a few plants the stamens are attacked by smut fungi and an example is furnished by the corn-cockle, a weed belonging to the pink family and to be met with in cultivated fields. Here the stamens, when mature, open in the ordinary way to cast out their pollen, but if the smut that sometimes affects them has gained a foothold, they might as well save themselves the trouble, for all the pollen grains will have been destroyed and in their place will be the spores of the smut.

Peat-moss smut. Still another kind of smut develops its spores in the capsules of the peat-moss, and under such conditions when the capsule opens to eject its spores there are no moss-spores present, but only the smaller black reproductive cells of the smut. Until recently this condition of things caused botanists to labor under a misapprehension concerning the life-history of the peat-moss and in most of the books peat-mosses are described as producing two kinds of spores, some large and others small. The supposed small spores of the peat-moss are, however, not peat-moss spores at all, but are developed on a parasitic plant which has the interesting habit of forming them in exactly the same little round capsule which the peat-moss had been to the pains of developing for its own spores.

The life of a smut. A large number of plants in Minnesota are affected by smuts and sometimes two or more varieties will be attacked by the same kind. More often, however, the smuts which are found on different kinds of higher plants are themselves specifically distinct. The life of a smut is interesting because it is typical of the manner in which many parasitic fungi develop. There may be selected for description the stinking smut of wheat. Inside the affected kernels clusters of spores are formed which upon the breaking of the kernels, during the threshing of the wheat or while it is being shovelled about in bins or while it is standing in its head, are liberated and fall upon the ends of other uninfected kernels. There they are caught in the little hairs which are present at the germinal end, and when the wheat kernel is sown and germinated the smut spores germinate also and their delicate threads grow in the tissues of the wheat plant keeping pace with the host as it extends higher and higher into the air. When the wheat flowers are formed and the rudiments of the fruits begin to appear some of the smut filaments grow into the young kernels and, as these develop, the smut filaments begin dividing themselves into spore-cells, exerting a disintegrating effect upon the interior of the kernel, so that finally one thus infected becomes filled with thousands of spores of the smut. The process may then be repeated and thus smut is perpetuated from year to year. On account of the habits of the smut it is a disease of grain which can be eradicated by the intelligent farmer, if he will take the trouble to kill all the smut-spores which are clinging to the hairy ends of his seed-wheat kernels. This can be done by "bluestoning," or by immersing the seed-wheat for five minutes in water of 132 degrees Fahrenheit. By such means the vitality of the smut spores is destroyed, for they are exposed at the end of the grain while the wheat plantlet itself inside the kernel is protected by the firm fruit-wall and is not injured by the poison or by the heat. By such methods if generally and continuously employed, it would be possible to terminate the enormous financial losses which farmers in Minnesota and the Northwest sustain from the various cereal smuts.

Rusts. Related to the smuts are a variety of plants which may for convenience be grouped under the general name of rusts. Of these a great many different kinds exist in Minnesota. They infest the leaves of numerous species of plants, the Labrador tea, the pines, spruces, and tamaracks, the goldenrods, asters, thistles, bellworts and poplars, the flax, willows, horsemints and sunflowers, the junipers, pears, apples, beans, violets and a great number of others.

Wheat-rusts. The forms of greatest economic interest are the three sorts of rusts which attack wheat. There are over 700 different kinds of rusts belonging to the wheat-rust type, many of which occur on grasses, but the majority on numerous other varieties of plants. The wheat-rusts are among the most remarkable of fungi from the singular custom which they have of changing periodically their habitation from wheat to other plants. Not only do they change their place of abode, but they change their form and structure as well, so that it would be impossible, unless one knew, to recognize the wheat-rust after it had migrated to one of the other plants upon which it has acquired the habit of developing. The three sorts of wheat-rust which occur in Minnesota alternate on different plants, one developing on barberry leaves and probably also on the leaves of some other species which has not been identified, another reappearing on buckthorn leaves, and a third on borage leaves. It must be remembered that these are three different varieties of wheat-rust. They cannot convert themselves into each other but are independent plants as distinctly as are oats and rye. It is well-known that there are two stages of wheat-rust, one of which develops in the early summer and autumn and is known as the red rust, the other developing in late summer and autumn and known as the black rust. The characteristic colors of the two stages are given by masses of spores growing in layers upon the plant-body of the rust which in turn consists of a network of parasitic threads living in the tissues of the wheat plant, the skin of which is burst by the fungus. It is the same plant body which produces the red spores forming red streaks on the wheat leaf that afterwards produces black spores in equally enormous numbers occasioning the black rust stage. The red or "summer" spores are ovoid, spiny bodies, properly described as single cells. Their walls are thinner than those of the black rust. The black, or "autumn" spores have smooth walls and are divided into two cells by a cross partition situated near the centre of the somewhat elongated and pointed or rounded body. Red-rust spores, when separated from their stalks by the wind, may be carried throughout the summer to other wheat plants, and thus the infection spreads possibly over a whole field. The black-rust spores remain dormant during the winter upon the stubble and debris of the field. In the spring each of the two cells of the black-rust spore develops a tiny jointed body upon which four very small thin-walled, colorless spore-cells are produced. Now is the time selected by the wheat-rust for the periodic change of habitation. It is known that the small spores thus produced do not so readily germinate if blown upon wheat plants, but

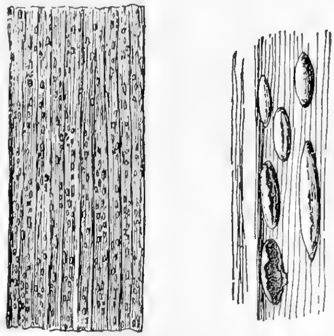


FIG. 11.—Patches of wheat-rust, natural size and enlarged. The red rust stage. After Atkinson.

FIG. 12.—Patches of wheat-rust, natural size and enlarged. The black rust stage. After Atkinson.

may find their way to the leaves of the barberry. When they fall upon the epidermis of such leaves they develop infection tubes, penetrate the skin and form a filamentous plant body within the soft inner tissues. At their time of fruiting they form two sorts of fruits, one upon the under side of the barberry leaves, known as *cluster cups*, the other, peculiar bottle-shaped fruits, upon the upper side. In the cup-shaped fruits large numbers of spherical orange-colored spores are produced which if blown away to a wheat field will infect the wheat. In the bottle-shaped fruits smaller elongated spores are formed, but it is not known how these germinate nor what becomes of them in the natural order of events. Barberries are by no means abundant in Minnesota, only a few of them existing in hedge rows, and while it is by no means inconceivable or absurd, on account of the winds which blow over the wheatfields of the Northwest, to suppose that barberries in the east might infect the wheat in Minnesota or the Dakotas, yet it is more probable, I think, that the wheat-rust passes its cluster-cup stage on some common Minnesota plant which has not yet been identified as maintaining this particular kind of rust, or that it omits altogether its customary migrations to other plants.

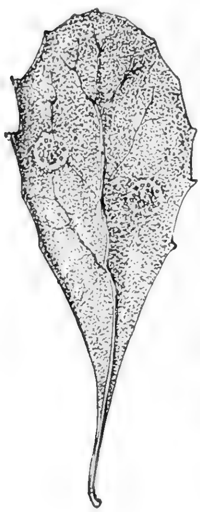
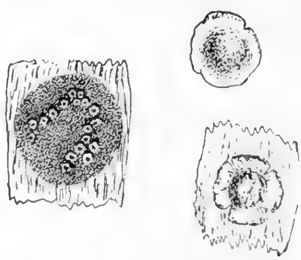



FIG. 13.—Wheat-rust in its barberry-leaf stage; to the left a barberry leaf with diseased spots; in the middle, a single spot with cups; to the right, two of the cups, in top view slightly magnified. After Atkinson.

It is apparent that such a disease as the rust offers difficulties to the economic farmer desirous of protecting his crop, far in excess of those presented by the smut, for while smut spores caught in the ends of the wheat kernels can be killed there by hot water, no practicable method exists of policing the atmosphere and preventing rust spores from finding their way to the young wheat. Therefore, the most feasible plan for combatting wheat rust is by the development of so-called "rust proof" varieties. While smut is, upon the whole, the easiest of the wheat-diseases to control, rust is the most difficult.

The remarkable migratory habit of the wheat-rust and its allies coupled with the extraordinary change in form which the fungus assumes upon the different habitats gives rise to some very surprising conditions in rust life-histories. For after the migratory habit had been formed it would appear that sometimes one or the other of the phases became extinct, so there are varieties of rusts which exist only in the cluster-cup phase,

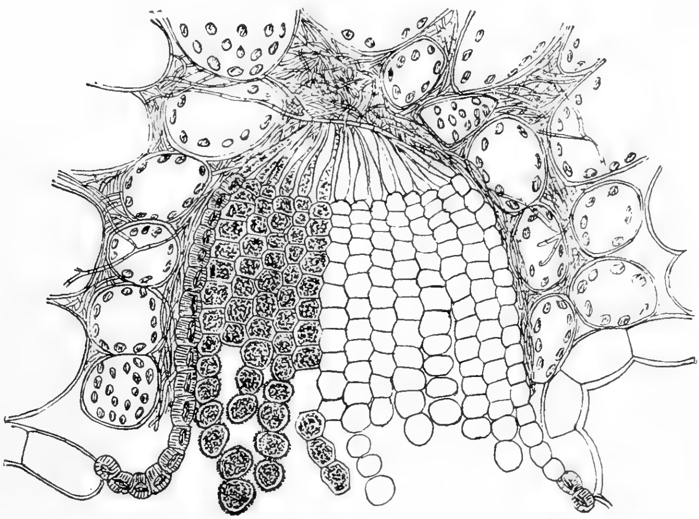


Fig. 14.—Magnified section through a cluster-cup of the wheat-rust in its barberry-leaf stage. Shows chains of spore-cells. The large cells at the sides are those of the barberry leaf much magnified. After Atkinson.

and others only in the red and black-rust phases. For a long time students of the fungi thought that the cluster-cups were entirely different from the rust, and it was only because people noticed more than a century ago that "barberry bushes," as the saying was, "blasted the wheat," that a hint was given to modern research, in consequence of which the astonishing behavior of the rust fungi is now more thoroughly understood.

Relatives of the wheat-rust. Among the relatives of the wheat-rust there are some forms in Minnesota characterized by little peculiarities which enable botanists to classify them in different genera. For example, the black-rust spores formed on some blackberries are three-celled instead of two-celled, and the cluster-cup masses on some gooseberries are developed upon protuberant filament-aggregates. Perhaps the three most remarkable forms are the pine-knot fungi which form knots sometimes as large as bushel baskets upon the branches of pine trees, the so-called "cedar-apples," which occur as curious bunches, the size of one's thumb and armed with orange horns, on the junipers, and the witch's brooms on balsam trees. These latter are immense, disordered tangles of branchlets forming masses sometimes several feet in diameter. The disordered branching is caused by the growth of a rust-fungus of the cluster-cup sort in the substance of the twigs. When this fungus fruits it produces its reproductive structures upon the leaves of the balsams, where they recall strikingly the rust produced on barberry leaves. The witch's broom is a notable object in the swamps of Minnesota. When large ones are developed on the balsam trees they look like great crows' nests up in the branches and very often birds and animals use the thick tangle of twigs to conceal their own dwelling places. On the spruce trees there is a similar tangle of branches produced by the agency of insects, but there is of course no development of the characteristic cluster-cup fruit-bodies upon the leaves. The related pine-knot fungus does not commonly fruit every year, but sometimes the whole surface of the knot will be found covered with the little orange pustules of the rust.

Chapter VIII.

Trembling Fungi, Club-fungi, Shelf-fungi and Mushrooms.

Trembling fungi. Somewhat related to the rusts, although one would hardly suppose it from their appearance, are the singular gelatinous yellow or pink wrinkled masses which are often found upon decaying logs in shady places. These cannot be mistaken for the plant-bodies of slime-moulds, because they are of a firmer cartilaginous texture. They are capable of producing over their surface a layer of spores which when separated by the wind or rains may propagate them upon other suitable substrata. From their tremulous character these plants are sometimes called "trembling fungi." Rather more highly organized but in the same general order of development are the leather-like gray skins which are often found upon the under sides of decaying twigs. Related forms are sometimes provided with little stalks and grow up cornucopia-like from the bark.

Club fungi. Another family of fungi which includes forms not so very different from these skin-fungi, comprises also those which stand up on the forest-mould like little yellow Indian-clubs, an inch or two in height. The upper end of such club-fungi is swollen, and it is there that the spore-bodies are particularly developed. Not all of the club-fungi are unbranched; but some of them are divided like the antlers of a deer, and yet others in which the branching is more copious grow in pearl-gray, yellow, white or pinkish tufts, several inches high, and covering spaces as large as a dinner plate. They may be recognized by the generally erect habit of all the branches, so that their forms remind one of the branching of certain night-blooming cereuses of the New Mexican desert. Commonly the branches are more or less cylindrical and blunt, but one form, which is not uncommon in hard-wood forests along river bottoms in the southern part of the state, has all its branches shaped somewhat like clam shells, so that the whole plant-body, often several inches in diameter, seems to be composed of numerous white shells overlapping each other and all attached to a common base.

Prickle-fungi. The prickle-fungi—at least some of them—might be mistaken for much branched forms of club-fungi; but they can be distinguished by the general downward tendency of the branches, so that in a well-known species not uncommon in the valley of the St. Croix where it grows upon decaying tree-trunks, there is a coral-like aspect to the whole plant-body. This variety is generally white, or slightly yellowish, or yellowish-brown in color, often as large as a man's head, and made up of a group of thick, irregular branches upon the under sides of which great numbers of prickles half on inch or more in length grow downward. Not all of the prickle fungi have exactly this kind of a plant-body. Some of them outwardly resemble toadstools, and might be mistaken for them if one did not look upon the under side where he would discover instead of the radiating gills of the toadstool the whole under surface of the cap covered with a growth of prickles. Upon the surface of these prickles the spores of the plant are developed, and by their cooperation the fungus is able to maintain itself from year to year.

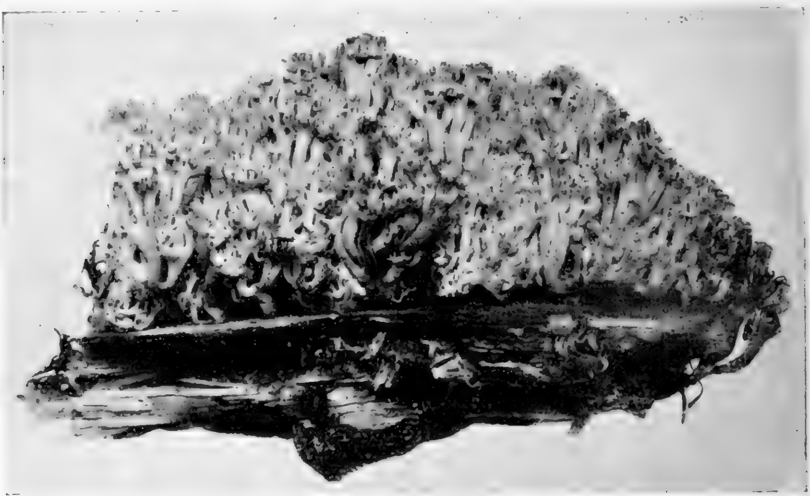


FIG. 15.—Growth of club-fungi on decaying wood. After Lloyd.

In these forms, however, and in many of those to follow, the conspicuous part of the plant is really nothing more than its highly developed fruit-body, while the vegetative portion consisting of a spongy or cottony substance lies imbedded in the decaying timber.

Shelf-fungi. Related to the prickle-fungi are the well-known pore-fungi, or shelf-fungi, which are such familiar objects in the woods of Minnesota. Often they seem to be growing upon living trees, but it will be found upon examination that they have

FIG. 16.—Shelf-fungus growing on dead stump of oak tree. After photograph by Hibbard.

attacked some wounded or dead portion of the trunk, for these fungi are none of them truly parasitic. They are more common, indeed, upon dead timber, either prostrate or standing. Very pretty examples of shelf-fungi are abundant upon the birch-trees of Minnesota, and this particular species is known as the birch-tree pore-fungus. The fruit-bodies hang down somewhat like bells, are of a white color, not woody but with much the consistency of punk or cork. They grow larger from year to year, the new growth covering that of former summers, and every season a new layer of pores is produced upon the under side. In the Minnesota woods there are a great number of different kinds of pore-fungi which show characteristic differences of shape, size, thickness, color, texture, and endurance. One of them, called the sulphur-colored pore-fungus, which grows in very large masses is edible when young, but the great majority of them while not poisonous, are too tough, leathery and woody to be very appetizing. Some of them, indeed, notably the great shelves a foot or more across which occur upon oak trees, are almost as solid as the wood of the tree itself.

Upon one occasion I noticed that in the pores of the under side of one of these fungi, a large number of mosquitoes had been caught by their legs and had afterwards been covered by a growth of cottony filaments of the fungus, and I wondered whether the plant might not derive some benefit from its apparent capture of insects and digestion of their bodies. It is not at all clear, however, that such a fungus should be included in the great category of flesh-eating plants, because it is a common habit of the fruit-body to inclose small objects which chance to be in its way. Sometimes when these shelf-fungi grow near the ground they will be found with grass leaves penetrating them and in such cases it is not to be supposed that the grass leaf has grown through the fungus, but rather that the fungus has grown around and has enclosed the leaf.

The pores of these interesting fungi are of different sizes and shapes. In some varieties they are almost invisible, they are so small. Other sorts have the pores much larger. In some the pores are circular, in others they are hexagonal or irregular in shape. In one kind which is common upon willows, forming fruit-bodies not more than two or three inches across, the pores are labyrinthine in shape, like the passages in the puzzle-gardens which are sometimes laid out in parks. There is considerable difference too in the upper surface of pore-fungi. Some of them are white and smooth as in the birch-tree form, while others are fuzzy. Some are hard and marked by annual rings showing where the growth of each year has jutted out beyond the growth of the previous year. Some are sticky, but rarely slimy in texture; some are cartilaginous or horny to the touch, and many are spongy and soft.

Different genera of shelf-fungi are established by botanists, principally upon the character of the pores. A genus which contains numerous highly poisonous species, is recognized by the readiness with which the pore-layer can be separated from the under side of the sterile portion of the fruit-body. One variety of these poisonous fungi is abundant in tamarack swamps throughout the state. The general shape of the plant is quite exactly like that of a toad-stool, a short thick stem rises from the ground, and on top of this a red cap is borne, from two to

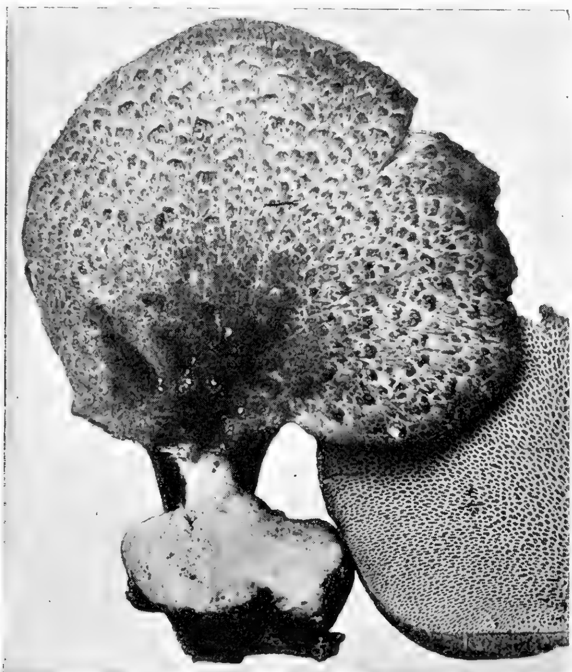
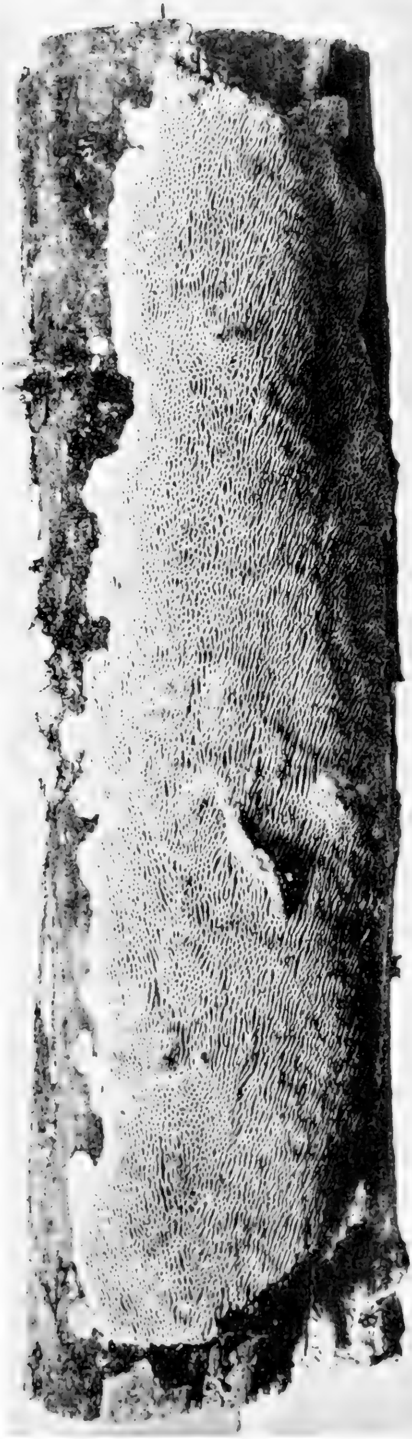


FIG. 17.—Upper and under sides of mushroom-like pore-fungus. After Lloyd.

five or even more inches in diameter. The top is of a dull crimson or maroon-red tint, with scale-like markings resembling a serpent's skin. Upon the under side will be seen a layer of large yellowish pores, separated from each other by thin partition walls in which the coloring substance is developed. If one pulls off the cap of this fungus and breaks it in two he will find that the whole layer of pores is very easily peeled away from the rest of the cap. Suppose now that one of these pores was magnified until it was as large as an ordinary



well. Then if one could enter it he would see the whole wall covered with ovoid spores, now apparently as large as apples. Since the pores all open downwards it is easy to see that if the spores fall from their supports they will gradually if not immediately tumble out through the opening and may then be distributed by wind or water. It is altogether best never to eat any kind of a pore-fungus in which the pore-layer is readily separable from the rest of the fruit-body, although there are a few harmless varieties even in this generally dangerous group.

Some shelf-fungi are not truly pore-fungi, but the under side is perfectly smooth or marked at best with low, longitudinal wrinkles. These may, perhaps, be considered as forms in which the pores have either not yet come to develop, or as varieties in which for some reason the pores have become shallower until finally they have been completely lost.

FIG. 18.—A pore-fungus lying flat upon a decaying branch. After Lloyd.

Mushrooms and toadstools. Related to the pore-fungi, and especially to those in which the pores are elongated or labyrinthine, are the well-known mushrooms and toadstools. There is little systematic difference between mushrooms and toadstools. People are in the habit of calling an edible toadstool a mushroom, and a poisonous mushroom a toadstool. The fact is that some of the species of the great mushroom genus are edible while others are not, and it is often extremely difficult even for an expert to distinguish between edible and poisonous varieties. The following are very good rules to follow if one feels an uncontrollable inclination to experiment with mushrooms as an article of diet:

FIG. 19.—Deadly variety of mushroom. After Atkinson. Bulletin 138, Cornell Ag. Exp. Station. This is sometimes known as the "poison cup."

Never eat a mushroom that is highly colored.

Never eat a mushroom that has pink gills.

Never eat a mushroom that seems to grow out of a little cup at the base.

Never eat a mushroom that has a milky juice.

Never eat a mushroom that changes color shortly after its substance is broken.

Never eat a mushroom with a pungent odor.

Never eat a mushroom with a sticky or slimy cap.

Never eat an immature mushroom unless absolutely certain what sort of a form it will be when mature.

None of these rules is absolute. There are exceptions to all of them, to some more than to others, but, together, they constitute a safe code and one cannot go far wrong in observing it.

Yet a single rule, which I believe to be the best, is to eat no mushrooms of any sort unless quite sure that they are edible, for some of the deadliest poisons known to students of plant chemistry are contained in the plants of this genus. One in particular, which grows from a little cup at the base and spreads out a rather thin cap is so fatal that a small portion of it is sufficient to cause death. Still on the other hand, it is true that a great many edible species are to be obtained in the woods and fields of Minnesota, and it seems a pity that such excellent food should go to waste when there are many people who would be glad to avail themselves of this form of nature's bounty.

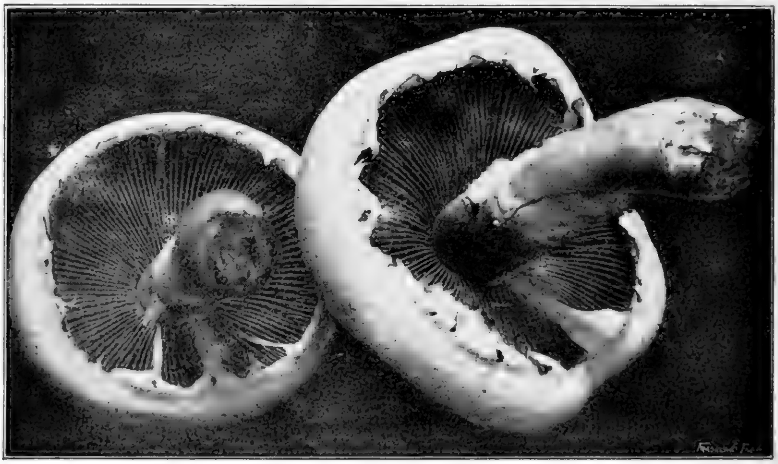


Fig. 20.—Under side of two mushroom-fruits. After Atkinson. Bull. 138, Cornell Ag. Exp. Station.

All true mushrooms are characterized by the presence on the under side of the cap, of radiating gills or plates, hanging down like the ornamental tissue-paper decorations which are fancied by proprietors of butchers' shops. Except for this general character their forms are various and some of them with long slender stalks and thin conical or expanded caps present a very different appearance from those with short, massive stalks and broad hemispherical caps. A few are devoid of definite stalks and protrude sideways from dead logs recalling quite exactly the shelf-fungi in their general habit of growth. The largest mushrooms are found in pastures and along roadsides, lifting themselves sometimes nearly a foot into the air, and provided with basin-shaped caps, six inches or more in diameter. Another overgrown form is common on decaying timber and has no central stalk but stands out somewhat like a bracket-shelf.

Deliquescent mushrooms. Not all of the fungi with radiating gills on the under side are classed by botanists as true mushrooms. One sort, which comes up in the autumn, late in September or in October, oozes into a black and filthy slime as it matures. When young the fruit-body is elongated, an inch or so in diameter, sometimes four inches in length, white in color, with blackish scale markings. In its early stages when properly

FIG. 21.—Common edible mushroom. After Atkinson. Bull. 138, Cornell Ag. Exp. Station.

cooked this is one of the most delicious of edible fungi; but after it has begun to decay it is neither appetizing nor healthful. The habit that these mushroom-like fungi have of decaying is a device for scattering their spores. They are visited by insects and the spores are picked up in the general slime to which their presence gives the black color, and are then carried away to be deposited elsewhere.

Miniature mushrooms. Another relative of the true mushroom is a very delicate little plant an inch or less in height growing upon decaying leaves in the forest or in wooded ravines. It has a shiny black cartilaginous stem like that of the maiden-hair fern and upon the top of this a white cap displays a small number of loosely arranged gills on the under side. The diameter of the cap is often no more than one-eighth of an inch.

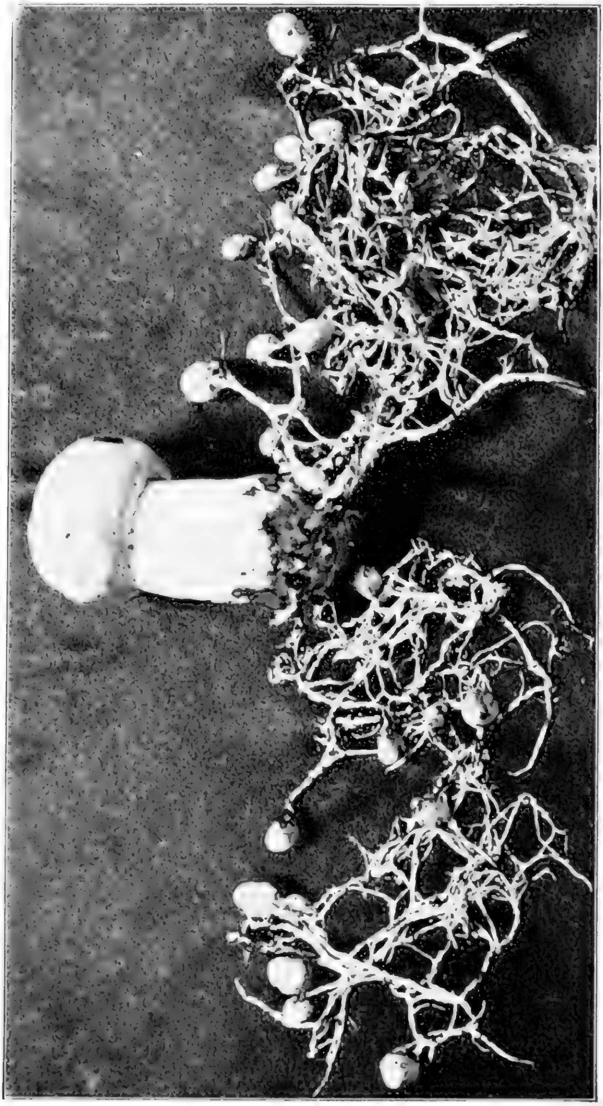


FIG. 22.—Development of mushroom-fruits on their underground vegetative tract. After Atkinson. Bull. 138, Cornell Ag. Exp. Station.

Milk mushrooms. Still another close relative of the mushroom is the milk-mushroom. The various species of this genus are supplied with a milky juice, white or variously colored, which oozes out if the flesh is broken. One kind with bluish gills and juice, gives off, when broken, a distinctive odor something like that of prussic acid and is very deadly. It is not uncommon under white pine trees in the northern part of the state.

A considerable difference in durability exists among the mushrooms and their near relatives. Some of them are delicate and watery in texture, lasting but a few hours after they are mature. Others are spongy, or of a texture like punk, while those found for example on railway ties become hard and woody even before they are altogether mature.

The true mushrooms are classified into five principal groups, depending upon the color of the spores. 1. Forms with black spores. 2. Forms with dark-brown spores. 3. Forms with brown spores. 4. Forms with red or reddish-yellow spores. 5. Forms with white spores. Among the dark-brown spored forms are a number of edible species. Here is included the ordinary edible mushroom which is cultivated for the market.

It is an easy matter to determine the exact color of mushroom spores by cutting off the cap close to the stem and laying it down on a piece of paper with the gills towards the paper. Within a few hours hundreds of thousands of spores will fall to the paper, tracing there the gill-arrangement and demonstrating the precise color of the spores. If with the point of a pen-knife a few thousands of these spores be lifted and placed under a microscope, they will be found to be somewhat egg-shaped or spherical cells usually with smooth walls and provided each with a bit of living substance in the interior. They are produced in clusters of four all over the surface of the gills. The gills themselves are made up of interlaced threads, which, when they come to the surface turn and grow perpendicular to it. Some of the threads expand their ends, upon which four little ears are produced. The tip of each of these bulges out into a tiny egg-shaped spore. A very narrow neck connects each spore with its stalk and when ripe the spore drops off of itself.

Chapter IX.

Carrion-fungi and Puff-balls.

Carrion-fungi. Another group of fungi not very closely related to the mushrooms but properly to be considered at this point includes the stinkhorns or carrion-fungi. These are among the most remarkable of all plants. During summer and autumn they spring up in door yards from a subterranean vegetative body which resembles a tangled mass of white rootlets. Upon some of these rootlets little knobs the size of a pin head will be found to arise just as in mushrooms. These grow rapidly until they become almost as large as hens' eggs, when suddenly the top of an egg is burst by the pressure of the growing parts within and in a surprisingly short time there is pushed out a cylindrical stalk—appearing very much as if it had been cut out of a loaf of bread, for it has the peculiar spongy texture of the well-raised loaf. This stalk is hollow and upon its top is borne a wrinkled cap perforated in the middle by an aperture. The surface of the wrinkled cap is covered with a slimy greenish-black mass of spores and mucilage. Once seen this plant will never be forgotten. It may perhaps be described pictorially as a vegetable confidence-game, for if there were any immoral plants certainly this would be one. It has almost precisely the odor of carrion and upon such an imitation of decaying flesh it bases its extraordinary method of distributing its spores. Attracted and deceived by the stench, various flies and burying beetles visit it and walk upon it apparently believing it to be what its odor indicates. They are even said to lay eggs upon it and to withdraw feeling no doubt that they have made that due provision for their young which their parental instincts suggest. During their investigations, however, they have inadvertently covered themselves with the sticky slime of the cap in which the spores of the plant are embedded and these they carry away and distribute, thus performing a work for the plant. But in a few hours the whole fruit-body decays and the eggs, if any had been entrusted to it under the apparently mistaken notion that it would be a good place for maggots to develop, all miserably perish. There seems to be no other way to describe such behavior except as obtaining service from the insect under false pretences, and if plants were really responsible creatures these carrion-fungi would doubtless find themselves in some plant-penitentiary.

Even more remarkable is the behavior of a Brazilian relative of the stinkhorn, which, in addition to all the devices that are employed by the Minnesota species, adds a conspicuous white veil, hanging down from the cap around the stalk. The veil is reported by travelers to be faintly phosphorescent at night and, if so, adds to the attractive influence which the plant might have upon night-flying insects. There are several species of stinkhorns in the northern United States, but up to the present time I have seen only three in Minnesota, one of which has a veil. It is quite certain, however, that others occur. The only way of eradicating them from a lawn, where they are offensive objects if produced in large numbers, is to dig up carefully and remove the underground portion, for if this is not done the plant will offer its repulsive fruits year after year.

Truffle puff-balls. Some plants, not very distant relatives of the carrion fungus, produce their fruit-bodies entirely underground. Such forms may be described as subterranean puff-balls. They are not unlike the well-known truffle of the markets in outward appearance, but are widely different in structure. A few of them have been found growing in Minnesota woods. Dogs or pigs can be trained to dig them, finding them by their odor, and, indeed, this is the method which is used by truffle-hunters in the woods of Europe.

Puff-balls. More familiar by far to the ordinary observer than these underground forms are the puff-balls which are so common in fields, pastures, woods and meadows throughout the state. A very considerable number of varieties of puff-balls may be found by any one who looks for them and is a close observer. One variety abundant in plowed fields, where it grows among the stubble after a corn or wheat crop has ripened, is the stalked puff-ball. This plant is distinguished by a gray stalk a quarter of an inch in diameter and two or three inches high. At its top is developed a little flattened spherical bladder, perforate in the middle, within which are innumerable brown spores. If the skin is squeezed the spores puff out at the top like so much brown smoke, hence the common name, *puff-ball*, which is applied to this plant and its relatives.

Other puff-balls have not the same slender stalk that has just been described. Several kinds are more or less pear-shaped, standing with the small end downward and variously marked in the different species. One variety is nearly smooth while another is covered with tiny warts of different sizes, sometimes arranged in patterns over the surface. In others the surface is spiny and sometimes the spines occur in little clusters, with their tops drawn together like the stems of corn when in the shock. If one of these puff-balls be cut lengthwise it will be seen that the lower part is spongy in texture and does not produce spores, so that this portion may be regarded as a short, thick stem. The upper portion, however, produces an abundance of spores which are ejected through an aperture in the ordinary manner.

FIG. 23. Warty puff-ball. After Lloyd.

Still other puff-balls have no stalks, but the whole fruit-body is a bladder filled with spores and some of the commonest of all Minnesota puff-balls belong to this division. They are found abundantly in fields and pastures and, when ripe, are flattened dark purplish or plum-colored bodies from a quarter of an inch to an inch in diameter. The whole inside of one of these fruits consists of a fluffy mass of spores and threads—the dried-up stems upon which the spores develop. In the woods a stemless puff-ball is found of a lighter color, growing often as large as a turkey's egg. Both this and its smaller relative of the pastures open somewhat irregularly at the end away from the ground, or perhaps at the side. Among the short-stemmed puff-balls two or three large varieties are found; one, the giant puff-ball, occurs larger than a man's head and almost spherical in shape, while another is in outline somewhat like a dinner bell with the mouth closed and mound-like.

Earth-stars. An interesting variety of puff-ball is the earth-star. This has an outer skin that splits radially, as one peels an orange, revealing the inner skin that encloses the spores. The little mouths of the earth-stars are nicely protected by a group of bristles which, by their sensitiveness to moisture, assist the distribution of the spores under conditions which are favorable for their germination. Apparently the use to the plant of splitting back the outer skin is the additional height that it attains from which its spores can be distributed. The points of the sections which have split bend under and lift the central ball a half inch or more into the air, and the spores have an added opportunity of catching some wind current, which, if they were closer to the ground, might not distribute them so far.

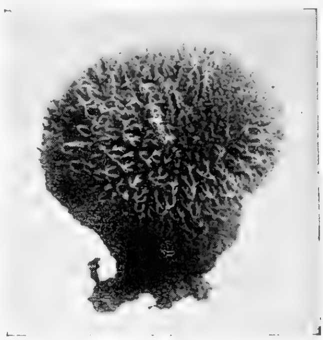


FIG. 24. Tufted puff-ball. After Lloyd.

Slitted puff-balls. A rather large puff-ball with a short stalk and a white egg-shaped head is sometimes found in fields and door yards, the small end of the egg pointing upward and the large end hanging down over the stalk which seems to grow up into a depression there. These puff-balls open by slits close down to the stalk, and the interior is found to be occupied by irregular, broken, brown plates, radiating vaguely from the stalk-region somewhat like the gills of the mushroom.

Bird's-nest-fungi. Among all the puff-balls few are more interesting objects than the little bird's-nest-fungi. There are three sorts of these common in Minnesota. None of them is very large for they do not exceed a quarter to a half inch in diameter. They are often seen growing on the planks of old sidewalks, in the cracks, or they may be found attached to twigs or bits of decaying wood. Each fruit-body is shaped like a vase or bowl, at the bottom of which half a dozen white or purple egg-like bodies are lying, so that it has the appearance of some tiny nest with eggs, hence the popular name which has been applied. If one attempts to pull out the "eggs" it will be found that each of them is flattened like two watch crystals placed together and is attached by a delicate cord growing from the "nest" and fixing itself upon the middle of one side of the eggs. It must be understood that the term "egg" as used here, and as used also for the young stinkhorns, should not suggest that such bodies have any of the real meaning of an egg, since it is applied solely on account of their shape. In the bird's-nest-fungus each "egg" is a miniature puff-ball, with spores enclosed within its membrane, and the whole bird's-nest-fungus fruit-body might be described as comparable to a little group of stemless puff-balls enclosed in a common vase or urn.

Hard-skinned puff-balls. Yet another sort of puff-ball is readily distinguished by its hard nut-like shell. Such plants are called hard-skinned puff-balls and some kinds of them grow to be larger than an ordinary coffee cup. They are white or brown in color and almost spherical in shape. When they open to eject their spores the whole top splits by four or five radiating clefts, and the sections of the shell curve back from the centre somewhat as did the outer skin of the earth-star. As they separate, the fluffy spores and threads of the interior are exposed as an umber mass upon which the wind has an opportunity to play, thus carrying off the spores to other favorable regions for development.

Ball-tossing puff-balls. In some respects more remarkable than any of the others is the ball-tossing puff-ball. This is a small variety, not larger than an ordinary pill, but a little larger than the pellets of the homeopathist. It occurs in clusters upon decaying wood and looks somewhat like slime-mould fruit only it has a more leathery skin, and would be recognized upon close observation to be different from the slime-mould fruits in outward appearance as well as in inward structure. The ball-tossing puff-ball has three layers of skin, one outside of the other. The two outer skins become perforate at the end of the ball, exposing the third and innermost skin which remains intact. The hole enlarges so that there comes a moment when the inner skin lies like a base ball in a tea cup, surrounded by the two outer skins which have taken a vase-like form. Very suddenly the middle skin separates from the outer skin everywhere except at the edges and inverts itself with explosive force. It is as if the lining of a porcelain kettle should turn inside out. By this means the little ball at the centre may be projected several inches into the air as if shot out of some tiny catapult. In this way the whole mass of spores enclosed in the inner skin is thrown to some distance from the point where the parent plant developed, thus adding to the favorable chances of the species in distribution.

Chapter X.

Yeasts, Morels, Cup-fungi and Truffles.

All of the higher fungi which have been described, enjoy one character in common; their spores are produced upon stalks. No matter how various the form of the fruit-body may be, in this one respect all the different varieties agree. The group of higher fungi now to be considered is marked by the production of spores in sacs, hence they all pass under the general name of sac-fungi.

Yeasts. One of the most simple forms is the yeast plant, familiar to housewives and brewers the world over. Yeast, as most people know, is a culture of fungi developed upon malt and hops and then transferred to various substances for purposes which differ in the different arts. In bread-making the value of the yeast lies in its power of liberating carbonic-acid-gas while it is growing in the dough. When a cupful of yeast is placed in a baking of bread and the dough is set away in a warm place beside the stove, the yeast-plants feed upon the substance in the dough and as they grow and reproduce they create among other waste products, carbonic-acid-gas and alcohol. When the bread is kneaded and allowed to stand again before placing in the oven, the kneading serves to distribute the yeast-plants evenly through the loaf and they continue to grow, forming bubbles of gas and small amounts of alcohol. When the lightness of the bread is assured the loaves are placed in the oven and the heat which is applied kills all the yeast plants, but the bubbles of gas have done their part in leavening the loaf.

In brewing, it is not the gas which is deemed so desirable, but the alcohol, and the yeasts are permitted to develop until the proper percentage of alcohol has been introduced. The hardening of cider, the fermentation of wine, and a variety of other processes are equally the result of fungus growth. Yeasts are sometimes impure or "bad" as the saying is. This is owing to the mixture with the genuine yeast of other fungal organisms, which liberate other and often undesirable substances. For example, certain acids are produced through the activity of yeast-like plants, and if such acid-forming yeasts are present in sufficient quantity, the bread or the beer becomes sour. Hence the cultivation of pure yeast is a prime necessity and when the housewife or the brewer finds by experience that yeasts in use are no longer pure, a fresh supply must be obtained from a neighbor or in the market.

Yeast is a widely distributed plant and will often appear as if spontaneously, just as black mould does when a substance suitable for its development is exposed to the atmosphere for a sufficient length of time. The yeast-plant itself consists of thin-walled, egg-shaped cells which have the power of budding. Somewhere the wall bulges and the bulge enlarges until it is the size of the parent cell. Thus a branching body can be built up, but the branches and buds readily separate from each other and in a favorable condition of temperature and food supply the growth of the plant is extremely rapid. When the yeast-plant forms spores, which it does not do very abundantly under ordinary conditions of growth, the contents of one of the egg-shaped cells will be seen to divide into four portions each of which becomes spherical in form and secretes about itself a wall of its own. Then, when the wall of the mother-cell breaks down, the spores separate from each other and may be distinguished from the ordinary yeast-cell by their smaller size, spherical shape and thicker wall. It is on account of their thicker wall, and probably, too, in consequence of some difference in the structure of the living substance within that they are able to resist the harmful influence of extreme temperatures much better than the ordinary yeast-cell. If the conditions favorable to rapid growth become for any reason unfavorable, the yeast plant is likely to undertake the formation of spores.

The particular substance that yeast attacks is cane-sugar. This it splits up, during its life-processes, into carbonic-acid-gas and alcohol. Such a process is called *fermentation*, or more precisely, alcoholic fermentation, because there are various kinds of fermentation which go on under different circumstances through the activity of different organisms. The peculiarity of the yeast plant is its capacity for setting up alcoholic fermentation and no other kind.

Besides the common yeasts a number of others exist. One kind which grows in cabbage, after it is cooked, produces the substances which give the flavor of sauerkraut. Another kind when introduced into milk causes it to ferment, and in the region of the Caucasus is used by the Tartars to change goat's or camel's milk into an intoxicating liquor.

Plum-pockets. Very closely related to the yeasts is a group of parasitic fungi capable of attacking a variety of plant-tissues. One kind, when it infects the young fruits of the plum or cherry produces what is known as *plum-pocket*. When such a fungus grows upon a plum it distorts it and gives it a singular, irregular baggy appearance which is easily recognized. The poplar trees in Minnesota are very often attacked by a pocket-fungus, which changes their green pods into yellow sacs distinctly larger than the ordinary pod. On cherry trees, a witch's broom formation in which the growth of the twigs is disordered, results from the presence of a fungus of this group, and upon alders another witch's broom arises under similar conditions.

FIG. 25. Pocket-fungus on sand-cherry. After Bailey. Bull. 70, Cornell Ag. Exp. Station.

Morels. In the sac-fungi which have been described no conspicuous special body is developed; but in the higher forms large bodies, rivalling the mushrooms in size, and of a great variety of form and structure may be produced. Of such, one of the best known is the morel. This superficially resembles, to some degree, the stinkhorn. It grows upon the ground and the fruit-body consists of a hollow, cylindrical stem, sometimes three or four inches in height and an inch in diameter. The texture, however, is much firmer than that of the stinkhorn stem and the cap upon the end, though wrinkled like the stinkhorn cap, is continuous with the stem and not slimy nor vile-smelling. Morels are edible and are said to be especially prized in Bohemia. They are often found growing in Minnesota woods and upon Minnesota hillsides, where their fruit-bodies, unlike those of the stinkhorn, ripen in the spring. If one should examine under a microscope a thin section cut through the wrinkled surface of the cap, it would be perceived that it consists almost entirely of sacs, in each of which eight oval spores are produced in a row. Each sac is cylindrical in form and not much larger in diameter than the spores which fill it. When ripe the ends of the sacs break or dissolve and the spores pour out one after another, but they are not, as was the case in the stinkhorn, universally carried away by insects, for they depend rather upon the wind and the rains for their distribution.

FIG. 26. A morel fruit-body. After Lloyd.

A number of plants closely related to the morel may be distinguished by the different shapes of their caps. In one the cap is saddle-shaped; in another somewhat urn-shaped; in a third the whole fruit-body is club-shaped and closely resembles some forms of the club-fungi which have been described above. In some the cap is peculiarly coiled and twisted, looking like a knot of angleworms. The colors of these plants are various—white, brown, slate-colored, yellowish, pinkish or red. They occur sometimes upon much decayed logs, but the majority of them are terrestrial. A few are of an almost gelatinous consistency but a greater number have, to the touch, rather the feeling of cartilage. Several of them besides the morel are edible

FIG. 27. Cup-fungi growing on decaying twig. After Lloyd.

and I do not know of any that are violently poisonous, although from their texture, a number of them would scarcely be attractive.

Cup-fungi. Not a distant relative of the morel is the cup-fungus, which in its numerous varieties is doubtless familiar to many of the readers of this volume. A dark slate-colored species of cup-fungus is abundant in Minnesota woods in early spring and produces cups an inch or more in diameter. If one cuts such a cup in two and looks at the cut surface it will be found that the whole fruit-body has a distinct lining like a porcelain kettle. The lining-layer is made up entirely of sacs and accessory threads running parallel with them. All of the sacs are cylindrical, slender and arranged perpendicular to the inner surface of the cup, while in each sac there are eight spores, ovoid in shape and developed in a row just as in the morel.

Another kind of cup-fungus is scarlet, almost as large as the one just described and equally familiar to most persons who go into the woods with open eyes. Besides such large cup-fungi there are a great number of smaller kinds, some of them grading down to the size of a pin-point, while between these and the large ones are all sorts of intermediate sizes. They differ too in color and in form and many of them are saucer-shaped, or merely flat discs, circular in outline. Such small discs of a bright yellow, or bright red color, are abundantly produced upon decaying wood and leaves.

In distinguishing the different kinds of cup-fungi the character of the margin should be observed. This is sometimes furnished with bristles or scales; sometimes it is smooth; sometimes it is rolled back, or it may be rolled in over the centre of the cup, disc or saucer. It is not possible, however, to recognize exactly all the different cup-fungi without an examination of their spores, for special sorts develop special kinds of spores in their sacs. Sometimes the spores are without partitions, while in other instances they are divided into little chambers. They may be smooth or provided with knobs, spines or emergences. Growing in the same layer with the sacs are commonly to be found much slenderer threads, which help to keep the sacs moist while they are developing their rows of spores. When the cup-fungus has matured its spores, the ends of the sacs—which all lie at the same level in the surface of the cup-lining—open or dissolve, and the spores are then thrown out.

One kind of cup-fungus which is common on manure-piles has a special explosive method of ejecting its spores. If such a cup is taken between the finger and thumb, held to the light and pressed gently, the sacs all open at once and violently eject their spores, so that for an instant a little wreath of smoke seems to fly from the top of the cup. This phenomenon is caused by a cloud of several thousand spores escaping simultaneously. The spores in certain species are not individually shot out from the surface of the cup, but rather the sacs themselves with the spores enclosed.

A particular variety of cup-fungus, very abundant in the woods of Minnesota, grows upon the ground and produces a hard, black underground tuber, as large as the end of one's thumb. This tuber has a firm skin, but when it is cut open the interior is softer and white. A bud forming under the skin of such a tuber develops a fruit-body, cup-like in shape, and provided with a slender stalk. A relative of this fungus produces on the twigs of tamaracks nut-like swellings from which little cups arise.

Maple-leaf tar spots. A great variety of cup-fungi and disc-fungi are parasitic upon the leaves of growing plants. Possibly the most conspicuous one in Minnesota is the tar-spot fungus of the maple, often seen developed on the upper surfaces of maple leaves as one or more black shiny bodies, a quarter of an inch or so in diameter, and of an irregular roundish shape. These are the fruit-bodies of the tar-spot fungus, and while the vegetative portion of the fungus is growing within the tissues of the leaf, the reproductive portion, consisting of a layer of sacs with spores enclosed, destroys the epidermis of the leaf and produces the conspicuous spot.

Truffles. The fruit-bodies of a few sac-fungi are developed underground and here belong the truffles, which may be described in a general way as underground cup-fungi, in which the cups have closed up into irregular egg-shaped bodies. Upon the rotting of the truffle the labyrinthine sac-layers are exposed and the spores escape. Truffles are among the most esteemed delicacies of the *gourmet*.

Green and blue moulds. Curiously enough the green and blue moulds which occur on bread, leather, decaying fruits and other objects of that sort are rather close relatives of the truffles. As was observed during the description of the rust-fungi, a fungus often has the power of producing more than one kind of fruit-body. The blue mould—if for a sufficient time left to itself—will form in addition to the ordinary patches of blue spores arranged in chains on swollen terminal cells of some of its threads, also certain miniature yellow truffles, not much larger than a pin-point. These little truffle-like fruits, just as happened in the study of the rust-fungi, were supposed originally, by botanists, to characterize entirely independent plants, but it is now known that the blue moulds and their relatives the green moulds can, under suitable conditions of growth and nutriment, produce the sac-fruit-bodies. Thus it is apparent that in the ability to form such tiny orange-colored "truffles" they are quite unlike the black mould which had no such capacity. The general plant-bodies of the different sorts of moulds and their general life-habits are, however, very similar, so that popularly they are all included under the same name. Botanically, black moulds and blue moulds are quite distinct.

Chapter XI.

Blights, Black Fungi and Root-fungi.

Blights. There remains to be considered a large group of sac-fungi, which from the color of their fruit-bodies are classed together under the name of black fungi. Very good examples of the black fungi are furnished by the blights which occur on the leaves of the higher plants. As a type, may be selected the lilac-blight, which in autumn forms a white scurf on lilac leaves. This scurf is the vegetative body of the blight and consists of a cobwebby mass of delicate, white, branching filaments, some of which penetrate the tissues of the leaf, while others spread themselves over its surface. If one, in the autumn, looks closely at a blighted lilac leaf it will be discovered that there are present on its surface a great number of tiny black specks which by the naked eye can be seen to have a spherical shape. These are the fruit-bodies of the blight. Within the black skin of each, sacs are formed, much as in the truffle, and in the sacs spores are produced. The fruits of the blights are many of them remarkable for their development of peculiar anchor-like appendages which grow out from the surface. In the lilac-blight these appendages are branched in a regular fashion forming at the ends a series of curved prongs. The willow-blight, on willow leaves, has the ends of its fruit-appendages hooked and such blights are called hooked blights. The blights common on grass leaves in autumn and causing portions of the turf to look as if a little whitewash had been spilled upon it are supplied with fruit-appendages which are not hooked or branched at the end. In another sort of blight the appendages are sharply pointed like thorns.

Toadstool-blight. A few of the so-called black fungi belie their name, for instead of black, their color is rather yellowish or red. Here may be included a curious fungus which is parasitic on toadstools. When a toadstool is affected by this parasite the gills are all destroyed and the area they occupied presents a pimply red surface. The pimples are small, about the size of a pin-head, and in each of them is developed a mass of spore-sacs. Such a plant illustrates the tendency of what were independent fruit-bodies in the truffles, the blights and the blue moulds, to aggregate themselves into layers. Such layers are in higher forms of black fungi variously disposed over branching or swollen bases, so that a large compound fruit-body is developed.

Ergots. A good example of an interesting black fungus with a compound fruit-body is the well-known ergot of rye. Ergots occur, however, upon other plants than the rye, and, for instance, a very interesting kind is found in the fruiting panicles of the wild rice. The life-history of an ergot is about as follows: The plant-body develops within the tissues of the grass and when the grass is ready to set its fruits, the ergot plant, somewhat after the manner of smuts, produces in some of the kernels, a dense network of filaments, occupying the place of the grain. The ergot does not here, however, form its spores as the smuts do, but gives rise rather to a tuberous propagative body, consisting of a softer white interior, with a black shell and exactly comparable to the underground tubers formed, as mentioned above, by one kind of cup-fungus. Such ergot tubers take about the same shape as the rye kernel, finally falling out from between the chaffy scales of the rye and lying dormant over winter. In the spring, buds arise under the skin of the tuber and grow out into little slender threads and at the end of each a more or less spherical swelling appears. The surface of the swelling is occupied by a layer of ergot fruit-bodies, in each of which a group of slender sacs, with long jointed spores, is developed. It should be added that other sorts of spores, ovoid in form, are produced upon wrinkles at the surface of the propagative tuber, so that as in so many other fungi, there are here two kinds of spore-cells. Either variety of spore falling upon the proper host plant will infect it and initiate the development of a new ergot plant-body.

Ergot is of considerable commercial importance on account of its tubers, which form certain alkaloids used in medicine. Of fungus alkaloids there is a considerable group, of which those in poisonous mushrooms, poisonous pore-fungi and ergot-tubers are examples. Ergot in rye sometimes occurs in sufficient quantities to poison persons or animals that eat the grain and where rye-bread is a staple article of diet it is necessary to remove the ergot-tubers before the rye is ground into flour.

FIG. 28. Leaf-spot disease caused by fungus. After Halsted.

Caterpillar fungi. Very closely related to the ergot is a small group of fungi which live parasitically in caterpillars and other insect larvæ. Sometimes on mossy banks one will notice a little reddish-yellow, pimply, club-shaped body rising up among the mosses and an inch or more in height. If this is carefully pulled out from between the moss-plants it will be found to spring from the body of some dead caterpillar or other insect. The plant-body of the caterpillar-fungus grows within the tissues of the insect and forms there a tuber-body similar to that of the ergot. From this a bud develops into the club-shaped stem over the end of which, and covering the sides, a layer of somewhat bottle-shaped fruit-bodies is produced. One kind of caterpillar-fungus has its compound fruit-body branched, so that the unfortunate caterpillar seems to be carrying upon its head an elkhorn-like protuberance three or four inches long. A remarkable variety of caterpillar-fungus has a slender tongue of sterile tissue projected beyond the end of the fruit-body area.

Leaf-spot-fungi. Among the black fungi a considerable number form what are known as leaf-spots. Very often on leaves little pale areas develop, not infrequently surrounded by a reddish circle. This red circle is caused by a secretion of red coloring matter by the leaf, owing to the irritation occasioned

FIG. 29. Leaf-spot fungus growing on pear leaves. After Duggar. Bull. 145, Cornell Ag. Expt. Station.

by the spot fungus. The pale centre of the red circle is the injured portion of the leaf, where the fungus has destroyed the cells and devoured the particles of leaf-green. If in autumn one looks very closely at a leaf-spot he will generally be able to see the tiny black fruit-bodies of the fungus. Usually they are separate from each other as in the blight, but a considerable proportion of them are blended together in layers, as was described for the much larger fungus, parasitic on the toadstool.

There must be at least a thousand different kinds of leaf-spot fungi growing in Minnesota. Not all leaf-spot fungi are certainly black fungi; but the great majority of them belong to that group. Neither do all leaf-spot fungi develop fruit-bodies, for some of them are able to form only a simpler sort of spore-cluster. Yet in most instances it is believed that this is because the fungus has abandoned for some reason the formation of true fruit-bodies. As already observed in the account of the wheat rust—a most instructive object of study—a fungus may acquire the habit of developing one kind of fruit-body upon one leaf and another kind upon another. It is very probable,

FIG. 30. Fungus spot-disease of strawberry leaf. After Bailey. Bull. 79, Cornell Univ. Ag. Expt. Station.

where leaf-spot fungi fail to develop their ordinary fruit-bodies and provide themselves with spore clusters, that they may on other plants develop the true fruit-bodies, or that they have, as is often probable, ceased altogether to produce them.

Not only do these spot-fungi find pasture upon the tissues of living leaves but closely related forms browse upon old pieces of paper, upon straw, leather, decaying cloth, the shells of nuts and seeds, and even upon such curious fields as the inner surface of roasted chestnuts, the feathers of fowls, the hair and hoofs of cattle, and, in short, wherever they can find food-materials suitable for their growth.

Twig-fungi. A large group of black fungi grow upon twigs and these may be known generally as twig-fungi. One of the most prominent forms is the black knot of plum and cherry twigs, a plant which is very common upon various species of wild plums in Minnesota, and upon the wild choke-cherry. It forms black swollen bodies, half an inch or so in height, and two or three inches or more in length, distorting the twig where it grows, and bursting the bark to display its layers of black fruit-bodies. A close examination of a black knot mass will show that its surface is covered with little round emergences or pustules, and each emergence marks the point where a bottle-shaped fruit-body is imbedded in the general layer. As before noticed, each fruit-body contains its lining of sacs in which the black knot spores are found—for the elaboration of which the plant-body derives sufficient sustenance from the cells of the twig which it robs of its sap. The black knot is but a single example of a large group of black twig-fungi. Some of them like the black coin-fungus form coin-shaped discs. Others develop a few little gourd-shaped fruit-bodies in a group. One curious kind of which there are in different parts of the world about 400 species known, forms on twigs little black patches in which three or four fruit-bodies are imbedded, one of the group being entirely different from the rest. The central one, in its bottle-shaped cavity, produces spores displayed on stalks, while the others produce spores developed in sacs. The spores produced on stalks are much

Fig. 31. Fungus spot-disease on leaf of false Solomon's seal. After Halsted.

smaller than the others. An explanation of this peculiarity may be obtained from the behavior of the blue mould. It will be remembered that in the latter kind of mould, spores were ordinarily formed on branches loosely distributed over the plant, while at other times tiny orange truffle-like fruit-bodies arose after the method of sac-fungi. Now if it can be imagined that the loosely formed spores of the blue mould are aggregated together in a bottle-shaped structure, they lining the interior of the bottle, there would arise a fruit-body like the peculiar central one of the plant in question. The name of a plant, which forms these two kinds of fruit-bodies is *Valsa*. Plants somewhat related to the *Valsas* are found on butternut twigs where they form little low black mounds.

FIG. 32. Fungus spot-disease on pear. After Duggar. Bull. 145, Cornell Ag. Expt. Station.

Staghorn-fungi. The last black fungus that needs consideration in this general survey of the important types is sometimes called the staghorn-fungus. It grows upon stumps, decaying timbers, sometimes on rafters in cellars, or in damp places about barns or granaries, and is a very curious looking object indeed. It is often three or four inches in height and shaped much like one of the antlers of a moose. Its whole surface is warty and black, each pustule marking the position of a fruit-body The interior of the plant is white and consists of a very densely tangled skein of threads. A smaller species is unbranched but stands up like a little black Indian club an inch or more in height and a quarter to half an inch thick through the thickest part.

The life of a fungus. There have now been passed in review a sufficient number of fungi to give a fair idea of the group as a whole. But the great variety of different species, and the almost innumerable peculiarities of structure, form and function which are possible, can scarcely be comprehended by any but a careful student of the group. Some general observations concerning their lives deserve to be made.

Regarding their nutrition this may be said—that they are *animal-like*. Not one of them has the power of making starch out of gas and water, as green plants have, and all of them must obtain organic substances from which to construct their bodies. In a great majority the vegetative area is inconspicuous because it is concealed in the sub-stratum upon which the fungus lives. The sub-stratum may be the soil, a rotting log, a living twig or leaf, a piece of paper, the hair or feathers of an animal or bird, a bit of dung, or, for aquatic fungi, various similar objects submerged in lakes, streams, pools or springs. Concerning the reproduction of the fungi, it may be noted that the higher forms commonly develop at least two kinds of spores, one being entirely disconnected with the breeding-habits of the plant, the other dependent upon the breeding act—a process which often takes place upon areas concealed in the sub-stratum. The rudiments of all true fruit-bodies, such as those of the cup-fungus, the morel, the ergot, the cater-

FIG. 33. Fungus spot-disease of bean pods. After Halsted.

pillar fungus, the black knot and all the other sac-fungi, arise as a necessary consequence of some fusion of cells, equivalent to that which took place in the black moulds. In the stalk-fungi, to which group the mushrooms, puff-balls, club-fungi and all their relatives belong, it is not so certain that a breeding-act is always the necessary precursor of the fruit-body, but there is much good evidence in favor of such a supposition.

All of the fungi which have been considered up to this point may be regarded as derived from certain of the lower algæ, while the bacteria—yet to be discussed—are very closely related to the blue-green algae. The algal fungi seem, for the most part, to be connected with the pond-scums, leading over to such forms as the black mould, or with the green felts, leading over to mildews and fish-moulds. It is reasonable to suppose that all of the higher fungi which have thus far been passed in review are derived, by a continuous series of improvements, from the algal fungi.

FIG. 34. Twig-fungus on currant canes. After Durand. Bull. 125, Cornell Expt. Station.

Root-fungi. There are a few rather remarkable types of fungi which should be treated separately. One of these is not commonly known to make fruits of any sort, and, since botanists depend upon fruit-bodies as the basis of their classification, it is difficult to say where these fungi about to be considered should be placed in the general system. They will be found encircling the roots of many kinds of trees or herbs, and sometimes developing within the outer tissues of roots or underground stems belonging to plants growing in very rich soil. An example of the first kind is to be met with on rootlets of the tamarack. Another is found upon the rootlets of the oak, and, often, too, upon the young roots of birches. Such fungi form rather thin, felted masses inclosing the roots as in sheaths. The sheaths become of a dark brown color as they grow older, but at first they are almost white. So constant is the association of the fungi with the roots or subterranean stems of some plants that they may be regarded as necessary concomitants of these higher plants. It is probable that they play a very important part in the nourishment of roots which they inclose or infest. It would seem that they have something to do with the conversion of the food materials in the soil into a condition in which they are the more easily absorbed and assimilated by the roots themselves. If this suggestion, which is generally accepted among botanists, is the correct one, there is presented the interesting fact that all the tamarack trees in a swamp and all the oak trees by the road-side are largely dependent for their life and prosperity upon the little sheaths of fungi which feed their roots.

In a considerable number of plants the fungal threads do not form a sheath around the outside of the root but grow in microscopic tangled masses resembling skeins of yarn, one mass in each of certain outside cells of the root. The orchids of Minnesota are provided with such structures in their roots and the Dutchman's pipe, the *Pyrolas*, and a number of other plants which live in humus soil, resemble the orchids in this respect. Sometimes underground stems among the orchids are, through the irritation of the fungus in their outside cells, peculiarly knotted and distorted into structures quite different from the ordinary forms of growth. A very good example of this is the coral-root orchid. Really this variety of orchid has no roots at all and the underground portion is a curiously modified branching root-stock, which from its resemblance to coral, gives occasion for the common name of the plant. There is good reason to suppose that some of such underground fungus-masses which enclose the roots of trees, or develop themselves in the roots of humus plants, were originally the vegetative bodies of truffle-like plants, and that on account of long association with the roots they have abandoned their fruiting habits. Seemingly they are able to maintain themselves without going to the trouble of fruiting, and in a sense they may be regarded as forming a partnership with the higher plants to which they have attached themselves. They can scarcely be called parasites because their presence is not harmful to the higher plant, but, rather, as has been explained, beneficial, because they enable it to use substances in its nutrition which would otherwise be beyond its power to absorb from the soil. Among the bacteria there are similar partnerships with higher plants, and they will be considered in their place.

Ear-fungi. There are some other obscure forms of fungi, such as the curious little necklace-like bodies, which sometimes live in the ears and throats of birds and animals. They may be considered as truly parasitic, but it is not easy to say exactly where they belong in an orderly classification. Sometimes they attack men and women and the bad habit of dropping sweet-oil in the ear as a remedy for ear-ache may stimulate their growth.

Chapter XII.

Lichens and Beetle-fungi.

The life of a lichen. The group of plants known as lichens is familiar to all observers. Some varieties are called gray or hanging moss by persons who do not discriminate accurately between these plants and the very different forms which are rightly known as mosses. A still greater error is made in common speech, when the little hanging, gray, flowering plant, so abundant in the south upon tree-branches, is given the name of "Spanish moss." Lichens are found in a great variety of positions. They are exceedingly prevalent all over the world on rocks, making characteristic patches on weathered cliffs, walls, boulders, and pebbles, provided there be not some constant agitation upon the surface of the rock, as by drifting sand or surf, which might prevent their growth. They are seen very commonly upon the trunks of trees, usually preferring the side toward the north. One characteristic lichen hangs from the branches of tamaracks everywhere in Minnesota, and is sometimes called "old man's beard" from its gray color and thread-like texture. Other varieties produce little patches on tree trunks and they may be distinguished by their generally circular form, by their flat habit of growth, and by their greenish, red, yellow or gray color, which is very rarely a pure leaf green, but varies more or less toward the other shades.

Stone-corroding lichens. Lichens upon stones are very often so firmly attached that they cannot be removed, having eaten their way into the stone by means of acids which they secrete for that purpose. Curiously enough, a lichen which can live upon limestone is not always able to live upon sandstone, because it takes a different kind of acid to corrode limestone from that which eats away the quartz of a granitic rock. A great many of the lichens upon stones are not, however, firmly

FIG. 35.—Rock-lichens growing profusely in a glacial pot-hole. Near Taylor's Falls. After photograph by Mr. E. C. Mills

attached, and such kinds may often, too, be found upon tree-trunks, fence-rails, twigs or the roofs of houses. A true rock-lichen does not commonly occur upon wood, so that different series of forms will be found if one examines the different habitats where these plants are wont to display themselves.

Structure of lichens. Lichens are very extraordinary plants, or rather *pairs of plants*, for a lichen is essentially a partnership between a fungus and an alga. Several different groups of algae are employed in the building up of lichen bodies, especially the blue-green algae—such as the water-flower—and the bright-green algae. I do not know of any lichens which employ red or brown algae in their partnership. Several varieties of blue-green and bright-green algae are concerned, but a particular species of lichen rarely exhibits more than one kind of alga and one kind of fungus in its partnership-structure. As will be explained, such partnerships are self-perpetuating, and the partnership comes to have the appearance and very much the character of a plant-unit, so much so, indeed, that for convenience lichens are generally viewed as independent unit-plants rather than as the double organisms which in reality they are.

FIG. 36.—"Old man's beard." A lichen growing attached to the twigs of tamarack. Lake Superior, north shore. Natural size, six inches in length. After photograph by Professor Bruce Fink.

If one makes a very thin slice through the plant-body of a lichen it will be found to consist of certain algal cells or filaments quite able to propagate after their kind, and these enclosed in a tangle of fungus filaments which are equally capable, for the most part, of developing their special types of fruit-bodies. In addition to the algal propagation which goes on among the algae of the lichen-body, and the fungal spore-formation which characterizes the fungal member of the firm, there is commonly a production, superficially, of little granules, consisting of two or three algal cells with a web of fungal threads around them. Such minute granules, which may form a greenish dust over the surface of the lichen, are separated from the region where they arise and serve as special partnership propagative bodies.

By means of the algal growth which goes on in the lichen body, the algal partner increases in size while it is protected by its fungus neighbor. The fungus, too, grows, keeping pace with the alga, and in this way the double organism increases in size. When the fungus bears fruits—a process which in some lichen plant-bodies occurs very seldom, and in a few forms apparently never—the spores that are produced are in many instances thought to be incapable of germination, and it would appear that then the fungal partner has entirely lost the power of existing independently of its alga. If the algae are removed by careful methods from the plant-body they are usually able to develop independently and could not under such circumstances be distinguished from the same kinds of algae living their ordinary life in pools or moist places. There are, however, exceptions to this rule, and some algae when removed from their long accustomed partnership do not find it easy to continue an independent existence, though in no case are they so helpless as may be the fungi. It must doubtless be assumed that lichens began to exist by the attachment of certain fungi to algae, and that such a relation proved mutually beneficial. Under it the algae were protected from desiccation by the presence of the moist fungus threads and the fungi were able to absorb nourishment from the algae, which they in turn, by means of their leaf-green, were able to manufacture from gas and water. As time went on these partnership structures began to improve along paths favorable to the more perfect work of the partnership as a whole, and hence in lichens there have arisen leaf-like bodies, and even little tree-like stems with leafy expansions upon them—not at all an unreasonable course of development, for clearly the problem of obtaining illumination is much the same for a lichen-partnership that it is for an independent moss or fern.

Lichen-fungi. The kinds of fungi which have formed a habit of entering such lichen-partnerships are as various as the species of algae. There are among them a few stalk-fungi, related somewhat to the mushroom group, and when these fungi bear

FIG. 37.—A lichen growing upon a rock, and covered with the characteristic saucer-shaped fruits of its fungus component. After Atkinson.

fruit, in the lichen-partnership, they produce their spores on stalks in groups of four just as the mushroom does. Most of the lichen-fungi are, however, sac-fungi, a few of which could be classified among black fungi, but by far the greater number in the group of the cup-fungi and the disc-fungi.

Kinds of lichens in Minnesota. There are probably some 500 species of lichens in Minnesota, and the total will rather exceed this estimate than fall below it when the work of discovery is completed. Among the simpler forms are a number of little circular discolored patches found on bowlders and cliffs. In the centre of such a discolored patch are scattered the irregular-shaped fungus fruit-bodies, in which are produced numerous spores incapable of germination. In rock-lichens of this sort the fruit-bodies are not exactly circular, as in the majority of the group. The algae which are present are of rather higher types than in some of the more complicated lichens. They belong to the class of bright-green algae, and sometimes branched, filamentous algae are found in the partnership, while at other times isolated green-slime cells are the rule.

Rock-lichens. The majority of rock-lichens in Minnesota include bright-green algae rather than blue-green, and the fungus, when it fruits, produces a circular disc, reminding one exactly of many of the cup-fungi. The centre of the disc is often variously colored, red, black, yellow, blue, purple, pink or dull green. The texture, too, of the lichen-body differs in different kinds, for in some it is papery and thin, while in others it may be brittle and encrusted. Again it may be leaf-like, or gelatinous. In addition to the closely attached forms growing upon rocks are certain loosely attached varieties—one very conspicuous species being held by a delicate stalk at the centre, and then spreading out into a round flat structure the size of a pond-lily leaf and much resembling a piece of leather. Related to this form on rocks is a kind which is common among mosses, producing a broad green, leaf-like expansion, but it may easily be recognized as a lichen if it is turned over to reveal the white fungus-like appearance of its under side.

Reindeer-mosses. Most remarkable of the lichens is the reindeer moss which is so predominant a form of vegetation in polar regions. There are a large number of different species and for the most part they grow upon the ground. Reindeer moss in Northern Minnesota often forms patches of hemispherical shape and as large as a bushel basket. Plants of this size must be very old, possibly over a hundred years, for they grow slowly and are of perennial habits. I have seen them most beautifully developed on an island in Lake Saganaga, where they covered the soil among the pine trees and I could not help remarking that they seemed to be as old as the pine trees above them, indicating what is rare in Minnesota, that the island had never been touched by fire. Beside these large reindeer mosses, which are the particular kind that bear that name, there are a number of small relatives common along roadsides, on clay banks and among mosses in the woods. One sort is called the cigar-moss by children because of the flaming red ends of its branches, while another might be mistaken for a cup fungus on account of its vase-like form, but would be easily distinguished by its grayish-green tint.

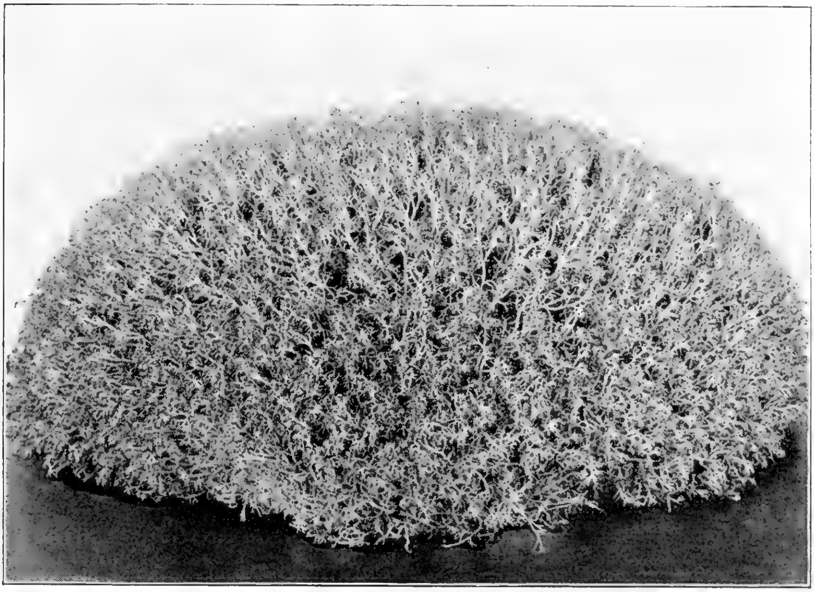


FIG. 38.—A tuft of "reindeer moss." Natural size, 2½ feet in diameter. Age, probably over one hundred years. North shore of Lake Superior. After photograph by Professor Bruce Fink.

A curious thing about the much-branched body of the reindeer moss is this, that it all belongs to the fruit-body area of the fungus. The real vegetative body is a flat, rather insignificant tract below, and instead of developing simple discs or cups upon the surface of this body, it is the habit of the reindeer moss to form much-branched cups which, unless one observes carefully their elaboration, would scarcely be recognized for their true significance.

Lichens are of much economic importance in the polar regions where they are for animals and even for man, a staple article of diet. Reindeer moss if cooked is edible, calling to mind the blanc-mange made from the red seaweed, known by the name of Irish moss or carragene, and previously alluded to. Some also of the gelatinous lichens are edible, but none of them is of any particular importance as an article of diet in Minnesota.

Black-fungi-lichens. A very few lichens, in which the fungus partner is a black fungus, are known to exist in Minnesota. They could not be recognized by their outward appearance from certain forms of the disc-lichens, but their fruit-bodies are little black bottle-shaped objects in which the spore-sacs are produced, and are quite different from the open plates and saucers of the more common varieties.

Lichen parasites. The study of lichens has been confused by the presence upon their bodies of numerous kinds of parasitic black fungi which really have no connection with the lichen whatever, but merely come to attack it just as their relatives attack the leaves and twigs of the forest. Yet when one remembers that a portion of the lichen itself may be a black fungus, it will be seen how puzzling might be the presence of a closely related black fungus parasite, and it is not remarkable that some of these parasites have been described as true fruit-bodies of the lichen.

Lichen partnerships. Although there are a great many partnerships in the plant kingdom there is no group of organisms where the principle of partnership has been carried so far as in the lichens, for the combination-structures have taken forms under the stress of their struggle for existence that neither of the two component elements would have been at all likely to assume if living independently. The reindeer moss, for example, has become a little shrub, while the "old man's beard" dangles its cylindrical stems and branches from tamarack bark much as if it were a plant of higher degree, and the flat leaf-like lichens which live among mosses spread themselves out to the sun quite like some of the flat liverworts. Indeed there arises in lichens a physiological division of labor in view of which areas similar to those in higher plants must appear. The outer layer of the plant-body is made up of fungus elements and serves as an epidermis, resisting the evaporation of moisture. The next layers underneath are crowded with algal cells and do the work of starch-making for the partnership. The central layers in cylindrical lichen-bodies are of a fungus character and perform the office of conducting moisture. The whole double organism, then, is built upon the same physiological plan as are the higher plants and has work to do which neither an alga nor a fungus living by itself could well do on land. It is true some algae, like the gulf-weed, develop leaves and branching stems, recalling in their appearance the higher plants, but on land it would scarcely be possible for an alga to adopt such a form, while it would be unnecessary for a fungus, having no leaf-green to illuminate, to assume structures essential to the requirements of leaf-green at work. But when the two organisms have been brought together into a partnership it becomes possible for this partnership to assume forms and structures favorable for the illumination of leaf-green, for the proper protection of it while at work, and for the maintenance of a sufficient supply of water.

Beetle-fungi. The group of plants to which I have given here the common name of beetle-fungi is so remarkable as to deserve separate treatment. In structure the plants are extraordinarily unlike any other fungi. They are certainly not uncommon in Minnesota, although from the peculiar places in which they live they have never been brought in by collectors, and, indeed, I have seen but a single specimen collected within the borders of the state. It is their habit to attach themselves by a tiny disc to the bodies of water-beetles and other insects living in damp places. Some varieties of them are occasionally to be found attached to the wing-cases of the little scurrying beetles that get together and whirl about upon the surface of quiet water. The plants resemble tiny brushes of camel's hair, a sixteenth of an inch in length or less, and when examined closely they have been found to be, in their structure, very much like the red algae. Indeed, they might almost be taken for red algae, which at some remote time had contracted the habit of obtaining food without the aid of leaf-green. Yet, in the details of their structure, in some respects they widely differ from the red algae. The character in which they most resemble the red algae is their method of breeding. Just as in the algae the egg-cells are here provided with slender cylindrical projections upon which the sperm-cells fix themselves, thus fecundating the egg and making the development of spores possible. But when spores are formed they are not, as in red algae, produced on stalks, but in sacs, and in this peculiarity the beetle-fungi resemble the sac-fungi. Taking all their qualities into account it may safely be said that they are but distantly related to the rest of the fungi and are entitled to stand in a group by themselves. More than a hundred and fifty of these curious beetle-fungi are known, most of them from America, and it will reward observers in Minnesota to search for them on the bodies of aquatic insects and of insects living in damp places.

Chapter XIII.

Various Kinds of Bacteria.

The story of the bacteria is one of the most astonishing that modern science has had to tell, and although they are the smallest and simplest of all plants, I have thought it best to devote an entire chapter to their discussion;—so many are the ways in which they touch human life. In these days almost everything is attributed in some form or other to a microbe, and when the extraordinary character of these remarkable plants is appreciated one is not surprised to read that some savant has discovered the microbe of crime, the microbe of drunkenness or the microbe of insanity, all of which have at various times been heralded by the newspapers. While crime, drunkenness and insanity are not the result of microbe activity, yet microbes actually serve in a number of capacities which at first sight seem quite as impossible, and one can scarcely blame the public for believing, as it does, almost anything that it is told about microbes, or for going to the other extreme and believing nothing whatever.

What a microbe is. The term microbe, meaning "little living thing," has been applied to some organisms which are not bacteria, as, for example, the slime-mould-like creature which is the cause of malaria, or the yeasts which have already been described in the chapter upon the fungi. By far the greater number of microbes are bacteria, and bacteria themselves are very lowly plants related to the blue-green algae, and to be considered, perhaps, as forms of this algal series which very long ago abandoned their leaf-green and began, like the fungi, to make their living in other ways.

Classification of bacteria. In size bacteria are the smallest of living things, the least of them being less in diameter than one thousandth of a millimeter, so that three hundred of them could stand side by side across the dot over the letter "i." Others of the group are comparatively much larger, the largest being barely fifteen-thousandths of a millimeter in diameter. Sometimes they cling together in chains or threads thus becoming filaments of considerable length. In form, bacteria are either spherical, ovoid, cylindrical, twisted like corkscrews, or irregularly shaped. They never possess leaf-green, though some of them are capable of producing coloring substances of other kinds. It is now impracticable to group the bacteria as was done years ago into different species based upon form. The older students called a spherical bacterium a coccus, an ovoid bacterium kept its name, while a cylindrical-elongated form was called a bacillus; but it has been shown that one and the same organism may successively assume the coccus, the bacterium and the bacillus shape. To-day it is more common to classify them physiologically, and there are recognized the following principal groups, not including, perhaps, all of the forms, but excluding only the unimportant ones. The groups are as follows:

A. Disease-producing bacteria: Of these there are two classes; those producing diseases in animals and those producing diseases in plants.

B. Ferment-producing bacteria: Of these there are four principal classes; those producing butyric acid, in which class are included most of the bacteria of putrifaction; those producing lactic acid, including the forms which make milk sour, of which there is a great variety; those producing alcoholic fermentation, like the yeasts; and those producing vinegar fermentation.

C. Heat-producing bacteria: Sometimes the cause of spontaneous combustion of cotton waste and the heating of ensilage and hay.

D. Light-producing bacteria: To which is attributed in part the phosphorescence of the ocean.

E. Color-producing bacteria: Including a variety of forms which produce different sorts of coloring substances.

F. Nitrifying bacteria: Which fix atmospheric nitrogen.

G. De-nitrifying bacteria: Which decompose urea.

H. Sulphur bacteria: Which produce granules of sulphur in mineral springs.

I. Iron bacteria: Which secrete iron rust or iron ores.

Substances formed by bacteria. Before presenting in detail an account of some of the principal forms under each of these groups, a few words may be said upon the general physiology of the bacteria, which, if thoroughly comprehended, will make clear how there may be a fundamental similarity in all the apparently dissimilar processes dependent upon bacterial action. Bacteria are living plant cells. As such they need food, and absorb it, using it in their own way and excreting their waste products which may be as various as the food substances, and the methods of digestion. The waste products given off may be solid, liquid or gaseous; and among the substances excreted are a great variety of organic compounds. From an economic point of view the most important waste materials of bacterial nutrition may be classified in three groups: 1. Organic poisons; 2. ferments; 3. nitrates or nitrites. For the moment, consideration of the iron, sulphur and de-nitrifying germs is omitted. If a bacterium secretes some poisonous substance in the body of an animal or of man, the higher organism will be poisoned just as if bitten by a snake. Disease-producing bacteria are principally those forms which, entering the animal body, grow there, nourish upon its tissues and produce poisons that are carried into the blood and, when in sufficient quantity, produce death. Plants are subject to such bacterial poisoning quite as much as animals. Pear-blight and potato-scab; carnation disease and cucumber-rot are well-known examples of bacterial plant diseases.

Ferments. Ferments are peculiar organic compounds which are remarkable for their property of initiating changes in other compounds. A very little, for example, of the ferment which is capable of converting starch into sugar, if put into a starchy substance will transform thousands of times its own weight of starch into the form of sugar. Nor will it be destroyed in the process, for it seems to take into itself the starch on the one side splitting off sugar on the other, but always remaining the same although it produces very great changes in the substances upon which it operates.

Nitrogen salts. Nitrates and nitrites are salts of nitrogen which are demanded by most higher plants as indispensable articles of food. Such organisms use scarcely any of the free nitrogen of the atmosphere. Further, they are able to assimilate ammonia but sparingly, and such a nitrogenous compound as urea is almost worthless as a food. Therefore, in three great fields of interest to the human race, bacteria are active; first, as causes of disease through the poisons they secrete; second, as the sources of ferments which are used in the various arts of brewing, wine-making and the dairy, not to mention tanning, cigar-manufacture, and a variety of technical processes which are dependent upon the proper control of ferment-bacteria; third, as fertilizers of the soil, where they live in countless billions and under a variety of conditions play their part in fixing the nitrogen of the atmosphere in the form of salts to serve as food for the plants of forest, field and plain.

Energy produced by bacteria. It should be remembered that among the activities of living things not only are there processes which result in the production of particular *substances*, but sometimes, also, in the development of particular forms of *energy*. Heat, for example, is a form of energy which arises in the human body, as a result of its vital activity, and light arises in the body of the glow-worm, in many fungi, and in a large variety of marine animals. It is not, therefore, astonishing that heat and light should be among the results of bacterial activity, and it may, therefore, be comprehended how two such apparently unrelated phenomena as an epidemic of smallpox and the phosphorescence of the ocean should each of them be but the results of bacterial growth and nutrition. In the one instance, the waste products formed are substances belonging to the group of organic poisons. Secreted in the body they injure its tone and may even shatter its mechanism, causing death. In the other, light is one of the results of bacterial activity, just as in the physiology of the fire-fly, and when innumerable germs are floating at the surface of the ocean they may give to it that faint, uniform illumination which is recognized as bacterial phosphorescence—a phenomenon which has been exactly reproduced in the aquaria of laboratories by artificial cultures of light-producing bacteria.

Substances and forces harmful to bacteria. Bacteria differ among themselves in the kinds of food which they demand, in the nature of the waste products which they produce, and in the varieties of substances by which they are themselves poisoned. Almost all of them are incapable of existing in direct sunlight. Hence there is much sound scientific basis for the belief that sunshine is healthful. Bacteria are destroyed when subjected to the action of certain chemicals—of which corrosive sublimate is the strongest germicide. Next to this, in general use, is carbolic acid, an excellent compound to employ for disinfection, like the one first named; while a great number of other substances may be used in the destruction of bacteria. One of the first methods resorted to in the history of the world was the utilization of sulphur fumes by the ancient Romans to prevent their grape-juices from fermenting. Singularly enough men learned how to keep bacteria out of their wine long before they practiced intelligently the important hygienic rules for keeping bacteria out of themselves. Formaldehyde gas is a strong disinfectant and is much used. Iodoform sometimes advertised as a useful germicide, is of doubtful utility.

Not only is it possible to destroy bacteria by sunlight, and by numerous substances such as corrosive sublimate and carbolic acid, but in various other ways, principally employed in laboratories. The application of heat is a most important mode of preventing the growth and development of bacteria, and is essential to many processes by which it is desired to destroy or prevent the appearance of bacterial life. Electric currents may also be employed and are said to be in use in some distilleries abroad, where wine is permitted to flow for a time in an electric field, thus preventing the development in it of certain germs which might be harmful to its flavor.

If, then, it be kept clearly in mind that bacteria have their definite food requirements, their characteristic excreta, solid, liquid, and gaseous, their enemies and their poisons, one is prepared to comprehend a great variety of technical, hygienic, surgical, medical, agricultural and other natural facts, which, until the behavior of bacteria was known, could scarcely be explained.

Disease-producing bacteria. There may now be examined the habits of some forms of bacteria in each of the groups named above. In Minnesota there must be two or three hundred different kinds of bacteria. New varieties are being discovered, one might say, every day, and no doubt a great number still await investigation. But of the disease-producing group there are some with which men are unfortunately only too familiar. I may name three of especial interest, and valuable in the illustration of different points. The diseases known as consumption or tuberculosis, typhoid fever and smallpox are certainly produced in the human body by three distinct species of bacteria, known respectively as consumption-bacteria, typhus-bacteria and smallpox-bacteria. The contraction of any of these diseases does not necessarily follow the entrance into the body of the bacteria, for, in the first place the bacteria may enter in a weak, non-virulent condition; in the second place, they may be destroyed in the body in a great variety of ways before they can develop and multiply sufficiently to do any harm; in the third place, they may find the body in a state which would prevent their nourishment so that they would die of their own accord. It is probably true that men frequently take into their bodies harmful germs, which, under the beautiful police-system of the blood, are snapped up by the white blood-corpuscles and destroyed before they can accomplish any mischief by their poison-secreting habits. That condition of the body, in whatever way it should be explained, under which bacteria of a certain disease cannot grow, is called *immunity*, and immunity may be apparently either inherited or acquired. Immunity to yellow fever seems to be inherited by certain classes of people living in the tropics, but it may be acquired by persons born outside the tropics after they have passed through the experience of acclimatization.

Contagious, infectious and invasive diseases. If, however, one is not immune to consumption, typhus or smallpox, and the germs of one of these diseases enter his system, and multiply too rapidly for the white blood-corpuscles to destroy them, then very soon what are termed the symptoms of the disease begin to appear and the patient *has* the disease, or rather, the disease has him, for he is now the prey of an invading force of tiny fungus parasites. Here a distinction must be made between three types of bacterial disease which affect animals, and are known as contagious, infectious and invasive diseases. A *contagious* disease is caused by a germ which can ordinarily live only in the body of the diseased animal or in that of some closely related form. An *infectious* disease is caused by a germ which may feed and develop in the body of the animal, but habitually feeds and develops in not-living substances, such as sewage, river-water or the soil. Both varieties of germ are alike in one respect, that they poison the body, for they secrete into it certain substances known under the general name of *ptomaines*, comparable as has been before said, to snake, alkaloid or albuminoid poisons. An *invasive* disease is produced by the development, in the body, of a germ which though not violently poisonous yet causes disease through the multiplication of the bacterium itself. Smallpox is an example of a contagious, typhoid fever of an infectious, and lumpy-jaw in cattle of an invasive disease, though the germ which causes the latter is scarcely a true bacterium. The cow with lumpy-jaw has the tongue and jaw leavened by the germ much as though they were loaves of bread, but the animal is not seriously poisoned and does not generally perish as quickly as does an animal when attacked by some fatal infectious or contagious disease like Texas fever, anthrax or hog-cholera.

Quarantine and sanitation. It is apparent that between contagious and infectious diseases—the one produced by what is called an obligatory parasite and the other by what is termed a facultative parasite—demand widely different hygienic methods of prevention. Against contagious diseases quarantine is the great preventive, for if the person who is diseased can be kept by himself others will not be affected. Against infectious disease hygiene is the great preventive, including here especially what is known as sanitation. When one knows that dangerous germs such as those of typhoid fever may develop and multiply in garbage heaps, in sewage, in unfiltered river water, in neglected reservoirs, in badly prepared foods and stale fruits, he understands the importance of removing his garbage, attending to his sewage, boiling his water and taking heed to his kitchen, his ice-box and his diet. All the methods of modern quarantine and sanitation are intelligently prosecuted in the light of an increasing knowledge of bacterial lives and habits.

Inoculation and vaccination. Passing from simple preventive measures to somewhat more complicated procedure it becomes necessary to consider the processes known as inoculation and vaccination. *Inoculation* is a name given to the intentional and actual transference of the germs of a disease to the body, and this under such conditions of general health that it is hoped the patient may contract the disease, become acclimated to it, so to speak, and thus avoid it at a time when his physical state might not be so favorable to withstand it. In the old days this means was adopted to diminish the mortality from smallpox and is still practiced in China. *Vaccination* is a name given to the injection, into the body, of a mild form of disease-bacteria; because when the body thus becomes acclimated it is more resistent to the virulent form. The remarkable discovery of Jenner that cow-pox was a mild form of smallpox, and that after vaccination had "taken," as the saying is, one would not then easily contract the malignant disease, was the precursor of other types of vaccination, such as those of Pasteur, who vaccinated successfully with mild anthrax and mild hydrophobia, thus rendering the vaccinated individual immune to the more virulent types of these maladies.

Koch's lymph. Quite a different attempt to control such a disease as consumption was that of Koch, whose famous lymph, a few years ago, was much exploited in newspapers and periodicals. It had been known for some time that the bacteria of consumption could be cultivated outside the human body upon a variety of substances such, for example, as beef-broth jelly. Cultures of the consumption germ were made in this way by Koch, and by means of glycerine an extract of their poison was prepared. The extract of poison was then injected into the body—a very different process from vaccination, because in that case the germs themselves are placed in the body of the patient. It had been observed that the consumption bacteria, like other sorts, produced around the patches where they grew, excreta to such an extent that they poisoned the tissues of the body and limited the growth of their own colonies, which were unable to absorb food from the poisoned tissue. Thus is explained the habit of the consumption-germ of making tubercles in the lungs. It was Koch's idea that he could, by means of his lymph, poison the lung-tissues artificially, not enough to kill the patient, but enough to prevent the bacteria from developing. In this effort he was not entirely successful.

Serum therapy. Another and more hopeful method of combatting infectious and contagious diseases after they have begun to develop in the patient, is supplied by the process known as *serum therapy.* In order to understand this it must be noticed that the relation between bacteria and an animal which they are infesting is reciprocal. Just as *they* poison the organism so do certain compounds in the blood-serum poison *them.* The substances generated in the blood and poisonous to bacteria are known technically as anti-toxins. Now acclimatization to germ diseases seems to be in part, at least, due to a development of anti-toxins in the blood-serum—that is, in the watery part of the blood in which the corpuscles are suspended. So if a horse or other animal be acclimated to a disease—diphtheria, for example,—and then the serum from such an animal be injected into the veins of a patient suffering from the disease in question, a supply of anti-toxins is put in a position where it can poison the disease germs. This treatment, indeed, has been reported as successful for diphtheria—so much so, that if proper serum is quickly obtainable, even a malignant case, taken in its early stages, can be combatted. A time may be expected when anti-toxins will have been discovered for all of the dangerous germ diseases which kill annually so many hundreds of thousands of the human race. Serum-therapy may be described as a sudden acclimatization of the blood through the injection of acclimated serum from another animal, and it is exactly comparable to the use of antidotes for ordinary cases of poisoning. The antidote, however, is taken directly into the blood and not into the stomach.

Diseases of animals and plants. Not only are men subject to a large number of bacterial diseases, but also domestic animals, birds, fish, tiny water insects and crustaceans, or even plants—and among the latter should not be omitted the bacteria themselves, for it is well-known that some varieties are so inimical to others that they may produce a growth which will destroy the original colony. Plant bacterial diseases, such as pear-blight, potato-scab, cucumber-rot and carnation-blight are not uncommon in Minnesota and considerable damage results from their activity. No highly effective methods of combatting them have as yet been devised. Plant-quarantine against infected plants, plant-hygiene and sanitation and the selection of resistant varieties represent about the extent of modern treatment.

Bacteria of putrifaction. Among the ferment-producing bacteria, those which convert organic substances into compounds of which butyric acid is an important member, are concerned in the processes known under the general name of putrifaction. Sometimes it is advantageous to distinguish between putrifaction and decay, both of which may be bacterial in their origin. When an organic mass putrifies it gives off offensive odors, but it may decay without such odors becoming noticeable. The offensive stench of putrifaction indicates that butyric fermentation is taking place and this is produced by bacteria which work in the absence of the free oxygen of the air. But the modification of organic bodies, known as decay, proceeds when there is an abundant supply of free oxygen for the bacteria. It should be noted, however, that some forms of bacteria are unable to live in the presence of free oxygen, while others are as dependent upon its presence. The odor of putrifaction towards which all have a feeling of repulsion, just as towards a snake lying coiled in the grass, is caused by volatile ethers or ill-smelling gases emanating from the putrifying mass. Such characteristic odors are instinctively recognized by the human race as indicative of danger—in this case due to the presence of bacteria. In themselves, it is difficult to understand how one odor should be preferred to another, but experience has taught to some extent what odors may be presages of danger and what may not, hence that natural repulsion when one is brought into contact with those useful and necessary changes by which dead bodies are converted into materials which can be used again in the round of life.

Canning of fruits and other technical processes. Various technical processes involve a control of the germs of putrifaction. Among many examples is the canning of fruits, meats and vegetables, where heat is applied to destroy the bacteria and the substances are then sealed up in such a manner that bacteria cannot gain ingress. Milk, too, is sterilized or Pasteurized, and preserved in bottles, a process in which heat may be used, or chemicals, notably boracic acid. Other processes dependent upon the exclusion of putrifying bacteria, are the salting of meat and fish, as when corned beef is prepared in vats of brine, the smoking of fish practiced by the Indians in Minnesota, as well as by the whites, the smoking and drying of meats, and all those in which cold is used as a preservative.

The refrigerator cars and cold-storage warehouses which are such important features of modern civilization, making it possible for Minnesota dressed beef and dairy products to be shipped even across the waters of the Atlantic, are purely devices for limiting the growth of putrifactive bacteria by keeping the temperature below a point where they can develop.

Bacteria in tobacco-curing. In the general group of putrifactive fermentive processes should be mentioned one or two which are not precisely like the others. For example, the "flavor" of tobacco and cigars is largely due to certain waste products of bacteria grown upon the tobacco while it is being cured. The difference between a "good" cigar and a "bad" cigar lies principally in the curing of the tobacco from which it is manufactured, and that is an operation in which bacteria take part. A technical method has even been devised by which the Havana bacteria have been cultivated, and it has already been applied upon a small scale to tobacco-curing in Germany. As a result of this process German tobacco, not at all the best, was converted into qualities which could not be detected by experienced smokers from the genuine Havana.

Tanning and retting bacteria. The tanning of hides is another industry which is dependent upon the action of bacteria, and likewise the separation of hemp and flax fibres in the vats where they are macerated.

Bacteria in the dairy. None of these processes is so important to Minnesotans as those of yet another line of industry in which bacteria play a necessary and extraordinary part. I mean the dairy industries, for the successful production of the best butter and cheese is as essentially dependent as is brewing upon the proper control of bacteria. Even the "June flavor" of butter has been artificially produced by careful control of its bacterial content, while in one word, the difference between the various brands of cheese, with few exceptions, lies in their bacterial flora. Edam, Neufchâtel, Gorgonzola, Camembert and Roquefort cheeses—distinct from each other in consistency, flavor, and odor—largely depend for these qualities upon separate kinds of bacteria, which easily appear in the "natural home" of each kind of cheese, because under such conditions of climate and soil they may be produced in cheese without artificial inoculation. But a cheese made in Minnesota may be inoculated with Edam germs or Brie germs, and if the control of its manufacture were as perfect as that which has been attained through the researches of Pasteur in the brewing industry, there would be little difficulty in sending out such choice products from any dairy in the world. Indeed, in Denmark, where dairy industries have reached such high perfection, pure cultures of Edam bacteria can be everywhere obtained and Edam cheeses can be manufactured at will. The flavor of the cheese and its odor come largely from ethers which are the result of bacterial activity. Since certain bacteria produce certain ethers, it is evidently necessary to keep careful control over the growth in the cheese and through failure to do this, highly offensive odors are exhaled by the cheeses of careless dairymen. This results from putrifactive germs gaining ingress to the mass and such cheeses, without straining the language, may be called diseased. A peculiar form of diseased cheese is the *blown* cheese in which gas-forming bacteria produce bubbles large enough to destroy the proper texture of the mass. Cheese may also be soured by the presence of lactic-fermenting bacteria, as well as by offensively-scented and undesirable butyric forms.

Ripening of cheese. One is now in a position to understand the various processes described as the ripening of cheese. After the cheese has been set away to ripen, and during this process, there is opportunity for the growth of desirable bacteria and moulds—for some kinds of cheese such as Stilton, are dependent for their flavors largely upon mould. When a dairy is manufacturing bad cheese it is evident that the "sanitation" has been poor, or that quarantine methods should have been adopted against offensive germs. Hence it is easy to understand how necessary is cleanliness in the dairy, for the practice of cleanliness includes both quarantine and sanitation.

Diseases of butter. All that has been said about cheese applies equally to butter, for the flavor of this product, including both its taste and odor, is dependent upon bacterial activity. Diseases of butter exist—of which rancid butter may serve as an illustration.

Diseases of eggs, bread, milk and cigars. Many other articles of food or stimulants may be diseased in the sense in which this term has been applied to cheese and butter. Eggs, for example, while still in the body of the fowl, may become infected with bacteria, and unless used within a short time after they are laid they become stale or bad. The extremely bad smell of an egg which has putrified is of bacterial origin and it is the same little plants which are the sources of the gas that causes the bad egg to explode when cracked. Bread, too, is sometimes affected with diseases through which it becomes sticky or ropy, and milk has a peculiar tendency to bacterial contamination. Milk that gradually turns blue upon standing, or that gradually turns red, or becomes filled with mucus, or that sours, or that curdles, or that gives off offensive odors, is generally affected by some disease. The so-called "turnip odor" of milk, popularly attributed to the cow having eaten turnips, is more often of bacterial origin than connected in any way with turnip roots. Tobacco is generally diseased and the singularly bad cigars which are everywhere encountered should be regarded as the proper prey of germs and be made objects of quarantine.

Diseases of meat, cheese, vegetables and ice-cream. Diseased canned meats, cheese, vegetables and ice-cream, not infrequently cause death to persons eating them, because such materials sometimes furnish a medium for the growth of bacteria that secrete dangerous poisons.

Milk-souring bacteria. The ferment-producing bacteria which have been hitherto noticed may be classed under the general head of butyric-acid ferment-producing germs. Another group of ferment-producing germs are those which occasion the composition of lactic acid. This was probably one of the first acids known to the human race, for the shepherds of pre-historic days, when their milk turned sour, were observing the result of lactic acid fermentation initiated by specific germs. To-day the souring of cream and milk may be brought about artificially in the dairy. Most butter-eaters prefer sour-cream butters, that is, butter made from cream a little soured. Just as it is now possible immediately to separate the cream from the milk by centrifugal machines, without waiting for it to rise, so is it possible to sour it by inoculation with lactic acid germs without waiting for spontaneous infection from the atmosphere. Milks and creams soured artificially are used in a number of dairies.

Fermented milk. Together with yeasts, there are lactic-acid fermenting bacteria employed in the manufacture of the fermented liquor made in the region of the Caucasus from goat's milk and known as kephir. In Minnesota, while the souring of milk is a natural phenomenon which has been observed by all, I am not aware that fermented milks are commonly produced.

Milk-curdling bacteria. Different from the souring of milk is its curdling, which takes place when rennet is placed in it. Rennet types of fermentation may be initiated by bacteria, although a more common source of rennet is the calf's stomach.

Souring of wine, beer, bread and ensilage. Lactic types of bacteria are not only common in milk but in wines and beers, so that in the brewing industry some sorts of souring which beer undergoes arise from lactic-acid germs, while others are due to vinegar-fermentation. The souring of bread by lactic fermentation is not unknown and in the souring of ensilage and fodder the activity of these bacteria is ordinary.

Vinegar-bacteria. Still another type of fermentation is the vinegar-fermentation by which sugars, such as those of sweet cider, are converted into acetic acid, commonly known as vinegar. In the manufacture of vinegar the activity of these bacteria is utilized and upon their growth depends every art in which vinegar is employed. Acetic acid ferments may originate also in beers and wines, in breads, and sometimes in fruit-jellies. The bacteria which produce the ferments are not all of the same sort but are of several different kinds.

Antiseptic surgery. One very important special technical process is largely dependent upon the control of various fermentive bacteria, namely, antiseptic surgery. The precautions which the surgeons take in entering upon an important operation, are intended to prevent the ingress of putrifactive or other fermentive bacteria into the wound through the operation. Hence the carbolic-acid-spray, the heating of the knives, lint, bandages and sponges, the dress devised to catch as little dust as possible, the cleanliness of all utensils, and the frequent illumination of the operating room in good hospitals by sunlight. With the success of antiseptic methods it has been discovered that pus or "matter," as it is popularly termed, is not an unavoidable concomitant of wound-healing. Wounds not of surgical origin, such as bullet-wounds, commonly undergo bacterial infection after which pus forms and, in serious cases, blood poisoning may follow. With the increase of humanitarian methods in warfare the time may come when sterilization of bayonets and swords will be insisted upon under the laws of nations, thus diminishing the mortality from wounds in battle. To-day, unless it were for the modern knowledge of bacteria and their habits, surgery would be as rough and ready and generally fatal as it was a hundred years ago.

Light-producing bacteria. Regarding light-producing and heat-producing bacteria there is little necessity to add anything to a mere mention of their occurrence in the state. It is true no ocean bounds the Minnesota of to-day and glows during the activities of light-producing bacteria, but sometimes upon rotten logs or upon damp places in the forest a faint phosphorescence is visible which may be attributed to the presence of light-producing germs. This power of illumination, however, exists in some higher fungi, so one cannot be sure that the dim radiance of decayed logs in the forest is due to bacteria unless a careful examination be made.

Heat-producing bacteria. The heat-producing bacteria, while they are, like all the rest, invisible, are known by their works, and their peculiar habits are tacitly recognized by the insurance companies which send inspectors to see that cotton wastes and refuse are not allowed to accumulate where they might be ignited by "spontaneous combustion." The impression should not be received that all forms of spontaneous combustion are of bacterial origin. Some are, however, and the power which bacteria of this kind have of raising the temperature in a mass where they are growing has been clearly demonstrated.

Color-producing bacteria. Turning now to the examination of color-producing bacteria much might be said, for this is a group of considerable interest and importance. In the middle ages and in regions where science has not yet dispelled the clouds of ignorance and superstition, many men have lost their lives on account of the appearance of red bacteria that excited the fears of those who saw them. The phenomenon of "blood-spots" on linen which has been lying in damp places, or upon bread or food-materials, is often due to the growth of bacteria with the power of secreting a red dye. When such spots appeared, very naturally, upon sacramental bread in the churches and monasteries of the Middle Ages, it was regarded as an extremely bad omen, and this same phenomenon in earlier times and in older civilizations was no less terrifying. Many an unfortunate man or woman has been seized and put to the torture on account of these red bacteria, and even yet their presence is regarded with superstitious horror in most parts of the world. Besides the red forms there are those capable of producing blue, pink and yellow dyes which are alike conspicuous. Such growths will appear "spontaneously," developing from atmospheric germs, upon the surface of steamed potatoes kept in moist places where they occur as more or less flattened hemispherical drops of colored slime. If a bit of slime is placed under a powerful lens it will be discovered to consist of unnumbered millions of tiny bacterial cells, imbedded in a common jelly of their own secretion. The shapes which such little masses of bacteria take when growing upon a steamed potato, or a piece of bread, may be compared with the tubercles formed in the lungs in cases of consumption. The mass of bacteria becomes inclosed, as it were, within a shell of its own excrement and may be thus prevented from extending uniformly and continuously over the surface of the potato.

Purple bacteria. One very remarkable kind of color-bacteria deserves especial notice since it is an exception under the general definition of fungi given above. Such bacteria are known as purple bacteria and they have the ability to develop in a thin layer just inside their cell-walls, a remarkable organic substance known as *bacterial purple*. It has been found that germs provided with bacterial purple in their cells are able to assimilate carbonic-acid-gas in the dark as well as in the light. The number of such germs is small, but they are of extraordinary interest because their behavior is similar to that of green plants which decompose carbonic-acid-gas in sunlight or under the electric arc, using the products in starch-manufacture. Bacteria with bacterial purple are, therefore, independently nourished plants in very much the same sense that green plants are, and they can use in their nutrition much the same simple food substances which will suffice for plants with leaf-green. It is not clear why bacterial-purple is limited to so small a number of tiny and lowly organisms, while leaf-green, which does much the same kind of work, is present in almost all of the types of higher vegetable life.

Nitrogen bacteria. Among the bacteria described as nitrifying, there are two principal classes, those which live in the soil or water, and those which associate themselves with higher plants, forming a chemical partnership that suggests, a little, the arrangement between the lichen fungus and its algal mate. Nitrifying germs which live independently in the soil or water have apparently the power of producing chemical changes, as a result of which the nitrogen of the air, or of ammonial compounds, is combined with minerals in such a way as to produce the nitrogen salts called nitrates or nitrites. Bacteria of this character are found in guano beds, and the ripening of guano into the high grade of fertilizing material, which it is known to be, must be attributed to the presence of nitrifying and de-nitrifying bacteria. Germs of this general group are found in Minnesota in old manure piles, and in other masses of decaying animal substances as well as in ordinary loam.

Bacteria on clover roots. Still more interesting are the nitrifying bacteria which join forces with higher plants and develop a nitrogen-fixing mechanism. If one pulls up by the roots the first patch of clover which he sees, and then carefully washes out the soil and examines the rootlets, he will discover upon many of them little irregular nodules the size of a pinhead. Upon cutting open one of these nodules and applying a suitable magnification it would be seen that the swelling on the root was caused by the growth in its tissues at that point of a colony of nitrifying bacteria. Apparently the presence of these bacteria is recognized by the plant as desirable, for an apparatus known as infection-threads is produced in the root-substance of the clover and prolonged into some of the root-hairs. Root-hairs, with infection-threads, pick up from the soil the nitrifying germs and these are then led back along the threads to the inner tissues where they develop and multiply in the nodules. A plant like clover, possessing such nodules, grows very much more vigorously than one without them and certain interesting agricultural experiments have illustrated this fact. In Alabama, for example, clover grown under conditions where the nodules could not form, produced only about one-sixth as much fodder to the acre as did the same kind of clover when grown in such a way that the nodules could develop. All kinds of peas, beans, alfalfas, clovers, vetches and other pod-producing plants, are capable of producing bacterial nodules. They will not form them if planted in a soil where no bacteria of the proper kind exist and this is a reason why clover crops fail to do well in certain regions where the conditions seem outwardly favorable. In Germany some laboratories have produced cultures of nodule-forming bacteria, which they supply to farmers under the trade name of *nitragin*. If, now, a soil in which nodules would ordinarily develop poorly, is inoculated with nitragin, the clover, pea or bean crop will grow with double, triple or quadruple vigor. Agriculturists may reasonably look forward to a period when the soil will be regularly inoculated for a variety of crops just as cheeses are inoculated for a variety of flavors. For these remarkable facts the explanation is not far to seek. During their life-processes the bacteria are able to fix the nitrogen of the atmosphere and develop nitrogen salts. But these nitrates and nitrites are precisely what the higher plant demands in its nutrition and it seizes and assimilates them. What is for the bacterium a waste-product is for the clover a food-product. In return for a supply of nitrogen salts developed and delivered in its root area, the clover affords protection to the bacteria against desiccation and supplies them with certain of its waste products for use in the bacterial economy. It is a striking fact that after a crop of clover with nodules has been harvested there are more nitrates and nitrites left in the soil than there were when the crop began to grow, and this, too, notwithstanding that clovers use themselves a considerable quantity of these salts.

Bacteria and crop-rotation. From the facts above presented it is possible to understand how the technical process familiar to farmers and known as "crop rotation" is at bottom bacterial. After nitrates or nitrites have been exhausted by the growth of cereal crops, or root-crops, such as turnips or sugar beets, the soil may be replenished and invigorated by the growth of some pulse crop, such as beans, peas or clover. It would be a great triumph of agricultural science if enough could be learned about the nodule-bacteria and their habits to train them to grow upon wheat, oats, barley or rye. The problem of the world's food supply would then be solved, for every cereal crop under such circumstances would "do its own rotating" and instead of impoverishing the soil the crop taken from it would leave it in a better condition than before. It is true, plants demand a variety of other substances in their nutrition than salts of nitrogen, but these are the only substances which are not present everywhere in almost unlimited quantities. Silicon, sulphur, phosphorus, calcium, potassium, iron, oxygen, hydrogen and carbon and the other elements appropriated by plants in their food-economy can usually be delivered in adequate quantities and in assimilable form. The peculiar inability of green plants to make any use of atmospheric nitrogen would in a few generations put an end to all plant and animal life on the globe were it not for the activity of nitrifying germs in the soil and water. Through the agency of these the store of nitrogen salts, from which plants can absorb the nitrogen they need, is constantly replenished and the successive generations of life are permitted to continue on the earth.

Other root-tubercle bacteria. Plants of the pea family are not the only ones that develop root nodules containing nitrifying bacteria, for such nodules are also produced upon alders and upon a plant related to the buffalo-berries of the western Minnesota prairie. Since these plants are not cultivated in fields their root-nodules are of less economic importance to the agriculturist.

Bacteria of urine. Of quite a different class from those just treated are the de-nitrifying bacteria which play an important part in the economy of nature by their ability to decompose urea. It is generally known that urea is the ordinary form of nitrogenous waste material excreted from the animal body, but this substance while a compound of nitrogen is not available for the nourishment of green plants until it is decomposed and recombined into nitrogen salts. The decomposition of urea, wherever it occurs, is ordinarily accomplished by the activity of de-nitrifying germs. As a result of their action, ammonia appears and this, again further reduced in complexity, may liberate free nitrogen to the atmosphere of the soil—and it is to be understood that ordinary soil contains a considerable amount of such gaseous material together with oxygen and carbonic-acid.

Sulphur bacteria. The sulphur and iron bacteria are of some economic importance from their growth in mineral springs. Sulphur bacteria, when present, occasion an odor of decaying eggs, revealing the presence of a gas known as sulphuretted hydrogen. During their nutrition granules of sulphur are deposited in their cells and they form a stage in that round of life in which sulphur waste products are given off by animals, then are broken up with the production of sulphur granules in the bacteria, which upon the death of the germ may be re-combined into sulphur salts and in this condition may again be used by green plants for food. Animals, then, directly as do the herb-devouring species and indirectly as do the flesh-devouring forms, make use of the substances produced by green plants and the waste is again begun and the process repeated.

Iron bacteria and iron-ores. Iron bacteria form iron precipitates where they grow and assist in the rusting of iron in some parts of the world. They frequently extract iron-rust from the waters of springs and form flocculent red masses of the oxide. There is reason to suppose that the masses of iron-ore in Northern Minnesota upon the Mesaba range were deposited there by the activity of iron-bacteria, living in the warm waters of an ancient ocean. We may imagine such a primeval sea, hot like the geysers of the Yellowstone, its waters impregnated with iron and furnishing a splendid field for the peculiar activities of the iron-bacteria. Living in such an ocean for thousands of years, as they may have done, there is nothing unreasonable in attributing to them the deposits of iron ore which during these latter days are being mined for commercial purposes.

Manifold relations of bacteria to man. Enough has now been said about the bacteria of Minnesota to justify their appellation of most extraordinary plants. It seems inconceivable at first thought, that iron-mining, cheese-making, phosphorescence in the forest, the tanning of leather, the rotation of crops, the ripening of guano, the blight of pear-trees, epidemics of typhoid-fever, the souring of milk and the sacrifice of innocent people when blood-spots have appeared upon the shew-bread, should all be various results of bacterial growth. Such, however, is the fact, and the whole may be comprehended upon returning to the statement made in the opening of the chapter, that bacteria are plants needing various foods and forming a variety of waste products. The poisonous ptomaine produced by bacteria in ice-cream may cause the death of an entire picnic-party; the waste products of a bacterial population of some ancient ocean, aggregated in enormous quantities, may furnish work for thousands of miners and lie at the foundation of great modern industries.

In this brief account by no means all of the possibilities of bacterial habits and characters have been exhausted, but enough has been said to open up this most fascinating field of investigation and to show in what a multitude of ways bacteria touch human life.

Chapter XIV.

Mosses and Liverworts as Links Between the Algae and the Higher Plants.

The plants known as liverworts and mosses constitute a group intermediate between the algae and the ferns. They may be regarded as the descendants of algae which at some remote time in the past climbed slowly out of the water and established themselves upon the land. They still retain a number of algal characteristics, although they have naturally, on account of their terrestrial habitat, varied from the structural types which were characteristic of the algae themselves. As is generally the rule, it is during their early stages that they most resemble algae. All mosses and liverworts when first developed from their spores, in a great many ways recall the algae. This is especially true of the lower group of liverworts.

The mosses and liverworts, embracing some five or six hundred Minnesota species, are found for the most part in groups of large numbers of individuals, for they are essentially social. A moss-tuft at the base of some tree or in some crevice of the rocks consists of hundreds of moss plants growing very close together and possibly all derived from the propagation of a single original individual which had become established at that point. Many of them prefer moist places and some are entirely aquatic, floating freely in the water, or attached to pebbles at the bottom of the lake or stream. Under such conditions they might possibly be mistaken for algae. It is not, however, probable that these aquatic mosses or liverworts are the ones most closely related to the algae, although such a supposition would seem reasonable. On the contrary, they may rather be regarded as land forms which have returned to the water as a secondary adaptation; for in a careful study of the plant world it becomes evident that plants in the history of their development have changed their habitations more than once.

Mosses are abundant, too, in very dry localities and are found in little blackened tufts upon the bare surfaces of bowlders and cliffs. Many of them cling to the bark of trees occupying positions like those frequented by lichens. Some are found regularly at the bases of trees, the trunks of which serve as concentrators of moisture; for when the rains fall upon the twigs of trees many of the drops are conducted along the branches to the trunk of the tree and in this way the region around the base of the trunk becomes more moist than the soil at a little distance. Having taken advantage of this natural irrigation-system a variety of mosses frequent the bases of tree-trunks. The kinds which grow in such positions are in general different from those growing on moist cliffs or on dry bowlders, or in swamps, or mixed with grass along the road-side edge or in fields, or on hillsides.

Mosses and liverworts are distinguished from each other in a variety of ways. They unite in having a young stage which resembles the plant-body of the algae. Upon this buds are formed that develop into the mature moss or liverwort plant. Liverworts constitute a group of organisms more variable than the mosses. They show more types of structure and have been described as Nature's experiment-ground from which the higher plants have originated. Two groups of higher plants are conceived to be improvements of the liverwort stock. These are the mosses (a terminal group) and the club-mosses or Christmas-green plants which gave rise to the ferns and pines. Though they are of somewhat different degree, as well as of different kind of structure, the liverworts and mosses may well be considered together. Their habits and habitats are much the same. In most instances their general appearance is similar, though there are some liverworts which have the flat, prostrate, leaf-like appearance of certain lichens, quite different from the leafy-stemmed habit of the mosses.

Breeding habits and life-histories. All of these plants produce true eggs and spermatozoids. After fecundation, the egg develops into what is called a liverwort-fruit or moss-fruit. But such fruits are really independent organisms, and here one meets with that remarkable fact in the life of plants technically known as *alternation of generations*,—a phrase which means that each alternate generation in the life-history is made up of similar organisms, while the generations between, although similar to each other, are, in structure, entirely dissimilar to the alternating generations.

The life-history of a liverwort or moss is briefly as follows: Inside the capsules—those little urns which rise on their slender stalks above a moss-tuft — large numbers of spore-cells are produced, in little spherical sacs, four spores in each sac. The sacs lie loosely in the interior of the developing urn. When the urn is ripe the sacs will have all dissolved, the spores will have separated from each other and in the form of a fine powder lie loose and dry within the urn. In mosses, the urn in most instances has a lid which is thrown off and then the spores are free to sift out over the neck and are carried away to places favorable for their germination. The variety of ways in which mosses and liverworts arrange to scatter their spores at the most appropriate times for their well-being need not here be discussed, but later will be given some attention.

When one of the spores has found a place where the moisture is sufficient for its growth its wall breaks and almost always a green cell is protruded. In a few liverworts the spores divide internally into a little group of cells before their walls break, but in most species this is not common. The green cell grows and divides, building either a little flat plate of cells, reminding one of the flat, fresh-water-algae, or a branching thread, reminding one of some of the thread-algae. In any case not all of the plant-body of this young moss or liverwort is green. Some colorless threads are produced which serve as root-hairs for absorption and attachment. Such an immature moss or liverwort plant is called the first-stage of the moss. The first-stage may continue for some time and in a few little mosses it forms a green mass of creeping threads which covers on clay banks a considerable area. Usually, however, the first stage in both mosses and liverworts is comparatively small and transitory. In peat mosses it makes a difference in the structure of the first-stage whether the spores germinate in water or on land. When they germinate in water the first-stage has been known to take the form of a branching thread, but when they germinate on land, the first stage becomes a flattened plant-body half an inch or more in length, and one layer of cells in thickness.

If mosses proceeded no farther in their development than the first-stage, they would be regarded as algae; but there is the capacity in all of them to develop *branches* upon the first-stage, arising from little buds of cells. The branch which thus arises quickly takes the form of the mature moss or liverwort and is known as the second-stage, or mature stage of the sexual plant. Sometimes this mature stage is itself a flattened body as in those broad, forked, green plates which are found so commonly on the damp sides of ravines. More often the second-stage takes the form of a stem upon which are borne leaves. In liverworts this stem is almost invariably quite prostrate, bearing two rows of leaves, right and left, and a third row of scales on the under side. Liverworts of this sort are therefore called, in common parlance, scale-mosses.

In the moss division of the general group there are no forms in which the second-stage is a flat forking plate of tissue, but without exception the plant-body consists of a leafy stem, sometimes unbranched, while in other varieties it may be branched in a definite manner, often with some of the branches subordinated to others, building up a fern-like or tree-like branch-system. Very often this leaf-bearing branch-system in mosses stands more or less erect and then the leaves are generally arranged around the stems in spirals quite as in higher plants. In one

FIG. 39. A male moss plant. The spermaries are produced in clusters at the end of the stem. After Atkinson.

FIG. 40. A female moss plant. The egg-organs are inclosed in the tuft of leaves at the tip of the stem. After Atkinson.

variety of moss in Minnesota the stem is erect and there are but two rows of leaves, each with a peculiar crest on its mid-rib. When, on the other hand, moss stems are prostrate in habit there is commonly something in their leaf-arrangement or in their structure which indicates that they were not always prostrate but have adopted this position for some peculiar reason. But among the "scale-mosses"—those liverworts which bear leaves in two rows—there is nothing in the structure to suggest that they ever maintained an erect position. Therefore, it is possible to make this general distinction between mosses and liverworts; that liverworts are essentially prostrate plants and that mosses are essentially erect plants in some of which the prostrate habit of growth has been secondarily resumed.

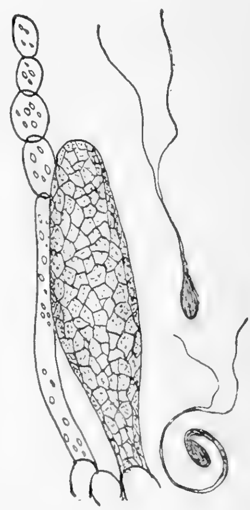


FIG. 41. The club-shaped spermary of a moss, much magnified, and two spermatozoids, very highly magnified. After Atkinson.

Of whatever sort the plant-body may be in the second-stage, it is always characterized by a variety of functions, of which the breeding-function may be regarded as the most important and secondary to that the nutritive. When mosses are about to breed they produce, in some species upon the same plant, in others upon neighboring plants—organs of two sorts. The male structures are commonly ovoid-cylindrical in shape, situated sometimes in little clusters at the ends of stems and surrounded by leaves of slightly different color, more purplish, yellowish, or reddish than the ordinary leaf. Along with these bodies, standing on their short stalks, there are ordinarily developed glandular hairs which serve to keep them moist by retaining a little water in their vicinity. Each ovoid organ consists of a layer of cells surrounding a central mass of small cells, several thousand in number. Each one of the small cells is capable of producing from the living substance of its interior, a single spermatozoid. When the whole organ is ripe, the end opposite the stalk opens, separates or dissolves and the cells of the interior are squeezed out. Their walls liquify and a horde of sperm-cells are liberated in the water which may have accumulated as dew or rain, or is, perhaps, the natural habitat of the plant. Each spermatozoid is provided with a pair of swimming threads by means of which it propels itself with great agility. Meanwhile upon the same plant, or upon neighboring plants of the same species, there have been developed egg-producing organs. These arise, mingled with glandular hairs upon the ends or surfaces of branches and consist at first of solid masses of cells, consisting of two well-marked areas, a spherical base and a slender neck protruded outwardly. When the egg-producing organ is ripe, the cells at the end of the neck separate from each other and a central row of cells in the neck turns into mucilage and oozes out, leaving at the bottom a large egg-shaped cell now inclosed in an organ shaped like a bottle with a long, slender, hollow neck. The opening from the exterior down to the egg is produced by the transformation into mucilage of a row of cells as has been described.

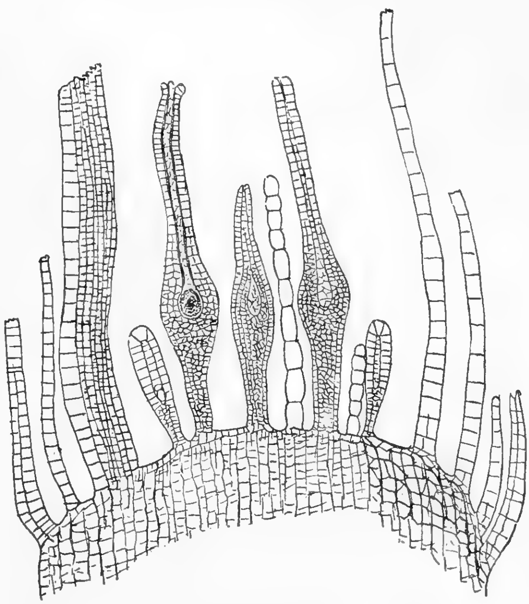


FIG. 42. Tip of a leafy moss plant, sectioned lengthwise and magnified. The flask-shaped egg-organs, one with an egg in place, are shown. These bodies are barely visible to the naked eye. After Atkinson.

Reproduction of mosses and liverworts. All mosses and liverworts produce sperms and eggs. Attracted in some manner by chemical substances dissolved in the water near the eggs, the spermatozoids find their way to the mouth of the egg-producing organ. They crowd into its neck, swimming down the canal which has been opened for them until they reach the egg lying at the bottom of the flask. One sperm more active than the others, or first upon the ground, buries itself in the substance of the egg, and immediately the egg forms around itself a membrane by which the ingress of other sperms is prevented. Such an egg is said to be *fecundated* and in a short time it divides by a cross-partition—in a direction perpendicular to the long axis of the bottle in all mosses and liverworts with the exception of the horned liverworts, in which the first partition is parallel with this axis. The egg now consists of two cells and this two-celled body is reasonably to be considered as the first-stage of the embryo-plant of the next generation. Such an embryo normally develops into a spore-producing capsule, provided in some species with a long and slender stalk, but in other varieties having only a short nub of sterile cells at the base. In the lowest family of the liverworts there is no stalk of any kind, but the entire matured product of the embryo becomes a little spherical capsule imbedded in the tissue of the sexual plant. Whatever may be its structure the capsule finally produces spores. The function of a moss or liverwort capsule may be described in brief as the production of as *many* and as *certainly germinable* spores as possible. In high types of moss-fruits the number of spores rises into the thousands, while in the lowest forms of liverwort-fruits, the number of spores runs from sixteen to sixtyfour.

What is meant by "alternating generations." It is evident that there exist, in the moss life-history, two plants alternating with each other. *One*, the sexual plant, has two phases, the immature or first-stage and the mature or second-stage. The first-stage does not, except in one kind of moss, produce the organs of sex, and in this peculiar moss it is not the egg-organs but the spermaries that are formed upon it. Therefore, one may describe the second-stage of the moss sexual plant as a *reproductive branch of the first-stage*. *The other*, the capsular plant of the life-history, is entirely devoid of sex, but is a spore-producing organism. This serves to illustrate one of the very remarkable differences between higher plants and higher animals. In higher animals a fecundated egg develops into an organism like one of those that coöperated in the production of the fecundated egg, thus the egg of a fowl develops into a fowl, and the egg of a fish into a fish; but the egg of the moss does not develop into an organism like the ones that coöperated in its production. On the contrary, it develops into an entirely different creature, in the body of which there may be produced some thousands of spore-cells and each one of these if planted under favorable conditions, may originate a new first-stage moss or liverwort plant. Upon one of the first-stages a great number of buds might then arise initiating the second-stage of the sexual form. Thus it is seen that while animals can generally derive but a single individual from a fecundated egg, mosses and liverworts—and higher plants still more strikingly—are able to bring into existence thousands of organisms from one egg. The only thing analogous to this in animals is the phenomenon of true or identical twinning. When twins are of precisely the same appearance and sex it is believed that they have developed by the two halves of the embryo in its youngest stage separating from each other. Each half, relieved from the pressure of the other, develops now respectively not into the right or left half of the body, as it normally would, but into a separate individual. If one can imagine, not twins nor quadruplets, but great numbers, even thousands of individuals to arise from a single animal's egg, he would have something comparable with the condition in plants which is known as alternation of generations.

The origin of the higher plants. In the light of what has been said it is apparent that the two alternating generations in the life-history of a moss or liverwort are not equivalent to each other, and one of them, the spore-producing generation, has no analogue in the life-history of those animals with which people are familiar. When, in the algae, an egg after fecundation, instead of developing at once into a new organism as an animal egg does, cuts itself in two into a pair of spores, it has accomplished *normally* what happens *accidentally* in the case of true twins. It seems that what is an accident among animals became the rule in the plant world; so in other algae the number of spores thus developed from a fecundated egg was increased to four or even to eight in the sphere-alga. Then in a little alga, the disc-alga, which has been regarded as standing closest to liverworts, the number of spores was increased to sixteen; and for one fecundated egg, by this division into sixteen spores, the plant was able, perhaps, to secure sixteen new individuals, provided that all the spores found the opportunity of germination. Such little clumps of spores, originating by the partition of a fecundated egg, then underwent a division of labor, so that the superficial spore-mother-cells acquired the character of capsule-wall-cells and did not ordinarily retain the power of spore-production. This was in order to protect the cells of the interior, which remained as true spore-forming cells, and there is, in such an instance, a fundamental peripheral sterilization of the spore-mass, so that it comes to consist centrally of *functional* spore-mother-cells while *sterilized* spore-mother-cells take the character of wall tissue. Really, by this time, a new kind of organism has come into existence, something entirely unlike anything in ordinary animal life-histories.

The new organism, beginning thus simply as a mass of spores, then in higher types assuming the form of a mass of spores enclosed in a wall, underwent further improvement in other families of liverworts and mosses until finally it became a large capsule with long slender stalk, several layers of wall cells and a supporting column of sterile cells running up the middle. By means of such improvements the possible number of spores was increased and they were better managed by the plant; for when the spores of a moss are distributed from a capsule on a tall slender stalk they will fall farther on every side, thus obtaining more favorable chances of persistence than if scattered from a short-stalked capsule.

To the philosophical botanist this profound need of counterbalancing the unfavorable conditions of the environment suggests itself as the occasion of *erect habit* in herbs, shrubs and trees. By maintaining the erect position plants can also enjoy better illumination; but it may be safely assumed, for the reasons that have been given, that the erect position and the slender habit of growth of the moss-fruit, based as it is upon an instinctive effort to enlarge the opportunities of spores, is the precursor of all erect habits in the terrestrial spore-producing areas of plants,—and essentially all plant shoots *are* spore-producing areas. Pine trees, for example, develop pollen, a form of spores, in their little cones. Roots never develop spores, and may be regarded as derivatives of that original end of the capsular plant which was nearest the sexual plant and was not thrust up for the purpose of scattering the spores.

This further fact next presents itself for consideration: that among the higher plants, *all prostrate forms of stems are secondary;* for stems must originally have been erect, like the moss fruit-body. Thus it is not surprising to learn that the oldest forms of terrestrial plants were of the forest rather than of the prairie type. This, at least, is the conclusion that is reached upon a study of the most ancient plant-fossils preserved in the rocks.

Chapter XV.

Liverworts of Minnesota.

Mud-flat liverworts. The lowest family of liverworts is characterized by a flat and prostrate leafless plant-body, such as may be seen in the little circular forms growing upon mud-flats. These may be recognized as different from lichens of similar habit by their bright green color unmodified by any tint of gray or blue. They occur as discs an inch or so in diameter and are made up of forking flat stems seeming to radiate from a common centre. The upper side has a spongy look which is caused by the existence of air-chambers in the plant-body. At the edge of the disc are the ends of the forking branches and each of these is notched, while at the bottom of such notches lie the growing-points of the branches. The tip cells of a branch do not divide so fast as the older cells and thus the older parts protrude beyond the true tip. This explains why the tips of all the branches in this family of liverworts are notched.

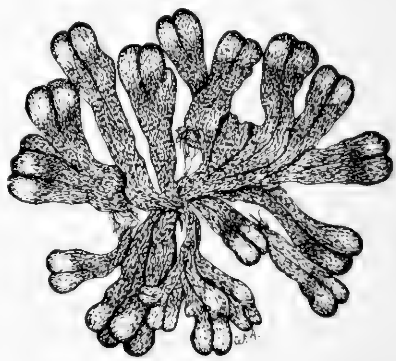


FIG. 43. Mud-flat liverwort, showing method of growth and branching. After Atkinson.

Floating liverworts. A close relative of the mud-flat liverwort, of which there are several different species in Minnesota, is the floating liverwort. The plant-bodies of this variety are found in ditches and small pools of water. Sometimes in lakes they are found entangled among the cat-tails and bulrushes along the water's edge. The plant consists of delicate forking branches of a bright green color, sometimes gathered together by the waves into masses as large as one's fist. The branches are ribbon-like and generally not more than a sixteenth of an inch wide, but they may be an inch or more in length. It is impossible to mistake this plant for an alga or for any form of duck-weed if one observes the notch at the tips of all the branches. The three-pronged duck-weed, which is often found with it, is a flowering plant and may be recognized by the convex ends of its little flat branches and the greater breadth of the stem in comparison with its extension.

Swimming liverworts. Another form of lower liverworts is the swimming liverwort, which might be mistaken for a duck-weed since it much resembles it in habit. It is its custom to float in large patches upon the surface of quiet pools. Each plant dangles from its underside a tuft of root hairs into the water thus obtaining special absorptive areas and counterpoises against being turned upside down by the wind. The swimming liverworts differ, however, from duck-weeds in being somewhat heart-shaped, on account of their terminal notch, while duck-weeds are rather oval discs or shaped something like little trefoils as they lie upon or in the water.

Cone-headed liverworts. The next higher family of liverworts has the same general character in the sexual generation which has been described for the mud-liverworts and their allies, but the plant-bodies are in many instances larger and more perfected. The cone-headed liverwort is an example of this group. It spreads out its broad forking branches of a dark green color upon logs, cliffs and bowlders in wet places. Its surface is marked by diamond-shaped areas in the centre of each of which is seen a whitish dome-like eminence not much larger than a pin-point. The width of a single branch is from a quarter to three-quarters of an inch while it may be several inches in length. On the under side are produced numerous root-hairs and tiny purple scales along the conspicuous mid-rib. When the cone-headed liverwort is fruiting, there will be observed during summer and autumn certain green cone-shaped branches close to the surface of the flat stem. In this condition they remain throughout the winter, but in early spring the stem of the cone-headed branch elongates into a pale stalk a couple of inches in height and about a sixteenth of an inch in diameter.

In two grooves along the stalk root-hairs are produced. The fruit-branch now resembles in outward appearance a small green-headed toadstool attached to the broad flat branch below. In the cone-headed liverwort there are, apparently, two kinds of branches, the ordinary vegetative and the special reproductive branches which bear the capsules. If one of the cone-heads be separated from the main stem in autumn or in early spring, it will be found that imbedded in the under side of the cone and surrounding the cavity about the stalk lies a ring of black capsules inclosed apparently in the tissue of the cone. The number of these capsules varies from three to eight, not usually exceeding the latter number. With the point of a pin they may be dissected out, if the little cones are handled with sufficient care and tact. Each capsule removed from the tissues which were surrounding it will be found to show over most of its surface a dull black color. But at the end, where the pear-shaped body was imbedded most deeply, for a little distance the color is green. With very great care, by the use of a sharp pin-point it is possible to remove an exterior membrane from the body which was dissected out of the cone-head and when this close outer membrane is separated a little object of a shiny black color, except at the pointed end where the color is bright green, will be obtained. If it has not been broken in the process of extraction it may now be split in the palm of the hand and a brown or blackish mass of spores and accessory cells may be removed from the interior. The shiny black capsule is the fruit-body developed from the liverwort egg and consists of a small, short green stalk or foot and a larger capsular portion, the whole constituting a slender pear-shaped object about a sixteenth of an inch in length.

In the cone-headed liverwort and in all its allies, mingled with the spores in each capsule, are certain very curious cells with microscopic spiral bands or hoops developed on the inner surfaces of their walls. These cells are of an elongated spindle-shape and their spiral bands are very sensitive to moisture. When placed under a powerful lens and moistened by the breath these cells writhe and struggle in a remarkable fashion, owing to the alternate shortening and lengthening of their spiral bands. The movement is not a vital one, but purely physical, like the warping of a plank, yet it serves a purpose in assisting the spores to escape from the capsule. By means of the writhing motion of these curious cells the spores are separated from each other and are not permitted, in the economy of the plant, to fall in an inert mass at one place.

In its stalked capsule and in the development of these *elaters*, as the writhing cells are called, the cone-headed liverwort marks an advance in its spore-producing generation over the mud-flat liverwort; for in that plant and its immediate allies the capsule had no stalk nor were there any elaters mingled with the spores. In the sexual generation of the cone-headed liverworts there exist a variety of other improvements in structure over the mud-flat species. The plant-body is much larger and more robust, the air-chambers are more regularly disposed, giving, as they shine through the skin of the plant, the diamond-shaped marking to the surface. Each air chamber has a central dome of colorless cells and in the middle of each dome there is an opening or air-pore which serves as an aperture through which an interchange of gases may take place between the starch-making cells that line the chamber—where they are best displayed on its floor—and the outer air.

Another improvement is observed in the production of special branches with cone-shaped heads for the development of the egg-producing organs. In the mud-flat liverwort neither these nor the spermaries were formed on branches differing in any important respect from the ordinary branches. Therefore, in the mud-flat liverwort when the egg had developed into an embryo the spore-producing capsule found itself imbedded in the general tissues of the sexual plant, and was not able to distribute its spores until the stem had decayed. But in the cone-headed liverwort with its special branches, the egg-producing organs, when their eggs had been matured, fecundated and developed into embryos, were all lifted up into the air a couple of inches or so by the elongation of the slender special stem. By this means the ring of capsules on the under side of the cone-head gain an opportunity to scatter their spores over a much wider circle, thus adding to their chances of germination and growth. In order to eject the spores the tiny green stalk of the capsular plant elongates a little just before the capsule opens, thrusting the end of the capsule out beyond the rim of the cone. In this way each capsule scatters its spores under much more advantageous conditions than were possible for the mud-flat liverwort.

The spermaries in the cone-headed liverwort are produced upon short blunt branches arising at the tips of ordinary

FIG. 44. The umbrella-liverwort; showing the prostrate vegetative body, and the upright branches on which the egg-organs are borne, and where later the capsular plants will be found perching. After Atkinson.

branches, but seeming to grow upon their surface because they are somewhat displaced in the after-growth of the whole sexual plant-body. A cut made vertically through one of these spermary branches would show a large number of ovoid sperm-producing organs apparently imbedded in the general surface of their special branch.

Umbrella-liverworts. Related to the cone-headed liverwort is the umbrella-liverwort, growing in localities similar to those favored by the plant just described. The flat stem is a little smaller, usually not of so dark a green, with somewhat crumpled margins and less conspicuous diamond-shaped areas on the surface. In this species the special branch which bears the ring of capsular plants has a head shaped somewhat like an umbrella with thick ribs but without a covering. The branch bearing the spermaries is larger with broader top than in the cone-headed liverwort, and after the spermaries have opened to release their sperm cells the general spermary-bearing branch elongates.

Purple-edged liverworts. In still another liverwort related to the two described, the plant-body is still smaller, averaging about a quarter of an inch in width and an inch or two in length, but distinguished by the same flat prostrate habit of growth, the same notched branch tips and the same little diamond-shaped areas upon the upper surface. This, from the color of the margins of its flat branches, may be called the purple-margined liverwort. Its special erect stems are shorter and more delicate than in the varieties before mentioned. The head which bears the capsular plants is rather flat, of somewhat square outline, and usually supports but four of the spore-producing capsular plants of the life-history.

Besides these, which are among the commonest forms in the state, there are a few others related to them but less likely to be encountered.

Cuplets and gemmae of the umbrella-liverwort. The umbrella-liverwort just mentioned is remarkable among species native to Minnesota for its production of curious tiny propagative branches clustered together, a score or more in a group, at the bottoms of little cups from a sixteenth to an eighth of an inch in diameter and borne upon the upper surface of the sexual plant-body. These little cups have a bottom composed of a layer of cells some of which bulge out from the general surface and divide into a stalk- and a head-cell. The head-cell then produces a small convex organ shaped somewhat like a pair of watch crystals placed with their concave surfaces together and notched at the sides. Such bodies are called *gemmae*. They may be regarded as little two-forked branches modified by the pressure of their mates in the cup, into the bi-convex form which they have assumed. Growing among such gemmae at the bottom of the cup are a number of mucilage-hairs which produce a slime capable of swelling. By this, as soon as they mature, the gemmae are lifted from their stalks and hoisted over the edge of the cup. They are then carried away by rain-water, or by currents if the plant is living in a ditch, to other places suitable for the growth of umbrella-liverworts. It makes no difference which side of a gemma falls toward the ground. The under side, after the gemma has fallen into position, produces root-hairs which attach it to the soil and the upper side begins the development of air-chambers while the whole branch increases in size. In this manner the plant is abundantly propagated without the intervention of eggs, sperms or spores.

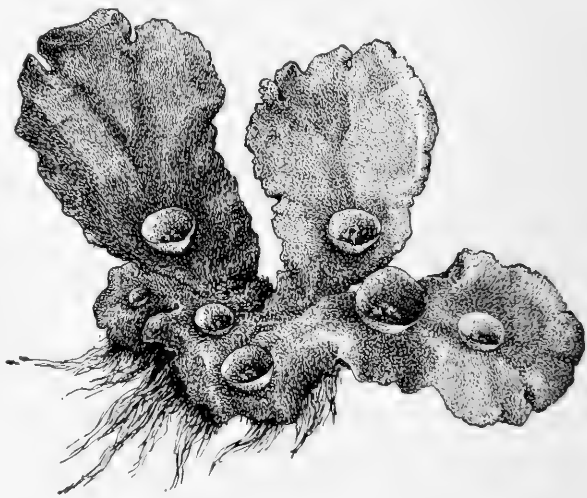


FIG. 45. Stem of the umbrella-liverwort, showing the little cups with bodies inside, which are employed by the plant for purposes of propagation. After Atkinson.

Another way in which liverworts propagate is much more antiquated than the gemma-method and probably suggests the origin of gemma-propagation. As the general plant-body grows and forks, the branches may become separated from each other by the dying away of parts behind the forks. Thus ordinary branches are isolated and if carried to a distance they may behave very much as gemmae do. Ordinarily, however, they remain attached to the soil and serve to propagate the plant only to adjacent portions of the sub-stratum. The gemmae may be regarded as tiny *portable* propagative branches and the apparatus for separating them from the floor of the cup in which they are produced may be regarded as a special improvement of the dying-away processes which served to separate the unmodified larger branches. The wall of the cup may be considered to be a protective layer of cells originating in earlier forms as a mere collar or ring and perfected in the umbrella-liverwort into the little cup or vase. Such small cups with their inclosed propagative bodies are the result of considerable improvement over earlier and cruder devices. In a liverwort known as the crescent-cup liverwort, the cup in which the gemmae occur is not circular in outline but is shaped like a crescent moon. Most liverworts do not produce such cups with gemmae growing from their bottoms, but are dependent rather upon their reproductive processes or upon the crude type of propagation in which ordinary branches separate from each other.

The liverworts which have been mentioned are related more or less closely to each other. They fall naturally into two series, a lower, in which the capsule has no stalk and a higher, in which very short stalks are developed that do not, however, elongate to any considerable degree in any of the species.

Horned liverworts. Quite a different kind is the horned liverwort, plants of which without doubt occur in all sections of Minnesota, but have been collected in but one or two localities. The sexual plant is a flat, somewhat irregular-shaped, green, prostrate stem devoid of leaves. It lies upon decaying timber or mud and forms circles which have not the bright, fresh green color of the mud-liverwort but are of a duller and darker hue. From the upper side of the plant-body spring slender horn-like projections which may become an inch or more in height. These horns are the capsular fruit-bodies of the plant and are developed from eggs produced in egg-organs imbedded in the upper surface of the flat green stem. It is a peculiarity of the capsular plant in this kind of liverwort that it never fully matures. It consists of a somewhat bulbous foot which is inclosed in the green prostrate stem and above the region of the foot are layers of cells which continue to divide, constantly forming new capsular tissue, so that the capsule may be said to grow from the base. The capsule consists of a wall, more than one layer of cells in thickness, and a central column of cells giving strength and support to the whole structure. Between the central column and the wall is the area where the spherical spore-mother-cells develop. Each of these is capable of forming its group of four spores. Mixed with the spore-mother-cells are some rather crude elaters which play their part in the distribution of the spores somewhat as did the more mechanically perfect elater-cells in the cone-headed liverwort and its allies. When the capsule of the horned liverwort is ripe, it splits longitudinally through its whole length and the two dry halves twist about each other and about the little column of the centre now exposed as a thread. By the twisting movement of the two halves of the capsule the distribution of the spores is facilitated.

This kind of liverwort is extraordinarily interesting to botanists because it seems to be a connecting link between the liverworts and the club-mosses. The horned liverwort differs considerably from the cone-headed liverworts, the mud-liverworts and their allies, in the character of its capsular plant. As will be seen from the description this is of higher structural rank. A greater proportion of its substance is sterilized, that is, not dedicated to the production of spores, while in the umbrella-liverwort the only sterile portion of the plant was the wall and the short stalk or foot. In the horned liverwort there exists in addition, a central column of cells making possible, by the support which it gives, the development of a much larger capsule containing many more spores. Furthermore, with its indeterminate growth the capsule continues and is not completed, as were simpler forms of capsular plants, after a certain definite number of cell divisions. In this capsular plant one observes the first tendency of such an organism to become perennial. In all other liverwort capsular plants there is aimed at, in the development, a definite and finished structure, and when the capsule has been once matured there is no further growth. Under such conditions it is not possible for a capsular plant to arise capable of maintaining itself from year to year. The horned liverworts do not really produce perennial capsular plants, but they indicate how in the asexual generation perennial plants might easily have originated; and it is believed that club-mosses are actually to be compared with such perennial capsules. While it is one of the rarer Minnesota liverworts, the horned variety is of peculiar interest and should be sought by amateurs in all parts of the state. It is very easily recognized by its peculiar habit. The only plants likely to be mistaken for it are certain kinds of reindeer moss in which similar slender horns are developed from a flat prostrate body. But these, like all lichens, can be easily distinguished by the gray or blue tint which is given to the plant by the fungus element. Besides, the erect horn-like bodies of the reindeer mosses do not split and are of course not capsules at all but erect portions of a fruit-body bearing little propagative granules over their surface or giving rise to superficial discs made up of sacs and sterile threads.

Leafy liverworts and their allies. The higher division of liverworts is represented in Minnesota by a considerable number of species. Some of them are very much like the lower forms in the habit of the vegetative body, while others are more moss-like, consisting of branched, prostrate leafy stems. These higher liverworts are divided into two series, those in which the plant-body is flat and leafless constituting one division and those in which a leafy stem is maintained constituting the other. All agree, however, in the general character of the capsular plant, and this, when it matures, stands erect upon the surface or at the tip of some branch of the vegetative plant. It is provided with a slender stalk which is usually of a translucent green tint, different in appearance from the brown or red stalks of most moss capsular plants. At the end of the pale green stalk is produced a black spherical capsule which, when ripe, generally splits from the tip, making four flaps that turn back to permit the escape of the spores and elater-cells. Plants classified as higher liverworts are often found upon the bark of trees or upon moist soil. When growing upon the smooth bark of the birch they make delicate green traceries, in their general appearance reminding one slightly of the sea-weeds. They do not form little tufts as mosses would in such positions but remain so tightly pressed to the surface upon which they grow that it is difficult to remove them without breaking their stems in pieces. In such liverworts it is not the stem of an egg-organ-bearing branch that elongates to assist the spores in their dissemination but the true stalk of the capsule, showing that the plant has developed in the spore-producing generation itself the structures requisite for assistance in spore-distribution. Unlike the horned liverworts, the capsules in this group, which are commonly spherical in form and considerably smaller, do not need and accordingly do not develop a central column of supporting tissue, but the entire cavity of the capsule is occupied by the spores and elaters.

A peculiar thing about the vegetative plant in many of the higher liverworts is the production of two lobes in the leaf, one of which is turned under the other. The one turned under and facing the lower side of the prostrate stem is sometimes modified into a little pitcher and is then called a *water-pocket* because it serves to retain moisture that in drouths the plant might find serviceable. In such little water-pockets on the under sides of certain liverwort leaves tiny worms often make their homes. It is difficult to see how they can be of any great advantage to the liverwort, but they are so invariably present in some species that there must be a partnership arrangement between the plant and the worms which dwell upon it. In the water-pockets, too, there are often found colonies of simple algae which avail themselves of the small drop of water to grow and develop. In certain exotic species the water-pocket becomes a trap which catches small insects, as bladderworts do.

A very great variety of leaf-forms characterizes the leafy liverworts. Sometimes the leaves are flat and scale-like, hence the name of *scale-mosses* which is commonly applied to plants of this group. Again the leaves are slender or dissected into fine teeth, and they may even become modified into little branching green bristles, which look quite unlike an ordinary leaf. In the tropics such leafy liverworts dispose themselves upon the leaves of larger flowering plants and often make characteristic patches of vegetation where there is an abundance of moisture. The greater number of kinds in Minnesota display themselves upon the bark or upon damp soil along with mosses from which they are not at first very easy to distinguish. They may be regarded as a special development of the liverwort type and among them are found the greatest variety of plant-bodies anywhere in the liverwort group, as well as the large majority of liverwort species.

None of the liverworts is of any particular economic importance, but they are all of great scientific interest on account of their intermediate position in form, structure and development between more primitive oceanic types of vegetation and later terrestrial types.

Chapter XVI.

Mosses of Minnesota.

The mosses may, like the ferns, be conceived to be the descendants of ancestral forms somewhat similar to the horned liverworts, although none of them are to-day very close in their structure and life-histories to that group of plants. All mosses are distinguished by the following peculiarities, in which they differ from liverworts. The second-stage of the vegetative sexual plant is in every instance a branched or unbranched, leaf-bearing stem. While it is sometimes prostrate in habit this position is an adaptive one and not original, as among the liverworts. Finally and most important, the young capsular plant before maturity always bursts the wall of the egg-organ in which it began to develop and never, like most liverwort capsular plants, matures while still within that membrane. A moss capsular plant is decidedly a creature of more complicated structure than a liverwort capsular plant and it consists, even in the simple forms, of a generally greater number of cells. There are, however, one or two mosses in which the capsular plants are greatly reduced in size, and these would scarcely come within the general rule.

Mosses have acquired the ability to live in much drier places than liverworts are accustomed to frequent, indicating their stronger adaptation to terrestrial life. While the rock-dwelling liverworts are found usually on moist cliffs or banks, it is not uncommon to find some mosses growing upon the driest bowlders, where a little crevice or hollow in the stone gives them a soil upon which their rootlets may work. Such mosses are generally of a blackish green color and look very crisp, crumbling easily if rubbed with the fingers. Yet in this condition they are not dead; for if moistened, they rapidly revivify and proceed with their functions of growth. Other mosses choose very wet localities. One variety, the river-moss, is a common aquatic plant in Minnesota, forming slender tufts of delicate leafy stems, attached to pebbles and rocks, on river-bottoms, in rapids or in pools. Besides this particular species of aquatic moss, there are a number of others which have the same habitat.

Peat-mosses. The peat-mosses belong to the lowest family and are in some instances aquatic. They are familiar objects in the tamarack swamps of Minnesota, where, if undisturbed, they may produce hemispherical patches usually of a gray

FIG. 46. Road across a peat-bog; tamaracks and birches in background. Near Grand Rapids. After photograph by Mr. Warren Pendergast.

color but often shaded with a purple, yellow or red, and rarely of a bright grass-green. They are peculiar for their power of absorbing water, and this they do by means of special water-reservoir cells which are mingled with the green cells of the leaves. Indeed the water-reservoir cells form the principal bulk of a peat-moss leaf, while the starch-making cells are disposed over them or between them in a delicate green network. The stems and branches, too, are covered with layers of such reservoir-cells so that if a tuft of peat-moss is wrung in the hands water can almost always be squeezed out as from a sponge.

The peat-moss vegetative plant consists of a central axis upon which are produced lateral leaf-bearing branches of two kinds. Some of them protrude at an angle from the axis and upon these the leaves contain leaf-green and are the starch-making areas of the plant. Others with pale leaves hang limply down along the axis, covering it and acting as conservators of moisture. The leaf-bearing branches commonly stand very close together forming a terminal tuft, and towards the end the axis itself is sometimes branched repeatedly. At the very tips of the branches, especially when they are young, a red or purple dye often stains the leaves and the surface-layers of the stem. This is a *warming-up* color and is useful as a device for raising the temperature around the delicate cells of the growing buds.

Formation of peat-bogs and coal. Peat-mosses are inherently social plants as are the rest of their group, and they often occupy large areas to the almost total exclusion of other kinds of plants, except certain cranberries and heaths, pitcher-plants, cotton-grasses and orchids which are to be sought in peat-bogs. Every year the axes of the plants increase in length and the older stems of former years sink lower into the bog. In this way the centre of bogs, especially those fed by springs, becomes often much higher than the circumference. Such raised peat-bogs have been studied in New Brunswick and occur also in St. Louis county, Minnesota. In such formations while one must ascend to pass from the edge to the centre, yet the texture of the bog becomes looser as the margin is left behind. When peat-moss has been growing thus for many centuries, filling what was once perhaps a lake, the remains of the old stems become matted together by the pressure of the heavy water-logged fresh areas above and after a time such a mass becomes compacted into what is known as peat—probably one of the stages in the production of coal. It is by no means certain that coal was developed from mosses like the living peat-mosses, but it is altogether certain that it originated in ancient swamps by the same general process which is to-day building the peat-bogs. So, somewhat as iron-bacteria deposited beds of iron ore in ancient warm oceans, mosses and other plants in the illimitable swamps of the coal age contributed their part to modern human industry.

Fruiting habits of peat-mosses. Peat-mosses are in such a favorable position for simple propagation by the development of branches which become separated from each other upon the death of the older portion of the stem, that they rarely fruit at all. Sometimes, however, whole bogs will be found in fruit at one time. The fruit-body is a little egg-shaped black capsule with bulbous base, the whole shaped somewhat like a dumb-bell with one end larger than the other and a short neck between. The smaller end of the dumb-bell is imbedded in the enlarged cushion-like tip of a slender, erect leafless branch of the vegetative plant. Around the bottom of the capsule may be found a thin broken membrane which is a relic of the wall of the egg-organ in which the capsule began its existence. Peat-moss capsules open by little circular lids which, when the capsule is ripe, separate from the bowl-part, allowing the spores to escape. It will be observed that for the elevation of the spores the same general contrivance is adopted by peat-mosses that appeared earlier in the umbrella-liverworts and their allies. The slender stem which lifts the capsule into the air is not a portion of the capsular plant as in the "scale-moss" liverworts and the other mosses; but, as in the umbrella-liverwort, it is a portion of the vegetative plant specialized for the purpose of elevating the capsule. When peat-moss spores germinate they develop under ordinary conditions a flat plate-like first-stage, but rarely this first-stage arises as a branching filament. The first-stage usually persists for weeks or even months, seldom, however, becoming very large and in no case exceeding an eighth of an inch or so in length. Upon the first-stage, buds form which mature into the ordinary peat-moss plants upon

FIG. 47. Peat-moss leafy-plants with capsular-plants imbedded at the tips of short leafless erect branches. After Atkinson.

which the microscopic organs of sex arise. The sperm-producing organs are spherical with long slender stalks and arise in the axils of the leaves. The egg-producing organs are formed upon the tips of certain branches and in each, as is the rule, a single egg is produced, and this when fecundated may segment into an embryo which in time matures into the capsular plant of its species.

Granite-mosses. Another group somewhat related to the last are the granite-mosses—representatives of which may possibly grow upon granitic rocks near Carlton peak and along the north shore of Lake Superior. They are small black tufted plants distinguished from all other mosses by the longitudinal splitting of the capsular plant by four lateral slits which do not meet either at the top or bottom of the capsule. When dry the capsule seems to shorten and the slits are thus opened so that spores may sift out at the sides. The valves of such capsules are somewhat sensitive to moisture and when conditions are unfavorable for the distribution of spores the slits are likely to remain closed.

In both of the families of mosses which have been described there is a central column of sterile cells giving strength to the capsule, and the spore-mother-cells are developed in the region between the column and the wall. In neither of the families does the column run clear through the capsule, but the spore-mother-cell area extends over its top like a cup set over a mould. Quite the same general structure of capsule was observed in the horned liverworts except that in those plants the growth of the capsule was not definitely terminated but continued from the base. In peat- and in granite-mosses the growth of the capsule is terminated after a time and it then contains no more vegetative cells capable of further division. Therefore, the capsule of peat- and of granite-mosses may be regarded as built on the general plan of a horned liverwort capsule, except that the power of continuous development is lost. It might be mentioned here for the sake of clearness that the *club-moss* spore-bearing plant is also supposed to be an improvement over the horned liverwort type. But in club-mosses and ferns a power of continuous growth is retained.

Higher mosses. A peculiar little group of mosses, very tiny and insignificant in appearance, form reduced capsules in which no central column exists. Mosses of this family have not yet been found in Minnesota, although they possibly exist. The rest of the mosses belong to a division sometimes called the true mosses, to distinguish them from the peat- and from the granite-mosses. There is no particular occasion for the use of the term "true" since all alike belong to the general moss division of the plant kingdom. There are more than 30 families of "true" mosses—not all of them represented in the state—and of "true" moss species there are probably from four to five hundred in Minnesota. The simplest true mosses are very small and the first-stage of the sexual plant is more conspicuous than the second, for the latter nearly always occurs as almost microscopic buds, each consisting of a short stem, three or four tiny leaves and a little group of spermaries or egg-organs at the tip. In these mosses the capsule has no lid and opens irregularly. Only a very few varieties with such capsules are known to exist in Minnesota and the great majority of mosses have capsules which open by lids and may be known as lid-mosses. It is impossible here to mention, even briefly, examples of all the different families of lid-mosses to be found within the limits of the state. In some kinds the plant-body is erect and the egg-organs are produced terminally upon the axis. In others the plant-body is not so commonly erect and the egg-organs are produced near the tips of the branches. In general the lid-mosses are divided into two principal series; those which bear their capsular plants at the tips of the stems, and those which carry them on the sides. Sometimes it requires a close examination of the moss to determine to which of the two series it belongs. A view of the whole tuft might lead one to suppose that the capsular-plants were terminal on the branches, but if a single plant were isolated from its neighbors and closely examined it might be discovered, perhaps, that the capsular plant was developed laterally.

White mosses, bark-mosses and dung-mosses. Among the many mosses which develop their capsular plants at the ends of the axes may be mentioned the white mosses—grayish green varieties that produce in the northern forest regions tufts the size of one's head. In these plants the leaves have very much the same structure as peat-moss leaves, hence the grayish green color of the tufts. Related to such varieties are many of the bark-mosses which attach themselves to the bark of trees, especially near the base of the trunk. In this series, too, occurs a kind of moss remarkable for stationing itself upon the excrement of animals and deriving part of its nourishment from organic substances. There are no mosses which are parasites upon other plants, or which absorb their food-materials ready-made, as do the fungi; but the dung-moss seems to be developing in that direction and its descendants within the next few hundred years may find themselves within the category of dependent plants.

Turf-mosses, rose-mosses and cup-mosses. Another group of mosses which belongs to the first series may be termed the turf-mosses from their prevalence in damp lawns, especially near the foundation of houses and around verandas. They evidently select regions a little more moist than the lawn-grass prefers. When they fruit they form somewhat pear-shaped capsules with large central columns of sterile tissue. Here, too, are the rose-mosses which produce what are called, for lack of a better term, "moss-flowers." Mosses of this sort growing in clusters in some shaded ravine or upon moist logs in the forest resemble clusters of little green roses a quarter of an inch or so in diameter. At the end of each short erect stem a rose-like cluster of leaves is produced and at the centre of each cluster the egg-organs or spermaries are developed in little clumps. Related to them are the small stolon-bearing mosses which under some conditions are erect-bodied plants, but when about to propagate have the power of pushing out prostrate, runner-like, leafy stems. These become rooted at the tips and thus enable the plant to widen its circle of growth.

Among the mosses of this general series there are some forms which produce gemmae a very little after the fashion of the umbrella-liverwort. In one variety, which may be called the gemma-cup-moss, cup-shaped groups of leaves at the end of a stem inclose a growth of tiny stalked gemmae. When the gemmae fall off they send forth alga-like threads of the first-stage and upon these threads buds may develop carrying the plant over into its second-stage. In other kinds the gemmae are produced upon the leaves, forming little clusters generally toward the tip of the leaf that bears them. In mosses, the gemmae cannot be viewed as they were in the gemma-liverwort, as little modified, specialized branches of the general plant-body, but they must rather be considered to belong to the first-stage. When they are produced upon a leaf or at the end of a stem, the best explanation seems to be this: The first-stage of the moss-plant is the most fundamental and is the original state of the plant. The second-stage—what is called the "moss-plant" —is a more or less highly organized reproductive branch. Then any cell of the second-stage about to develop as a propagative body would naturally grow out into the filaments of the first-stage; and this actually takes place when moss leaves or bits of stem are separated from the rest of their body. But when gemmae are produced it would seem that these filaments, growing out from the ordinary cells of the plant-body, have gained the power of forming small, massive, bulging tubers in which more nutriment can be stored than in the ordinary slender filaments. So then the gemmae, although apparently borne upon the body of the second-stage, should be considered as really belonging to the first-stage of the moss sexual plant.

Hairy-capped mosses. A number of other forms must be passed with brief mention. Among these are the hairy-capped mosses, remarkable for the peculiar structure of their leaves, for the formation of capsular plants during the summer and autumn of one year and their maturation during the spring of the next, and for the curious Robinson-Crusoe-like hoods that are carried on the tops of the capsular plants. They are many of them adapted to very dry localities and are common in pine barrens.

The second series of lid-mosses includes those forms in which the egg-organs are developed near the axils of leaves rather than terminally upon the stems.

River-mosses. Here are the river-mosses, characterized by their three-ranked arrangement of leaves without midribs and the short stems of the capsular plants. Since the capsules are formed below the surface of the water there is no necessity of their being borne on long slender stems. The object of the slender stem is to aid in wind-dissemination of spores and obviously, then, short stems might be expected to support the submerged capsules.

Arbor-vitae mosses. The arbor-vitae moss, developing prostrate branches of a peculiar fern-leaf aspect and growing in moist woods, furnishes another example in which the egg-organs are not terminal on the stem. The branch systems of this moss are exceedingly beautiful objects. They consist of central stems with lateral rows of shorter branches diminishing towards the apex of the main axis, so that the whole branch-system looks like a small green fern-leaf or feather. Sometimes three or four of such feather-like branches are produced in a series, one attached to another. Such a structure illustrates the development of branches of different orders in the same plant-body. The axial branches may themselves bear other axial branches and these latter may bear the subordinated short branches.

Tree-like mosses. In the tree-like moss which is found growing near decaying logs in the forest or on dark wooded banks, the axial branch stands erect like a little tree-trunk on different sides of which are arranged the subordinated branches so that the whole aspect of the plant is very much like that of a miniature palm-tree two or three inches high. These tree-like mosses have also another sort of stem which runs along the ground—a kind of rootstock from which the erect stems spring. The leaves upon the trunk of the tree-like moss are brown scales without leaf-green and it is only upon the secondary branches—the short branches—that leaves with leaf-green are abundantly formed. In high-types of moss plant-bodies a considerable differentiation may exist between the kinds of stems. There may be prostrate creeping stems, erect axial stems, divergent secondary foliage stems, prolonged stolons extended for propagative purposes, and special stems upon which the egg-organs and spermaries are particularly aggregated.

Carpet-mosses and pool-mosses. Among the mosses of this highest division, the carpet-mosses which cover the surfaces of fallen logs, peeling off regularly in carpet-like masses, furnish a type in which a considerable variety of branching exists. Some plants of the carpet-moss varieties are quite aquatic in their habits, and are to be sought not so much in the running water which the river-mosses frequent as in quiet pools among algae, in overflowed meadows and in lakes.

Spore-distribution by mosses. Before closing the account of the mosses it will be profitable to examine somewhat more fully the methods of spore-dissemination which are employed by the highly developed forms, and the carpet-mosses may be chosen as examples. Here the plant-body is variously branched, the branches being interlaced and the whole spread out in a soft green turf. On some of the lateral branches rising vertically into the air are borne the capsular plants. Their slender stalks are of a reddish-brown color and if closely scrutinized will be found to be twisted or fluted. They are an inch or more in length and at the end, nodding strongly to one side, is the slender urn-shaped capsule with a distinct lid. The cells of the wall where the lid joins the urn are peculiarly flat and low, so that when the proper conditions of moisture are at hand the urn easily cuts off its lid and on account of the inclined position of the capsule opens its mouth towards the side. The greater portion of the mouth of the urn is closed by a plug consisting of the end of the central strengthening column, and only a narrow circular slit between this plug and the wall is left through which the spores may be sifted out. After the lid has fallen two rows of curious, slender teeth are seen to project outside the circular slit arching over it toward the centre. These teeth are very sensitive to moisture and when

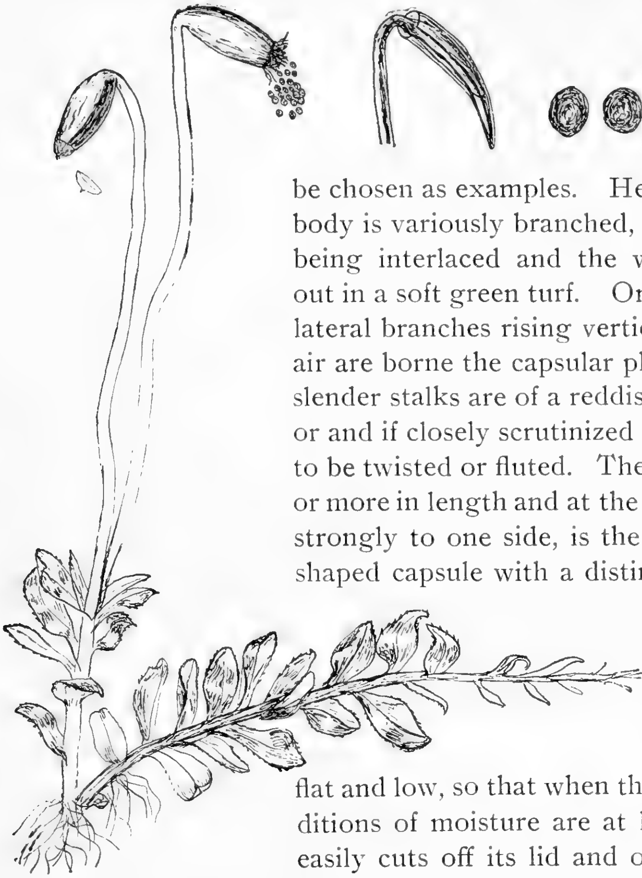


Fig. 48. A moss leafy-plant, with prostrate propagative branch and erect female reproductive branch. On the latter two egg-organs have developed their eggs into capsular plants, one of which is ejecting spores. The two round bodies are spores much magnified. After Atkinson.

the conditions are favorable for spore-dissemination they separate from each other a little and allow the spores to scatter out between them. But when the conditions are unfavorable they close over the slit and the spores are not permitted to escape. The ring of teeth is one portion of the automatic spore-distributing machinery of the capsular plant and the twist in the stalk is another device which plays its part in the perfected mechanism. Under varying states of moisture the stalk slowly twists and untwists so that the mouth of the nodding urn is carried through a circle dispersing its spores as it turns from side to side. Such an apparatus insures the dissemination of spores toward all points of the compass and the teeth at the edge of the urn may be depended upon to retain the spores if the conditions are not suitable for their ejection.

Such artifices as these, together with the large size of some moss-capsules and the considerable number of spores which they contain, mark an advance over liverwort mechanisms and the moss capsular fruit, exceedingly nice in its adaptations, is the most perfect and logical result of those lines of development which were begun in the peat-moss capsule. The failure of the moss capsular plant to achieve the highest rank is because of its having lost the valuable power of indeterminate development which was possessed by its horned liverwort prototype.

Superiority of the moss-capsule over the liverwort-capsule. Another point of difference between the moss capsular-plant and that of the liverwort, and indicating the higher rank of the former, lies in the greater development of starch-producing areas in the moss. This is why the capsules of liverworts are generally black while the capsules of mosses are generally green. The liverwort capsule is merely a thin shell surrounding the spores and the black color of the whole body is given equally by the spores and their wall, but the wall of the moss-capsule is like a leaf in its physiology. It consists of several layers of cells, the outer portion of which functions as skin, while underneath there are areas in which leaf-green is formed. Thus the moss capsular plant is not merely an elaboration of a fecundated egg into a group of spores enclosed in a protective membrane, but it is in a marked degree an independent organism. It is quite independent so far as its assimilative power goes, and if, instead of remaining perched upon the sexual plant at the point where its parental egg-organ was developed, it had the knack of stepping off and driving its own root-system into the soil it would be entirely independent. This, however, is exactly what the ancestral *fern* capsular plants are supposed to have done, so that the fern plant as it grows in the woods may be compared properly, not to the leafy moss-plant but to a very highly improved moss capsular plant with leaves and roots of its own.

A primitive attempt to develop a special leaf-area is seen in the capsules of the dung-mosses. In these the region between the capsule proper and the stalk is flared out into a green collar and this is essentially a starch-making expansion of the general plant surface. But that is precisely what a leaf is structurally, for it also may be described as normally a starch-making expansion. It is true a great many leaves come in higher forms to assume entirely different functions, but the appearance of the leaf must be regarded as connected with starch-making, for originally this was probably the function of all leaves, however far some modern forms may have abandoned it.

Had the moss capsular plants not originally given up, in the peat-moss types, the power of growing continuously, or if they had independently attained this power, there is no reason why they should not have given rise to many interesting and complex higher forms. But no matter how perfect a moss capsular plant may become, no matter how skillfully it may distribute its spores, or provide for the manufacture of starch by its own leaf-green independent of the parent sexual plant, it always comes to a point when it is completely mature, can develop no farther, must eject its spores and perish. For this reason mosses constitute what is called a *terminal type* and there are no higher forms of plants regarded as derived from them.

Chapter XVII.

Christmas-green Plants or Club-mosses.

The plants known as *club-mosses* are the ones so abundantly used in the manufacture of Christmas-green decorations, wreaths and festoons. Their spores are collected and sold at the drug-stores under the name of lycopodium powder, since the small, smooth, oily spheres are very difficult to moisten and are useful to prevent chafing. There are about twelve species in Minnesota, of which some, known as the smaller club-mosses or rock-club-mosses, are distinguished by the possession of two sizes of spores, the significance of which will be considered later. All Minnesota species of club-mosses are terrestrial, growing particularly in the pine woods, and they are known also as ground-pines. In the tropics, however, and in the southern hemisphere there are varieties of club-mosses which perch upon the branches of trees and hang in festoons along the trunks.

FIG. 49. Branch of a club-moss plant, bearing two cones; with a single leaf of the cone, showing the spore case and one of the spores, the latter much magnified. After Atkinson.

Life-history of a club-moss. The life-history of the common Christmas-green club-moss is somewhat as follows: The spores, produced in large quantities, germinate near the surface of the ground and there form diminutive sexual plants about the size of pinheads. Upon these tiny creatures the spermaries and egg-organs are produced. The sperms have two swimming-hairs like those of mosses. The general structure of the spermary and egg-organ is quite like that in the horned liverwort, and the sexual plant of the club-moss may be compared to a horned liverwort prostrate stem very much reduced in size. When an egg lying at the bottom of the organ which produced it has been fecundated, it segments by partition-walls. One of the first two cells develops into the embryo. Some of the cells later produced form the first leaf of the embryo plant. Another group forms the apex of the stem, and still another matures into a bulbous body which nurses upon the tissues of the sexual plant; while, much later, from the interior of a root-like elongation a group of cells pushes its way out as the first true root.

In all the higher plants roots seem to have originated from inner portions of the plant-body and may be regarded as being everywhere protrusions of the sap-conducting areas, so that the root is essentially an absorbent tract, while its functions of support are secondary.

The embryo plant thus started on its career continues to grow, thickening its stem, forming new leaves and branches and multiplying its roots. Unlike the moss capsular plant, but like the capsular plant of the horned liverwort, it never of its own accord stops growing, but only when the growth is terminated by outward unfavorable conditions. As it grows and branches year by year, it soon becomes strong enough to form spore-producing areas of its own.

In club-mosses the spores are in little pouches, one on the upper side of each leaf on the cone-shaped tip of some branch. The end of the branch which produces spores becomes covered with leaves, sometimes of a different color, drier and paler than the ordinary foliage leaves. Such cones are equivalent to the cones of pine-trees which are supposed, indeed, to have arisen from similar simple types. Each cone consists of an axis clothed with spore-bearing leaves. Since the latter in most club-mosses are specialized to some extent for their reproductive functions, they progressively abandon the starch-making function; hence, not needing illumination, they stand closer together, overlapping each other as they would not do if dependent upon the sunlight for leaf-green energy. Having taken such positions they become bleached and while the general plant-body of a club-moss is provided with green, unbranched, rather needle-shaped leaves, the cones by their yellow color and flatter and more closely crowded leaves, become distinct areas of the plant. Yet in types of club-mosses lower than the ordinary Christmas-green variety, the same leaf which produces a spore-case upon its upper surface is also depended upon by the plant for leaf-green work, and the division of labor marks only the higher types.

The lowest in structure of all club-mosses is a New Zealand form not more than an inch and a half or two inches in height and typically unbranched. A single slender erect axis is produced, bearing foliage leaves near the base in a little rosette, while above, the end of the stem develops as a cone with small spore-forming leaves. Such a plant may be regarded as equivalent to the cylindrical capsule of a horned liverwort in which longitudinal and transverse bands of sterile cells have been developed —something which was foreshadowed in certain horned liverworts—separating into chambers the general layer of spore-mother-cells surrounding the central column. It is conjectured that the sterile tissue in the ancestral plants underneath each chamber bulged out into a leaf-like expansion and these leaves separated from each other longitudinally. Therefore the axis or stem of a club-moss is conceived to compare best with the central cylinder of supporting tissue in a horned liverwort capsule and not with the stalk of a moss capsule. The leaves of the cone are conceived to compare with sections of the capsular wall, each section bearing on its inner surface its own portion of the spore-mother-cell tract. The root is conceived to be a new structure, and outgrowth of the central cylinder. The tip of the horned liverwort capsule is regarded as equivalent to the tip of the cone in a club-moss. All these points may be best understood by comparison with the simple New Zealand club-moss in which abundant branching of the spore-producing plant does not take place.

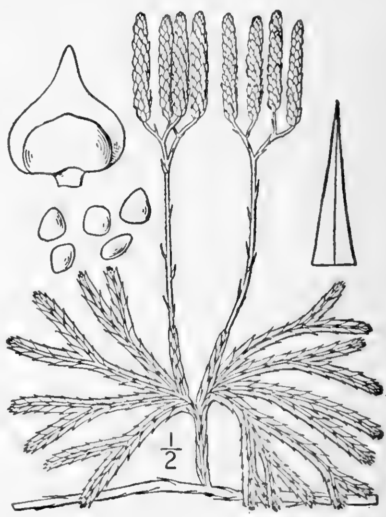


FIG. 50. Flat-branched club-moss. After Britton and Brown.

As the spore-producing plant of the club-moss has acquired new powers and new perfections of structure along vegetative as well as along spore-producing lines, so the sexual plant—the one developed from the spore—has become reduced and is simpler, smaller and less important than the sexual plants of liverworts or mosses.

Different kinds of club-mosses in Minnesota. The different kinds of club-mosses in Minnesota are distinguished by different habits of branching, different shapes of leaves and the varying distinctness with which the cone-area is blocked out in the general plant-body. Some, as the tree-like club-moss or ground-pine, have erect stems with subsidiary branches like those of a pine. Another kind has the leaves flattened in a peculiar way like the leaves of the white cedar. In still another species the plant-body branches loosely and trails over the ground, while in yet another the stem forks, and tufts of branches are produced, reminding one a little of the true-mosses.

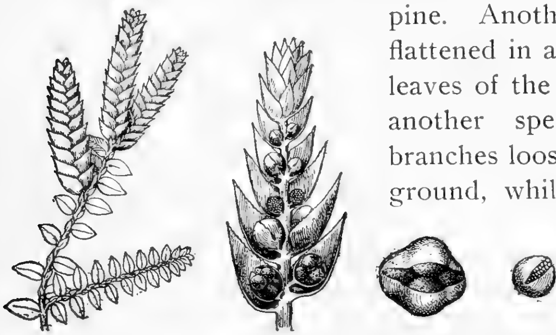


FIG. 51. Smaller club-moss. To the left a plant with three cones, next a single cone dissected to show the spore cases, next a single large-spore-case with four spores revealed, and on the right a small-spore-case with the small spores sifting out. After Atkinson.

The rock-club-mosses. The smaller club-mosses or rock-club-mosses are pretty abundant throughout the state wherever dry rocks or rocky hills occur. The leaves in the common species are pressed close together along the stem and each has at the end a white bristling hair, giving a hoary appearance to the whole plant. The cone-areas are not so distinctly different in appearance from the rest of the plant-body as in the larger club-mosses. The great peculiarity of these plants is their production of two kinds of spores. In some of their spore-cases two hundred or more small spores will be produced, each somewhat pyramid-shaped, while in other spore-cases—perhaps in the very same cone—there will be produced four much larger spores with variously marked walls and of a generally spherical shape. When a smaller spore germinates, it produces a little male plant so insignificant that it never comes outside its spore-wall, but forms and matures altogether within. This little male creature produces a few sperm cells. When the spore-wall breaks, as it does eventually, the sperm-cells are liberated and swim away in the water after some rain or heavy dew. When the large-spores germinate each produces a female plant which, like the male, remains within the spore and does not push out as did the sexual plants of liverworts, mosses and the larger club-mosses. The female is very much larger than the male, and each plant fills the spore from which it developed. When the female is mature, one, or sometimes more, egg-producing organs are formed at the surface of the cell-mass inclosed in the large-spore. After the egg-organ with its inclosed egg has matured, the wall of the large-spore breaks just over the imbedded neck of the egg-organ. This permits spermatozoids to enter and by means of one of them the egg is fecundated and begins segmenting into an embryo in which stem-areas, root-areas, leaf-areas and nursing-foot-areas are produced. In the smaller club-moss a great reduction of the sexual generation is apparent. The sexual plants do not even come outside of their spore-walls. They do no independent vegetative work but the species depends for its subsistence upon the starch-making power of the spore-producing plant.

Origin of the seed of higher plants. The smaller club-mosses while of slight economic importance are of extraordinary scientific interest because they illustrate how in the history of the vegetable kingdom that important structure, the *seed* of higher plants, probably originated. The habit of the female of remaining within the spore must have antedated the origin of the seed. In seeds not only does the female remain within the spore but the spore remains within its case and the female obtains fecundation of her egg by the coöperation of a pollen-tube, while the spore-case need not open. When the embryo has begun to form from the egg the whole spore-case, with some adjacent layers of cells, ripens and a seed is the result. The smaller club-mosses foreshadow this still more strongly in some species where the large-spores begin to germinate internally before they fall from their spore-cases. Yet no smaller club-moss-plant ever really produces a seed, for in all of them sooner or later the spore is ejected from its case and thus there is prevented from arising the exact combination of conditions upon which seed formation depends.

Chapter XVIII.

Ferns and Water-ferns.

Related to club-mosses in about the same manner that true mosses are related to horned liverworts are the ferns, a very ancient and singular group of plants. In Minnesota about fifty species occur, found for the most part in woodland. One variety, the brake, is an exceedingly common plant in all burned districts of the forest region.

Adder's-tongues and moonworts. There are two principal groups of ferns recognized by botanists. Of the lower group, the so-called grape-ferns or moonworts and the adder's-tongue ferns are specimens. In these each leaf consists of two lobes, one—the so called sterile lobe—being devoted entirely to starch-making, the other—the so called fertile lobe—having for its exclusive function the production of spore-cases. The fertile lobe grows from the inner face of the sterile lobe, occupying relatively to the sterile lobe the same position maintained by the spore-case of a club-moss with reference to the leaf upon which it was situated. It is believed that the fertile lobe of an adder's-tongue fern-leaf is equivalent to a large, chambered and overgrown spore-case as displayed in the club-mosses, and it is believed that the sterile segment of the leaf is equivalent to the blade of the spore-case-bearing leaf in the club-mosses.

The adder's-tongue ferns with their slender fertile lobes bearing two rows of spore-cases and their undivided sterile segments, are simpler than the grape-ferns with their palmately branched leaf-segments. In these plants the spores upon germination give rise to little tuberous sexual plants which lie almost imbedded in the soil and are devoid of leaf-green, being humus plants. Upon such little tubers the egg-organs and spermaries develop and after fecundation the egg forms an embryo which nurses for a time upon the sexual plant, then thrusts its own

FIG. 52 Adder's-tongue fern After E. N. Williams in *Meehan's Monthly*.

roots into the soil and begins an independent life. The spore-producing plants like those of club-mosses are perennial, but the egg- and sperm-producing plants die within a few weeks or months after they are formed.

Quillworts. A very curious group of plants known as quillworts, found growing on lake bottoms in northern Minnesota, are considered to be distant relatives of the adder's-tongue ferns. They produce two sizes of spores, large and small, and quite as in the life-history of the smaller club-mosses the large-spores give rise to internally developed females, while the small-spores produce diminutive males not protruded beyond the spore walls. Embryo quillwort plants originate from the fecundated eggs and when they have become old enough renew the production of spores. These are formed in curiously partitioned chambers at the base of, and on the inner face of the long quill-shaped leaves. The spore-producing area of the leaf occupies the same relative position with reference to the starch-making area that was seen in club-mosses and adder's-tongue ferns. The upper portions of the leaves contain air-chambers by means of which the leaves stand erect at the bottom of the lake. Some varieties of quillworts, also represented in Minnesota, grow in swamps and marshes and cannot be distinguished except by the closest observation from tufts of sedge or grass.

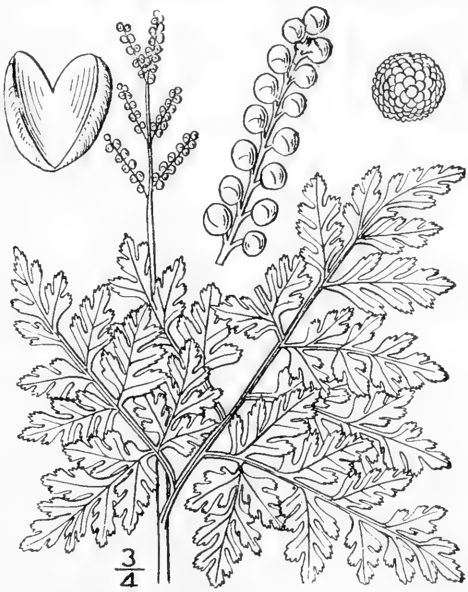


Fig. 53. Virginia grape-fern. After Britton and Brown.

Ordinary ferns. Quite different in a number of structural details are the "true" ferns, the group to which almost nine-tenths of the Minnesota species belong. These are plants with habits of growth which are, in a general way, pretty well known by all who frequent the woods. Of true ferns there are nine families, only four of which are represented in Minnesota. The filmy ferns, the tree-ferns, the forking ferns, the twining ferns and the Borneo ferns are not represented by plants indigenous to the state. The families present are the bracken-ferns and their various allies, the flowering ferns, the floating ferns and the four-leaved water-ferns. Of these the lowest in type are the flowering ferns, three species of which occur in Minnesota. One of them, known as the interrupted fern, is a common plant, presenting a peculiar appearance as if somewhere near the middle of the large leaf two or three leaflets had shriveled. These leaflets, unlike

FIG. 54. A quillwort plant. After Atkinson.

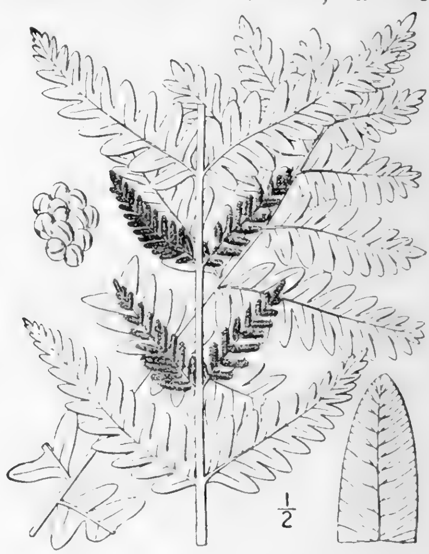


FIG. 55. Clayton's or interrupted fern. After Britton and Brown.

the rest, have a brown and withered look. If examined closely it will be discovered that this is due to their being covered with spore-cases of a brown color, while the rest of the leaflets produce no spore-cases whatever. Another fern of this family is the cinnamon fern which forms leaves of two sorts, some much larger and green, adapted solely to starch-making, others smaller, of a cinnamon color and devoted particularly to spore-making. A third species is sometimes known as the royal fern. The leaves are compoundly branched and leaflets towards the tip produce spore-cases, while lower branches of the leaf make leaf-green and form no spores.

Of the common ferns belonging to the family of bracken-ferns, there are the polypody, abundant upon rocks in all

FIG. 56. Bed of ferns. Sensitive fern in middle of foreground. After photograph by Williams.

parts of the state; the maiden-hair, with its slender, wire-like leaf-stems and graceful leaflets, common in woodlands; the bracken-fern with its loosely branched leaves; the cliff-brakes growing in crevices on cliffs and high banks; the spleen-worts and lady-ferns with their delicate leaves; the walking ferns found upon rocks and so named from their habit of stretching out their long leaves and driving the tips into the ground forming there buds from which new plants develop;

the beech-ferns; the shield-ferns, and the bulblet-ferns recognized by the formation on their leaves of bulbils which drop off and propagate the plant. Besides these there are the little brown *Woodsias* found upon rocks and distinguished by the dry aspect of their leaves, and, in rich woods, the sensitive ferns and ostrich-ferns peculiar among bracken-ferns for the development of two kinds of leaves much as in the flowering ferns. The ostrich-fern especially is a regal plant. Growing in damp glades of the forest it spreads its tall graceful fronds, outlining a green Corinthian capital. In the centre there spring up four or five smaller feather-shaped brown leaves which have abandoned starch-making and devote themselves entirely to the production of spores.

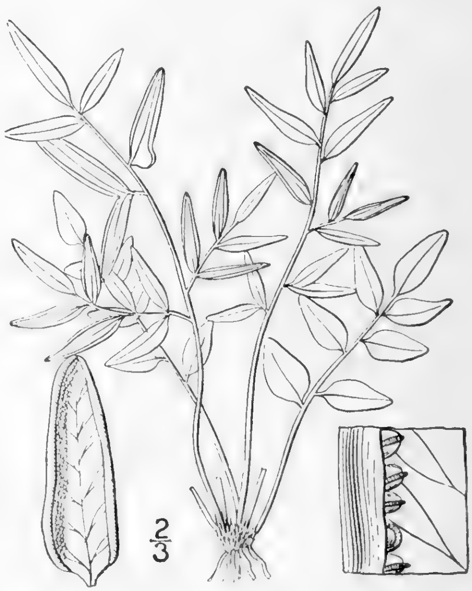


FIG. 57. Cliff-brake. After Britton and Brown.

The four-leaved water-fern. Most remarkable in some respects of all ferns is the four-leaved water-fern. It does not always grow in water but is found in dry creek-beds at the extreme western edge of Minnesota. The plant-body consists of a thread-like, creeping, branched stem from which small leaves, resembling four-leaved clovers, arise. These are the vegetative leaves of the plant, but the spore-producing leaves are modified into capsules about the shape of an ordinary bean but considerably smaller. If one of these beans is chipped on the side and placed in a dish of water it will open like a clam-shell and in about twenty minutes a centipede-like object, three or four inches long and as thick as a crochet needle will uncoil itself. It seems absolutely impossible that so large an object could have been packed away inside the bean-like leaf. The backbone of the centipede-shaped affair has, however, the appearance of clear jelly and is enormously swollen by the absorption of water. The "legs" of the centipede, twelve to eighteen in number on each side, are yellowish and upon close examination appear to be elongated transparent sacs in each of which a number of pearly yellow bodies of generally oval

FIG. 58. The interrupted fern (in background) and shield-ferns (in foreground). After photograph by Williams.

shape are situated. These bodies are spore-cases, some of them containing sixty-four small-spores and others containing one large-spore, each. As in quillworts and smaller club-mosses, the small-spores produce little reduced males while the large-spores develop females. The egg of the female, never more than one to the plant, segments, after fecundation, into an embryo which sucks up all the surplus food-materials that were deposited in the large-spore, produces a root of its own, thrusts it into the soil or water and begins an independent existence. The Minnesota variety is a land-dwelling species of a group which is more generally aquatic, hence the name of water-fern.

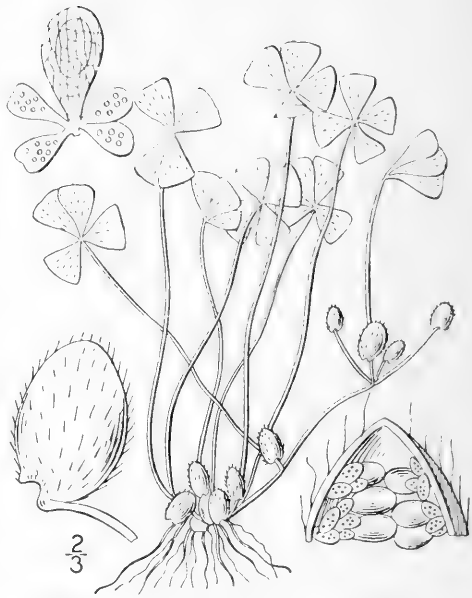


FIG. 59. Four-leaved water-fern. After Britton and Brown.

The fusion of the egg and the sperm in ferns can take place only after heavy rains, or when the melting snows of early springs have flooded the station of the plant. All ferns, and indeed, most plants, up to and including the cycad-palms and ginkgo trees, are essentially aquatic in their breeding habits. Most of them have motile sperms provided with swimming hairs, and unless there is a medium in which the sperm can swim it will never reach the egg.

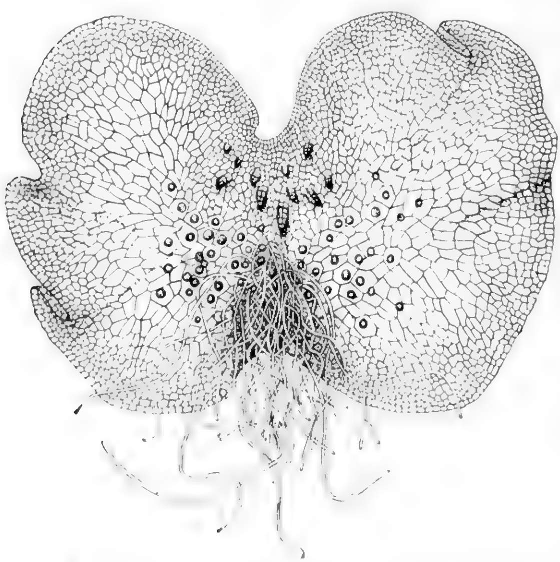


FIG. 60. A sexual fern-plant somewhat magnified. Its natural size is about a quarter of an inch across. The round bodies are spermaries, the chimney-shaped ones are egg-organs, seen from below. After Atkinson.

Floating ferns. The family of the floating ferns is represented in Minnesota by a little plant called *Azolla*, not uncommon in greenhouses, where it floats upon the surface of the water in tanks. It has a much branched stem and tiny, rather ovate leaves. The whole body resembles that of a scale-moss. As they grow the leaves form peculiar cavities, opening by a narrow aperture through which a little alga inserts itself and is a constant companion of the *Azolla* plant, for in all *Azolla* leaves are found growths of this little blue-green alga. Like the leaves of the scale-mosses, those of *Azolla* have two lobes, one, the floating lobe, lying upon the surface of the water and the other, the submerged lobe, lying below. The spore-cases are borne in groups upon the submerged lobe.

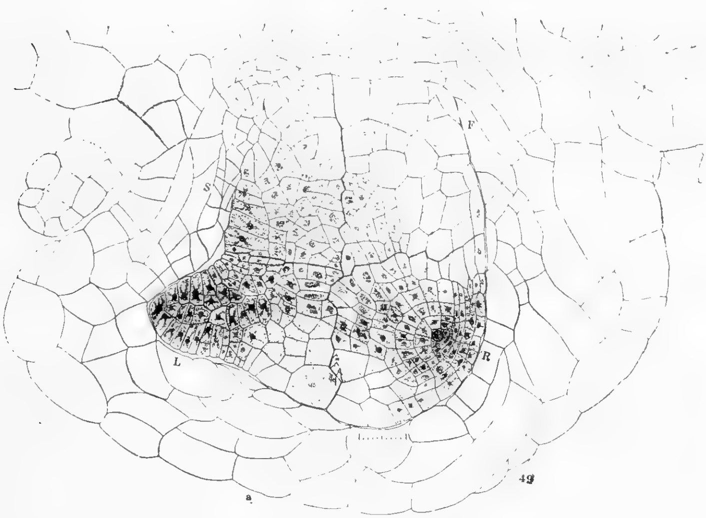


FIG. 61. A fern-plant embryo imbedded in the enlarged egg-organ, where it arose by segmentation of an egg. S, tip of rudimentary stem; L, tip of first leaf; R, tip of primitive rootlet; F, nursing foot. Much magnified. After Atkinson.

There are two kinds of spores, large and small, and several of the spore-cases which produce small-spores are developed in clusters and inclosed by a general protective wall. The spore-cases which develop the large-spores occur singly within such a wall and each large-spore-case produces a single large-spore. When the small-spore-cases open, simultaneously several small-spores escape imbedded in a lump of frothy mucilage upon which curious little anchor-shaped barbed hairs are disposed. The large-spore, when its case opens, is found to have one end of its wall provided with low flat-topped excrescences from each of which a tuft of delicate threads protrudes. As the frothy masses in which the small-spores are imbedded drift near one of the large-spores, their anchors become entangled in the hairs of the large-spore, and thus one or more of the masses is secured in such a position that when the small-spores germinate, protruding from each a little tubular plant-body, the sperms, formed by the male, will not have far to swim to reach the egg.

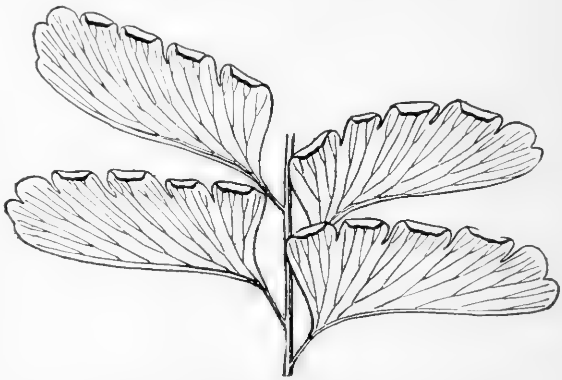


FIG. 62. Portion of maiden-hair fern-leaf, showing marginal pockets, which serve to protect the clusters of spore-cases under each flap. After Atkinson.

Explanation of what fern leaves really are. In all the ferns belonging to the series known as the true ferns, the spore-cases are little stalked pods containing from one to about sixty four spores, never much exceeding that number. These spore-cases may be seen in the polypody, forming on the under side of the leaves small brown circular patches. In the maiden-hair and bracken-ferns they occur under pocket-shaped flaps of the leaf-margin. In the shield-ferns each group of spore-cases on the under side of the leaf is protected, at least while young, by a shield-shaped or umbrella-shaped membrane growing over the group. It is the rule among the true ferns that the leaf which bears the spore-cases also serves as the starch-making organ of the plant, but in the os-

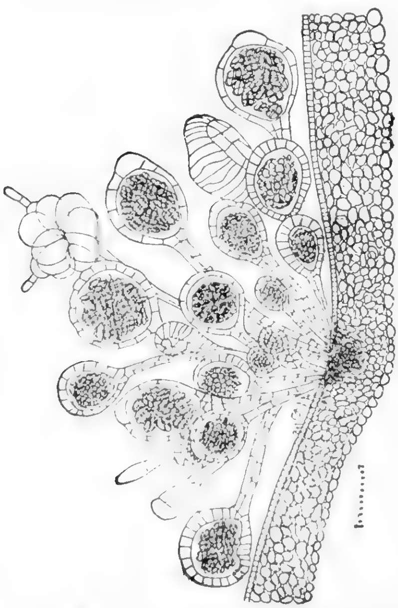


FIG. 63. A patch of spore-cases on the back of a common polypody-fern-leaf. Magnified. After Atkinson.

trich-ferns, the sensitive fern, one of the flowering ferns, the four-leaved water-fern and some other forms which have not been mentioned, there is a division of labor and the leaf which makes starch is not also designed to produce spores.

In comparing the true ferns with the adder's-tongue ferns, it would appear that the condition of things is somewhat peculiar. Since it bears the spore-cases it would seem that the

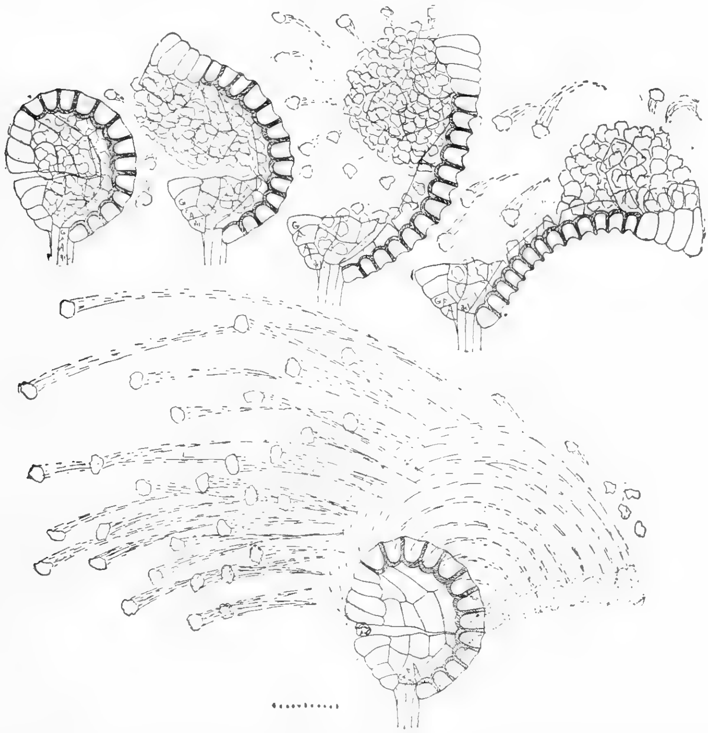


FIG. 64. Spore-cases of the common fern, much magnified, showing how the spring back reverts and then snaps shut again, throwing the spores as from a sling. After Atkinson.

ordinary fern-leaf compares only with the fertile lobe of the adder's-tongue fern-leaf. This fertile lobe has greatly enlarged and assumed the function of starch-making. At the same time the spore-cases have come to be developed from special cells at its surface, not from mounds of cells as in the lower form. What, now, has become of the sterile segment of the adder's-tongue fern-leaf? The most reasonable reply to this question that can be offered is that it has undergone steady reduction and

FIG. 65. A walking-fern climbing down a hillside. Buds form at the very tips of the slender leaves and grow into new plants. After Atkinson.

has finally disappeared. In a family of tropical ferns not represented in Minnesota are found traces of this sterile segment as stipular plates at the bases of the leaves. Therefore, we arrive at the interesting and remarkable hypothesis that the entire fern-leaf compares with a much elaborated and improved club-moss *spore-case*. It will be remembered that the fertile segment of the adder's-tongue leaf was believed to be an overgrown chambered spore-case arising from some club-moss-like

FIG. 66. Maiden-hair ferns and lady ferns. After photograph by Williams.

ancestral condition. Therefore, among true ferns the common type of leaf in which both starch-making and spore-production are combined, is the primitive one. By a division of labor, some leaves quite abandoned the habit of producing spore-cases and others in the same plant intermitted the production of leaf-green. Thus are explained the two sorts of leaf in the ostrich-fern and the same explanation serves for the cinnamon fern and its allies and for the four-leaved water fern.

In a word, the most distinctive feature of the ferns is this: They loosened that cone-arrangement of leaves which had arisen in the club-mosses and greatly developed the spore-case-area of each leaf until such an area became itself a leaf-like structure, while the original blade of the leaf deteriorated and disappeared. The pine trees, also related to the club-mosses, pursued a very different course of development and retained the cone as a structural unit. From bodies somewhat similar to pine-cones it is probable that the flowers of all higher plants arose. The club-mosses then have originated two great lines of improvement, one in which the cone was abandoned as a structural feature, giving rise to the *ferns*, the other, in which the cone was retained as a structural feature, leading to the *flowering plants.*

Chapter XIX.

Scouring-rushes and Horse-tails.

The peculiar family of plants known as scouring-rushes or horse-tails was very much better developed during the age when coal was being deposited than it is to-day. Most of its species are extinct, but there remain, widely distributed over the world, some forty different varieties, of which ten occur in Minnesota. They are not very closely related either to the ferns or to the club-mosses, although they clearly belong in their general vicinity. The unbranched forms are known as scouring-rushes on account of the usual deposit of silica in their outer layers. This mineral is useful for scouring tinware, and rushes are actually thus employed by some housewives in the country. The branched forms are known as horse-tails from their peculiar aspect as they stand in fields, in the woods or along the roadside or railway tracks.

Each variety of scouring-rush or horse-tail is distinguished by an underground rootstock which shows much the same structure as the above-ground portions. Sometimes on the rootstocks tuber-like propagative swellings are formed. Both the erect and subterranean branches are divided into very distinct joints which may be separated from each other like sections of stove-pipe, hence the plants are also called joint-rushes. In some species the plant produces only one kind of erect stem and at the tip of this, or more rarely at the tips of lateral branches, firm and solid cones are borne, each made up of little shield-shaped leaves with central stalks. The leaves are arranged in circles about the axis, not in spirals as in the cones of club-mosses. On the under side of each of the shield-shaped leaves a ring of spore-cases is developed, commonly about eight in a group. The cones bear the leaves so close together that from their mutual pressure they assume a more or less hexagonal outline.

Scouring-rushes with two sorts of erect stems. In a few of the species there are formed two kinds of erect stems. One is pale or reddish in color, softer to the touch, provided with longer leaves below the cone, devoid of leaf-green and devoted to the work of spore-production. The other is repeatedly branched, the branches arising in circles at the top of each joint of the stem. Upon such erect stems no cones are ordinarily displayed, but the whole plant-body is green and starch-producing. Both kinds of erect branches are, however, very similar in internal structure. They are hollow and their wood-threads are arranged in a circle, usually with air-canals between them and within them. At the top of each joint a group of leaves arises in a ring. These are not used for starch-making but are reduced and scale-like and commonly blended together by their edges into a collar closely enveloping the lower part of the joint immediately above. On the special spore-producing branches the leaves are often larger and less completely fused together. Sometimes the leaves are black in color with gray tips, as in a well-known joint rush of Minnesota. In all the varieties the starch-making is done not by the leaves but by the branch-system, so that in this respect the plants resemble the well-known asparagus, to which they bear, however, no close botanical relation.

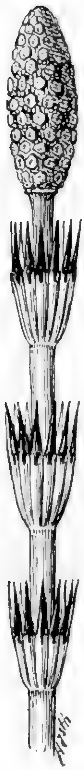


FIG. 67. A fruiting stem of the horse-tail. The shield-shaped spore bearing leaves are aggregated in a cone. After Atkinson.

When the spore-cases on the shield-shaped leaves open to eject their spores, the spores may be shaken out into the hand as a green dust. If one watches this dust as it lies upon the hand immediately after having been shaken from the cone, it will be seen that within a couple of seconds after its deposit it *fluffs* and becomes of a lighter color. By warming it gently with the breath it regains its darker hue and more solid appearance, but in a couple of seconds it fluffs again as it did before. This remarkable behavior is explained if the spores be examined under a good microscope. It will then be observed that apparently attached to each of them are four delicate spoon-shaped appendages which are very sensitive to moisture. These, when dampened, contract around the green spherical spores, hugging them tightly, but as they dry they straighten, loosening the spore-mass in the process. This is why the moistened dust seems more solid than the same dust when dry. The spoon-shaped appendages originate by the splitting of the outer wall of the spore into two ribbons, as if a couple of peelings had been removed. An idea of the arrangement can be obtained by imagining the cover of a base-ball unsewed and laid back. The two pieces of cover would then occupy much the same position with reference to the ball as do the four longer and slenderer spoon-shaped appendages with reference to the spore.

Germination of spores. Although all the spores are of the same size and appearance, yet it is the nature of some of them upon germination to develop little green, prostrate males, something like small horned liverwort plants, while others develop females, slightly larger than the males but in general closely resembling them. Both the male and the female scouring-rush plants are provided with leaf-green, emerge from the spores, strike their root-hairs into the soil and lead an independent existence. The males produce microscopic spherical spermaries in which arise spermatozoids with large numbers of swimming threads. The females produce a few egg-organs of the characteristic bottle-shape, at the bottom of each of which a single egg is formed. After the fecundation of the egg during rains, or when in some other way plenty of water is available as a medium for the locomotion of the sperms, the embryo of the scouring-rush begins to grow very much as did that of the fern. An erect stem is first produced, then from its base a rootstock. If at the end of the year the erect stem dies, buds on the rootstock remain to form the stems of the succeeding year. By means of its underground stem the

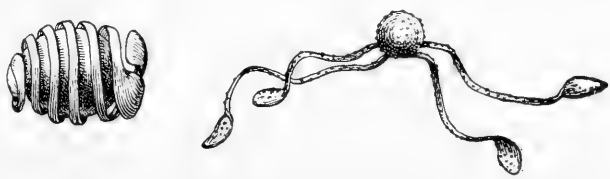


FIG. 68. Scouring-rush spores; to the left a spore with appendages curled up, in moist air; to the right a spore with appendages extended, in dry air. After Atkinson.

spore-producing generation of the plant is perennial, but the sexual plants die after they have performed their functions.

Male and female plants. It is now possible to understand the meaning of the curious sensitive appendages of the spores. The spores when ejected are separated from each other into little groups by the writhing of their appendages. The individual spores are not, however, entirely isolated, and that degree of moisture which is favorable for germination impels the appendages to pull the neighboring spores close together, so that when they germinate, male and female plants shall not be too far apart for the convenience of the swimming sperm. This is a very good example of the extraordinary adaptive relations which come to exist between sexual and spore-producing plants of the same species. The appendages of the spores have seemingly no meaning in the life-history of the spore-producing plant itself, but they function in such a way that the task of the sperm-producing plant is made easier and thus the development of fecundated eggs is insured, for the perpetuation of successive generations. Upon clay banks, where there are shade and moisture, one will often find among the young scouring-rushes or horse-tails some of the tiny sexual plants looking very much like diminutive liverworts as they lie more or less prostrate upon the soil.

Different sorts of horse-tails and scouring-rushes. The different kinds of horse-tails and scouring-rushes in Minnesota are distinguished by slight structural peculiarities that need not be discussed in detail. The rigid, jointed, unbranched forms, three or four feet in height, which grow along shaded banks are perhaps, in their tissues, the richest in silica or sand, and are the ones which have particularly merited the name of scouring-rushes. The very much branched variety which is such an abundant weed in neglected fields, along roadsides, and in the edges of woods, is a different species. A third species, in which the lateral branches curve downward in a characteristic way, is abundant in northern woods and is named the forest horse-tail. Still another kind is often found growing at the edges of ponds and streams, now and then forming great patches in bays and occupying the same general position that is ordinarily selected by bulrushes. This, which may be termed the water horse-tail, is commonly not very much branched although under certain growth-conditions it is capable of branching almost as abundantly as the field horse-tail. A curious dwarf variety two or three inches high is sometimes found growing in tufts in deep woods. It is reported from the St. Croix river valley, but I have not seen authentic specimens of it from Minnesota.

Underbrush habits of horse-tails. When the branched varieties of horse-tails grow in the edges of woods they often become very much taller than in fields. This they accomplish by thrusting out their rigid side-branches in every direction and permitting them to rest upon the twigs of surrounding shrubs or herbs. Thus they can distribute their weight in such a way that the main stem is relieved and the axis may extend itself vertically farther than otherwise. Plants which lean in such fashion upon surrounding plants are known as *braced-plants.* They are not exactly dependent for their well-being upon the presence of other plants as are the climbers and twiners, but they do derive some advantage from their habit of letting a portion of their weight rest upon plants near them.

It is really, if one stops to think of it, quite as much of an engineering problem to erect a slender stem as to build an Eifel tower, and it is no less impossible to extend a leaf into the air without due regard to the strength of materials than it would be to build a cantilever bridge from wet paper. Plants manifest architectural design and the problems of structural engineering are not at all unlike those requiring solution by the human architect or bridge-builder when he enters upon the plans of a new structure. So it is obvious that the bracing of the side branches of horse-tails, thus diminishing the strain upon the main axis, might enable it under the same general type of structure, to reach a greater elevation into the air. In South America, by bracing devices scouring-rushes grow to a height of twenty or thirty feet, though they are not thicker than an ordinary walking-stick. Where the forest is dense and dark such a plan is seen to be highly advantageous and perhaps even necessary, but in the lighter, thinner forests of Minnesota there is no need of such extreme length.

Chapter XX.

What Seeds are and how they are Produced.

About 150,000 different kinds of plants produce seeds. A seed may be defined as a young plant and its reserve-food-material enclosed within a normally protective layer. Sometimes the food-material is deposited beside or around the plantlet, as in the seeds of Indian corn and wheat. Again the food-material may be collected in the plantlet itself, giving to it a white, meaty appearance, and pumpkin and bean seeds are of this structure. It is a mistake to say that plants grow from the seed, or rather it is a half-truth, for the question is whence did the plantlet come that is already present in the seed and needs only to renew its development when the seed germinates? This can be answered in a word. Leaving out of consideration some abnormal or peculiar conditions of development, it may be said that all plantlets in seeds arise from eggs. The next question is whence comes the egg from which the plantlet in a seed develops? The reply is, that the egg, as in all other instances, is produced in the body of a female plant. Still another question—where is one to look for the female plant of a rose or willow, or any other seed-producing species? To this inquiry the answer is, the female, like all other females in the great series of terrestrial plants, develops from a spore. Again, one inquires, where is the spore to be sought? To this is the response that it is formed in the young *ovule* or rudimentary seed, occurring as a more or less oval, cylindrical or elongated cell in the centre of the seed-rudiment.

What then is the seed-rudiment? It is a spore-case which produces at its centre the single, large, thin-walled spore. In seed-plants such a spore is called an *embryo-sac* and it may easily be found by opening young pine-seeds in cones not more than twelve months old. Unlike the large-spores of the smaller club-moss, these seed-plant spores are not ejected from their spore-cases, while, just as in the smaller club-moss, they develop females which are retained within the spore-wall and upon the bodies of these females egg-cells are formed. How is it possible for such an egg, developed and retained within the tissues of a spore-case, to obtain fecundation? Here comes into play an adaptation on the part of the male-plants of the seed-producing varieties. Where is one to look for the male cottonwood tree? Like other male plants it originates from a spore, not, however, the large-spore, enclosed in the rudimentary seed, but the small-spore known as the pollen-grain, developed in large numbers upon special leaves known as *stamens*. What sort of a plant arises when a pollen spore germinates? Before replying to this question another must be asked. Where does a pollen-spore germinate? Not upon the soil, or in the water, as did the small-spores of ferns and smaller club-mosses, but upon a certain portion of the body of a spore-producing plant of its own species, a part usually in close proximity to the rudimentary seeds. This area upon which a spore of the smaller kind is able to germinate is known as the *stigma* in higher flowering plants, but in the lower families the pollen-spores fall immediately upon the immature seeds.

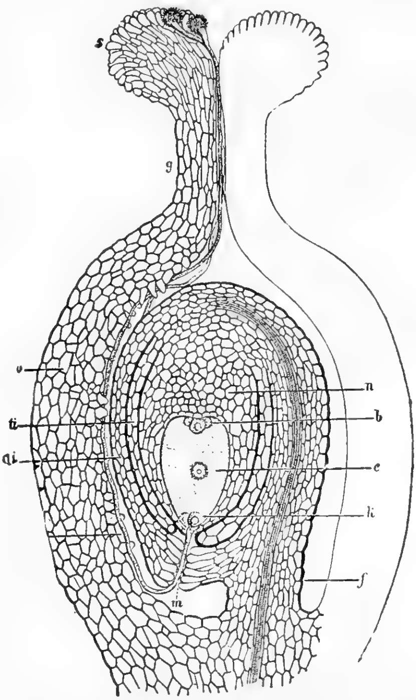


FIG. 69. Diagram of an ovary, with one seed-rudiment, in a higher seed-plant. s. The *stigma*, where two pollen-spores have germinated; o, wall of ovary; f, stalk of ovule; ai and ii, rudimentary seed-coats; n, spore-case, with single large spore, which has germinated to produce the reduced female plant; k, the egg; e, the body which forms the albumen; b, other cells of the female. The male plant is shown as a tubular thread growing towards the egg. After Atkinson.

Breeding habits of seed-plants. Returning now to the question, what sort of a plant arises when a pollen-spore germinates, the reply is, a delicate thread, like a cobweb, comes into existence and grows much as a parasitic fungus filament would grow through the tissues of the immature fruit down to the surface of the large-spore, imbedded in the rudimentary seed. By this time the female has developed within the large-spore and has produced her egg. The end of the *pollen-tube*, as the male is termed, penetrates the wall of the large-spore and transfers a male nucleus, or sperm, which fuses with the egg and thus fecundation is accomplished. Then the egg becomes an embryo which grows and produces a short stem, one or more seed-leaves (in most plants) and a root. While the embryo is developing, the tissues of the spore-case and the membranes surrounding it become modified into the outer layers or *seed-coats*. When the embryo pauses in its growth and passes into a temporary dormant condition the seed is said to be *ripe*. It may not, however, be able at once to germinate.

If the reader has closely followed this explanation he will be aware that is is improper to call a pollen-producing plant a male and he will understand that there is no comparison at all between the sowing of pollen-spores on a stigma where they are to germinate and a breeding habit, although the older botanists supposed that such analogy existed. It is found that seed-producing plants, like the smaller club-mosses, have two sorts of spores, small-spores producing males, and large-spores, females. As in the lower type, so also in the seed-plant, there is a retention of the female within the wall of the spore from which she originated. Unlike the smaller club-mosses, the male plant is not retained within the wall of the small-spore, but protrudes in the form of a thread of miscroscopic minuteness. The retention of the large-spore within its spore-case, together with the adaptation of the male plant so that fecundation may take place without the opening of either the large-spore or its case, lays the foundation for that compound and complex body, the seed.

By these devices the embryo is kept in close proximity to the vegetative areas of its species and in a pine seed there are represented *three successive generations*. The coats of the seed and sometimes a portion of the food-supply, as in water-lilies, belong to the *older* spore-producing generation, for they are parts of the same plant that produced the large-spore. The meat of the seed, or *albumen*, belongs to the female, for it is produced within the large-spore as it germinates. The embryo plantlet of the seed belongs to the *new* spore-producing generation and arises by the segmentation of an egg. After it has renewed its development—when the seed has germinated and the plantlet has become old enough—it will be able in its turn to produce spores. Therefore, the life-history of a cottonwood, for illustration, is twice as complex as that of a man. While there are only two kinds of individuals in the human species, there are four in the cottonwood: first, the pollen-producing tree or staminate cottonwood; second, the seed-rudiment-producing tree or pistillate cottonwood; third, the male cottonwood or pollen-tube arising from the pollen-spore and growing as a parasite upon the tissues of the young cottonwood fruit; fourth, the female cottonwood, a microscopic plant inclosed in her spore deep within the rudimentary seed. Indeed there may even be *five* kinds of cottonwoods, for in higher seed-producing plants there is strong reason to suppose that the albumen of the seed is in reality a degenerate plantlet—a twin brother of the embryo—produced from an egg, rather than, as in the pines, a portion of the female plant-body.

From this discussion it will be seen how inaccurate is the common statement that higher plants grow from seeds while lower plants are produced by spores and it is understood how erroneous is the phrase, so general, especially in popular works, that the spores are the *seeds* of the fungi or ferns. The higher plants produce spores just as truly as do the lower plants, but in the former a peculiar relation of dependence has come to exist, precisely the reverse of that which was observed in the liverworts. In the latter the capsular plants, that is, the spore-producing plants, were dependent upon the sexual plants for their food-supply and remained perched upon their bodies all through life. In the club-moss group these little perched plants learned how to maintain an entirely independent existence and put forth leaves and roots of their own. In the seed-plants they have become so important and powerful that they do all the vegetative work of their species while the once stronger and larger sexual plants are reduced to microscopic structures of an altogether dependent life-habit. A few definitions may not here be out of place and will be given in as untechnical language as possible.

Definitions of certain words. *Pollen* is a dust consisting of small spores, capable, upon germination, of producing male plants. The *embryo-sac* is a large-spore developed in the rudimentary seed and capable of producing a female. The pollen-spores are produced in special spore-cases situated on leaf-like organs called *stamens.* The embryo-sacs are commonly produced singly in bodies called *ovules* borne upon leaves known as *carpels.* An axis upon which stamens or carpels or both are generated is called a *flower.* An ovule which has matured, normally as the result of a breeding act, is called a *seed.* The carpel, or carpels of a flower with the enclosed seeds, is called a *fruit.*

Two series of seed-producing plants. There are two series of seed-producing plants, the lower, in which the pollen-spores fall directly upon the immature seeds and germinate, and the higher, in which the carpels close around the immature seeds and the pollen-spores fall and germinate upon a special portion of the carpel or carpels known as the *stigma.*

Chapter XXI.

Ground-hemlocks and various Pines.

Of lower seed-plants there are five living and at least two extinct families. In Minnesota but two of the five living families are represented. These are the yews and the pines.

Ground-hemlocks. The yews are represented by a single species, the ground-hemlock, a well-known plant of wooded banks and forests throughout most of the state. In England a species of yew exists which becomes a large tree, but of the four species in America none reaches any very great size, and the ground-hemlock is the smallest of the group. It is an evergreen shrub with leaves much like those of the balsam, and recognized by its crimson berries the size of small gooseberries. The berry of the yew, however, is not a *fruit* but a *seed*, surrounded by a red pulp-cup which may be regarded as a basal outgrowth. Of all seed-producing plants in the state the yew gives its seeds the least protection. In pines the seeds are enclosed by the scales of the cone, and in all higher seed-plants the seeds are developed within fruits and are never, from the first, exposed, as in the ground-hemlock. The red pulp which encircles the yew seed makes it attractive to birds and it is disseminated by their agency. Besides the seed-rudiments on the branches, the yew produces little round cones consisting of axes upon which are borne a few shield-shaped leaves. Each of these resembles the spore-producing leaves of the scouring-rush and on the under side of each a circle of pollen-spore-cases are developed. The yew plants, of all Minnesota seed-bearing forms, produce the largest number of pollen-spore-cases on a single stamen. Usually the number is four, often but two, while in the yew the number may be six or even more. The microscopic male and female yew plants are short-lived, but the spore-producing plant, beginning as an embryo in the seed, then after the germination of the seed achieving independence, is a long-lived shrub of somewhat prostrate habit, and with dark-green leaves and tough-fibred wood in which resin does not occur, while it does in plants of the related pine family.

Pines of different sorts. The pine family includes 13 or 14 Minnesota species out of a total of about 300 distributed over all parts of the world. In these the rudimentary seeds are produced upon the inner sides of scales or carpels which, like the stamens, are aggregated into cones. The pines and their allies may therefore be said to produce two kinds of flowers, staminate and pistillate.

Among the members of the pine family in Minnesota may be mentioned the tamarack, a deciduous tree of social habit; the pines of which three varieties, the white, the jack and the red or Norway, grow within the borders of the state and are dominant species of the northern forest; the spruces, of which there are three varieties, the black, the white and the muskeg; the balsam or fir, common in swamps; the white cedar or arbor-vitae, a tree that flourishes best in the northern part of the state; the hemlock, very rare in Minnesota, but occurring in two isolated patches in St. Louis county and Carlton county; and the junipers, of which there are four species, one tree-like in habit and known as the red cedar, the others low shrubs and called savins or junipers.

The white pine. Among all these plants the white pine, the most important timber tree of the state, is of especial interest. Its wood is light, resinous and easily worked. It is used in the manufacture of lumber, laths, shingles, matches, sashes, doors, blinds, woodenware, telegraph poles and the masts of ships. Many millions of dollars are invested in mills for its manufacture into lumber, and in railways for the transportation of the logs. This tree often grows over a hundred feet in height with a trunk sometimes more than three feet in diameter. Its bark is rough and deeply divided by clefts. When growing in the open, as sometimes upon hills, for example, near lake shores in Cass county, the lower branches are much prolonged and the whole tree has a broadly conical form. But when a native of the forest the lower branches become shaded out of existence and the tree has the well-known compressed slender appearance. The topmost branches usually dispose themselves in a flamboyant manner, which makes it possible to recognize this variety of pine as far as it can be seen. The leaves are slender prismatic needles, borne in groups of five, on special short branches. They are of a somewhat bluish-green color, and during their first winter are inclosed in small bright green buds. The staminate cones are light-brown, egg-shaped, about a third of an inch long and mature in a single season. The pistillate cones are somewhat smaller at first, of a purplish color and borne on the topmost branches of the tree, while the staminate cones are usually developed on the lower branches. Originally the pistillate cones are erect, but during the first year of their lives they become heavier and take a horizontal position. At this time they are nearly an inch in length. The next year they grow rapidly, become pendulous, and reach their full size in mid-summer. They are now six inches in length and seven-eighths of an inch or thereabout in diameter. During the autumn of the second year, they open and scatter their brown seeds, each of which is furnished with a delicate wing by means of which it is disseminated by the wind. Within the seed will be found an edible albumen, with, however, a strongly resinous odor, and in the centre of this stands the straight young pine with from eight to ten seed-leaves growing in a crown about the short apex of its stem. The root, before it issues from the seed, is already provided with a root-cap and the stem-area below the seed-leaves is short. The white pine contains more resin than any other variety, yet it is not ordinarily used in the manufacture of turpentine as is the pitch pine of the south.

FIG. 70. White pines on the rocks at Taylor's Falls. After photograph by Williams.

Pine trees do not spring up again after fires with nearly the vigor possessed by a number of hardwood trees. In Minnesota hundreds of thousands of young trees are annually destroyed by fire and their place is occupied by plants which are comparatively worthless in the commerce of the state.

The Norway or red pine. The other commercial pine of Minnesota is a somewhat smaller tree, averaging fifty to eighty feet in height. This is commonly called the Norway pine by loggers, though a more correct name would be red pine. The bark is of a reddish tint and much smoother than that of the white pine. When standing in groves the tops of the red pines are round, not irregular and crested as are the tops of the white pine. The leaves are produced in pairs on short special branches. They are dark-green, five or six inches in length and shaped somewhat like half-cylinders. The staminate cones are longer and slenderer than those of the white pine, grow in more elongated clusters and are of a purplish color. The pistillate cones are at first almost spherical, red in color and a quarter of an inch or more in length. Like cones of the white pine these pistillate flowers take two years to mature and finally drop from between their scales the smaller, darker seeds with wings shaped differently from those of the white pine seeds. The seedling plant has fewer seed-leaves and is limited to eight, while five, six or seven are more common numbers. The wood is not so easily worked as that of the white pine, nor do the logs float so well in drives. The timber is, however, abundantly employed in the manufacture of buildings, trestles and sometimes in railway construction.

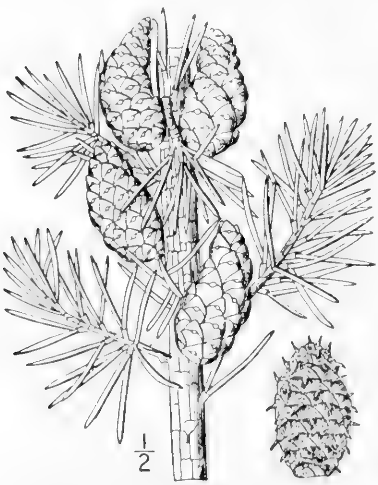


FIG. 71. Jack pine. After Britton and Brown.

The jack pine. The third species of pine in Minnesota, the jack pine, is very prevalent in sandy soil throughout the northern part of the state. It is a smaller tree than either of the others, but may in groves reach the height of seventy or eighty feet. The top is more pointed or spire-like than that of the red pine and the bark is rather thin and irregularly divided, a little like elm bark. The leaves arise in pairs and are much shorter than those of the red pine, varying from three-quarters of an inch to one and a quarter inches in length. The staminate cones are produced in clusters much like those of the red pine, but smaller. The pistillate cones are nearly spherical in shape,

FIG. 72. Rock-vegetation near Duluth. White pines, white cedars and junipers. After photograph by Williams.

purple in color and appear on the topmost branches of the tree. When the pistillate cones mature during the second season of their lives they are generally curved to one side, by which character they may be recognized and distinguished from the short cones of the red pine. The seeds are small, winged, and blackish in color and the embryo plantlet has only four or five seed-leaves. There is no difficulty in discriminating even between the seedlings of the three species. The wood of the jack pine is not strong and is little used as lumber, though it is cut for firewood in some parts of the state and occasionally employed in the manufacture of posts or ties. This pine is particularly abundant in the region around Brainerd, where it covers hundreds of square miles in an almost unbroken forest.

The white cedar. The white cedar or arbor-vitæ is a tree fifty or sixty feet high with a short, thick trunk. It is especially abundant in the far northern region of the state, not coming south so readily as the pines. It is prominent along lake shores on the international boundary and its branches jutting out over the water make picturesque scenery on the shores of most lakes east of Rainy lake. The leaves are large and remote on older shoots, but on the younger, which are arranged in flat, fern-like groups, they are short and tightly lapped over each other like shingles. The flowers, opening in the spring, are purple in color and the fruits ripen in a single year. The seeds are winged along both margins, thus differing from the pines in which the wings are principally terminal, and are only an eighth of an inch long. Seedling plants of the white cedar have but two seed-leaves, in this respect resembling most higher seed-plants. The wood is very light and peculiarly durable, sweet-scented and brown in color. It is highly prized for railway ties, shingles and fencing lumber and is used by the Indians in the manufacture of paddles and as ribs for their canoes. They employ also the inner bark in the manufacture of mats, cutting it up into strips which they dye and plait elaborately in quaint and traditional patterns. Young arbor-vitæ plants are used in Minnesota for hedges.

The hemlock. The hemlock is a tree sometimes 110 feet in height with a trunk four feet in diameter, but in Minnesota, in the two small patches where it is known, it does not reach this size. The lower branches are generally drooping and the leaves are short and flat, dark-green above and lighter below. The cones are slightly longer than the leaves. The wood is soft and light, brown or white in color and the general appearance of the twigs with their foliage is quite similar to that of the ground-hemlock—hence the common name of the latter. The two plants, however, are really members of different families. Hemlocks are of much economic importance from their bark, to the exclusion of other varieties, being employed in tanning. The substance known as tannin is abundant in hemlock bark and by its action upon hides they are cured and converted into leather.

The tamarack. The tamarack differs from the other Minnesota pines in its habit of shedding its leaves in autumn. The leaves are never of the dark rich green of the spruces, firs or pines, but are of a paler color. In autumn they turn golden yellow before they fall and after the severe frosts of November

Fig. 73. Tamarack swamp with sedge border. After photograph by Williams.

they separate from the twigs by means of cork layers and the tree passes the winter in a leafless condition. Tamaracks occupy wet ground, forming by their growth the well-known feature of the landscape known as the tamarack swamp. The cones of the tamaracks are small. The wood is hard, resinous and durable, weighing twice as much as that of white cedar, and is used in the manufacture of railway ties, as fence poles and for fire-wood. Occasionally, too, it is manufactured into telegraph poles.

The spruces. The spruces are known for their spire-like habit of growth and serve as the Christmas trees of the children. They do not grow to any great size in Minnesota although the white spruce under suitable conditions may reach a height of 150 feet. In Minnesota the black spruce seems to be rather more frequent and together with tamaracks, or to their exclusion, forms characteristic swamp growths, the trees standing very close together. A slightly different variety, the muskeg spruce, with peculiar drooping branches is particularly abundant in such localities. Spruce leaves are short and four-sided, spreading in all directions from the twig. The cones are small and plump, with shell-shaped scales closely lapping over each other. In the white spruce the cones are oblong and somewhat cylindrical in form, while in the black spruce and muskeg spruce they are egg-shaped in general outline. When the leaves of the black spruce die they fall, leaving little hummocks on the twigs. None of these plants except the true pines has special leaf-bearing branches which separate as a whole when the leaves have finished their work.

The balsam. The balsam or fir is a slender tree growing in somewhat drier soil than that preferred by the tamaracks and black spruces. In Minnesota it rarely exceeds a height of 40 feet. The leaves are flat and sessile, arranged apparently in rows right and left on the twig, but really in spirals. The twigs have a much flatter look than the twigs of spruces. Only one species occurs in Minnesota and this has a smooth bark in which resinous blisters are formed. The whole plant is sweet-scented and the wood is soft and light. From the resin blisters is derived the product known as Canada balsam. The balsam tree may be known from the spruces by its erect cones as well as by the flat branch systems, for in spruces the cones are pendulous.

The junipers and red cedar. There remain to be mentioned the junipers, a group of evergreens remarkable for transforming their pistillate cones into little round blue berries. The scales of the cone become fleshy, inclosing the seeds. They are fragrant and an extract of juniper is used in the flavoring of gin. Birds pick the berries, thus providing for the distribution of the seeds. Therefore, as one would expect, the seeds are not winged as in most of the other pines. One of the junipers, the red cedar, grows in Minnesota as a tall tree. It is not very common in the state, but is found at Redwood Falls and on lake shores and bluffs at a few isolated localities in the southern part. The leaves are short and broad with sharp points and are developed in four rows. The red cedar is the most widely distributed plant of its family in North America. The wood is light, perfumed, of a reddish color, except in the outer layers, where it is white. It is largely used in cabinet making, in the

FIG. 74. Red cedars on the banks of a Minnesota lake. After photograph by Williams.

manufacture of lead pencils, and is believed to be so particularly distasteful to moths that closets in which woolen clothing and furs are to be hung during the summer months are sometimes lined with it.

The other junipers of the state are low shrubs. One is characterized by spreading awl-shaped leaves arranged in whorls of three, and this form sometimes grows into a low tree. The others are prostrate shrubs creeping over the rocks or sand, and are abundant in the northern part of the state where they form a distinctive vegetation on some of the islands in Lake of the

Woods and Rainy lake. Their leaves, like those of the red cedar, lap over each other, are short and slightly pointed. They stand in four rows, giving the branch upon which they are borne a square appearance.

Characters of lower seed plants. There are a number of features in which the yews and pines agree. The seeds of each are produced in such a way that when young the pollen spores may fall close to their ends, so that the only tissues through which the pollen-tube must grow to reach the female plant are the cells of the spore-case that surrounds the large-spore in which the female plant is situated. For this reason the lower seed-plants are sometimes called the naked-seeded plants. While the seeds are maturing they are enclosed, except in the ground hemlock, quite as truly as are those of higher forms. In the juniper-berry, for illustration, when it is full grown, the scales which constitute the little fleshy cone are blended at their edges in such a manner that the seeds are entirely enclosed and cannot at all be termed naked. In the pines proper, too, the young cones appress their scales so tightly that the seeds are quite as effectually protected as they would be in the closed fruits of higher types. At first, however, even in the junipers, the scales of the immature cone are open and it is possible for pollen-spores to fall between them, thus reaching the ends of the young seeds growing upon their inner surfaces.

A character in which the lower seed-plants all agree is the production of albumen in the seed before the egg of the female is fecundated by the sperm-nucleus of the pollen-tube. In the higher seed-plants the albumen of the seed, when present, does not form until the egg which is to produce the embryo has received its fecundation. The albumen of the seed may be regarded as the body of the female plant and the young embryo nurses upon it during its life within the seed just as the young spore-producing plants of a liverwort or moss nurse upon the vegetative body of the sexual plants of their species.

In still another respect the lower seed-plants agree and differ from all the higher seed-plants. In them, on the body of the female plant produced within the large-spore, true egg-organs are formed, each enclosing an egg and provided with a short neck the end of which is near the inner surface of the spore-wall. In higher seed-plants there is no definite egg-organ, but the egg lies loosely among the other cells of the extremely reduced and degenerate female.

Relation between lower seed-plants and primitive seedless plants. A very remarkable character, which shows clearly the connection between smaller club-mosses and lower seed-plants, is not known to be presented by either of the Minnesota families of the latter group, though it is now described for two that are exotic. It is, however, a fact of such extreme interest that it should be mentioned at this point.

FIG. 75. Rock on the St. Croix river, near Taylor's Falls. Shows zonal distribution of trees. White pines stand on top of the rock, and birches and poplars on the sides. After photograph by Mr. H. C. Cutler.

In the sago-palms and ginkgo trees the pollen-spores fall as in other naked-seeded plants, upon the ends of the immature seeds, then germinate and produce their pollen-tubes. In the end of each pollen-tube in these plants there develop a pair of motile spermatozoids provided with swimming lashes. In the cycad family to which the sago-palm belongs, are a few American species finding their home in Florida. In these when the pollen-tube comes close to the egg a motile spermatozoid swims into it, peeling off its swimming-lashes in a spiral coil and leaving them at the edge of the egg just inside its wall. The remainder of the sperm-nucleus finds its way to the centre of the female cell. In higher forms of naked-seeded plants, of which the yews and pines are examples, the swimming-lashes of the spermatozoids seem to have been quite abandoned. They are indeed no longer necessary, for the old algal type of aquatic reproduction has been finally outgrown. It is a most remarkable and impressive fact that in all the terrestrial forms, from the liverworts up to the cycads, including all the ferns, club-mosses and their allies, the primitive aquatic nature of the plant reasserts itself during the reproductive phase and one finds such plants as the granite-mosses, accustomed to life upon bare, dry rocks, quite unable to bring their sperms and eggs together except immediately after heavy rains, when the surface of the rock is flooded with water, thus enabling the aquatic sperms to use their swimming threads. This long persistence, ages after the aquatic habitat had been abandoned by the ancestral algae from which the higher plants are supposed to have arisen, is a striking example of the really profound inertia of living structures.

Chapter XXII.

From Cat-tails to Eel-grasses.

Higher seed-plants. The characters of this group are as follows: the rudiments of the seeds are protected by the fusing together of the specialized leaves upon which they are borne into a fruit-rudiment known as the *ovary*. The leaves which thus fuse are called *carpels*. In some types the ovary consists of a single carpel, in others, of several carpels blended into a single fruit-rudiment, while the number of carpels in a flower varies in the different families. The female plant, produced in the large-spore of the seed-rudiment, consists of a few cells, commonly eight in number, near the time that the egg is fecundated. The albumen of the seed is not of the nature of a female plant, but is rather to be considered as the twin of the embryo, and does not form until after the sperm and egg have fused. In the latter characters it will be seen that the higher seed-plant differs from the lower.

The lower class of higher seed-plants. There are two principal classes of higher seed-plants. The lower class is distinguished by the production of embryos with but a single seed-leaf. In such plants the stem develops fibrous or woody threads which become entirely mature and do not blend into a cylinder from which to form a layer of growing tissue between the wood and the bark. Hence the stems of perennial plants of this class do not show "annual rings" of growth like those of the other and higher class. For the most part the leaves have parallel veins although some, such as those of the jack-in-the-pulpit, the smilax and the skunk-cabbage have netted veins. The flowers are ordinarily made up of five whorls of leaves, the two lower and outer whorls constituting the *perianth*, then two whorls of *stamens* and, in the centre, one whorl of *carpels*. The number of leaves in a whorl is generally three, but in certain types the number varies, especially in the three inner whorls, so that water-plantains, for example, produce a large number of separate carpels at the middle of a flower while grasses produce but one. A variety of plants belonging to this division of the vegetable kingdom exist in Minnesota. The class is divided into *orders* of which eleven are recognized, and the orders are divided into *families*.

Cat-tails. The cat-tails belong to a small order, including also the bur-reeds and the screw-pines, the latter of which are not represented in the state. Cat-tails, however, are common enough at the edges of marshes, swamps and lakes, and a single species, the broad-leaved cat-tail, is familiar in such localities. It is provided with a creeping rootstock which lies imbedded in the mud. The leaves are slender and flat, sheathing the upright branches of the rootstock by their bases. The flowers are of two sorts, some containing only carpels and others only stamens. The two kinds are produced in the same spike-like cluster, the staminate aggregated above and the pistillate below. The brown cylinder or "cat-tail" is the compact mass of pistillate flowers. The little fruits are provided with cottony hairs and burst when they have been lying in water for a short time. Each seed consists of a hard shell within which is considerable albumen surrounding a single embryo plantlet.

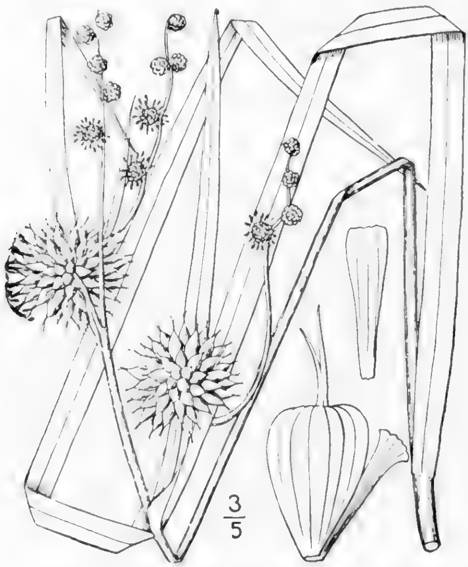


FIG. 76. Bur-reed. After Britton and Brown.

Bur-reeds. There are at least six sorts of bur-reeds in Minnesota. They occupy similar habitats to those preferred by the cat-tails. Their prostrate creeping rootstocks are rooted in the mud and from them erect branches arise. On these are developed grass-like leaves. The flowers are of two sorts as in the cat-tails, and are gathered in globular heads, varying in size from a pill to a large marble. The staminate heads are smaller and higher on the stem than the pistillate. The fruit has but a single cavity. The seeds are furnished with considerable albumen and within this the embryo stands nearly straight. These plants are sometimes mistaken for sedges, but are easily recognized by their globular flower-heads of two sorts on the same general branch. Sometimes the heads are provided with stalks; in other varieties they are sessile.

The second order in the ascending series includes seven families, of which five are represented in the Minnesota flora.

FIG. 77. Lakeside vegetation. Just off shore is a growth of the floating pondweed, then of arrowheads, while further out are reeds and rushes. After photograph by Williams.

Pondweeds. These are for the most part submerged plants growing in ponds, lakes and slow streams throughout the state. About twenty Minnesota species are known to exist in such localities. They all root at the bottom of the water. Their stems are slender, often branching, and when taken out of the water are limp, owing to their poor development of woody tissue. The flowers are commonly collected in spikes which in spring are barely thrust above the water in order that the wind may carry the pollen from the stamens to the stigmas. These spikes are the little objects upon which lake-flies like to perch

—as must often have been observed by every one who has fished in Minnesota lakes.

The different species of pondweeds may be distinguished by their leaves. In one common variety leaves of a somewhat oval shape float upon the surface of the water, but besides these there are present upon the submerged portions of the plant short, reduced, grass-like leaves. In another with leaves somewhat similar, but crowded together and altogether submerged, there will not be found the special grass-like leaves. Still another has clearly two very different sorts of leaves, some finely dissected and others elliptical in outline. In yet another the leaves are all delicate and thread-like. A great variety in the shape and size of pondweed leaves may be observed upon looking down through the clear water upon submerged bars where they grow so luxuriantly.

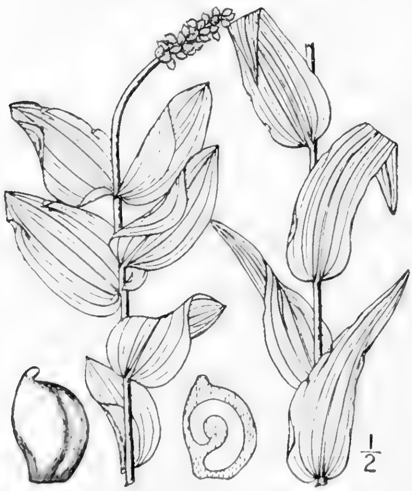


FIG. 78. Clasping-leaved pondweed. After Britton and Brown.

In all these plants the seeds are curved or straight and the embryo has no encasement of albumen. The fruit, in which are the seeds, consists of four little bodies much like diminutive peaches. Very closely related to the pondweeds are the naiads which may be distinguished by the solitary pistil which forms the fruit. They grow in exactly similar localities and one species is common in Minnesota.

Arrow-grasses. A third family is known as the arrow-grasses. Four species are described from Minnesota localities and are to be found in some abundance in tamarack swamps, especially in the northern part of the state. The leaves are rush-like and the flowers, arranged in terminal, loose spikes, produce stamens and pistils upon the same axis, while from three to six carpels fuse together to make the fruit. One variety of arrow-grass is discriminated by the small number of flowers in the spike. All of these plants are perennial and some of them are to be pretty generally met with in all portions of the state, while others are rare. They should be sought in rather moist peat-bogs or in marshes at the edges of lakes.

Water-plantains and arrowheads. A fourth family includes the water-plantains, the arrowheads and a few related plants in which the flowers are similar though the leaves are of different appearance. The common water-plantain is known by its large oval leaves, two or three inches in length and with several strong longitudinal ribs. The flowering stem is much branched, bearing a number of pretty flowers each with three round white petals, from six to nine stamens and usually several separate

FIG. 79. Evening scene in Minnesota. Arrowheads, bulrushes and willows in foreground. After photograph by Williams.

carpels which form, as the structure matures, a little fruit-cluster. The embryo in the seed is curved like a horse-shoe and there is no albumen. These plants produce large masses or colonies in favorable localities. They are abundant in ditches and pools and along railway tracks, as well as in pond margins and in marshes, but they do not commonly occur in peat-bogs or tamarack swamps, except at the edges.

Related to the water-plantains are the arrowheads, plants of similar habitats and generally to be distinguished by their broad leaves, shaped like spear-heads. The arrowheads, like the pondweeds, frequently put forth two kinds of leaves, and if a plant is pulled up by the roots it will be discovered very possibly that there are broad or slender grass-like leaves submerged in the water. In one Minnesota variety the arrow-headed leaves float upon the surface of the water like those of the pond-lilies, but more commonly they are not natant. In some species all of the leaves are grass-like or slender, while the plants must be recognized rather by their characteristic flowers. A large number of separate carpels are produced in each flower and when it ripens the group of carpels become a more or less spherical head. In each of the closed carpels or ovaries is a single erect seed slightly curved.

FIG. 80. Arrowhead. After Britton and Brown.

In Minnesota there are at least six species of arrowheads.

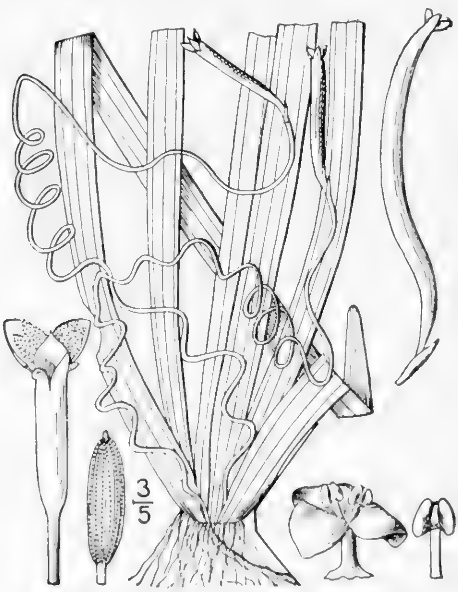


FIG. 81. Eel-grass. After Britton and Brown.

Eel-grasses. A fifth family in this second order includes the well-known eel-grass, the plant which gives so delicate a flavor to the flesh of the canvas-back duck, which is very fond of pulling it and eating the soft parts of the leaves and stems. There is something very remarkable about the way in which this plant produces its flowers. The general plant-body consists of a short stem rooted in the mud on the bottoms of lakes near their edges. The leaves are long, grass-like and of a diaphanous translucent green, rarely floating at the surface, more generally submerged and ascending. The pistillate flowers are produced at the end of a very long, slender spiral stem which rises in sinuous coils through the water, bringing the flower just to the surface. The staminate flowers are in clusters on a short stem deep down in the water. When they are nearly ripe they separate from the stem and rise to the surface, where they open, revert their perianth leaves and are free to be blown about on the quiet surface of the pool like so many miniature boats. Some of them thus approach the pistillate flowers and the pollen-spores can fall upon the stigmas where they germinate. After pollination the long, coiled stem contracts and pulls the pistillate flower down into the depths where it may ripen its fruit in safety. The fruit itself is a cylindrical capsule with numerous seeds.

In near affinity to the eel-grass is a little plant which is sometimes called ditch moss or water weed and is known by its short leaves of a crisp texture when taken from the water. The leaves are opposite, rather close together and commonly not more than half to three-quarters of an inch in length. Their points are often turned back so that a characteristic appearance is given to a branch.

Chapter XXIII.

Grasses and Sedges.

The third order is not represented in Minnesota, but the fourth order, which includes the grasses and sedges, is abundantly represented by a large variety of forms. There are in the state about 160 different species of grass and about the same number of sedges.

Grasses. Grasses are characterized by their habit of forming the sort of fruit which is termed a *grain*. They are, in Minnesota, all of them annual or perennial herbs, but in India and the Orient some varieties become large trees, in which condition they are termed bamboos. The stems are for the most part hollow, the leaves slender and sheathing, though some panic grasses have broad leaves—or even ovate leaves in certain foreign species. The flower clusters are generally spikes composed of little spikes known as *spikelets*. In the flower clusters and flowers, the leaves are developed as chaffy scales and the flowers themselves lack any colored perianth. There are usually three stamens and the ovary has but one cavity producing but a single seed. The ovary is conceived to consist of one carpel, the other two having disappeared. The branched stigma on top of the rudimentary fruit is feather-like, and for its pollination the chief agent is the wind. The ripened fruit inclosed in its chaffy scales is called a grain. The seed inside the grain is not separate but fills up the fruit-cavity so that the whole is one solid

FIG. 82. Wild rice and pond lilies. After photograph by Williams.

body. There is always albumen in the seed and the embryo lies toward one side, nursing on the albumen by its peculiar sucker-shaped seed-leaf. This may be seen when one carefully removes the embryo or germ from a corn fruit or from a wheat kernel. It will then be noticed that the embryo has on one side a flattened disc which presses itself against the albumen, and by it the plantlet nurses as the seed begins to germinate.

FIG. 83. Beard-grass. After Britton and Brown.

There are several tribes of grasses recognized: the maizes, to which Indian corn belongs; the bluejoints, including also the sugar-cane; the panic-grasses, with which the barnyard grass, the sand-burrs and their allies are grouped; the rices, of which the Minnesota representative is the well-known wild rice or Indian rice; the canary-seed grasses; the timothies and millets, including also some sand-binding grasses and tumbling-grasses; the oats, comprising the well-known wild oats and a number of kindred genera; the fescue grasses, with blue-grass and reed-grass as types; the buffalo-grasses, and the barleys with which tribe are also grouped both wheat and rye. Only two of the large tribes of grasses are unrepresented in Minnesota by native varieties. These are the maizes and the bamboos; but Indian corn, one of the maizes, is so abundantly cultivated that it may rightfully be regarded as a Minnesota plant.

FIG. 84. Barnyard grass. After Britton and Brown.

Varieties of grasses. It is not possible in the space at command to give any adequate idea of the various species of grasses which grow within the borders of the state. The majority of them are turf-forming plants and are marked by strong underground rootstocks which branch and creep beneath the surface of the soil, sending lateral offshoots into the light. A great many different types of flower clusters are to be met with, varying from the solid spikes of the timothy or millet to the very loose and straggling clusters of the tumble-grasses and blue-grasses. A few grasses are aquatic, permitting their leaves to float on the surface of the water. These may be recognized, when in flower or in fruit, by the characteristic grass-like aggregates which they produce. Some are semi-aquatic, finding their homes on the edges of lakes or swamps, as, for example, the reed-grasses and the wild rice. A number of varieties are found only in tamarack swamps and marshes or where there is an abundance of shade. A few, with sparsely clustered flowers and rather broad, thin leaves, frequent the depths of the forest, but the great majority are to be looked for in meadows and on the prairie. Some of them, like the buffalo grass, with their shriveled aspect and vigorous root-system, indicate a strong adaptation to dry regions or deserts.

FIG. 85. Minnesota Muhlenberg grass. After Britton and Brown.

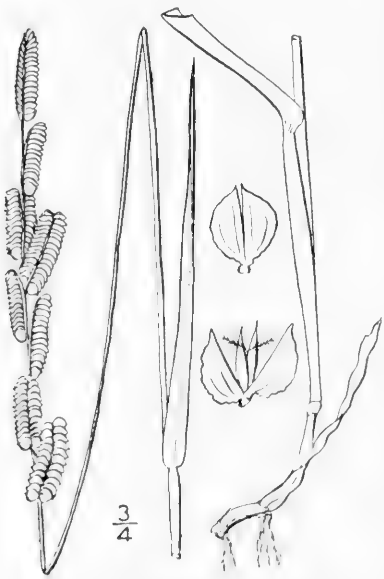


FIG. 86. Beckman grass. After Britton and Brown.

Indian corn. Sometimes in the grasses the flowers are separated so that the staminate flowers occur in different clusters from the pistillate, just as in the cat-tails. It is so with the Indian corn, where all the staminate flowers normally develop in the area known as the tassel, where all the pistillate flowers are gathered together on a thick stem and form the ear. In the Indian corn the process which connects the stigma with the ovary is long and slender and is known as the silk. Surrounding the cluster of pistillate flowers on their thick stem or cob is a group of somewhat modified protective leaves known as the husks of the corn. Since the plant depends upon the wind for carrying the pollen-spores to the stigma, the silk threads protrude in a little tuft at the end of the ear. By selecting ears which have not yet opened to expose their silk and inclosing them in a gutta-percha bag it would be possible to prevent the development of the kernels.

FIG. 87. Indian corn in the shock. After photograph by Williams.

A number of cultivated varieties of Indian corn are recognized, differing in minor peculiarities. Hybrids between different varieties are interesting and sometimes red and white corn are crossed; in that instance tinted kernels may develop upon the cob. Or if red, white and black varieties are grown together in the same field some kernels may be fecundated by male plants arising from one kind of pollen while others depend upon males developed from other pollen, so that the ears contain kernels of each color.

Wild rice. Another grass which is of interest from its importance as an economic plant among the aborigines of the state, is the wild rice or Indian rice. The Chippewas call this plant *manomin* and gather it in the autumn of the year for food.

It occurs in large quantities, especially in narrows between lakes, in outlets or inlets, but not so commonly in bays or stagnant water. It is not so frequent in lakes without an outlet. The

FIG. 88. Wild rice in a Minnesota lake. After photograph by Williams.

grain is longer and thinner than the rice of the orient, but when boiled is quite as agreeable to the taste as the cultivated form. The Indians collect it in September, beating it into their canoes.

and after harvesting it is winnowed by hand. Under the crude manipulation of the Indian much chaff is usually left with the grain, so that the wild rice cake or porridge which the Indian makes is not always so appetizing as one might desire. The wild rice, when it flowers, behaves somewhat like Indian corn, but both varieties of flower-clusters are rather broad panicles. The spikelets contain one flower each and the pistillate spikes are borne higher on the stem than the staminate, thus reversing the relative position in the Indian corn. Each staminate flower contains six stamens. The pistillate flower consists of a single ovary with two divergent feathery stigmas.

FIG. 89. Wild rice. After Britton and Brown.

Wheat. More important to man than any other grasses in Minnesota are the wheats, which form the principal agricultural product of the state. In the wheat the flowers are perfect, not separated as in the corn or wild rice. Surrounded by its own cluster of stamens each pistil is normally sure of pollination. When the fruit develops it forms an ovoid grain with the embryo basally and laterally disposed. A large number of varieties of cultivated wheat are known, the hybridization and selection of which are of the utmost importance to the agriculture of the future, since by such intelligent methods will it eventually be possible to produce varieties which are rust-proof and far richer in flour-making substances than are the wheats of to-day.

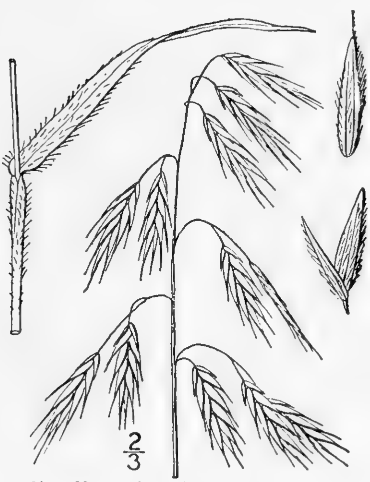


FIG. 90. Kalm's brome-grass. After Britton and Brown.

Distribution of grass grains. A few grasses in the state have interesting special methods of distributing their fruits. The sand-bur, for example, encloses its fruits in bur-like scales. If carefully examined, the points on the burs will be found to have barbs directed backwards along their sides, so that a bur sticks very closely to the fur of an animal or to clothing and thus brings about the dissemination of the fruits within. Another grass known as spear-grass, or to children as "fairy's spears," is remarkable for the "self-planting attachment" of the grain. In this variety the grain is enclosed in a chaffy scale, the end of which is prolonged into a slender awn, while the base is sharply pointed, hard, and possessed of hairs pointing backwards. When such grains fall upon the soil the tips penetrate a little, owing to the heaviness of the seed. The slender bristle then begins to coil and uncoil under the stimulus given to it by changes in the moisture of the air. Since the grain holds all the ground that it gains on account of its backward-pointing hairs it is slowly driven into the soil and thus enjoys a certain advantage over varieties which have not such self-planting mechanism. Grasses are not alone in apparatus of this sort, for the fruits of the clematis and of some geraniums are similar to a degree. Other species of grass are provided, upon their fruits, with expansions or tufts of cottony hairs, by which the wind assists them in their dis-

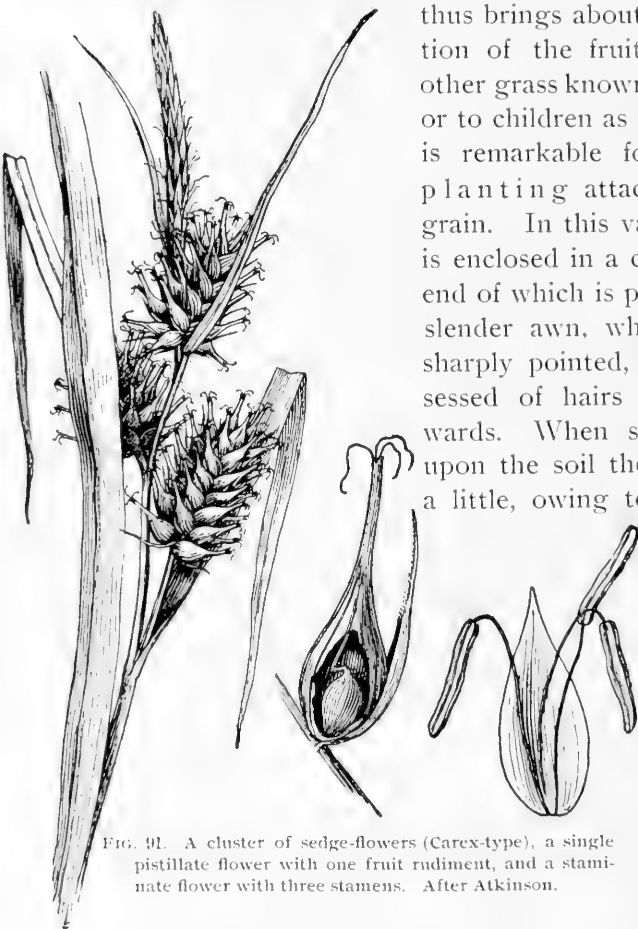


FIG. 91. A cluster of sedge-flowers (Carex-type), a single pistillate flower with one fruit rudiment, and a staminate flower with three stamens. After Atkinson.

tribution, while tumbling grasses—after they have ripened their seeds—separate their flower-clusters, bring them together into balls and permit the wind to roll them over the plains or meadows.

Mat-grasses and dune-grasses. A few grasses take the form of what are known as mat-plants or carpet-plants. These are found in waste fields and the plant-body has a marked prostrate appearance, lying flat upon the ground and producing, if uninterfered with, a circular disc a foot or more in diameter. Such vegetation-forms could not very well arise in the forests or in marshes, but are characteristic of open, sandy fields. Peculiar varieties of grasses are usually found on sand-dunes. These, of which the wild rye is a conspicuous example, have a luxuriant subterranean body made up of rootstocks and roots by which they bind the sand together—hence they are known as sand-binding grasses. The planting of grasses of this sort where sand-dunes show a tendency to encroach inland, is often sufficient to stay the advance of the dune. In France such grass-planting is employed by the inhabitants along the coasts of Brittany to prevent the beach sand from being blown continuously in shore. In northern Indiana, between Chicago and Elkhart, there is an area where the sand of Lake Michigan has been blown inland for many miles, covering the soil and by its thick drifts making valuable farms worthless. In such positions considerable growths of wild rye would serve to bind the sand and raise a barrier to its farther encroachment.

FIG. 92. Cyperus-sedge. After Britton and Brown.

Sedges. The sedges are a family of plants closely akin to the grasses and with them constituting the fourth order. They are mostly grass-like in appearance, though some, like the bulrushes, are singular in aspect owing to their special habitats. As compared with the grasses they present some differences which may be kept in mind and should enable one to distinguish the two families at a glance. The stems are slender, generally solid, instead of hollow as in almost all the grasses. Very often the sedge stem is triangular or quadrangular, a character

FIG. 93. Cotton-grasses growing in a bed of peat-moss. Near Grand Rapids. After photograph by Mr. Warren Pendergast.

not at all common among grasses. Some sedges, however, like grasses, have cylindrical stems. The leaves are, when present, altogether grass-like. The flowers resemble those of grasses, except that the number of stamens is rarely more than three. The ovary is one-chambered, develops a single seed and in general resembles the ovary of the grass. The stigma is often three-cleft but sometimes simple or two-cleft. The fruit is ordinarily a *three-cornered nutlet* with mealy albumen and minute embryo.

Cyperus-sedges. Here are included the *Cyperus* plants. To this genus the familiar umbrella-plants of window gardeners belong and here, too, is to be placed the papyrus of Egypt, famous in ancient days as a substitute for paper. The papyrus stems were pounded out into flat plates which, matted together, furnished the papyrus rolls upon which so many ancient manuscripts are written. In Minnesota the *Cyperus* sedges are found principally along the muddy borders of ponds and streams, in marshes, ditches and wet places. In many of them the stem is triangular with most of the leaves clustered at the base. The spikes are often borne in the kind of cluster known as an *umbel*,

FIG. 94. Lake border vegetation. Bulrushes and reed-grasses. After photograph by Williams.

of which the parsley family furnishes such good examples. Sometimes these umbels are loose and compound, in other species they are compacted into almost globose heads, while in still others they are lax and simple.

Cotton-grasses. In this family are the cotton-grasses, such characteristic plants of the tamarack swamps and peat-bogs of the state. The fruits of the cotton-grasses are clothed with white bristles growing up from under their bases so that the head of a cotton-grass looks much like a tuft of cotton at the end of a slender stem. There are several varieties in Minnesota.

Bulrushes. Here are also the bulrushes and their allies, a number of which are natives of the state. The most common bulrush is the one that forms beds at the margins of many Minnesota ponds and lakes. This plant has stout creeping rootstocks which branch underneath the soil of the bottom. Lateral branches of the main stem arise into the air, growing sometimes from seven to nine feet tall, with a few sheathing leaves at the base and a leaf or two at the point where the flower-cluster branches originate. The erect stem as a whole is a slender green cylinder, whip-shaped and beautifully constructed to withstand the wind and surf of its habitat. The bulrush is an example of a small adaptational group known as surf-plants. The leafless character of the stem may be regarded as the result of experience in surfy water, for in such a position the leaves, if they had existed, would probably have been torn away and the plant has therefore learned how to exist without any leaves over the principal portion of its surface.

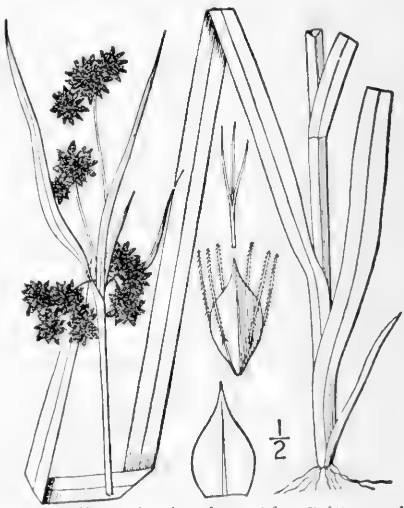


FIG. 95. Bulrush-sedge. After Britton and Brown.

There are a variety of reasons why different plants abandon their leaves. Sometimes the leafless habit is an adaptation to very dry atmospheres; therefore a number of desert plants are leafless, because if they had leaves they would tend to transpire moisture more rapidly than they could absorb it. Again, the absence of leaves may be an adaptation to strong winds; thus the switch-plants on the islands of the Adriatic may be regarded as varieties which have abandoned their leaves because of the frequency of violent blasts that would be likely to tear or destroy them. In the bulrush, however, the leafless habit is partly a response to the prevalence of surf in places where the plant is accustomed to make its home.

Many bulrushes have three-cornered stems and grow in marshes or even upon prairies, but these are to be connected with the ordinary cylindrical bulrush of lakeshores because of the exact similarity of their flowers and fruits. Indeed, the three-cornered stem was probably primitive and the cylindrical, adaptational.

Carex-sedges. The largest genus of plants in Minnesota —after the rusts—belongs to the sedge family, and there are about 110 species of *Carex* in the state. The Carices are grass-like sedges, for the most part small and slender plants and perennial by underground rootstocks. Each pistillate flower develops a sac-shaped leaf which incloses the rudimentary fruit, so that when ripe it stands in a little bladder, reminding one somewhat of the ground-cherry, only very much smaller. These sacs may be either papery or hard and they may be either smooth, furrowed or winged. Usually the stigmas are protruded far beyond the top of the sac which itself takes the form of a bottle, and through the neck of this the stigmas are thrust. Sometimes the stigma is two-lobed, while in other species the number of the lobes is three. A considerable variety exists in the shape of the sac in which the fruit is formed. Sometimes it is slender, while again it is swollen or even globose. In many sedges the pistillate flowers—their fruit-rudiments inclosed in the sacs—are displayed in special spikes or heads, while the staminate flowers stand in other spikes above or below the pistillate—if the two occur on the same general axis—or entirely separate from them. Among the Carices the flower clusters, in their general shape and in their position on the plant-body, show great variety. Sometimes they are cylindrical and pendulous, again cylindrical and erect or ascending, again globose or loosely aggregated. In still

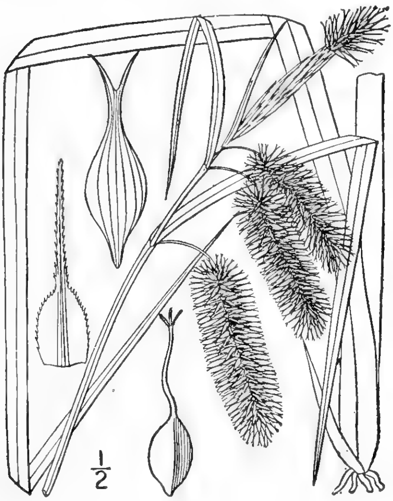


FIG. 96. Carex-sedge. After Britton and Brown.

other instances they form long clustered groups made up of numerous spikes of flowers. One of these little sedges is an extremely common flower of early spring, dotting the prairies with its little yellow spikes of staminate flowers below which whitish spikes of pistillate flowers are formed. The yellow color is given by the stamens themselves.

Some of the sedges are robust, strong plants, almost like bulrushes in their general aspect, while others are very delicate, low-tufted plants, bringing to mind the smaller sorts of grasses. In the classification of this large genus of plants a variety of characters are taken into consideration—the number and position of the flowers, the character of the sac which incloses the fruit, the distribution, shape and color of the scales, the width, length and texture of the leaves, the number of branches of the stigma and the general distribution of the flowering tracts upon the axis where they develop. Economically, sedges are by no means as important as grasses; neither are their stems so valuable as fodder, nor do their fruits serve to feed mankind as do those of the rice, wheat, rye and maize, all of which belong to the other family of the order. Yet a considerable industry is being developed in the manufacture of matting from one common Minnesota variety and the plants are not without their uses.

Chapter XXIV.

From Callas to Water Star-grasses.

The fifth and sixth orders—the palms and cyclanthuses—are not represented in Minnesota, but the two families of the seventh order are, by a few well-marked species. Here come the plants of the arum family, comprising in Minnesota the jacks-in-the-pulpit, the calla, the skunk-cabbage and the sweet-flag. These are of somewhat different habits and structure, but they agree in producing their flowers upon fleshy spikes subtended or surrounded by peculiar leaves known as *spathes*. The common jack-in-the-pulpit, for instance, develops such a fleshy spike of flowers and the spathe encircles the cluster as a curious hood. The spathe in the calla lily of greenhouses forms a white, vase-like chalice beneath the fleshy spike, while in the skunk-cabbage it becomes a livid purple cowl open at one side. In the sweet-flag the spathe is prolonged straight above the apparently lateral fleshy spike and seems like a continuation of the flattened stem. In most of these plants the rootstocks are commonly short and solid and contain a very acrid sap. The unpleasant taste of the Indian turnip is given in part by crystals of lime oxalate enclosed in certain cells of the bulb.

The fruit of the arums is a berry. In the jack-in-the-pulpit the berries are scarlet and mature in the autumn. In the sweet-flag they are crowded together and gelatinous—often failing to mature. All of these plants have special peculiarities of growth that would be interesting to follow in detail and a few points are particularly worthy of attention. If in the curious flower clusters of the skunk-cabbage a thermometer be inserted, and after fifteen or twenty minutes it be removed and read, it will be found that the temperature may be from five to fifteen degrees higher than that of the surrounding air, showing the power of the purple substances in the spathe, together with the respiratory activity of the fleshy spike, to increase the temperature. In the jack-in-the-pulpit flower the peculiar little club-shaped sterile end of the spike is probably a respiratory organ and together with the special coloring substances does its part in raising the temperature. Small insects learn that these flower clusters offer them comfortable shelter and seek them, and as a result pollination is secured. The flowers of most of the arums depend upon this ability to furnish heat rather than upon perfumes, gaudy colors or the secretion of nectar to attract their insect visitors.

FIG. 97. A skunk-cabbage in early spring, before the leaves have unfolded. The purple hood covering the flower cluster is shown on one side. After Atkinson

Burrowing bulbs. Another curious feature in the lives of many arums is the burrowing habit of the young bulbs. If a flower pot about six inches tall is filled with rich loam and some seeds of the skunk-cabbage or jack-in-the-pulpit are planted about half an inch below the surface and permitted to germinate, the plantlets when they burst forth will at once begin the formation of bulbs by expanding the lower portions of their stems into round and solid bodies. In a week or so after such a bulb has been formed, if sought where it first appeared, it cannot be found, for by this time it will have burrowed to the bottom of the pot. In this manner the erect rootstocks of skunk-cabbages sink a foot or two into the soil—as any one who attempts to dig up a perfect plant will soon discover. The way that this is accomplished is by the development of contractile roots on the young nodes. Four or five of these roots are sent obliquely down into the soil on different sides of the stem. When they are long enough they produce some short lateral branches near their tips, thus anchoring themselves. They then contract and the bulb or stem—the base of which may be sharply pointed—is pulled down into the earth. By this means the plant establishes its stems sometimes twenty inches below the point where they began to form. The contractile roots, differing considerably from the ordinary absorptive roots, may be recognized by their large size and by the wrinkles on their surface.

Although the berries of most of the arums are exceedingly unpleasant to the taste, some birds seem to fancy them and their bright red color in the jack-in-the-pulpit, calla and skunk-cabbage is no doubt in the nature of an advertisement to attract the attention of such as will eat them.

All of these plants except the sweet-flag grow in rich soil, in deep woods, ravines or swamp borders. Like most shade-loving plants, they have large leaves of thin texture. The jack-in-the-pulpit is a typical shade plant in structure. Unlike most of its class, its leaves are netted veined and the broad, thin blades are fitted to catch as much sunlight as possible. The flowers in this plant are commonly of two kinds. The staminate may occur either upon the same fleshy axis with the pistillate, and just above them, or upon a separate axis. The peculiar club-shaped elongation of the flowering axis in the jack-in-the-pulpit is not characteristic of the calla, the skunk cabbage or the sweet flag, for in the latter plants the flowers cover the axes to their tips. The sweet-flag occupies a different habitat from the others preferring the edges of streams and swamps. Its rootstocks are used in pharmacy and are often collected and chewed by children, for they have not the acrid taste and are harmless. The leaves of the sweet-flag are similar to those of the blue flag or iris and quite different from the great oval leaves of the skunk-cabbage, the small heart-shaped leaves of the calla, or the three-parted leaves of the jack-in-the-pulpit.

Duckweeds. The duckweeds are small natant or submerged plants which form green scums on pools and puddles. They have no foliage-leaves but develop little flat, oval or triangular stems which float upon the surface of the water. Some of them have roots which hang down as counterpoises, but others are without roots and appear suspended in the water as tiny green ovoid balls not as large as a pin-head. The latter are the smallest of all flowering plants and are marvels of reduction. When the duckweeds flower, which they very seldom do, the stamen and pistil stand together in a little depression on the surface. For the most part these plants depend upon propagation for their persistence and do not reproduce by seeds. In Minnesota there are five or six species. The two kinds of duckweed which are most abundant are the ivy-leaved or three-cornered duckweed and the smaller duckweed. In the latter the floating discs are about an eighth of an inch in diameter and of nearly circular shape. In the former the plant-body is branched more abundantly and builds up a group of three-cornered or arrowhead-shaped branches. In each of these plants a single root hangs down from the middle of the plant-body.

Another somewhat larger duckweed, with discs a quarter of an inch or so in diameter is easily distinguished by the formation of tufts of roots on the under side. In these plants there are traces of an original terrestrial existence, although they have become so much modified by their aquatic life that they now resemble some forms of algae. Nevertheless the roots in all the species which produce these organs are supplied with root-caps, structures of value to all terrestrial plants, because they protect the young roots as they penetrate the soil. They are, however, of no value to aquatic plants and some aquatic plants shed their root-caps. The little floating fern of Minnesota is interesting from its general habit of dispensing with the root-caps shortly after the roots have begun to extend into the water. But when plants like the floating fern or the duckweed develop roots with caps and afterwards drop these caps, now become useless, into the water, it may be assumed that they are, by this action, indicating their original terrestrial habits and proclaiming as distinctly as possible that they were not always floating plants. Of the duckweeds the one most perfectly adapted to the aquatic habitat is at the same time the most simple of all flowering plants. One must carefully distinguish between that simplicity of structure which is rudimentary and the similar simplicity which comes from reduction. Low types of plants like some of the algae are simple in form, like the smallest duckweed, but *their* simplicity need have no complexity behind it. Sometimes these tiniest of duckweeds, mere little green specks in the water, lie at the surface and produce each on its upper side a neat little stamen and pistil quite in the style of their earlier terrestrial days.

The eighth order includes eleven families, of which but four are represented in Minnesota, the yellow-eyed grasses, the pipeworts, the spiderworts and the pickerel-weeds.

Yellow-eyed grasses. There is one species of this family in Minnesota. It is not very common but occurs in the vicinity of the Twin Cities. The general appearance of the plant is grass-like and a few little yellow flowers, each with three distinct petals, are formed in the axils of a group of scales which stand in a more or less ovoid head at the tip of a slender erect stem. The most favorable place to seek these plants is near the edges of a tamarack swamp where the country is somewhat open, or on banks near the shores of lakes. The size of the plant and its general appearance reminds one a little of the blue-eyed grass, a common plant of the iris family, but the color of the flowers at once serves to distinguish it.

Pipeworts. Related to the plants last described are the curious little forms known as pipeworts, of which a single species has been found on the muddy shores of some Minnesota lakes near St. Paul, in Chisago county, in Douglas county and in Cass county—stations indicating a wide distribution over the state. The pipeworts have very short stems on which little tufts of grass-like leaves are borne. From the centre of the tuft rises a slender stem one to six inches in height. At the end of this is formed a spherical head of minute flowers. If the plant grows beneath the surface of the water, as it often does, the erect stem may be several feet in length, coming up like a wire from the bottom of the pool and bearing the little head at the surface of the water. The name *pipewort* is given on account of the hollow stem which bears the flowering head.

Blue-eyed-Marys. The spiderwort family includes two Minnesota species, the common spiderworts or blue-eyed-Marys frequent on banks, along roadsides and railway tracks and at the edges of meadows. The plants are mucilaginous and when broken excrete a viscid slime. The leaves are rather thick, grass-like in form, and arise from a simple or branched stem. The flowers are produced in generally terminal umbels and are of a bluish-purple color an inch or so in diameter. There are three purple petals and three green calyx leaves below. There are three carpels fused together to form the fruit rudiment, surrounded by six stamens. When the ovoid fruit is mature it splits by three longitudinal lines equi-distant from each other, as does also the iris fruit. The stamens in these plants possess tufts of interesting purple hairs which are very beautiful objects for microscopic study.

Pickerel-weeds. A somewhat common green-house member of the pickerel-weed family is known as the water-hyacinth and is similar in its flowering clusters to the rather rare native pickerel-weed of Minnesota. Any one who has seen the flowers of the water-hyacinth will recognize the pickerel-weed if he chances upon it at the edges of a marsh or in tamarack swamp. The leaves are thick, shaped somewhat like those of the arrowhead, and arise from a prostrate rootstock. The flowering stem stands erect, bearing one large heart-shaped leaf, with some sheathing bracts at the base. The whole flowering stem varies from one to four feet in height, while the large leaf may be ordinarily as much as six inches long. The flowers are pale blue and delicate in texture like the flowers of the water-hyacinth. They occur in clusters on a somewhat fleshy spike at the base of which is a small thin spathe.

Water star-grasses. Related to the pickerel-weed and a member of its family is a little mud-flat plant known as the water star-grass. When growing in water the stem of this plant is two or three feet in length, no thicker than a knitting-needle, branching frequently and possessing short, very slender leaves with rather sharp points. The flowers are of a lemon-yellow color and one or two are produced at a time. This form is, however, rare in Minnesota and usually the water star-grass appears on mud-flats as a plant two or three inches long with characteristic lemon-yellow flowers, each with six equally colored portions.

To this order belong also the pineapples and Spanish mosses of the south and several tropical families not represented in the United States.

Chapter XXV.

Rushes, Lilies, Blue Flags and Orchids.

The ninth order includes the rushes, the lilies, and their allies, the bloodworts, the amaryllises, the yams, and the blue flags or irises. These all unite in the general character of the flower which is made up of the six portions belonging to the perianth, three or six stamens and three fused carpels. The flower of the familiar Easter lily is, in its structure, typical of the whole order.

Rushes. About twenty species of rushes occur in Minnesota. They are for the most part perennial grass-like herbs, common upon sand beaches, in prairie sloughs and back a little way from the borders of marshes or swamps. The flowers are ordinarily clustered and are characterized by the inconspicuous chaffy appearance of the six perianth leaves. They are not, however, subtended by scales and arranged in spikelets as are the grass and sedge flowers; and rushes need not be mistaken for any of the lower families if their flowering tracts are carefully observed. The fruit in rushes is a small capsule which splits at the sides like the much larger fruit of the iris. The seeds vary in number from three to several. There are usually three or six stamens in each flower.

FIG. 98. Sedges and rushes. After photograph by Williams.

Two genera of rushes, the wood rushes and the bog rushes are found in Minnesota. The wood rushes are recognized by their habitat and by the position of the bractlets beside the flowers. The bog rushes, while of the same general appearance, commonly produce more seeds in each capsule than do the wood rushes. No little variety exists among the rushes in the shape of their flower-clusters. Generally they are rather flat-topped, but some species exhibit the flowers in globular heads and others in loose panicles.


FIG. 99. Dog's-tooth violet in flower. After Atkinson.

Lilies and their allies. About forty species of plants belonging to the lily family are known to occur in Minnesota. Among them may be mentioned the trilliums, or wake-robins, the hellebores, the asphodels, the bellworts, the clintonias, the false and true Solomon's seals, the asparagus, the tiger-lilies, the dog's-tooth violets and the wild onions. These plants occupy a variety of habitats. Some, like the asphodels, are to be sought in tamarack swamps; others, like the bellworts and Solomon's seals, in the edges of the woods; others, like the clintonias and trilliums, in the

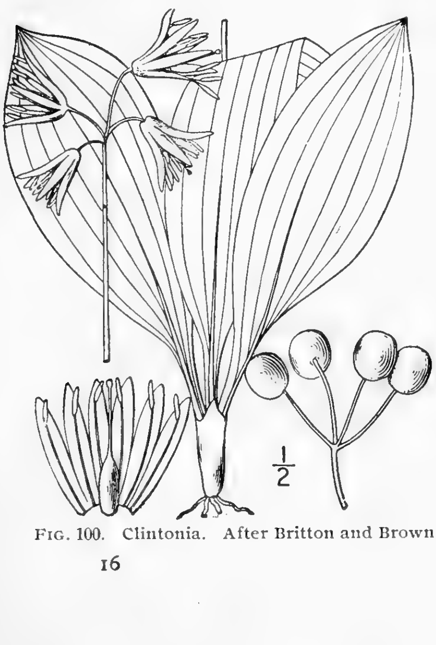


FIG. 100. Clintonia. After Britton and Brown.

depths of the forest. One interesting form, known as alkali-grass, grows on the high prairies in the western part of the state. The onions are found in six different varieties and are best developed in the prairie region of Minnesota, but they occur also in the forests.

The hellebore is notable as the source of the alkaloid *veratrine*, a valuable medicinal compound. The bellworts, of which there are three varieties, are common and attractive flowers of the middle spring. The onions, with their characteristic bulbs, smooth in some species, in others fibrous or reticulated; the tiger lilies of three sorts with their showy flowers, the dog's-tooth violets of three varieties with their peculiarly spotted leaves and white or yellow flowers are all familiar and common forms. The peculiar habit of the Solomon's seals which separate the erect stems of the year from the strong perennial subterranean rootstocks in such manner as to give rise to circular scars, has occasioned the common name. Asparagus which grows wild in Minnesota differs from the rest of the family in being largely devoid of leaves, the fine green foliage consisting of small starch-making branches rather than true leaves.

FIG. 101. Blue flags. After photograph by Williams.

Smilax. Among the lilies may be included also the green briars or smilaxes, noticeable for their netted leaves and, in most varieties, tendril-bearing stems. Five species of smilax are known to occur in Minnesota. The flowers in these plants stand in umbels and the fruits mature as berries of a red or blue color, shading towards purple or black. The stems, which twine or climb upon the vegetation near them, arise from large swollen underground rootstocks. One variety of smilax common in Minnesota is quite destitute of tendrils and exists as an erect herb a foot or so in height. Some of the smilaxes are very bristly with prickles upon the stems or edges of the leaves, while others are smooth.

Yams. A single species of yam is common in woods throughout the southern part of Minnesota. The body of the plant is herbaceous or slightly woody. Underground rootstocks are produced from which slender twining vine-like stems arise, bearing heart-shaped broad leaves with elongated pointed tips. The flowers are small and borne in elongated clusters. When the plant fruits, deeply three-furrowed papery capsules are formed in each of which from three to six very flat thin seeds are enclosed. The rootstock is fleshy and some of the tropical varieties are of commercial value as articles of food. The sweet potato, sometimes confused with the yam, is an entirely different plant.

Fig. 102. Stream-side vegetation. Blue flags in foreground. After photograph by Williams.

Blue flags. In Minnesota the iris family includes three species. One, the blue flag or iris or fleur-de-lis, is a familiar object in swales and marshes and is common throughout the state. The large blue flowers are borne on erect stems with leaves similar in appearance to those of the cat-tail. The stems arise from woody tuberous rootstocks. The three-celled ovary matures into a capsular fruit in which the seeds are very much flattened by mutual pressure.

Blue-eyed grasses. The other plants of the iris family are known as blue-eyed grasses. Of these, two species, by some botanists combined into one, occur in Minnesota. They are but diminutive blue flags, being tufted grass-like plants with small blue flowers about a quarter of an inch in diameter. They are to be found in meadows and upon wooded slopes.

Star-grasses. One species of star-grass is fairly common in the southern part of Minnesota. In general appearance it is grass-like with a swollen solid bulb of rather oblong shape and usually about half an inch in diameter. Upon a somewhat short erect stem, generally surpassed in length by the leaves, are borne three or four yellowish flowers, of small size, in a flat topped cluster. This plant cannot be mistaken for the yellow-eyed grass because it has not the spherical scaly head from which originate the flowers in the latter variety.

Besides the families of the ninth order which have been mentioned there are four others not represented in the state. Nor are the plants of the tenth order found so far beyond the tropics. It is to this order that the bananas and the zingibers, the cannas and the arrow-roots belong. Cannas, however, with their unsymmetrical red flowers and large leaves are planted for ornament in many Minnesota lawns and parks.

Orchids. The eleventh order includes but two families, one of which is not found in Minnesota, while the other, the orchid family, presents a number of interesting varieties. Of orchids there are about 45 species in the state, including the rein orchids in a number of forms, the tress orchids, the *Arethusas*, the *Pogonias*, the *Calypsos*, the coral-roots, the putty-roots, and the lady's slippers or moccasin flowers, together with some others. Orchids differ from the rest of their class, so far as Minnesota is concerned, by developing flowers with *bilateral* symmetry, while the flowers of lilies, irises, yams and the rest are *radially* symmetrical like a star-fish. Orchid flowers have a distinct upper and under side like snap-dragon or pea flowers. This is probably because for ages they have stood laterally on their stems and long ago in response to this habit came to show a difference between the side toward the ground and the side toward the skies. Many orchid flowers display a long spur, as do the larkspurs. Others produce boat-shaped or slipper-shaped bags as does the moccasin flower. In none of them has the flower the even, radial symmetry possessed, for example, by the tulip or the tiger lily. Not only for the presence of flowers of this type, a character which they share with the cannas and bananas, are the orchids noted, but also for the immense number of very small seeds which they produce.

In numerous orchid flowers a peculiar reduction of some of the stamens takes place, so that in many of them there remains but a single functional stamen out of the group, the others being reduced to mere vestiges. In the lady's slipper, however, two stamens of the group remain functional. The curious shapes of orchid flowers are connected with insect pollination and the orchid flower may be regarded as a machine, or treadmill, in which some definite species of insect, different for the different species of orchids, is temporarily captured and forced to work for the purposes of the flower.

FIG. 103. Yellow lady-slipper. After photograph by Mr. R. S. MacIntosh.

In the common round-leaved orchid of Minnesota, which has but a single stamen, if a pin be inserted into the spur of the flower, passing along a groove between the two pollen-pouches of the stamen, a couple of circular adhesive discs spring out and attach themselves to each side of the pin. On each of these discs is a stalk at the end of which a mass of pollen-spores is collected. The two little masses stand up like diminutive Indian clubs for an instant and then droop forward. Here one sees the mechanism designed for the moth that pollinates the flower. When the insect comes to the plant it finds attractive perhaps only one flower of the two or three which are finally produced. It stands in a definite position, generally upon the portion of the flower turned toward the ground, and introduces its bill into the spur where a little honey is secreted. In order to obtain the honey it must thrust its bill along the groove where the two adhesive discs are situated. When the insect has sipped the drop of honey which it seeks, having been drawn to it by the perfume and color of the flower, it flies away, carrying with it the two pollen-masses, one on each side of its bill. Immediately after the insect leaves the flower the two pollen-masses bend forward and the next flower visited receives these pollen-masses fairly on the sticky end of the stigma, where the pollen-spores germinate and give rise to the male orchid plants. From this second flower the moth carries away a fresh pair of pollen-masses.

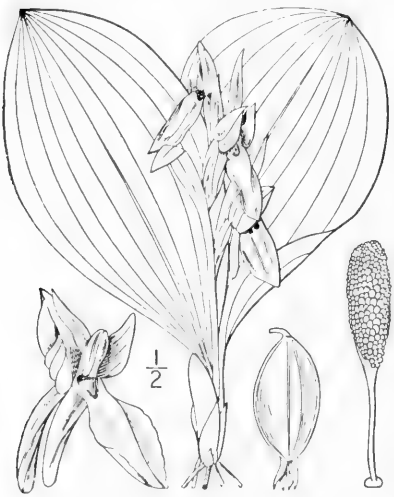


FIG. 104. Wild orchis. After Britton and Brown.

Such very wonderful and perfect devices secure what is termed *cross-pollination.* The pollen is taken from one flower and carried to the stigma of another upon another plant, thus apparently insuring a greater vitality and breadth of experience in the embryo plantlets which are to be developed in the seeds. A variety of such mechanical devices are employed by plants. Those of the orchids with their automatic adhesive discs and curving-stalked pollen-masses being among the most marvelous in their perfection. Yet it may be said that the orchids are over-refined and almost too perfect. The exactness of the machine is indeed so great that the chances against its working are apparently infinitesimal. The seeds, however, are so small and the embryo plantlets are provided with so little nutriment with which to enter upon their independent life that the great majority of them must certainly perish. The orchids, in their development, have given their attention, so to speak, to the elaboration of highly complicated methods of cross-pollination, but have at the same time neglected the proper nutrition of the plantlet in the seed. For this reason orchids are everywhere rare plants. One scarcely ever finds them in great beds such as those in which many other sorts of plants habitually occur, and possibly their infrequency may be attributed to the failure on their part to produce sufficiently virile seeds.

The habitat of Minnesota orchids is somewhat various. The moccasin flowers which, especially in their fruiting season, are poisonous to the touch like poison ivy, are to be met with in tamarack swamps or drier localities throughout the state. There are six varieties in Minnesota, differing in the size, shape and color of the flowers. One of them, the yellow moccasin, is the legal "state flower." About a dozen varieties of rein-orchids may be found, and in these several flowers are produced in a spicate cluster. The flowers in some of the rein-orchids are fringed like those of the fringed gentians, and one, with rather large purple flowers, is not uncommon in damp places both north and south. Another variety with fringed petals is found in tamarack swamps. In this the flowers are greenish or almost white. Still another type of orchid, not very common anywhere except in the woods north of Lake Superior, is the rattlesnake plantain. In this the leaves are shaped much like those of the common plantain and are curiously mottled with different shades of green. The tress-orchids are delicate, slender plants, six inches or so in height, not uncommon in pine woods near the bases of old stumps. They may be distinguished from the other orchids by their somewhat spirally twisted spikes of flowers.

Perhaps the most ornamental native orchid, when seen under favorable conditions, is the *Calopogon* or grass-pink. This is most prettily conspicuous in northern peat-bogs, where it grows among the cranberries and kalmias, often forming patches of considerable size. The flowers are of a beautiful shade of purplish pink and are visible for some distance on account of their brilliant color.

The coral-roots have very small and poorly developed leaves. They are humus plants, deriving their nutriment to a large extent through the coöperation of fungus filaments in the superficial layers of their rootstocks, and the singular coral-like appearance of the infected rootstocks has occasioned the popular name of the plant. There are three varieties, rather more common in northern woods than in the southern part of the state.

In several of the orchids bulbs are produced, and in the little putty-root, not very rare in hard-wood timber where the ground is covered with decaying vegetable mould, the bulb is well-formed and about the size of one's thumb.

The only Minnesota orchids known to be poisonous to the touch are the lady's slippers, and, especially in the autumn, it is advisable to avoid handling these plants. The leaves and stems are furnished with two kinds of hairs, some pointed and apparently harmless, others with globular tips which secrete small quantities of oil. Either the oil itself or substances in solution may irritate the skin, and careless handling of a plant is frequently the beginning of much discomfort. In the early spring, when they have first come above the ground, their secretions do not seem to be so virulent. The seeds of the lady's slipper are very light and after the pods containing them have opened they depend upon the wind for distribution. That the plant should be more poisonous while the seeds are maturing is possibly a device to discourage grazing animals from attacking it at this time.

Chapter XXVI.

Poplars and Willows.

There have now been passed in review the principal Minnesota types of higher seed-plants in which a single embryonal leaf is produced. In all such forms the first leaf springs from the tip of the nascent plant in the seed, and the rudiment of the stem arises as a lateral protuberance of the young embryo.

Plants with two-leaved seedlings. The plants included in the lower class are not so numerous as the species which belong to the other and highest group of the vegetable kingdom. The latter produce a *pair* of seed-leaves by bulgings at the end of the young spherical embryo shortly after it has begun to form from the fecundated egg. The two seed-leaves are developed opposite to each other and between them is situated the growing point of the stem, so that when seedlings of plants of this group come above ground they may generally be recognized by the pair of seed-leaves between which the little bud of the stem gradually unfolds itself. There are, however, some exceptional cases which need attention before passing on. In a few forms the growth of one of the seed-leaves is at a very early stage arrested, so that when in a ripe seed the plantlet is observed it may seem to have but a single seed-leaf. This is true of some bladderworts. Another irregularity is to be noticed in the embryos of certain parasitic plants like the mistletoe or dodder. In these the seed matures without the development of any seed-leaves whatever, and the embryo, upon dissection of the seed, will be found to exist as a tiny, more or less spherical body near one end. Here, too, it may be recalled that some members of the pine family produce a *pair* of seed-leaves, yet they would not on that account alone be included in the class now under consideration. In all instances of irregularity it is conceived that special influences must have been brought to bear upon the embryo plantlet to modify it from the ordinary type; but when the other structures of the plant are taken into account there is usually no difficulty in assigning it to its proper class.

Stem structure. A very constant character of plants of the highest class is the presence in the stem of fibres in which a longitudinal layer of cells remains without finally maturing. In trees, the seedlings will be found to have at first a little circle of such fibres, which by mutual pressure upon each other become blended together around the central pith. The layer of cells known as the *cambium* in each of the fibres thus joins with the layer of a fibre next to it and a *cylinder of cambium* originates, inclosing the young wood and inclosed by the young bark. This layer of cells ordinarily gives rise, during every year, to new wood tissue and new bark tissue. The oldest parts, therefore, of a tree-trunk, are the outside where one can lay one's hand, and the heart-wood. The bark is younger as one cuts from the outside toward the wood, but the wood is younger as one cuts from the centre toward the bark. In a tree there are just as many bark rings as there are wood rings, but the outer bark is constantly sloughing off, being cracked by the expansion of the wood within and by exposure to the disintegrating effects of the weather. Besides this, the ring of bark that is formed by the cambium during a year is commonly not so thick as the ring of wood. For these reasons bark may be only an inch or more thick, while the wood from circumference to centre may measure even several feet.

Herbs and trees. To non-botanical observers it is sometimes difficult to explain that there is no very essential difference in structure between an herb and a tree, providing they both belong to the same general family of plants. The elm is so very much larger than the nettles which grow in its shade that upon any one who considers the two together it naturally makes a very different impression. Yet, nevertheless, the general plan of structure in the two is very similar. In the nettle there is a disposition of woody tissue inside, with bark tissue outside, just as in the elm, but the tree persists possibly for hundreds of years, thickening its trunk with every season, while the stem of the nettle dies at the end of the first season of growth. The proper way to compare trees and herbs in order to understand their similarity is this: Let an herb be pulled up by the roots and laid down before one. Then let a fresh leaf-bearing twig of a tree, such as a willow or poplar, be selected and removed from the last year's branch upon which it is standing. Let one of the young roots of the tree, if it is found, be attached to the end of the twig that was broken from its support. Let the two specimens be placed side by side and their fundamental resemblance will become apparent. The same fact will be understood if one com-

FIG. 105. Cottonwoods on the Minnesota. After photograph by Williams.

pares the seedlings of trees with the seedlings of herbs. In essential respects they will appear altogether similar.

Other characters of plants with two-leafed seedlings. The plants included in the highest class ordinarily produce leaves with netted veins and the flowers are built generally upon the plan of four or five rather than upon the plan of three. That is to say, while one finds three sepals, three petals, six stamens, and three carpels forming the fruit-rudiment in many flowers of lower-class plants, one would more probably find four or five sepals, four or five petals, four, eight or some other number of stamens, and five carpels, or more, fused together to make the fruit-rudiment in the flower of a plant belonging to the higher class. In both classes of higher seed-plants there are many variations from the rule and in some plants of the highest class, flowers very similar in general plan to those of the lily might be observed. Yet the differences which have been pointed out are fairly general and in most instances serve to distinguish the proper class of a plant in question.

The highest class, comprising over 120,000 species, is by far the richest in forms of any in the vegetable kingdom. Two sub-classes are recognized, in each of which are grouped a number of orders. The higher sub-class comprises all those forms in which the petals are normally fused together by their sides to make a corolla-tube—a structure of which the honey-suckle, or the morning-glory affords typical examples. When, however, the petals are distinct from each other or are quite reduced and insignificant, the flower is regarded as typical of the lower sub-class.

Casuarina trees. The first and lowest order of the highest class includes a curious family of trees, the casuarinas, not represented in North America. In appearance their branches would remind one of those of the horse-tail. They are abundant in northern Australia and the Malay archipelago, and differ from most other seed-producing plants in forming more than one large-spore in the ovule, so that in a single seed more than one female plant may arise. Another odd habit of the casuarinas—which appears, however, in some of the other families of the class—is the penetration of the seed-rudiment by the pollen-tube, not through a canal at its tip, as is the rule, but through a cleft in the base. Therefore the seed-rudiment, which, it must be remembered, is equivalent to a spore-case in the ferns, may be regarded, in these plants, as splitting open and partially exposing the spores inside—a behavior recalling very strikingly the ordinary opening of spore-cases in lower forms.

Lizard's-tails and peppers. The second order includes four families of which the pepper family is the most important. Here belong the peppers and cubebs from which spices are obtained. They are nearly all tropical and none of them occur in Minnesota.

A single curious little plant, the lizard's-tail, belonging to a related family, is found in far northern Minnesota. The lizard's-tail is an herb with heart-shaped leaves and flowers arranged in little spikes like those of the dooryard plantain. There are no petals or sepals and the stamens grow from the base of the ovary, which consists of three or four carpels, sometimes fused and sometimes almost separate. From four to eight seeds are formed in the fruit and in each seed there is an abundant albumen. The embryo is small and located near the end of the

FIG. 106. Poplar vegetation of burnt district. Near Rat Portage, Ontario. After photograph by the author.

seed, imbedded in the albumen. These plants are to be sought in swamps or near the edges of small woodland lakes.

Willows and poplars. The third order includes but a single family—the willow family—to which the willows and poplars belong. About eighteen species of willow and seven species of poplar grow without cultivation in Minnesota. The willows are wind-pollinated plants with rather slender leaves. The poplars are insect-pollinated and have generally broad, triangular or heart-shaped leaves. This family of plants is characterized by separate flowers, the staminate and pistillate occurring in different clusters, and both kinds are arranged in erect spikes or drooping catkins. The fruit is an oblong or rounded capsule containing small seeds with numerous white silky hairs instrumental in distribution of the plantlets in currents of air. There is no albumen in the seeds.

Poplars. The poplars in Minnesota are represented by the very common white poplar, the large-toothed poplar, the cottonwood, the balsam-poplar, the balm of Gilead, the silver-leafed poplar—sometimes called silver-leafed maple—and the Lombardy poplar. The last two are not native plants, but occur spontaneously, having escaped from cultivation in some parts of the state. Of them all, the white poplar is the most abundant tree throughout the northern part of the state, and is not uncommon in the southern counties. This, indeed, is the most widely distributed tree in North America. It often reaches a height of seventy-five or one hundred feet, but in the region of the Great Lakes does not apparently grow so large. The wood is soft and is of great importance, together with spruce, as the variety employed in making wood-pulp, from which paper is manufactured. It is used also for firewood, and is a most prominent plant in burned districts, readily reaching them by its buoyant air-distributed seeds. The leaves are hung upon stems of peculiar shape and tremble in the slightest breeze.

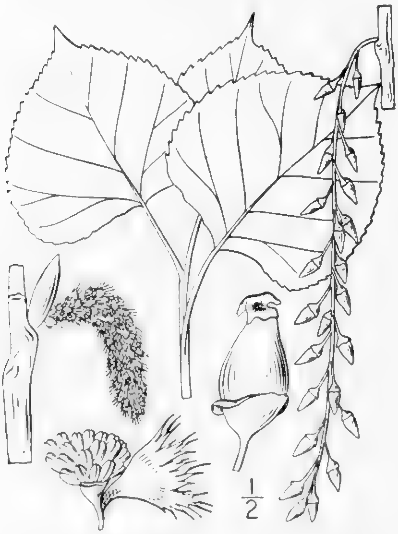


FIG. 107. Cottonwood. After Britton and Brown.

The large-toothed poplar has much ampler leaves with broad teeth upon their margins. By these characters it may be distinguished from the white poplar. It prefers soil damper than does its relative and is generally found upon the more sheltered banks of lakes. Its wood is also of value in the manufacture of paper.

The balsam-poplar has longer, sticky leaves and the balm of Gilead—a variety with more spreading branches—is cultivated as a shade tree in some parts of the state. The leaves are dark green on one side and dirty brown or white on the other, and are considerably longer than those of any other Minnesota species.

The cottonwood, which may be distinguished from the white poplar by the glistening paler green of its leaves, is an abundant tree throughout the state, and is found along streams where it often forms considerable forests. Under favorable

Fig. 108. Peach-leafed willows on shore of stream. After photograph by Williams.

conditions it may grow to the height of a hundred feet with a trunk seven or eight feet in diameter, but I have seen none in Minnesota to exceed five feet in thickness. The wood is of little value save for pulp and fuel. In the older towns and villages of Minnesota the cottonwood has been freely planted; but it is not regarded as the most desirable of shade trees, for it is always dropping something from its boughs—either staminate flower-clusters, cotton, scales or leaves—and it litters a lawn or street throughout the spring and summer. The staminate flowers of the cottonwood are crimson in color, borne in rather dense drooping catkins. The pistillate flowers, produced on other trees, are green in color, and likewise gathered in pendent clusters. The capsule opens by three clefts and is regarded as composed of three carpels. A considerable number of silky-tufted seeds are produced in each capsule.

The other poplars need no special mention since they are not indigenous to the state. One of them, the Lombardy poplar, with its spire-like habit of growth, is an attractive and valuable ornamental tree. It is propagated by cuttings and seems to have lost the power of fruiting. No doubt almost all the

FIG. 109. Clusters of willow flowers; on the left the pistillate flowers and on the right the staminate. Each pistillate flower consists principally of a single fruit-rudiment, and each staminate flower of two, or sometimes a larger number of stamens. After Atkinson.

Lombardy poplar trees in America might be traced back to a single poplar egg. The tree which developed from the embryo plantlet was originally propagated by cutting the twigs and planting them in the soil. The process was repeated and in this way a vast number of Lombardy poplars have come to exist—a very odd thing, indeed, when one thinks of it and compares it with the behavior of animal eggs.

Willows. The willows of Minnesota are not all trees like the poplars. The majority are shrubs—some of them low bushes like the myrtle-leafed willows in peat-bogs and tamarack swamps. A few, however, are trees and of goodly size. The distinctive habitat of willows is along the banks of streams and around the shores of lakes or marshes. Their twigs are used in the manufacture of wickerware; and bushed-willows or pollarded willows, are favorite plants for hedge-rows in the east and in England, but are not so frequent in Minnesota. The two most conspicuous willow trees of the state are the black willows with their slender leaves bearing conspicuous stipules at the base, abundant in the north, and the peach-leafed wil-

FIG. 110. Beach vegetation, Garden Island, Lake of the Woods. The long-leafed willow forms the outer zone, and the black willow the inner. After photograph by the author.

lows, with much broader leaves and devoid of stipules on mature twigs, more common in the south.

The hoary willow, the gray willow, the pussy-willow, the heart-leafed willow, the myrtle-leafed willow and the long-leafed or sand-bar willow are encountered ordinarily as low shrubs up to ten or twelve feet in height. The familiar "pussies" of early spring are the spicate flower-clusters of some willow from which the bud-scales have opened or fallen, revealing the branch covered with bractlets in the axils of which the flowers will open. The edges of the bractlets have silky hairs which serve to protect the flower-buds during the cold nights or occasional freezing weather of early spring.

As beach plants, the long-leafed willow, the hoary willow, the heart-leafed willow, the shining-leafed willow and a few others are common, especially along sand-bars, where there is considerable spray from the surf. At Lake of the Woods some very interesting willow-clothed beaches have been observed. Different species of willows on such beaches often arrange themselves in zones, one variety nearer the water, and another farther back. Some of the willows, notably the hoary willow and the heart-leafed willow, along the shores of northern lakes, grow in a very regular more or less hemispherical fashion, resembling the trimmed shrubs of some city park.

The bark of the willow is bitter and is sometimes used as a febrifuge in place of quinine, but it is not particularly efficacious.

Chapter XXVII.

From Bayberries to Oaks, Elms and Nettles.

Bayberries. The fourth order includes but a single family, of which two species grow in Minnesota—the bayberry, found on lake shores along the international boundary, and the sweet-fern, rather abundant in the northern part of the state and extending south to the vicinity of Minneapolis. These plants are shrubs, their leaves dotted with resin glands, and the name "sweet-fern" is given on account of the scent which arises from the glands. The two sorts of flowers are separate and in catkins somewhat like those of the willows but shorter and plumper in appearance. The fruit is a nut or stone fruit, differing in this respect from the willow fruits, which are capsules. The leaf of the sweet-fern is especially characteristic, resembling in shape a willow leaf with deep narrow incisions along the margin.

The fifth and sixth orders are not represented in Minnesota. One of them contains a few species of New Caledonian plants, the other, one species found in the southern United States.

Walnuts and hickories. The seventh order comprises but a single family, in which are classified the walnuts and hickories, both represented in Minnesota. There are present two species of walnuts—the black walnut and the butternut—and three species of hickories—the white hickory or shell-bark, the pig-nut hickory, and the swamp hickory. The walnut family is a group of trees with compound leaves and separated flowers. The staminate flowers stand in catkins and are furnished with a perianth. The pistillate flowers are solitary or in small groups. The ovary is one-chambered and contains a single seed-rudiment. The fruit is similar to that of a peach in which the fleshy part should split and separate as three or more husks. The seed is large, inclosed in the stony inner layers of the fruit, the whole constituting the well-known walnut, hickory-nut or pecan. There is no albumen in the seed and the two seed-leaves are large, wrinkled and oily, forming the "meat" of the nut. The black walnut occurs in the southern part of Minnesota, where it is found in low glades along streams. Almost all the large trees have been cut for their very valuable wood, useful in cabinet making. This is of a rich, dark brown color and takes a high polish. The butternut is more abundant and is a frequent inhabitant of groves in the river valleys, especially through the southern part of the state. It is not commonly more than forty or fifty feet high in Minnesota, though it is known to grow twice as tall. The wood is of a light brown color, easily polished and of much value in the manufacture of furniture and cabinet work, though by no means the equal of the black walnut.

FIG. 111. Hickory trees. Lake Minnetonka. After photograph by Williams.

Hickories. The three kinds of hickories in the state may be recognized by their leaflets, nuts and buds. In the shell-bark hickory the leaflets are from five to seven in number, with hairy margins. The nut is four-angled, pale or whitish in color. In the pig-nut hickory, with the same number of leaflets, these are usually smooth or slightly furry, but not hairy at the margin. The nut is oblong, with a slightly bitter kernel. In the swamp hickory the leaflets are from five to nine in number, the nut thin-shelled and short. The buds in winter are yellow. The wood in all these plants is very heavy, strong and tough, and is used in the manufacture of wagon-tongues and plow-handles, while the young saplings of the swamp hickory are split and bent into barrel-hoops. The nuts are common in markets, but are not so agreeable to the taste as the pecan nuts, which are derived from a species of hickory that does not grow in Minnesota. Hickories are often a hundred feet in height, with tall trunks two feet in diameter

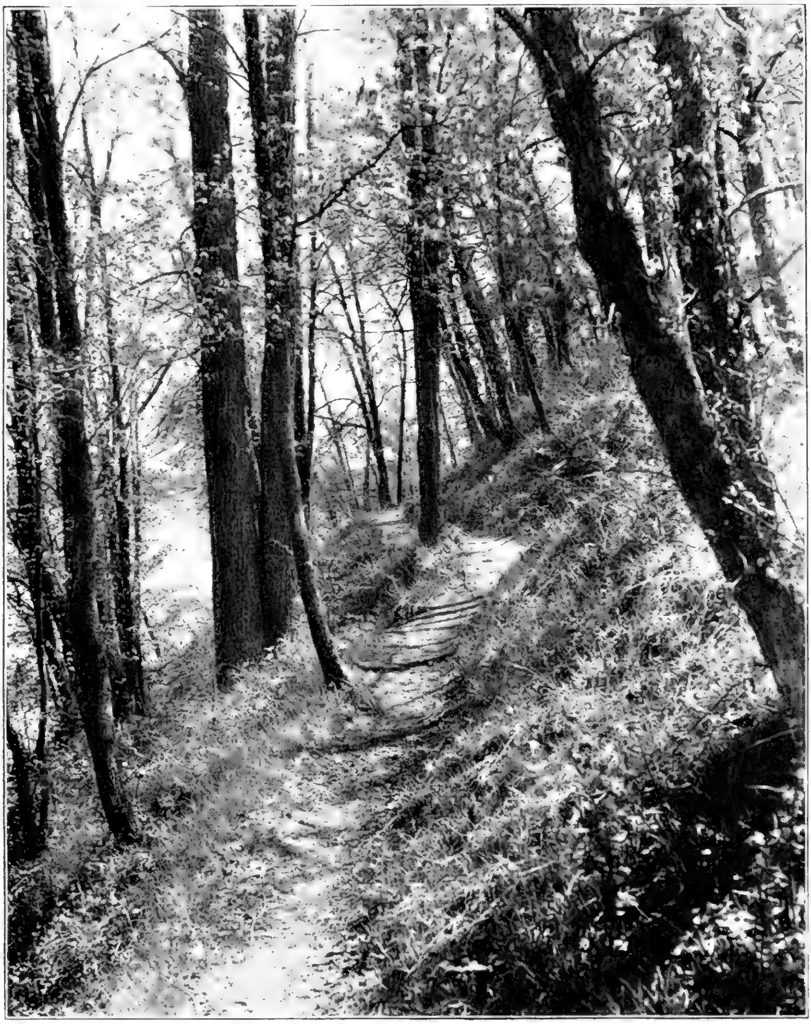


FIG. 112. Ironwoods and oaks. The smaller trees are ironwoods and hop-hornbeams. Lake Calhoun. After photograph by Hibbard.

at the base. They are among the most valuable of the hardwood timber trees of the state.

The eighth order comprises two families, one including the hazels, ironwoods, hop-hornbeams, birches and alders; the other the beeches and chestnuts, not represented in Minnesota, and the oaks which form a large and characteristic portion of the hardwood forest of the state.

Ironwoods. Of ironwoods there is a single species in Minnesota, known also as the water-beech or hornbeam. This plant is a small tree with very strong, tough wood. It is found principally along streams. It has the leaves of a birch, but when in fruit displays each of its little nuts at the base of a large three-lobed bract shaped somewhat like a spear-head. By means of these bracts and also by the rough bark, quite unlike birch-bark, the ironwoods may be distinguished. Related to them are the hop-hornbeams, the fruit clusters of which look very much like hops, while the general appearance of the tree is similar to that of the ironwood. An examination of such an hop-like fruit cluster will show that it is an axis upon which little nuts are formed, each one inclosed in a membranous sac structurally equivalent to the spear-shaped bract of the ironwood.

The hazels. The hazels, of which there are two varieties in the state, are shrubs with broad notched leaves. They produce their staminate flowers in catkins and the pistillate flowers in very inconspicuous little buds from which the stigmas of the pistils protrude as red threads. In the common hazelnut, which is so abundant as underbrush in the woods, the nuts, when mature, are inclosed in ragged scales not prolonged very much beyond the ends of the nuts. In the beaked hazelnut, a somewhat larger bush, ten or fifteen feet in height, the nuts are inclosed in scales which grow out into a long tubular beak, a structure by which this plant is easily distinguished from the more common variety. The nuts of the hazels are much larger than those of the ironwoods and hornbeams, are edible and are gathered in quantities in the autumn.

Birches. Of birches there are six species in Minnesota, the black birch, the canoe or paper birch, the river or red birch, the yellow or gray birch, the low birch or tag-alder, and the scrub or glandular birch. These plants range in size, in the different species, from large trees to low bushes, but may be recognized in most instances by their bark, which peels off in thin layers, most easily in the canoe birch, but with very little difficulty in the others. Of the trees, the canoe birch will be known by its white bark, the river birch by the stems of the fruiting catkins and the brown or greenish-brown bark, the black birch by the sessile fruiting catkins and the leaves of shining green, the yellow birch by the dull green color of the leaf, otherwise like the black birch. All of these just mentioned are trees, while the rest are shrubs. In the low birch the twigs are not covered with glandular pimples, but such are present on the twigs of the glandular birch. Of all the birches the

FIG. 113. The paper or canoe birch. After photograph by Williams.

canoe birch is the most interesting, on account of the peculiar bark that plays so important a part in the domestic arts of the Indians who employ it in the manufacture of a great variety of useful objects. Their canoes and the houses, dishes, baskets, drinking-cups and scrolls for writing are produced from birch-bark; while from the wood they manufacture a variety of tools, snow-shoe frames, sledge-runners and tepee-poles. By the whites, birch wood is employed in cabinet making, for spools, for shoe-pegs and for lasts. The wood of the red birch or river birch is of particular value in the manufacture of fur-

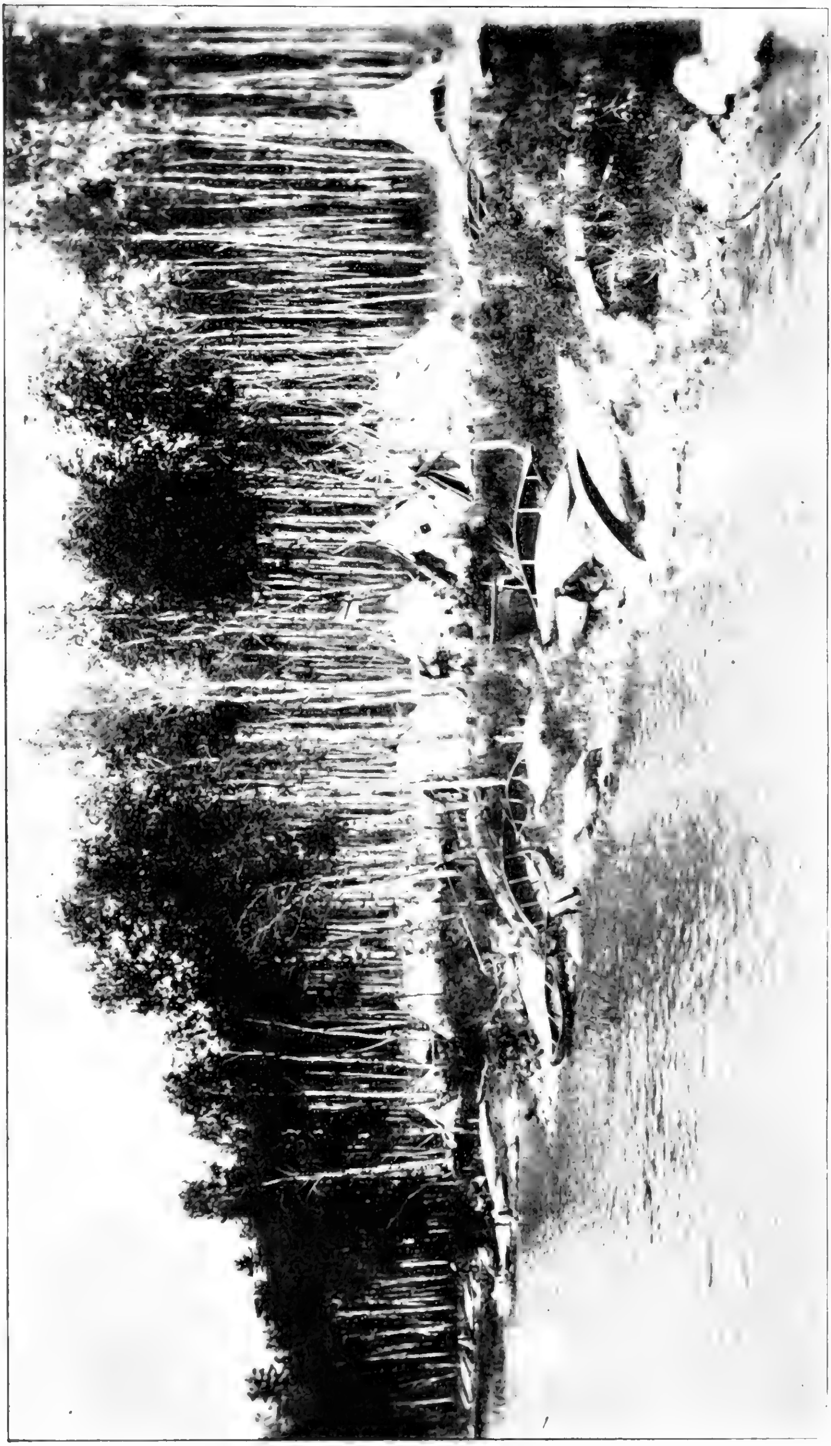


FIG. 114. An Indian encampment, Lake of the Woods. The vegetation is principally the canoe birch, and the canoes and tepees illustrate the uses to which birch-bark is put by the aborigines. After photograph by Wright. From *Minnesota Botanical Studies.*

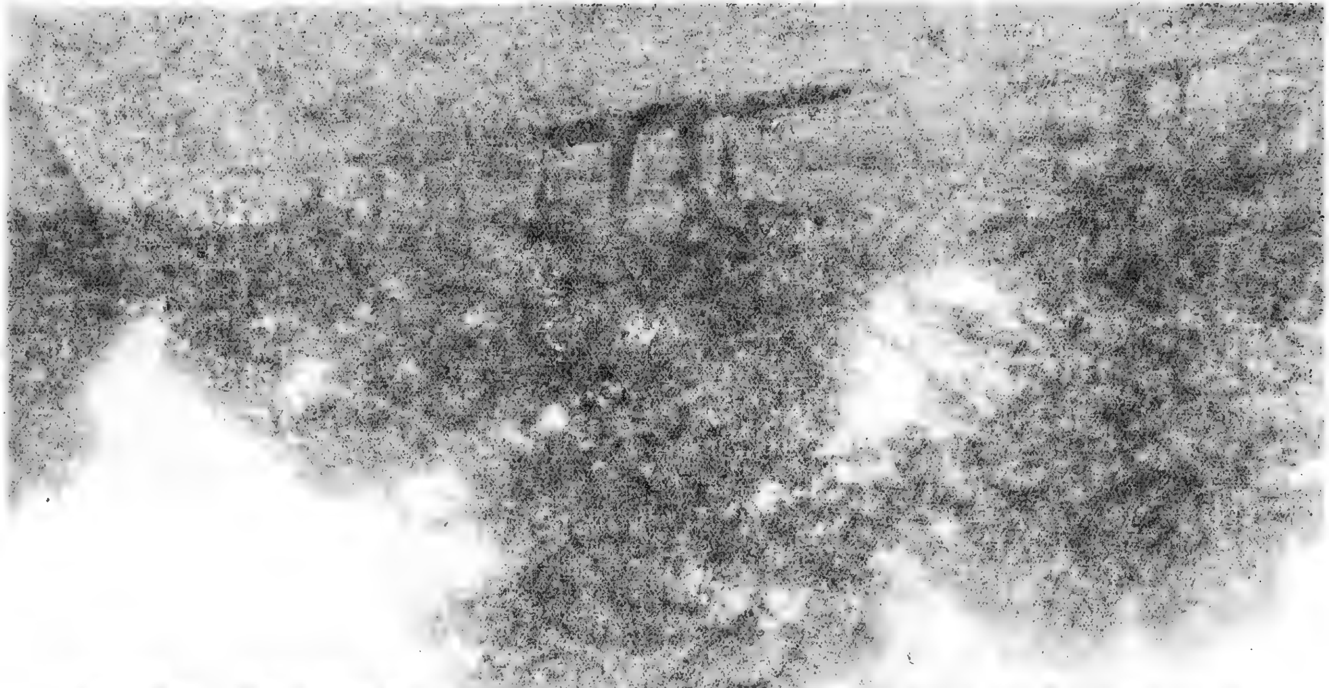


PLATE II. In the black oak country. Near the Chisago lakes. From a photograph by Dr. Francis Ramaley.

FIG. 114. An Indian encampment, Lake of the Woods. The vegetation is principally the canoe birch, and the canoes and tepees illustrate the uses to which birch-bark is put by the aborigines. After photograph by Wright. From *Minnesota Botanical Studies*.

niture, being utilized as an imitation of mahogany. For this purpose, too, the wood of the black birch is even more excellent. This species, however, occurs but sparingly in Minnesota and is found only in the extreme northern part of the state. It is from this species that birch-oil and the extract used in flavoring birch beer are manufactured. Of the shrubby birches the most abundant is the low birch which is found in peat-bogs pretty commonly throughout the state.

Alders. Related to the birches are the alders, of which two varieties occur in Minnesota, the green alder and the black alder. These may be distinguished from the low birch, which they resemble, by their more entire leaves and short, compact, cone-like clusters of nutlets. The low birch has rather more elongated spikes of pistillate flowers, two and a half times as long as they are thick, while the alder spikes are about half as long again as thick. The alders are to be looked for in tamarack swamps or in open woods, where, especially in damp places, they may form an underbrush.

Fig. 115. An oak twig with leaves and both sorts of flowers. The one with three prongs is the pistillate flower; the other, with five stamens, is the staminate. The staminate flowers grow in drooping clusters. After Atkinson.

Oaks. There are in Minnesota seven species of oaks, the red, the scarlet, the black, the white, the bur, the chestnut and the scrub chestnut-oak. Oaks form a large genus of plants, comprising some three hundred species and well distributed throughout the temperate regions of the northern hemisphere and at high altitudes in the tropics. There are some sixty species in North America. They are distinguished by the fruit known as the acorn, consisting of a nut or one-seeded fruit, inclosed within, or standing in a cup composed of numerous bractlets ordinarily grown together and woody. In some oaks the fruit matures within a year, but in other varieties a longer time is required. Oaks are employed for a variety of purposes—as firewood, in the manufacture of timbers in which great durability is demanded, and as plants from which tan-bark may be procured. The acorns are eaten by domestic animals, and the various species are prized as shade-trees.

FIG. 116. Oaks and blue flags. A marshy place in the oak-woods. After photograph by Williams.

The different varieties in Minnesota may be thus distinguished: Of those forms in which it takes the acorn two years to mature, the red oak has leaves green on both sides and the acorn cup much broader than high, while in the scarlet oak the cup of the acorn is about as high as broad, the leaves are smooth on each side, and the inner bark gray. In the black oak, which is much like the scarlet oak in appearance, the leaves on the under side develop a few hairs where the veins branch, and the inner bark is orange in color. In all three species which have been mentioned the acorns do not mature until the autumn of the second season. In the scarlet oak the foliage turns scarlet red in autumn, while in the black oak the leaves turn brown. In this way the three related species may be distinguished. In some instances, it should be mentioned, the inner bark of the scarlet oak is red rather than gray. The other Minnesota oaks mature their acorns in the autumn of the first year. Of these the white oak is distinguished by its deeply lobed leaves and shallow cups, while the bur-oak has the cup deep and composed of scales which form a bur-like growth different from the smooth hard cup of the white oak. In the remaining native oaks the leaves are notched but are not lobed in the characteristic oak fashion, and in both of them the acorns are sessile on the branches. The chestnut-oak is a tall tree with grey bark and has a chestnut-like aspect. The scrub chestnut-oak is a shrub with the leaves considerably broader than in the chestnut-oak proper.

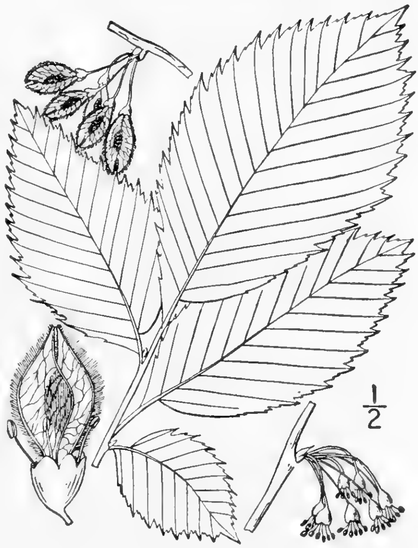


FIG. 117. American elm. After Britton and Brown.

Some of the oaks, notably the black oak, cling to their leaves for a long time after the frosts have killed them, sometimes even throughout the winter. This habit is possibly the indication of an original southern range for the black oak and a late extension of its range to the north, so that it has not fully learned how to cut its leaves from the twigs as the other more northern varieties are able to do. The bur-oaks in Minnesota, together with the black oaks, form oak-barrens. These wastes, covered with grotesquely branching trunks, form picturesque forests in the central part of the state.

The ninth order includes three families, the elms with the hackberries, mulberries and Osage oranges; the India-rubber trees, figs, hemps and hops, and the various kinds of nettles.

Elms. Of the elms there are represented in Minnesota three varieties, and one species of hackberry. The elms which are present in the state are the white or American elm, the slippery or red elm, and the rock- or cork-elm. Their flowers are small, clustered or solitary, quite devoid of petals. The ovary is one or two-celled, with a solitary seed. The fruit of the elm is winged. In the hackberry it is a berry-like nut. The seeds have little albumen. The three varieties of elm which occur in Minnesota may be distinguished by the following characters: When the young fruit is very hairy and the branches are without

FIG. 118. American elm. Lake Minnetonka. After photograph by Williams.

corky wings, the tree is the white elm. When the fruit has no hairs, is larger and the twigs are not supplied with corky wings the tree is the slippery or red elm. When the fruit is hairy and the branches are provided with curious flat cork wings, especially prominent on the young twig, the tree is the rock- or cork-elm. All of these occur in similar regions and, together with the basswoods, maples and oaks, form the most abundant growths in the hardwood forests of the central part of the state. Elms are generally to be recognized by the uneven bases of their leaves, by the strong development of the terminal buds of their branches, and by the little, oval, flattened fruits with wings on each side or extending entirely around the middle. The wood of the elm is tough and is employed for ox-yokes, the handles of tools and portions of farm machinery. The inner bark of the slippery elm is mucilaginous and is thought to have some medicinal virtue. It is frequently gathered by children.

Hackberries. The hackberry, which in its flowers and foliage much resembles the elms, is distinguished by the production of a berry-like nut. It is abundant throughout the southern part of the state and occurs in a few localities far to the north; as for example, on Sable island, Lake of the Woods. The trees are valuable shade trees and are common along the streets of towns and villages.

Mulberries and hops. The mulberries are represented in Minnesota by the red mulberry—a species reported from the southern part of the state. It is a tree with fruits superficially resembling those of the red raspberry. These are not, however, like those of the raspberry, produced from a single flower, but are rather aggregates of fruits like the spikes of the birch, or the catkins of the poplar. The foliage of a mulberry is not unlike that of the elm. The fruit-clusters are edible and the tree is both ornamental and valuable in cultivation. The common hop, related to the mulberries, is a twining vine with rough stem and foliage, and found in thickets and woodsides throughout the state. It is more abundant in the central and northern portions of the state than southward. The general appearance of the fruiting area is like that of the hop-hornbeam, but the floral structure is in most of the essential details like that of the mulberries. Hops are of value in the manufacture of yeasts and have besides a distinct medicinal value. They are gathered as herbs in Minnesota but not, so far as has been learned, on a commercial scale.

Hemp. The hemp, introduced from Asia, is a very abundant roadside weed and a denizen of waste fields throughout the state. It is a robust annual herb, growing to a height of more than ten feet, forming thickets, and really becoming a sort of herbaceous tree. The inner fibrous bark is exceedingly tough and is pounded out of the stem by special machinery and converted into rope and mattings. It is not generally employed in Minnesota for these purposes, though it is evidently capable of producing as strong a fibre here as elsewhere. The hemp leaves are divided into from four to eight or nine slender lobes arranged in palmate fashion. The staminate flowers are arranged in panicles, while the pistillate stand in short leafy spikes.

Nettles. The nettles are represented in Minnesota by the stinging and the slender nettles, the wood-nettles, the clear-weeds, the false nettles and the pellitories. The first two varieties of nettles, one of which is introduced, are distinguished by the different shape of their leaves. In the stinging nettle

FIG. 119. Roadside vegetation of nettles and vines. Winter aspect. After photograph by Williams.

the leaves are ovate in outline, while in the slender nettle they are lance-shaped and slender pointed. Both of these plants are provided with peculiar stinging hairs, consisting of cells with very sharp points and swollen bases around which a group of cells comes up like a cup. Hairs of this sort are found on both the leaves and stem. Upon being brushed against, the ends of these hairs break, forming a chisel-like point which penetrates the flesh and the cup of cells around the base of the hair contracts and injects irritating poison, very much as if from a syringe. The peculiar stinging sensation which arises when one touches a nettle is a result of this injection of acid into the flesh.

The wood-nettles, from their name to be looked for in the forest, have tall stems as much as four feet in height, stinging hairs like the ordinary nettles, and flowers disposed in axillary compound clusters. The leaves are thin, shaped much like those of the stinging nettle, and provided with a solitary stipule which often falls off. The clearweeds have no stings. The leaves are opposite and the stems are translucent and succulent, resembling the stems of the touch-me-not. The leaves are delicate and thin. The flower clusters are borne on short stems in the axils of the leaves. The clearweed is a shade-plant, preferring deep woods where there is an abundance of moisture. The false nettles resemble the true nettles in outward appearance and are found in similar localities. They have, however, no stinging hairs. The pellitories have willow-shaped leaves, are devoid of stipules and develop the flowers in little clusters at the bases of alternate leaves. The flower clusters are of the general nettle type.

The tenth order is best developed in Australia and South Africa and has no native forms in Minnesota.

Chapter XXVIII.

From Sandalwoods to Buttercups.

Toad-flaxes. The eleventh order includes six families, one of which, the sandalwood family, is represented in Minnesota by three species of toad-flax. In this same order are included the mistletoes and other curious parasitic forms of vegetation. The toad-flaxes belong to a group known as root parasites. They seem to be independent plants, but if their roots are carefully dug up it will be found that they have attached themselves to the roots of other plants growing near them, and that from these other plants they are sucking their food. They are, in Minnesota forms, slender herbs with leaves shaped like those of a willow and with flowers in corymb clusters, or cymes. The fruits are drupes or nuts. There is abundant albumen in the seed, but the embryo is small and imbedded near one end. The berries of one of the toad-flaxes are of red color and are edible. These plants occur in dry or moist soil, and one variety is very common throughout the state. They ordinarily have a rather peculiar brownish-green foliage—except the pale toad-flax, of which the leaves are lighter green. Some exotic sandalwoods occur as trees, and from them the highly scented sandalwood of jewel-boxes is obtained.

Wild gingers. The twelfth order comprises three families, two of which are remarkable aggregations of alien parasitic forms, while the other includes the wild ginger and pipe-vine or Dutchman's-pipe of Minnesota. The parasitic *Rafflesias*, which belong to this order, are among the most extraordinary of plants. One, which is found in the island of Sumatra, is famous for having the largest flower in the world, over a yard in diameter, of the color of livid flesh, and of a very penetrating, unpleasant odor. These flowers originate as buds, resembling cabbage heads, upon the exposed roots of certain Sumatran trees or vines. The vine or root has, however, no structural connection with the cabbage-head bud. This is developed upon a curious parasitic plant-body that lives within the tissues of the vine, bursting its way out when about to flower. The flower is much more conspicuous than the rest of the *Rafflesia* plant-body. Some small relatives of the *Rafflesias* are found on certain pod-bearing trees in the southern states. Their little flowers burst through the bark of the twig in which the plant-bodies are growing, thus apparently producing the remarkable phenomenon of twigs with flowers growing in the crevices of the bark. Here, however, as in the Sumatran variety, the twig is only the host-plant and the flower is a portion of the internal parasite.

The two Minnesota members of the order are not parasites, but are independent green plants. The wild ginger, of which several species are known to exist in the United States, is met with in Minnesota on shaded banks of ravines where the root-stocks of the plant, branching and scented, send up short erect stems usually with a pair of large kidney-shaped leaves and producing single, purplish-brown flowers very close to the ground. The calyx of the flower has three leaves with slender pointed tips. These are recurved in the Minnesota variety. The calyx is fused with the surface of the six-chambered fruit-rudiment which develops numerous seeds in two rows in each chamber. When ripe, the fruit is a capsule inclosed in the calyx, and it bursts irregularly.

Pipe-vines. The pipe-vines are twining vines with alternate leaves—in the Minnesota species heart-shaped. Curious irregular tubular flowers are formed, destitute of petals and with the calyx adhering to the base of the ovary. The edge of the tubular calyx is divided into three lobes and the flower is curved into a horse-shoe shape. These remarkably shaped flowers are insect-traps. Insects are induced to enter them and are forcibly detained as prisoners until they can be covered with pollen. They are then released to visit some other plant. The pipe-vine is found only in the southeastern counties of Minnesota, while the wild ginger is abundant throughout the state.

The thirteenth order includes a single family in which are gathered the true sorrels and docks, the rhubarbs, the buckwheats and the smartweeds.

Docks and smartweeds. In Minnesota there are ten varieties of docks and about twenty five of knotweeds or smartweeds. The smallest of the docks has spear-head shaped leaves and is known as sorrel. The other docks are some of them large-leaved plants most luxuriant in marshes or swamps. Among them are the water-, the swamp-, the yellow, the golden, the red-veined, the pale, and the curly-leaved docks, differing principally in leaf characters. The only one in Minnesota with sour leaves is the sorrel, and on account of this pleasant acid taste the leaves are often picked and eaten. These sorrels are not to be confused with the sheep-sorrel, in which the leaves are shaped like clover leaves,—an entirely different kind of plant. The different species of dock, besides by their leaf characters, are to be distinguished by the wings on the fruits.

The smartweeds, knotweeds, or bindweeds fall into three groups of species; some, in which the leaves are shaped like those of the willow, others, in which the leaves are small and slender, and still others with heart-shaped or arrow-shaped leaves and twining or climbing stems. The forms with willow-shaped leaves are known under the general name of smartweeds; those with the small leaves are called knotweeds, jointweeds, knot-grass or doorweeds, while those with arrow-shaped or heart-shaped leaves are termed bindweeds, false buckwheat or tear-thumbs. They are all similar in the structure of their flowers and fruits. One variety, the water-smartweed, produces its stem under the water and sends its leaves to the surface, where they float like the leaves of the pond-lily. The flowers are clustered in bright pink spikes thrust above the surface of the water. Another kind with similar habit is found as a surf-plant in northern lakes. The ordinary smartweeds grow in moist soil and ditches, where their bright pink or red spikes of flowers are conspicuous objects. The knotweeds are common mat-plants of dooryards. In most of the varieties stipules at the bases of the leaves coalesce and form tubular sheaths around the stem. The bindweeds or false buckwheats occur either as twining vines with heart-shaped leaves and flowers like those of the buckwheat, or they grow with slender erect stems reclining against the vegetation near them and supporting themselves by sharp recurved prickles. These are known as tear-thumbs, and belong to a small adaptational group of hook-climbing plants.

The fourteenth order includes the goosefoots or pigweeds, and the amaranths, known also as pigweeds, redroots or tumbleweeds, including the coxcombs and one variety of water hemp. Here also are the four-o'clocks, pokeweeds, ice-plants, carpetweeds, purslanes and portulacas, pinks, cockles and catchflies, besides some other families not represented in Minnesota.

Pigweeds. The goosefoots are represented in Minnesota by about fifteen species, many of which are introduced. Here are the common, scurfy-leaved, pale pigweeds of farm-yards and roadsides. Several sorts of these pigweeds occur in the state. Here are also to be placed the winged pigweeds, plants found on lake shores, especially upon sandy beaches in the central part of the state, and the bugseeds, abundant on the beaches of Mille Lac and near Duluth — also the blites on the shore of Lake Superior, and two salt-marsh plants very rare in Minnesota, but reported from salt marshes in the Red river valley.

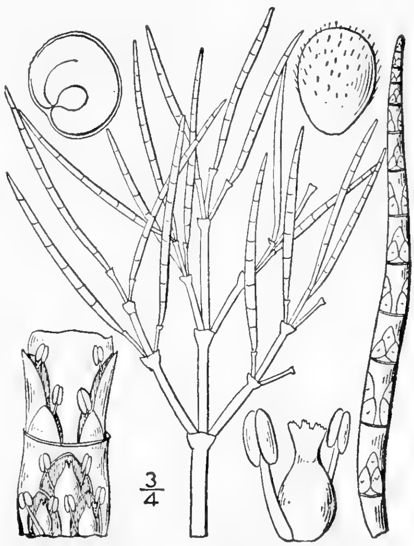


FIG. 120. Glasswort. After Britton and Brown.

Glassworts. One of these salt-marsh plants, the glasswort, is a curious, leafless, succulent organism, resembling some slender cactus-forms. In color it is green during the summer, but turns red in autumn. The stem is from six inches to two feet tall, repeatedly branched and provided with tiny scales at the nodes of the fleshy branches. These scales are all that remains of the leaf-system. Glassworts are abundant in salt marshes along the Atlantic ocean and occur at various points inland. Such leafless, succulent plants seem to have a peculiar reason for reducing their evaporative surface. It is not on account of the scarcity of moisture, as in the instance of the cacti, nor of surf, to which bulrushes are adapted, nor of high winds, in response to which the switch-plants have taken their peculiar forms; but rather on account of the presence in the soil of salt in such quantities that, if the plant had a large evaporative surface, it would absorb so much salt-water from the soil to meet the evaporation that its tissues would become surfeited with saline deposits.

The other saline plant, known as the western blite, occurs in the Red river valley, in the region of Pembina and St. Vincent. It is a fleshy herb, with thick or cylindrical leaves quite sessile upon the twigs. It maintains the same generally succulent character that characterizes the glasswort, but has not undergone so great a reduction of its leaf-tract.

FIG. 121. Pokeweed. After Chesnut. F. B. 86, U. S. Dept. Ag.

Russian thistle. Another variety of pigweed, not native to the state, but introduced in large numbers, has excited a great deal of attention on account of its rapid development in the wheat fields of the Red river valley. This is the Russian thistle, a tumbling weed, succulent when young, but turning hard, dry and thorny when older. A variety of plant very similar to the Russian thistle is found along the Atlantic seacoast. It has not, however, the bushy branches of the thistle.

Coxcombs. The amaranths or coxcombs also include a very common tumbleweed which grows in globular form, two or three feet across. The common coxcombs of the country flower-garden are relatives of this, and the redroot pigweed, a familiar barn-yard plant, is another closely related form. Still another amaranth grows flat upon the ground in dooryards and along the roadside, in its appearance somewhat resembling purslane.

Water-hemp. The water-hemp which grows in swamps has flower clusters reminding one of the common amaranth of the dooryard. The leaves are slender and willow-shaped, while the habitats selected by the plant are preferably the gravelly shores of lakes or rivers in the southern part of the state.

Pokeweeds. The pokeweed family is represented in Minnesota by a single species that occurs in the southern part of the state rather rarely. In this plant the fruit is a black berry with from five to fifteen chambers, one seed in each chamber. The root is poisonous, and the whole plant has a strong, unpleasant odor. It may always be recognized by the division of its stem-pith into disks separated from each other by cavities.

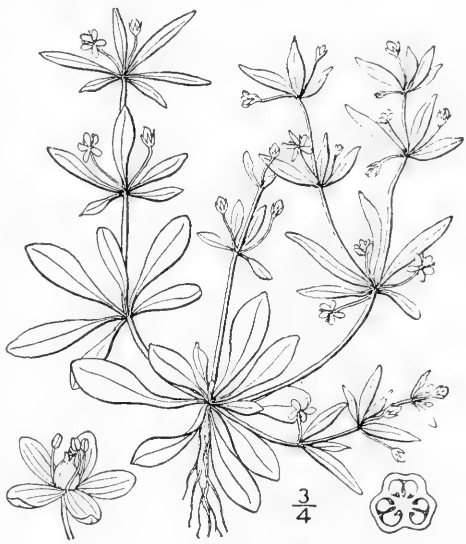


Fig. 122. Carpetweed. After Britton and Brown.

Four-o'clocks. The four-o'clocks are represented by three species known as umbrella-worts, and remarkable for the involucre which stands below the pink or reddish flowers. Three to five flowers occur in a single circular involucre which, when the fruits develop, becomes enlarged and papery. The flowering area in this order is more ornamental than that of former families; yet there are no petals, the colored portion being of the nature of calyx.

Carpetweeds. The carpetweed family is represented in Minnesota by the common carpetweed, a mat-plant forming prostrate disks of vegetation, made up of the much branching, flat, plant-body. The leaves are in whorls, a character by which this plant can be distinguished from other mat-plants of waste fields. The flowers are small, borne in the axils of the leaves, and without petals. The carpetweed grows in the same regions that many mat-grasses, mat-knotweeds, purslanes and mat-spurges select.

Purslanes and spring-beauties. Of the purslanes three genera are native to the state: the common purslane or "pusley," a prevalent weed in dooryards and gardens, the rock purslane, appearing upon ledges of granitic rock in the Minnesota valley, at Taylor's Falls and at Duluth, and the spring-beauties or *Claytonias*, of which there are three varieties. In the state there are two species of purslane: the common garden form with leaves round at the end, and the notched purslane with leaves notched at the end. The latter plant is doubtless a native of Minnesota, while the former is a recent immigrant. Purslane is one of the most common of the mat-plants and is remarkable for the numerous flowers which it produces in a season and for the little pods which open by a lid, revealing a large number of small seeds within. The rock purslane is a diminutive herb found growing in the crevices of granitic or eruptive rocks, especially in the Minnesota valley between New Ulm and Big Stone lake. The stem bears at the base a few alternate,

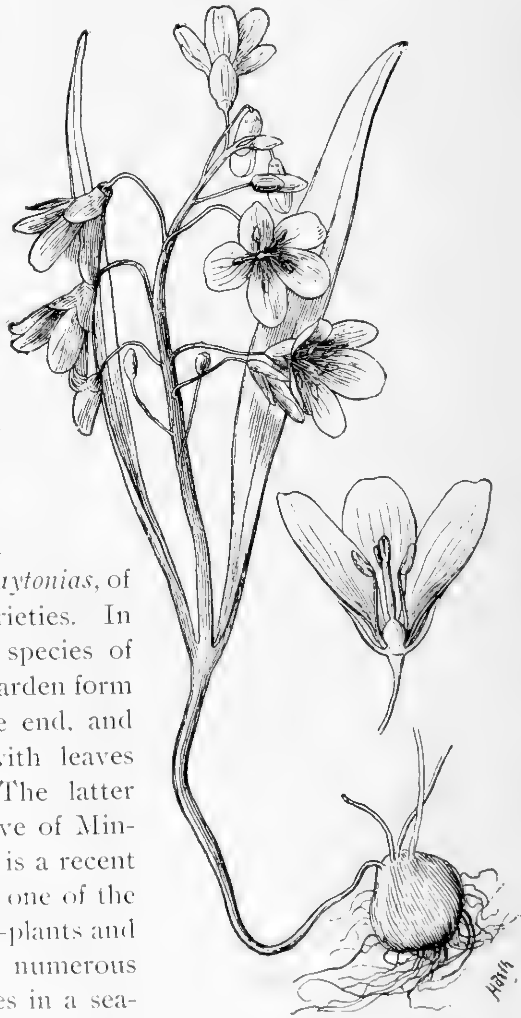


FIG. 123. Spring-beauty in flower. After Atkinson.

almost cylindrical leaves, from among which rises a slender peduncle, four to twelve inches high, upon which the small portulaca-like flowers are arranged in flat-topped clusters or cymes.

The spring-beauties are succulent herbs with delicate flowers of a pinkish color, developed in terminal cymes on short slender stems. In two of the species the roots are tuberous, while in the third they are fibrous. In each flower are two sepals, five petals and five stamens. The fruit is a three- to six-seeded capsule opening by three clefts. The two varieties with tuberous roots may be distinguished by the leaves on the stem. In the ordinary form the leaves are narrow and linear, while in the rarer variety they are lance-shaped. They are not uncommon plants in the southeastern part of the state, flowering in spring.

Corn-cockles, chickweeds and carnations. The pink family contains about twenty five Minnesota species. Herein are the corn-cockles, the campions or catchflies, the pinks, the soapworts, the chickweeds, the stitchworts, the pearlworts and the sandworts in their different varieties. The plants of this family are all small herbs with opposite entire leaves, both sepals and petals present and a single ovary ripening into a capsule or unopened nut. The corn-cockles are not native to the state, but have been introduced into the wheat fields of the Red river valley. They have red flowers which are very ornamental. The catchflies are so named from the very sticky calyx of the flowers. The chickweeds, sandworts and stitchworts are diminutive, generally white-flowered herbs of no particular importance, but rather abundant in woods, along the beaches of lakes and in low places on the prairies. The cultivated pink or carnation belongs to this family, and while its flowers are doubled and distorted by the selection which has been given to them by horticulturists, yet they preserve the general type of their family, and may serve as comparative plants when some of the wild forms are under investigation.

All the families of the fourteenth order unite in one peculiarity, that of having the embryo in the seed coiled around the albumen. In some seeds the embryo is curved almost like a snail-shell, while in others it is not bent more than a horseshoe. The albumen lies inside the coils of the embryo, which are appressed to the seed-coat layers. The lower families of the order are devoid of perianth, while in the higher families, such as the pinks, both calyx and corolla are well developed.

Almost all the families hitherto mentioned—with the exception of the pinks and portulacas—are characterized by the quite general failure of the flowers to develop two kinds of perianth leaves. When only one layer or whorl of perianth leaves is present in the flower, this group of parts is regarded as the calyx, hence the great majority of plants in the families that have been under examination are considered to be devoid of petals. In the remaining families both calyx and corolla are for the most part present, although there are numerous exceptions, especially in the lower families of the series.

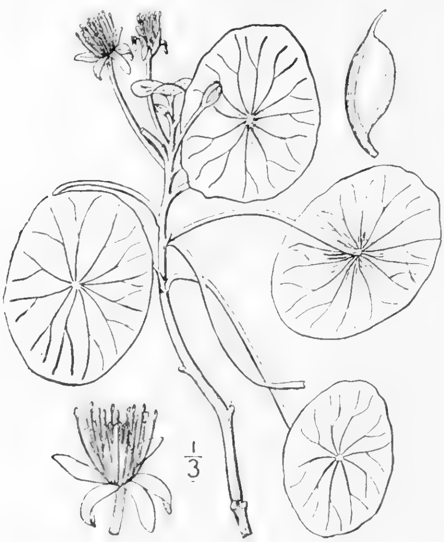


FIG. 124. Water-shield. After Britton and Brown.

The fifteenth order includes the water-lily family and a curious little related plant known as the hornwort, also of aquatic habit. Here, too, is placed the well-known crowfoot family; to which the anemones, larkspurs, peonies, buttercups, aconites, columbines, marsh-marigolds or crocuses, gold-threads, meadow-rues and clematis belong. In this order, also, are included the barberries and their allies, the moonseeds, the magnolias, the pawpaws, the laurels and a few small exotic families not represented in the United States.

Water-shields. The water-lilies in their various forms are familiar inhabitants of the lakes and ponds for which Minnesota is so justly famous. There are a number of varieties, some more common than others. One of the most interesting is the water-shield, which alone has perfectly shield-shaped leaves that always float upon the surface of the water. The leaves of the Indian lotus are also truly shield-shaped; however, many of them do not float upon the top of the water, but rise above it. Besides, the leaves of the water-shield are oval and not more than four inches in length, while those of the lotus are circular and much larger. Water-shield flowers are purple, less than an inch in diameter, and the whole plant is easily distinguished from any other kind of water vegetation that might be mistaken for it by a very abundant deposit of transparent jelly over the stems, buds, flower pedicels and the under sides of the leaves. The leaves are commonly purple

FIG. 125. Water-lilies. After photograph by Williams.

below and dark green, shaded with purple above. The presence of the purple dye on the under sides of floating leaves is not uncommon. It will be found to some extent in water-lily and pond-lily leaves and in the leaves of the floating pond-weed. The purple substance is a heat-producing color, and apparently such sunlight as the plant does not utilize in starch-making may be converted into heat by the lower layers of the leaf and employed as a source of energy in various growth-processes of the plant. The stem of the water-shield is sometimes several feet in length, and it creeps at the bottom of the pond as a slender rootstock. In the flower there are from twelve to twenty stamens and from four to eighteen carpels, separate from each other, forming in the fruit a cluster of one or two-seeded nuts.

Pond-lilies. The pond-lilies may be known by their broadly arrow-shaped leaves with rounded bases, their yellow flowers, and their fruits, consisting of a number of carpels united together in a compound body. There are two varieties in Minnesota: the common yellow pond-lily, abundant throughout the state, and the small yellow pond-lily, of which the flowers are less than an inch in diameter when open. The latter species is limited to the northern district between Duluth and Lake of the Woods. The pond-lilies have thick cylindrical rootstocks, which show conspicuous scars where the leaves break off. In the large pond-lily there are sometimes submerged leaves which are thin and almost circular in shape. These submerged leaves are always present in the smaller pond-lily.

Water-lilies. The water-lilies, of which three species occur in the state, may be recognized by their white flowers, rounder leaves and almost globular fruit. The form known as the tuber-bearing lily is probably more common than the sweet-scented lily, though both are found growing side by side in the same ponds. In the tuber-bearing lily the rootstock is thick, with an abundant production of short lateral branches that readily separate and serve to propagate the plant. In the sweet-scented lily the rootstock is thick and but sparingly branched. Furthermore, the flowers of the sweet-scented lily are very fragrant, while those of the tuber-bearing lily are either scentless or but slightly fragrant. These two varieties are the abundant ones. In a few lakes along the international boundary may be found the small white water-lily, with its flowers scentless and scarcely two inches wide. In this variety the petals are generally in but two rows instead of being disposed in numerous whorls as in the common forms. The leaves are considerably smaller but of the same general shape.

The great pale rootstocks of the water-lilies and pond-lilies are often torn up by the ice and cast ashore in early spring.

They are spongy, and when released from the bottom of the lake float to the surface.

Indian lotus. The largest flowered and most interesting of the native water-lilies is the Indian lotus—not very frequent in Minnesota, and confined to a few localities. It occurs in the Mississippi river at Red Wing, Mendota and La Crosse; also in Lake Pepin and at the extreme north end of Halstead's bay, Lake Minnetonka. The leaves are shield-shaped with central stem, and from one to two feet broad. Some of them are raised above the water and become slightly vase-shaped, while others float upon the surface. The flowers, which may be ten inches in diameter, though not commonly reaching this size, are of a pale cream-color, and differ from those of the other water lilies. The fruiting area is quite remarkable. The top of the flower stem is flattened out into a biscuit-shaped body in which the little nuts, the size of an acorn, are imbedded. They loosen as the fruit matures and rattle about so that the lotus in some districts goes by the name of "rattlebox." This plant belongs to the same genus in which the famous lotus of the Nile and the Orient is classified. The true oriental lotus is also known in the east as Indian lotus because it grows in India. Such a fact is illustrative of the confusion that sometimes arises when only popular names are employed in the designation of plants.

The water-lilies, like very many aquatic flowering plants, display their flowers at the surface of the water, and, after pollination has been effected, close the flower into a bud again and retract it beneath the surface, ripening the seeds beyond the reach of aerial dangers. The lotus, however, ripens its fruits in the air.

Hornworts. The hornworts are apparently very rare plants in Minnesota, but are known to grow in the vicinity of St. Paul and Minneapolis—in White Bear lake and Lake Calhoun; and in the western part of the state—in Lakes Osakis and Alexandria. They are submerged plants with slender stems, and the leaves are arranged in whorls and are finely dissected into thread-like filaments. The flowers are produced singly in the axils of the leaves and are less than half an inch in length. There are numerous stamens in each staminate flower, while the pistillate flower develops a single one-chambered ovary, containing a solitary seed rudiment. The fruit is like a miniature lotus nut. There is no albumen, and the embryo is remarkable for having four seed leaves instead of two. This, however, may be regarded as due to a forking of the seed leaves as they develop.

Magnolias. Magnolias do not occur in Minnesota. Their flowers are very much like those of the water-lilies, and they may be regarded as terrestrial, tree-like water-lilies, or conversely, water-lilies might be considered as magnolia-like plants which at an early time went into the water and adapted themselves to the aquatic life. Related to the magnolias are the tulip-trees or whitewoods which are such noble forms in the forests of Indiana and Ohio.

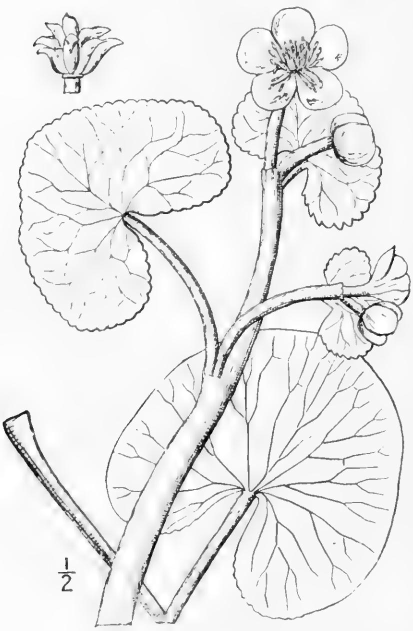


FIG. 126. Marsh-marigold or cowslip. After Britton and Brown.

The pawpaws, abundant southward, constitute a family of the fifteenth order, but are not known to occur so far north as Minnesota.

Crowfoots. The crowfoot family is abundantly represented in Minnesota where there are to be found one species of golden root, two of marsh-marigolds, one of goldthread, one of false rue-anemone, two baneberries, the red and the white, one columbine, three larkspurs, seven or eight anemones, two hepaticas, one rue-anemone, one pasque flower or gosling, two clematises, one mousetail, twenty buttercups and their allies, and three meadow-rues. Many of these are common flowers of the spring and summer. The marsh-marigolds, termed also crocuses, are abundant throughout the state, their yellow flowers blooming in early spring. A peculiar form, known as the floating marsh-marigold, occurs among the northern lakes. It is much like the ordinary variety except that its leaves float upon the surface of the water and the plant is generally small. The goldthreads are little three-leaved plants with white, buttercup flowers and slender, bright yellow rootstocks, by which they may be recognized. They are abundant in tamarack swamps. The baneberries are erect herbs with large compound leaves. The flowers are small, white and arranged in terminal racemes. One variety produces red berries and the other white. The columbines are particularly abundant upon rocky hillsides, on cliffs and along river gorges. The flowers are recognized at once by the spurs on the petals, and stand with their mouths directed downward. The spurs are supplied with honey glands at the tip, and the whole contrivance is a machine for obtaining cross-pollination through the agency of insects.

Larkspurs. The larkspurs are the first type of two-sided flowers that have been encountered in the discussion of plants with pairs of seed-leaves. Their flowers stand in terminal clusters, are loosely arranged and shaped so that there is no difficulty, even when they are separated, in determining how they stood upon the stem. One of the petals is provided with a spur as in the columbines. This again is an apparatus to utilize some insect for the advantage of the plant.

Anemones and Hepaticas. Anemones are herbs with rather characteristic flowers and fruit-bodies. In one type the nutlets of the fruit are massed in cylindrical clusters, clothed with woolly hairs. In others the clusters of nutlets are more nearly spherical. Closely related to the anemones are the *Hepaticas*, known by their three-lobed, shining leaves and their purplish flowers put forth in early spring. One kind of *Hepatica* has its leaves rather round-pointed while the other shows much sharper lobes. Akin to the *Hepaticas* is the rue-anemone, which develops three-parted leaves, each lobe of which is again divided into three. The stem, four to seven inches in height, arises from a little cluster of small tuberous roots shaped like diminutive beets. This plant may be distinguished from the false rue-anemone, which resembles it superficially to a marked degree, by the character of the tuberous roots. In the false rue-anemones the tubers do not form a little cluster near the base of the stem, but develop, in many instances, two or three of them on the same root and often some distance from the base of the stem. Besides, the fruits of the true rue-anemone are aggregated as nutlets at the tip of the fruiting stem, while in the false the fruits are not strictly nuts but capsules, opening along one side to release the seeds. There are several seeds in each cap-

FIG. 127. False rue-anemone growing in pots. University plant house. After photograph by Professor D. T. MacDougal. From *Minnesota Botanical Studies*.

sule of the false rue-anemone, but only one seed in each nutlet of the true. Both plants are abundant in the woods throughout the state.

Pasque flowers and clematis. The pasque flower or gosling is known to the children of Minnesota as the first flower to bloom in early spring. There are several kinds of flowers which really open before the pasque-flower, but they are either rare or inconspicuous, so that the pasque flower may be popularly regarded as the earliest flower of the year. The sepals are of a pretty light purple color, and the whole flower is an inch or more across. Around its base is a group of hairy involucral leaves. At the center is a circle of separate carpels which mature into a head of nutlets, each of which has a long plume-like appendage, recalling the similar structures in the fruiting heads of clematis. In this latter plant, which in Minnesota occurs as a climbing vine, the same general appearance of the fruiting heads is to be observed, and consequently the pasque flower is also termed the ground-clematis. The true clematises are not always climbing vines throughout the United States, but the Minnesota varieties both belong to the vine division of the genus. They have an odd way of climbing, for, not being provided with true tendrils, they twine their leaves around such supports as come in their way, thus using the stems of the leaves just as a squash vine uses its tendrils. This habit of the clematis gives an idea of how, in some instances, tendrils may have originated. After the leaves of a plant acquired the habit of turning themselves about twigs or other supports that came in their way, there arose a division of labor, in consequence of which some leaves devoted themselves to their new function and gradually abandoned their starch-making, thus becoming converted into true tendrils, while others assumed no tendril functions, but continued as the starch-makers of the plant.

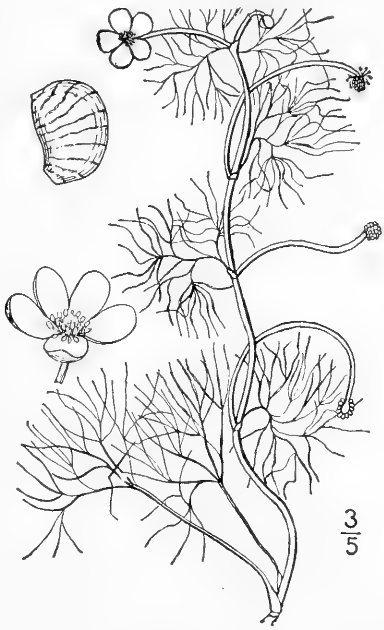


Fig. 128. White water-buttercup. After Britton and Brown.

Mousetails. The mousetail is a little herb three or four inches in height, known to occur in the extreme southwestern part of the state. The center of the flower is prolonged into a spike-like axis upon which the nutlets are arranged in spirals. From the resemblance of this axis or receptacle of the flower, to the tail of a mouse has arisen the common name.

Buttercups. Buttercups are well-known plants, usually with yellow flowers by which they may be distinguished from anemones, the flowers of which are pale. There are a number of sorts characterized by the different forms of the leaves, the sizes of the flowers and the shapes of the nutlets or groups of nutlets in the fruiting state. Three buttercups in the United States are aquatic, and two of these occur abundantly in Minnesota. Owing to their aquatic habit the water-buttercups have finely dissected leaves consisting of thread-like filaments, and their flowers are white. The two varieties may be distinguished from each other by the rigidity of their stems when withdrawn from the water. The white water-buttercup collapses into a flabby bundle when lifted from the water, while the stiff water-buttercup does not, but maintains the ends of its stems in a rigid position. The water-buttercups are interesting plants to observe on account of the automatic curvatures of the flowering pedicels. The flowers are exposed above the surface of the water and after pollination the stems bend over, as if aware of what was needed, and thrust the flowers into the water, so that the fruits are matured below the surface. Such beneficial habits are ordinary among water plants, which are generally compelled to expose their flowers for wind or for insect pollination, but afterwards derive advantage from ripening

FIG. 129. Early meadow-rue. After Britton and Brown.

their fruits under less dangerous conditions. Thus the flowers of the water-lilies, of the pondweeds, or of the eel-grass are in a variety of ways retracted. What the eel-grass secured by a spiral contraction of the flowering stem is accomplished by the water-buttercup through an automatic curvature. Such curvatures are sometimes employed by terrestrial varieties for the insertion of their fruits into the soil. Thus the peanut plant flowers above the ground and then thrusts its young pods into the soil, where they mature underground.

Meadow-rues. The meadow-rues are robust perennial herbs with leaves compounded repeatedly on the plan of three. The flowers are small, whitish-green and aggregated in large panicles or racemes. In one variety, the most common in Minnesota, there are two sorts of flowers, staminate and pistillate, borne on different plants, so that all the flowers on a plant will be of one kind or the other. The other two species have each on the same plant three kinds of flowers, some producing only stamens, others producing only pistils, and others in which both stamens and pistils occur. One variety is often glandular or waxy in the texture of its leaves, while the other is smooth or slightly hairy, but not glandular or waxy. The former blooms earlier than the latter and is usually shorter, reaching in favorable positions three to seven feet in height, while the latter attains a height of from ten to eleven feet. Although the species in which the flowers are always separated, and a single plant produces only one kind, is easily identified, the other two are hard to distinguish.

Most of the plants in the crowfoot family have pungent juices, and from some of them highly poisonous substances, such as aconite, are obtained.

Chapter XXIX.

From Barberries to Witch-hazels.

Barberries. The three plants of the barberry family which occur in Minnesota are of quite different appearance. One, the common barberry, introduced from Europe, grows as a wild plant in the southern part of the state, but is by no means abundant. It is a smooth shrub with ovate saw-tooth-margined leaves and flowers produced on drooping racemes in the axils of some the leaves. The flowers are yellow and unpleasantly scented. The fruit clusters are racemes of scarlet sour berries, somewhat oblong in shape and about half an inch in length. Many of the leaves are reduced to three-pronged thorns. This is the plant which is famous as the host of the cluster-cup stage of the wheat rust, and for this reason it is a dangerous shrub to cultivate. The other members of the barberry family are herbs. One of them, the blue cohosh, is found in shaded woods, growing a foot or more in height and resembling, to some extent, the meadow-rue. But when the cohosh fruits it produces clusters of blue berries which are in reality seeds, for they burst the thin fruit wall when young and mature outside of it. The other, known as the may-apple or wild mandrake, has, at the base, large shield-shaped leaves almost a foot in diameter, while the upper leaves are deeply lobed, lighter green above than below. The flowers are white, somewhat butercup-like, nodding from the axils of the leaves and one or two inches wide. A true fleshy berry of a yellow color is produced, two inches long and edible. This plant occurs in damp woods along the flood plains of streams flowing into the Mississippi, in the extreme southeastern portion of the state.

Moonseeds. The moonseeds, represented in Minnesota by a single form, are characterized by the disk-shaped or coin-shaped seeds, hence the popular name. The Minnesota moonseed is a common vine, with leaves shaped a little like the leaves of the wild grape, though not so deeply angled. The underground portion is yellow and Indians use it for medicine. The flowers are of two sorts, developed on different plants. The fruit contains a stone which is curved into a circle, marked by clefts and strongly flattened on the sides. The bunches of fruits are bluish-black in color and resemble a little the fruits of the wild grape. They are easily distinguished, however, by the presence in each of the flat stone, very different from the pear-shaped seeds which are found in the berries of the grape.

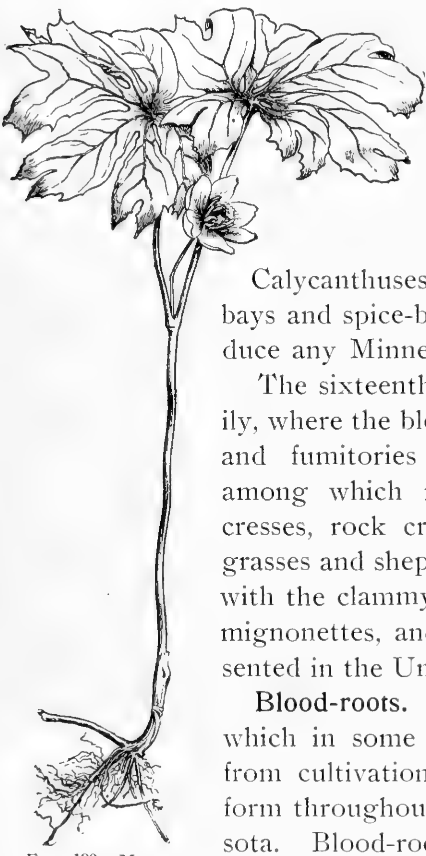


Fig. 130. May-apple, or mandrake, in flower. After Atkinson.

Calycanthuses and laurels, where the sassafras, bays and spice-bushes are grouped, do not produce any Minnesota varieties.

The sixteenth order includes the poppy family, where the blood-roots, Dutchman's breeches and fumitories are classified; the mustards, among which may be mentioned the water cresses, rock cresses, whitlow-grasses, pepper-grasses and shepherd's purses; the caper family, with the clammy-weeds and spider-flowers; the mignonettes, and two other families not represented in the United States.

Blood-roots. Besides the common poppy, which in some parts of the state has escaped from cultivation, the blood-root is a common form throughout the greater portion of Minnesota. Blood-root flowers are to be seen in the spring in open woods, where their white petals and great abundance make them attractive objects. The plant is named from the red juice which exists in its horizontal underground rootstock. On the latter, branches arise, bearing leaves—those at the base scale-shaped and the upper ones large, heart-shaped or kidney-shaped, with several lobes. The flowering stem displays usually but a single flower in which there are two sepals that early fall to the ground. The petals, eight to twelve in number, inclose the numerous stamens. At the center the rudimentary fruit appears as an oblong, narrow, one-chambered pod, made up of two carpels and ripening into a capsule with numerous seeds. The later leaves of the year grow much larger than those formed at the time of flowering and by their activity create considerable reserve food material which is packed away in the underground part ready for use by the buds of the next season.

FIG. 131. Clammy-weed. After Britton and Brown.

Dutchman's-breeches. The Dutchman's-breeches or squirrel-corn, of which two species occur in Minnesota, are delicate and interesting plants of the woodland, where they grow on shaded banks. The leaves are compounded repeatedly on the plan of three and the slender flowering stem bears several nodding flowers flattened laterally in a peculiar manner. The shape of the flower gives occasion for the common name. Below the ground, in the Dutchman's-breeches, a number of bulbous scales may be discovered. When fresh they are speckled with red dots. In the squirrel-corn, the flowers of which are not so bifurcated as those of the

FIG. 132. Blood-root. After Britton and Brown.

Dutchman's-breeches, the slender rootstocks bear a number of little spherical tubers. The common bleeding-heart of flower-gardens is a relative of these two native species.

Fumitories. The fumitories, with yellowish or pinkish, two-sided flowers, occur in Minnesota in four different forms. Among the more common is the pale fumitory with whitish-green leaves compounded on the plan of three. This plant is most abundant in the northern part of the state, where it grows often on sandy beaches. The golden fumitory, frequent in the southern part of the state along railway embankments and in woods, is a smaller, darker green plant, with golden yellow flowers arranged in terminal racemes. Another variety, the yellow, not so common as the golden fumitory, may be recognized by its paler leaves, like those of the pink-flowered northern form; but this species has yellowish flowers, not so bright as those of the golden fumitory, and quite different from the pinkish type of the pale fumitory. Still another, found at the extreme southern edge of the state, has much smaller flowers than the others and foliage much like that of the pink species.

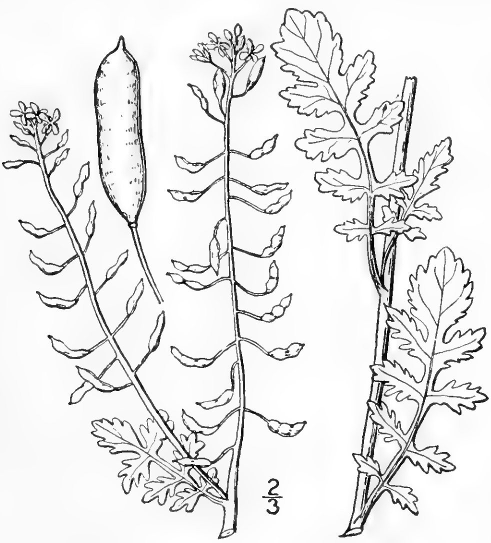


FIG. 133. Water-cress. After Britton and Brown.

Mustards. The mustard family is distinguished, for the most part, by a pungent peppery sap, so that after one has tasted water-cress or pepper-grass he can usually determine, by chewing the foliage, the relationship of other plants of the family. A variety of mustards occur in Minnesota, about fifty species in all. Besides this, several are cultivated, such as the cabbage, the cauliflower, the radish and the turnip. Mustards are recognized botanically by their pods, flattened lengthwise or crosswise to the partition which runs along them. In some pods the partition is evanescent, as in the garden radishes. Very common forms are the pepper-grasses with little circular pods, the shepherd's purses with heart-shaped pods, the hedge-mustards with their long and slender pods, the rock-cresses growing upon cliffs and along gorges, the water-cress abundant in cold streams issuing from springs, and the other cresses, some in the fields, some in the woods and others in marshes or swamps. In a great many of the mustards of Minnesota the leaves are narrow and deeply lobed along the sides. A number bear, at the surface of the ground, rosettes of leaves from which the slender flower-bearing axis arises. The flowers are usually arranged in racemes and are commonly white or yellow in color, constructed on the plan of four. Four sepals, four petals, six stamens and two carpels, united into a single pod, constitute the parts of the normal mustard flower. One of the smallest of the land-flowering plants in Minnesota is the whitlow-grass, a cress which produces a tiny rosette of leaves and a little stem an inch or two in height, on which a few minute white flowers are borne.

Fig. 134. Pitcher-plant. After Britton and Brown.

Pitcher-plants. The seventeenth order includes the pitcher-plants, grouped in two families, to one of which belongs a common Minnesota variety, and the sundews and Venus' fly-traps. All of these plants are carnivorous and are very remarkable for the skillful devices by which they catch the insects that form a part of their food. The Venus' fly-trap, which in conservatories is sometimes cultivated, from its Carolina home, is a little herb with leaves built upon the general plan of a steel trap. The base of the leaf is somewhat elongated and provided with wings of green tissue. Above the middle there is a strong constriction, and the end of the leaf is almost round, with a longitudinal rib separating it into two halves.

On the upper side are some sharp-pointed hairs, and when an insect alights upon a leaf and irritates the hairs a couple of times the two sides of the leaf snap together with a movement sufficiently sudden to catch the insect, after which its body is digested by the plant. A little less sensational but none the less accurate are the fly-catching habits of the common Minnesota pitcher-plant which grows in abundance throughout the tamarack swamps of the state. The leaves of this plant are hollowed out as vase-like structures, and are usually half full of water. The margin of each pitcher is protected by a flap on which are arranged a number of hairs pointing downwards. Within, the surface of the pitcher is very smooth. Inquisitive insects which alight upon the flap find it easy to walk in the direction in which the hairs are pointed, but difficult to move in the other direction. Thus they are guided to the smooth rim of the vase and tumble in. Digestive ferments are secreted by the action of glands or of bacteria which inhabit the water in the pitcher, and the bodies of the insects are converted into food-material for the bacteria, and directly or indirectly find their way into the tissues of the pitcher-plant itself. The flower of the pitcher-plant, standing on its slender, erect stalk, is conspicuous by its purplish petals and by a very extraordinary umbrella-shaped stigma which arches over the short stamens, protecting their sensitive pollen-spores from the cold of the bog where these plants select their abode. Besides, this umbrella-shaped stigma serves as preventive against the flower being pollinated by its own pollen. The pollen spores germinate on the points at the angles of the umbrella. The fruit is made up of five fused carpels and contains numerous small seeds.

Sundews. Related to the pitcher-plants are the sundews, which are found throughout the state in deep tamarack swamps or peat-bogs. There are four varieties, distinguished by the shapes of their leaves, to be looked for in Minnesota. The round-leafed sundew is as common as any. In this the leaves are almost round, on slender stems, spreading out in a little circle at the base of the delicate, erect flowering axis. The leaves are half an inch or so broad and covered over with prominent red glandular hairs. Another variety has the leaves ovate or spoon-shaped. In still another, the leaves are long-ovate, four or five times as long as broad, while in yet another the leaves are shaped almost like grass leaves, one to three inches long and slightly spoon-shaped toward the tip. In all the different species the glandular hairs are present. When a small insect alights upon one of the leaves the sticky secretions of the hairs interfere with its movements, while the hairs at the edge of the leaf bend inward and push the insect down into a helpless position. The whole leaf then seems to close around the unfortunate ant or fly, and after a time, by means of digestive ferments, its body is converted into nutriment for the plant. In Portugal and Spain a variety of sundew is by the inhabitants commonly employed in place of fly-paper. Another foreign variety lives in the water, has leaves much like the Venus' fly-trap and snaps up little water insects. These plants do not depend for food entirely upon the insects they catch. They are all provided with leaf-green and devour insects only in an incidental way.

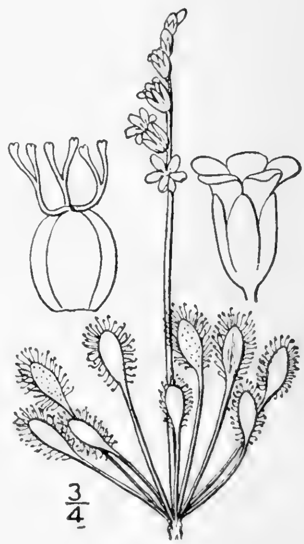


Fig. 135. Sundew. After Britton and Brown.

The eighteenth order includes the riverweeds; the orpines; a family of West Australian pitcher-plants; the saxifrages, to which the hydrangeas, gooseberries and a number of herbs belong; the witch-hazels; the sycamores; and the roses. In the last-named family are included the spiræas, apples, quinces, mountain-ashes and June-berries, the roses, strawberries and a number of related herbs, the raspberries, blackberries and brambles and the plums, almonds, peaches and apricots. Furthermore, in this eighteenth order is included the great pulse family with the acacias, the sensitive plants, the tamarinds, the redbuds, the sennas, the honey-locusts, the lupines, brooms, laburnums, clovers, indigo-plants, locust-trees, ground-peas, peanuts, beans, peas, and all the allied varieties in which the type of pod known as the *legume* is formed. Besides, there are some smaller families classified here, so that this is one of the largest and most important of all the orders of flowering plants.

Riverweeds. Of the riverweed family there is a single Minnesota species which grows attached to stones under water in strong rapids or cataracts. The riverweed belongs to a family of herbs best developed in the tropics and very remarkable for marvelously perfect adaptation to the submerged life. The plant-body of many of the riverweeds resembles that of an alga, the leaves being poorly distinguished from the stem on which they are borne. The flowers and fruits are produced entirely under water and are surrounded by involucres resembling the spathes of the arum family. In the Minnesota variety—the only one common in North America—the flowers are sessile, there is no perianth and there are two stamens united together at the base. The fruit-rudiment is ovoid, with two short stigmas. The general appearance of the plant is that of a dense tuft of finely divided leaves attached to the stones at the bottom of the water. The flowers are small and easily recognized by the two partly fused stamens, standing like a little fork beside the ovary. In the fruit arise a number of small seeds with straight embryos and without albumen. The riverweed has been collected in Minnesota on the International boundary, in the Granite lake rapids, at Minnehaha falls and at Lake Pepin. The most interesting thing about the riverweed is its entire abandonment of terrestrial methods of flower-production and pollination. While pondweeds are compelled to lift their spikes of flowers above the surface of the water to accommodate themselves to the persistence of ancient methods of wind-distribution in vogue during the days when their ancestors were dwellers on the land, the riverweeds have freed themselves from this necessity and have the ability to maintain themselves quite submerged in deep water, as if they were algae. Some other varieties of flowering plants flower under the

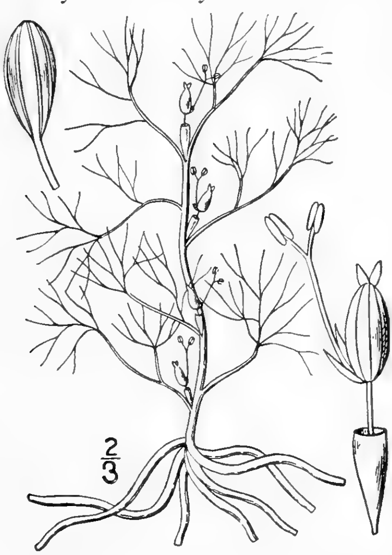


FIG. 136. River-weed. After Britton and Brown.

water, as, for example, the marine eel-grass, so common along seashores around the world. This plant is famous for its development of thread-shaped pollen-spores—a form more favorable for aquatic pollination than the ordinary round spores common in most other plants. There are no flowering plants, however, which are so strongly adapted to the aquatic life as are the riverweeds. Even the tiny duckweeds, floating like green specks at the surface of quiet pools depend upon the wind for the distribution of their pollen and produce their pollen sacs and stigmas in the air as did their terrestrial progenitors.

Stone-crops. The orpine family is represented in Minnesota by the native stone-crop and the introduced "hen-and-chickens." The stone-crop, which grows in ditches and swamps, is a slender, erect plant with smooth leaves and stem. The flowers are produced, at the tip of the stem, in cymes on recurving branches from one to three inches in length. The flowers have five sepals, ten stamens, usually no petals, and five rather imperfectly fused carpels in each of which a number of seed-rudiments are produced. Many of the orpine family are rock-dwelling plants and belong to the adaptational group known as *leaf-succulents.* The "hen-and-chickens" is an example of this group. Its leaves are very fleshy and thick, often grayish-green in color and arranged in rosettes, from the centre of which the erect, central flowering stems are developed. Such plants inhabit little crevices in cliffs, and the fleshy character of the leaves is doubtless in response to the difficulty of obtaining sufficient moisture for the roots. The ditch stone-crop, however, prefers moist places, and has leaves of quite ordinary appearance.

FIG. 137. American alum-root. After Britton and Brown.

Saxifrages. The saxifrage family includes in Minnesota the gooseberries and currants, of which there are nine species; the saxifrages, with four species, one of which, the swamp saxifrage, is found in peat-bogs and tamarack swamps throughout the state; a single species of *Sullivantia;* two species of alum-root; two miterworts; one false miterwort; and one golden saxifrage.

The swamp saxifrage has large, rather whitish green, long ovate leaves and a central hollow stem, somewhat thick at the base, upon which cymes of flowers are arranged in an open panicle. Another saxifrage found on dry rocks along the north shore of Lake Superior, has rather succulent leaves, forming a thick rosette at the base of the flowering stem. This plant propagates by little offsets like the hen-and-chickens.

FIG. 138. Marsh Parnassia. After Britton and Brown.

Alum-roots. The alum-roots, common on dry hills or rocks, have leaves shaped somewhat like those of the gooseberry and erect panicles of flowers at the end of a slender axis. The flowers are whitish-green or purplish and inconspicuous. There are five stamens. The ovary is one chambered, with numerous seed-rudiments and ripens into a two-valved pod which splits from the end, curving the tips away from each other. The two varieties in Minnesota are distinguished by the appearance of the flowers. In the American alum-root the calyx of the flower is bell-shaped and regular. In the rough alum-root the calyx is bell-shaped and very oblique with unequal lobes. Both plants are sometimes found in dry woods but are more abundant as rock plants on high ledges or as crevice plants on barren islands. The miterworts and golden saxifrages are delicate little herbs with leaves shaped somewhat like those of the gooseberry and with the general saxifrage type of flower. In the common miterwort or bishop's cap the five petals are shaped like tiny feathers.

Parnassias. The *Parnassias*, of which one species is common throughout the state while the other two grow especially on the north shore of Lake Superior, are swamp plants with entire, broadly spoon-shaped, strongly ribbed leaves and terminal solitary flowers of a white or creamy yellow color, arising at the end of a slender erect axis. Usually a single sessile heart-shaped leaf is displayed one-third of the way up the flowering axis. The flowers of *Parnassia* may be recognized by the little clusters of imperfect stamens produced at the base of each of the five petals.

Gooseberries and currants. The largest genus of saxifrages in Minnesota is the one to which the gooseberries and currants belong. There are probably six gooseberries in the state, and the different sorts are recognized by the shape of the leaves and the character of the fruit. One, the prickly gooseberry, is common everywhere, and in this species the fruits are covered with prickles. Of smooth gooseberries there are four or five sorts distinguished by characters of the flowers and leaves. Of currants there are four sorts, among which, one, the flowering-currant, is not native. The other three are the skunk currant, with its prostrate branches and disagreeable odor, common in the northern part of the state; the wild black currant, abundant throughout the state; and the red currant, most abundant north of a straight line connecting Fergus Falls with Duluth. The gooseberries have the flowers arranged for the most part in small clusters or they are solitary, while the currants produce racemes of flowers ripening into bunches of fruit. The fruits are spherical berries, having a somewhat different taste in the gooseberry division of the genus from that characteristic of the currants. Each berry contains a few seeds with slimy or gelatinous outer and hard inner coats. The flowering-currant, with its bright yellow flowers, is a native of the western plains and is abundantly introduced in Minnesota.

Witch-hazels. The witch-hazel family is represented in Minnesota by a single species, the well-known witch-hazel of the southern part of the state. This is a shrub superficially resembling the hazel in some respects, but with bright yellow flowers in the axils of the leaves. The flowers are remarkable for blooming during the autumn of the year as the leaves are falling. The petals are very slender and elongated, and there are four perfect and four imperfect stamens, while the capsule opens by two valves. The witch-hazel is much used in the production of an extract reputed to have healing virtues similar to those of arnica, but by some believed to have no medicinal value whatever.

Sycamores. Sycamore trees scarcely occur spontaneously in Minnesota, the state being too far north for their development.

Chapter XXX.

Roses, Peas and their Relatives.

The rose family is represented in Minnesota by from sixty-five to seventy species, among which are herbs, shrubs and trees, while all unite in the general character ot the flower.

Meadow-sweets. Here are to be grouped the *Spiræas*, meadow-sweets or ninebarks, of which there are three varieties in the state. The most common is the willow-leafed *Spiræa* a frequent and abundant meadow plant in every district. All of them are shrubs with alternate leaves—in the ninebark somewhat lobed and shaped a little like the leaves of the currant, but in the meadow-sweet or *Spiræa*, with the outline of willow leaves. The flowers are borne in terminal panicles, or large clusters, and in two of the species are of a white or slightly purplish color, while in the third they are of a handsome pink. The meadow-sweets are common plants in swamps and swales as well as in meadows, and one variety is very abundant on the rocky shores of northern lakes, growing often partly submerged under water. While much smaller, the flowers of the *Spiræas* are in their general appearance much like apple blossoms.

Crab-apples and chokeberries. The apples and mountain-ashes, with the June-berries and hawthorns, constitute a very clearly defined series of the rose family. Of apples and quinces, which together with the pears form a characteristic series, there are five sorts in Minnesota—three wild crab-apples and two varieties of chokeberries. There is no difficulty in recognizing these plants, because they have the typical apple fruit. The common crab-apple is a small tree with ovate to triangular leaves, distinguishable from the western crab-apple or chokeberry, which also occurs in the state, by the general outline of the leaves. In the western crab-apple the leaves are oblong or ovate, but not so triangular. Still another form of crab-apple has somewhat larger oval leaves with shallow notches at the margin.

The chokeberries are shrubs ordinarily to be looked for in swamps or damp woods. The flowers are considerably smaller than those of the crab-apples, but decidedly similar. The fruits, too, are not different in essential particulars from those of the crab-apples, but are not so large, averaging about the size of a well-grown gooseberry. In one of the chokeberries the fruit is bright red when ripe, while in the other it is almost black.

June-berries. Of June-berries there are four or five species growing in Minnesota. These are all shrubs or trees with flowers resembling those of the apple, but with more berry-like fruits, smaller on the whole than the fruits of the apples. In the common June-berry the fruit is spherical, sweet to the taste and of a reddish color. The shad-bush, a variety of June-berry, may be distinguished by the white, woolly appearance of the foliage when young, changing to smooth when older. In both of these varieties the leaves are somewhat elongated, like plum leaves. In the round-leaved June-berry, the leaves, as the name indicates, are almost round, while in the alder June-berry the leaves are oval, notched more deeply towards the tip than towards the base.

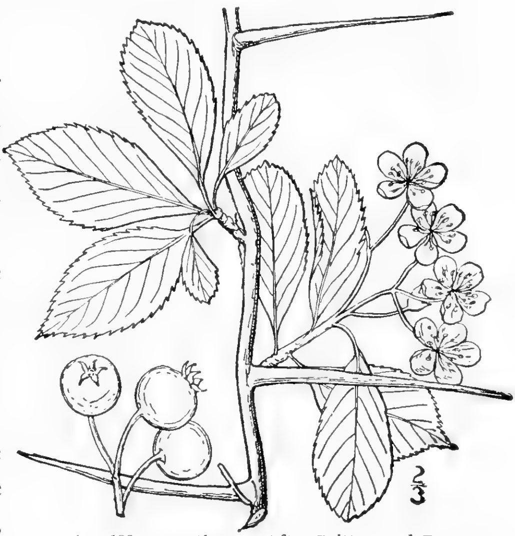


FIG. 139. Hawthorn. After Britton and Brown.

In all the varieties so far discussed the fruits are more or less apple-shaped. One other, which occurs at the extreme northern edge of the state, in cold bogs, is a low shrub, smooth throughout, with a purple pear-shaped fruit, half an inch or so in length.

Hawthorns. Neither the apples nor the June-berries are thorny, and by this character they may be distinguished from the hawthorns, which have somewhat similar fruits. Hawthorns are commonly furnished with slender, pointed branches, giving to the twigs a peculiar spurred appearance. Between the different varieties it is exceedingly difficult to discriminate. About six species exist within the state, and they are to be classified by the shapes of the leaves and the outlines and surfaces of the fruits. The flowers are borne in flat-topped clusters, reminding one of the flat-topped elder inflorescences. The fruits are never large, being in all the species about the size of chokeberries. Sometimes hawthorn trees fail to produce thorns or form them but sparingly. It is not then easy to distinguish them from the June-berries or chokeberries; but in such instances the flower clusters are usually distinctive, for while those of the hawthorn are, for the most part, flat-topped, the lower flowers having longer stems than the upper, the clusters in June-berries and chokeberries are panicled or but slightly flat-topped.

Fig. 140. Apple-blossoms. After photograph by Williams.

Mountain-ashes. The mountain-ashes are very close to the apples and hawthorns. Indeed, they may be regarded as apples with diminutive fruits and compound leaves. Two sorts of mountain-ash may be looked for in the Minnesota woods. They are both low trees with compound, feather-shaped leaves and small white flowers in terminal, compound, flat-topped cymes. The fruits are little red berries, quite like the apple fruits, except that the core has not the papery walls of the apple. They may be distinguished from all the other apple-like plants by their compound leaves. The American mountain-ash is discriminated from the western mountain-ash by the shape of the leaflets. In the first named species they are slender and willow-like, while in the other they are elongated-oblong and not so sharply pointed. The fruits in the two varieties are very similar but average larger in the western mountain-ash. Both varieties are very ornamental as lawn trees, but the western mountain-ash is more desirable for cultivation in Minnesota than the other, on account of the larger and handsomer flat-topped clusters of fruits.

Strawberries and fivefingers. A group of herbs, including the strawberries, fivefingers and avens, should be mentioned here. There are a number of varieties of them, some sorts abundant in meadows and fields, others distributed in swamps and along the shores of lakes. The strawberries in particular are abundant and easily recognized by their three-compounded leaves, by their habit of producing runners for propagation and by their clusters of little seed-like fruits upon the swollen conical axis of the flower. This axis becomes red and fleshy as it matures, and is the edible portion of the strawberry. The other herbs, such as the fivefingers, closely resemble the strawberries in the character of the flower, but do not form fleshy axes for their fruits. The avens is an erect herb, rather easily mistaken by the casual observer for some kind of anemone in fruit. One sort which is common in Minnesota produces fruit clusters quite similar in appearance to those of the clematis, having the same plumy appendages on the nutlets. None of these herbs, except the strawberry, is of any particular economic importance. They are all, however, throughout the state, com-

FIG. 141. Marsh fivefinger. After Britton and Brown.

mon objects in open woods and along the edges of moist meadows. The way to distinguish an anemone from a five-finger or avens is this: the flowers of the fivefingers have apparently a double calyx formed by the uniting in pairs of the stipules at the bases of the calyx leaves. The anemones have no such double calyx. Besides, the stamens in the anemones and buttercups are arranged in spirals, while those of the fivefingers and avens are arranged in whorls.

Agrimonies. Two curious little herbs, known as agrimonies, have leaves resembling rose leaves, the flowers in narrow, spike-like racemes and the calyx swollen up around the fruit and furnished with a number of hooked bristles. The little fruits which become attached to one's clothing in the woods in autumn, if they are conical in shape and if the base of the cone is barbed, are those of the agrimony. The bristles do not really belong to the fruit, but arise from the calyx, illustrating how the plant may use the same areas for different purposes. In apples, mountain-ashes, June-berries, and chokeberries the calyx grew up around the fruit and became fleshy. That is to say, the real fruit of the apple is the core, the flesh which is eaten being the outer portion of the flower and not the central ovary or group of ovaries. The agrimony fruits, like those of the apples, pears, quinces and hawthorns, are adapted to animal distribution; but the method of distribution is different. In the apples, calyx-leaves become an inducement to animals to eat the fruits and thus the seeds, remaining uninjured, are distributed. But in agrimonies the calyx is so constructed that with its inclosed fruit and seeds it attaches itself to the fur of animals and in this manner obtains dissemination.

Raspberries and blackberries. Very closely related to the fivefingers and strawberries are the brambles, including here the varieties with edible fruits known as raspberries and blackberries. About ten species occur in the state. The different flavors in the fruits give occasion for the classification into raspberries and blackberries, and there are no important structural differences, since both plants belong to the same genus. They are shrubs or herbs with characteristic fruitlets like miniature plums aggregated together upon a fleshy swollen axis developed from the centre of the flower, and somewhat like the conical base of the strawberry nutlets. One difference between blackberries and raspberries is in the texture of this axis. In raspberries it becomes drier and the cluster of fruitlets separates from it, but in blackberries it remains fleshy and there is no separation of the fruit cluster from the receptacle. Of raspberries there are in Minnesota five varieties, including the red and black raspberries, two dwarfed species, and the sour raspberry, in which the fruit is less pleasantly flavored than in the others. Of blackberries there are four sorts,—two varieties of high blackberry, one low blackberry and one swamp blackberry.

In all these plants the stems are shrubby. In the Arctic dwarfed raspberry the plant-body is herbaceous, unarmed, and only three to ten inches in height, but not creeping. Another peculiar little *creeping* raspberry, seldom found in Minnesota, has leaves like those of the violet, and might even be mistaken for a violet unless seen in flower or fruit.

FIG. 142. Roses. After photograph by Williams.

Rose-bushes. The roses are shrubs with large and conspicuous flowers which cannot well be mistaken for those of any other variety. The different sorts in Minnesota may be distinguished by the shape of the leaflets, the presence or absence of prickles, the shape of the fruit, and the stipules on the leaves. The common prairie rose, for example, has distinct stipules and the leaves are disposed along a prickly stem. There are usually from seven to nine round-ovate leaflets in each leaf. The smooth, or meadow rose, is at once known from the prairie rose by the scarcity of prickles, only a few of which ever occur upon the stem. Neither of these varieties climbs. A climbing rose is found, however, in thickets in the southeastern portion of the state. In this there are often three or five leaflets to the leaf. Yet another sort is recognized by the prickly midribs of the leaves. The swamp rose and the pasture rose may be known by the presence of a pair of extra large prickles just below the stipules at the base of each leaf.

This description does not extend over all the wild roses of the state, but without going into technical details gives an idea of their differences. All the roses are marked by a special type of fruit which may be compared, perhaps, to a strawberry turned inside out; that is to say, the nutlets or fruits are aggregated not upon a convex, but upon a concave receptacle. The calyx grows up around this concave end of the flower, and the

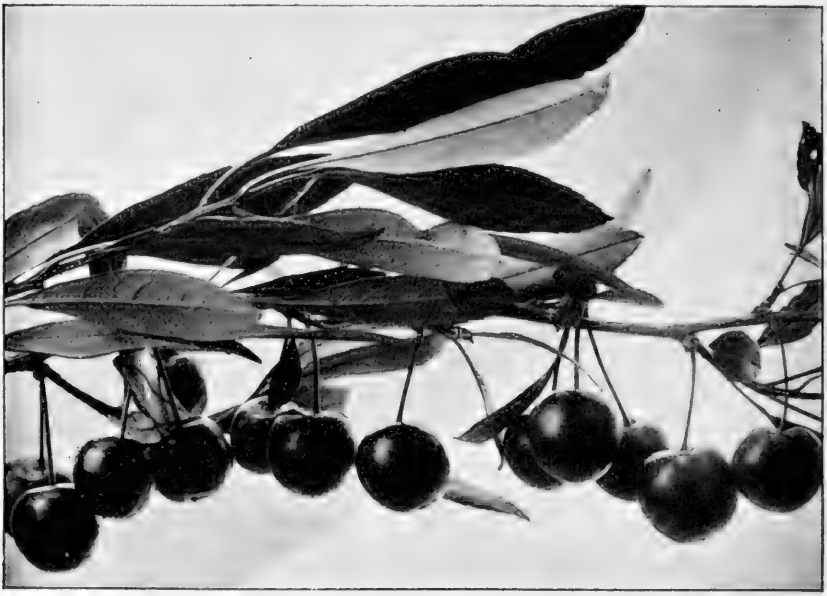


FIG. 143. Sand-cherry in fruit. After Bailey. Bull. 70, Cornell Ag. Expt. Station.

nutlets are inclosed within its red and fleshy substance. Some roses have the fruits, or hips, as they are called, protected by a growth of prickles, while in others they are smooth.

Plums, peaches and cherries. A well-marked sub-family of roses includes the plums, cherries, peaches, apricots and almonds. These are all trees or shrubs with bitter bark and foliage. The bark, leaves, and seeds contain small quantities of prussic acid,—a substance which has, when chemically prepared, about the same odor as the kernel of a peach stone. The flowers are of the ordinary rose type, except that there is only a single carpel instead of five or more as in other roses. This single carpel, or pistil, at the centre of the flower, contains one or two seed-rudiments and the fruit matures as a stone fruit. The outer wall of the pistil becomes fleshy, while the inner grows hard and produces the stone. Inside, the one or two seed-rudiments mature into the kernels. Plums have a smooth or waxy outer surface for their fruits, while peaches and apricots have this surface downy. In almonds the fleshy tract does not develop and the nuts may be described as peaches with dry pulp. Of plums there are two principal varieties, —the plums proper and the cherries. In Minnesota there are one or two species of plum, including the very common wild plum, a tree ten to twenty feet in height, with red, purplish or yellow fruits. The stone is flattened, with one edge sharp and the other grooved. Besides this common variety, at the extreme northern edge of the state are trees of the Canada plum, averaging somewhat larger than the ordinary sort, with broader leaves and larger, longer fruits. In addition to these two varieties of true plums there are six sorts of cherries. Almost the only difference between the plums and the cherries is the flavor of the fruit, though cherries as a class have rather more globular fruits than plums. The Minnesota varieties are the dwarfed or sand-cherry, common on sandy beaches, especially in the northern part of the state; the wedge-leafed cherry with fruits four or five lines broad; the western sand-cherry, resembling the wedge-leafed cherry in its foliage but with fruits nearly twice as large, found on prairies in the western part of the state; the pin-cherries with sour small fruits, without bloom, with

Fig. 144. A cluster of choke-cherry flowers and a single flower dissected. After Atkinson.

spherical stones and arranged in clusters of three or four; the choke-cherry, with fruits of a red color or sometimes nearly black, in clusters like those of the currant; and the black cherries, forming their fruits in clusters similar to the last mentioned, but always dark purple or black in color and somewhat flattened vertically. The choke-cherry can be distinguished from the black cherry by the very astringent taste it possesses. The fruit of the black cherry is sweet and not so astringent.

Comparison of different types of rose fruit. The fruits in the various sorts of roses appear to be quite dissimilar, while in reality they are but different elaborations of the same general types. It may serve to explain them if they are briefly compared with each other and described as modifications of some common fundamental form. In the first place it should be noticed that the number of carpels in the flower varies from one in the plums and peaches to fifty and more in the strawberries. These carpels are generally separate from each other, forming independent pistils; but in the spiræas, apples, mountain-ashes and their relatives, the small number of carpels, ordinarily four or five, are produced close together, so that they seem almost to blend in one body. In other instances the carpels are quite distinct and separate, as in the strawberry. An apple may be compared to five almond nuts placed close together and surrounded by a thick fleshy layer. Each segment of the apple core is a ripened carpel containing one or two seeds. A strawberry may be compared to an apple core with the flesh removed and the number of carpels increased to fifty or more, very much diminished in size and situated on the surface of a swollen fleshy axis. A plum, or cherry, or peach, may be compared to one segment of an apple core with the papery membrane greatly thickened and converted into two layers, the outer soft and pulpy, the inner hard and stony. A blackberry may be compared to a strawberry in which all the nutlets have matured after the fashion of plums or cherries. A raspberry may be compared to a strawberry with a dry pulpy centre and plum-like nutlets which separate from their axis in a group. The curious bur-like fruit of the agrimony may be compared to an apple of conical shape with the fleshy part modified into a layer on which are arranged numerous prickles with hooked ends. The clematis-like fruit of the avens may be compared to a strawberry in which the pulpy part is dry and the ends of the nutlets are prolonged into plumes, enabling each nutlet to be distributed by the wind.

The majority of the rose fruits are adapted to animal distribution, but the fivefingers and the avens depend rather upon the agency of the wind. The rose hip, as has been said, may be compared to a strawberry turned inside out, with an apple-like pulp growing up around it. One can easily see at the end of an apple opposite the stem, and at the end of the rose hip more clearly still, the five points of the five calyx leaves, which have become fleshy and assist in the distribution of the seeds. The colors, perfumes, essences and sugars of the ripe fruiting areas, whether these areas be the axis of the flower, as in the strawberry, the swollen calyx leaves, as in the apples, hawthorns, pears and rose hips, or the ovary walls, as in the plums and cherries, are in all instances adaptations for the attraction of birds and animals. So that, in being eaten, such fruits accomplish their own ends and are not to be regarded as unfortunate, like the fruits of wheat and corn that never "intended" themselves to be eaten, but stored up their food materials entirely for the benefit of their own enfolded plantlets. From this point of view it is apparent that there are two classes of edible fruits, those made edible by the plant for animal distribution, and those adapted to the nourishment of the seedlings, but seized by animals contrary to the well-being of the plant. Of the former class apples are examples, of the latter, the cereal grains.

The pea family. Related to the roses is the great pulse family in which the pod-bearing plants of the world are classified. The lower genera of pulses have more or less regular flowers with radial symmetry, but the higher genera form butterfly-shaped flowers like those of the sweet peas, and of a shape distinct from that of any other flowers in the plant kingdom. There is never any doubt whatever about the classification of a plant if it shows the butterfly-shaped blossom. The pulse family as a whole, however, is a group based rather upon fruit than upon flower structure, for all the species are marked by the production of pods or legumes. The legume is a fruit developed from a single carpel, with from one to many seed-rudiments produced in a row along one side, in the interior. The forms of pods are very various. Sometimes they are shaped quite like the familiar pea-pods or bean-pods. Again they are broken up into joints, each joint containing a single seed. Often the pods are coiled like snail shells. Some varieties have small pods, reminding one, in their appearance, of the nutlets of the strawberry, but differing in their almost universal habit of opening down both edges to release the seed. About 7,000 species are included in the pulse family, making it almost three times as large as the rose family. The lower division of pulses, in which the flowers are not of the true butterfly shape, though sometimes approaching it, is represented in Minnesota by two trees—the redbud and the Kentucky coffee-tree—and four herbs, including three sennas and a desmanthus.

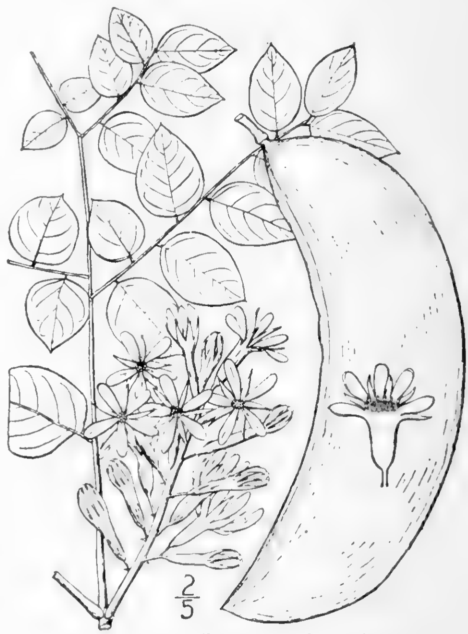


Fig. 145. Kentucky coffee-tree. After Britton and Brown.

Redbud trees. The redbud, or Judas-tree, is reported as occurring in the extreme southern portion of the state, but the only specimens that I know of are cultivated, and it is probably not native to Minnesota. The flowers have the look of the butterfly flowers of the higher genera, but the broad petal, known as the standard, is inclosed by the wings in the bud. In the true butterfly flowers the reverse condition obtains. The leaves of the redbud are heart-shaped and the flowers are pink and borne in short lateral clusters. The fruit matures into a flat, oblong pod which opens like the pod of a locust. The wood is heavy, coarse-grained, dark brown or red, with lighter colored sap-wood.

Kentucky coffee-trees. The Kentucky coffee-tree is a large forest tree indigenous, but somewhat infrequent, in the southern part of the state. It is especially abundant near Mankato, in Nicollet county. The leaves are doubly pinnate and the flowers are produced in racemes and are regular in appearance. Some of them are staminate, others pistillate, while still others are provided with both stamens and pistils. The pod when fully grown is from five to ten inches long and two inches wide, somewhat flattened, of a dark brown color, with several seeds. These pods hang unopened on the branches throughout the winter. In the following spring they split along the edges and reveal the large brown beans, which are remarkable for their exceedingly hard coats, their albumen and the orange-colored seed-leaves of the embryo. The wood of the tree is light brown tinted with red and of some value in cabinet-making. The coffee-trees select rich deep woods as their habitat, and are beautiful forms under cultivation. They cannot be mistaken for any other of the native Minnesota varieties, since their large, thick pods are altogether distinctive.

Sennas. The sennas are also known as sensitive peas or wild sensitive-plants. The three varieties which grow in Minnesota produce yellow flowers, almost regular,—that is, rose-like and not two-sided in appearance. The American senna has curved, rather smooth pods, three to four inches in length. The large-flowered sensitive pea has for the most part straight and slightly hairy pods, while the small-flowered has shorter straight pods and flowers considerably less than half the size of the other. The desmanthus is one of the pod-bearing plants in which the pods are clustered together in heads. It is a small herb with doubly pinnate, fern-like leaves, regular flowers aggregated in spherical heads, and short curved pods clustered together in dense heads, each pod containing from two to five seeds. These plants would not be mistaken for clovers, in which the pods are also clustered, on account of their fern-like leaves and regular flowers. Besides, the pods are very much larger.

Of the pulses, with butterfly-shaped flowers, there are between 75 and 80 species in the state, including the false indigos, the wild peanuts and wild beans, the vetches, prairie clovers and tick-trefoils, the wild licorices, the ground-plums, locust trees, *pommes de terre*, sweet clovers, lucernes, alfalfas, red, white and yellow clovers, lupines and rattle-boxes. Most of these are herbs. A few, like the false indigos or lead-plants, are shrubs, and one, the locust, is a well-known tree.

Herbaceous false indigos and rattle-boxes. There are two different kinds of plants belonging to different genera, known under the general name of false indigo. Some of them are herbs with creamy or white flowers in conspicuous racemes. Three kinds of herbaceous false indigos are known to occur in Minnesota. The pods in these plants are inflated and ovoid in shape. The flowers of the white false indigo turn black in drying. The leaves consist for the most part of three leaflets and the plants are large, averaging from two to four feet in height. Related to these false indigos are the rattle-boxes. The Minnesota species has apparently simple leaves with prominent stipules at the base of some. The pods are ovoid and inflated and the seeds rattle in them, giving the occasion for the common name.

Fig. 146. Wild lupine. After Britton and Brown.

Lupines, sweet clovers and clovers. Lupines, of which one species is common in Minnesota, have the flowers arranged in terminal, conspicuous racemes like the herbaceous false indigo flowers. The leaflets, however, are seven to eleven in number, growing out in radial fashion from the tip of their common stem. The flowers are generally blue and the whole plant is of an erect habit, from one to two feet in height. The pods are not much inflated, but flattened and leathery. By means of the leaves there is no difficulty in distinguishing these plants from other pulses. The lucerne, or alfalfa, has violet or purple flowers aggregated in loose clover-like heads or racemes. The pod in this variety is twisted up like a snail shell.

The sweet clovers are represented in Minnesota by two varieties, the white sweet clover and the yellow. These are bushy, branching herbs sometimes eight or nine feet in height. The small flowers are arranged in slender racemes. The pods are short-ovoid, and often—unlike most legumes—fail to open. The peculiar fragrance of the flowers indicates adaptation to insect pollination.

Six or seven kinds of clover, only one of which is native, occur throughout the state. These are plants with leaves composed of three leaflets, and flowers aggregated on short pedicels in more or less globular or elongated heads. The flowers at

FIG. 147. Sweet-clover bushes. After photograph by Williams.

the edge of the head mature first, and, as they are pollinated, often curve downwards, leaving the field clear to the unpollinated flowers to attract insects. The pods of the clovers, like those of the sweet clovers, often fail to open, and, when they do, separate along only one of the margins. If it were not for the butterfly-shaped flowers such plants might escape classification as pulses. The three most common clovers in the state are the prostrate, with branches lying upon the ground, the common white, and the red clover. The flowers of the prostrate clover are yellow. Besides these, there are a few other introduced clovers, one of which may be known by its oblong heads.

Rather closely connected with the clovers are the little herbs known as lotuses—no relatives, however, of the water-lily lotuses, for this is an instance where common names are confusing. In these plants the pods are more elongated. They occur singly and hang down in a limp position when mature, while the flowers are small, rose colored and with darker standard. The leaves are for the most part made up of three leaflets. A lotus may be known by its solitary drooping pods.

Indian turnips. The *pomme de terre*, or prairie-turnip, or Indian turnip, is an herb somewhat branched, of robust habit, and arising from a tuberous root. The flowers are in hairy ovoid spikes and the leaves are made up of five radiating leaflets. The pod is oblong, smooth and inclosed in the calyx. Two other plants of this genus are abundant in the state. One is conspicuous for its silvery leaves and is known as the silver-leafed prairie-clover. The silvery appearance, as in the buffalo-berries, is given by hairs on the surface of the leaves. There are from three to five leaflets to each leaf and the flowers are of a blue color, sessile and in small clusters. Another variety, the many-flowered prairie-clover, has leaves similar in form to the silver-leafed variety, but without the hairs which give them the metallic lustre. In this variety there are a number of small blue flowers aggregated in loose racemes.

FIG. 148. White clover. After photograph by Williams.

Shrubby false indigos. The shrubby false indigos occur in Minnesota in three varieties. These plants are remarkable for the modification of the butterfly-shaped flower, for all of the five petals, except the standard, have disappeared, so that the flower has but one petal. This is of a purplish, violet or blue color. The leaves are pinnate with from twenty to fifty leaflets, arranged opposite each other on their common midrib. The large false indigo is from five to twenty feet in height, with spike-like purple racemes of flowers from three to six inches in length. The pods are short, usually with two seeds, and the surfaces are covered with little oil glands. It is common along the shores of lakes. The low false indigo is a smooth shrub, not over a foot in height. The flowers are arranged in spicate racemes, usually solitary. They are of a purple color and sweet-scented. The plant is at home in the southwestern districts, preferring the prairie to the forest.

The lead-plant, which is one of the most abundant prairie shrubs in the Minnesota valley, is covered with white hairs and averages from one to three feet in height. The leaves develop twice as many leaflets as in the other varieties, sometimes twenty or more on each side of the common midrib. Several blue racemes of flowers generally occur close together. The pods are hairy and not markedly glandular.

Prairie-clovers. Of the true prairie-clovers there are three Minnesota species,—the purple, the white, and the silky. These plants have leaves made up, in the silky variety, of from ten to twenty leaflets, and in the other two, of from five to nine. The purple prairie-clover has commonly from three to five leaflets and in all the varieties they are small and slender. The flowers are arranged in dense spikes, and very often such spikes will be found with girdles of flowers blooming around their middles, while above the buds are still unopened and below the fruits have set and the petals withered. By this habit, together with their other characters, they may be recognized.

Locust-trees. The locust, or false acacia, is a handsome tree and is noted for its beautiful pendulous racemes of large white flowers, very fragrant and opening in the late spring. The trunk, farther south, is sometimes three or four feet in diameter, but rarely exceeds a foot in the colder climate of Minnesota. The leaves are made up of from eleven to fifteen leaflets pinnately arranged. The pods are much flattened, with winged edges, and the seeds ripen in separate chambers, and, when the pod opens, remain adherent, some of them to one side of the pod and others to the other. The halves of the thin pod serve the seeds as wings for their distribution by the wind. Young twigs of the locust tree have thorns at the bases of the leaves, but the older branches are unarmed.

Ground-plums. The common ground-plum of the prairies is one member of a little group of pulses including about ten species in Minnesota. Most of them have slender, purplish, lilac or whitish flowers in rather loose racemes. The leaflets are much like those of the smaller shrubby false indigos; that is, they are composed of numerous small oval leaflets on each side of a slender axis. In the ground-plum the pod, when it matures, is fleshy and may be eaten when cooked. Not all of the Minnesota varieties of ground-plum have this fleshy pod. In others the pod is quite dry.

Two plants closely related to the ground-plum may be distinguished from it by the longer, more conspicuous racemes of showy flowers. One of them in particular, which grows in the western part of the state, has bluish-purple flowers on a tall, central, erect stalk and is a very prominent flower of the prairie. This plant is sometimes called loco-weed or loco-vetch. The other member of its genus is of a beautiful silvery lustre, owing to the soft white hairs that cover the leaflets and their axes. In neither of these loco-weeds is there a branching plant-body above ground, but the leaves seem to spring in a tuft from the roots, while in the centre the erect flowering axis lifts itself above their tips. The pods are incompletely divided into two chambers by a deep partition extending lengthwise through the pod almost to the back.

Wild licorice. A common herb of the Minnesota prairie is the wild licorice. This plant may always be recognized when in fruit by the ovoid pods covered with hooked bristles. No other Minnesota pulse has just this sort of pod, which is, indeed, not unlike a small cockle-bur head. The flowers, produced in rather dense spikes, are of a cream color varying to white. In these plants the roots are thick and sweet to the taste and are sometimes used as a substitute for licorice. The flavor, however, is different from that of the true licorice and is scarcely so agreeable. The leaves are of the same general character as those of the last plant mentioned, except that they are not silvery in color, and are marked by minute glandular dots.

Tick-trefoils. The tick-trefoils are characterized by their pods which are constricted between the seeds and separate into pieces, each pod appearing to be made up of joints. One kind, rare in Minnesota, and limited to the north shore of Lake Superior, has the flowers in rather dense, violet-colored, terminal racemes. The pod consists of from three to five smooth joints shaped somewhat like eggs. The other tick-trefoils, of which there are eight or nine reported to grow within the confines of the state, have much less noticeable flower clusters, and the flowers are small and loosely arranged on their axes. Sometimes they are terminal and sometimes produced in the angle above the leaves. The pod is very flat and usually separated into a number of joints. Sometimes the pod is straight along one edge, while the other edge is indented like the teeth of a saw; but in other instances both sides of the pod are indented. The different kinds of tick-trefoils cannot be distinguished from each other without a critical examination; but it may be said that their principal differences are in the shapes of the leaflets, the arrangements of the pods in clusters, the surfaces of the pods and their methods of jointing. They are found for the most part in woodlands and usually stand up from two to six feet in height. In most of them the pods are provided with hooked bristles, by means of which they cling, either as a whole, or broken up into their joints, upon the fur of passing animals, or upon the clothing of their human visitors.

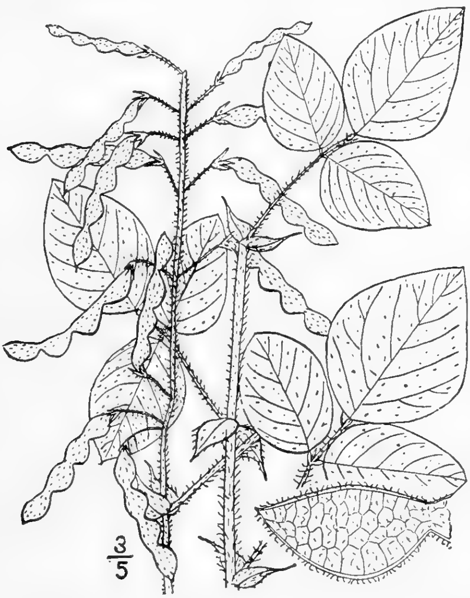


FIG. 149. Tick-trefoil. After Britton and Brown.

Bush clovers. Seven species of bush clovers are reported from Minnesota. Several of these are known as wand plants; that is, plants which stand up slim and tall without any lateral branches. One of them, the bushy headed or round headed bush clover, is a common object with its brown, pod-bearing heads aggregated in coffee-colored clusters at the top of a slender stem from two to five feet high. The stems bear a number of three-compounded leaves in which the leaflets are shaped somewhat like those of the willow. One of these bush clovers has a creeping stem and might be taken for a true clover were it not for the egg-shaped pods which are larger and dissimilar to those of the true clovers.

Vetches and beach peas. The vetches and beach peas may be recognized, wherever they occur, by the formation of tendrils at the tips of their leaves. There are about ten species in Minnesota. They are found in woods and swales and one variety is very conspicuous on sandy and gravelly beaches throughout the northern part of the state, being particularly abundant at Lake of the Woods and Red lake. This variety, which is known as the beach pea, is seen at its best on the seashore. The differences in the vetches lie in the shapes of the leaves and pods, the colors and sizes of the flowers and the development of the tendrils. In general, however, they are supplied with pinnately compounded leaves with one or two tendrils taking the place of the terminal leaflet or pair of leaflets.

Wild peanuts and wild beans. Not far removed from the beach peas are the groundnuts, wild peanuts and wild beans. In these there are commonly from three to five broad leaflets to each leaf. The stems are slender and twine or climb over the vegetation near them. The flowers are small, blue, pink or violet, and are generally gathered together in rather small clusters. These plants are abundant in the edges of woods. The wild peanut forms two kinds of flowers, small purple or white, ordinary butterfly-shaped flowers on lateral racemes, and peculiar little flowers without petals, on certain slender prostrate stems which trail along the ground. By means of these two kinds of flowers there is no difficulty in recognizing the wild peanut. The wild beans resemble the wild peanut in their general appearance, but are devoid of the curious inconspicuous flowers. The groundnut usually displays five leaflets in each leaf instead of three, but has the same slender vine-like habit of growth that characterizes the others. All these plants will be found in thickets and underbrush, trailing or climbing over the bushes and thus exposing their own foliage to the light.

Chapter XXXI.

From Geraniums to Maples and Touch-me-nots.

The nineteenth order includes the geraniums, the wood-sorrels, the nasturtium vines, the flaxes, the rues and prickly ashes, the polygalas, the spurges, castor-beans, and tapiocas, the water-starworts and several families not represented in North America. A variety of interesting plants in this order are cultivated, or are employed for various economic purposes. For example, the coca tree, from which the well-known anesthetic, cocaine, is manufactured, should be grouped here; also the oranges, limes and lemons, and the ailanthus tree, introduced from China. To the spurge family, too, of this order, there belong a number of singular cactus-like plants most abundant in South Africa. Several of the families are represented in Minnesota, but most of them by only a few species.

Geraniums. Four varieties of geranium occur wild in Minnesota. These all have regular flax-like flowers and slender capsules which open by five clefts running lengthwise of the pod. A peculiarity of the geranium pod is that, when it opens, it does so suddenly, splitting from the base upward. Five pieces, each carrying a seed at its lower end, split off in this manner from a central column and the seeds are projected some distance into the air as if thrown from a catapult. The different kinds of wild geraniums may be distinguished by their leaves. The common spotted-leafed geranium has rose-colored flowers and leaves palmately divided and spotted. The red-robin has much smaller leaves without the conspicuous spots. The Carolina geranium has its leaves cut up into finer segments than the others and the flowers are of a pale, whitish hue.

Wood-sorrels. The wood-sorrels are well-known for their three-leafleted leaves, not unlike those of the white clover, but with a distinct acid taste. There are at least three varieties in Minnesota and probably a fourth. In one, the white wood-sorrel, found only in the northern part of the state, the flowers, in general appearance like those of the flax, are white and the flowering stems and leaves arise from a slender, scaly rootstock. At the base of the plant are borne, on recurved pedicels, curious small flowers which do not open, but mature their fruits, after close-pollination, from stamens developed side by side with the fruit-rudiment. The other wood-sorrels have violet flowers in one species and yellow flowers in the other. The violet-flowered wood-sorrel comes from a brown bulb not unlike the bulbs of certain lily-like plants. For some reason bulbs are but rarely produced by plants belonging to the highest class. The violet wood-sorrel is, however, one of the exceptions. The yellow wood-sorrel is much more branched above ground than the others. Its leaflets are sensitive to the touch and if rubbed for a moment with the fingers they will close. The yellow wood-sorrel forms slender pods; the white wood-sorrel produces short and rounded pods, while the pods of the violet wood-sorrel are ovoid.

Flax. Of flax there are in Minnesota three wild species not very easy to distinguish from each other. In one, the flowers are blue like those of the cultivated flax, which sometimes escapes as a weed. The wild blue flax may, however, be known by the capsule which in fruit is much longer than the calyx. Besides this variety there are two wild flaxes in which the flowers are yellow. They may be distinguished by the length of their capsules. In the grooved yellow flax the capsules are from one to one and a half lines long, while in the stiff yellow flax they are from two to two and a half lines long. Furthermore, in the grooved yellow flax the upper part of the stem is clearly grooved, while in the stiff yellow flax the grooving is not distinct. Flax is cultivated for fibre and for seeds. From the seeds linseed-oil is manufactured, and from the fibre linen is made.

Nasturtiums. Nasturtiums, with their pretty, round, shield-shaped leaves, are favorite plants in borders and window-gardens in all parts of the state. The plant, however, is not a native. Perhaps the most interesting thing about it is the great sensitiveness of its leaves to the direction from which they are illuminated. A plant placed in a window will within a short time incline all its leaves so that their surfaces are perpendicular to the rays of sunlight. If the pot is now turned around, in a short time the leaves will slowly swing back and accommodate themselves to the new direction from which the light is shining.

Prickly ashes. The rue family is represented in Minnesota by two shrubs. One, the prickly ash, is abundant throughout the southern part of the state, extending as far north as Leech lake. The other, known as the three-leaved ash, three-leaved elm or hop tree, is reputed to occur in southeastern Minnesota. The prickly ashes sometimes grow into small trees. Their leaves are alternate, resembling those of the common ash trees, and there are from five to eleven leaflets in each leaf. The flowers are borne in little clusters, appearing in the early spring before the foliage, or while the leaves are beginning to emerge from the buds. The flowers are green and of small size. They mature into black, egg-shaped capsules, each containing one or two black and glistening seeds. The twigs of this plant are armed with thorns. Prickly ashes are common on hillsides, along rivers and at the edges of oak woods.

Three-leaved elms. The three-leaved elm has a fruit very similar in appearance to that of the slippery elm, though the plants are not particularly related to each other. The leaves are made up of three leaflets, and the fruit has a decidedly bitter taste, quite different from that of a true elm fruit.

Milkworts. The polygala family produces some small herbs known as polygalas, milkworts and snakeroots. The Seneca snakeroot is gathered in quantities on account of the medicinal value of the rootstock. These plants may be recognized by their flowers, generally in racemes or spikes, but in some instances becoming condensed into heads, and by the three petals united into a tube which is deeply cleft on one side. Two of the sepals are larger than the other three and there are usually eight stamens. The fruit is a small capsule and the seeds have peculiar appendages.

Spurges. Fifteen species of spurges occur in Minnesota. Most of them are mat-plants, forming disks of much branched vegetation similar in appearance to the carpetweeds and purslanes. Some of them, however, are erect, as, for example, the very beautiful "snow-on-the-mountains," famous for the pure white borders of the leaves. This is also known as the white-bordered spurge. Many of the mat spurges which have been alluded to are common along railway tracks and roadsides. All of them have a milky juice, and in Minnesota, a mat-plant with a milky juice is pretty certain to be a spurge. The different kinds of spurges are marked by the different sizes and shapes of the leaves, the smoothness or hairiness of the stem, and the surface of the seeds. One erect type, rather common in the western part of the state, is known by its red seeds sculptured over with a fine network marking. Another, the flowering spurge, is a very deceptive plant to the amateur botanist. It seems to have clusters of flowers about the size of flax flowers, arranged in loose, flat-topped terminal clusters. But each of the flower-like areas is in reality itself a cluster of flowers and the four or five white petal-like leaves are not really parts of the flower, but are bracts surrounding the clusters. Like the other spurges, this plant may be recognized by its milky juice. It cannot well be mistaken for other milky-juiced forms, such as milkweeds or wild lettuce, but it might be mistaken for one of the dogbanes, from which it differs, however, in the whorl of leaves standing at the base of the flowering area of the stem. Besides, the real structure of the flowers is altogether different, as may be learned by close observation.

Water-starworts. The water-starworts or water-fennels are very small, insignificant herbs found growing on mud-flats, or submerged in flowing water, or in ponds. Three varieties occur in Minnesota, all of them with low slender stems and opposite leaves with flowers in their axils. In one kind, which grows in flowing water, the leaves are linear and about half an inch long. In another, which may grow in the water or upon the mud, the leaves are ordinarily spoon-shaped, while in still another they are ovate. In all of them, however, the linear type of leaf may prevail and it is then very difficult to tell them apart. Tiny green plants found growing on mud-flats or submerged in the water may be classified as water-starworts, if they have opposite leaves with an inconspicuous bud-like flower in the axil of each.

The twentieth order includes the crowberry family; the sumacs, poison-oak and poison-ivy; the false mermaids; the horse-chestnuts, maples, box-elders; and the touch-me-nots, together with the hollies, bittersweets, wahoos and bladdernuts, besides some other families not represented in Minnesota.

Crowberries. Crowberries are heath-like shrubs and resemble diminutive yews. Their branches are generally not more than eight to twelve inches in length. Each branch is covered with densely crowded leaves of an evergreen aspect and with the margins rolled over toward the under side. The plants generally grow in tufts, forming large mats. The crowberries are rather rare in Minnesota, but are known to occur on the north shore of Lake Superior and in Aitkin county and along the international boundary. The flowers are inconspicuous, developed in the axils of some of the leaves toward the tips of the branchlets. The fruit is a black stone-fruit, less than half an inch in diameter. This curious little shrub is unlike any other in the state. It cannot be mistaken for a yew because in that the fruits are scarlet.

FIG. 150. Sumac bushes, with golden-rods in foreground and maples in background. After photograph by Williams.

False mermaids. The false mermaids are odd little herbs with pinnate leaves and deeply lobed fruits cleft into from two to five nutlets. They are marsh plants and grow as slender, more or less prostrate herbs, with solitary white flowers, triangular in shape. No other plant in Minnesota resembles the false mermaid.

Sumacs and poison-elders. The sumacs include seven varieties and are met with pretty commonly throughout the state. With one exception—the fragrant sumac—they are abundant. They are shrubs with pinnate leaves and invite attention by their large panicles of small stone-fruits, bright red in color in some of the varieties, and gray or white in others. The innocuous varieties of sumac, of which there are four or five in the state, may be recognized when in fruit by the massive *red* clusters. The leaves are made up of from nine to thirty one leaflets, except in the fragrant sumac, which bears three-leafleted leaves and much smaller clusters of stone-fruits. The poisonous varieties may be avoided by noting their gray or white stone-fruits. There are two of these, the poison-elder (poison-sumac, poison-dogwood, poison-ash or poison-oak) and the poison-ivy, both extremely unpleasant to come in contact with. The poison-elder grows for the most part in swamps and is pretty abundant among tamarack throughout the northern and central portions of the state. It becomes more rare in the southern and western districts. When in fruit it is easily recognized by the production of panicled currant-bunch-shaped clusters of gray stone-fruits. The leaves are composed of about seven leaflets arranged in pinnate fashion. From the shape of its leaves this plant is also called the poison-ash, and it is known

FIG. 151. Poison-sumac. After Chesnut. F. B. 86, U. S. Dept. Ag.

in some localities as the poison-dogwood. Farther south the plants reach a height of twenty to twenty five feet and are small trees, but in Minnesota the poison-elder rarely exceeds from eight to twelve feet. This plant is much more irritating than the poison-ivy and is the cause of many of the severe cases of skin-inflammation in the autumn—the season when it is most virulent.

Poison-ivy. The poison-ivy, with currant-bunch clusters of gray fruit, like those of the poison-elder, differs from the latter in being a low bush or woody vine, in one variety climbing, but bushy in another. The leaves are made up of three leaflets, resembling somewhat the leaves of the wake-robin or trillium. Poison-ivy in fruit should not be mistaken for any other Minnesota plant, but careless observers sometimes take for it the woodbine, a member of the vine family in which the leaves are made up of *five* leaflets. Both the poison-elder and the poison-ivy secrete a highly poisonous volatile oil which rises in an invisible mist from the foliage of the plant. It is often not even necessary to have handled the plant for symptoms of poisoning to develop. Merely approaching within a few feet of it will often suffice. One can understand how this is possible by noticing the distance at which he can smell the perfumes arising from sweet-scented foliage or flowers, as for example, from the wormwoods or the magnolias. Just as the air is permeated in the one instance by the perfume, may it in the other be filled with the poisonous exhalations. Among the antidotes for ivy or elder

FIG. 152. Poison-ivy. After Chesnut. F. B. 86, U. S. Dept. Ag.

poisoning are the acetates of lead or zinc, made into concentrated solutions and applied with a cloth or sponge as a wash for the affected parts. Salol is also a specific.

The ordinary innocuous sumacs are, from their brilliant autumnal tints, very beautiful shrubs of the Minnesota copses and hillsides. The poisonous varieties do not show the rich hues of their harmless relatives.

Hollies. One sort of holly bush is not uncommon in the state. It is a shrub, usually six to twelve feet in height in Minnesota, with leaves shaped like plum leaves, but rather thick, dark green and smooth above, turning black in autumn. Hence the bush is sometimes called black alder. In late autumn, clusters of red stone-fruits, spherical in shape, are found at the bases of the leaves. The flowers are of two sorts, staminate flowers devoid of pistils and perfect flowers with both stamens and pistils. The Minnesota variety of holly has not the spiny leaves of the Christmas holly, but its stone-fruits are of the same brilliant red, though rather smaller. Another kind of holly, the mountain holly, with grooved stone-fruits or capsules and smaller smooth-margined leaves, occurs in the southeastern part of the state. The deep longitudinal grooves in the fruit serve to distinguish it from the swamp holly. Hollies and poison-elders very commonly grow close together among the trees of tamarack swamps, and those gathering holly berries in the autumn will do well to observe any suspicious elder-leafed shrubs that are near by, and avoid them.

Climbing bittersweets and wahoos. One species of bittersweet and two wahoos represent their family in Minnesota. The bittersweet is a twining vine, often climbing up the trunks of small trees in the woods and displaying its stem along their branches twenty feet or more from the ground. The leaves are alternate and shaped somewhat like plum leaves. The flowers are produced in racemes and mature their fruits as orange-colored, spherical capsules, half an inch or less in diameter. These fruits split open by three clefts in autumn and show a red, pulpy structure inside.

The wahoo or spindle-tree, sometimes known also as burning-bush, is a shrub from six to twelve feet in height in Minnesota. The leaves are plum-shaped, the flowers are purple,

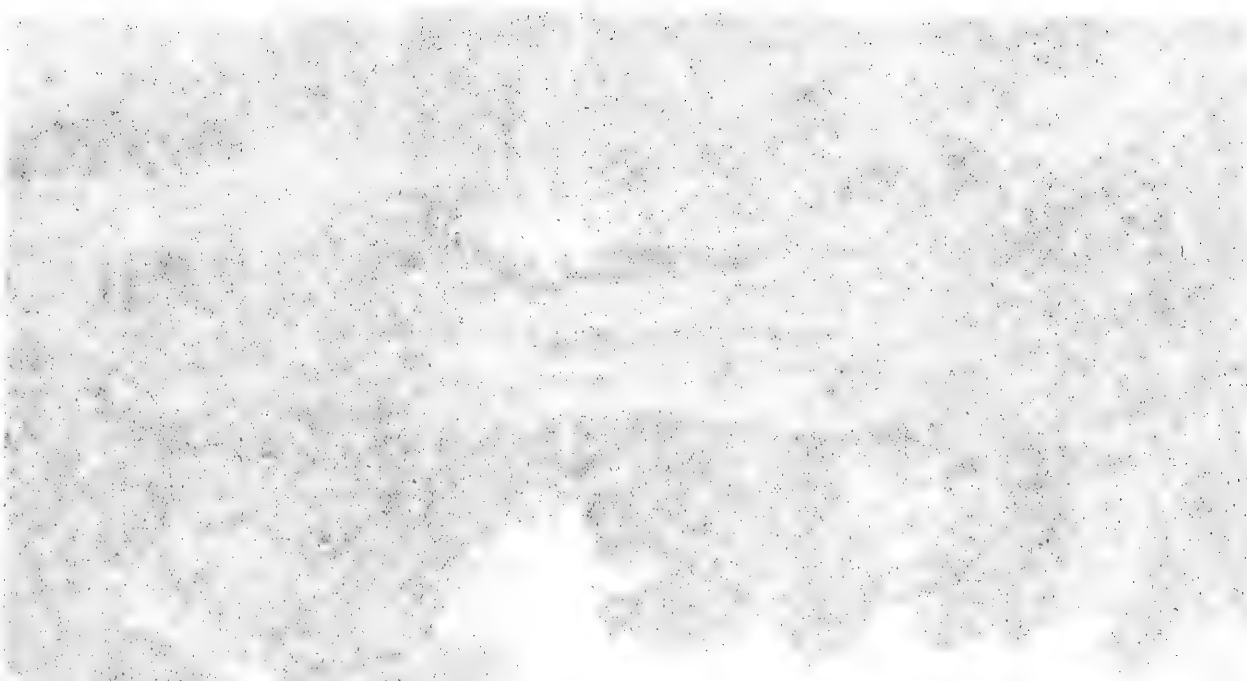


PLATE III. Pond with lilies. Ramsey county. Around it are growing oaks, willows, sumacs and blue flags, milkweeds and smartweeds. From a photograph by Williams, [illegible] are the acetate of lead or zinc, made into concentrated solutions and applied with a cloth or sponge as a wash [illegible] affected parts. Salol is also a specific.

[illegible] sumacs are, from their brilliant autumnal tints, very beautiful shrubs of the Minnesota copses and hillsides. The poisonous varieties do not show the rich [illegible] of their harmless relatives.

[illegible]lies. One sort of holly bush is not uncommon in the [illegible] usually six to twelve feet in height in Minnesota, with leaves shaped like plum leaves, but rather thick, dark green and smooth above, turning black in autumn. Hence [illegible] called black alder. In late autumn, clusters [illegible] stone-fruits, spherical in shape, are found at the bases of [illegible]. The flowers are of two sorts, staminate flowers devoid of pistils and perfect flowers with both stamens and [illegible]. The Minnesota variety of holly has not the spiny leaves [illegible] Christmas holly, but its stone-fruits are of the same [illegible], though rather smaller. Another kind of holly, [illegible] holly, with grooved stone-fruits or capsules and [illegible]gined [illegible] occurs in the southeastern part [illegible] state. [illegible] longitudinal grooves in the fruit serve [illegible] it from the swamp [illegible]. Hollies and poison-[illegible] close together [illegible] that are near by, and avoid them.

[illegible] bitter-[illegible] represent their family in Minnesota. [illegible] is a twining vine, often climbing up the trunks [illegible] and displaying its stem along their [illegible]es twenty feet or more from the ground. The leaves [illegible] like plum leaves. The flowers [illegible] produced [illegible] racemes and mature their fruits as orange-[illegible] capsules, half an inch or less in diameter. [illegible] clefts in autumn and show a [illegible].

[illegible] sometimes known also as burning bush, [illegible] twelve feet in height in Minnesota. The [illegible] the flowers are purple,

borne in axillary cymes, the fruits are singular, deeply-lobed, three or four-parted capsules. When the capsules split along the sides, a red, fleshy mass is shown within similar to that observed when the bittersweet capsules open. The climbing habit of the bittersweet serves, however, at once to distinguish it from the common wahoo. A rare species of wahoo is a trailing shrub.

Bladdernuts. Bladdernuts are branching shrubs with peculiar, large, deeply three-lobed bladdery capsules. The leaves are made up of three leaflets and the clusters of flowers arise in their axils. These plants may be readily recognized by the capsules which resemble three small pea-pods blended together by their backs and separate at their tips. They are not uncommon in the southern part of the state, where they inhabit the edges of woods.

Maple trees. Seven kinds of maple, including the box-elder, occur in Minnesota. These are the soft maple, the red maple, the sugar or hard maple, the black maple, the moosewood maple, the mountain maple, and the ash-leaved maple or box-elder. All of these plants may be known by their production of two-lobed fruits provided with wings. The fruits separate into halves when ripe and each half, furnished with its wing, obtains distribution by the wind. The box-elder is the only Minnesota maple with pinnate leaves. In this plant each leaf is made up of from three to seven leaflets. The other maples, in which the leaves are simple, may be distinguished by their flowers, leaves, bark and fruits. The soft maple and the red maple display their flowers before the leaves emerge from the buds and are among the earliest flowering Minnesota species. The flowers of the common soft maple have no petals and are, therefore, rather inconspicuous, while the flowers of the red maple have showy red or yellow petals. The sugar-maple, or hard maple, and the black maple form the flowers on long drooping stalks and at the same time that the leaves unfold. The leaves of the sugar-maple are smooth on the under side, while in the black maple they are hairy below, usually over the whole surface and always on the veins. The moosewood maple and mountain maple open their flowers in terminal racemes *after* the leaves have unfolded. In the moosewood maple the racemes are drooping, while in the mountain maple they are erect.

Of these plants, the soft, red, hard and black maples are large and handsome trees, while the moosewood and mountain maples are small trees or shrubs. The black maple has a rough black bark. The sugar-maple is utilized in the manufacture of sugar, obtained by boiling down its copious sap in the springtime. The red maple has scarlet or crimson bark on the younger trees. The soft maple has whitish bark with leaves more notched than in the hard or black varieties. The moosewood maple has leaves with two deep notches making three sharp lobes toward the end. All the lobes are about equal in size. The mountain maple has leaves similarly three-lobed, but the middle lobe is much the largest.

FIG. 153. Leaves and flowers of the sugar-maple. After Atkinson.

Soft maples. The soft maples are abundantly planted in Minnesota for shade trees, for which purpose, however, they are not so valuable as hard maples. Under favorable conditions they grow to be large trees, over a hundred feet in height. The branches are brittle and many of them are markedly pendulous like the branches of the weeping willows. The leaves are five-lobed, bright green above and whitish or silvery below. In autumn they turn yellow. The flowers are produced in little heads on short lateral branches, and there are two kinds, staminate and pistillate, often borne on the same, but sometimes on different trees. The fruits hang on slender, drooping stems, and very often one side of the fruit fails to mature. As soon as the seeds fall to the ground, or the next season, they may germinate, and the seedlings develop their first leaves and terminal bud during June. Maple wood, from this species, is hard and is used in the manufacture of woodenware or furniture. Soft maples are abundant throughout the southern part of Minnesota and extend north to Beltrami county.

Red maples. The red maple commonly occurs in Minnesota as a bush or low tree, but may, under the best conditions, reach a height of over a hundred feet. The bark is of a dark gray color. The leaves are whiter below than above, and in autumn exhibit beautiful hues of scarlet and orange. The flowers are borne much as in the soft maple and the fruits some-

FIG. 154. A grove of sugar-maples. Near Lake Minnetonka. After photograph by Mr. E. C. Mills.

what resemble those of the latter species, though the wings are more incurved. The red twigs, brilliant autumnal color, and more conspicuous flowers distinguish easily this maple from the soft maple. Its wood is heavy and one variety of it, known as curly maple, when polished is very beautiful. In Minnesota the red maple is one of the earliest trees to assume the autumn tints, and, with the sumacs, gives a vivid color to hillsides before the deep red of the scarlet oaks appears.

Sugar-maples. The sugar-maple is a large, round-headed tree, sometimes growing in Minnesota to a height of seventy five or eighty feet, and, under the most favorable conditions, to nearly twice this height. On the trunk the bark is of a light gray color, while on young twigs it is orange or yellow-brown. The leaves are darker green than those of the soft maple and assume a variety of colors in the autumn, some trees turning scarlet, others crimson, others yellow. If a particular tree is yellow one year it will be yellow the next, the tint of the autumn foliage being apparently an individual habit. The pistillate flowers are more commonly borne towards the tips of their branchlets, while the staminate flowers are on the sides, and lower down. The wood is strong and tough, more valuable than that of any other common maple. It is useful for fuel and is employed in the manufacture of flooring, furniture, tool-handles and portions of machinery. Bird's-eye maple and a form of curly maple are obtained from diseased trunks of the sugar-maple. It is this species which supplies the greater part of the maple sugar, though that is also made from the black maple and from the moosewood by the Indians of northern Minnesota. The sugar obtained from the sugar-maple is of a somewhat better quality, however, than that derived from the other species.

Fig. 155. Moosewood maple. After Britton and Brown.

Black maples. The black maple is very closely related to the sugar-maple and is possibly only a variety of it.

Moosewood maples. The moosewood maple occurs in Minnesota as a small and bushy tree with red-brown twigs and striped bark of a brown color. The leaves are smooth on both sides, turning yellow in autumn. The flowers open in late spring, the sterile and the fertile being produced on the same plant, but in different clusters. The wood is light and soft. The name "moosewood" is applied from the habit which the moose have of chewing the young twigs on account of their sweet juices.

Mountain-maples. The mountain-maple in Minnesota is a rather low shrub. The leaves turn scarlet or orange in autumn and the flowers are of two sorts, generally produced in the same cluster, the staminate towards the tips and the pistillate toward the bases. The wood is soft, light, and of little commercial value.

Box-elders. The box-elder grows as a small tree, thirty or forty feet in height, though farther south it becomes larger. The bark is of a brown or gray color; the twigs are purplish with a white bloom. The leaves do not show any brilliant autumn coloration. There are two kinds of flowers, staminate and pistillate, always borne on separate trees. The staminate flowers hang in clusters on thread-like stalks, while the pistillate droop in loose racemes. The fruits mature in autumn and often cling to the trees throughout the winter. When they fall in autumn, as they more commonly do, the stems on which they were produced remain until the succeeding spring, attached to the twigs that bore them. The wood is soft and weak, but is employed in the manufacture of some woodenware and for wood-pulp. This is a favorite shade tree along the streets of Minnesota towns. When growing wild it is to be looked for especially beside streams and in low woods.

FIG. 156. Touch-me-not. After Britton and Brown.

Buckeyes. The horse-chestnut family is represented in Minnesota by the buckeye, a plant which is probably introduced into the state by the agency of man and is nowhere abundant, though it occurs as if native in a few southeastern localities. It is a small tree with long-stemmed leaves made up of about five willow-leaf-shaped leaflets. The flowers, borne in terminal panicles, are of a yellow color, not so striking in their appearance as those of the horse-chestnut. The fruit is a spiny, spherical capsule, an inch or so in diameter, becoming smoother with maturity. The seeds, of which one or two are produced in a fruit, are large and have glistening coats. The wood is soft and white and, in Ohio and Indiana where the tree is more abundant than farther northwest, is used in the manufacture of woodenware.

Touch-me-nots. There are two species of touch-me-nots in Minnesota. Both of them are shade-loving plants, and grow in swamps, damp woods and ravines, where the light is not too strong. Their stems are translucent and one can see the fibrous threads through the skin. The leaves are very thin, of ovate shape, and with toothed margins. They wilt almost immediately if removed from their stem. The flowers are colored—in one variety, orange speckled with brown, in the other pale yellow—and two-sided, looking a very little like snapdragon flowers, to which, however, they are not related. The fruit is an oblong or slender capsule of a bright green color and succulent when ripe. If pressed gently between the thumb and finger, or if brushed against, the fruit splits violently into strips which coil together, ejecting the seeds with explosive force. The touch-me-nots are perfect examples of the adaptational group of plants known as shade plants. They are pale in color throughout, with thin, rather large leaves and an abundance of moisture in their tissues. They do not secrete purple coloring substances in marked quantities either in their leaves or in their stems. They are very abundant in Minnesota near rivulets, in wooded ravines, in tamarack swamps and around springs.

Chapter XXXII.

From Buckthorns to Prickly-pears.

The twenty first order includes two families, the buckthorns, of which there are two species, and the vines, with four grape-vines and one Virginia creeper.

Dwarf alders. The alder-leafed buckthorn, or dwarf alder, is a shrub found growing in swamps and recognized by its plum-shaped alternate leaves, in the axils of which small flowers arise. There are no petals, and the calyx is urn-shaped with four or five teeth at the margin. The stamens are borne on the calyx between its notches. The fruit is berry-like, containing three nutlets within. The character of the fruit and the structure of the flower easily distinguish this shrub from others which might be mistaken for it.

New Jersey teas. Besides the buckthorn, there are two varieties of New Jersey tea or redroot, one of which is pretty abundant throughout the state, while the other is less common. These plants are small shrubs, the two species being distinguished by the shapes of the leaves. One, the American redroot, has ovate, while the other produces lance-head-shaped oblong leaves. In both varieties the flower is very similar to that of the buckthorn. The calyx-parts are fused together at their base and have five notches at the margin. Between these notches the stamens are borne, five in number, while under each stamen arises a curious ladle-shaped petal of a white color. The black fruits are dry and deeply three-grooved, and when mature they separate longitudinally into three hard nutlets. The American redroot is more abundant in dry woods, while the smaller redroot prefers rocky places, barren soil, dry hillsides or bluffs, or the tops of knolls in the rolling prairie. The name, "New Jersey tea," arises from the use of the plant in place of tea by American soldiers during the Revolution.

Wild grapes. The wild grapes can scarcely be mistaken for any other plants, except, perhaps, the moonseeds, from which they are known at once by their more or less pear-shaped seeds.

FIG. 157. Tree covered by grape-vine. After photograph by Williams.

They are all of them tendril-bearing, climbing, shrubby vines, with characteristic maple-like leaves. The flowers are either altogether separated, or of two sorts on the same plant. It is not usual to find among grapes what are known as *perfect* flowers, with both stamens and pistils. The fruit is a spherical berry of a blue or purplish-black color, edible and containing from two to four seeds. The four varieties of grapes in Minnesota are the fox-grape, the summer grape, the frost-grape, which is the common one, and the riverside grape, which is likewise abundant except along the north shore of Lake Superior. The different grapes may be discriminated from each other by certain structural characters. The fox-grape and the summer grape have leaves with cottony under sides. The other varieties have leaves with smooth, or only slightly hairy under sides. In the fox-grape the berries are rather large, with a strong musky fragrance, and the cotton on the under sides of the leaves is of a brownish color. The summer grape has small berries without the musky fragrance; and the cotton on the under side of mature leaves is almost white. The riverside grape may be distinguished from the other smooth-leafed variety by the bloom on its berries and by its trailing or low habit of growth, while the frost-grape climbs high, often swinging itself on the branches of trees, and produces black shining berries, ripening after frost and not possessing the distinct bloom of the riverside grape. In all of these vines the fruits hang in panicles and droop from the weight of the berries.

Virginia creepers.. The Virginia creeper or woodbine, is an abundant plant in most sections of the state. The tendrils of this vine often form little sucker-like disks by which they attach themselves to walls or fences, making the plant a desirable climber in dooryards and about houses. The leaves are composed of from five to seven leaflets, five being much the more common number. The fruits are grape-like, with from one to four seeds, and are borne in forking clusters that stand erect owing to the strong pedicels and smaller weight of the whole as compared with a bunch of grapes. The berries are not edible.

The twenty second order includes six families not represented in Minnesota, and in addition to these the basswoods, and the mallows to which the hollyhock of country gardens belongs.

Basswoods. One variety of basswood, known also as the American linden or whitewood, is native within the borders of the state. It is a handsome tree, reaching a height of seventy feet or more, very abundant in the hardwood belt throughout Minnesota, and only less common along streams and on hillsides in the northern woods. Its range extends to Thunder bay, Lake Superior, and along the international boundary to Lake of the Woods. The trunk is rather slender, not more than two feet in diameter in the northern portions of its range. The leaves are large and broad, unevenly heart-shaped at the base and turning yellow in autumn. The flowers are produced in cymes upon a stem that bears at the base a remarkable

FIG. 158. Virginia creeper on tree trunks. After Schneck in *Meehan's Monthly*.

wing-shaped bract which is coherent until about its middle with the flowering stem. The fruit is a hard berry, and within it are one or more seeds. Two or more of the berries are matured in a cluster and the stem of the cluster with the adherent wing-shaped bract separates from the tree. The centre of gravity of the cluster and the shape of the wing are so exactly coördinated that the whole affair whirls through the atmosphere, making of itself a little parachute. By this means the berries are often distributed to a considerable distance. The wood is pale brown in color, light, and rather weak. It is employed principally in the manufacture of wood pulp or paper and in the production of some kinds of furniture and woodenware. The inner bark, which is papery, is used by nurserymen to tie buds into scions. The basswood is a very desirable shade tree and is frequently planted in dooryards and along streets. The European basswood or linden, which gives the name to the famous street "*Unter den Linden*" of the German capital, is sometimes planted in the United States, but is not particularly abundant in Minnesota. Unlike the American species, it has no scales at the base of the petals in the flower.

Mallows. The mallow family includes a little group of herbs, mostly introduced from Europe, such as the hollyhock, the creeping-charley or cheese plant, the velvetleaf, the ketmias or rose-mallows and some others. There are a few native species, none of which is very common. Among them are the *Callirrhoe* and false mallow of the southwestern corner of the state, the glade-mallow, a rare plant of the southwestern section, and the halberd-leafed rose-mallow, found occasionally along the Mississippi river in the vicinity of the Twin Cities.

Mallows may be distinguished from other plants by the development in the flower of large numbers of stamens all blended together by their bases into a tube which surrounds the fruit-rudiment. The latter has several compartments and encloses one or two seeds in each. The embryo is curved and contains albumen. Sometimes the flowers are large and showy, as in the hollyhock, while in other varieties they are rather small. The common round-leafed mallow or creeping-charley, also known as cheese plant, from its disk-shaped little fruit-bodies, sometimes eaten by children, is a common plant in dooryards and waste places. The flower is like that of the hollyhock, only much smaller and of a pale blue color. The high mallow is an erect plant of biennial growth, with fruits quite similar to the creeping variety and leaves shaped like those of currants. The crisp mallow has the margins of the leaves crisped like some varieties of lettuce, while the general shape of the leaves reminds one very much of the high mallow. The *Callirrhoes*, of which at least one variety, and probably two, are to be found in Minnesota, are known also as poppy-mallows. They are herbs of the prairies and should be looked for particularly in the far southwestern portions of the state. One of them is occasionally found along railways as far east and north as Minneapolis. The two varieties of *Callirrhoe* are distinguished

FIG. 159. Basswood trees. Shore of Lake Calhoun. After photograph by Hibbard.

by the shape of their leaves. The triangular-leafed poppy-mallow has the lower leaves somewhat halberd-shaped, while the other puts forth deep-lobed round leaves. The flowers in each of these varieties are rather large and showy, purple in color, verging towards red. The prairie mallow resembles closely in general appearance the poppy-mallows, but may be distinguished by the silvery foliage and the red flowers. The glade-mallow displays rather small white flowers in terminal clusters. The leaves are shaped very much like those of the soft maple, only smaller. The whole plant is an erect, slender herb from four to eight feet in height. It has been found in damp woods in Goodhue county, and occurs in such localities as far west as Mankato. The native rose-mallow is an herb, three to five feet in height, with leaves heart-shaped or three-lobed on the upper side, velvety to the touch. The flowers are large and of a pretty pink tint, growing darker toward the centre. In fruit, the calyx is inflated into a bladdery sheath not unlike that of the ground-cherries. The ketmia is a low herb with deeply-cleft leaves. The flowers are large and yellow, with purplish centre, and remain open but a few hours; hence the plant is also known as the flower-of-an-hour. Like that of the halberd-leafed rose-mallow, the calyx in this variety inflates itself into a little balloon-shaped bag around the fruit. Another name for this plant is black-eyed Susan. It is rather abundant in waste fields and vacant lots in the vicinity of St. Paul and Minneapolis.

Velvetleafs. The velvetleaf, which is sometimes encountered in the southern part of the state, is a large herb, often six feet in height, with leaves in size and shape like those of the linden. They are, however, of a soft velvety texture; hence the common name applied to the plant. The flowers are yellow and are borne in the axils of small leaves toward the ends of branches. The twelve or more carpels which make up the fruit are separated from each other by deep longitudinal grooves, and the appearance of the whole fruit-body is something like that of a circle of milk-pitchers set close together with their lips pointing outward.

None of the mallows is of any particular economic importance. The hollyhock and the ketmia are cultivated for ornament, and it is in this family that the marshmallow—a plant with mucilaginous root, used in the manufacture of a popular confection—is grouped.

The twenty third order includes twenty six families of plants without any Minnesota representatives and but three families of which Minnesota species are known. Many of the families are small exotic groups of plants, but among them are some important economic varieties. The tea-plant, a member of the tea family, cultivated in Japan, China and Ceylon, is classified here,—also the camphor plant, the marcgravias, the tamarisks, the passion-flowers and the begonias. The families represented in Minnesota are the St. John's-worts, with about a dozen species, the rock-roses, with three or four species, and the violets, with about twenty species.

St. John's-worts. The St. John's-worts are herbs with opposite leaves, which are always marked with glandular dots or small black specks. The flowers are borne in panicles or cymes at the apex of slender stems. In each flower there are five sepals and five petals, with a number of stamens sometimes united into clusters. The ovary is one-chambered, with from three to five interior longitudinal ridges, along which the numerous seed-rudiments are attached. At the top of the capsule, which is generally pyramidal-ovoid in form, from three to six separate stigmas are borne. In some of the Minnesota varieties the longitudinal interior crests of the fruit-rudiment project clear to the centre, thus making a three- to five-chambered capsule. The flowers are regular in appearance. The different varieties of St. John's-worts may be recognized by their general habit of growth; by the sizes and shapes of the leaves; by the character of the flower-cluster, which, as has been said, is either flat-topped or panicled; and by the cross section of the fruit, which is, when mature, in all instances a dry capsule—sometimes one-chambered, sometimes three-chambered and sometimes five-chambered. In all these the leaves are ovate, slender or elongated. One variety, the marsh St. John's-wort, is found only in swamps. It may be recognized by its three-carpeled red capsule.

Rock-roses. The rock-roses include three or four plants, of ledges or barren soil, known as frostweeds, *Hudsonias*, pinweeds, beach heathers or false heathers. The frostweed, which is a pretty common plant throughout the state, is a woody herb one or two feet in height with two kinds of flowers,—some with petals and clustered in terminal cymes, the others much smaller, without petals, almost sessile in the axils of the leaves. The leaves are shaped like small willow leaves and are covered with a gray growth of hairs. The petaled flowers are light yellow, with hoary sepals. The fruit is a capsule ovoid in shape and divided into three chambers, in each of which is a large number of seeds.

Beach heathers. The *Hudsonia*, or beach heather, is a plant of local occurrence in Minnesota, abundant on rocky islands at Rainy lake; on Sable island at Lake of the Woods; on sand dunes in Anoka, Sherburne and Wright counties; and on rock ledges in the Minnesota valley, along the St. Croix and lower Mississippi. It is a densely tufted herb, with very small, oval leaves, covering each other like shingles on a roof. The flowers are small, yellow and sessile, produced in clusters towards the ends of the branches. The whole plant has a hoary aspect, from the minute white hairs with which its stems and leaves are covered. It is an abundant dune and crevice plant along the international boundary, more frequent north than south, but found on high rocks even to the southern border of the state.

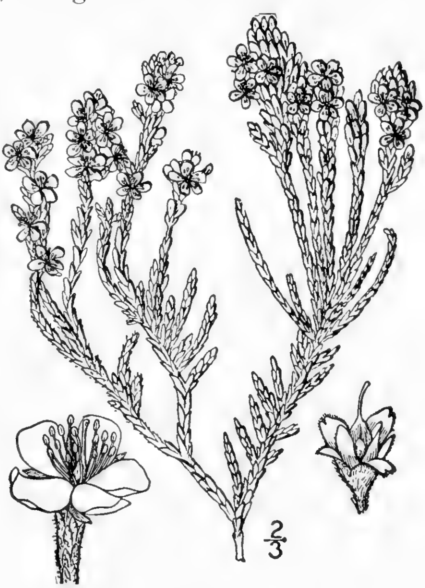


FIG. 160. Beach heather. After Britton and Brown.

Pinweeds. The pinweeds grow in great abundance along the St. Croix river, in open woods or by the roadside, but are less common elsewhere in the state. Minnesota has one or two varieties, which may be known by their small simple leaves, in most instances less than half an inch in length, and by their large numbers of green or purple flowers gathered in terminal panicles. The common Minnesota variety is about a foot in height, slender and usually unbranched below the region of the flowers. The fruits, when they mature, are capsules with three longitudinal furrows marking the three carpels of which they are constructed.

Violets. Violets, of which there are several species in Minnesota, are well-known as flowers of the springtime and are remarkable for a number of structural peculiarities among which may be mentioned the development of their flowers singly upon slender, almost leafless stems; for the upper- and undersidedness of the flower, which in this respect superficially resembles the flowers of larkspurs or of orchids; and for the production in many varieties of small flowers, close to the surface of the ground, incapable of opening, and, therefore, pollinated by their own pollen. The violets of Minnesota may be divided into the stemless and stemmed varieties. Actually they all have stems, but in the so-called stemless sorts the leaves and flower-bearing axes arise from short, erect or prostrate *underground* stems, so that the leaves seem tufted at the root, while in the stemmed varieties, so named, there is more or less branching of the above-ground portion of the plant-body. The stemless varieties have, for the most part, purple, lilac or white flowers, while in the stemmed violets, yellow, white or cream-colored flowers are also to be found. Among the violets of the state, which are abundant and easily distinguished, are the larkspur-leafed or prairie violet, with deeply-cut leaves, apparently made up of seven or eight incised leaflets; the meadow violet, with heart-shaped leaves; the arrow-leafed violet, with leaves shaped like arrow-heads; the bird's-foot violet, similar in general appearance to the prairie violet, but distinguished from it by the beardless petals; the round-leafed violet, with abundant closed flowers, developed later in the year than the open ones; the marsh-violet, with its pale lilac petals marked with darker veins; the sweet violet, with small, white, sweet-

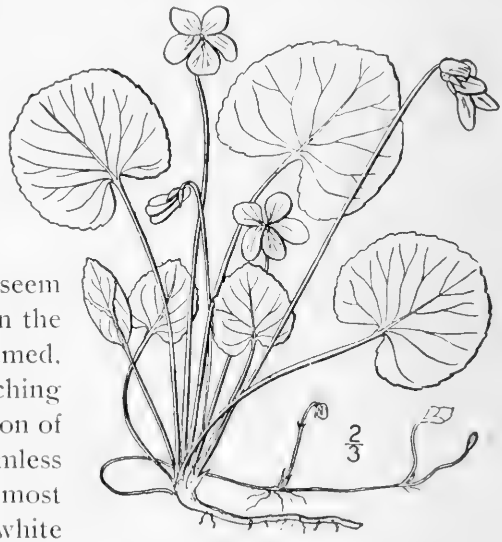


FIG. 161. Sweet white violet. After Britton and Brown.

scented flowers, abundant in two varieties in the tamarack swamps of the state; the kidney-leafed violet, with leaves of a broad kidney shape and longer than the flowering stem; the lance-leafed violet, with leaves shaped like those of the willow. All these belong to the stemless group. Among the stemmed forms are Nuttall's violet, a prairie variety, with elongated, lance-shaped leaves; the halberd-leafed violet, with leaves shaped like arrow-heads and yellow flowers like those of the preceding species. Here, also, is the common yellow violet of the woods, with heart-shaped and kidney-shaped leaves and hairy stems, usually solitary. Very similar to this is the smooth, yellow violet, with narrower heart-shaped leaves, smooth stems and foliage, and clustered growth. Related to these yellow-flowered species is the Canada violet of rich woods, with its violet or whitish flowers and heart-shaped leaves, and the very similar striped violet, with cream-colored, white or blue flowers. Both the latter have stems five to fifteen inches in height and not tufted. The Labrador violet, with smaller heart-shaped leaves and purple or white flowers, may be distinguished by its tufted growth and its production of closed flowers later in the season than the ordinary open ones. The sand violet is known by the strongly notched, slender stipules of the leaves. The flowers are of violet color, the stems are tufted and the leaves are kidney-shaped or heart-shaped, on stems longer than their blades. The long-spurred violet of the Isle Royale and Grand Marais region may be recognized by the slender spur of the flower, in length equaling or exceeding the petals. Besides the native forms the common pansy has escaped from flower-gardens in the southern part of the state and sometimes occurs as a dooryard weed.

Violets show in their two-sided flowers an adaptation similar to that seen lower in the series in the two-sided flowers of the pulse family and of the larkspurs, or, still lower, in the flowers of orchids.

Prickly-pears. The twenty fourth order includes but a single family, the cacti, to which belong three species of prickly-pears and the purple cactus—rock-plants of southern Minnesota. The cactus family is a very extraordinary group, in which stems have become fleshy and consolidated, while leaves have been modified into a defensive armor. These plants indicate a strong adaptation to desert life. Their massive, leafless stems—leafless in the sense of producing no ordinary foliage leaves—suggest the scantiness of the soil-moisture which they are able to absorb, and because it is so hard to obtain, they have abandoned, as far as possible, their evaporating surfaces. Some of them, like the melon-cacti, have not only lost their foliage, but have shortened their stems into spherical or ovoid melon-shaped bodies. They have large roots, usually extending to a considerable distance in all directions from the base of the stem.

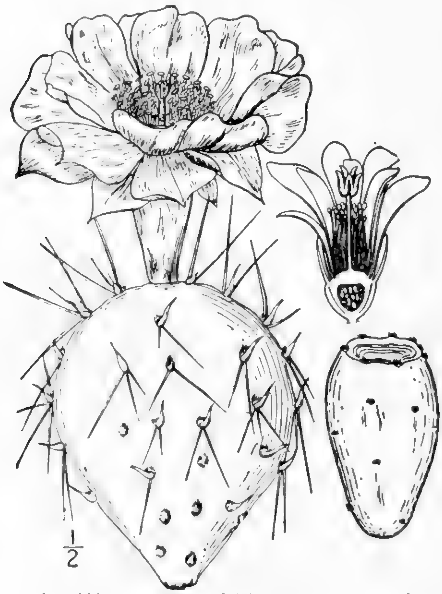


FIG. 162. Western prickly-pear cactus. After Britton and Brown.

The strong defensive armor of spines, which most varieties possess, suggests a danger to which the plants of an arid region are exposed, owing to the absence in such districts of abundant forage for herb-eating animals. The three Minnesota species of prickly-pear are all of them wanderers from the southwestern plains, where they developed their peculiar characters, and now that they have entered the more favorable northern region they retain the o r g a n i z a t i o n best adapted to their original home. They are not infrequent in the Minnesota valley, on ledges of rock near New Ulm and Redwood Falls. One variety occurs at Taylor's Falls, in the valley of the St. Croix, while two are abundant on the rocks in Pipestone county, in the vicinity of the old Indian quarry. Perhaps the Indians have had something to do with their introduction from the southwest. The three species may be distinguished by their spines and fruits. The western prickly-pear produces a fleshy edible fruit, free from spines, from one to two inches long, shaped somewhat like a pear, borne upon the flat, sinuous joints of the stem. In this variety the spines on the stem are not numerous. They occur in groups of from one to four. The flowers are yellow with a red centre. The other two prickly-pears have smaller fruits, covered with spines and drier in texture. The many-spined prickly-pear bears on the flattened stems little masses of bristles in tufts, with from five to twelve spines in a group. They are slender, from half an inch to two inches in length. The brittle prickly-pear produces, on the more egg-shaped joints of the stem, from one to four central spines, varying from a half to one and a half inches in length. Each group of central spines is surrounded by from four to six lateral shorter prongs. The spines in this species are gray, becoming black toward the tips, while in the many-spined prickly-pear the thorns are whitish and not black toward the tips.

The purple cactus is known by its almost globular, warty and thorn-covered stem, from one to five inches in height, arising either singly or in tufts. The flowers are terminal and solitary, and are purple or purplish-red. This species is reported only from the vicinity of Ortonville, and probably does not grow elsewhere in the state.

Chapter XXXIII.

From Leatherwoods to Dogwoods.

The twenty fifth order comprises eleven families that are not represented in Minnesota and five that are. Among the exotic species are the pomegranate, the mangrove, the myrtles and eucalypti, the melostomas, the Brazil-nuts and a number of forms peculiar to South Africa. In Minnesota there are found one species of the leatherwood family, three species of buffalo-berries and silverberries, four species of the loosestrife family, eighteen or twenty evening primroses and about six varieties of water-milfoil.

Leatherwoods. The leatherwood is a shrub from two to six feet in height, not uncommon along streams in woods and thickets throughout the greater part of the state. It is most abundant from Duluth to Lake of the Woods and is not to be expected in the southwestern portion of the state, although it extends to New Ulm and Blue Earth county. The leatherwood has yellowish-green twigs, with alternate, broadly oval, entire-margined leaves. The flowers are disposed in clusters of three or four, appearing while the leaves are emerging from the bud. The perianth is bell-shaped, with eight stamens borne upon its inner surface and protruding from the mouth. Every alternate stamen of the group is longer, while the intermediate ones are shorter. The fruit is oval in outline, red in color, and about half an inch in length. The bark is poisonous, acting as a violent emetic. This shrub may be known by the yellowish color of the flowers and bark, the stamens alternately longer and shorter, and the red stone-fruits.

Buffalo-berries. The three species of buffalo-berries are silvery shrubs, particularly abundant in the Red river valley, in one variety extending as far east as the north shore of Lake Superior. They may all be recognized by the curious scurfy growth on the leaves, which gives to them a silvery lustre upon both sides in the silverberry and silver buffalo-berry, but upon the under side alone in the Canada buffalo-berry. In this latter species a few scurfy shield-shaped hairs develop on the upper sides of the leaves. The silverberry has alternate, oblong leaves, while buffalo-berries have opposite oblong leaves. The flowers are bell-shaped, without corolla. The stamens are four or eight in number, borne on the inner surface of the perianth. The silverberry, which is a most attractive and beautiful shrub, is silver-colored, not only with respect to the leaves, but over the young twigs as well. The fruit is oval in shape, silvery in color, with a grooved stone. It ripens in August and is edible. The two varieties of buffalo-berries have the same general appearance as the silverberry, but are distinguished by their opposite leaves. In the Canada buffalo-berry the leaves are green on the upper side, silvery below, and the twigs are not thorny. In the silver buffalo-berry the leaves are bright silver-colored on both sides and the twigs are generally thorny. The fruit of the Canada buffalo-berry is harmless, but flat and tasteless, and is either of a red or yellow color. The fruit of the silver buffalo-berry is of a delicious flavor and is used by housewives in the Red river valley in the manufacture of jellies and preserves.

Loosestrifes. The loosestrife family includes some insignificant herbs with opposite leaves and small axillary flowers, solitary in the *Rotala*, aggregated in axillary clusters in the swamp loosestrife, solitary again in the true loosestrife. The *Ammanias* and water-purslanes strongly resemble the water-starworts in their superficial characters, but may be distinguished by their flowers. They are, like the water-starworts, small aquatic or mud-dwelling herbs, with opposite leaves and axillary flowers. The water-purslane, indeed, has often been mistaken for the water-starwort or water-fennel. In the water-purslanes and *Ammanias* the calyx is bell-shaped with four notches at the margin, but in the water-starwort there is no perianth whatever. The fruit of the water-purslane is a globular capsule with two chambers, but that of the water-starwort is flattened and deeply grooved on the flattened surfaces, dividing it into two distinct portions. The *Ammanias* are larger herbs than the water-purslane, but resemble the latter variety in general characters. One variety of *Ammania* occurs in the state, and it may be recognized by the opposite linear leaves, with clasping bases and sharp tips. From one to five flowers, the petals of which soon fall from the bell-shaped calyx, are produced in the axils of each leaf. In the water-purslane the flowers are solitary in the axils of the tiny, opposite, slender leaves and are very small, green and inconspicuous. The *Rotala* resembles an *Ammania* in its larger size, varying from two to six inches in height, but has the small axillary flowers of the water-purslane. Unlike those of the water-purslane, they are furnished with four small petals between the four lobes of the bell-shaped calyx. The swamp loosestrife, which occurs in the St. Croix valley, has stems from three feet to ten feet in length and with whorls of willow-shaped leaves. The flowers are nearly an inch in breadth and are clustered in purple cymes in the axils of the whorled leaves. The *Lythrum*, or purple loosestrife, is a plant of low moist ground, with alternate, stemless, lance-shaped or oblong pointed leaves and purple flowers, solitary in the upper axils. These plants are not uncommon along low lake shores throughout the southern part of the state. A most remarkable peculiarity of the loosestrifes is the formation of very extraordinary structures in the cells of the outer seed-coats. In some of the varieties each cell of the layer which makes up the surface of the seed is provided with a curious cork-screw-like apparatus, developed in its cavity and capable of being turned out into the ground, where, together with hundreds of other bodies of the same nature, it assists in drawing the seed into the soil.

Evening-primroses and fireweeds. The evening-primroses—the family to which the cultivated fuchsia belongs—include two species, known as false loosestrifes, from their resemblance to the true water-purslanes. They have the same opposite leaves, axillary flowers and general habits of growth. There are, however, four stamens, and capsules with four compartments instead of two. These false loosestrifes are rather unusual plants of ditches, swamps and muddy banks in the southern part of the state. To the evening-primrose family belongs also the fireweed or willow-herb, abundant in two varieties, especially in the northern part of the state on burnt-over tracts. The fireweed is an erect herb, with purple flowers in broad terminal racemes and willow-shaped leaves arranged alternately upon the stem. The capsules split into four sections and release the numerous seeds, covered with cottony hairs, by means of which they are distributed abundantly in the wind. Closely related to the fireweeds are three or four species of willow-herbs with slender capsules packed full of small tufted seeds. Here, too, should be classified the evening-primroses and *Gauras*, with their fuchsia-like yellow flowers. Five or six varieties of evening-primroses occur in different parts of the state. The white evening-primrose is limited to the western portion. The shrubby prairie evening-primrose is common over the prairie district. The most abundant is the ordinary evening-primrose of roadsides, known by its yellow flowers, with four large petals and calyx growing up around the fruit-rudiment and adherent to it The *Gauras* are rare herbs, or half-shrubs, not abundant except in the southwestern districts. They may be known by the fuchsia-like flowers, red in one species—the scarlet *Gaura*—and pink in the other. The flowers are smaller than those of the evening-primroses, but rather larger than those of the willow-herbs.

Enchanter's nightshades. Two herbs of woodland districts, known as enchanter's nightshades, are grouped in the evening-primrose family. They are low herbs with the habits and appearance of shade plants. Their leaves are opposite and are more or less triangular. The small white fuchsia-like flowers are borne in loose terminal racemes, and the capsules, when they mature, are covered with hooked prickles. The little pear-shaped burs that are found upon one's clothing after an autumnal ramble in the woods will probably be the fruits of the enchanter's nightshade. The two varieties of nightshade may be distinguished by their size, one of them varying from a foot to two feet in height, while the other is seldom over five inches tall.

Water-milfoils. The plants known as water-milfoils include five or six Minnesota species, of which the so-called mare's tail or jointweed is the most striking in form. It is a slender, erect, unbranched plant, found growing on wet mud or in the water, and has a stem composed of joints like those of the well-known scouring-rushes. At each joint, however, is a whorl of from six to twelve green, lance-shaped leaves. The plant cannot, therefore, be mistaken for a scouring-rush, for it has functional foliage leaves. Another kind of water-milfoil is the mermaid-weed, with two sorts of leaves. If the plant has grown partly submerged, the leaves below the surface of the water will be like feathers, while the leaves above will be oval and only slightly notched. The flowers are borne in the axils of the leaves above the water and the fruit is triangular in cross section, with three deep grooves. The true milfoils are exceedingly abundant in the lakes and ponds of Minnesota. They may be recognized by their jointed pale-reddish stems, with whorls of feather-shaped leaves each with fine thread-like dissected lobes. The flowers are borne in the axils of small, oval leaves, toward the end of the stem, where it emerges from the water. The flowering stem protrudes above the surface like the spike of a pondweed. No pondweed, however, has these whorls of feather-shaped leaves. Three or four different varieties of water-milfoils occur within the state, and the plants need not be confused. For the most part milfoils prefer deep water and are found growing along with pondweeds outside the lily-pad zone and on bars or sandy bottoms.

The twenty sixth order includes three families, each of which is represented by Minnesota forms. These are the ginsengs, the parsleys and the dogwoods. The Minnesota forms of the ginsengs and parsleys are all herbs, while the dogwoods are all of them shrubs—one, the dwarf dogwood or cornel, being only three or four inches high. The others, however, are shrubs of good size.

Spikenards, wild sarsaparillas and ginsengs. To the ginseng family belong five Minnesota species—the spikenard, the wild sarsaparilla and wild elder, together with the ginseng or "sang" and the dwarf ginseng or groundnut. The first three are characterized by leaves made up of leaflets arranged as in the ash, that is, the leaflets are pinnately grouped. In the last two the leaflets are arranged as in the Virginia creeper—that is, palmately grouped. The spikenard is a large herb, from three to six feet high, with thick, sweet-scented root. The leaflets, arranged in pinnate groups, are developed in such manner as to form one large three-branched leaf, of which there are several upon the branching stem. The flowers are arranged in the kinds of clusters known as umbels, characteristic also of the parsley family. In the spikenard the umbels are massed together into a large panicled inflorescence. The fruits, forming very large and ornamental bunches when ripe, are of a red-purple color, globular in shape and not edible.

The wild sarsaparilla is not furnished with an erect, branching stem, but the leaves and flowering axes arise from a long, underground rootstock. The flowers are produced at the apex of the flowering axis in a group consisting usually of three umbels, arranged so as to form a flat-topped cluster. The fruit is purplish-black, nearly spherical, and longitudinally grooved. The wild elder has leaves like those of the elder bush. The umbels are numerous and simple, aggregated together in groups towards the end of the leafy, erect stem, and the fruits are dark purple, five-grooved when dry. The whole plant is more or less beset with slender bristles.

FIG. 163. Ginseng. After Britton and Brown.

The two varieties of ginseng may be distinguished by their leaves. In the true ginseng the leaves are made up of five stalked leaflets, while the leaflets in the dwarf ginseng are sessile and vary from three to five in number. In both plants the leaves are arranged palmately, and in each there is a swollen root—almost globular in the dwarf ginseng, and ovoid-tuberous and sometimes branched in the true ginseng. The dwarf ginseng rarely exceeds six inches in height, but the true ginseng may reach the height of a foot and a half. The flowers and fruits are arranged in small umbels. In the true ginseng the fruit is crimson, while in the dwarf ginseng it is yellow. Ginseng roots are commercially valuable on account of the use which the Chinese make of the plant in their pharmacopœia.

By American or European physicians the plant is not considered to be of any medical value whatever.

The parsley family. The parsley family in Minnesota includes about thirty-five species of herbs, very difficult to discriminate without a technical examination of their peculiarities. In all of them the flowers are produced in compound or simple umbels, with the exception of the curious button-snakeroot, which resembles in its appearance a one seed-leafed plant much more than it does the other members of the parsley family. In this the leaves are parallel-veined and grass-like and the flowers are clustered in heads. Among the varieties of parsley found in Minnesota are two sorts of pennyworts, two sorts of black snake-roots, the cow-parsnip, the hog-fennel, the cowbane, the water-hemlock, the meadow-parsnips and water-parsnips, the hone-worts, poison-hemlocks and the sweet cicelys.

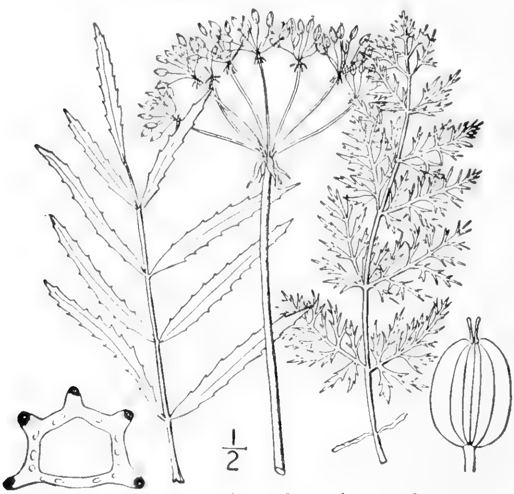


FIG. 164. Water-parsnip. After Britton and Brown.

The plants have in this family, for the most part, compound leaves, but in a few species the leaves are simple, as in the button-snakeroots, the introduced hare's-ear, the *Zizias*, and the pennyworts. In most of the forms the leaves are compounded like those of the well-known water-parsnips or wild parsnips. In all the varieties the fruit is dry and consists of two carpels, which are at first united but finally separate from each other along their faces, so as to produce two half-fruits, in each of which a single seed is inclosed. There are usually oil-tubes in the fruit, so that the odor of caraway seeds is a peculiarity of most of the fruits in the family. It is upon the characters of the mature fruit that the specific descriptions are based, rather than upon those of the flower or of the vegetative tract; for the flowers, and to some extent the plant-bodies, are very similar throughout great numbers of species and genera.

In the sweet cicelys the fruits are adapted for animal distribution. They are elongated, pointed, armed with barbed hairs and grouped in very loose umbels. These are common plants in the woods throughout the state, and the slender, pointed seed, which attaches itself to one's clothing during a forest ramble, is generally the half-fruit of one or the other species of Minnesota sweet cicely. The snakeroots form little bur-

FIG. 165. Wild parsley. After photograph by Williams.

like fruits in loose, few-flowered umbels. These are, like those of the sweet cicelys, intended for animal distribution; but most parsley fruits have smooth or ribbed surfaces and do not attach themselves to animals. In some the fruits are winged to a degree, and probably obtain distribution through the agency of the wind. The roots of certain plants of the parsley family are very poisonous, and to children eating those of the poison-hemlock or of the wild parsnips or cowbane, they often prove fatal. To the parsley family belong some garden vegetables, such as carrots and parsnips. Here, also, are the plants furnishing coriander and caraway seeds. The perfume, myrrh, is obtained from a European variety.

Dogwoods. There are eight varieties of dogwood in Minnesota, all of them rather closely related. In dogwoods the flowers are rather inconspicuous and borne in heads, to be regarded as compact umbels. In some of the varieties about four large white, petal-like leaves are produced just below the head of flowers, so that, as in the sunflower family, the whole head resembles a single flower. Two Minnesota species have these handsome white leaves below the flower heads. One, the dwarf cornel, or bunchberry, is a little shrub from two to eight inches in height, with the upper part of the stem herbaceous. The above-ground branch, which is generally simple, arises from a prostrate, slender rootstock. The leaves are ovate, with several strong longitudinal ribs, and are clustered in a whorl below the pedicel of the flower-head. In fruit the dwarf cornel produces from each flower a little ovoid or spherical stone-fruit of a scarlet color. The fruits are aggregated in heads as the flowers were, and form characteristic red bunches, giving occasion to one of the common names.

FIG. 166. Water-hemlock. After Chesnut. F. B. 86, U. S. Dept. Ag.

The other dogwood, in which conspicuous, white petal-like leaves are clustered below the flowering head, has these leaves very large, an inch or more in length, strongly notched at the tip. Sometimes in this variety, known as the flowering dogwood, the petal-like leaves are pinkish, but more commonly they are white. The bush occurs rather sparingly along the Mississippi river, from Stearns county to the Iowa line. Its fruits are very similar to those of the dwarf cornel, but are a little more elongated. They have the same scarlet color and cherry-like structure. In the rest of the Minnesota dogwoods, including the shrubs known as red osiers and kinnikinics, the flowers are larger and looser, cymose or paniculate, and not provided with the large, petal-like bracts beneath. The shrubs are distinguished from each other by their foliage, the shape of their flower clusters, the color of their twigs and the stones of their fruits. The round-leafed dogwood, very abundant throughout the state, is a bush from three to ten feet in height, much branched and furnished with broadly ovate, entire-margined leaves. The fruit is of a light blue color and has an almost globular stone. Closely related to the round-leafed dogwood is the silky cornel or kinnikinic, distinguished by its silky-haired twigs, quite different from the green, smooth twigs of the round-leafed dogwood. The fruit is of the same light blue color, but the leaves are somewhat slender, approaching in their shape ordinary plum leaves. The rough-leafed dogwood grows a little larger than either of its relatives which have been mentioned and may be recognized by the reddish-brown, hairy twigs, the rough, hairy upper surfaces of the leaves and the spherical, white fruits, in which the stone is but slightly furrowed and not much flattened. Bailey's dogwood is very similar in appearance, but has rather narrower lance-shaped leaves and white fruits, in which the stone is flattened and furrowed along the edge. The red osier or kinnikinic is one of the most frequent varieties through the northern and central portions of the state. It is a shrub from three to fifteen feet in height, with bright red or purple, smooth

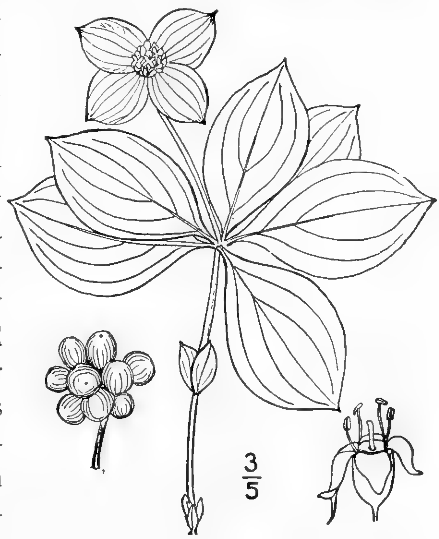


FIG. 167. Dwarf cornel. After Britton and Brown.

twigs, sometimes slightly hairy towards the tips. The leaves are broadly ovate and the fruits are white, with stones of a generally globose shape. This variety, together with the silky cornel, is utilized by the Indians—under their name of kinnikinic—as an adulterant of tobacco. The inner bark of the twigs is collected and dried, mixed with the tobacco and believed by the Indians to improve its flavor. It should be mentioned that the Indians apply the same name to other materials which they use in a similar manner, as for example, sumac leaves. The name of the Redwood river is said to be derived from the red osier.

The panicled dogwood is, perhaps, the most abundant species in the southern and through the central portions of the state. It is, like its relatives, a branched shrub, and has smooth, gray twigs. The leaves are lance-shaped, with slender tips. The fruits are white in color and have slightly furrowed stones.

All the dogwoods which have been described are characterized by opposite leaves. One other kind, the alternate-leafed cornel, is not uncommon in Minnesota, except in the region of the international boundary. As its name indicates, the leaves are alternate. The fruit is of a blue color and has a channeled stone. In the southern portions of its range this variety sometimes becomes a small tree, but in Minnesota it remains of shrubby habit. The wood is heavy, close-grained and of a reddish-brown color.

Most of these varieties of dogwood grow best in damp woods or thickets and along the shores of lakes. The dwarf cornel, however, is by preference an inhabitant of tamarack swamps, where it is found along with wintergreens and lady's-slippers. It is abundant, too, in the pine woods, particularly in shaded places. The dogwoods are exceedingly beautiful shrubs when disposed along broad lake beaches, where they select the back-strand or mid-strand and often form handsome hemispherical plant-bodies ten feet or more in height and fifteen feet in breadth, growing regularly and looking as if they had been trimmed by some careful gardener. Together with certain varieties of willows which have the same habit of growth, they are among the most noticeable plants of level lake shores, especially in the northern part of the state. They abound, too, around meadows and in the edges of woods or along streams.

Chapter XXXIV.

High Types and Low Types of Flowers.

There have now been passed in review the twenty-six orders of two seed-leafed plants which agree in showing no fusions of the petals of the flower into corolla tubes. Indeed, some of them have no petals. But in such forms as produce flowers with petals, the typical honeysuckle tube or morning-glory funnel is not developed. A number of differences in flowers and fruits have been recorded, and it may not be amiss, before passing to the consideration of succeeding orders, to note briefly the general law under which flowers vary from lower types to higher. There is a distinction, pretty clear in the mind of the botanist, between lower or simpler sorts of flowers and higher or more complex kinds. The distinction does not, however, consist in showiness, size, color, perfume or abundance. Considered botanically, some large and beautiful blossoms are lower in type than other tiny, inconspicuous flowers that might almost escape the observation of the amateur.

In order to understand the distinctions which have weight with botanists it is necessary to remember from what sort of structures flowers are believed to have developed. A prototype of all flowers is the pine cone—an aggregate-body is foreshadowed even among flowerless plants, notably by the club-moss cones. It will be recollected that in club-mosses the ends of many of the stems gathered their leaves more closely together than elsewhere, and on the upper side of each of such leaves was placed a little spore-containing sac. The cone of the club-moss is an axis upon which spore-bearing leaves are distributed. As has already been suggested, in the discussion of the club-mosses, the primitive type of spore-bearing leaf had also, as part of its duty in the plant economy, the starch-making work of an ordinary leaf. But by a division of labor, some leaves, especially toward the tips of branches—therefore raised higher from the ground—devoted themselves particularly to spore-manufacture, leaving the starch-making to lower leaves on the stem. Naturally it was more important for the plant to use, for spore-production, those leaves farthest from the ground, because if produced at a height the spores could be distributed over a wider area.

When the habit of making two kinds of spores became fixed among the distant ancestors of modern seed-bearing plants, the clusters of spore-bearing leaves or cones came, in the pines and their allies, to be specialized, so that one cone devoted itself to the manufacture of the small-spores while another produced only large-spores in the little cases on its leaves. Thus there originated the very different pollen-bearing and seed-bearing cones, which may be observed in such plants as the white pine, tamaracks and junipers. Probably, however, in some varieties there was not this separation, upon their special axes, of the two sorts of leaves; but one sort arose toward the tip of the axis, while the other appeared lower down, so that *mixed* cones, with carpels or large-spore-bearing leaves toward the tip, and stamens or small-spore-bearing leaves toward the base of the axis, originated. After the seed-habit had become fixed, it is apparent that the same advantage which club-mosses derived from having their spore-producing leaves highest on the stem, would now be derived from having the seed-rudiment-producing leaves, or carpels, highest on the stem. The advantage of height above the substratum which was manifest in the distribution of *spores* would be retained as favorable to the distribution of *seeds*. The primitive higher flowering plants no doubt had their seeds distributed by the wind, and it was, therefore, important, from the plant's point of view, that the carpels should stand higher in the flower than the stamens. This will account for the *central* position of the pistil and the *peripheral* position of the stamens.

The crowding together of the leaves of the flower, which became possible when they abandoned their starch-making functions, may be seen foreshadowed even in the cones of the club-mosses. It becomes still more marked in the pines, while in flowering-plants the great majority have the cone or flower-axis so short that it is actually flat or even depressed in the centre, as in roses. To this rule, however, there are a number of important exceptions, as for example, the little mousetail, a member of the crowfoot family, with its elongated axis, upon which the nutlets are produced. The anemones, also, and some of the rose family, like the strawberry, have conical or cylindrical floral axes upon which the carpels are distributed. These elongated axes may not, indeed, in such instances, be really primitive, but may rather be secondarily adaptive. Yet the highest types of flowers do not have such long axes, but are flat, with the carpels central and the stamens in encircling rings. If, now, one can imagine a pine cone, the tip of which is composed of seed-bearing scales, while at the base are disposed the pollen-scales or stamens, and then imagine further that the tip of this axis is pressed down with the thumb until the whole becomes flat and saucer-like, it is apparent that the seed-bearing scales will now be at the centre, while the pollen-bearing scales will form a ring around the outside of the saucer. Precisely such change in shape of the ancestral cone is believed to have taken place in the plant world under the slow workings of structural improvements through the ages. Many advantages in flowers might be derived by the passage from the elongated to the flattened type of axis. If, for example, the flower came to depend for pollination upon insects, the flattening of the axis might make the work of the insects surer, or if the flower depended upon its own pollen for pollination, the bringing of the stamens and the stigmas into the same plane would, perhaps, facilitate the process. Of course the ancient prototypes of flowers could not be expected to have these flattened axes, because in them the division of labor between spore-producing and starch-making leaves had not arisen, and each leaf on the axis had to stand in such a position that it could get light for itself from the sun without shading too much the other leaves near by. Elongated flower-axes, like those of the pines, remind one of earlier days, in which such axes had, in addition to their production of spores, also a starch-making work to perform. Any flower which retains in its structure the marks of *earlier, less improved* conditions, is conceived in this respect to be of lower type than one which has lost these marks, and this is the true criterion of rank among flowers. Precisely the same thing is apparent in human society, for a civilized man who retains characteristics which may have been valuable to the savage but have been outgrown during the progress of civilization, is regarded as of lower grade than his fellows.

The flattening of the axis of the flower into a disk is possibly the most fundamental evidence of improvement; that is, of passage from a lower to a higher type. Connected with this flattening arose a rearrangement of the parts of the flower. In the pine cone the scales are arranged spirally, just as if they were foliage leaves, but in apples the stamens and carpels are produced in whorls. A spiral arrangement of stamens and carpels, because it is more like the fundamental grouping of foliage leaves upon a stem, is believed to indicate a lower type of flower than when whorls are substituted—a grouping not so common among foliage leaves, but quite unobjectionable for spore-producing leaves. Even among the pines the tendency to gather the leaves of the flower into more compact clusters may be seen in such plants as the junipers and red cedars.

Again, as flowers came to be blocked out as definite spore-producing tracts, made up of leaves arranged on a shortened axis, the leaves below the stamens became modified from their proximity to the true floral parts. Thus the area known as *perianth* came into existence. By a further specialization perianth came to consist of outer perianth—that is, lower perianth, or *calyx*, and inner—that is, upper perianth, or *corolla*. Under such conditions what may be known as a typical flower appeared, and such a typical flower may be described as an axis, bearing essential leaves, viz., carpels and stamens, surrounded by the accessory leaves of the calyx and corolla.

In all the four regions of the typical flower modifications and improvements are possible. The carpels, for example, may blend together into a single fruit-rudiment or pistil. Thus the fruit of the lily is regarded as made up of three carpels blended together. Such a blending would be regarded as an improvement over the separate condition of the scales in the cones of the pine. It is certainly farther removed from that primitive arrangement in which, on account of their starch-making duties, the leaves were necessarily separate. After having thus become blended, conditions might arise, when, by the deep grooving of the pistil, the carpels would again be separated and such a secondary separation would mark a higher type than the original blended condition. It is sometimes difficult to tell whether a separation of the carpels is primitive or secondary. In the region of the stamens the separate leaves indicate a primitive type, while the blending of the stamens into a tube, as in the mallows, is regarded as an improvement, and consequently indicates a higher type. Likewise the blending of the parts of the calyx into a tube is regarded as a modification of that original condition in which the calyx leaves were separate.

Not only may parts of the same group blend with each other, but they may also blend with the group next to them. Thus the production, in orchid flowers, of stamens apparently springing from the surface of the pistil is regarded as evidence of the blending together into one body of what were originally separate stamens and pistils. For this reason the orchid flower, in which such a condition has arisen, is regarded as higher in type than the lily flower, for in the latter the blending of stamens and pistil has not been effected. A great many such blendings exist. Sometimes the stamens are produced upon the petals or upon the calyx leaves. Sometimes both the petals and stamens seem to arise from the calyx, indicating a fusion into one body of all three regions of the flower—a condition evidently remote from the primitive type, and, therefore, indicative of higher rank. Especially is the blending of the calyx with the surface of the pistil regarded as an improvement over the condition in which these two areas are quite distinct. Apple flowers, for example, develop petals and stamens upon the calyx and the latter is blended with the surface of the carpels, giving an additional protective layer to the seeds and permitting the important function of assisting in seed-distribution to be borne by a part of the flower below the essential organs. In willow-herbs, too, or fireweeds, the calyx is blended with the pistil, and when the capsule is mature it consists of two protective layers around the seeds instead of one. All these blendings of parts indicate higher rank.

Another way in which flowers become modified from primitive forms is by the development of differences between the parts of the same area. The violet flower, with one of its petals spurred, is conceived to be higher in rank than the linden flower, in which all the petals are alike. Irregularity of the flower marks some improvement over regularity, and it should always be remembered that the irregular flower is irregular for a purpose. The irregularity may be, and usually is, an adaptation to the habits of the insects which effect pollination. Therefore, the strongly irregular flowers of orchids, beautifully adapted to the sizes, shapes, weights and feeding-habits of bees or moths, are improvements over the regular flowers of tulips, blue flags and trilliums. Irregularity may arise in a variety of ways. A very common type is two-sidedness of the flower and the substitution of the two-sided symmetry for the radial symmetry. Just as man, whose body can be divided into approximately equal halves by only one plane, is on this account a higher structural type than the starfish, the body of which may be divided into several approximately equal portions by planes radially disposed, so the two-sided flower of an orchid, or that of the pea or larkspur, must be regarded as structurally higher than related radially-symmetrical forms, such as lilies, acacias, lindens or buttercups.

Along with the development of upper- and under-sidedness in the flower go a number of changes in the shapes, positions, numbers and sizes of the floral organs. Thus in the pea flower, one petal is larger than the others, and forms the so-called standard. The other four petals, grouped in pairs, constitute the so-called wings and keel of the flower. The stamens are blended together into a tube, but one stamen in the plane of symmetry stands distinct from the rest. The carpels, too, in the pea flower become reduced in number and the pod is often flattened in the plane of the symmetry.

There should be no difficulty in comprehending how a flower that manifests in its whole structure a great departure from the primitive type should be considered as higher than a flower that approximates in its structure more closely to the early conditions. It must be observed, moreover, that the different orders of flowering plants do not constitute a single series of advancement. One order may show improvement along one path, while another shows improvement in quite a different direction. In the same order the lower families may have regular flowers, while the flowers of the higher families have acquired more specialized irregular shapes. The proper arrangement of the orders is not one of sequence, but rather the kind of arrangement that is seen in genealogical charts, or in the trunks, main branches, secondary branches and twigs of a tree. Grasses and sedges, for example, represent the perfection of certain lines of development. Orchids represent the perfection of another line of improvement, and dogwoods occupy relatively another terminal position. Yet it is possible in a general way to regard the plant with two-leafed seedlings as showing a higher type of embryo-structure than the plant with one-leafed seedlings, and when the orders of plants are discussed in sequence, the former group is considered, as a whole, subsequent to the latter. On this account, however, it should not be supposed that willow flowers are of higher structural type than orchid flowers, for orchids are among the most perfected of plants with the lower type of embryo, while willows are among the least perfected types with the higher kind of embryo. In general, that higher class in which the petals are blended into corolla tubes marks, in this respect, an advance over those plants in which such blending does not exist. But it would be a mistake to suppose that the flower of the cranberry is structurally more complicated than the pea or the violet flower. As in the case of the willows and the orchids just compared, the cranberry belongs to one of the lowest orders of corolla-tube-producing plants, while the peas and violets are relatively high types of the generally lower series, in which no corolla tubes are formed.

With this explanation of a somewhat difficult point—looking toward an answer to the question, why is one flower considered of higher type than another?—there may now be discussed the eight remaining orders of two-seed-leafed plants in which corolla tubes rather than separate petals are almost universally the rule.

Chapter XXXV.

From Wintergreens to Chaffweeds.

The twenty-seventh order includes six families, two of which, the wintergreens and the heaths, are represented in Minnesota. About twenty two species of heaths are native to the state. Here are classified the huckleberries, cranberries, blueberries, snowberries, bearberries, trailing arbutuses, checkerberries, leatherleafs, *Cassiopes*, rosemarys, laurels, *Menziesias*, and Labrador teas. To this family belong also the azalias, rhododendrons and heathers.

Wintergreens. The wintergreen family in Minnesota comprises nine or ten species of true wintergreens; the one-flowered wintergreen, two pipsissewas or spotted wintergreens, the pine-drops, the Indian-pipe or corpse-plant, and the pine-sap or false beechdrops. The last three plants named do not exhibit leaf-green but absorb their food from the humus of the forest floor, taking up organic substances and manufacturing no starch of their own. The others are green plants with somewhat the appearance of the heaths, except that they are not so shrubby. The wintergreens, from branched underground rootstocks, produce upright stems usually less than a foot in height. The flowers are commonly grouped in a single slim terminal raceme, each flower nodding or erect in the axil of a small bract or scale. In some of the varieties the flowers have the stigmas and stigma-stalks bent down, while in others the stigma projects in the centre of the flower.

The round-leafed wintergreen, very abundant in pine woods, throughout the northern part of the state, has rounded or broadly oval leaves, of a leathery texture, shining and evergreen, and spreading out at the base of the straight, tall flower-bearing axis. The flowers are white, rather large and sweet-scented and are arranged, eight or ten together, in their racemes. The green-flowered strongly resembles the round-leafed wintergreen, except that the leaves are of a dull green color above and the flowers are greenish-white with slight fragrance. The shinleaf, unlike the two preceding species, has papery rather than leathery leaves, and these are broad and rounded with blades rather longer than their stems. The flowers in this variety are greenish-white and very sweet-scented. The bog wintergreen, found in cold peat-bogs, has the leaves of the green-flowered wintergreen—that is to say, they are broadly oval, leathery and of a dull green. The flowers, however, are purple, thus easily distinguishing this variety. The pink-flowered or heart-leafed wintergreen is very similar to the bog wintergreen, but may be recognized by the heart-shaped bases of the leaves. The flowers are rose-pink or sometimes purple.

All the wintergreens mentioned have the stigma depressed towards the under side of the flower. The remaining varieties have central stigmas. The lesser wintergreen resembles in most of its characters the green-flowered, but has the thin leaves of the shinleaf wintergreen. The stamens do not, as in the previous varieties, diverge from the fruit-rudiment, but close around it in the open flower. The serrate-leafed wintergreen has flowers very much like those of the lesser wintergreen, but the leaves are almost plum-leaf shape with teeth along the margin.

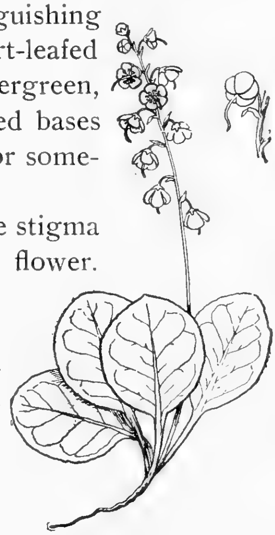


FIG. 168. Wintergreen plant in flower. After Atkinson.

Besides the forms already noted, there are two others that are but slightly different from the typical varieties. The round-leafed wintergreen sometimes produces leaves red-veined or red instead of shining green, and in this form it is known as the red-leafed wintergreen. The serrated wintergreen, which is usually from four to ten inches in height, with a number of flowers in a one-sided raceme, may exist as a low plant, less than four inches high, with from three to eight flowers and rounded leaves. It is then known as the low serrated wintergreen. The leaves of all the species are rather pleasant to the taste. The fruits they mature are five-grooved spherical capsules which split into five sections to release the small seeds.

The one-flowered wintergreen has the same evergreen leaves that characterize the ordinary varieties, but is peculiar for the production at the end of a slender axis of a single, rather large, drooping, white or pink flower, about six inches or less in height. The leaves are almost round, with short stems, and are gathered in tufts at the base of the flowering axis. This variety of wintergreen is limited to the northern portion of the state, where it occurs among the moss in deep balsam, spruce or tamarack woods.

Pipsissewas. The two kinds of wintergreen known as pipsissewas or spotted wintergreens, if they are found in fruit can be distinguished at once from the preceding forms. In the other wintergreens, when the capsules open, the clefts are woolly at their edges, but in the pipsissewas the clefts in the capsules are not at all woolly. The rarer variety of spotted wintergreen may also be known by its more willow-shaped leaves with remote notches in the margins and by the disposition of the white or pinkish flowers in cymes rather than in racemes. The leaves in this variety are spotted with white along the veins, but the commoner pipsissewa has bright, shining leaves without spots, considerably shorter and broader than those of the rarer kind. The flowers are clustered four or five in a group, in a somewhat flat-topped inflorescence at the tip of their axis. Both of these plants prefer drier woods and are sometimes abundant under the pines. They appear also in hardwood timber, but rather more sparingly.

Pine-drops. The pine-drops is a rare herb of the northern part of the state. It forms an upright, unbranched slender stem from six inches to three or four feet in length. This stem is of a reddish or brown color, with a few scaly leaves which are not green, since they make no starch. At the end of the stem are numerous, nodding, bell-shaped white flowers, each arising in the axil of a little scale. Each seed has a small thin wing on the end. The root area is unusually small.

Indian-pipes. The Indian-pipe, otherwise called the corpse-plant, is of very striking appearance. Several stems usually grow together in a tuft, and the whole plant-body is commonly of a snow-white color, with yellowish or reddish scales. At the tip of each stem is a single, nodding flower, around which the bracts are white. This variety is not uncommon throughout the state and is to be looked for in deep woods where a rich layer of decaying leaves has collected.

Pine-saps. The pine-sap, more abundant in the pine woods and extending south to Gull lake and Taylor's Falls, resembles the Indian-pipe or corpse-plant in almost all particulars, but it may at once be identified by its having several flowers clustered at the tip of each stem, instead of the single flower of the more common variety.

The three plants last mentioned are quite fungus-like in their habits of food-collection. Unlike most flowering plants, they do not produce leaf-green. They may be described as plants which have lost the power of making their own starch, and have learned, through the coöperation of root-fungi, to take their food in complex form from the decaying remains of other vegetation. Structurally they are not very different from the wintergreens, and so must be classed with them rather than with the fungi, which physiologically they resemble. Wintergreens are not the only kind of flowering plants that have given rise to such types of fungus-like forms. Among the orchids it will be remembered that the coralroots showed the same tendency to take their food "ready-made" rather than to manufacture it independently from carbonic-acid gas and water.

Labrador teas. An abundant variety of Minnesota heath growing in bogs, especially through the northern part of the state, is the Labrador tea. It is an evergreen shrub with leaves shaped very much like those of the willow, green upon the upper side and covered with a soft, rust-brown wool below. The margins of the leaves are somewhat curled over toward the under side. The flowers, borne in umbels, are white, and each matures a five-chambered, oblong dry capsule, that splits from the base into five segments. The plant abounds especially in spruce swamps and among tamaracks. It is scarcely absent from a single spruce swamp in the state. A form, known as the narrow-leafed Labrador tea, with much slenderer leaves than the common species, grows along the Pigeon river in

Cook county. From this plant, which is fragrant if crushed, the oil known as *Ledum oil* is manufactured.

Menziesias. The *Menziesia* is a small shrub, three or four feet in height, with obovate deciduous leaves and pretty, nodding umbels of bell-shaped, purplish flowers. The calyx and corolla are generally four-lobed and there are eight stamens, while the fruit is a spherical or ovoid capsule, splitting into four segments.

Kalmias. The laurel or *Kalmia*, occurs in cold peat-bogs as far south as Gull lake. It is a little shrub, usually not more

FIG. 169. Kalmia flowers. After Atkinson.

than eighteen inches high, with opposite, linear, evergreen, pale green leaves. The flowers, borne in terminal umbels, are purple and broadly bowl-shaped, with five marginal notches and ten stamens. The shape of the flower will serve to distinguish this plant from the rosemary, which somewhat resembles it. On the under side the leaves are white.

Moss-plants. The *Cassiope* or "moss-plant," is found along the palisades north of Duluth, extending, doubtless, to Grand Portage. It looks like a moss, being densely tufted, evergreen, and only from one to three inches in height. The leaves are very small and crowded, and the flowers are borne singly at the ends of leafless pedicels arising from the tips of branches or from the axils of the leaves. The flowers are white and nodding, and each matures a spherical capsule with a large number of small seeds. No other plant in Minnesota resembles, in general habit, this tiny shrub.

Rosemarys. The rosemary, found in cold peat-bogs throughout the northern part of the state, is a shrub one or two feet in height, with few branches. The leaves are slender, willow-shaped, darker above than those of the *Kalmia*, but with the same white under sides and incurved margins. The flowers, however, are nodding and vase-shaped, rather than erect, spreading and bowl-shaped, as in the *Kalmia*. The capsule is more nearly spherical than that of the *Kalmia*.

Trailing arbutus. The trailing arbutus is a rare plant in Minnesota, occurring, however, near Duluth and on the Kettle river and in the valley of the St. Croix. It is a prostrate, trailing, branching shrub, with alternate, oblong, leathery, evergreen, entire leaves. The blossoms are pink, borne in clusters toward the ends of the branches. They are sweet-scented and mature into spherical, furry, five-chambered capsules.

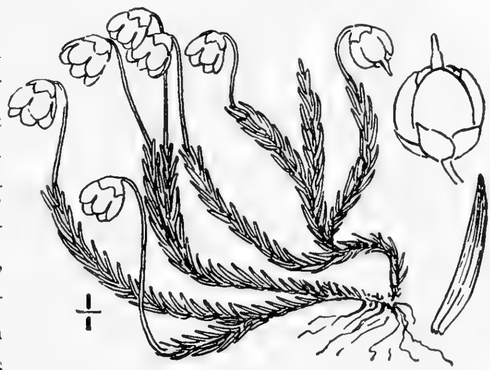


FIG. 170. Moss-plant. After Britton and Brown.

Checkerberries. The checkerberry, an abundant plant in the pine woods throughout the northern part of the state—rarely extending, also, as far south as Lake Pepin—is a little shrub with slender, prostrate or underground stems, from which erect branches arise to a height of from two to six inches. Its leaves are oval, slightly toothed, evergreen and shining, dark above and paler beneath. The flowers nod in the axils of the leaves and are white, broadly vase-shaped, and with five marginal teeth. The fruit is bright red and of a distinctive agreeable flavor. This plant is also known in Minnesota as wintergreen and partridgeberry.

Bearberries. The bearberry, growing best on sandy soil, is abundant through the northern part of the state and extends south very sparingly to Winona county. It is a little trailing shrub, with leathery entire, evergreen, spoon-shaped leaves and a few small, white, vase-shaped flowers in terminal racemes. The berries are red and rather tasteless.

Leatherleafs. The leatherleaf occurs in cold bogs from the north shore of Lake Superior to Lake of the Woods, and south into the valley of the St. Croix. It is a branching shrub, usually about two feet in height. The leaves are evergreen, oblong, ovate in shape, and when young provided with scurfy hairs or scales on both sides. The flowers are produced in large numbers towards the ends of the branches. Each flower nods in the axil of a leaf, is white and urn-shaped and produces a spherical, deeply five-grooved fruit.

Blueberries and cranberries. The blueberries and cranberries, of which there are about eleven varieties in the state, include some well-known forms. Here are to be classified the bog huckleberry, the dwarf bilberry, the thin-leafed bilberry, the tall bilberry, the tall blueberry, the Canada blueberry, the low blueberry, the mountain cranberry or cowberry, the deerberry, the small and the large cranberry. Most of these are found only in the northern part the state, especially along the international boundary and the north side of Lake Superior, extending, as so many northern plants do, down the valley of the St. Croix, through which in early days Lake Superior drained into the Mississippi river.

Blueberries. The different kinds of blueberries or bilberries are to be discriminated by their foliage and by the flavor of the berries. The one most common is the dwarf or low blueberry, gathered in large quantities for the market. Its fruits are blue with a whitish bloom and are of very pleasant flavor, enjoyed alike by the Indians and the whites. The plant is a low shrub, with pale green leaves, not evergreen. Its flowers are vase-shaped, small, and white or pink.

The deerberry, which resembles the blueberry in some respects, is considerably larger—three or four feet in height. The berries, shaped like the blueberries, are greenish or yellow and not edible. This variety is also called the squaw huckleberry.

The Canada blueberry, found growing in much moister soil than the ordinary form, has smaller berries, of a blue color, with a bloom. It may be distinguished by the entire margins of the leaves, quite different from the notched margins of the low blueberry. The bog blueberry has pink flowers and small ovate leaves. The cowberry may be recognized by the sour red berries and the evergreen leaves. The flowers and fruits are in structure altogether similar to those of the blueberries.

Cranberries. The two kinds of cranberries found in the state are both bog plants, with very slender creeping stems, having small thick evergreen leaves apparently disposed in two rows along the branches. In the small cranberry the berry is almost spherical, while in the large cranberry an oblong or ovoid berry is produced. In the flowers the corolla lobes are turned backward toward the stem. By this character the cranberries can be distinguished from the cowberry, which has a bell-shaped flower. Both species of cranberry are red or spotted, and acid to the taste.

Fig. 171. Small cranberry. After Britton and Brown.

Snowberries. The snowberry has a plant-body which reminds one of that of the cranberries, but the flowers are ovoid vase-shaped, and the fruit is of a pure white color. Like the cranberries, they are found in cold peat-bogs and in tamarack swamps. This plant is particularly abundant in the region about Duluth.

Huckleberries. One variety of huckleberry is found between the Kettle river, Cass lake, and the international boundary. The plant-body reminds one of the blueberry, but the fruits are black, without a bloom, sweet to the taste and clustered in erect or nodding racemes.

Primroses. The twenty-eighth order comprises three families of plants, of which only one, the primrose family, is represented in the state. Of primroses there are fourteen or fifteen

Minnesota species, including two varieties of primrose, one *Androsace*, one water-pimpernel, two loosestrifes, the curious little sea-milkwort, the poor man's weather-glass, and the chaffweeds. Besides, there is a plant known as the starflower and another as the shooting-star, both to be classed in this family. The true primroses are found only along the north shore of Lake Superior. They are small plants, with a tuft of rather long, willow-shaped leaves, from the centre of which a stem arises, bearing at the tip a little umbel of pink flowers.

The *Androsace* is a tiny plant, often not more than an inch in height. It is of about the same size as the little whitlow-grass of the mustard family. The leaves are produced in rosettes. From these slender flowering axes arise, usually more than one, and at the end of each of them is an umbel of small white flowers. This plant may be distinguished from the whitlow-grass by its umbels in place of racemes. It is more common on prairies in the western part of the state.

The water-pimpernel grows near springs and in the edges of brooks. It is from six to eighteen inches in height, somewhat branched, with membranous oval leaves. The flowers are tiny and bell-shaped, produced numerously in loose racemes. The calyx is blended with the base of the fruit-rudiment and the seeds are very small. The loosestrifes and the false loosestrifes grow for the most part in wet places or in fields, and may be recognized by their bright yellow, primrose-like flowers. In some of the varieties the leaves are in whorls, while in others they are opposite. The flowers in some sorts are solitary in the axils of the leaves, but in others they are in terminal racemes or flat-topped clusters. In one kind, the tufted loosestrife, a swamp plant abundant throughout the state, the yellow flowers are grouped in dense racemes which stand in the axils of the opposite, willow-shaped leaves.

The starflower grows in deep woods along with the dwarf cornel and the wintergreens. It is a little plant with prostrate rootstock from which a slender stem rises to a height of about six inches or less. Two or three white star-shaped flowers are produced from the tip of this stem and directly under them are from five to ten willow-shaped, slender leaves, all standing in a circle.

The sea-milkwort is found in some saline marshes in the Red river valley. It is a small, branched herb, with opposite, fleshy leaves, in the axils of which small, stemless, pink or white flowers are produced. Each flower is broadly bell-shaped.

The poor man's weather-glass or scarlet pimpernel is introduced from Europe, in some waste fields. It has the opposite leaves and open tubular flowers of its family, but the color of the flowers, which are produced singly on the stems in the axils of the leaves, is scarlet or pink with a darker centre. They open only in the sunshine, hence the common name.

The chaffweed, to be met with at the Pipestone quarry in Pipestone county and probably elsewhere on rocks in the Minnesota valley, selects moist depressions and grows as a little branched, insignificant herb with small, alternate entire leaves, in the axils of which little pink, stemless flowers are produced. The capsule, when it matures, splits by a circular cleft, cutting off its upper portion as a lid, recalling the purslanes.

The shooting-star may be recognized at once among all the other flowering plants of the state by the curious position which the petals take in the open flowers. The young flowers are erect, but as they grow older the flower is inverted. When they open the petals turn completely back, so that while the stamens point downward, the petals, which are of a purple or whitish color, have their tips directed upward. When this plant begins to set its fruits, the stems of the flowers straighten again, so that the tips of the young capsules point upward. The petals of the open flower are often twisted, giving to the plant a peculiar and characteristic appearance.

Chapter XXXVI.

From Ash trees to Verbenas.

The twenty-ninth order includes four families, none of which is native to Minnesota. Here are grouped the persimmon trees of the south, the benzoin gum trees, the gutta-perchas and the butter seeds, and the ebony tree, the hard black wood of which is capable of taking a high polish and is much prized.

The thirtieth order includes the ashes, the gentians, the dog-banes and the milkweeds, all represented in the Minnesota flora. There are also two other families without Minnesota representatives, in one of which is classified the strychnine plant.

The ash family, besides the common ash trees, comprises also the lilac bushes, the olive trees and the jasmines. Lilac bushes, with their handsome panicles of fragrant tubular flowers, are well known as dooryard shrubs throughout the state. They are not, however, natives of North America.

Of ashes there are five species in Minnesota, namely, the white, the red, the green, the blue and the black. Ash trees, botanically considered, are noteworthy as being the highest type of trees native to the state. In all of them the leaves are compound, consisting of several leaflets arranged pinnately upon a common axis. The fruit in all the varieties has a strong terminal wing, by means of which it is distributed in air currents. The different kinds of ashes may be known by the foliage, the character of the wing on the fruit, and the appearance of the young twigs.

White ashes. The white ash is a tree, reaching under favorable conditions a height of 120 feet, but not growing so strongly in Minnesota. The bark is dark brown and the wood is heavy, firm and tough, universally employed in the manufacture of tool handles and agricultural machinery. The leaves are composed usually of seven leaflets, somewhat broadly willow-shaped, dark green above and light green and often hairy below. The body of the fruit is cylindrical and the wing is terminal, not at all or but very slightly extended down the sides.

Green ashes. The green ash is a smaller tree than the white ash, and its wood is somewhat inferior in quality, though strong. The leaflets are similar to those of the white ash, but rather broader. The fruit is commonly winged down the sides. The twigs and the flower stems are smooth or only very slightly hairy.

Red ashes. The red ash is a tree of about the same height as the green ash, not exceeding thirty or forty feet in Minnesota. The twigs and flower stalks are covered with velvety hairs and the fruit is generally winged down the sides.

Blue ashes. The blue ash may be recognized by the four-sided young twigs, the smooth foliage and the leaflets—numbering from seven to eleven,—slender and of a more willow-shaped outline than in the preceding varieties. The fruit is broader, shorter and heavier in appearance than that of the white ash, and is winged down the sides.

Black ashes. The black or elder-leafed ash, unlike the others, is a swamp tree, occasionally growing also in low, wet woods along streams. There are from seven to eleven leaflets in each leaf, but the twigs are cylindrical, not four angled. Both the blue and the black ash are large trees, sometimes reaching a height of a hundred feet or more. The bark in both varieties is of a gray color. The wood of the black ash is heavy but not very strong, and the tree is noticeable for the stemless character of the lateral leaflets, in which respect it differs from all the other ashes. This tree is often affected by an insect which produces large "witches-brooms" or galls.

Ash flowers are rarely perfect. Usually they are separated, the staminate flowers blooming on one tree and the pistillate on another, though in other instances both separated and perfect flowers are found on the same tree. The calyx is small, or it may be altogether wanting. The corolla, too, is sometimes lacking. There are usually two stamens inserted below the fruit-rudiment, or on the base of the petals when they are present, and the stigma is two-cleft, so that the fruit-rudiment has two chambers, in each of which a couple of seed-rudiments are produced. Only one of the seed-rudiments ripens, so that when the fruit is mature it ordinarily contains but a single seed, supplied with albumen, and inclosing the straight embryo plantlet. The flowers are borne in panicled clusters and are of a greenish color. All five varieties, except the blue ash, are pretty common in Minnesota. The white ash and the green ash are the most abundant. The red ash abounds particularly down the upper Mississippi to the White Earth reservation, and on the Rainy river. The blue ash is found only in the far northern portions of the state along the international boundary and near the sources of the Mississippi.

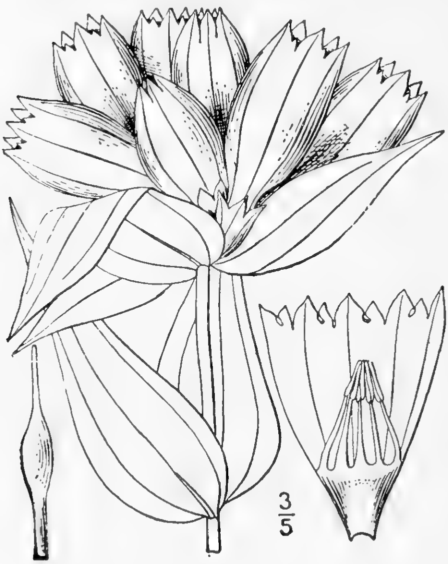


FIG. 172. Yellow gentian. After Britton and Brown.

Gentians. The gentian family includes in Minnesota about ten species of gentian, one spurred gentian, one buck-bean and one floating-heart. The two plants last named are either aquatic or denizens of wet bogs, but the others are terrestrial. The gentians proper are noted for their beautiful blue flowers, blooming late in the year. Two of the ten varieties are known as fringed gentians, because the edges of the lobes of the corolla tubes are frayed out into a blue fringe. The larger fringed gentian has opposite, stemless, broad-based leaves. The smaller fringed gentian has leaves slender at the base and narrower, of willow-shaped or linear outline. The other gentians are not fringed. In some the flowers open into little blue bells, but in one, known as the closed gentian, the corolla does not open at all, or only by a small pore. Of those that open, the northern gentian may be recognized by the row of ragged threads which arise just below and inside the notches of the corolla tube. The leaves are opposite and lance-shaped. The stiff gentian and the oblong-leafed gentian are very similar, but have not the shredded filaments in a circle within the lobes of the corolla. The oblong-leafed gentian has between each of the five notches of the corolla tube a little ragged, toothed appendage. The plant-body is smooth. The downy gentian is quite similar to the oblong-leafed, but may be known by its solitary stems, while those of the oblong-leafed gentian are clustered. In all the sorts that have been mentioned the stamens are distinct and spreading. In the remaining varieties the stamens bend together and cohere by their tips into a ring around the fruit-rudiment. The soapwort gentian is a form with the flowers of the closed gentian and opening but slightly at the tip. The leaves are opposite, but in the closed gentian they are in whorls around the clustered flowers. The yellow gentian produces its bell-shaped flowers at the ends of stems or in the axils of upper leaves, quite after the mode of the closed gentian, but they are of a greenish or yellowish white instead of blue. The narrow-leafed gentian somewhat resembles the downy variety, but may be distinguished by the coherence of the stamens in a tube. The leaves are slender and willow-shaped. The red-stemmed gentian is like this, with broad-based, lance-shaped leaves.

Many of the gentians are found in bogs or in moist meadows. In the autumn of the year, together with *Parnassias*, they form extensive beds in the low wet meadows along river valleys. The spurred gentian has a spur at the base of each of the corolla lobes, making the flower somewhat of the shape of a columbine. They are rather smaller, however, and of a purplish or white color. This plant is found along the north shore of Lake Superior and throughout the northern part of the state to Lake of the Woods.

Buck-beans. The buck-bean is a pretty common plant on floating bogs and among the reed-grasses along the shores of lakes. From a thick, scaly rootstock stems arise, bearing leaves in shape somewhat like large clover leaves and of a pale green color. The flowers are borne in panicles and are white or purple, decidedly attractive in appearance. This plant is frequent in the Chisago lakes and generally throughout the state. In the northern lakes it becomes very abundant and is often found growing luxuriantly in great beds almost to the exclusion of other vegetation.

Floating-hearts. The floating-heart is an odd little water plant with a rootstock that creeps in the mud at the bottom of ponds. There are two sorts of leaves. Those which are submerged are grass-like and clustered around the base of the stems, which are thread-like and sometimes ten feet in length. At the surface of the water there is borne a single broadly heart-shaped floating leaf, a little umbel of yellow flowers, and a cluster of curious tubers. No other plant in the Minnesota flora is anything like the floating-heart in appearance. The grouping of a bunch of tubers, an umbel of yellow flowers, and a single, broad heart-shaped floating leaf at the end of a slender stem arising from the bottom of a pond will serve at once to designate it.

Dogbanes. Three species of dogbanes exist in the state. One of them is known as Indian hemp. All of them have a milky juice, so that they are often mistaken for milkweeds. They may be recognized, however, by their flowers, which are somewhat bell-shaped and do not have the five singular, horn-like appendages of the petals distinctive of most milkweed-flowers, and connected with the remarkable pollination-contrivance of that family of plants. One of the dogbanes—more abundant in the northern part of the state—has a spreading, generally forked stem, with opposite broad leaves, and, in loose terminal cymes, white flowers which mature slender cylindrical pods. In these are enclosed a large number of seeds with tufted flying-hairs at their ends. The Indian hemp sends up erect branches, but not broadly forked at the summit like those of the spreading dogbanes. The flowers are produced in rather thick clusters at the apex, or arise from the axils of the leaves. Still another variety of dogbane, with clasping leaves, occurs in the southern part of the state.

Milkweeds. The milkweeds form a family of plants with pods and seeds like those of the dogbanes, but with most extraordinary flowers, gathered in most instances in umbels, and fitted for pollination by insects. These are captured by the flowers, as if in a trap, after which pollen masses shaped like the old-fashioned saddle-bags are attached to their legs. In Minnesota there are a dozen species of ordinary milkweeds and five green milkweeds.

Each milkweed flower consists of a five-parted calyx, usually small. Within, there appear the five corolla lobes, turned back around the pedicel of the flower when it opens. Next are five curious hood-shaped appendages of the corolla, known as the *corona*. Inside of each hood is a horn-shaped process, while the stamens fuse together into a tube around the central fruit-rudiment. When an insect visits the flower in search of honey, it catches its legs in grooves between the hoods of the corona, and in attempting to escape must drag its feet over a part of the stamen where a viscid forked body is located, and this with a couple of pollen-masses attached to it is pulled out of the flower. By means of a bit of silk thread any one can, with proper care, extract the little saddle-bag, thus imitating the work which the flower exacts from its insect visitor. Often bees are not strong enough to jerk their legs free from the cleft in which they are caught, and they may sometimes be seen hanging head-downward from the milkweed flower, despondent or dead.

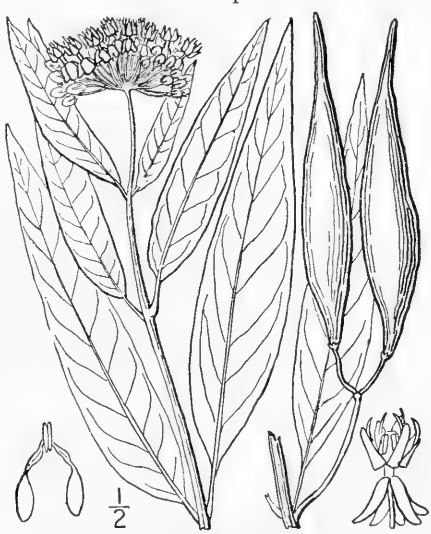


FIG. 173. Swamp milkweed. After Britton and Brown.

The different sorts of milkweeds in Minnesota may be identified by the shapes of their leaves, the colors of their flowers and the surfaces of their pods. One milkweed, common on prairies, has bright orange flowers, and this sort is known as the butterfly-weed. Its leaves are alternate and hairy and the pods stand erect and are covered with fine hairs. Another group of milkweeds has the flowers purple and the leaves opposite. Here are classified the purple milkweeds, with stout, smooth stems two feet or more in height and leaves of an elongated, pointed oval shape. They are found in dry fields. The swamp milkweed is similar in appearance, but has smaller clusters of flowers and slenderer willow-shaped leaves, usually quite smooth. It is to be looked for in swamps or marshes. The hairy milkweed is similar to the swamp milkweed and is found in similar stations, but has very hairy leaves. In all varieties the umbels of flowers are crowded toward the top of the plant and are erect, as are the pods.

Sullivant's milkweed and the blunt-leafed milkweed are smooth, pale green plants with stout stems and rather broad, blunt leaves. The capsules in Sullivant's milkweed are borne on straight erect stems, but in the blunt-leafed milkweed the downy, slender capsules stand on stems curved downward like the letter "S." The tall milkweed, or poke milkweed, has lance-shaped leaves and the capsules stand erect upon pedicels which grow diagonally downward. The four-leaved milkweed is recognized by the leaves toward the middle of the stem, standing in whorls of four.

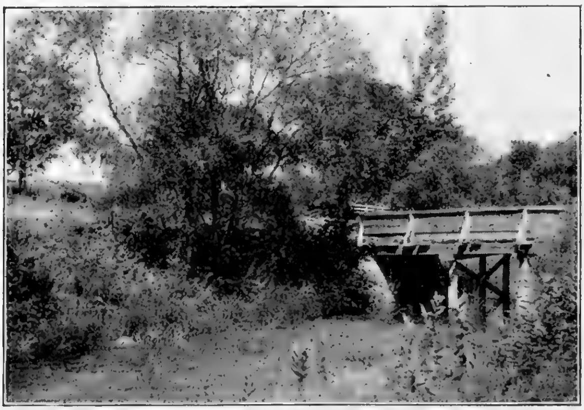


FIG. 174. Brookside vegetation. Milkweeds in foreground. After photograph by Williams.

Two milkweeds, known as the common milkweed and the showy milkweed, are distinguished by the pods, the surfaces of which are covered with short, soft, somewhat elongated tufts or warts. The common milkweed has oblong leaves, while the showy milkweed, named on account of the large purplish-green flowers, has broad, ovate leaves. Both these are very prolific in fields along roadsides and in damp places throughout the state. The oval-leafed milkweed is a plant of the southern and western prairies. It is recognized by its smaller, greenish flowers arranged in few or in solitary umbels toward the tip of the stem. The leaves are rather broadly willow-shaped and cottony on both surfaces. When quite mature the upper surfaces of the leaves become smooth. The whorled milkweed has very narrow leaves in whorls of from three to seven. The pods are slender, two or three inches long, and smooth.

The green milkweeds may be distinguished by this character: The hoods of the corona do not inclose spur-like projections. Otherwise the flowers, flower-clusters and pods are very much like those of the true milkweeds. Here are classified the broad-leafed green milkweeds, with lance-shaped or broad willow-shaped leaves; the Florida milkweed, with slender, willow-shaped leaves, difficult to distinguish from the two varieties of the broad-leafed form—in one of which the leaves are really grass-shaped, while in the other they are lance-shaped. The broad-leafed milkweed and its varieties have, however, sessile umbels of flowers, while the Florida milkweed displays each umbel on a stem of its own. Besides the varieties of green milkweed which have been mentioned, there is another known as the woolly green milkweed. It is characterized by a solitary terminal umbel and woolly or hairy leaves, and is found on prairies.

The thirty-first order includes a number of families, most of which are represented in Minnesota. Here are the morning-glory family, to which the morning-glories, sweet potatoes and dodders belong; the phloxes; the waterleafs; the borages; the verbenas; the mints; the nightshades, including the ground-cherries, capsicums, potatoes, tomatoes, tobaccos and petunias; the figworts, with the snapdragons, mulleins, hyssops and fox-gloves; the bignonias, with the catalpa trees; the broom-rapes, a curious group of parasitic plants; the *Gesneras*, to which the *Gloxinias* belong; the bladderworts; the *Acanthuses;* and the lopseeds. Several families, including some of those mentioned, have no species native to Minnesota. The following, however, present Minnesota forms: The morning-glories, phloxes, water-leafs, borages, verbenas, mints, nightshades, figworts, broom-rapes, bladderworts and lopseeds.

Morning-glories. The morning-glory family is represented in Minnesota by three species of morning-glory or bindweeds and five species of dodder. The morning-glories are recognized at once by their familiar funnel-shaped flowers. In two of the varieties the stem is twining or trailing, while in the erect morning-glory it stands independently and does not twine, except sometimes very slightly at the tip. One of the climbing morning-glories has arrow-head-shaped leaves and pink flowers about two inches long. The other variety has ovate, blunt-pointed leaves, often very large and somewhat heart-shaped at the base. The form with the arrow-head-shaped leaves is much more common and is found trailing over shrubbery in thickets or in the edges of woods.

Dodders. Dodders are very curious parasitic plants, closely related to the morning-glories. They may be considered as twining morning-glories which have acquired the habit of sucking up their food from the bodies of the plants upon which they climb. As a consequence of this habit their leaves have been reduced to tiny scales, being no more employed in starch-making, and their stems, no longer green, have become yellow or white in color. Dodder often produces great intricate tangles of threads, like so much yellow yarn, looping over the herbs or shrubs from the tissues of which they extract their nutriment. Another variety of dodder that grows on the stems of sunflowers, goldenrods and asters, looks like three or four turns of rope around the axis of the host plant. The relationship of the dodders to the morning-glories may be seen in their capsules and seeds which strongly bring to mind the well-known pods of the ordinary cultivated morning-glory. In Minnesota the following varieties of dodder may be distinguished: The field dodder, with sepals of the calyx

Fig. 175. Dodder in flower; the parasite is seen to be clutching tightly the stem of its host plant. After Atkinson.

united into a tube, sessile flowers, fringed corolla scales and obtuse calyx lobes, the stems pale yellow and thread-like, with the flowers in little clusters; the smartweed dodder, most abundant on smartweeds, similar to the field dodder, but with the thread-like stems of an orange-yellow color and the calyx lobes acute; Choisy's dodder, developing stemmed flowers with distinct corollas, the lobes of which are curved in over the capsule; the hazel dodder, growing mostly upon hazel bushes, with capsules capped by the shriveling corolla; the button-bush dodder, with corolla lobes spreading, not curved over the capsules, and the capsule flattened and globular in form; and Gronovius' dodder, found, like the button-bush dodder, on a variety of herbs and shrubs, but with pointed capsules. In all these dodders the flowers are in rather loose clusters, when compared with the remaining variety, known as the massive dodder. In this species, occurring mostly on goldenrods, asters, sunflowers and other herbs of the composite family, the flowers are borne in very large numbers and very close together, quite concealing the stem. The little dodder flower-clusters, therefore, give the appearance of a coil of rope, turned three or four times around the axis of the host-plant.

The stems of all the dodders have sucking organs which are driven through the skins of their host-plants and expose their surfaces in the soft tissues. Through them the juices of the host-plant are absorbed for the benefit of the dodder. This kind of parasitism is derived from the habit of twining originated by those prototypes of the dodders, the morning-glories. It is interesting to notice just how the parasitic habit probably arose in this instance, because, in others, parasitism began in quite different ways.

Phloxes. The phlox family includes the Greek valerians, phloxes, *Gilias* and *Collomias.* In all the Minnesota varieties the flowers are tubular, with the lobes of the corolla spreading. The fruit-rudiments are three-chambered, maturing into three-chambered capsules. Four sorts of phlox occur in Minnesota: The wild sweet-william, the downy, the blue, and the smooth phlox. They are distinguished by the shapes and textures of their leaves and by the colors of the flowers.

In the blue phlox the flowers are blue and each petal lobe is notched at the end. The other phloxes have pink, white or purple flowers. Of them, the downy phlox is soft, velvety, hairy or downy to the touch. The smooth phlox is quite smooth with pink flowers and the lobes of the corolla are longer than the tube. The wild sweet-william, or common phlox, looks like the smooth phlox, but has flowers in which the lobes of the corolla are considerably shorter than the tube. In all the phloxes the leaves are simple, not lobed. The *Polemonium* has the flowers of a phlox, blue in color; but the leaves are pinnately compound like those of the ash. It is an herb about a foot high, with weak ascending stem arising from a short rootstock. The *Collomia* has flowers of the phlox type, aggregated in clusters at the tips of the stem. They are purplish or white, but the leaves are alternate, not opposite as in the phloxes. The little *Gilia* of the western edge of the state, where it is found on high prairies near Lake Benton, is a tufted plant with flowers in dense heads, each provided with a calyx, the lobes of which are awl-shaped and come up around the corolla like five stiff bristles. The leaves are small, pinnate and spiny.

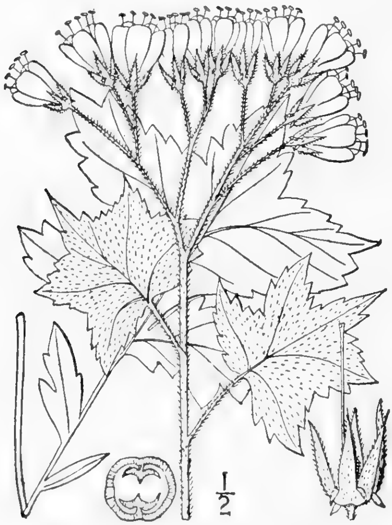


FIG. 176. Virginia water-leaf. After Britton and Brown.

Waterleafs. The waterleaf family includes two waterleafs, one *Ellisia* and two *Phacelias*. The waterleafs are herbs with large, pinnately cleft leaves and violet or purplish flowers developed in umbels or cymes. They are exceedingly abundant on the level, damp floors of woods along streams through the southern part of the state. The Virginia waterleaf has the stamens a good deal longer than the corolla and the stamen-stalks are hairy. The other waterleaf, called the appendaged waterleaf, has stamens but very little longer than the corolla. Another way of distinguishing the two varieties is by the calyx which in both is five-notched, but in the appendaged waterleaf a little scale grows out of each of the calyx notches, while this scale is absent in the Virginia waterleaf.

The *Ellisia* is an herb, four inches or so in height, with leaves a couple of inches long, deeply pinnately-lobed, shaped somewhat like those of the shepherd's-purse. The flowers are borne singly on their stems, and are white and bell-shaped. In fruit the calyx enlarges and looks like a small paper star, in the middle of which the globular capsule is attached. The two *Phacelias*, both very rare plants in Minnesota, have leaves somewhat like those of the *Ellisia*, but with purple or blue flowers in clusters. One sort has them in terminal racemes, on both sides of which the flowers are borne. In the other kind the flowers are all grouped on one side of the raceme.

Borages. The borage family includes the comfreys, false gromwells, puccoons, lungworts, forget-me-nots, stickseeds, hound's-tongues and mudworts. Several of the varieties are introduced from Europe. There are, in all, about twenty-five varieties growing wild within the limits of the state. Borage flowers, in outward appearance, are a good deal like those of the phlox, though often very much smaller. The stamens are borne upon the tube of the corolla and the fruit-rudiment, made up of two carpels, is deeply grooved, so that when the fruit matures it has the appearance of four one-seeded nutlets standing close together within the calyx. The leaves are generally alternate. The stems are rarely square, but in almost every instance cylindrical. The whole plant-body is commonly hairy, sometimes very much so. Plants with the sort of tubular, flaring-topped flowers, found in the sweet-william, and accustomed to ripen four little hard nutlets from each flower, may pretty safely be put down as borages, unless their stems are square, in which instance they should be looked for in the mint family.

Hound's-tongues. The hound's-tongue is a weed of waste places and woods, with stems from one to three feet in height. The flowers are blue or reddish-purple and occur in somewhat flat-topped clusters. Another sort of hound's-tongue, with much slenderer, almost willow-shaped leaves, is an immigrant from Europe. Its flowers are arranged, in most instances, in one-sided racemes, and these clusters show a tendency to bend over like a shepherd's crook.

Stickseeds. The stickseeds are very abundant plants in the Minnesota woods. Four or five varieties exist, distinguished by the shapes of their leaves and the character of the flower-clusters. In all of them the four nutlets, which constitute each fruit, separate from each other, and on their backs carry a number of barbed hairs, or thorns, by which they attach themselves to the fur of animals, or to the clothing of man, thus obtaining distribution. Among the various little fruits and seeds which anchor themselves to one's clothing, in the woods, those of the stickseeds may always be known because they are shaped something like the quarter of an apple and come in groups of four. The tip of each of the thorns along the backs of these nutlets is barbed just like a harpoon, so that when the burs affix themselves to clothing it is difficult to remove them. Of the Minnesota varieties, two are very rare and are known to occur only in the extreme northwestern corner of the state. The others, however, are abundant throughout all portions.

Lungworts. The lungworts are also called bluebells, but they are not to be confused with the Canterbury-bells, which belong to quite a different family. They are erect, smooth or downy herbs and have blue, bell-shaped flowers with somewhat narrowed tubes. The flowers are borne in large terminal, hemispherical clusters, sometimes flattened out and loose in appearance. The tall lungwort possesses rough leaves, while the Virginia lungwort has its foliage quite smooth.

Forget-me-nots. Two sorts of forget-me-nots occur in the state. They are little, low, rough-leaved plants, in one variety with small blue flowers, and in the other with white. They are annual or biennial and produce tufts of leaves near the base, from which the leafy flowering stem arises. The flowers are borne in one or two-sided racemes, often bent over like a shepherd's crook.

Puccoons. The puccoons are known by their yellow flowers, varying towards orange or white. One of the commonest early spring flowers—the hoary puccoon—is classified here. In this plant, at the end of the stem, six inches or more in height, a little cluster of orange yellow flowers is developed. When it fruits, four white, hard, smooth and shining nutlets are produced, protected by the five-lobed, green and hairy calyx. The yellow puccoon, a form that is abundant on prairies, has trumpet-shaped flowers of a lemon or bright yellow color. Its leaves are slenderer than those of the hoary puccoon and have not the same white-hairy appearance, though they are rough to the touch. This plant, later in the season, produces much smaller, pale yellow, *closed* flowers, which, after pollination by their own pollen, mature fruits. The broad-leafed puccoon has ovate or ovate-lanceolate leaves and may be thus distinguished. Its flowers are yellowish-white or yellow. The European puccoon has yellowish-white flowers scattered along the ends of its branches, but it matures the same white hard nutlets that characterize its American relatives.

FIG. 177. Blue verbena. After Britton and Brown.

False gromwells. The two species of false gromwell may be known by their extraordinarily rough and hairy foliage, strong-veined leaves and inconspicuous white or greenish flowers, produced in leafy one-sided racemes. There are four nutlets begun in the flowers of the false gromwell, but only one of them is likely to mature, so that if ripened fruiting specimens alone were at hand, it would be difficult, at first sight, to include these plants in the borage family. The nutlets are white and hard, like those of the puccoons.

Bonesets. The comfrey or boneset has purple or yellow flowers, brown nutlets, lance-shaped leaves, hairy foliage and thick roots.

Verbenas. The verbena family includes, in Minnesota, six varieties of wild verbena and one variety of fogfruit, or *Lippia*. These are all herbs, with, ordinarily, opposite leaves and flowers very much like those of the borages, but collected in spikes or heads, and not in one-sided racemes. The fogfruits have two-lipped flowers, and it is doubtful whether any of them actually occur in Minnesota. The fruits of the verbenas, when mature, separate into four nutlets, just as do the fruits of the borages. If there is any question whether a plant is a verbena or a borage it may generally be decided by opening the corolla tube and counting the stamens adherent to its inner surface. If there are four, the plant is a verbena; if there are five, it is a borage. Of course there are a great many other kinds of plants with four stamens, but the combination of four stamens on the corolla tube, flowers in racemes, spikes or heads, and fruits consisting of four nutlets, pretty distinctly indicates a verbena.

The six verbenas of Minnesota may be distinguished as follows: One of them is a mat plant, growing in waste fields along roadsides and on prairies. The whole plant-body is prostrate and often spreads out over a circle a yard in diameter. The flowers are purplish-blue and borne in spikes. The leaves are of various shapes, but some of them, at least, are likely to be cut, from the margin toward the midrib, by deep notches. The hoary verbena is recognized by the soft, hairy leaves, of an ovate form, almost stemless, with the edges sharply notched. The blue flowers stand in dense leafy spikes. No other verbena has this soft hairy leaf-surface. The nettle-leafed verbena and the wild blue verbena also have ovate or oblong leaves, but in these varieties each leaf has a distinct stem. The nettle-leafed verbena has usually white flowers or pale blue, while the blue verbena, as its name indicates, produces bright blue flowers. The other two verbenas have different foliage from the erect forms that have been mentioned. The narrow-leafed verbena has very slender, or at most, willow-shaped leaves with blue flowers in slender, dense spikes. The European verbena, with an erect habit, has, at least on the lower part of its stem, leaves deeply toothed to the midrib, like those of the prostrate verbena. The flowers are purple or white, produced in numerous, very slender spikes, three to six inches in length.

Chapter XXXVII.

From Peppermints to Plantains.

The mint family in Minnesota includes about forty species, among which are the pennyroyals, mints, peppermints, bugleweeds, basils, calamints, horsemints or bergamots, *Blephilias*, catnips, anise plants, hyssops, dragon's-heads, skull-caps, hedge-nettles and dead-nettles.

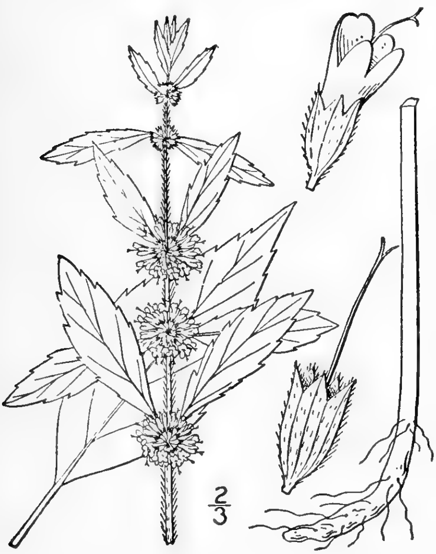


FIG. 178. Wild mint. After Britton and Brown.

Mints may be recognized by characters as follows: Their stems are almost always four-sided with opposite leaves and aromatic foliage. The flowers are usually strongly two-lipped, though in some Minnesota varieties they are nearly regular. The stamens, borne on the inner surface of the corolla tube, are generally four in number, two of them longer than the other two; but sometimes the short ones become reduced to thread-like appendages. The fruit, as in borages and verbenas, consists of four one-seeded nutlets. It is almost always possible to identify a mint by rubbing a little of the foliage between the fingers and noticing the fragrant odor, like that of catnip or peppermint. The presence of the scent, even if the flowers are regular instead of two-lipped, will serve to indicate the mint, especially if its stem is four-sided.

Wood-sages. Among the mints some varieties may be identified by characters not too minute. The wood-sages and false pennyroyals have the fruit-rudiment lobed into four sections, but not fairly divided into four nutlets as in the rest of the mints. The wood-sage is a slender herb from one to two feet tall, and is to be looked for in thickets through the southern part of the state and in the Red river valley. The flowers are distinctly two-lipped. The false pennyroyal is of similar habit, six inches or more in height. The flowers are small, blue, almost regular, and disposed in flat-topped clusters arising from the axils of the leaves.

Skullcaps. Of those mints which separate their fruit-rudiment into four nutlets, the skullcaps may be known by the curious little bulging protuberance upon the back of each flower. Skullcaps are, for the most part, small herbs, with leaves of various shapes, and strongly two-lipped flowers, generally of a blue color. Four kinds occur in Minnesota.

Fig. 179. Clump of horse-mint (in middle of picture). After photograph by Williams.

The rest of the mints may be divided into two series. In one the corollas are two-lipped, and the upper lip is concave. Here are included the catnips, the dragon's-heads, the heal-alls, the false dragon's-heads, the hedge-nettles and hemp-nettles, in all of which there are four stamens with pollen pouches. The sages, horsemints and *Blephilias* have the same kind of corolla but only two of the stamens produce any pollen pouches. The other series of mints includes those forms in which the corolla tube is nearly regular, or, if two-lipped, has the upper lip flat or but very little concave. Here are to be grouped the pennyroyals, the basils, the hyssops, the mountain-mints, water-hoarhounds and peppermints, in all of which the flowers are clustered in small dense whorls in the axils of the leaves. Sometimes, when many of these whorls arise close together, near the end of the stem, they become confluent into a spike.

Horsemints and dragon's-heads. Of the various mints several are decidedly handsome plants. The horsemint, for example, with its heads of two-lipped flowers, is an abundant and beautiful herb of the woods. There are two sorts in Minnesota, one with a yellowish flower and the other with pinkish or purplish heads. The dragon's-heads, with their light blue flowers in close clusters and the false dragon's-heads with rose-colored flowers are interesting plants of the northern and central portions of the state. The water-mints, found in great abundance in springs and along the edges of brooks, present a variety of forms, many of which, except by minute characters, are difficult to distinguish from each other.

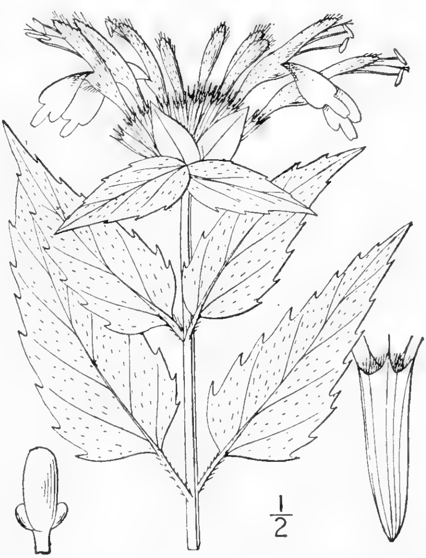


Fig. 180. Horse-mint. After Britton and Brown.

Some mint flowers are very interesting mechanisms for the utilization of insects in the work of pollination. In the sages, for example, the two stamens are hung on levers and rest under the arched upper lip of the flower. When a bee visits the flower it stands upon the lower lip and thrusts its bill down towards the base of the flower, as it does so, striking with its head the short arms of the levers. The two long arms bearing the pollen pouches are thus brought down on the back of the insect like hammers, leaving there a couple of patches of pollen spores, several hundred spores in each patch. After this mechanism of the flower has been set in motion by the visit of a bee, the slender stigma-stalk of the pistil drops down from the hood where it was resting and takes such a position that its end will be dragged across the back of a bee that subsequently visits the flower. In this way bees going from flower to flower commonly carry pollen from one plant to stigmas of another.

Mint extracts, as is well known, are of considerable excellence for a variety of purposes. They are used in perfumery and confectionery, and in some medical preparations. Many of them are gathered as household remedies.

Ground-cherries. The nightshade or tobacco family includes about fifteen Minnesota varieties, of which only eight are native. Here are the ground-cherries, plants known also as ground tomatoes, and recognized by the much inflated bladdery calyx, which incloses the little tomato-like berry. The name ground-cherry is given because, in the common species, the berry is about the size of an ordinary cherry. Several different kinds occur in Minnesota. The various sorts may be known by the presence or absence of underground stems, by the smoothness or hairiness of the leaves, and also by the shapes of the leaves, by the color and sizes of the flowers, and by the shape of the calyx in fruit. The most common species in Minnesota are the clammy, the leaves of which are clammy and viscid to the touch; the Virginia, with smooth leaves, sometimes more or less hairy; the prairie; the long-leafed, and the Philadelphia ground-cherry, all of which have underground rootstocks. Besides, there occur the low, and the cut-leafed, in the first of which the leaves are ovate and entire, while in the second the margins are strongly notched. In neither of these plants is there any underground rootstock and the plants are therefore annual, springing up each year from the seed.

Nightshades. Besides the ground-cherries there are three varieties of nightshade—herbs with flowers resembling those of the potato and arranged in cymes. The black or deadly nightshade is an annual, smooth, unpleasant-smelling herb, with entire or slightly notched ovate leaves, and black, spherical, smooth berries, without a bloom, hanging on nodding stems. The cut-leafed nightshade, which in its fruits resembles the ordinary variety, may be known by the pinnately-lobed leaves and the greenish-black or green colored fruits. The prickly nightshade, or potato-bug plant, is covered over with prickles both upon the leaves and upon the stem. Even the berry is very prickly. This plant, having been introduced from the west, is sometimes found along railway tracks, and it has the unenviable distinction of being the original food of the potato-bug. From it, a few decades ago, when potato cultivation began to be undertaken in Iowa and Nebraska, this destructive insect migrated to the fields. The climbing nightshade has stems from two to eight feet long. The leaves are heart-shaped, often with two leaflets at the base. The flowers are bluish in appearance and like those of the potato or tomato, while the berry is red and as large as the end of one's thumb.

Jimson-weeds. The jimson-weeds, which occur sparingly as introduced forms in the southern part of the state, are tall, unpleasant-smelling herbs, usually three or four feet high. The flowers are large, sometimes two inches broad, shaped rather like morning-glory flowers, but more deeply notched along the edge. The capsule, an inch in length, is prickly and bursts irregularly.

Wild tobacco. Wild tobacco is found in the vicinity of Indian reservations, having escaped from their fields. The flowers are petunia-like and the leaves are broadly ovate and smooth along the edge. A many-seeded capsule, splitting longitudinally into two halves, forms the fruit.

Figworts. Nearly fifty different varieties of figworts are known to occur in Minnesota. Here are classified the mulleins, the toad-flaxes, the turtle-heads, the monkeyflowers and snapdragons, the false pimpernel, speedwells, *Gerardias*, Indian pinks, cow-wheats, louseworts and yellow-rattles. Figworts may be distinguished from mints, for which they might be mistaken, by their generally cylindrical stems and their two-chambered, or rarely one-chambered capsular fruits, different in appearance from the deeply four-lobed, or four-nutleted fruits of the mints. Mullein fruits are, in their structure, typical of the figwort family. The flowers, however, are, for the most part, strongly two-lipped, recalling those of the mints, but the aromatic, minty odor is absent.

Mulleins. Mulleins—common plants in fields and pastures —are well-known on account of their woolly leaves, which have much the feeling of flannel. A careful examination of a mullein leaf will show that its surface is covered with little, much-branched hairs, standing close together like so much miniature shrubbery. In the spring of the year the leaves form dense rosettes at the surface of the ground, and later an erect, tall flowering axis is developed, from two to six feet in height. At the end of this a spike of yellow, almost regular flowers is borne. In each flower there are five stamens.

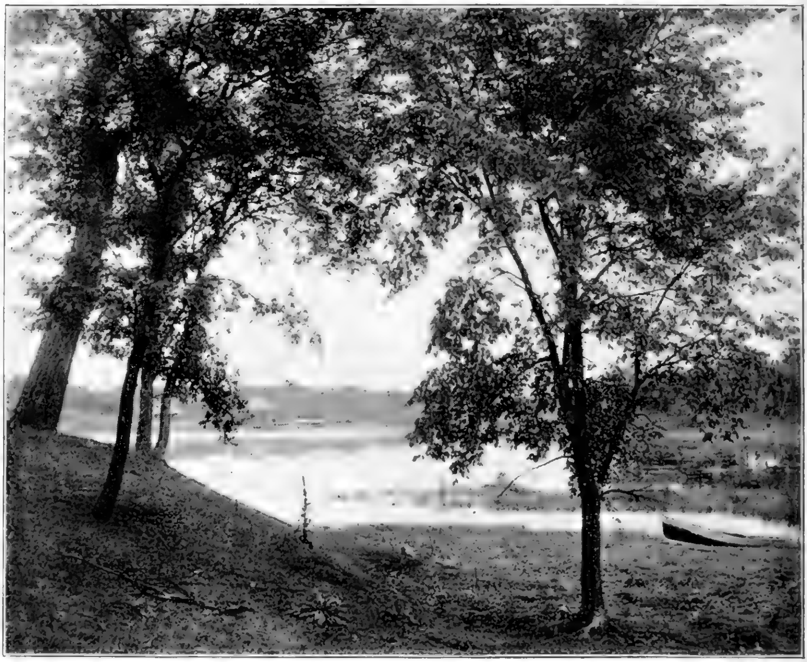


FIG. 181. View in Minnesota lake district. Shows in center two mullein plants in characteristic positions. After photograph by Williams.

The leaves are alternate. In these characters the mulleins differ from the rest of the figworts, in none of which are there five pollen-bearing stamens, and in most of which there are two-lipped flowers and opposite leaves, though the latter character is by no means universal.

Toad-flaxes. The toad-flaxes are recognized at once by their snapdragon-shaped yellow or blue flowers, provided with a spur like that of a larkspur flower. The common toad-flax of roadsides and fields blooms in the summer and autumn.

The flowers are yellow and are arranged in a dense raceme at the end of the slender stem, not usually more than a foot in height. The leaves in this variety are linear. The Canada toad-flax, not an abundant plant in Minnesota, resembles the ordinary sort except in the color of its flowers, which are bluish or white.

Pileworts, turtle-heads and snapdragons. The figwort or pilewort is a tall herb, often five or six feet high, with a large terminal panicle of small purplish, two-lipped flowers of curious shape. There are five stamens, but only four of them produce pollen sacs. The fifth is reduced to a little scale. The stems are somewhat four-sided, but the plant has the typical figwort capsule, with two chambers, opening along the partitions. The turtle-head is a swamp plant, with white or pink flowers, large in size and borne in the axils of the upper leaves, or in terminal spikes. The flower is shaped somewhat like a turtle's head, hence the common name. The seeds in this variety are provided with wings. The snapdragons, known also as beardtongues, and the monkeyflowers have usually bell-shaped or mouth-shaped flowers. Several different kinds of beard-tongues occur and they are especially abundant on dry banks or high bluffs in the prairie region of the state. The monkeyflowers, of which there are two sorts, have the flowers on distinct stems in the axils of the leaves. Each flower seems to have an upper and lower jaw, closed together like a mouth. One variety has blue flowers and the other has yellow. Both are found in swamps or along streams,—not, however, in peat-bogs or tamarack swamps, or only very sparingly.

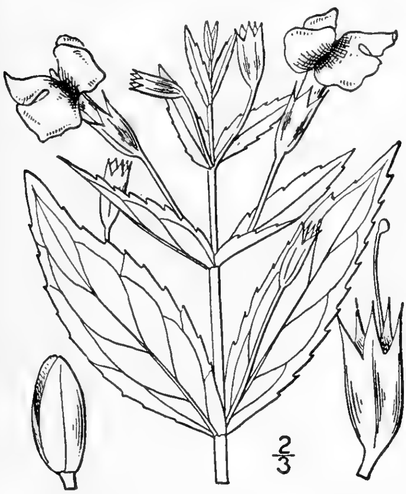


Fig. 182. Monkey flower. After Britton and Brown.

Hedge-hyssops. The hedge-hyssops are mint-like in their appearance, but lack the fragrance of the mint. There are two or three varieties, one of which occurs in peat-bogs. The flowers are considerably smaller than those of the turtle-head, beardtongue or monkeyflower, but have a strongly two-lipped aspect. There are four stamens, in one variety all pollen-bearing, and in the others only two with pollen.

Speedwells. The speedwells, of which there are several species, have only two stamens. They are usually provided with capsules of a heart shape, caused by the deep lobing of the typical figwort fruit. Many of them are found in wet places along the muddy shores of ponds or in woods. One of them is a tall herb, often six feet in height, with willow-shaped leaves in whorls of from three to nine, and several dense, spike-like racemes of flowers, the central one of which develops first. The flowers are small, and white or blue. In this variety the capsule is not heart-shaped. The plant is common in the edges of woods.

Fig. 183. Lousewort. After Britton and Brown.

Gerardias. The *Gerardias*, with about ten Minnesota species, are abundant in various localities, but are most often found among sedges along the shores of lakes or on dry prairies. The flowers are not distinctly two-lipped, but are almost bell-shaped, usually of a pink color, varying towards violet, purple or yellow. The leaves are commonly linear, or at most lance-shaped. The showy flowers, slender leaves and capsules of the figwort type, half inclosed in the calyx, or almost surrounded by it, will serve to distinguish these plants.

Indian pinks. The Indian pinks, or painted-cups, form their two-lipped flowers in leafy spikes. Many of the leaves in each spike are themselves colored scarlet or yellow, giving to the whole structure a much more ornate appearance than would be produced by the flowers alone. One painted-cup has scarlet leaves; another has yellow leaves, while yet another is supplied with green leaves to accompany the flowers.

Cow-wheats. The cow-wheats, louseworts, yellow-rattles and eyebrights are remarkable for their partial parasitism upon neighboring plants. If a turf containing one of these varieties is dug up and the earth very carefully removed by washing, it will be found that the rootlets of the figwort attach themselves to those of neighboring plants and in this way extract food material from the bodies of their hosts. Such plants are called root-parasites. The dependent habit of these root-parasites is not, however, so thoroughly fixed that they derive the principal part of their nutriment in such an irregular manner They are all of them green plants with well developed leaves. The flowers are two-lipped, have strongly convex upper lips, and are of various colors—white in the cow-wheat, yellow in the rattlebox, cream colored in the louseworts, and lilac or purplish in the eyebright.

FIG. 184. Bladderwort. After Britton and Brown.

Catalpa trees. One tree related to the figworts, and belonging to the bignonia family, is cultivated in Minnesota, especially in the southern part of the state. This is the catalpa, a very beautiful tree with large leaves shaped somewhat like those of the linden and handsome purple-mottled, bell-shaped, two-lipped flowers, produced in loose clusters. The pods when full-grown are a foot or more in length, cylindrical and slender. In every pod a large number of winged seeds are matured and the wings stand out on each side of the seed like the wings of a bird. Catalpa seeds have their center of gravity very nicely balanced between the wings, so that they lie flat in the air, and if there is a current of wind they soar in circles like hawks, and are often carried to great distances.

Bladderworts. Relatives of the figworts are certain very extraordinary aquatic plants known as bladderworts. In Minnesota all the forms live in the water, except a little plant called the butterwort, which grows upon rocks along the north shore of Lake Superior. In the tropics, however, a number of bladderworts grow as perching plants upon tree trunks. For the most part, true bladderworts have no roots, but extend in the water their much-branched, floating body, from which slender stalks arise, bearing yellow, snapdragon-shaped flowers. The leaves of these plants are decidedly compound and consist of thread-like divisions, upon which are produced, usually in large numbers, little, clear, flattened, shrimp-shaped bladders. Each bladder contains generally a bubble of gas along with some liquid, and by aid of the bubbles the plants are enabled to float free in the water. Being surrounded by liquid, they have little need of roots, and have therefore abandoned them. The bladders are not, however, employed solely as floats, but each one has an aperture, guarded by a trapdoor, which opens inward but not outward. Small aquatic insects find their way into these bladders, but cannot escape, since the door of the bladder cannot be opened from within. Digestive glands are present on the inner surface of the bladders, and the bodies of the little animals are used by the plant as part of its nutriment. Bladderwort stems resemble somewhat those of the water-milfoils, but the latter are not free floating plants and are attached to the bottom, nor have they the remarkable shrimp-shaped bladders on their leaves. Bladderworts in flower are immediately recognized, for no other free-swimming plants produce two-lipped flowers. Each corolla is provided with a spur like that of the toad-flax flower and is visited by insects which effect pollination. The fruiting capsule is like that of the figworts, with numerous small seeds. In Minnesota there occur five varieties of bladderworts—to be discriminated by minute differences in the flowers, leaves and bladders.

Butterworts. A close cousin to the bladderworts is a curious little plant known as the butterwort. It grows in the crevices of rocks along the north shore of Lake Superior, reaching in such stations a height of three or four inches. The leaves are oblong, clustered at the base of an erect axis that bears a single nodding, two-lipped violet flower. Each leaf has a greasy feeling and is provided with a viscid secretion in which insects are caught. In the greasy substance digestive ferments are elaborated, and by means of these the bodies of the insects are converted into food for the plant. Through the rennet-like ferments secreted by their leaves butterworts,

FIG. 185. Cancerroot. After Jellett in *Meehan's Monthly*.

if placed in it, will curdle milk. They are actually thus employed in the domestic cheese-making of Lapland and northern Scandinavia.

Cancerroots. The broom-rapes, including plants known as cancerroots, beechdrops and squawroots, are represented in Minnesota by three, and probably more species. They may be regarded as derived from the cow-wheats and louseworts, just as were the dodders from the morning-glories. They are strongly parasitic by their roots and have lost their green color, becoming whitish or pale like the Indian-pipes or corpse-plants. They have not, however, the dead white color of the corpse-plant, and their flowers are bent in the middle and are, in one variety, slightly two-lipped, and in the other two, strongly. The one-flowered cancerroot sends up several slender, erect stems, from three to eight inches high, at the end of each of which a single whitish-violet flower is borne. A few little scales of a pale color appear at the base of the flowering axis. The stem of the plant is subterranean and sends out a number of roots which attach themselves to the roots of neighboring plants. The clustered cancerroot pushes its main stem out of the ground from two to four inches. On this several single-flowered axes are developed. The flowers in both varieties are about an inch in length. A third species, the Louisiana broom-rape, may be recognized by the production of numerous short-stemmed flowers in a terminal spike, upon which also several scaly leaves arise. The whole plant stands up from four to eight inches in height. The flowers are purplish, and the stems and scales are of a pale, yellowish-green color.

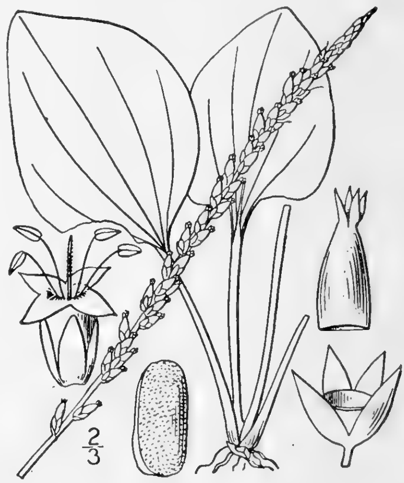


FIG. 186. Rugel's plantain. After Britton and Brown.

Lopseeds. The lopseed family is represented in Minnesota by its only species, a plant with the general aspect of a nettle, but bearing two-lipped flowers in slender spikes from three to six inches long towards the tip of the plant. After the flowers have been pollinated they turn downward and lie flat against the axis upon which they were borne, giving a curious barbed appearance to the spike. From this habit the name "lopseed" is given.

Plantains. The thirty-second order includes but a single family, that of the plantains, one variety of which is a common and troublesome weed in lawns throughout the state. The stems of the plantains are very short, situated underground, commonly in an erect position. A cluster of leaves with prominent longitudinal veins are borne on this short stem and from the center of the tufts of leaves an axis arises, in the plantains proper prolonged into a dense spike of flowers. In the related shoreweed, not known to occur in Minnesota, the flowers are solitary on the erect axes. Each plantain flower is provided with a four-lobed corolla and calyx and there are ordinarily four stamens, though the number in some species is reduced to two. The fruit-rudiment matures into a two-chambered capsule that splits by a circular cleft, thus removing the tip as a lid and allowing the seeds to escape.

In Minnesota there are six or seven varieties of plantain. The common plantain of dooryards has broad, smooth or slightly hairy leaves, arising from a thick, short rootstock. The spikes are long, slender and many-flowered. The pod opens by a ring around the middle. Rugel's plantain resembles this closely, but has fewer flowers in a spike and the pods split below the middle, so that the lid is the larger portion. The rib-grass, or rib plantain, is introduced from Europe and is recognized by its slightly hairy, lance-shaped, or broadly grass-like leaves, and its pod splits at about the middle. The salt-marsh plantain, known from the saline soils of the Red river valley, has oblong, lance-shaped leaves and pods splitting below the middle. The heart-leafed plantain has broad, heart-shaped leaves of a purplish-green color with smooth surfaces. The spike is not continuous but is interrupted by short, flowerless areas. The pod splits at about the middle. The woolly plantain, found on prairies in the Minnesota valley, especially upon high knolls, has silky or woolly, very slender grass-like leaves. The whole plant, from the hairs, has a white aspect. The pods split at about the middle. The bracted plantain has grass-like leaves, but is not furnished with silky hairs and the spike is clothed with slender green bracts or scales which protrude considerably beyond the ends of the flowers. The pod splits below the middle.

Chapter XXXVIII.

From Bedstraws to Lobelias.

The thirty-third order includes the madder family, to which the exotic coffee and cinchona plants belong. From the latter quinine is manufactured. The Minnesota species are all herbs but one—the button-bush—and include about ten kinds of bedstraw, the partridgeberry and two *Houstonias*. In addition to the madders, the thirty-third order includes the honeysuckle family, with the honeysuckles, twinflowers, snow-berries, high bush cranberries, arrowwoods, elders and horse-gentians; the adoxa family, with a single small herb known as the musk crowfoot or moschatel; and the valerian family, with two valerians and two lamb-lettuces. The teazel family, to which the fuller's-teazel belongs, is not represented in Minnesota.

Bedstraws. Of the madder family the little bedstraws of the woods are well-known forms. Their stems are four-sided, their leaves are apparently in whorls and are mostly slender or willow-shaped. The stems are armed with recurved barbs, so that they cling to one's clothing. The flowers are small, white and clustered in flat-topped cymes, often aggregated in compound panicles. Each flower exhibits a four-lobed calyx and a four-lobed corolla, upon which four stamens are borne in the notches. The fruit consists of two nutlets, side by side, and in each of them a single seed is formed. The different kinds of bedstraw are distinguished by the character of the nutlets, the color of the flowers, and a number of minute peculiarities which can scarcely be recognized without the use of a microscope. Most of the Minnesota varieties have fruits provided with hooks, but in some the fruits are quite smooth. The slender, trailing, clinging stem, whorled leaves, four-lobed flowers and two-nutleted fruits will serve to identify these plants. One variety is a common prairie flower.

Partridgeberries. The partridgeberry is a slender, creeping evergreen plant with opposite leaves. It is easily mistaken for a heath, from which it must be distinguished by its white, sessile, four-lobed flowers, each with four stamens and four-lobed stigmas. The flowers are borne in pairs at the ends of the stems. The fruit is a berry-like body, red in color, and consisting of two fused stone-fruits, in each of which there are four seeds. In fruit this plant is easily mistaken for a cranberry; but the berries, while edible, have a flavor different from that of true cranberries.

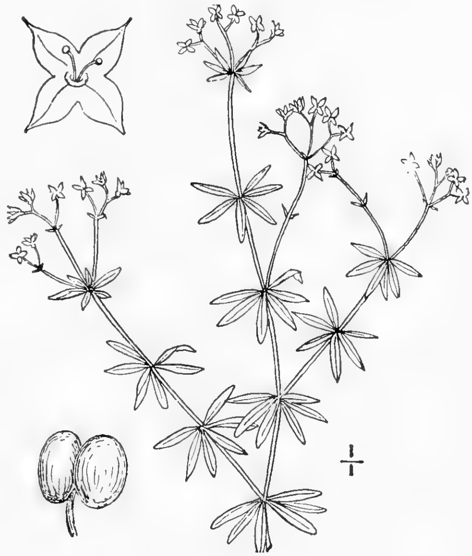


Fig. 187. Bedstraw. After Britton and Brown.

Button-bushes. The button-bush is a shrub with opposite leaves of the familiar plum-leaf shape and with spherical heads of white flowers. The cluster of flowers is about an inch in diameter and all over its surface the slender stigma-stalks of the pistils protrude like so many short threads. The flowers themselves are crowded together very tightly, but upon being removed show the four-lobed corolla and calyx of the madder family. This plant is found in the St. Croix valley and along the Mississippi, below the confluence of the St. Croix.

Fig. 188. Partridgeberry. After Britton and Brown.

Bluets. The *Houstonias*, or bluets, are erect herbs with opposite leaves, usually tufted, and not over ten inches in height.

The flowers are funnel-shaped with the four calyx and corolla lobes and the four stamens of their family, but the stigma is two-lobed. The flowers are blue or lilac or almost white, and are arranged in flat-topped clusters. The fruit is an almost spherical capsule. The fringed *Houstonia* has a fringe of hairs along the margins of the leaves, while the long-leaved *Houstonia* has none.

Elder-bushes. The honeysuckle family comprises a group of shrubs, vines and herbs, with opposite leaves and tubular, generally five-parted, flowers, the calyx of each of which adheres to the surface of the fruit-rudiment, so that the corolla tube and the calyx seem to spring from the top of the undeveloped fruit. Here are included the elders, of which there are two varieties in Minnesota, the one forming a flat-topped cluster of flowers from each of which a purple or black stone-fruit is produced, and the other, panicle-clusters and stone-fruits of a scarlet or red color when ripe. The berries of both varieties are edible. The leaves are compound like those of the ash, and when bruised have a curious strong smell. Elder flowers have five-lobed corollas with five stamens, each placed in a notch.

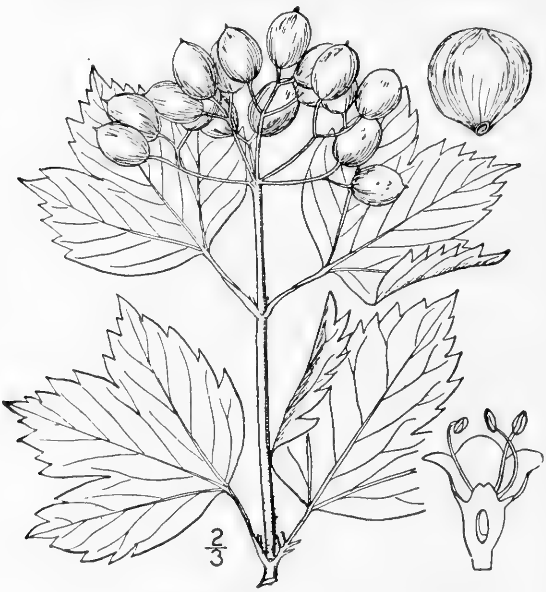


FIG. 189. High bush cranberry. After Britton and Brown.

Black haws and high bush cranberries. Related to the elders are the bushes known as black haws, sheepberries, arrowwoods, high bush cranberries, or *Viburnums.* There are seven or eight varieties in Minnesota. The high bush cranberry is a shrub, eight to twelve feet in height, with opposite leaves shaped somewhat like those of the maple. The white, honeysuckle-like flowers are produced in more or less flat-topped clusters, and each one matures into a stone-fruit with much the flavor and appearance of the cranberry. The maple-leafed arrowwood has the same maple-shaped leaves seen in the high bush cranberry, but the stone-fruits are nearly spherical and black. This variety does not grow more than six feet high. The downy-leafed arrowwood, with elm-shaped leaves, has black, oblong stone-fruits. Another sort, very similar in the foliage, has almost spherical fruits of a dark blue color. Both these arrowwoods have coarsely notched leaves. The withe-rods and sheepberry *Viburnums* have plum-shaped leaves with fine teeth along the edge. In the withe-rod the fruits are of a pink or blue color and the stone is round, or slightly flattened. In the sheepberry the fruits are blue or black, with flat disk-like stones.

These various *Viburnums* are found in moist woods or swamps. Some of them, like the sheepberry, the downy arrowwood and the high bush cranberry, are not uncommon throughout the state, especially toward the north. The others are rarer or local in their distribution.

Horse-gentians. The horse-gentian, or feverwort, is a common herb in rich woodland, especially throughout the southern and central portions of the state. The leaves are opposite, entire and in most instances blended by their bases around the stem, so that the stem seems to grow through the leaves. The flowers arise in the axils and are of a purplish hue. The stone-fruits are orange-red, hairy, and have three nutlets.

Twinflowers. The twinflower, not uncommon throughout the wooded portion of the state, grows among moss and might be mistaken for the partridgeberry. The slender branches trail over the ground, producing small opposite leaves, and occasional side stems, at the ends of which pairs of nodding flowers are borne. The flowers of the partridgeberry are erect and four-parted, but those of the twinflower are five-parted. There are usually, however, but four stamens. The fruit is nearly spherical, with a single ripened seed.

Snowberries. The snowberries are little shrubs not over five feet high, and in one variety rarely over six inches. They have white, berry-like fruits produced in clusters in the axils of the leaves, except in one species in which the berry is red. The leaves are ovate, smooth-margined, opposite and honeysuckle-like. The flowers are small, with four or five teeth to the corolla and the fruits have two seeds each. The different varieties may be recognized as follows: The red-berried form, known also as the Indian currant, is at once distinguished by the color of its fruit. Of the three with white fruits the wolfberry protrudes its stamens and stigma-stalks slightly from the flower, while the other two do not. Of the latter, the snowberry is an erect shrub one to four feet in height, while the low snowberry branches diffusely and averages from six to ten inches. All four varieties are to be found in the edges of woods, along lake shores and in rocky places.

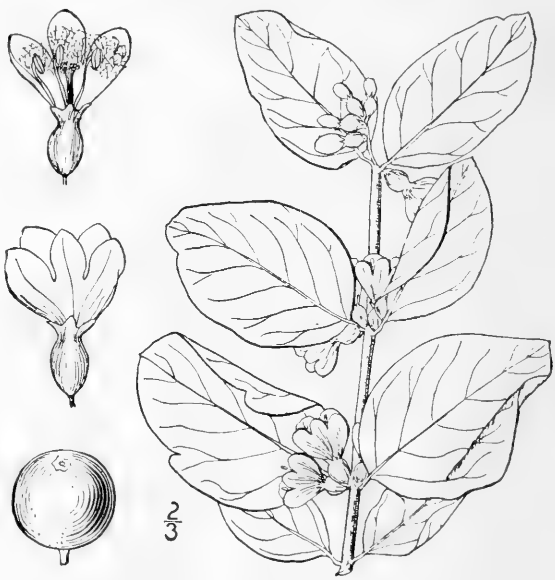


FIG. 190. Snowberry. After Britton and Brown.

Honeysuckles. Of the honeysuckles, some are climbing vines while others are spreading shrubs. The flowers are produced in little spikes and are themselves generally large and conspicuous. The hairy honeysuckle, the smooth honeysuckle, Sullivant's honeysuckle, and the yellow honeysuckle, all have the leaves near the flower clusters grown together by their bases around the stem. Those just mentioned are vines. The blue honeysuckle, the swamp-honeysuckle, the fly-honeysuckle and the involucred honeysuckle are shrubs, varying in the different species from one to ten feet in height. The hairy honeysuckle is known by its hairy leaves. The smooth-leafed honeysuckle has red berries. Sullivant's honeysuckle has yellow berries and yellowish-green flowers. The yellow honeysuckle has bright orange-yellow flowers, that are sweet-scented. The blue or mountain-honeysuckle is a shrub one to three feet in height, with oblong leaves, pairs of yellow flowers and bluish-black berries. The swamp-honeysuckle has red or crimson berries. The fly-honeysuckle has bright red berries, and the involucred honeysuckle, with yellow flowers and black berries, may be distinguished by the production of bractlets surrounding the fruit.

The bush-honeysuckle has the flowers and general foliage of the true honeysuckles, but the fruit is a capsule, not a berry. The Minnesota species is a shrub from two to four feet in height, with plum-shaped leaves the margins of which are finely notched. The flowers are yellow, produced on stalked umbels in the axils of the upper leaves. This plant is very abundant in open pine woods throughout the state.

Moschatels. The *Adoxa*, or moschatel, otherwise known as musk crowfoot, is a little herb with the appearance of a small anemone. It is not more than six inches high. The leaves are compounded on the plan of three, each of the three leaflets being again compounded or deeply lobed. Three or four leaves of this sort are borne at the base of the flowering axis—which is slender and erect, carrying a pair of three-parted leaves opposite each other and a little above the middle. At the end of the flowering axis is a small head of from three to six flowers, all of them five-parted with a forked stamen produced in each notch. The fruit is a green stone-fruit, with from three to five nutlets. This little plant, the only one of its family, has been found in Winona and Goodhue counties. It is to be sought among the rocks in dark ravines and is an arctic-American form, reaching its southern limit in Minnesota and northern Iowa.

Valerians. The valerian family includes four Minnesota species, two valerians and two lamb-lettuces or corn-salads. They are strong-smelling herbs with the characteristic odor of the drug valerian. The two species, known respectively as tobacco-root and swamp valerian, have pinnately divided leaves, with slender leaflets, and erect stems from one to four feet in height, bearing panicles of tubular flowers with opposite bracts. The calyx is fused with the fruit-rudiment and consists of from five to fifteen bristly teeth, which stand out like little feathers around the mature fruit. The fruit has but one chamber and is strongly ribbed. In the tobacco-root the flowers are of a yellowish-white color and are often separated. The root of this plant is edible. The swamp valerian has flowers of a pink or whitish color and the stem-leaves consist of a larger number of leaflets than in the tobacco-root. Valerian flowers are, in structure, very similar to those of honeysuckles, from which they can be known by their slight irregularity and by their stamens, from one to four in number. The fruit also contains but a single seed and is not, as in honeysuckles, a stone-fruit with pulpy exterior.

The two corn-salads are rather low herbs, from one to two feet in height, with opposite, smooth-margined leaves and small flowers, clustered in heads that are loosely arranged on the forked, flat top of the main axis. The fruits are somewhat triangular in outline, smooth and enclosed by the calyx, growing closely around the fruit-rudiment. There are three stamens and the stigma is three-lobed. These plants can be distinguished from members of the honeysuckle family by the number of their stamens, and from the valerians by the absence of feathery appendages on the top of the fruit.

The thirty-fourth and highest order of plants comprises the gourd family, to which belong such common garden plants as melons, citrons, cucumbers, squashes, pumpkins and bottle-gourds. Only two varieties, the wild cucumber and the star-cucumber, are native to Minnesota. In this thirty-fourth order are grouped also the bluebells and lobelias, three small families not represented in the United States by native species, and the large and important sunflower family, to which a great variety of herbs known as "*Composites*" belong. The three Minnesota families of the thirty-fourth order are known by the fusion, or close approximation to each other, of their stamens. In the gourd family the flowers are for the most part regular—as they are also in the bluebells. In the lobelias the flowers are strongly two-lipped, reminding one of mint or snapdragon flowers, while in the sunflower family the flowers are always aggregated in dense, flat-topped, spherical or cylindrical heads and are either all tubular like honeysuckle flowers, all two-sided and strap-shaped like dandelion flowers, or partly tubular and partly strap-shaped in the same head, as is the case in sunflowers. In the latter instance the tubular flowers are centrally disposed in the head, while the strap-shaped flowers form one or more marginal rows and are then called ray-flowers, because they radiate from the center of the disk.

Gourds and cucumbers. The plants of the gourd family are almost always provided with tendrils by which they climb, and they belong to the highest group of climbing plants which exists. The leaves are alternate and are generally large and palmately divided like maple leaves. The calyx is fused with the surface of the ovary and the petals arise from the calyx. The corolla is often so deeply notched that it is broken up into five separate petals, returning thus to the condition of the flowers in a lower series. There are from one to three stamens. The fruit-rudiment is from one to three-chambered, commonly three-chambered, as may be noticed on the dining table when sliced cucumbers are served. The seeds are for the most part flattened and contain no albumen. Extremely large fruits with great numbers of seeds are produced by some of the species of this order. The well-known prize pumpkins of the fairs, and the Georgia watermelons furnish abundant proof. Generally the fruits do not open, but release their seeds by decay or after they are eaten by animals, but in some varieties explosive fruits are known. From these the seeds are ejected as from a catapult, or are shot out into the air as from a gun or mortar.

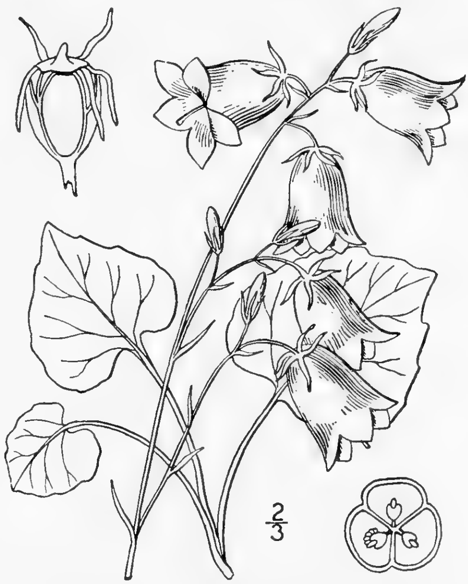


FIG. 191. Blue-bells. After Britton and Brown.

The star-cucumber is an herbaceous vine with palmately-lobed leaves shaped like those of the moonseed. The flowers are separated, both kinds being borne on the same plant. The fruit is one-chambered and matures but a single seed. Three or four of such fruits are borne together in a little bunch at the end of a short nodding stem. The surface of the fruit is spiny and it does not open to release the seeds. This form of wild cucumber is not very common in Minnesota, but occurs throughout the southern part of the state.

The wild cucumber, or balsam-apple, like the star-cucumber is a climbing herbaceous vine with rather deeply lobed leaves, shaped somewhat like those of the hard maple. The flowers are separated, both kinds occurring on the same plant. The staminate flowers are numerous in conspicuous slender racemes, but the pistillate flowers are generally solitary, and each one ripens an egg-shaped green fruit covered with weak spines and containing from two to four seeds, that are released by the opening of the fruit at the end. The number of seeds in the fruit, the opening of the fruit, and its ordinarily solitary character, will generally serve to distinguish this plant from the star-cucumber.

FIG. 192. Blue lobelia. After Britton and Brown.

Bluebells. The bluebell family includes four bluebells, one little herb known as the Venus' looking-glass, and six species of lobelia, all of which, except the Venus' looking-glass and the water lobelia, are rather common in Minnesota. The bluebell, or harebell, is an abundant plant in rocky places and meadows throughout the state. Its beautiful, blue, bell-shaped flowers are borne in a slender raceme, with several very narrow bract-leaves at the bases of their stems. The root-leaves of the plant are in most instances rounded, or heart-shaped, but sometimes all of the leaves are slender. A variety of this plant, with solitary erect flowers crowning the stems, occurs in the northeastern part of the state. The marsh-bellflower has very slender stems, with narrow alternate leaves, and the flowers, often almost white, are smaller and paler than those of the harebell. The shape of the flower is more open. The tall, or wood-bellflower, is a wand plant of the woods, varying from two to six feet in height. The leaves are lance-shaped and the flowers—generally of a brilliant blue color, but sometimes pale or white—are crowded in a loose, terminal spike with numerous leaves intermingled. In this variety the bell-shape of the flower is lost and the five notches of the corolla stand out in a plane, making a wheel-shaped flower an inch or so in breadth. In all these plants the fruit is a capsule with from three to five chambers. There are several seeds, and the calyx comes up over the fruit or fuses with the lower end of it.

Venus' looking-glass. The Venus' looking-glass is known by the small, strongly clasping, shell-shaped leaves, in the axils of which the violet or blue flowers are gathered. The plant is uncommon but may be looked for in the edges of woods.

Lobelias. Lobelias, as has been said, might from the shape of their flowers be mistaken for mints or figworts. Their capsular fruits are, however, quite different from the four nutlets which the mint develops and the flower may always be distinguished from that of a figwort or mint by the blending with each other of the stamens. One variety of lobelia—rare in Minnesota—is aquatic, commonly rooting in the mud at the border of lakes or ponds. It has hollow, quill-shaped submerged leaves, clustered around the base of a slender stem from six to eight inches in height, and at the end of this the pale blue flowers are gathered in a loose raceme. The cardinal-flower, or red lobelia, to be found in swamps or rich soil along the lower Mississippi, is recognized at once by its conspicuous scarlet flowers, arranged in a many-flowered raceme. The leaves are willow-shaped and the whole plant is generally over two feet in height. The flowers are about an inch long. The large blue lobelia, common throughout the southern part of the state, much resembles the red lobelia, except that its flowers are bright blue. In both these varieties white flowers are sometimes produced. The pale blue lobelia is a slender plant of dry soil, abundant in the southern part of the state and recognized by its smaller flowers, four or five lines in length. The leaves are rather thick, of an oblong shape, with short stems, but the stem-leaves are generally sessile. The flowering raceme is very long and slender, reaching a maximum length of two feet and, commonly, of eight to fifteen inches from the tip to the lowest flower. The Indian-tobacco lobelia, not so frequent as some of the others, may be identified by its broadly plum-shaped, pointed leaves and its light blue flowers in rather loose, spike-like racemes. Kalm's lobelia, the commonest of all the varieties in Minnesota, is especially abundant in peat-bogs, on banks of lakes and streams and in meadows. It is a slender plant, with light blue blossoms in loose, few-flowered racemes. The flowers are about the size of those of the pale lobelia, or rather smaller, but they are not exhibited in the long slender clusters, characteristic of the other varieties. The fruit of the lobelias is a capsule, usually with two chambers, and to its surface the calyx-tube is closely attached.

Chapter XXXIX.

Dandelions, Ragweeds and Thistles.

The last and highest family comprises the plants known as *Composites.* It includes some 11,000 species of herbs and shrubs, with a very few trees, well distributed over all regions of the world, and is characterized by the aggregation of the flowers into composite heads. These heads are subtended by groups of bract-leaves to which is given the name of *involucre.* The involucre is a green, closely packed series of scales, such as may be seen below the head of a sunflower or thistle. In some plants, such as the burdocks or cockleburs, the involucre produces bur-like, hooked or barbed groups of bristles, by means of which all the fruits of a head are distributed as a unit.

There are two main series of composite plants, one of which is distinguished by the presence of a milky juice, while in the other no milk exudes on the breaking of the stems or foliage. Dandelions, lettuce, sow-thistles and chicory serve to illustrate the first series, while asters, goldenrods, burdocks, sunflowers, thistles, cockleburs and ragweeds are examples of the second. The composites with milky juice develop what are known as strap-shaped corollas for all the flowers of a head. Such strap-shaped corollas may be conceived to arise by the splitting of a tubular corolla—like that of a honeysuckle—down one side, near to the fruit-rudiment. Very often, as in dandelion flowers, five little notches will be found at the edge or tip of the strap. These represent the five fused petals of the original tubular flower. Those members of the composite family which have no milky juice produce, in many instances, at the margin of the head, the strap-shaped flowers; but some, and often all the flowers in a head are tubular, like miniature honeysuckle flowers. The sunflower or the daisy furnishes an example of a head in which strap-shaped flowers are produced laterally and tubular flowers centrally, and the thistle furnishes one in which all the flowers are tubular.

In composite flowers the stamens generally have their pollen-bearing portions fused together into a ring, while their stems are free. The fruit-rudiment is composed of two carpels, with a single chamber in which a single seed matures. The calyx is always fused with the surface of the fruit-rudiment, and in a great many varieties the calyx produces a bristly or scaly series of appendages for distributing the fruits in air currents. The well-known parachutes of the dandelion are such areas, with the margins frayed out into circles of little bristles. Sunflower fruits are provided with a pair of scales similarly derived from the calyx. When the fruits are enclosed in burs, the calyx sometimes, as in the cockleburs, develops this flying apparatus but poorly, while in other instances, as in the burdocks, flying appendages are produced upon each fruit, probably reminiscences of an earlier condition when the bur-method of distribution had not been perfected. The modified, aeronautic calyx of the composite flower is known as *pappus*.

FIG. 193. Chrysanthemum in flower. After Miller. Bull. 147, Cornell Ag. Expt. Station.

There are in Minnesota between 240 and 250 species of composites, including the ironweeds, the blazing-stars, the thoroughworts or bonesets, the asters, the fleabanes and *Boltonias*,

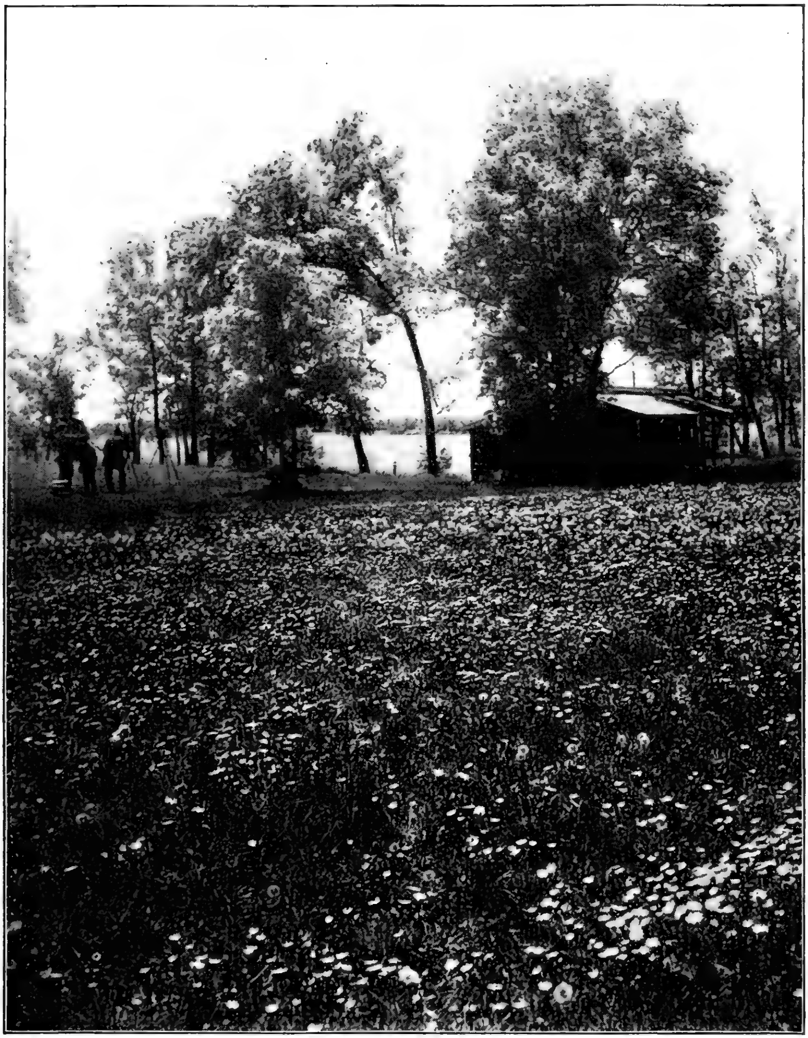


FIG. 194. Dandelions in flower. Lake Calhoun. After photograph by Hibbard.

the goldenrods, the rosinweeds or compass-plants, the cone-flowers, sunflowers, tickseeds, bur-marigolds or beggar-ticks, sneezeweeds, chrysanthemums, tansies and yarrows, cudweeds, everlastings, ragworts, thistles, burdocks, ragweeds, cockleburs, marsh-elders, chicories, hawkweeds, rattlesnake-roots, wild lettuces, dandelions, sow-thistles and corn-flowers. In some of these groups there are a large number of Minnesota species. For example, there are six sorts of blazing-stars, six thoroughworts, nine or ten fleabanes, thirty goldenrods and about forty asters, besides eleven or twelve wormwoods or sage-brushes, ten or eleven thistles and fifteen sunflowers.

The composite family may for convenience be divided into three sub-families, the dandelions, the ragweeds and the sunflowers. To the dandelion family about thirty Minnesota

FIG. 195. Dandelions in fruit. After photograph by Williams.

species belong. The characters by which they are classified are minute and it is not possible to go into them in detail. A few of the common forms may, however, be described.

Dandelions and their relatives. The dandelion is known by its broad flat head of yellow flowers, becoming closed in the early stages of fruiting. In later stages the head opens again and the disk of the flower-cluster becomes convex. On this the little spindle-shaped nutlets are situated. Above each nutlet the calyx is prolonged into a rigid thread at the end of which the pappus-hairs diverge in an umbrella-shaped circle.

The sow-thistles have small, yellow dandelion-like flower-heads, arranged in panicles or in flat-topped clusters. The pappus, as in thistles, stands in a tuft on the top of the nutlet. The meadow salsify has flowers and fruits very much like those of the dandelion, but the leaves are all more grass-like in appearance. The autumn dandelion has a few leaves clustered about the base of a rather slender, erect stem, at the end of which a dandelion-like flower is borne. The fruit is slender and the pappus-bristles are brownish in color and on close observation are seen to be like little feathers. The dwarf dandelion has generally two kinds of pappus bristles, an outer row of short brown scale-like bristles and an inner row of slender, erect, stiff, barbed bristles. The hawk's-beards, with flowers decidedly similar to those of the dandelion, have a copious pappus of slender bristles, arising in a spreading tuft from the top of a many-furrowed fruit. The closely related hawkweeds can scarcely be distinguished by any but very minute characters. The wild lettuces look much like some of the hawkweeds, but the flowers are more often blue than yellow. The prickly lettuce, a *compass-plant*, may be distinguished from the sow-thistle, which it somewhat resembles, by the dandelion-like fruits, with the pappus elevated above the tip of the nutlet on a slender prolongation of the calyx. Its leaves are prickly, and those on the stem may twist so that their edges point up and down. The whole plant is generally flattened by the twisting of its leaves, and the ends

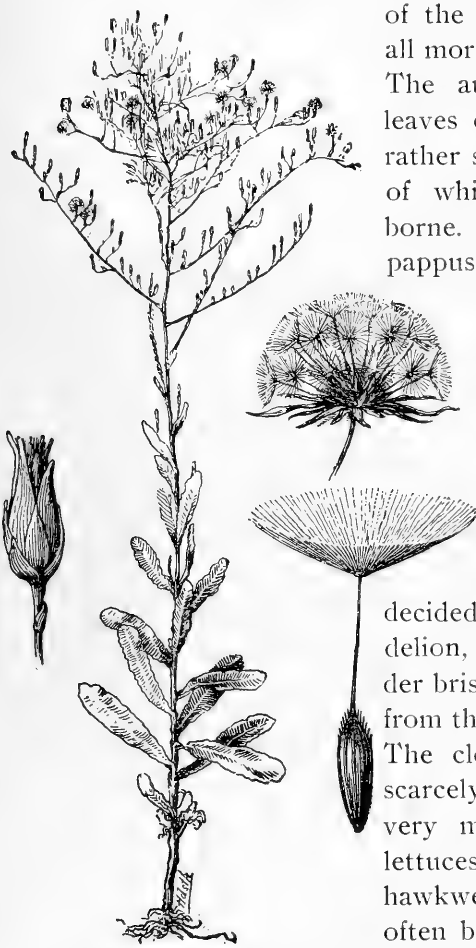


FIG. 196. Wild lettuce, a compass-plant; the fruits stand in heads, and each fruit is provided with a parachute of bristles. After Atkinson.

of the leaves show a tendency to point either north or south. One observing the plant carefully can easily see that the leaf-area as a whole exposes its surface toward the east and toward the west. The blue-flowered varieties, some of them wand-plants from three to twelve feet in height, are known by the copious heads of small blue flowers arranged in compound panicles. They are common at the edges of woods.

FIG. 197. Rattlesnake-root. After Britton and Brown.

A curious little flower, known as *Lygodesmia*, is a desert plant with rigid branching stem about a foot in height, and with small, awl-shaped leaves and flowers in pink heads of from three to twelve, giving to the whole cluster quite the appearance of a small carnation. It is a wanderer from the plains of the south-west. The *Nothocalais* and its relatives are prairie plants with grass-like leaves and dandelion-like heads. The rattlesnake-roots, some varieties of which are abundant in the Minnesota woods and in shaded ravines, may be known by their heads of flowers, nodding in the common forms, arranged in panicles and of a pink or purplish color. One of these with curiously triangular leaves is abundant in deep woods, flowering in autumn, and with its mature fruits surmounted by a deep brown tuft of pappus hairs.

FIG. 198. Cocklebur. After Britton and Brown.

Ragweeds and cockleburs. The ragweed family, with six or seven native species, includes the ragweeds, cockleburs and marsh-elders. The cocklebur, of which two varieties occur in Minnesota, is known by the conversion of the involucre of each pistillate head into a two-pronged, many-hooked bur in which two fruits are enclosed. A striking peculiarity of the cocklebur is that one of its two fruits will germinate the first season, while the other ordinarily lies dormant for a year. The marsh-elder is, in Minnesota, a tall roadside weed with leaves shaped like those of the cocklebur. The panicled heads of green staminate flowers are intermixed with small pistillate flowers without corollas. The ragweeds, of which three species are common in Minnesota, are also known as "hay-fever plants," because their copious pollen-spores produced in the autumn will, if inhaled, sometimes germinate in the nostrils and the little thread-like male plants will then irritate the nasal membranes of persons subject to the disease. The tall ragweed, which sometimes grows fifteen feet in height in low ground along roadsides, has three-divided leaves and numerous slender racemes of heads. The other ragweeds have pinnately divided or compounded leaves, and are a foot or two tall.

Fig. 199. Ragweed. After Britten and Brown.

Sunflowers and their relatives. The sunflower family has about 200 native species. Here are classified the ironweeds, herbs of moist soil with willow-shaped leaves and purplish small heads, arranged in flat-topped clusters; also the thoroughworts, distinguished from the ironweeds, which in outward appearance they much resemble, by the pappus. In thoroughworts this is composed of numerous slender bristles, while in the ironweeds it is double, the inner whorls alone being constituted of bristles, while the outer is made up of short scales. Related to the thoroughworts are the blazing-stars of the prairies and thickets, some sorts being also very prominent in open pine woods. These are wand-plants, with handsome pink or purple heads, of massive appearance in ordinary varieties, all arranged in a spike-like cluster at the end of the upright stem. The leaves are very narrow, like short grass leaves. The gum-plant or *Grindelia*, may be known by its sticky leaves and heads,—the latter with yellow rays and yellow disk flowers.

Fig. 200. Autumnal vegetation of marsh border. Thoroughwort or joe-pye weed. After photograph by Williams.

The goldenrods are, for the most part, wand-plants with densely panicled small yellow heads. In many varieties the heads are arranged in one-sided racemes and these are aggregated together in paniculate clusters, in three varieties becoming flat-topped. Some goldenrods, found in prairie districts, have rather narrow leaves, while others, natives of deep woods, have them very broad, ovate or oblong. The different kinds of goldenrods may be known by the sizes of the heads, by the arrangement of the heads in compound flower-clusters and by the texture and shape of the leaves. Daisies and oxeye daisies, asters and *Boltonias* are kindred to the goldenrods. The asters, which bloom so abundantly in the autumn of the year, may be known by their generally purple or whitish ray-flowers, their pappus, consisting of a single series of hair-like bristles, and their disk flowers of a red, purplish or brownish color. Some asters which live in the forest have very broad and heart-shaped leaves, while others, at home in the open, produce leaves that are slender or even awl-shaped. The flowers are ordinarily arranged in compound panicles or flat-topped clusters, very numerous in some species, in others fewer. The one-sided, racemed inflorescence aggregates of the goldenrods are found in a few species. Asters are to be distinguished from each other by the same characters mentioned for the goldenrods.

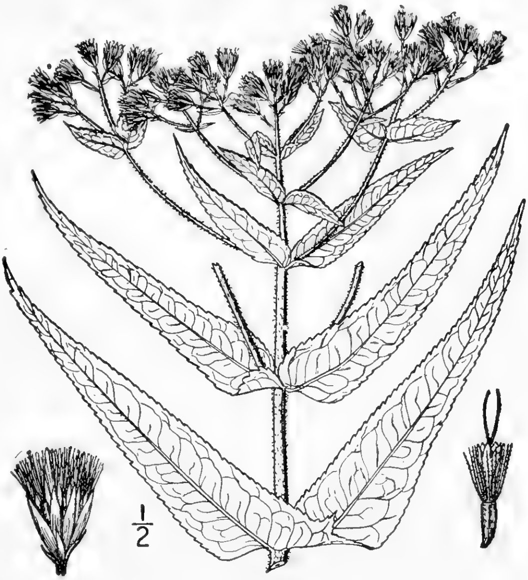


Fig. 201. Boneset or thoroughwort. After Britton and Brown.

Fig. 202. Blazing-star. After Britton and Brown.

Fleabanes have commonly very slender, thread-like ray flowers, usually of a white color, shading often into violet or purple. The everlastings, to which the common little Indian tobacco belongs, are for the most part woolly plants with separated flowers. The staminate flowers are produced on one plant and the pistillate on another, or they may both arise on the same plant. The rosinweeds include three rather marked varieties, among which is the Indian cup, in

FIG. 203. Autumnal composite vegetation. In foreground golden-rods, sunflowers and asters; in background, on brow of cliff, wormwood or sage-brush. After photograph by Williams

which the bases of the large leaves are grown together around the stem, forming deep cups, through which the four-angled stem seems to grow. Water is caught in these cups and they are often filled with the dead bodies of insects. It is probable that the plant is partially carnivorous like the pitcher-plants. The flowering heads are yellow, like small sunflowers. The compass-plant rosinweed produces near the surface of the ground a number of leaves a foot or more long, with very deep lobes running from the margin to near the midrib. These leaves stand upright and arrange themselves with their edges north and south. A third variety, known as the prairie-dock, displays large, long heart-shaped leaves, a foot in length and six inches or more in width at the base. They compose a large, loose rosette and do not stand erect like those of the compass-plant. In each variety the flower heads are yellow, both in the disks and in the rays. The related oxeyes or sunflower herbs, as their name indicates, resemble sunflowers closely.

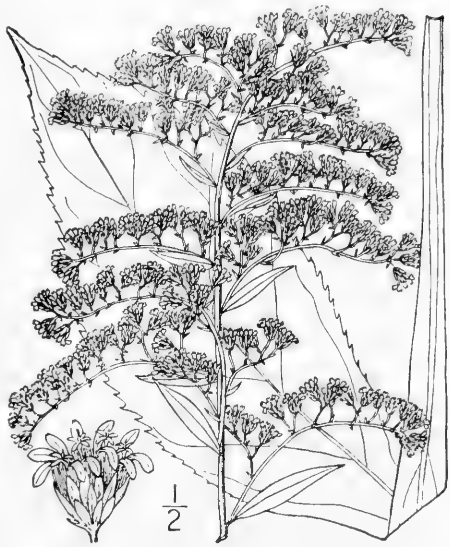


Fig. 204. Early golden-rod. After Britton and Brown.

In the coneflowers the disk is hemispherical, conical or columnar in contour. One variety, the long-headed coneflower, has the disk flowers arranged in a cylindrical, pointed cone, of a brownish color when mature, with a few large yellow ray flowers at the base. The sunflowers are mostly upright herbs, with heads consisting of numerous tubular disk flowers surrounded by conspicuous yellow rays. The ray flowers contain neither stamens nor pistils and are purely for the purpose of attracting insects to the less ornamental stamen- and carpel-bearing flowers of the disk. Such a division of labor between the different flowers of the head marks a very high degree of specialization. In some sunflowers the foliage leaves are opposite while in others they are alternate. Some have sessile leaves, while in others they are stemmed. In some the foliage is smooth, while in others it is rough, and in some the disk flowers are purple, while in others they are yellow. The shapes of the leaves and of the flower heads differ in the different kinds; and the arrangement of the flower heads varies slightly, though ordinarily they are either solitary or in flat-topped clusters. To this genus of plants belongs the artichoke, the rootstock of which bears tubers.

The tickseeds are little yellow-flowered composites, with the pappus much reduced, appearing commonly as a couple of small

FIG. 205. Asters and golden-rod. Banks of the Mississippi. After photograph by Williams.

teeth at the end of the somewhat winged nutlet. The bur-marigolds produce yellow flower heads, from the disk flowers of which arise fruits with two or more strongly barbed bristles upon each, for in these plants the pappus has lost its aeronautic characters and is adapted to fasten the fruits to the bodies of wandering animals. The little flattened, pitchfork-like seeds which stick to one's clothes in the autumn are those of the bur-marigold or beggar-ticks. The several different varieties are known by the shape of the nutlets, by the foliage and by the flowering heads. One, the highest type of aquatic vegetation in Minnesota, is called the water-marigold, or Beck's marigold, and is found in ponds and brooks. Its submerged leaves are all dissected into thread-like lobes. The flowering heads, distinctly composite in their appearance, are thrust out of the water, and just below them a few willow-shaped leaves are borne. The nutlets produce from three to six barbed bristles and are fitted for attachment to the plumage of birds or the fur of animals.

The yarrow is an erect herb, a foot or two in height, with leaves of strong, tansy-like odor, dissected pinnately into numerous tiny segments. The heads are very numerous, borne in dense terminal flat-topped clusters. The ray flowers are white or pink. Tansy, a common herb escaped from cultivation, is known by the highly aromatic foliage and the pinnately divided leaves. Wormwoods, of which there are several sorts, contain the peculiar bitter principle used as a flavoring substance in the manufacture of absinthe. Many of them are very white or silvery, from the numerous hoary hairs with which the leaves and stems are covered. The heads are small and aggregated in dense spikes, compound racemes or panicles, and the foliage exhales a characteristic aromatic odor. Colts'foots, to be found in marshes, may be known by their thick horizontal rootstocks, by their scaly stems on which, in flat-topped clusters, a few heads are borne, and by their large root-leaves—in one variety palmately divided like the leaves of some anemones, and in another of a broadly arrow-head shape. Related to the

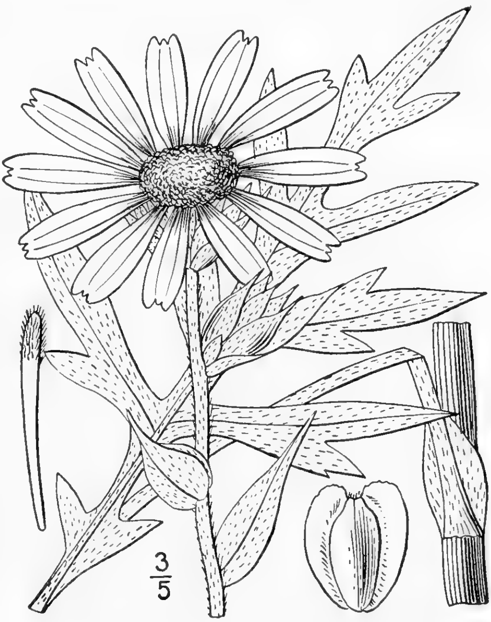


FIG. 206. Rosinweed compass-plant. After Britton and Brown.

colts'foots are the arnicas, fireweeds and Indian plantains. Three varieties of the latter occur in Minnesota. In one of these the leaves are similar to those of the dooryard plantain, while the small flowering heads are borne in large flat-topped clusters at a height of from two to six feet. In another form the leaves are kidney-shaped, while in still another they are triangular, deeply toothed and provided with a white bloom on the under side. The groundsel, ragworts, squaw-weeds and butterweeds or *Senecios*, are relatives of the Indian plantains. The eight or nine varieties which are found in Minnesota have somewhat the appearance of yellow-flowered asters. In most of them there are, as in mustards, rosettes or root-leaves different in shape and appearance from the stem-leaves, and the flowers are commonly borne in flat-topped clusters. These plants cannot be mistaken for the hawk-weeds and their allies because they have no milky juice. One variety, the marsh fleawort, or marsh groundsel, is an abundant swamp plant with a beautiful flat-topped cluster of yellow heads borne on a very stout, hollow stem from six inches to two feet in height. In some of the groundsels the leaves are deeply pinnately divided, while in

FIG. 207. Cone-flowers. After photograph by Williams.

others they are more nearly entire. The root-leaves in all instances, with perhaps one or two slight exceptions, differ in appearance from the leaves on the flowering stems and are generally larger.

The burdocks are herbs with very large ovate leaves, cottony on the under side, but becoming dark green above. Two varieties occur in Minnesota, the large burdock and the small. The flowering heads in each are surrounded with involucres, the scales of which become hooked at the end and barbed so that the whole flower head separates when in fruit and is distributed on the fur of animals. The seedlings of the burdock spring up, therefore, in little clusters, one from each of the numerous enclosed fruits. Both species are locally known as "wild pie-plant" on account of their large leaves like those of the rhubarb.

FIG. 208. Prairie cone-flower. After Britton and Brown.

Thistles are stout herbs of wand-like habit, often ten feet or more in height and with handsome heads made up of pink or purple tubular flowers. The foliage and the involucre is protected by spines and the fruits are provided with abundant pappus, sometimes of plumy and sometimes of hair-like bristles. Related to the thistles is the bachelor's-button or corn-flower. In this variety the marginal flowers of a head are not strap-shaped, but are overgrown tubular flowers, blue or purple in color.

Summary statement. There have now been passed in review a considerable number of Minnesota plants, sufficient to illustrate all the important groups. The lower groups are marked by relative simplicity of structure, increasing in complexity to the highest. Such plants as the thistles and sunflowers occupy in the plant kingdom a position similar to that of man in the animal kingdom. Structurally they are the most improved. Especially in the composite family should it be observed that the *flower cluster* has become an area perfected under somewhat the same laws that were seen to govern the perfecting of the *flower.* It will be remembered that the flower itself is supposed to have originated from groups of leaves arranged on a slender axis. As this axis abandoned its starchmaking work, the leaves were gathered into a more compact structure by the shortening of their general stem. Thus from cones like those of the pines arose the flatter aggregates of spore-bearing leaves known as "flowers" in the higher plants. These flowers were essentially branches of the stem and in the lower families such branches more commonly maintained their primitive position with reference to each other, so that the flowers were arranged loosely upon the plant. In higher forms definite flower clusters of particular shape came into existence and the law of condensation finally permitted the production of the flat-topped cluster of the sunflower in which hundreds of flowers are gathered together on a broad circular disk. Among these flowers of the disk a division of labor

FIG. 209. Water bur-marigold. After Britton and Brown.

FIG. 210. Corn-flower. After Britton and Brown.

arose so that some flowers abandoned their stamens and pistils and became converted into neutral ray flowers, useful in adding to the attractiveness of the cluster, thus possibly inducing insects to visit it more freely. The heads of flowers came themselves to stand in definite compound clusters, so that just as there was a spike of *flowers* in the plantain family there later came to exist a spike of *flower-heads*, as in blazing-stars, and just as the flowers of the high bush cranberry learned to stand in flat-topped clusters, so in the thoroughworts and asters. heads of flowers were arranged in similar inflorescences.

Each flower of the composite head shows a high degree of fusion between its parts. That is to say, it is a flower of high rank. The originally separate carpels are blended in pairs into the fruit-rudiments, one to each flower. The stamens in all Minnesota genera of composites except one are fused. The petals of the corolla are blended into a tube which in some of the flowers becomes split, to make the strap-shaped corolla of the dandelion or the strap-shaped ray flower of the daisy. The calyx parts are blended together into a calyx tube and this becomes fused with the surface of the fruit-rudiment, developing in many of the genera a distributing apparatus made up of bristles, variously arranged and of various structure. The leaves below the flowering head, in such forms as the burdock and cocklebur, become modified to assist the distribution of the seeds.

Three types of higher plants may be regarded as terminal, the orchids standing at the top of the series of plants with one seed leaf, the dogwoods at the top of the lower series of two seed-leafed plants, and the sunflowers, dandelions and thistles at the top of the highest series. Among orchids, the flower cluster was not highly improved as such, but the perfecting tendencies worked rather toward the production of a much complicated floral mechanism, irregular in shape, reflecting the strong influence of those forces which develop bilateral symmetry, and very exact in its adjustment to the habits of the insects which co-operated in its pollination. The clusters of the dogwood, although not so fully perfected as those of the sunflower, showed, in the arrangement of their flowers, some tendency towards the perfection of the flower cluster as a unit.

Especially in the flowering dogwoods and dwarf cornels, with their conspicuous bracts below the heads of flowers, did there arise an adaptational response to the tastes and habits of insects, equivalent to that secured in sunflowers by the specialization of the ray flowers. In the bunching of the edible fruits of dogwoods and in their high coloration, the *fruit-cluster*, as such, became a definite factor in the mechanism of seed distribution; for the aggregation of the fruits made them more attractive to birds and animals, therefore more likely to be disseminated than if they had been scattered loosely over the general surface of the plant. In composites, winged distribution has, for the most part, been adopted, and in this family highly colored, pulpy and edible fruits do not exist. The aggregation of the flowers, however, is perfected and the co-operation of the calyx, from which the pappus is formed, makes the distribution of the fruits quite as certain as among the dogwoods.

A sunflower head may, upon the whole, be regarded as the most perfect structural response to the static conditions of the plant world, just as the human head, with its wonderfully perfected brain and sense organs, may be regarded as the highest structural response to the dynamic conditions of the animal world and of animal life.

Chapter XL.

Adaptations of Plants to their Surroundings.

It has already been remarked that plants which resemble each other in external form must not for that reason alone be considered as related. Indeed, quite the opposite is often true, and plants that are outwardly very dissimilar are found upon careful examination to bear the marks of kinship. Thus, the locust tree and the pea vine are really connected with each other much more intimately than are locusts and ashes, although the latter are similar in size, in habit of growth and even in the production of such special types of starch-making organs as pinnately-compounded leaves. Plants may, however, for purposes of investigation be arranged in groups according to their adaptations to the various conditions of life and growth. Such adaptational groups will include plants of widely different genealogy, but throughout there will be discovered certain similarities of structure and habit. Thus, for example, among aquatic plants there are often striking likenesses in structure between comparatively unrelated forms, and it is in many instances a puzzling problem to determine just which structural resemblances are indicative of true relationship and which are indicative of similar adaptations to similar conditions. The submerged leaves, for illustration, of the water crowfoot or water buttercup are in general appearance not particularly different from the submerged leaves of the bur-marigold. In both plants those leaves produced underneath the surface of the pond in which they live are dissected into fine, threadlike portions. Again, the quillworts, plants belonging to the fern alliance, bear the same type of cylindrical hollow leaves that is distinctive of the water lobelia—a member of one of the highest families of flowering plants. Or, passing to plants of a different habit of growth, it may be noted that the curious, compressed forms of vegetation characteristic of cacti are almost exactly reproduced in members of the unrelated spurge family at the Cape of Good Hope. The pitcher-plant and sundew have developed apparatus for catching small insects and converting them into food for their own uses, and somewhat similar contrivances are met with in the bladderworts and butterworts; but the two groups of plants, so far as true relationship goes, are very widely separated. With such facts in mind, it is apparent that, if genealogical connection be ignored, plants may be grouped according to their adaptations. By this means certain interesting truths may be emphasized concerning the influence, upon plant structures and habits, of the surroundings. Before entering upon any discussion of the various adaptational groups of plants represented in Minnesota, such as water plants, desert plants, carnivorous plants, perching plants, mat plants, wand plants, shade plants, sun plants, rock plants, marsh plants and a number of others, it may be briefly noted what are the principal external conditions to which plant structure and habits are adapted.

Gravity. A plant, like any other natural object, must maintain itself under the constant influence of the force of gravity, and it is, therefore, necessary that it should be architecturally well constructed. An imperfectly constructed tree trunk could not bear the weight of its branch-system, nor of its thousands of leaves and possibly of fruits, unless—precisely as in works of man, such as elevators, aqueducts or bridges—the laws of engineering had been obeyed. Certain necessary ratios exist, therefore, between the thickness of tree trunks, the tenacity of the wood, the height of the tree, the number of branches, and the angles at which they stand upon the main axis. For this reason a limit is fixed for the height of land vegetation, beyond which it is extremely difficult to pass. If, however, in the life of the plant some method is found by which support can be obtained from without, much longer stems can then be produced and they can remain of slenderer habit. Thus the climbing bittersweet, the wild grape vine, the trumpet-creeper, the pipe-vine, or the bean, are enabled to produce stems much longer in proportion to their thickness and strength than would be possible if they did not utilize neighboring vegetation to help bear the weight of their leaves, twigs, flowers and fruits. The support that is obtained by a plant stem need not necessarily consist of the vegetation around it, but the stem may lie flat upon the ground, as does the strawberry runner. Thus supported, it can remain slim and fragile, but it could not do this if it main-

FIG. 211.—Bur oak and bracken fern. Illustrates relation between strength of stem and the weight to be borne. After photograph by Hibbard.

tained an erect habit. Again, water surrounding the stem and leaves of a plant may furnish the necessary support, and the plant is free to produce slender organs which collapse when removed from the water that buoys them up. Thus, in the pipewort, which, from the bottom of a lake, lifts a thread-like stem ten feet or more in length, an organ is formed that could not be thus developed under ordinary terrestrial conditions.

A great many other adaptations besides these simple ones of length and thickness of shoots might be discussed at this point. For example, it is necessary that seeds or fruits, borne at the tops of trees, should not be of such structure that they would be broken and injured by falling to the ground. Cocoanut seeds, therefore, which are heavy and are produced at a considerable height, have thick, hard shells and are not injured by their fall. A definite relation commonly exists between the stem of a leaf and the blade, or flat portion, so that the leaf is extended in a position such that its leaf-green can do the work of starch-making under the influence of sunlight. So the stems of large leaves are generally strong and often of a half-cylindrical shape, giving the strength of an arch to the lower surfaces. The network of the large leaf is stronger than that of the small leaf, just as a large umbrella must have a stronger frame than a child's parasol. If leaves or fruits are produced close to the ground they may become larger, while remaining more delicate in structure, than if they were produced at a considerable height. In the one instance the fall would be harmful, while in the other the influence of the wind would enter as a factor.

Mechanical forces. Besides being exposed to the force of gravity acting constantly upon its structure, and consequently rendering due attention to strength of materials a prime requisite in plant architecture, the organism is subjected to various forces which would tend to demolish it unless it met them with properly constructed areas. As examples of such agencies, there might be mentioned currents of air, which if violent are often known to damage the bodies of plants; currents of water, to which plants growing in rapid streams are particularly exposed; the action of waves, to which the various surf plants must adapt themselves; and the pressure of soil, air and water, by which the different parts of plants are constantly affected. In erect terrestrial vegetation elasticity is to a certain degree a requisite of structure. This is particularly true of such stems as are slender, unsupported, and exposed to the influence of wind or surf.

Beautiful examples of elastic plant organs are furnished by any field of grain over which a gust of wind is passing. The stems with their heavy heads of fruit, under the breeze bend almost to

FIG. 212.—Willows and bulrushes. The latter are typical surf-plants. After photograph by Williams.

the ground, then as the air becomes calmer elastically swing back again into the erect position. Or, when it is blowing a great gale along the lee shore of some Minnesota lake, one may see the bulrush stems beaten into the water by the wind and surf, only to rise again erect and unharmed when the waves are calm. Such elasticity is procured by special structural areas in the stem, disposed in highly accurate fashion so as to take up the lateral strains evenly and effectively. The cross-section of a bulrush stem shows it to be as cunningly constructed as the finest bridge-truss, with girders, flanged in the regulation style, made up of the so-called "tension pieces" and "compression pieces" of the architect, and constituting an altogether admirable piece of structural engineering. Such contrivances are not needed by plants growing under other conditions and will not be found. Elasticity, for example, is not a noteworthy characteristic of the stem of submerged aquatic plants living in quiet pools; but if the stem grows in running water it is sometimes more elastic. Roots, in general, being underground in their habit, are not so much exposed to occasional displacing forces as are stems and, therefore, are by no means so elastic. It is easy to compare, in these regards, a grass stem and a grass root. If the living erect stem of a rye plant is bent down it quickly resumes its original position; but if the root is bent to one side the resumption is but slight, or there is no resilience.

In certain parts of the world, where heavy falls of snow occur, a weight is in this way piled upon the branch system, and the plant perhaps responds to such a climatic state by growing in the form of a flat, prostrate shrub, as many of the heaths have done. Or, if it be a tree, it learns to produce strong drooping lateral branches like those of the spruces. When grown in a lawn, these trees retain the droop of their branches or branchlets—originally a structural device for shedding masses of snow, that might otherwise break the branches by their weight.

Plants that produce abundant and heavy fruits must, if they support the weight of these fruits, develop strong branch systems, or otherwise the body of the plant will be broken. Of this the apple trees of orchards furnish good examples. The branches of the apple are pulled into a more horizontal position by the increasing weight of the fruit and many of them actually droop. The main branches will, however, be found to be strong and well buttressed against the trunk. Very often, under a heavy branch the trunk of the tree is especially strengthened to bear the weight. And so, too, against the massive roots of a tree, the trunk is often buttressed because it is against these points that the pressure is exerted, when the tree top is pushed laterally by the wind. Plants with comparatively slender branch systems may mature large fruits if they let these fruits lie upon the ground. This is the device adopted by the gourd family, and the gigantic pumpkins and squashes which are so often exhibited could scarcely be borne, except under very exceptional conditions, upon plants that carried the whole weight of such enormous bodies themselves. Some plants, it is true, manage to suspend extremely heavy fruit areas. Thus, the banana forms a bunch of fruits weighing in the aggregate some scores of pounds. But it is borne close to the main trunk and is hung in such a way that the strain is not unbearable. Cocoanuts, which form heavy fruits at a considerable height, have them placed close to the center of the tree, not out near the tips of the branches like those of the apple.

The relation between the sizes of leaves and their exposure to the winds has already been mentioned. It is not possible for large, thin and delicate leaves to maintain themselves under climatic conditions in which heavy winds are prevalent. If large leaves occur in windy districts, their edges are strengthened by special adaptations of the leaf network. Very beautiful examples of strengthening devices for the edges of leaves may be seen in milkweeds, basswoods or catalpas. In the latter tree, especially, the edges of the large, heart-shaped leaves are faced by arch after arch of network, making the margin of the leaf very strong against any lateral tearing agent.

A consideration of the points which have been thus briefly presented will show how reasonable it is that the longest stemmed plants in the world should be oceanic, for such stems have water on every side to support them. It will be equally apparent how reasonable it is that the most massive plant structures and the strongest should be the trunks of trees on land, for these, of all plant organs, have the greatest need of strength if they are to perform their work and meet the forces to which they are subjected. The difference of elasticity between different plants growing under different conditions, or between two differently conditioned organs of the same plant, will appear altogether comprehensible. After such facts have become familiar it should not be difficult to infer something of the history of a plant from its general architectural construction. The droop in the branches of a spruce tree comes to have its significance, and the prostrate bodies of the cranberry or partridgeberry tell a similar story of the flattening effect produced by heavy falls of snow.

Heat. Another natural force to which plants must necessarily adapt themselves is that of heat. Therefore, under different temperatures different forms and habits of vegetation may arise. The range of temperature under which dormant life can be maintained is apparently a pretty wide one—between 400 and 500 degrees centigrade. The spores of some bacteria can endure boiling for an hour or more and, for a short time, a dry heat somewhat higher, while certain seeds have been exposed for a season, without killing them, to the low temperature of liquid aid. But the limits of plant growth, so far as regards temperature, are considerably narrower. A few blue-green algæ are able to maintain themselves in hot springs, the waters of which would burn the hand, while the little red-snow plant grows upon snowdrifts on mountain tops. Between these limits—scarcely 100 degrees centigrade—are the temperatures at which active plant life and growth is possible.

The form of plants is quite different under an average low temperature from that which is developed in areas of greater warmth. So, therefore, a very characteristic arctic vegetation arises in contradistinction to that of the tropics. A comparison of polar with tropical vegetation will serve to indicate what are the influences upon plant form and structure of relatively high and relatively low temperature. For the most part the vegetation of the polar regions is dwarfed, consisting of low, tufted plants, little shrubs, stunted herbs, mosses and lichens. In such regions the great luxuriant trees and herbs of the tropics are unknown. So, in the matter of size, the poles and the tropics favor just the opposite sorts of plants. In polar regions there is only a short growing season and during the rest of the year the temperature is so low, and the illumination so poor, that plants, like many of the animals, are compelled to pass into a dormant condition. Not all of them hibernate in the same way. A few polar species are annuals, shooting up from the seed during the short polar summer, rapidly maturing their flowers and fruits, and passing the long cold winter as little plantlets, wrapped up in their protective seed coats. There are, however, a greater number of biennial and perennial polar plants. Some of these are shrubs, like the poplars and willows, which grow a very little from year to year, quickly mature their flowers and fruits, and pass the winter in a leafless, dormant state. Such a rhythm in the plant, established to meet the rhythm in the outer world, results, as has been previously noted, in that general habit of shedding the leaves which characterizes so many plants of the polar and temperate regions.

Besides their dwarfed size and their various habits of hibernation, plants of cold regions exhibit numerous protective devices against the cold. The seed coats are thick, and sometimes the seeds are inclosed in warm fruits; the leaves and stem are often clothed with hairs; the young twigs are covered over with protective scales, forming the well-known object that is called a *bud;* and "warming-up colors" are developed, especially where there is need for them to protect the delicate portions of the plant. The ends of the shoots are particularly rich in the warming substances. Peat-mosses are good examples of this, for in a great many of them the ends of the branches are violet, red or purple, while lower down they remain green. Bud scales are commonly purple, and alpine and polar flowers are more likely to be blue or violet than yellow or red. By this means the temperature of a flower in which the delicate pollen spores are formed, or the temperature of a young twig, surrounded by its purple bud scales, is raised somewhat, and the unfavorable influence of the cold is, to some extent, counteracted. The efficiency of the "warming-up color" may be tested experimentally by any one who cares to take the trouble. If two similar thermometer tubes are selected and around the bulb of one of them a green leaf is tied, while around the bulb of the other a purple leaf, such as that of the beet or of certain begonias, is wrapped, and the two thermometers are then laid in the sun, after a short time it will be found that the one with the purple leaf is registering from six to ten degrees higher than the other.

So, too, if a thermometer bulb is imbedded in a bunch of violets and laid in the sun, while another is imbedded in a bunch of primroses, the one in the violets will register a higher temperature after both have been lying together in the sunlight. The recognition of the warming-up color of plants as a heat-producing substance gives a basis for the explanation of a great many facts that would otherwise be difficult to understand. Autumn foliage can be understood to be a definite response of the plant to the falling average temperature, by the development of a heat-producing area of its own. The purple bud scales, so common in trees that grow outside the tropics, purple tints in bark and in leaves, and the purplish or reddish colors of flowers, are all recognized as having the same general significance.

At this point it is possible to understand how, in a great many species, the color of flowers may have originated. As has already been explained, the flower is essentially the end of a branch, and the coloring substances which it contains are possibly to be attributed to protective heat-producing substances present in the race-history long before flowers were developed as such. When flowers came to be formed it was important that their pollen should be protected against cold, and the heat-producing colors were not abandoned but accentuated. In many blue, violet and red flowers it is possible to read a story of defence against cold. Hence is made clear the reason for so many very early flowers, like the pasque flower, maple flowers, violets and anemones, being purplish in color, and for late flowers, such as the gentians, having the same blue or purple hue. It is also easy to understand how flowers on the mountain tops should be so often blue and that flowers of the polar regions should show the blue, violet or reddish tints. With such facts in mind it is possible to recognize violets and anemones as, for the most part, northern plants, while goldenrods and evening-primroses indicate a southern origin.

Another useful habit of plants in polar regions is their tendency to form stores of reserved food-material, such as underground fleshy roots, stems or tubers, or subterranean bulbs. A great variety of plants with such habits are common in Minnesota. On account of its provident behaviour the plant is able to begin the development of its flowers and fruits immediately after the cold of winter is past. When the growing season is short, it is particularly important for plants to ripen their fruits speedily, or they will not be able to ripen them at all, and under such stress, in the plants of cold countries, very rapidly growing flowering stems are produced. Arising from a fleshy root, a starch-packed tuber or a solid bulb, they open their first flower perhaps within a week after the snow has gone, finishing their fruits before the end of spring. Such unnecessary haste in a climate like that of Minnesota indicates an adaptation to a colder region; and the willows and poplars, for example, which scatter their fruits in the spring or early summer, may be found abundantly distributed far to the northward, even to the barren lands of arctic Canada. More leisurely plants which do not ripen their fruits until the late autumn, such as the grapes, the gourds, the goldenrods and the asters, by this very fact show their southern ancestry, and they will be found better developed in the south than in Minnesota. The colors of flowers, the methods of hibernation and the presence or absence of reserve organs, such as bulbs, are all of much value in determining the probable climatic history of a plant.

Some movements in plants are significant as indicating an adaptation against loss of heat. A great many flowers close at night. This is particularly true of the flowers of northern plants, though it is a device which is common enough in many species growing in regions where the nights are cool. By the closing of the flower nocturnal radiation of heat is diminished and thus the pollen spores are protected against undesirable chills. Sometimes the flowers do not close, but place themselves in peculiar sleep-positions. Thus a pansy flower, which is erect in the daytime, bends over and faces the ground at night. Such new night attitudes are not limited to flowers, but may be adopted by leaves as well. At night the leaves of the clovers and locust trees will be found in quite different positions from those which they maintain during the day. The nocturnal position is probably a device for limiting the radiation from the plant body. Incidentally it is useful in preventing the condensation of dew. Such modified positions are sometimes taken suddenly, as by the leaves of the sensitive plant, an instance for which no doubt other and special reasons must be assigned. In general the so-called sleep of leaves and flowers is an adaptation to the falling temperature after the sun has set.

When plants grow in warm regions they often manifest a number of characters which are the reverse of those to be looked for in plants whose home is nearer the poles, or at a greater elevation. Thus in many tropical plants the production of special reserve storage organs is less considerable than among related species of colder climes. Buds are not so carefully protected. Furry coats on the leaves or twigs are not so abundantly formed—except, it should be said, by desert plants in which furry or hairy coatings arise as a protection against the too ardent rays of the sun. In the tropics, since hibernation is unnecessary, the various hibernating habits fail to appear, and plants do not so commonly grow as biennials. The foliage is not shed at the end of a definite growing season, but normally drops only when exhausted or when shaded out of existence by younger foliage between it and the sun. The heat-producing qualities, as manifested by color, are not so marked a feature, and a great many white, yellow and mottled flowers occur, like those of most tree-top orchids in the equatorial forests. Evergreen plants, such as the live-oak, flourish in the south; in temperate regions the oaks are deciduous, though retaining the character of trees, while in the far north, oaks, which would be trees in more southern ranges, become stunted into little shrubs. It is possible, in view of such facts, to understand how dwarf shrubs may occur in certain genera, as, for example, the dwarf cornel among the dogwoods; the dwarf snowberry, among the honeysuckles; or the dwarf willow, among the willows. It is possible to understand, too, how very hairy varieties may develop under climatic conditions different from those which favor the production of smooth varieties of the same plant. The silky dogwood may thus be regarded as a species showing in its foliage a response, either to the lower average temperature, or to more direct illumination by the sun than the smooth-leafed dogwood.

Light. Another form of energy, which has a strong effect upon the structure and habits of plants, is light. Some plants are so constructed that they can exist with much less illumination than others. This is particularly the case if they are devoid of leaf-green, and certain fungi are able to grow and mature their fruit-bodies in absolute darkness. The ordinary green plant must, however, be supplied with illumination sufficient for the use of the starch-making machinery,—for leaf-green may be described as a variety of *light-engine*. Hence there arise, especially in the leaf-areas of plants, a variety of adaptations by means of which the leaves are spread out to the sun. If a plant

FIG. 213.—Elm tree growing in the open. Light is received on all sides. After photograph by Williams.

is growing where it is not shaded by other plants, it may assume the mat or carpet habit of growth; but if it is shaded by other plants it must become taller in order to get its share of illumination. The positions of leaves on the plant body are, in the economy of the plant, often very carefully adjusted, so that one leaf fits quite exactly into the spaces between other leaves. Thus, what are known as *leaf-mosaics* are formed. The leaves sometimes make a rosette at the base of the fruiting stem, a condition that may be seen in a dandelion, in the evening-primrose, or in the mullein. In other plants the shapes of the leaves are modified by their mutual relations to each other upon the general stem tract. Thus the one-sidedness of elm or hackberry leaves will be found to be dependent upon the relative positions of the leaves upon the twig. The side of the leaf which is less protuberant is the one that is shaded by the leaf above. The sizes of leaves vary considerably with their illumination. Thus the leaves of plants in shady places are generally larger than those of plants growing in the sun. The trillium and jack-in-the-pulpit leaves, for example, are considerably

FIG. 214.—Two-leafed wood-lilies. These plants have the broad leaves of shade plants and the white, conspicuous flowers. After photograph by Hibbard.

broader than the ordinary leaf of their class. Some grass leaves belonging to species growing in the deep woods are decidedly broader than ordinary, and the forest-dwelling asters and goldenrods are conspicuous for their broad leaves, quite different in shape from the willow-like or linear leaves of the sun-loving varieties.

It is well known that light retards that actual increase in size of plant organs which alone should be called growth. It is well to distinguish between *growth*, meaning by this, increase in size, and *nutrition*, meaning by that, increase in substance. Plant stems usually become more extended in the dark than in the light. Thus, if potatoes are allowed to sprout in the cellar the stems produced under such circumstances are quite different

FIG. 215.—Jack-in-the-pulpit. A shade plant. After photograph by Hibbard.

in appearance from those grown in the ordinary way. Consequently, the principal hours of growth are those of the night, and corn-staiks, if carefully measured, will be found to increase in length most rapidly between midnight and morning.

While light has a retarding influence upon the growth in length of stems, it has a strong directive influence upon organs, so that they tend to place themselves parallel with the rays, or transverse to them, as their nature may be. It is well known how the leaves of geraniums growing in the window turn toward the light. Nasturtium vines turn very quickly and if one of these plants be put in the window, it will in a short time stretch out its leaves toward the light and place them vertically to the rays, thus securing a maximum illumination for the starch-making apparatus. Some plants are not thus sensitive

FIG. 216.—Leaves of the sensitive fern, a shade-loving variety. After photograph by Hibbard.

to light. For example, such climbing plants as the ivy or the woodbine do not instinctively bend toward the light, because to do this would tear them from their supports; therefore, they remain either insensible to the directive influence of light, or they actually turn from it, as do most roots.

Where the light is strong and abundant, there are often developed purple layers on the under sides of leaves to utilize the surplus light by converting it into heat and employing it for the growth-energy of the plant. This is true of such large floating leaves as those of the water-shield, in which the upper side of the leaf is green and the lower is purple. The giant lily of the Amazon, sometimes cultivated in aquatic gardens of parks in Minnesota, has great shield-shaped leaves, two feet or more in diameter, and fitted to float upon the surface of the water. The edge of the leaf is turned up to prevent ripples from breaking over the surface. While the upper side is green the under side is violet or purplish. The surplus light, not used in starch-making, is, in such a leaf converted, by the purple coloring matter, into heat, and is not lost.

When leaves form rosettes an adaptation for saving the surplus light is often noticeable. Thus, the under sides of dande-

FIG. 217.—The Virginia creeper on the walls of the old round tower, Fort Snelling. This plant does not turn towards the sun, but clings to the shaded wall. After photograph by Williams.

lion leaves are commonly purple; and in a great many other rosette-forming plants the leaves of the rosette will have the color scheme which has been described. Hanging or swinging leaves that are swayed by the wind, for reasons that are sufficiently obvious, do not so often have the two sides colored in this manner.

Protection of the leaves against an illumination strong enough to injure the starch-making machinery within, is of various types. Sometimes the leaves are covered with scales, or hairs, thus tempering the light. Sometimes they are capable of changing their positions, so that when exposed to direct sunlight they shift from the transverse to a more vertical position. This is true of leaves in the compass plant and many leaves on a variety of herbs. In some of the Australian blue-gum trees the leaves stand with their edges vertical, and similar positions are very often maintained by grasses of the prairie. When a plant has adopted the mat habit of growth, indicating the absence of shade around it, it commonly shows very small leaves, and no Minnesota mat plant, lying exposed to the full glare of the sun as it does, has large leaves.

Moisture. The adaptations of plants to moisture are various. Some plants live quite submerged in water, and others find

FIG. 218.—"Gallery woods," near Minnesota Falls, valley of the Minnesota, in the prairie district. Dependence of trees upon moisture is illustrated by their grouping in declivities. After photograph by Professor R. D. Irving.

their most congenial home in deserts, or on the surfaces of inhospitable rocks; while between these two extremes of station there are a great number of intermediate conditions worthy of careful and extended investigation. All plants need some moisture. Usually this moisture is absorbed by a special area of the plant known as the root system. But leaves are, in some varieties, able to absorb moisture, and aquatic plants characteristically absorb over their whole surface. There are sometimes presentations of liquid to the plant which it finds undesirable. For example, foliage guards itself by a variety of devices against the heavy rains of the tropics. Many of the same contrivances may be seen in plants of northern regions. If leaves are exposed to a heavy rainfall the surfaces are often lacquered or waxy, and, by means of the coating, rain is diverted and there can be little danger of the tissues becoming water-logged. Upon such leaves grooves or furrows may be developed. Through these the water is quickly drained and is not allowed to accumulate. Slender points are distinctive of leaves upon which too much moisture accumulates for the good of the plant, and especially in tropical forests are these rain-tips, as they are called, ordinary characters of the leaf. It has even been shown that trees growing in the spray of waterfalls develop leaves slightly different in shape from the ordinary leaves of the species and marked both by furrows on the upper side and by elongated tips. Because of the danger of rain or dews clogging the air pores of leaves these tiny apertures are in most instances assembled on the lower surfaces of leaves, where they are protected. Or, if they occur on the upper surfaces there are hairs, or pegs of cell wall substance, or blooms of wax or shellac, which guard them and make it difficult for them to be wet. Such protections against moisture are particularly common in flowers, where it is essential that the pollen should be kept dry. The shapes of the petals, the positions of the stamens, and a variety of other adaptations make the wetting of pollen by rain improbable. Many fruits are furnished with blooms of wax or with hairs by means of which they easily shed water. No such contrivances are to be looked for in the root system, or on the leaves or stems of submerged plants. In water-lily leaves and other floating varieties, where the air pores are all upon the upper surface of the leaf, decidedly waxy coatings are often developed to keep the water from the pores. In some varieties, as, for instance, the oleander, the pores open into special chambers or depressions, on the under sides of the leaves, and the mouths of these are guarded by "non-wettable" hairs, thus affording absolute protection to the air pores. Many of the different positions, shapes and textures of leaves and flowers are to be ascribed to such adaptations against unfavorable moistening.

The root tract of plants, which in most instances is the special absorptive area, is fitted by structure and position for the work it has to do. The young roots are furnished with innumerable delicate hairs and these are thrust between the crevices of the soil to collect whatever moisture there may be present. If, however, the roots are immersed in the water and hang down like the little balancing roots of the duckweeds, root hairs are not then so abundantly produced because moisture is plentiful everywhere around the root and no special arrangements for its collection are necessary. Moisture, after having been collected by the plant through the activities of the absorbing surfaces, is evaporated, and the residue is left in the plant, either to be combined with other substances in the plant chemistry or to remain as a useless by-product. Evaporation and transpiration of water vapor are the ordinary methods by which plants rid themselves of the superfluous water they have absorbed; but some varieties exude it in drops from special water-excreting glands. Thus, fuchsia leaves, if well supplied with water at the root, will excrete it in little drops from each tooth of the leaf margin.

There are at least three conditions under which plants find it undesirable to excrete or transpire water rapidly. One condition is that of the desert, where there is very little water to be obtained, and its rapid transpiration by large evaporative surfaces would result in the wilting of the whole plant. Another condition under which rapid evaporation is undesirable is that of bogs and marshes, and the reason is just the opposite. Here there is such an abundance of moisture that the rapid evaporation of it might maintain an unnecessarily strong stream through the plant tissues. A third condition is where the soil-water is impregnated with salts, and if rapidly evaporated it would be as rapidly absorbed, and the salts would accumulate in the plant tissues to such an extent that they might interfere with vital processes. Consequently there are three groups of plants so situated that, while they permit water to evaporate from their leaves and stem, their adaptations of structure are for slow transpiration. The cacti, with their solid stems and reduced leaf surfaces, are examples of one class. The tamaracks and spruces, with their small needle-shaped leaves, are examples of another, and the sea-blites and glassworts of the salt marshes furnish examples of the third.

A variety of contrivances have been devised by plants to retrench their evaporation. A simple one is the reduction of the evaporating surface. Thus, leaves become small or are altogether abandoned, as in the cacti and glassworts, or the leaves may become thick and succulent, as in the purslanes and claytonias. Sometimes the skins of the leaves are greatly thickened and the air pores are reduced in number, as in the leather-leafed wintergreens and heaths. Often the margins of the leaves are rolled in so as to cover the air pores and protect them from the rays of the sun, as in many prairie grasses, or in the crowberries. Sometimes the leaves are covered with scales or scurf, as in the buffalo-berries. Sometimes strong ethereal oils are produced. These form a "scent-vapor-sheath" around the plant, and thus temper the rays of the sun. For such a reason many desert plants are strongly perfumed, as are wormwoods or sage-brushes. The positions of the leaves upon the stem, and their shapes, are often automatic, regulative devices, connected with the evaporation of moisture. Good examples of leaf-position unfavorable to rapid evaporation are furnished by the cat-tails, flags and sweet-flags of marshy places. In these the ribbon-shaped leaves stand erect and their surfaces are not exposed to the strong illumination of the sun. Hence the evaporation is slight.

Electricity and magnetism. The adaptations of plants to the forces of electricity and magnetism are not well understood, nor have they yet been fully studied. It has been suggested however, that points on leaves, and spines or thorns, may in some instances be devices for the collection of atmospheric electricity.

The soil or substratum. The relations of plants to the soil are somewhat various. The texture of the soil may be either loose or firm. Good examples of loose soil are furnished by sand dunes, and there are a variety of special sand dune plants, the underground parts of which, meeting with little resistance, branch copiously in every direction. The low fertility of drifting sand makes such a broad expansion of the root area essential, and as a consequence the plants that are able to grow on sand dunes commonly bind the sand by their extensive root systems, and may even, if they have become sufficiently established, stop its drifting. In very resistant soils, such as hard clays, less copiously branched root systems are produced. The temperature of the soil, as well as its texture, has a variety of well-marked effects upon root areas, as has also the consistency, the chemical constitution and the aeration. Soils which are very poorly aerated, such as those disposed underneath sheets of water, often make it necessary for roots developed in them to send up aerating tubes or organs. The well known "knees" of the swamp cypresses of the Atlantic region are examples of such organs. A greater or less percentage of nitrogenous substance, lime, magnesium, iron or silica, in the soil has a distinct determining effect upon the forms of plants.

Especially interesting is the soil known as humus, a type which contains a large percentage of decaying organic material. In such a soil many plants without leaf-green are enabled to grow, and upon the humus of the forest floor a wealth of mushrooms, club-fungi, cup-fungi, slime-moulds and various related forms are displayed. Some seed-producing plants, such as the pine-drops, the Indian-pipe, and the pine-sap, together with the coralroots and others, have learned to abandon their leaf-green and have adopted the habits of life similar to those of the fungi.

Other living things. The proximity of other living things is a condition of the surroundings that cannot be disregarded in the discussion of plant adaptations. These neighboring creatures may be either plants or animals. In response to their presence a large variety of curious structures and habits have come into existence. The carnivorous plants catch and eat small insects with which they come in contact. Parasitic fungi, such as the caterpillar fungus or the fly-cholera fungus, attack certain small animals and use their bodies for a soil in which to grow and mature. The roots of louseworts, toad-flaxes, and cancerroots, reach out and attach themselves to the roots of neighboring plants, in some instances deriving their whole sustenance in this manner. A great variety of little fungi develop upon the leaves, twigs, flowers or fruits of other plants, having become accustomed to eke out an existence in this dependent manner. Many plants perch upon other plants; thus, the Spanish moss of the south hangs in festoons from the live-oaks, and the orchids of South America sit in rows, like so many partridges, upon the branches in the forest. The lichens of more northern regions similarly perch themselves upon the trunks, or branches, of trees; and with these, too, a number of mosses and liverworts will be found. Sometimes the perching-plant adroitly selects a position where it will receive more moisture than elsewhere. So, many mosses grow around the bases of tree trunks,—for the tree with its branches serves as a drain, by which the water of rains is brought to the position pre-empted by the moss. Lichens and mosses alike select the degree of illumination that they prefer, and in northern latitudes arrange themselves on the southern sides of tree trunks if they require stronger illumination, but on the northern sides if their requirements lie in the other direction. Some perching plants acquire the habit of driving their roots into the branch upon which they stand. Thus originated the parasitism of the mistletoe and related plants,—quite a different method of its development from that shown by the cancerroots, which learned to clutch the roots of neighboring plants and drive little sucking organs into their soft and nutritious tissues.

Another result of the mutual proximity of plants is the development of climbing or twining species. Some climb by means of prickles, thorns or hooks, and thus the brambles or tear-thumbs lift themselves upon surrounding vegetation. Others, like the scouring-rushes, brace themselves by means of lateral branches and lift their slender stems farther into the air than they could without assistance. The clematis vines twist their leaf stems around twigs that chance in their way and thus show a tendency toward tendril production. Other vines, like the smilaxes, the grapes, or the wild cucumbers, develop perfected tendrils, and by aid of these lift themselves high up on the stems or branches of neighboring trees. The bittersweets, morning-glories and hops learn to roll spirally their slender stems around the shrubs that stand near them, thus twining to a considerable height.

All such habits must have arisen by degrees, and each of them, when accentuated, might encourage dependent habits of nutrition, finally resulting in parasitism. Thus, the twining habit of some morning-glory vine may have given, in some earlier epoch, opportunity for the production of the parasitic dodders.

Intra-specific adaptations. A last group of adaptations that may be considered here are those connected with spore distribution and seed distribution. It is necessary for the well being of the species that new individuals should be given an opportunity to develop. Thus arose such simple primitive adaptations as the elongation of the spore-bearing plant in mosses and liverworts, so that the spores could be distributed over a wider area. More perfected apparatus enabled the spores to be distributed under conditions of moisture such that they would most certainly germinate. As spores assumed a division of labor, devices were adopted by which the two sexual plants might be produced close together, thus insuring fecundation of the eggs. The ancestors of the seed-bearing plants originated methods of keeping the young embryo close to the vegetative areas of the preceding individuals in the species line. In this manner there arose in the plant kingdom such complex structures as flowers and seeds. With the added complexity of structure it became possible for a great number of slight differences in detail to exist and thus the highest division of the plant world, that of the seed-bearing plants, is also the one in which the greatest number of different species are described. A vast number of intricate adaptations for pollination, embryo-nursing, and seed distribution came into existence. In some families of plants wind pollination, or wind distribution of seed, became the rule, while in others the seeds are distributed by animals and the pollen spores are planted on the stigma of the flower by the same animate agents. All the manifold variety of form in flowers and fruits may be regarded as due to adaptations, more or less perfect, by which the two sexes of plants are developed sufficiently near together, by which the young plants may derive benefit from supplies of nourishment produced by maturer individuals of their species, or by which they are placed under conditions favorable for their growth and for the best interests of the species as a whole.

FIG. 219.—Dandelion fruiting in shady spot. Shows the slender stems and erect root-leaves of the shady habitat, and fruits adapted for wind distribution.
After photograph by Hibbard.

Chapter XLI.

Hydrophytic Plants.

The different adaptational groups of plants may be best classified under three main divisions, according to the relation between the structure of the plant and the moisture of surrounding conditions. For one series of plants the moisture of the surroundings may be considerable, for another it is ordinarily slight, while for the third a middle condition is maintained. Thus, there are three principal adaptational groups, known respectively as *hydrophytes*, of which aquatic species are typical; *xerophytes*, of which desert inhabitants are characteristic forms; and *mesophytes*, in which group may be classified the common herbs of meadow and forest, growing under medium conditions of moisture. It should be noted in passing that while the essential structural adaptation of desert plants is toward the slow evaporation of moisture, there are also other conditions, besides those of desert life, that make rapid evaporation undesirable. Hence plants growing in peat-bogs, such as tamaracks and spruces, or plants growing in saline localities are said to have the xerophytic type of structure and, like true desert plants, are slow to transpire moisture. A number of different subdivisions of the three main classes may be described, and one should regard the marsh and swamp varieties, and those living in saline soil, as furnishing the transition to the true middle group, that of the mesophytes, which will here be discussed after a brief account of the other two.

Out of fourteen classes of hydrophytic plants described by Eugene Warming, in his classic work upon adaptational groups of plants, eight are represented in Minnesota. Those unrepresented are either arctic or alpine, such as the snow plants, or marine, such as the seaweeds, and the mangrove swamps of oceanic coast lines.

Plankton. The first class of hydrophytic vegetation is that known under the technical term of *plankton* vegetation. By this is meant the passive, free-floating vegetation, not rooted or attached to the soil in any way. To this type, no doubt, belong the earliest forms of life that appeared upon the crust of the earth. Here are to be classified many algæ—such as the familiar water-flower of Minnesota lakes, which, as will be remembered, is a type of blue-green algæ. A number of Minnesota varieties belong to the algal plankton, for here are included not only the water-flower, but such forms as the sphere-alga, the pond-scum, the desmids and diatoms, the rolling alga and a number of others. Some of these plants are characterized by the production, between their filaments, of interlocked gas bubbles, by which they are enabled to float at or near the surface of the water, and thus to receive the sunlight. In many of them there are formed reproductive bodies provided with swimming lashes, and by the aid of such little motile cells the plant may be distributed throughout the water of a lake or pond.

Another group of plankton vegetation is constituted by the bacteria that live in water. A great many different sorts are known; not only from fresh water, but from the sea. Any drop from a Minnesota lake or river, if carefully examined by the proper methods, would be found to contain great quantities of the bacterial organisms.

Still another group of plankton vegetation is what may be called derived, or secondary plankton. This group is composed of passive, free-floating plants which are, from their structure, evidently derived from ancestors that were rooted. To this division belong the little water fern *Azolla*, the duckweeds, forming such abundant scums on stagnant pools, and the bladderworts, together with some varieties of liverworts, such as the swimming *Riccia* and the floating *Riccia*. A number of peculiar adaptations exist in plants of the derived plankton. Often in their bodies there are air chambers by means of which they float. These may be seen in cross sections of duckweed plants or *Riccias*. Sometimes the air chambers are developed as special pouches or bladders, as in bladderworts, where they also fulfill another function—that of capturing small animals for food. If the plant floats on the surface of the water, with its upper side exposed to the air, as do the duckweeds, certain special structures are necessary. First of all, proper counterpoises must be carried to prevent the plant from being turned upside down by the ripples. In the duckweeds these counterpoise areas are readily seen to be roots, or groups of roots, but in the smallest of the duckweeds no counterpoise exists as a special organ, since from the very small size of the plants they are able to ride the waves without their upper surfaces being wet. In one of the water ferns—the little *Salvinia* plant, common in greenhouses, where it grows in tanks—two rows of leaves on the floating stem are thrust down into the water and act as counterpoises; but in the wild water fern—the tiny *Azolla*—just as in the duckweeds it is the slender roots that perform this function. Sometimes skillful combinations of counterpoises and floating apparatus are effected, as in the handsome water-hyacinth of conservatories—a species which has become a great pest in the rivers of Florida. In these plants the bases of the leaves, which arise in rosettes, are swollen into spongy, spherical floats, an inch or more in diameter. Below such a circle of floats a tuft of roots hangs down into the water, and it is quite impossible for any ordinary gust of wind to turn the plant upside down.

A second group, also, of adaptations are interestingly developed in the free-floating higher plants by means of which the upper surfaces of natant organs are protected against wetting. Sometimes the surface is very smooth and glistening and the water rolls from it in the spheroidal form just as it does from a buttered plate. This is the condition to be observed in the larger duckweeds. The upper surface of the small disc-like stem of these plants is somewhat convex and very smooth. If water is poured upon a group of duckweeds as they float upon the surface of a pool it will roll off as from the proverbial duck's back, and will leave the little plants as dry and glistening as before. One of the duckweeds, the three-cornered variety, is a partially submerged plant and therefore has not this power of shedding water. Another arrangement is seen in the water fern, *Salvinia.* The upper surfaces of the floating leaves are provided with curious tufted hairs, the tips of which spread out in three or four branches If one of the

Salvinia plants is taken between the thumb and finger and thrust under the surface of the water, air is imprisoned between the tufted hairs and the whole plant glistens as it is submerged. If it is released it rises instantly to the surface, buoyed up by the air chambers in its leaves and stem, and when it emerges the upper sides of the leaves will be found perfectly dry.

Of the planktonic flowering plants of Minnesota, some depend upon the wind for pollination, as do the duckweeds, while others, such as the bladderworts, are adapted to insect pollination. The flowers, therefore, of the duckweeds are extremely inconspicuous, while those of the bladderworts are pretty, yellow, snapdragon-like and elevated upon stems some inches in length, so that they become noticeable objects and are easily found by wandering bees or flies. Some free-floating or plankton plants are particularly protected against the attacks of small aquatic grazing insects or animals, while the bladderwort actually catches and eats the little insects that gather in its vicinity. The *Salvinia* plant is provided, on its submerged counterpoise leaves, with sharp-pointed hairs, and these stand out on every side in bristling defence. The sharp-pointed hairs are particularly useful because the fruits of the *Salvinia* are borne under water, on the submerged leaves, and it is important that they should be protected. The under sides of the floating leaves have also a defence of sharp-pointed hairs, but the hairs on the upper side, since they have a different purpose—that of keeping the surface dry—are of different structure.

Swimming plants. Closely related to the plankton, or free floating vegetation, are the animal-like little plants that swim about in the water seeking decaying organic substances upon which to feed. They are abundant in stagnant water where there is sufficient organic food material. A Minnesota plant, known to botanists by the name of *Euglena*, is an example of this class of hydrophytes. It is able, by means of its green color, to assimilate carbonic-acid gas in the presence of sunlight. It takes up its nitrogenous food from the organic substances dissolved in the stagnant water and is, therefore, in its method of nutrition, partially dependent. The *Euglena* plants are of microscopic size and countless myriads of them in stagnant pools often form dense green scums of a granular appearance. Zoölogists consider them animals.

Rain-water plants. A little class of obscure plants are regarded as of hydrophytic character, since they live on rain-water. The green slime that forms upon mud flats, the bacterial skins that arise upon soil highly charged with organic substances, the blue-green algæ that thrive between the particles of sand upon a moist beach, and the curious algal or bacterial organisms that live under the surface of damp sandstone cliffs, looking like cobweb threads when a bit of the cliff is chipped off, might be given as examples of this class.

Attached water plants. Another adaptational class of hydrophytes is furnished by those species which live attached to stones, either at the bottom of streams or lakes, or upon the surfaces of wet cliffs, or those of bowlders exposed to spray. Several algæ are found in such localities. On wet cliffs a variety of green algæ are to be looked for, and here, too, especially near waterfalls, will be found the very few kinds of red algæ which occur in Minnesota. Sometimes a dark brownish-purple skin of slimy algæ may be seen on cliffs wet by the spray of waterfalls, and this may be a growth of red algæ. In similar localities, and on stones in rapidly running streams, the wire like, reddish-brown algæ of the Minnesota flora are to be sought.

Some higher plants select similar localities—for example, the river moss so common in swift, rock-bottomed streams, where it grows attached to stones and lies in tufts with the current. The very curious riverweed, of which one variety exists in Minnesota, affixes itself to stones in waterfalls, and closely resembles an alga. It is remarkable because it is the only kind of Minnesota flowering plant that opens and pollinates its flowers entirely below the surface of the water. A characteristic structure of attached rock plants in rapid water is the holdfast, an organ which has more the office of an anchor than of an ordinary root. In the river moss the ordinary slender root hairs characteristic of mosses are gathered together in strands, thus giving additional strength, and by means of these little cables entwined around the rough corners of the stones the plant holds itself in place. Plants of this sort with holdfasts and with submerged vegetative tracts naturally do not have abundant air chambers as in the floating varieties. On the contrary, air chambers are often entirely absent. Where, too, the plant is anchored and free to undulate its branches with every ripple of the water there is little occasion for strong mechanical tissues, and no need for air pores or any of the devices for protecting them. Elastic tissue is, however, somewhat useful, and in many plants of this class it is formed. A great number of the submerged plants are slimy to the touch, especially in the ocean. This is well known to be true of seaweeds and it is also the case with river moss and riverweeds. Such slime-coverings may be useful as protections during periods of low water, or they may reduce the friction, upon the tissues of the plant, of the flowing water.

FIG. 220.—Vegetation of ravine. The home of mosses and liverworts. The plants in front are touch-me-nots. After photograph by Williams.

Still another class of water plants are attached under water to loose soils, sand or mud. The water eel-grasses may, perhaps, be taken as examples of this group. Holdfasts are not here developed simply as anchors, but there may also be branching root systems upon which, however, root hairs are often wanting.

Shore and bar plants. The most important class of water plants that are of genuine aquatic habit, so far as developed in Minnesota, are those which may be known as the shore plants and bar plants. These are attached or submerged varieties, growing upon loose soil, generally in communities, with the plant body either entirely submerged or with the leaves floating. The flowers are entirely aerial and pollination cannot go on under the water. It is difficult to distinguish this class of aquatic plants from the related swamp plants that grow close down to the water's edge; and in fact, sometimes the same kind of plant appears both as a lake-border and as a marsh plant, as, for example, the common yellow pond-lily, which may grow upon mud flats, or more ordinarily out a little distance in the pond. Of the shore and the bar plants a number of different varieties belonging to various groups occur in Minnesota. Among the algæ, the bass-weeds, so common as the outer zone of shore plants in almost every Minnesota pond or lake, are most prominent. In some ponds, especially the smaller ones of swales, prairies or meadows, the water mosses are abundant. These have a different adaptation from the river mosses. They do not have strong holdfasts by which to maintain themselves in rapidly flowing water, but are spongy masses of vegetation and evidently near relatives of the carpet

FIG. 221.—Stream-side vegetation. Ironweeds, thoroughwort, mullein, sedge, speedwell and shrubbery. Hydrophytic vegetation in water's edge. After photograph by Williams.

mosses of the woods. When they fruit, the spore cases are sometimes thrust above the surface of the water, but often the spores are shed below the surface. To this group of plants may be referred also the water lobelias, pipeworts, quillworts, the four-leafed water fern and others, including a variety of flowering plants, such as the eel-grass, the water buttercups, starworts, water-lilies, water smartweeds, floating arrowheads, pondweeds and water milfoils.

A number of different and interesting adaptational characters exist among the shore plants. Commonly, when altogether submerged, they have very much divided leaves, as do the water milfoils or water buttercups. If part of the plant is submerged and part exposed, the leaves of the submerged portion may be finely dissected, while the leaves of the emergent area are simple and but slightly notched. Of this the water bur-marigold is an example. Again, the leaves are all submerged and ribbon-shaped, as in the water eel-grass, or they may be quill-shaped, with air chambers, as in the quillworts and water lobelias. When some of the leaves are floating and others are submerged, the floating leaves are often larger and broader than the submerged. Thus, in the floating arrowhead the natant leaves are arrowhead-shaped, while the submerged leaves are grass-like; or, as in the water-shield (not, however, the Minnesota variety), the floating leaves are shield-shaped and the submerged leaves are finely dissected. In other instances, as in the water-lilies, the difference between the submerged and floating leaves is not so great, but a slight variation in texture is not hard to observe. The fine dissection of the submerged leaves of so many aquatic flowering plants is evidently an adaptation, by which a considerable absorptive power is added to the ordinary starch-making function of the leaf. Such finely dissected leaves are easily maintained under water, but they would be likely to shrivel on account of too rapid evaporation if developed in many land forms. The floating leaves, like those of the planktonic vegetation, have adaptations against moistening, so the upper side of the shield-shaped leaf of the Minnesota water-shield will be found to be waxy and difficult to wet. The generally oval or circular shape of floating leaves, or floating stems like those of the duckweeds and swimming *Riccias*, may be regarded as a response to the equal lapping of the waves against the edges of the leaf from all directions. These floating leaves, or stems, are very often purple on the under side, so that the surplus light is converted into heat.

Fig. 222.—Birch trees along a lake shore. Bar vegetation in background. After photography by Williams.

Ribbon-shaped leaves are not so common, but are found as the submerged variety in those arrowheads which have two sorts of leaves, and in some of the pondweeds, as well as in the ordinary eel-grass. More frequent are small, numerous, narrow leaves, or leaves cut up into small and narrow divisions. A number of the pondweeds have such submerged leaves, as also the water milfoils, the waterweed, the mare's-tail and the water starworts. Least usual is the quill-shaped leaf, found however, among Minnesota species in the quillworts and in the water lobelias. Some of the pondweeds have broad, thin, papery leaves, crisp like lettuce, in some varieties, but of a texture different from that of land forms. In general, submerged leaves have no air pores, or these are very sparingly produced. The epidermis or skin of the leaf is not as strongly developed as it is in the case of terrestrial leaves that are fitted for evaporation. Such leaves are decidedly more absorptive than are those of land plants, this function being favored by the thin walls of the skin cells. In originating the forms of aquatic leaves the illumination had probably something to do, and the elongated, ribbon-like leaves on submerged portions of arrowhead plants may be considered, perhaps, to be extended on account of the semi-darkness caused by the water.

The stems of these water plants are as various in structure as the leaves. Sometimes, especially where the soil is loose, the stem becomes a creeping, branched rootstock. This may be embedded in the soil at the bottom, as in pondweeds and water-lilies, or it may creep along the bottom, as in water buttercups and water milfoils. Sometimes the stem is short with the leaves arranged in rosette fashion—for example, the water eel-grass and the quillwort. In all of these plants the stem is perennial. A few annual water plants, however, exist, such as the naiads. In such, the stems die when the water freezes and the plant comes up from the seed the following spring. By far the great majority of water plants are perennial. The massive storage organs of bulbous land plants such as the jack-in-the-pulpit, or the onion, are not typical of aquatic vegetation. In general their stems are characterized by a considerable development of the cortical region, together with a poor development of the vascular region. Mechanical tissue is not at all abundant in the greater number and most of the stems and leaves are limp when taken from the water. In the cortex of the stems and leaf-stocks air chambers are common.

A variety of propagative processes are characteristic of water plants. Sometimes they pass the winter in an evergreen state at the bottom of ponds under the ice. The eel-grasses and water starworts do this. Sometimes their leaves are destroyed by the winter's cold and new ones are produced from storage areas of the rootstock, from buds, or from special propagative bodies. The special propagative bodies of water plants are very interesting. The pondweeds sometimes form little buds, that are separated from the plant body and become distributed to a distance. The bladderworts are remarkable for their production of green winter buds, known as *hibernacula*, which, in the autumn of the year, or in the spring, may be seen at the end of bladderwort stems. In such buds the leaves are very densely crowded together into a diminutive green cone and the sections of the stem with crowded leaves may be separated from the general plant body and serve to propagate the species. The calla,—rather a marsh than a water plant, but often living in the water,—has a similar habit of separating winter buds as propagative organs.

The distribution of different kinds of shore and bar plants depends upon a variety of conditions,—the character of the soil, the depth of the water, its quiet or agitation, and its temperature. The bass-weeds form the deep water zone. Warming states that they may grow in 75 feet of water, but usually they do not grow nearly as deep as this. The waterweeds prefer shallower water, the pondweeds still shallower, while the water-lilies grow close to the reed-grasses and bulrushes. The latter are accounted also as marsh vegetation, because so much of their starch-making surface is lifted above the water.

The reproductive processes of water plants of this group retain the characters of the original land habitat, so far at least as the flowering plants are concerned. Thus, the flower clusters are always produced above the surface of the water, and pollination is effected either by the wind, by currents of water, by wind and water combined, or by insects. Where the flowers are conspicuous, as is true of water-lilies or pond-lilies, insect pollination is the rule. Where they are inconspicuous, as in the pondweeds and water milfoils, wind pollination is the rule. A peculiar case is that of the eel-grass, which produces its pollen-bearing flowers in large numbers on submerged spikes. Each pollen flower separates from the spike and rises to the surface of the water, where it opens. The pistil-bearing flowers are produced singly on the ends of long, thread-like stems, and open at the surface of the water. The little pollen-producing flowers are blown about like so many tiny sail-boats, either striking their stamens against the stigmas of the pistillate flowers, or giving the wind an opportunity to carry the

FIG. 223.—Trees along a river bank. Soft maple and cottonwood. Minnesota river. After photograph by Williams.

pollen from one flower to the other. In the naiads and in some of the pondweeds, the pollen-spores are carried in the water, by ripples on its surface, from one flower to the other. The majority of these water plants retract their fruits under the surface to ripen them. Sometimes the stem of the fruit-bearing flower shortens spirally, coiling down into the water as in the eel-grasses. Sometimes the stem curves and thrusts the young fruit under the surface. A few water plants mature the fruits above the surface of the water, and of such the Indian lotus is an example.

The depth at which quondam land plants are able to grow is in some instances very great. Thus Magnin is authority for the statement that one variety of moss was found at a depth of nearly 200 feet in an Alpine lake, showing on the part of an originally terrestrial plant a very high degree of adaptation to the aquatic life. Nothing of this sort is known to occur in Minnesota, and beyond 25 feet only algæ and bacteria are likely to be discovered, while into such deep water pondweeds and waterweeds rarely extend.

Abyssal vegetation and modified hydrophytes. The various classes of hydrophytes which have been discussed may be grouped under the general name of aquatic vegetation. Some forms of aquatic vegetation are scarcely represented in Minnesota,—for example, hot spring vegetation, the various seaweed classes, and snow vegetation. Those which have been discussed comprise the bulk of Minnesota aquatic species. The class described by Warming as abyssal vegetation occurs, however, in the deep waters of Minnesota lakes from 50 feet below the surface to greater depth. The darkness is so great in such abysses that green plants scarcely exist, though blue-green algæ and diatoms are known to occur at depths from 250 to 300 feet, being able to utilize the extremely small amount of light which penetrates to them. Most abyssal forms are bacteria. These occur in the deepest waters, either suspended or in films along the bottom, forming, in such depths, a living slime or ooze, as may be determined by microscopic examination of deep lake soundings. The bacterial vegetation occurs also in moist organic substrata, such as the bodies of animals, where a large percentage of the substance is water. So the parasitic bacteria of disease, either of plants or of animals, might possibly be described as forms of hydrophytic vegetation. The bacteria, too, which live upon decaying organic matter, such as the sulphur bacteria and the ferment-producing bacteria, may be regarded as constituting a sort of water-loving vegetation, and, therefore, may be classified here.

Swamp vegetation. The remainder of the hydrophytic classes may be included under the general term of swamp vegetation. This is the plant group that shows itself typically in swamps, in bogs, in marshes, moors and tundras.

Several different classes exist, all of them characterized by the development of the underground portions of the plant—that is, the roots or rootstock—in moist soil, while the aerial por-

FIG. 224.—Marshy place at the edge of a wood. After photograph by Murdock

tions, especially the starch-making areas, are exposed to atmospheric evaporation. Like the majority of aquatic plants, most of the swamp plants are perennial. A great many of them produce underground or prostrate rootstocks. These organs are underground in sedges, scouring-rushes, reed-grasses, sweet-flags, cat-tails, some of the cranberries, brambles and primroses. They are above ground and prostrate in many of the heaths and club-mosses. The tissues of swamp plants are, as those of water plants, likely, in a variety of species, to be spongy. Thus, the rootstocks of the cat-tail, the rootstocks and stems of the scouring-rush, the leaves of many sedges and the leafless erect stems of bulrushes contain a great number of air chambers, giving them a spongy consistency. Some

Fig. 225. Ferns in tamarack swamp, Lake Calhoun. After photograph by Hibbard.

swamp plants have special aerating organs, of which cypress "knees" are examples. But these structures do not occur, so far as I know, on any Minnesota species.

Most swamp plants have adaptations for limiting the transpiration of water from their shoots and leaves; that is to say, they are in this character like the xerophytes of desert regions. Among the various devices for reducing transpiration may be mentioned the hairiness of many swamp plants, such as the swamp-saxifrage. Sometimes special pegs are produced around the air pores, as in many sedges and smartweeds. Sometimes that region of the leaf where the air pores are the most abundant

FIG. 226.—Swamp saxifrages. The large root-leaves are adapted to the shade of the swamp. The whole plant is hairy. Tamarack swamp, Lake Harriet. After photograph by Hibbard.

is covered with a cottony or woolly coating, as are the under sides of the leaves in the Labrador tea. Again wax coatings

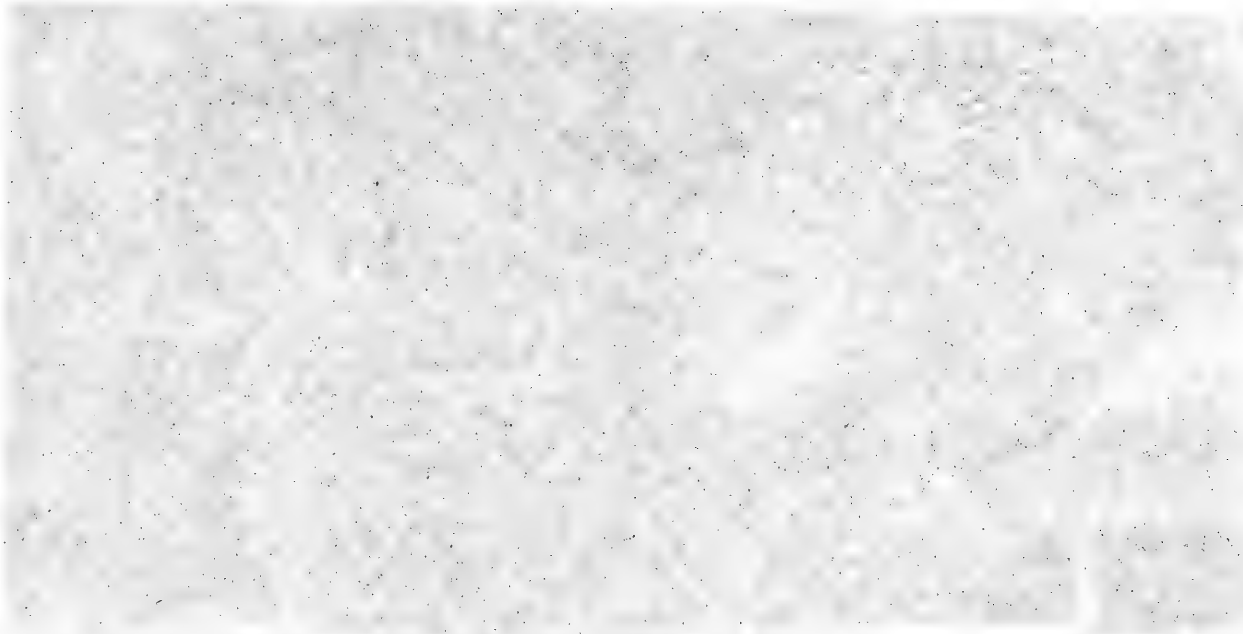
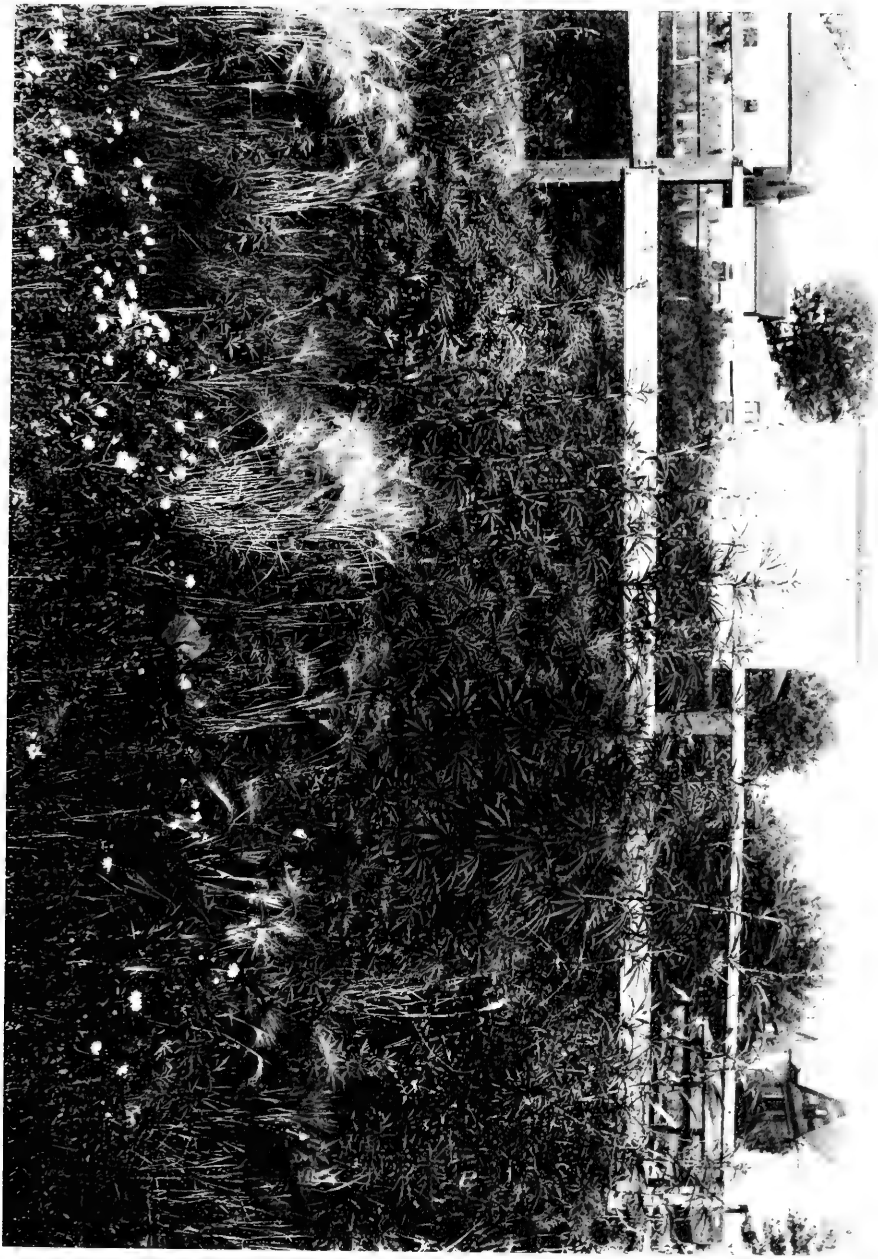


PLATE IV. Roadside vegetation near St. Paul. The most conspicuous plants are hemp, wormwood, squirrel-tail grass and daisies. From a photograph by Dr. Francis Ramaley.



may be found on the leaves, as on those of the rosemary, the cranberries, and the swamp blueberries. Sometimes the epidermis of the leaf or stem is very thick, as in the bulrushes and sedges. Sometimes the leaves are leathery, as in partridge-berries, cranberries and *Kalmias*, and this is a common adaptation among heaths. Sometimes the leaves are small, slender, and with but little surface for evaporation, a character that may be seen in many heaths and sedges. In some varieties the leaves are greatly reduced, as in the scouring-rushes, the bulrushes, some of the sedges related to the cotton-grasses and many of the true rushes. Or, if present, the leaves may be almost cylindrical, as in the *Scheuchzerias*. Again, the leaves may be needle-shaped, as in tamaracks or spruces. If the leaves are broader they often stand vertically so as to expose only their edges to the direct rays of the sun. This is well illustrated by the blue flags, the sweet-flags, the blue-eyed grasses, the yellow-eyed grasses and the cat-tails. Where these broader leaves do not stand vertically they are sometimes rather few in number. This may be seen in the reed-grasses and wild rice. Broad leaves of swamp plants are often rolled in along the margins—the same adaptation found among desert grasses. Thus, crowberry leaves and many sedge and grass leaves in the swamp-dwelling species, are rolled. Sometimes the air pores are developed but very poorly on the upper surfaces where the leaves are spread out to the sun. All of these characters may be regarded as limiting the transpiration of the shoot and leaves.

Special reasons may be given for the leaflessness of some swamp plants, as for the bulrushes which belong to the category of surf plants. Their leafless, whip-like stems are adapted to withstand the impact of surf. The temperature, also, of the water has something to do with the appearance of the xerophytic characters. They are more prominent where the water is cold. So especially in peat-bogs and cedar swamps does one find a variety of sedges, heaths, rushes and cone-bearing trees, all characterized by slow evaporation.

Reed marshes. To the class of reed marshes belong a variety of shore formations and swamp formations common in Minnesota. Here should be classed the wild rice beds and the beds of rushes and reed-grasses. Here, too, should be included the beds of cat-tails, of blue flags, of arrowheads, burweeds, callas, sweet-flags and sedges. In such regions a variety of accessory plants habitually develop, such as the swamp butterweed, the buck-bean, the swamp-docks and several members of the parsley family. These plants often arrange themselves in zones dependent upon the relative moisture of the soil, or upon the depth of the water that covers the rootstocks and roots. Thus, along the borders of Minnesota lakes, bulrushes generally grow

Fig. 227.—A marsh-loving sedge, showing fruit clusters. After photograph by Hibbard.

outside of reed-grasses, and reed-grasses outside of sedges, showing the exact adaptations of these kinds of plants to the moisture-content of the soil and to the water covering their underground portions. Most of the plants in reed swamps are provided with rootstocks by means of which they propagate. The strong rootstocks of bulrushes and cat-tails may serve as examples. While pushing a boat through a bed of bulrushes a careful observer will notice that the rushes stand in rows, and these rows designate the position of the prostrate rootstock in the bottom. From such branching rootstocks, common to sedges, cat-tails, bulrushes and reed-grasses, the aerial or lateral branches arise. The rootstock commonly bears scale leaves. These may be well seen if a cat-tail plant is dug up and washed. Among the perennial rootstock-forming herbs, which are the characteristic plants of reed swamps, a few shrubs are often found growing, such as willows and alders.

Wet meadows. A second class of swamp vegetation is known as swamp-moor or wet meadow. In such regions there is a high percentage of ground water, but under ordinary conditions the subterranean portions of the plants are not directly covered by standing water. Such meadows exhibit in Minnesota a variety of plants, for the most part sedges, grasses and rushes, but with a strong intermixture of other plants, including such varieties as the shield-ferns, marsh-marigolds, the *Parnassias*, some gentians, buck-beans, orchids, willow-herbs and parsleys. Here, too, swamp-saxifrages and pitcher-plants are often to be found. Mingled with the herbage which is the predominant vegetation of such wet meadows a variety of shrubs may grow, including dogwoods, willows, dwarf birches, buckthorns, and spiræas or meadowsweets, and, in northern parts of the state, heaths or crowberries. A considerable moss vegetation exists in such wet meadows, including sometimes peat-mosses, but also carpet mosses, hairy-capped mosses and others. Sometimes moss meadows occur, forming a transition to peat-bogs and peat-tundras. In arctic regions such wet meadows are inhabited often by lichens to the exclusion of other plants. As is also true of aquatic vegetation these wet meadows are tenanted for the most part by perennial species.

Peat-bogs. A particular type of swamp vegetation is the peat-bog. It differs from the ordinary wet meadows in the chemical character of its soil. Chalk and potassium are present in peat-bogs in smaller quantities than in wet meadows, and it has been shown that the nitrogenous content of peat-bogs is less than that of wet meadows. Humus, therefore, forms better in wet meadows than in peat-bogs. On account of the low nitrogenous content of the peat-bog there is a poorer development of bacteria and vegetable remains are, therefore, better preserved if sunken in peat than if embedded in the bacterial soil of a wet meadow. The distinctive plants of peat-bogs are the peat-mosses, the most abundant and in some respects the most remarkable of all the mosses. A considerable number of different species occur in Minnesota. They are extremely spongy and contain a large amount of water in special cells of their leaves and stems. Besides the peat-mosses a number of other mosses will be found in peat-bogs, with a variety of liverworts. Here, too, is the favorite home of many sedges, such as the cotton-grasses, of many grasses and lilies, of rushes and of orchids. Heaths are a marked feature of peat-bogs and almost all the Minnesota varieties are to be looked for in such localities, where one finds the Labrador tea, the *Kalmias*, the rosemarys, the cranberries, the snowberries, the leatherleafs and the bilberries. Mingled with them are a number of other peat-bog-dwelling plants belonging to various families. Here one will find the sundews and pitcher-plants, the dogwoods, brambles and sweet-ferns, the myrtle-leafed willow, the tag-alder and the crowberry. Especially distinctive of such areas are spruces and tamaracks and these are the most characteristic trees of peat-bogs in the Minnesota region. They are often very much dwarfed by the cold water and by the low percentages of mineral salts which these waters contain. Especially when growing in the wet region of the bog are the trees diminutive; and spruce trees 75 years old and but little over an inch and a half in diameter have been found in Minnesota peat-bogs.

It is probably on account of the low nitrogenous content of the water that carnivorous plants, such as the pitcher-plant and sundews, have developed particularly in peat-bogs. They are able by their insect-catching habits to supply, from the bodies of their victims, nitrogen to compensate for the scantiness of this element in the soil.

Most of the species in peat-bogs are perennial. On account of the open, meadow-like character of typical peat-bogs the snow accumulates in heavy sheets and this will perhaps account to some extent for the prevalence of prostrate shrubs like the heaths. No doubt also the prostrate habit is resultant from the necessity for slow evaporation. Since the heaths do not lift their leaves into the air on erect shoots so abundantly as do other kinds of shrubs, they avoid that agitation by the wind which would promote evaporation.

Peat-tundra. The type of vegetation known as peat-moss tundra is sparingly developed in Minnesota. It may be described as a kind of dry peat-bog. I have seen isolated and

FIG. 228. A pitcher plant in flower; tamarack swamp. The leaves are converted into insect-traps. After photograph by Hibbard.

limited peat-moss tundra formations at Lake of the Woods, where, on some of the rocky islands near the Northwest Angle

Inlet, dry peat-moss turfs form in the depressions of the rock. Mingled with the peat-moss were the reindeer-moss lichens and the bluebells and juniper bushes, which are such distinctive rock plants of this region.

Swamp underbrush. Another type of swamp vegetation developed in Minnesota is known as swamp shrub or swamp underbrush. This consists for the most part of birches, willows, buckthorns, black haws, hollies, dogwoods, alders and poison sumacs. Where a reed swamp or wet meadow has grown up to underbrush this sort of formation appears. When the swamp underbrush has arisen, sufficient shade is produced to permit the development of certain accessory herbs that would not otherwise be so abundantly present. In such regions, for example, violets and touch-me-nots, gentians and thoroughworts are often abundant. Such swamp underbrush sometimes grows along the edges of peat-bogs and lakes and in this situation willows and dogwoods particularly abound. Willows, also, very often form rings around the shores of small, low islands, mud flats, or sand bars in lakes or streams, while the higher land of the centre is occupied by elms, cottonwoods, maples or basswoods. This is a very common example of zonal distribution in Minnesota.

There have now been passed in review the principal types of hydrophytic vegetation. Apparently the strong preponderance of water in the substratum, as for the swamp plants, or surrounding the plant body, as for aquatic vegetation, has a number of definite influences not only upon the structure of plants, but upon their grouping. The depth of the water, the character of the soil, the chemical substances held in solution in the water, the temperature, agitation, or quiet, and other conditions, all have their influence and it is not at all an accidental matter whether a particular moist region develops as a peat-bog, as a reed swamp, as a wet meadow, or as a swampy underbrush. In all the hydrophytic vegetation classes perennial species are predominant. A great many of them are herbs, while some are shrubs, and a few are dwarfed or specialized trees.

Chapter XLII.

Xerophytic Plants.

The plants classified under the general name of xerophytes are, in their selection of habitats, just the opposite of aquatic plants. They grow typically under conditions of slight moisture and some of them are able to maintain themselves in the most arid regions of the world. Thus, a distinctive desert vegetation, such as may be found in the Sahara, or in the deserts of Arizona, has come into existence. A number of plants, although not inhabitants of the desert, find it difficult to obtain sufficient moisture and assume the xerophytic type of structure. Good examples of these are the orchids that live in tree tops and dangle their roots in the damp air of tropical forests. Since this is a slow way of accumulating moisture, such plants are often cactus-like in form. Not being exposed to the attack of grazing animals, as are the cacti, they do not become armed with thorns and spines, but they have often the same massive bodies that are found in true desert plants. A great variety of secondary conditions serve to modify and regulate the appearance of xerophytic structural characters. Thus, some xerophytic plants living in sand differ decidedly from others living upon rocks. Those developed in soil rich in nitrogen differ from those that have but a scant supply of this element available for their roots. The saline substances present or absent in the soil may modify the plants growing upon it. For this reason a difference arises between the vegetation of limestone and granitic regions and some plants are known to be indicative of limestone soils just as others are of the presence of quartz.

Desert plants. A variety of devices are employed by xerophytic plants to regulate the evaporation or transpiration of moisture. Sometimes during extremely dry seasons desert plants abandon their leaf structures entirely, thus responding to the arid conditions quite as plants of temperate regions respond to the approach of winter. Trees in deserts often drop their leaves after the short rainy season is over and pass into a winter-like condition, during which they evaporate much less moisture than would be necessary if their leaves were expanded to the ardent rays of the sun. For this reason, too, a great many desert plants are annual, and in the compact form of seeds withstand the dry season of the year. When the rain has come again the seeds germinate rapidly and in a short time the flowering and fruiting processes are completed. It is remarkable, in a desert, when the rainy days are at hand, to observe the extraordinary rapidity with which plant organs of various sorts appear upon what was before an arid waste.

Many desert plants develop underground bulbs and rootstocks which persist without sign of life during the dry time of the year and, when there has been a short season of rain, suddenly put forth flowering stems and foliage. Another way of meeting the aridity and dryness of the air is by the rolling up of the leaves. This is well seen in the buffalo-grasses, in some of the wormwoods or sage-brushes, and in a variety of sedges, grasses and mosses. By means of this reduction of the evaporating surface at the critical time, the desert plants which employ these adaptations are able to prevent too great evaporation. Another method adopted by plants in arid regions is the modification of their leaf positions, and a number of leaf-movements are regarded as protective against undue evaporation of moisture. Many plants of the pea family in desert regions have such special leaf-movements. Still another method is the setting of the leaves on edge, as in compass-plants; and the rosinweed compass-plant and the lettuce compass-plant of the Minnesota flora, by twisting their leaves so that only their edges are presented to the direct light, illustrate such adaptations. Since the strongest illumination in the northern hemisphere is from the south, these compass-plants turn most of their leaves so that the flat sides face east or west, and thus they are exposed to the least direct sunlight possible.

In the desert regions of the world, leaves sometimes hang from the stems so that the light strikes them as little as possible during the day. Still another device for limiting transpiration, common among desert plants, is the formation of leaf structures that evaporate moisture but slowly. The prismatic leaves of pine trees, the leathery leaves of heaths and hollies, the scale-covered leaves of buffalo-berries and silverberries, the slender cylindrical leaves of many rushes, the ribbon-shaped leaves of many grasses and sedges are all examples of such protective structures. Some leaves are fleshy and succulent, like those of the live-forever, the purslane, the spring-beauty or the portulaca. The leaves of century-plants are types of this kind of adaptation.

Not only are leaves variously modified, but stem areas as well, in the above-ground portions of xerophytic plants, respond to the conditions around them. Thus, some stems are leafless, as in certain of the cacti. Such leafless stems may be somewhat flattened and may have green rinds by which they carry on their starch-making. Sometimes the stems are cylindrical, as in the bulrush. Sometimes, as in the asparagus, the leaves are absent from the plant body, or are reduced to scales and their place is taken by little needle-shaped branches that carry on the starch-making function. Sometimes the stem is converted into a solid gourd-like body, as in the melon-cacti and prickly-pears. By such forms and structures of leaves and stems the transpiration of moisture is greatly reduced.

Another modification appears in those plants which have coatings of one sort or another to protect the leaves and stem. Thus, the bloom on the leaves of a century-plant, the hairs and bristles on a mullein leaf, the clusters of dead leaves that are retained by some plants for a year or more, the incrustations of chalk, wax, slime, shellac or gum, all have their value in reducing evaporation. The internal sliminess of the leaves of century-plants is a familiar fact. Well known, also, is the resinous matter so commonly seen to exude from the leaves of pines and their allies. Various other adaptations exist which cannot be discussed at all fully. The intimate structures of leaves, the position of the starch-making bodies in the leaves, the position and character of the air pores, all have a significance.

Some plants have glands the function of which is to secrete salty deposits on the leaves. These salty deposits have a strong affinity for moisture and may serve to collect it from the exterior. Many desert plants are known by their pungent odor, very perfect examples of which are the wormwoods or sage-brushes. It has been shown that the vapor of the ethereal oils,

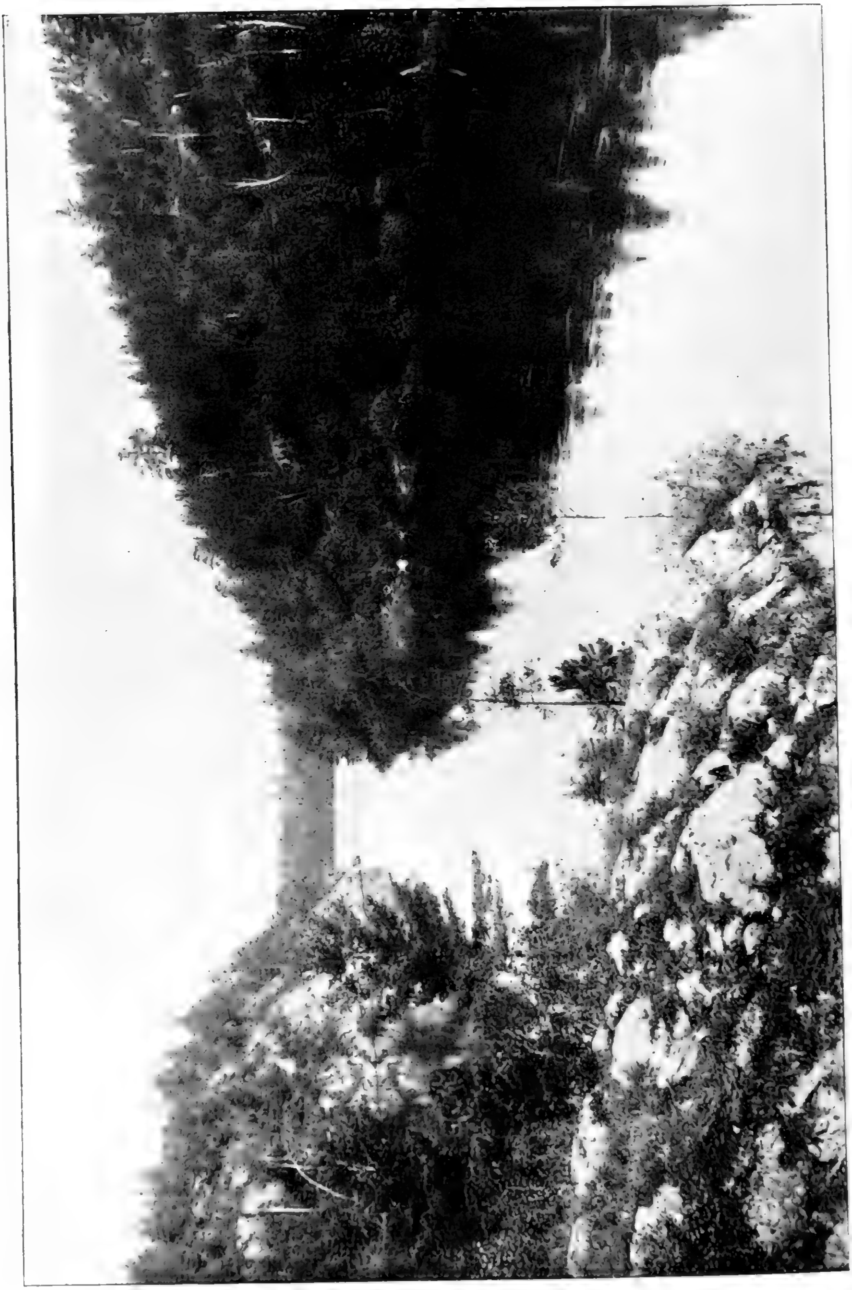


FIG. 229.—Rock vegetation, Lake of the Woods, near Keewatin, Ontario. Junipers, bellworts, pines ferns, poplars and grasses predominate. After photograph by Wright.

existing in such plants, when commingled with the atmosphere reduces its permeability to heat, and thus the constant exhalation of perfume from the body of a wormwood is to be regarded as a device for tempering the heat of the sun. No doubt some of these strongly scented substances are of value, too, as discouragements to grazing animals. By all such adaptations in the above-ground portions of a plant it is clear that a reduced transpiration is effected. The below-ground organs, such as the roots or rootstocks of desert plants, are often important as reservoirs of moisture. Some varieties, like the wild morning-glories, produce very large roots, and often the root system of a desert plant is much greater in extent than the above-ground portion.

A number of classes of xerophytic plants exist, many of them represented in Minnesota. While the state does not include any desert regions, yet there are numerous tracts upon which xerophytic plants would find a habitat—for example, sandy barrens, dry rocks, sand dunes and high sand beaches, high prairies and meadows, or the dry branches of trees. Some of the characters of these different classes may be discussed more in detail.

Rock plants. Rock vegetation is well defined and includes a number of species that are not common elsewhere. A large portion of it is made up of mosses and lichens; and on dry cliffs, exposed bowlders or crags, as well as upon ledges of rock, a number of rock lichens and rock mosses are prolific. These plants require but a small amount of water and are often provided with several of the special adaptations against transpiration. The common little black tufts of moss which are found upon bowlders, under ordinary conditions look perfectly dry and shriveled, but if wet they quickly revive and their green color becomes more apparent. Many of the lichens growing upon rocks have the same shriveled, dry appearance betokening adaptations affecting evaporation. In order to attach themselves to the bare surfaces of rocks, lichens secrete, as has already been stated in the chapter on lichens, certain acids able to corrode limestone or quartz. The plants cling closely to the corroded surface and they cannot possibly be detached without destroying them. Some algæ are capable of living on rocks and there pass into a dry, dormant condition, except when the rock is wet with rain. In Minnesota a number of pinks, rock-roses, purslanes and Canterbury-bells make their home upon rocky ledges or shores. Here, too, there are to be met with a variety of ferns, such as the cliff-brakes, the polypody and others. With them may be found numerous grasses, plantains, verbenas, evening-primroses, ragweeds, capers, and saxifrages. Upon such rocky ledges may also be discovered, especially in the northern part of the state, the juniper bushes and the ground-hemlock. Rock-succulents are not common in

FIG. 230.—Growth of hardwood trees upon a rocky island. Northwest angle, Lake of the Woods. After photograph by the author.

Minnesota; but the prickly-pear cactus of Pipestone and the rock purslane of the Minnesota valley, are examples. More often grasses with rolled up leaves, junipers with needle-shaped or scaly leaves, saxifrages with hairy leaves and other adaptational types will be present. The larger rock plants, needing more soil for their root areas, grow in crevices and may be found abundantly wherever the rocks have been split and soil has formed in the clefts.

Moss heaths. Another class of xerophytic vegetation includes the moss heaths. These are dry, moss-covered stretches.

Mingled with the mosses there may sometimes be small shrubs or herbs. Such moss heaths are to be found upon some of the islands in Lake of the Woods and Rainy Lake.

Lichen heaths. A related class may be described as lichen heath. The characteristic plants of this formation are the reindeer mosses; and very beautiful examples exist along the northern limits of the state. The dry, rounded, thin-soiled islands in Lake Saganaga give perfect examples of lichen heaths. A few trees and shrubs are present, but the characteristic and predominant vegetation is composed of reindeer mosses with little heaths, grasses, rushes, verbenas, and vetches mingled with them.

Shrubby heather. Another class not so extensively represented in Minnesota as elsewhere is the shrubby heather, in which the ground is covered by little heath bushes, mosses, club-mosses and junipers. Yet such heaths to a limited extent exist in the northern part of the state. Mingled with the heaths proper are a number of composites, such as those goldenrods, asters, and fleabanes which prefer dry open localities.

All of these rock and heath groups of plants are strongly xerophytic in their general features. They are, in many instances, to be regarded as responses to sterility of soil rather than aridity of climate.

Sand plants. Very closely connected with rock vegetation is the sand vegetation of dunes, beaches and barrens. The sand is lacking in moisture, which percolates through it readily, lacking also in nitrogenous substances and, therefore, to some degree not unlike a rock tract, hence naturally presenting similar types. A great many plants which can grow upon rocks can also grow upon sand dunes and, as a result, in the northern part of the state, junipers, for instance, occur in about equal frequency upon bare rock ledges and upon sand dunes. A special type of sand vegetation is that of sandy beaches, where the proximity of lake water makes the soil moister than it would otherwise be. For this reason the plant inhabitants of beaches are often mesophytic rather than xerophytic in character, while close to the water's edge true hydrophytes may establish themselves. Dunes are particularly characterized by sand-binding plants, such as the wild rye, the junipers, some sedges, rushes and grasses. Mingled with the herbaceous plants are a few shrubs and trees, such as the hackberries, choke-berries, poplars, oaks and ashes, with brambles and roses as underbrush. Sand barrens in Minnesota fall for the most part into three classes, jack-pine-barrens, oak-barrens and sandy wastes. The distinctive plant of the pine-barren, a common formation in the central portion of the state, is the jack-pine. Along with trees of this species, a number of underbrush plants, herbs, mosses and lichens establish themselves. Here blueberry bushes are abundant and other heaths. In such woods the de-

FIG. 231.—Vegetation of sand dunes, Isle saux Sables, Lake of the Woods. In the foreground is the sand cherry and scrub poplar, in the center, a juniper bush and in the background, plums. After photograph by the author.

velopment of wand plants is common, and in the autumn the forest floor is resplendent with the yellow heads of sunflowers, the purple spikes of blazing-stars, and the white or blue inflorescences of asters. Sandy wastes are characterized by the development of mat plants, such as carpetweeds and spurges. Mingled with these are to be sought many rosette plants like the evening-primrose and the plantain.

The prairie. A most characteristic xerophytic formation in Minnesota is the prairie—especially the high rolling prairie, which differs considerably from ordinary meadow or pasture. Much of the level prairie is mesophytic rather than xerophytic. Here a variety of grasses, pulses and composites grow luxuriantly. Such a region is the home of tumbleweeds, compass-plants and prairie turf-building varieties. Some strongly xerophytic lilies, such as the onions, are found in profusion upon the plains. Over unbroken prairie, between the plants established upon it there exists a great competition. This goes on not only between the under-ground portions, but also

Fig. 232.—The valley of the Minnesota river in the prairie district. Abundant grass vegetation. After photograph by Professor R. D. Irving.

between the erect structures. Thus, some prairie plants grow tall and strong in order to get the light that they require. Sunflowers, indeed, may be regarded as the kings of the prairie. Their erect, vigorous, annual stems are like trees as compared with the more humble grasses, and where they occur in abundance they may, to the seeing eye, be regarded, perhaps, as indicative of how the forests of the world will appear hundreds of thousands of years in the future. One may look forward and imagine sunflowers and their kind grown taller and stronger, a hundred feet or more in height, and even able to usurp the place of the trees that are now abundant in the woods.

A great many prairie plants are annual, but some of them are shrubby and perennial. The shrubs are for the most part low. This is no doubt in response to the moisture-condition, because if they were high and loose, like the dogwoods and willows of moister localities, their evaporation would be too great.

All of the formations that have been described are distinctly xerophytic and in all of them the moisture-content of the soil is comparatively small, while its temperature may be high.

Pine forests. At this point it might be well to call attention again to the xerophytic characters of coniferous forests, especially tamarack and spruce swamps, balsam thickets, and river-bluff lines of junipers or red cedars. Probably the whole pine forest may be regarded as xerophytic. The needle-shaped leaves of the white and red pines are slow to transpire moisture, and the pine forests reach their highest perfection along ridges equivalent, in their topographical character, to the ridges of rolling prairie. The moisture-content of such soil must be below the average. Along with the pines a number of xerophytic mosses, such as the hairy-capped moss, of ferns, such as the bracken ferns, and of flowering plants, including the wintergreens, several heaths, and a variety of asters, are common. In such forests wand plants grow luxuriantly along with the shrubby underbrush.

Air plants. When growing upon a substratum in which nutritive substances required by the plant are lacking or small in amount, the surrounding atmosphere is drawn upon for the food supply. Plants that habitually do this are termed air-plants. The Spanish moss, tree-top orchids and perching ferns of the tropics afford typical examples. In temperate regions the perching vegetation is composed principally of lichens, mosses, liverworts and algæ. Much of the rock vegetation previously mentioned may also be included in this class, and here, too, may be classified the lichens and mosses that attach themselves to the bark of trees, to fence rails, to the walls of buildings or to absolutely arid soil.

Chapter XLIII.

Halophytes and Mesophytes.

The adaptational type of vegetation known as salt vegetation, or the halophytic group, is very sparingly represented in Minnesota. It reaches its best development in the mangrove swamps of the seashore, and on salt-impregnated beaches or marshes close to the ocean. A few salt plants are, however, to be found in the state. In the Red river valley they are sometimes most prolific upon saline or alkaline soil. Here are encountered the sea-blites, the glassworts and the Russian thistle, together with several salt-loving goosefoots, salt-loving purslanes and grasses. One of the plantains is capable of growing in salt marshes. The most general character of salt marsh vegetation is its sparseness—a character presented, for example, by a growth of Russian thistles. Such plants are usually some distance apart, not close together as in most other formations. Salt plants, like many bog plants, are stamped with the xerophytic structural adaptations. The succulence of the glasswort and the great reduction of its leaf surfaces is distinctively suggestive of the cactus type. The fleshy leaves of the goosefoots and purslanes call to mind similar characters of rock or desert succulents. If the body of a glasswort is chewed a strong saline taste will at once be recognized and will serve to demonstrate that salts are carried from the soil, where they exist so abundantly, into the juices of the plant. The typical salt-succulents are not ordinarily armed with thorns or spines as are the typical desert-succulents. This may be because there is not such absolute sparseness of vegetation in the general locality and they are, therefore, not called upon to bear the brunt of attack by hungry animals.

Succulents in general. At this point it may be desirable to bring together for comparison the different sorts of succulent plants. They may be divided into two general groups, leaf-succulents, such as the purslanes and century-plant, in which the leaves are the principal succulent organs; and stem-succulents, such as the cacti, in which the leaves are reduced to thorns and the stems have become fleshy. Of adaptational types there are the following: desert-succulents, generally armed with thorns; rock-succulents, more commonly unarmed; salt-succulents, like the glassworts, sometimes armed; and tree-top-succulents, generally unarmed. Of the latter group tropical orchids furnish illustrations. Some of the leaf-succulents develop their leaves in rosettes and belong also to the class of

FIG. 233. Cottonwood trees on the Minnesota river. After photograph by Williams.

rosette vegetation; the century-plants, the live-forevers, and the little hen-and-chickens are examples of this group. The tree-top-succulents, also, of the orchid family, to be seen in greenhouses, in a number of instances develop their leaves in clusters upon short stems. Other leaf-succulents, however, have the stems slender and branching. This is true of the purslane, the rock purslane and the Russian thistle. Succulents may have arisen through direct influence of the environment, by the warming of the soil. This would tend to increase the absorptive power of the roots, so that desert-succulents in particular might be regarded as plants that in a warm soil have swollen themselves full of water and, during the course of generations, have adopted permanently the fleshy structure.

Mesophytic vegetation. A number of other plant formations remain to be catalogued under the general head of mesophytic vegetation. The term is applied to those plants which are intermediate, in their reaction to moisture, between hydrophytes and xerophytes. The characteristic mesophytic formations of Minnesota are the hardwood forests, the meadows, the

FIG. 234.—A Minnesota meadow bordered by shrubbery and deciduous forest. After photograph by Mr. W. A. Wheeler.

cultivated fields and gardens, the roadsides and the mesophytic shrub, such as underbrush at the edges of forests, or the widely distributed scrub, composed of little oaks, sumacs and maples. In all these formations the plant-covering is thick and a large number of perennial species exist.

Meadows. Meadows or pastures are composed for the most part of grasses and accessory herbs, such as verbenas, flax, sorrels, buttercups, anemones and thistles. Here, too, gentians and speedwells will be found, together with primroses and thoroughworts. Occasional xerophytic plants enter such meadows and one may find in them mulleins or scouring-rushes growing among the typical mesophytic grasses and herbs. In such localities plants of xerophytic tendencies may often be distinguished by their rosettes of leaves. In the meadows mosses and sometimes ferns occur. With the meadows should be compared the broad expanses of mesophytic prairie, especially those of the Red river valley and the Minnesota.

Cultivated fields. Cultivated fields and gardens, where the soil is stirred by the plow or spade, come to be occupied by a group of vegetation classified by the farmer as crop and weeds. This is, of course, a purely economic classification, and to get the proper botanical idea of a cultivated field all thought of human interest in the kinds of plants that grow must be eliminated. It will then be discovered that the field is occupied by a dominant formation which owes its selection and abundance to the distribution of its seeds or fruits through human agency. A number of accessory plants are also developed, including a variety of common grasses and herbs. Into such fields some xerophytic forms, like the purslanes, introduce themselves, but the majority of the plants will not show conspicuously the xerophytic adaptations of structure which have been described; that is, the weeds of a cultivated field are not predominantly silky or strong-scented, or succulent, or plants with the edges of their leaves rolled in together. In such localities, rather, will be found the thistles, the fox-tail grasses, the oxeye daisies, the amaranths, pigweeds and wild parsleys, together with some kinds of buttercups and clovers. Such a field in its general composition bears a close resemblance to pastures or meadows. A particular kind of field is produced when the soil is sandy or alkaline. Or, if the soil is very hard, composed of clay closely packed together, the vegetation covering it will be different from that of ordinary cultivated fields. Sand-loving plants or mat plants will come in and establish themselves prominently along with carpetweeds, purslanes, thistles and wild lettuce.

Roadside vegetation. With such wastes of weeds as have been described, roadside vegetation may be connected and the strong resemblance between it and that of a neglected field is at once apparent.

Mesophytic shrub. Of mesophytic vegetation classes, in which shrubby or woody plants are predominant, a number of

FIG. 235.—Roadside vegetation in summer. After photograph by Williams.

special varieties might be described for Minnesota. Here would come the oak scrubs, the sumac and maple underbrush,

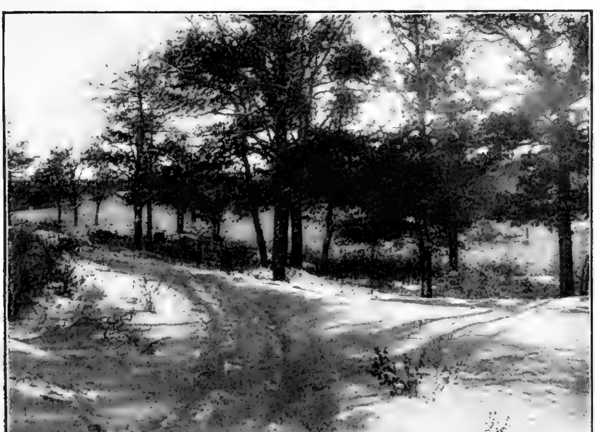


FIG. 236.—Roadside vegetation in winter, St. Anthony Park. Oaks, sunflowers and golden rods. After photograph by Williams.

the hazel scrub which is particularly abundant in Minnesota and the poplar scrub in which the dominant plant is the common poplar. Dogwoods, roses, hawthorns, plums, ashes and other shrubs are prominent as components of this general formation. Along with these go usually a number of wand plants, herbs that thrust their slender stems up between the shrubs, thus getting illumination. Of these the goldenrods, the willow-herbs, the evening-primroses and the asters are examples. Here, too, one will find a variety of climbing or twining herbs or vines, and the wild beans and wild peanuts, the bindweeds and morning-glories, are to be expected. The floor of the underbrush will be occupied by a number of little grasses

FIG. 237.—Autumnal underbrush, Mississippi river, between Minneapolis and St. Paul. Golden rods, asters and sumac. After photograph by Williams.

and low herbs, some of which may be vagrant xerophytes with the rosette habit of growth or with other characters by which they can be recognized.

Hardwood forest. The hardwood forest of Minnesota, especially as developed along river bottoms, where it is made up of ashes, maples, basswoods, oaks and elms, furnishes an example of what is meant by mesophytic forest. Upon sand barrens where the bur-oak finds a congenial home the conditions are almost xerophytic and, therefore, oak-barrens were mentioned under a previous topic.

Certain conditions of the forest floor arise, owing to the decay of the falling leaves, that make such a region favorable for the development of humus plants, and a number of them are likely to be found there, as, for example, the coralroots, Indian-pipes and wintergreens. Many shade plants hide in the dense woods and one finds, in their depths, the trilliums, the jacks-in-the-pulpit, the broad-leafed asters and broad-leafed goldenrods, and upon moister ground, the touch-me-nots, the anemones and the clintonias. In such woods a number of vines have their growth, such as the wild grape and the climbing bittersweet, or, of slenderer habit, the hop and the clematis. A characteristic of hardwood forest is the remarkable luxuriance with which spring flowers of various sorts are produced. Before the leaves have come out upon the trees the forest floor is covered with flowering herbs. The autumn flowers of the forest are not so conspicuous as in the prairie regions, perhaps because there is not so much possibility of attracting the attention of insects at a distance, owing to the proximity of tree trunks and to the shadows thrown by the leaf crowns. In the spring, before the leaves have appeared, such conditions are minimized and the development of a conspicuous flower might be of more advantage to the plant.

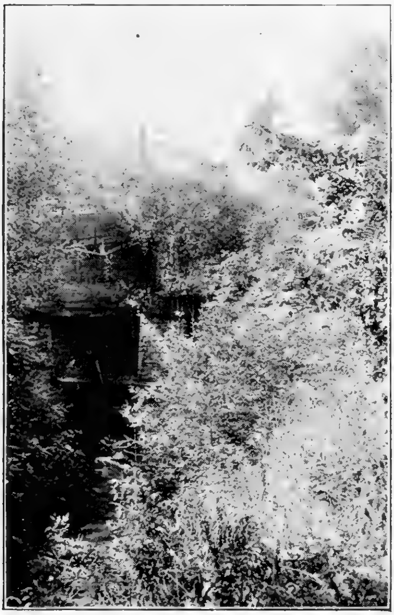


FIG. 238.—Neglected corner in the Minneapolis manufacturing district. Weeds and shrubbery. After photograph by Williams.

General considerations. It must not be supposed that every plant formation in nature is purely hydrophytic, purely xerophytic, or purely mesophytic. On the contrary, mixed formations are exceedingly common. A little change in the topographical features of a region, a difference in illumination or in exposure to wind, a slight modification of the chemical or physical condition of the soil, or any one of innumerable other variations in the surroundings may suffice to alter the vegetation which has become established. Thus, in a well-kept lawn, where conditions are normally mesophytic, plantains and dandelions—both of them mesophytic in structure—will probably be among the most troublesome weeds. But let the lawn be established on a soil too porous and easily dried, or let the season be below the average in rainfall, and very promptly xerophytic mat plants, such as spurges and prostrate verbenas, and xerophytic grasses, such as the sand-burs and other similar

FIG. 239.—Modern hardwood forest of the St. Croix valley, near Osceola. After photograph by Professor W. R. Appleby.

vegetation, will begin to encroach upon the turf. Vegetation coverings, wherever they are formed, are quite as sensitive to changes in surrounding conditions as is a city lawn, and for this reason the infinite variety of woods, fields, marshes, swamps and prairies has come to exist.

A very broad classification of the influences which affect plant adaptations is that made by the German authority, Schimper. He distinguishes essentially—1, *climate;* 2, *substratum,* and 3, *neighbors.* By *climate* he means the complex of atmospheric and cosmic influences, including, for example, all the influences of solar light and heat and those of atmospheric vapor and wind.

By *substratum* he means the soil, whether it be rich in calcium, sodium or nitrogen. By *neighbors* he means the surrounding plants and animals which by their proximity affect the habits or structures of the plant in question. Thus, in accordance with the origin of their most characteristic adaptations, he divides vegetation into three fundamental groups, viz., climatic formations, substratum formations, and neighborhoods. Desert plants, for instance, may be grouped among the climatic, salt-succulents among the substratum, and carnivorous plants among

FIG. 240.—View of Fort Snelling, showing midsummer vegetation. After photograph by Williams.

the neighborhood formations. The further extension of such a classification is perhaps sufficiently apparent without multiplying examples. Aquatic plants would form a special class.

Yet under even so general an analysis it must be evident that very many plants—indeed, most of them—will appear in one group or another, as attention is diverted to one or another aspect of their adaptation. The tree-top orchid as an air-plant falls into the group of climatic formations, but as a plant enabled through the coöperation of its root fungi to use decaying materials for food, it comes within one of the neighborhood formations. No adaptational classifications that have yet been devised are altogether accurate, but those by Warming and Schimper are the most practicable.

Chapter XLIV.

Maintenance of the Plant Individual.

Like every other living thing the plant must maintain itself or die. For different kinds of plants the normal duration of life may greatly vary. Thus, the microscopic females of certain orchids, hidden, as they are, deep within the rudimentary seeds of their species, may exist for but a few days or weeks. On the other hand, in the cañons of the Sierra Nevada, there still stand, challenging the winds and the winters of the centuries, *Sequoia* trees that were saplings when the pyramids were new, noble trees when Rome was in her glory, and already giants of the western forest when Columbus set sail on an unknown sea.

Whether the life of a plant be long or short, it may be described as arising and continuing through a series of adjustments, complex, subtle, immemorial, between the forces and the substances of Nature. The materials of which the plant is made are certain ordinary chemical elements. Their number and their character can be determined by recorded methods of analysis. The energy manifested by the plant in its assimilative processes, in its growth, and in its movements is but a transformation of the energy with which it is supplied through its food and through the warmth and illumination of the sun. Yet it is impossible to reduce the living plant to the terms of an equation in chemistry and mechanics. That this cannot be done is because the plant is really a microcosm. The problem of its existence is as difficult and as profound as that of the universe. There it stands beside one's doorstep, humble, passive and inarticulate. Yet it responds to the forces of light and gravitation reaching it from the depths of infinite space. It is touched by terrestrial dews and breeze, and, after its fashion, reacts to such local stimuli. It is moulded by the inheritance which comes to it through an ancestral line reaching down the dim and distant ages to the very moment when the first living particle appeared on the surface of the earth. Thus, the child of two infinities, it baffles interpretation; for in the heart of every flower is the riddle of the Sphinx.

From such a conception the poet may derive his inspiration and the moralist may instill his lesson. But it is the duty of the student of science to put aside all feelings either of exaltation or depression and to endeavor to collect such facts as are attainable, even when he recognizes that ultimate explanations lie far too deep to be reached by the plummet of human thought. In such a spirit the plant has been questioned by modern science and somewhat is known of the story of its life. In very simple fashion I shall endeavor to picture it as an organism at work.

Living substance. The essential groundwork of every living organism is a material known as *living substance*, or protoplasm. By no means all portions of an organism actually consist of this living substance, although all portions have arisen through its activity. It is as the spiders spin their webs, or as men build their cities. The living substance is the organizing body and the completed plant or animal is the resultant organization. As long as the organism contains this living substance it may be said to be alive; but when the living substance is destroyed throughout its body the organism is then said to be dead. No longer held together by the forces inherent in its builder it may be resolved again into the elemental substances from which it was constructed. Just so, to continue the illustration, will a city, if abandoned by its inhabitants, fall into ruins and finally crumble into dust.

Death of an organism may be sudden or gradual. Thus by fire, for example, a plant or animal may in a few moments be converted from a living being into a handful of ashes and a wreath of smoke. Again, death may be slow, creeping from organ to organ, and even when the organism as a whole is no longer living there may in some of its tissues still remain portions of the living substance. The whelming of Pompeii by the fires of Vesuvius might be taken as an illustration of the first condition and the gradual but relentless march of a pestilence might illustrate the other.

Since plants have no nerves by which shocks are transmitted to a central system and thence to every portion of the body, they die much more slowly than do animals.

Location of the living substance. Only in very lowly creatures, such as the slime-moulds, does the greater part of the body consist of living substance. The jelly-like masses described for such organisms are among the best examples of pure protoplasm. Generally the body of the plant consists, for the most part, of wood, bark, cellulose, starch, oils, water, sugar, ash and a great variety of other compounds manufactured at different times by the living substance. One examining a tree or herb in the ordinary way can neither see nor touch any of the living substance, whatever, but must lay his hand upon leaf-skin, cork or some of the various other peripheral materials of the plant. It is not otherwise if an animal be investigated in like superficial manner. The living substance lies concealed within the walls of the city it has built. To see it and to study it most delicate manipulation is necessary.

Certain portions of plants are transparent and at the same time contain living substance. Such areas are favorable for observation. If, for example, some of the hairs that grow along the stem of a tomato-vine are carefully removed, placed in a drop of water and examined under a sufficiently powerful microscope, it will be discovered that they are composed of cylindrical joints. Each joint has a wall transparent as glass, and, within, most of the interior is occupied by water. There is also present, however, a pellucid slime, very conspicuous when once identified. It keeps up a remarkable streaming motion and tiny granules in it are carried along like boats in a rapid current. The direction of the stream changes from time to time. Eddies form in the current. Sometimes the streams flow together from different parts of the cell interior and a mound of slime is formed. Sometimes the streams fork again and again, making a network within the cell. The motion may cease if the temperature is lowered or raised beyond certain limits. It ceases, also. if the cell becomes dry or if it is exposed to the vapors of ether or chloroform. A slight electric shock stops the movement, but after a time it may begin again. A strong electric shock stops it forever. This streaming, pellucid slime is the living substance.

Not only in hair-cells does the living substance commonly occur, but in many other portions of the plant. It is found at the tips of all young roots and buds. In the green cells of leaves it is always present. It will be found in certain of the conducting-areas of the plant—in the leaf network and in the young fibers of the stem. In trees and shrubs it occurs neither in the mature bark nor in the mature wood of the trunk, branches or woody roots. Between the bark and wood there exists, however, in ordinary trees a thin layer—no thicker, indeed, than tissue paper—known as the *cambium*. In this layer of cells the living substance will be found. It occurs in all spores, eggs and spermatozoids, in all very young organs and tissues, and in general in all growing parts of the plant.

Physical structure of the living substance. Years ago when investigation of the living substance was in its infancy it used to be described as a "structureless slime" or as "living jelly"—these phrases indicating how little was really known of its organization. The researches, however, of the last fifteen years in particular, have revealed that the intimate structure of the living substance is extremely complex—so much so, indeed, that a new science, the science of the cell, has developed, until to-day libraries can be collected in this field alone. It would appear that, just as the body of a plant or animal is composed of cells and their products, so the particle of living substance in each active cell is itself composed of smaller bodies and their products, the whole constituting an organism of extreme complexity. It may properly be said that there are now known three hierarchies of life—social life, individual life, and cell life. In the first of these man has his place as a component body, in the second he exists as a self-sustained individual, while in the third lies the living basis of his organization.

Modern research has shown that the motion seen in a living cell lying under the microscope of the observer is by no means disorderly or unrelated. On the contrary the kaleidoscopic changes in the living substance are now known to have profound significance in nutrition, growth and heredity. The difference between the old idea and the new may be suggested by an illustration. Suppose some observer stationed in an air-ship many miles above the battle-field of Waterloo. Perhaps by the use of powerful glasses he could have made out a vague commotion far below him, but he could scarcely have distinguished what actually was happening. To an observer on the hills near by, the battle would have presented a very different meaning. Thus, the earlier students of living substance, because they could not see all that is revealed to the observer of to-day, fell into the error of thinking that they had under their microscopes a "structureless slime."

Living substance is by no means homogeneous. Sometimes it shows a fibrous structure made up of innumerable meshes and threads. Again it appears as a foam or emulsion consisting of an intricate combination of larger and smaller bubbles. At one time, when more saturated with water, it is liquid, plastic and mobile. At another, when like a sponge it has expelled a portion of its moisture, it seems almost solid and is passive and immobile. Thus the living substance in the active cells of a growing hair and in the dormant cells of an ungerminated seed may seem very different. By the absorption or expulsion of water living substances may pass from one condition to the other.

Chemical composition of living substance. The following chemical elements are components of living substance: carbon, oxygen, hydrogen, nitrogen, sulphur and phosphorus. In the higher plants the following metals are also necessary for the formation of living substance, although they do not become essential components of protoplasm: iron, potassium, magnesium and calcium. Numerous other elemental substances, such as sodium, lithium, manganese, silicon, chlorine, bromine, and iodine are frequently found in the bodies of plants; but they do not appear to be everywhere either essential components of the living substance or necessary reagents for its construction.

It must not be supposed that all living substance is of exactly the same chemical composition. To say that no two particles are precisely alike would probably be nearer the truth. Although the number of the essential elementary components is so small, many atoms of each kind are present and the variations in their relative positions and combinations might be almost infinite. Certainly, however, the difference between one piece of living substance, such as the egg of a fish, and another, such as the egg of a fern, consists less in chemical composition than in physical structure. Chemically, all living substance lies within limits which have been just outlined.

Physiological character of living substance. The following are the most important physiological characters of protoplasm: 1. *Assimilation*, the power of initiating and maintaining complex chemical changes by which not-living matter is brought into the living condition and into relation with the living substance. 2. *Growth*, a term here applied to the increase of living substance in mass. 3. *Irritability*, the quality of responding, after a manner determined by heredity, to impulses originating within or without the body. 4. *Reproduction*, the power of separating, from the body, portions of living substance that, under the influence of heredity, may recapitulate the developmental stages of the parent. Together with assimilation, in its broad sense, goes on a variety of chemical processes. By these, waste products are formed and excreted, accessory products are combined and modified, and a variety of complex substances are broken down into simpler forms, thus liberating energy that is either used in growth and movement or reappears as body-temperature, phosphorescence, electrical disturbances or some form of mechanical work.

Requisitions made by living substance on its environment. In order to maintain its physiological processes, living substance must have a supply of matter and a supply of energy. The supply of matter, or the *food* of the organism, may be of great variety, provided that it contain the necessary chemical elements in assimilable form. The great primal source of *energy* is the sun and upon its light and heat all living things, in the final analysis, will be found depending. Some, however, like the fungi and the animals receive much of this energy indirectly. It is utilized directly by the green plants, the color of which indicates the presence in their tissues of that extraordinary accessory product of living substance—leaf-green, or *chlorophyll*. This leaf-green that stains either the entire living substance of the cells that are set aside for starch-making, or certain specialized portions, is a form of "light-engine" by which the energy of the sunlight is set at work building up starch out of such simpler substances as carbonic-acid gas and water.

The food of plants. In general the diet upon which a plant can live is simpler than that necessary for an animal. The important elements are principally obtained from sources as follows: Carbon is collected from the carbonic-acid gas of the atmosphere; oxygen both from the atmosphere and from water; nitrogen from salts in the soil, but not from the atmosphere; and hydrogen from water. Sulphur, phosphorus and the metals are obtained from soluble salts in the soil. In exceptional instances the sources may be other compounds than those mentioned. Thus nitrogen and possibly hydrogen may be taken from ammonia products, but this would be very unusual. What has been stated refers to green plants alone, for plants without leaf-green demand a much more complex diet. Their carbon they may obtain from sugars and from proteids; their nitrogen from proteids; their oxygen and hydrogen from water, from sugars or from proteids; their sulphur and phosphorus from the soil, or perhaps from proteids; and their metallic substances from soluble salts in their substratum.

The plant does not ingest solid particles of food as does the animal—though to this certain carnivorous plants are *quasi* exceptions—but receives its nutriment either as gases, liquids or solutions. The absorptive tract of the plant is often specialized so that one area is fitted better for absorption of gases and another for absorption of liquid solutions. Thus in the ordinary green plant it is the foliage that characteristically absorbs carbonic-acid gas and oxygen, while the root-system absorbs water with nitrogen compounds and metallic salts in solution. Aquatic plants are more generalized, as are also air-plants—although the latter use their exposed root-system very much as if established on a firm soil. Humus plants and parasites obtain their food from the bodies of other plants or animals or from decaying organic substances.

Partnerships for obtaining food. Some extraordinary partnership arrangements for securing food have been developed in the plant world. Thus, in the lichen-body a fungus and an alga live in partnership and obtain their food quite as if they constituted an independent green organism. So, too, do many humus plants, such as coralroots and pine-saps, depend upon the presence, in their underground portions, of root-fungi. By aid of these they can secure from the soil organic substances that alone they could not collect. In return for such service they harbor the fungus in their tissues.

Intra-specific partnerships. Among higher plants a remarkable division of labor exists. By it the spore-bearing plants of the species exist as the primary food-gatherers, while the egg-producing and sperm-producing plants live dependently upon them, having no original food-collecting capacity of their own. Thus, among flowering plants the female, quite devoid of leaf-green, lives upon substances stored up for her use in the rudimentary seed borne by the spore-producing plant. The male, also, among flowering plants, lives parasitically upon the tissues of the immature seed or fruit. Similar conditions are known to exist among certain ferns and club-mosses. Other highly interesting inter-relations for nutrition are those between the mother plant and the offspring, as in cone-bearing trees; or between the twin embryos in seeds of higher flowering plants. In the latter instance one of the twins customarily gorges itself with food for the benefit of the other, and by the latter it is ultimately devoured. In such a life-history as that of the sunflower, for example, only the ordinary green leaf-bearing plant of the species is an independent collector of food. Upon it depend the male and female plants, the albumen-plant of the seed, and, for a time, the embryo-plant that is later to develop into a new leaf-bearing individual.

Storage of food. After absorbing its food materials from the air, soil, water or bodies of other organisms, these are recombined by the plant into characteristic products. In green plants the first visible product of assimilation is starch. This substance originates in the leaves and other green portions under the influence of sunlight. It arises as little white granules. These may grow to a considerable size, but are ordinarily attacked by ferments, converted into soluble sugars and conveyed along the conduction-paths of the plant either to growing areas where they are used in construction, or to storage areas, such as bulbs, tubers, fleshy roots, seed-albumen or budcores in which they are deposited as starch or as oils. Proteid substances, originating also in the foliage of the green plant, may be carried away in the form of peptones to growing tracts, or to storage organs, where they may take the shape of little granules, known as farina grains or aleurone grains. Storage layers commonly occur along the conduction-paths, while special storage organs are produced in a variety of plants. Of such storage organs an ordinary potato, onion, beet or carrot may serve as familiar examples.

Ultimate disposal of the food. The materials taken into the body of the plant and subjected to the elaborative processes initiated by the living substances must be either retained as part of the body or excreted. The high manifestation of energy that characterizes the animal is by no means so characteristic of the plant. In other words, constructive processes preponderate in the plant-world and a greater proportion of material received as food remains in the body of the plant than in the body of the animal. Excrements are, therefore, not so abundant among plants as among animals. Indeed the principal plant excreta are gaseous. From the leaves are given off oxygen, a waste-product of starch-making, and water vapor. Water in the fluid state is also rejected by many plants. Carbonic-acid gas, a waste-product of respiration, is excreted from the surface of the plant, both in the area of the shoot and of the root. Solid excreta, however, are not formed by plants.

When retained in the body of the plant, food materials may assume a great variety of forms. A certain portion is utilized in the production of new living substance, but by far the greater amount is stored as cellulose, bark-substance, wood-substance, gelatine, crystals, organic acids, coloring material, tannin, alkaloids, glucosides, oils, fats, resins, gums, reserve-food and cell sap. Many thousands of plant products are known, so marvelous is the chemical activity of the living substance.

Growth. The term *growth* is rather an ambiguous one, since it is applied in several different ways. It should at least exclude *nutrition*, and should generally indicate increase in size. Sometimes, however, there may be an increase in mass without a visible increase in size, and it seems difficult in such an instance not to apply the term growth to the process of enlargement. For the sake of clearness at least three types of growth should be distinguished: 1, growth of living substance; 2, growth of cells, and 3, growth of tissues and organs. The first takes place as a result of constructive assimilative processes, and may or may not be accompanied by a visible increase in size. The second may go on without increase in mass either of the living substance or of the organ to which the growing cell belongs. The third may occur while mass of living substance and cells are increasing, but sometimes even while mass is stationary or diminishing. Thus by change in shape of its component cells an organ may elongate, though while it does this there may be no actual increase in substance. Nevertheless such an elongation might appear as visible growth. Such an analysis is somewhat disregardful of refined and technical terminology, but is not seriously at variance with the truth.

Growth of living substance. The most important fact to be kept in mind concerning the growth of living substance, is that it is not simply an accretion of new material. Growth goes on in varying degree among the innumerable component parts of the living substance, each growing in its own way and at its own rate. Thus results the growth in aggregate of the whole. To illustrate this, let there be imagined a village full of children. After a year or two had passed the children would have grown and the total human weight of the village would have increased. Some, however, of the children would have grown more than others,—some, even, might not have grown at all. The final result, however, a general increase in weight, was not obtained by mere accretion. In such fashion does a microscopic piece of living substance grow. It grows as an *organism*, not as an office-building nor as a snow-drift.

For living substance, the limits of growth above which mechanical support, such as partition walls, strengthening beams, and retaining membranes, becomes desirable, are generally below the limits of unaided vision. For this reason most plant cells are of microscopic size. The cell may, in a complex tissue or organ composed perhaps of millions, be regarded as resulting from the necessity of individualizing small pieces of living substance. It is true, cells vary greatly in size. The smallest are those of the bacteria. The largest are those of certain oceanic relatives of the green felt—an alga belonging to the bright-green group. Yet even in the latter, the body, as large as a hen's egg, which exists without partition walls cutting it in all the planes of space is equivalent rather to a cell-aggregate than to a single cell.

Just why the limits between which cells vary in size should be what they are, is a difficult question to answer. The cause must be sought in the structure and qualities of the living substance and in the conditions of the outer world as they react upon it. A proper comparison would be with the towns and cities of the human species. These vary in size between mere hamlets to cities like London, Paris and New York. Cities with fifty million inhabitants, however, do not exist, because with human society organized as it is they cannot be maintained. To explain exactly the causes that have fixed 6,000,000 rather than some other number as a population limit beyond which human cities have not yet developed, would require a more exhaustive knowledge of anthropology and sociology than any one possesses. Still more impossible is it to state why the limits of cell size are precisely what they are. It is, at the same time, clear that, as in the instance of the cities, the reason lies essentially in the nature of the organism—that is, the living substance which builds the cell.

The largest masses of living substance in which cell compartments have not appeared are the jelly-like bodies of the slime-moulds. These aggregates of protoplasm, in patches the size of a dinner plate, are sometimes found on decaying timber. Because they are not provided with internal mechanical support they lie flat and shapeless upon their substratum.

Origin of the cell as a structural unit. One is now in a position to understand why living substance almost universally displays itself in the microscopic individualized portions known as *cells*. The cell is an adaptation fitted to enable the living substance, under the stress of outward conditions, to perform its physiological functions in a better way than if this adaptation had not been called into being. There is reason to suppose that mechanical support and protection against shock might have been the principal necessities under which primal masses of living substance came to develop the cell-habit. In both plants and animals cell structure is almost universal and both kinds of creatures are said to be *composed* of cells. It must be observed, however, that the cells are not the fundamental units of structure, but are themselves individualized areas arising through adaptation of the living substance to its surroundings.

The growth of cells. Certain distinctions appear to exist between the growth of cells and the growth of living substance. When the living substance grows there is an actual increase in its mass. A cell, however, may grow by distending itself with water and there need be no absolute increase in its living substance. A typical cell shows a delicate wall surrounding the living substance, and a portion of the latter is differentiated from the rest as a complex body termed the *nucleus*. Within the meshes of the living substance cell sap occurs. A normal condition of such a cell is the plump, water-swollen, elastic state known as *turgor*. If enough of the cell sap is lost by evaporation through the delicate wall, the turgid condition is no longer maintained and the cell becomes limp and flabby. An organ composed of cells,—as for example, a leaf,—when the cells have lost their turgidity through evaporation, becomes wilted. In such a condition cell growth cannot go on, and it may be stated categorically that for the growth of *cells* turgor is a prerequisite.

Maintenance of turgor. In order to understand how turgidity of a cell is established and maintained, the common physical phenomenon of liquid dialyzing through a membrane must be thoroughly understood. The living substance of a cell, having an avidity for water, will readily absorb it if it can be obtained. Since, however, having adopted the cell-habit, each particle of living substance is surrounded by a continuous membrane or cell wall, the liquid, to reach the interior, must filter through this membrane. It is a fact of observation that certain liquids or solutions pass through membranes much more readily than do others. Thus, if a bladder be filled with brine and placed in a tub of fresh water it will soon become swollen, because the fresh water passes inward more rapidly than the salt water passes outward. If, however, a bladder, distended with fresh water should be placed in a tub of brine the reverse action would take place and the bladder would become limp. If, further, syrup were placed in the bladder and brine around it, the first instance would be repeated and the bladder would become swollen. Such observations indicate that syrup passes more slowly through the membrane than does brine. In general it may be said that solutions of relatively complex chemical substances move through membranes more slowly than do solutions of relatively simple substances. The phenomenon of dialysis through a membrane is termed *osmose*.

Living cells, since they are provided with cell sap and membranes, are in a condition to maintain osmotic relations either with neighboring cells or with any moisture-containing medium that surrounds them. The presence or absence of osmotically active compounds dissolved in the cell sap has much to do with the regulation of turgor, as it has also with the conduction of food-solutions from one part of an organ to another. Thus, not only are the various cells of a root-surface kept turgid by the maintenance of an inward flow of liquid from the soil, but compounds such as soluble salts of nitrogen or of metals are transported—along special paths in the higher plants—until they reach, perhaps, a starch-making and proteid-making organ such as the leaf. Not only is this upward flow of crude food solutions normal for the higher green plants, but simultaneously there is, of refined food-products, such as sugar and peptones, a downward flow from the leaves to other parts of the plant, even to the most distant rootlets.

A growing cell may then, upon the whole, be regarded as a self-inflating bladder, which, through the activity of the living substance, absorbs water from its surroundings. It does this by the aid of osmotically active compounds produced by the living substance and dissolved in the cell sap. In highly organized plants, such as the ordinary trees, other factors besides osmose enter into the ascent of the sap, but need not here be discussed.

Growth of tissues and organs. Tissues, that is, structural cell-aggregates, and organs, that is, physiological tissue-aggregates, grow by the growth of their component cells. There may be, however, cell-growth without, in a strict sense, growth of the tissue or organ. For example, a nasturtium leaf-stalk bends towards the light, and there may be enlargement of cells on the convex side, or contraction of cells on the concave side, or both; yet such a curvature should scarcely be called growth of the *organ*. Growth of a tissue or organ might perhaps be defined as permanent enlargement arising through growth of the component cells.

There are ordinarily distinguished three important stages in the growth of an organ. These are: 1, the stage of cell-multiplication; 2, the stage of cell-enlargement; 3, the stage of cell-differentiation. A mature organ commonly consists of very many more cells than would be found in the same organ when immature. But since all cells arise from preceding cells and never, so far as known, in any other way, whatever, it is evident that there must have been a general division of pre-existent single cells into cell-groups. This leads to an inquiry into the nature of organ-rudiments. It may be stated broadly that the rudiment of any plant organ is either a single cell or a group of cells. The stems and leaves of a moss or of a liver-wort, the stems and roots of ferns, the spore-cases of "true" ferns and, perhaps, even the stems of pine trees, are examples of organs arising from single-celled rudiments. Of organs arising from groups of cells there might be mentioned the roots, stems and leaves of the higher seed plants, the spore-cases of club-mosses, the spore-cases of seed-producing plants and, in brief, organs generally in higher forms.

The tip of a growing organ is commonly occupied by a little group of cells in process of division. Thus the tips of roots, the tips of buds inside the covering of overlapping scales, and the tips of very young leaves, will be found to consist of small, thin-walled cells, packed full of living substance, and each capable of dividing into two cells by the formation of partition walls. In such rudimentary areas the cells are at first very similar, but before long some cells of the mass begin to assume shapes and structures that are distinctive. Close behind the growing tip of a young root the skin-cells will have begun to flatten and the cells of the central conduction-path will have begun to elongate. These differences and many others become progressively more marked and in older parts of the root each tissue—the skin, the wood, the pith, the reservoir-tissue, the bast, the cork, the milk tissue and the skeleton tissue —will have become developed with its own structural peculiarities.

In growing organs the cells live together somewhat after the manner of individuals in a community. They influence each other in a variety of ways—by mutual pressure, by contact, by transfers of solutions, by propagation of impulses and even by direct interchange of living substance. In growing tips the partitions between the cells often have extremely minute perforations through which the protoplasm is continuous from cell to cell. By this continuity the tip remains an organic unit, and every plant organ, from the earliest rudiment, must be regarded, not as built up, cell upon cell, in the manner that bricks are laid in some edifice of human construction, but rather, as an elaboration of living substance growing under the restraints of physical and chemical law, under the ever present influences of the surroundings, and under the hereditary bonds of the cell-habit.

Irritability. This term is applied to that quality of living substance manifested when, by contraction or chemical change, it responds to stimulation; and when the response is apparently altogether disproportionate to the stimulating cause. Starch-making under the influence of sunlight is not classified as a form of irritability, since it is a reaction not particularly different, in degree, from the reaction that goes on when a photographic plate is exposed to the chemical rays of the sun. There is here no apparent disproportion between cause and effect and the reaction does not essentially differ from similar changes that might be initiated in altogether lifeless substance. But when a nasturtium vine places its leaves perpendicular to the rays of the sun, accomplishing this by a very complicated series of changes in the shapes of cells and in the living substance itself of the leaf-stems, there is a reaction out of proportion to the immediate cause and possible only since a mechanism exists, and this mechanism has been put in motion by the sunlight. Irritable responses, as made by the plants and animals of to-day, indicate not only mechanism capable of responding, but connote also an inheritance through the ages in view of which the mechanism is what it is. As in all other manifestations of the living substance, irritable phenomena are related with past time as well as with the present. Here, indeed, lies one of the principal differences between a living thing and an insentient mechanism composed of springs, wheels, pulleys, levers and rods. One has a past; the other is a creature of the present.

Irritable behavior of living substance. While all manifestations of irritability must be attributed to responses by the living substance, it is convenient to examine first those responses made by living substance, *as such;* and later to consider the irritable responses of cells and organs. A further distinction may be made, for purposes of analysis, between *induced* and *automatic* responses. Really, all responses are induced by stimuli; but if these stimuli originate *within* the living substance—as a result of subtle rearrangements of its component structure—the responses may then be termed automatic, in contradistinction to responses which are plainly induced by external stimuli. Thus, the extraordinary marshalling into groups of the component parts of a mass of living substance, before division of a cell takes place, would be termed automatic; the lashing of a swimming thread, such as that of a spermatozoid, is also automatic; but the contraction of a portion of protoplasm when exposed to a slight electric shock would be regarded not as automatic but as induced.

Examples of automatic irritable phenomena in living substance are very numerous. Here should be classified the streaming movement, the lashing movement, the crawling movement, and the spontaneous contractions of protoplasm. Here, too, should be grouped those amazing evolutions by which the nucleus of a cell divides itself into two, prior to cell division. It is by no means a mere halving of the nucleus that then takes place; but a complex segregation of certain portions on one side and certain portions on the other side of a neutral line, the whole recalling military marchings and countermarchings, or the working of some ingenious manufacturing contrivance, such as the pressroom of a metropolitan newspaper. Automatic movements are dependent upon suitable outward conditions,—as are also induced movements. Thus, too high or too low a temperature, too strong or too weak illumination, or some other condition of the environment, may prevent their appearance. They are not, however, the normal immediate responses to the presence of certain temperature or light conditions and, therefore, cannot be regarded as actually *caused* by light or heat, as are certain induced movements.

Among induced responses of living substance might be mentioned the change in position undergone by particles of leaf-green when the illumination becomes intense. In many higher plants the particles of leaf-green, so abundantly distributed through the cells of the leaves. are shaped like two watch-crystals faced together. That is, they are lens-shaped and biconvex. When exposed to weaker illumination they customarily turn their broad faces towards the light; but if the illumination becomes too intense they shift their positions until only their edges are presented to the rays. Another example of an induced irritable movement is afforded by some free-swimming cells that normally swim either towards a source of light or away from it. Certain organisms of microscopic size are known to swim invariably towards the positive or towards the negative pole of an electric field. Still others are directed by chemical substances in solution. Thus, the minute *Euglena* plants swim towards concentration of organic substances that would be suitable for food, and spermatozoids, directed by chemical emanations, swim towards the eggs of their species So invariably are these directive movements induced that if a very weak solution of sugar, malic acid, or whatever the specific chemical may be, is placed in a capillary glass tube and then immersed in a dish of distilled water containing stimulable spermatozoids, they will swim into the tube by thousands. From such experiments it is learned that the spermatozoid finds the egg with which it is to fuse, because it is induced to swim from a weaker to a stronger solution of some substance that the egg is excreting.

Still another example of an induced movement is furnished by the large jelly masses of living substance characteristic of slime-moulds. These have a habit of climbing up upon the bodies of herbs or other objects and spreadlng themselves out on the leaves or elsewhere, as a preliminary to the production of spores. The significance of such a habit is not hard to understand, for through it the spores when produced are likely to obtain wider distribution. The movement is, no doubt, induced by the force of gravity. *Stimulated* by this force the jelly mass crawls upward. Such behavior is an excellent example of an irritable response to an outward stimulus. Clearly such an upward movement is distinctly different from the upward movement of a balloon. The jelly mass is much heavier than the air and it crawls away from the surface of the earth because the force of gravity induces its mechanism to make this form of response. There is a great difference between mechanism, as such, and the material of which the mechanism is constructed. If it were not *alive* it would respond to the force of gravity precisely as a stone does.

Irritable behavior of plant organs. While, as has been stated, all phenomena of irritability must receive their ultimate explanation in the structure and nature of the living substance, yet it is expedient to separate, in an analysis, the irritable behavior of organs from that of living substance. As before, and under the same conditions, the manifestations may be grouped either as automatic or as induced.

Among examples of automatic irritable phenomena in a growing organ, there might be named the movements of growth, as they are termed. It may be discovered by careful observation that a stem in process of elongation does not increase in length regularly, but in such a way that the tip describes a spiral in the air. This growth-movement is termed *nutation*. It may best be detected by taking, at intervals of a few moments, a continuous series of photographs of some growing shoot. By comparison of the different pictures it will be learned that the stem has not been thrust straight up, but that it has been nodding, first to one side and then to the other, in a highly erratic manner. In part, the movement is determined by external conditions of nutriment, illumination, temperature, among others, but there is also an automatic quality in the movement of nutation which permits it to be mentioned here.

Another remarkable automatic movement—in this instance, in a mature organ—is that of the leaflets in an exotic member of the pea family, known as the "telegraph plant." The leaf of this plant is composed of a large central and two lateral and smaller leaflets. The central leaflet is quiet, but the two small blades keep up a flapping motion, which, although slow, is plainly visible. Of what use this may be, no one clearly knows. Possibly it serves to frighten away leaf-cutting ants, but this seems doubtful. In any event such a movement is typically automatic. It takes place only under suitable conditions of temperature and nutrition, but these conditions cannot be termed the *cause* of the movement. That, indeed, must be very complex and should be sought in the intimate structure of the plant.

Induced movements of organs are numerous—so numerous, indeed, that it may be said of every organ that it is capable of making a variety of irritable responses to the impulses reaching it from the outer world. Among the various effective stimuli are the forces of gravity, light, heat, magnetism and electricity, also air, moisture, matter in solution, matter in contact, and various mechanical tensions, pressures and strains.

While not the only methods of response, very characteristic reactions of organs to an outward stimulus are by maintenance of positions parallel with, or perpendicular to, the force-lines of the stimulus, or by curvature in some definite direction. Thus, under the constant action of the force of gravity, shoots ordinarily maintain an erect position, growing *against* the force; while roots grow *with* the force. Both positions are manifestations of irritability. In the various plant-positions, there is also to be distinguished an automatic type of irritability. Thus, quite apart from the force of gravity, root and shoot grow in opposite directions. They will do this if whirled on a horizontal wheel, as in the experiment of Knight, who thus demonstrated the similarity between the response to centrifugal force and that to gravity, for in such an apparatus shoots grow towards the center and roots towards the rim. There is, so to speak, a *polarity* in plant organs. They have tips and bases, or upper and under sides, or fixed and free ends. In the maintenance of polarity automatic influences are at work. For this reason counteraction of the force of gravity, by revolution of the plant upon a vertical wheel, does not permit the plant organs to become shapeless and unrecognizable. On the contrary, they retain their polarity, though their direction may be different.

Nevertheless the constant action of the force of gravity may be said to induce the upright position of a normal shoot. It is true this position may be modified in a variety of ways by a variety of forces, or by the so-called correlations of growth. A lateral ray of sunlight may force a shoot out of the perpendicular, either towards the ray, as in the nasturtium, or away from it, as in the ivy. And in an organ-complex, such as the branching crown of a tree, the mutual interrelations of the twigs cause positions to be taken which are quite the reverse of those that they would take if growing by themselves. The young sapling of the soft maple, for example, grows erect. When it begins to branch the branches form angles with the primitive stem, and, in a mature tree, twigs will be found growing directly downward, perhaps—a thing that they would not do unless correlated with the other branches of the tree. Sometimes the erect position of one organ inhibits such a position in a subordinated organ. An illustration of this is often seen in pine trees. As long as the terminal shoot is active it is the only one to maintain the erect position; but let it be destroyed and a lateral shoot will bend into the erect position. Evidently the lateral shoot has the structure fitted to maintain the erect position and was prevented from so doing simply because correlated, as a lateral branch, with the original terminal axis.

When all necessary reservations have been made it becomes apparent that most plant organs are strongly influenced by the direction from which the forces of light and gravity may strike them. Evidence of this may be seen whenever a grass stem beaten down by hail lifts itself again, or in the leaning towards the light, of plants in a window-garden.

Besides the manifestations of irritability that have been alluded to, there are many others, to which but a cursory reference can be made. Roots bend from a less moist to a more moist substratum. They commonly bend away from the light. Greater or less warmth may exert a directive influence upon growth. Chemical substances in solution influence aquatic organs. A number of organs grow towards oxygen or towards the air. Others grow away from it. Thus, if several pollen-spores germinate in a drop of sugar solution all the pollen-tubes will grow towards the center of the drop, and away from the air in which it may be suspended. Some organs place themselves against a stream of water, while others grow with the current. Some organs bend towards the positive electric pole, others towards the negative. Growth in a magnetic field shows that magnetic force has its directive influence. Contact induces curvatures. Root tips upon touching a hard body become convex toward the body that touches their sensitive area. Tendrils, on the other hand, and twining stems become concave toward the body that touches their sensitive surfaces, thus enabling themselves to seize hold of supports. A wound often induces curvature. Thus, branding a root tip with a hot wire induces it to curve to one side. In general, the plant is a sensitive creature feeling easily slight changes in the surroundings and accommodating itself to them, so far as possible, by irritable curvatures.

Special organs of irritability are present in many plants. Of these the *pulvinus* of the pea family and the tendril of gourds or smilax, might be cited as illustrations. At the base of each leaflet of a bean plant, for example, may be noticed a short section of the leaf stem in which the color is deeper green than elsewhere. A similar section exists at the base of the main leaf-stem. Such an area is called a pulvinus and is the motile organ of the leaf. When provided with pulvini, as are beans, clovers, wood-sorrels and several other plants, the leaves easily change their positions under slight stimuli. Clover leaves examined at night will be found to be in sleep-positions different from those of the day, and doubtless induced by falling temperature and less illumination. Leaves with pulvini commonly make automatic movements, most noticeable in the telegraph plant mentioned above. Some leaves with pulvini are highly sensitive, and of this condition the well-known *Mimosa* is an example. In this plant a slight shock or burn causes the numerous leaflets to fold together and the whole leaf to drop downward on its stem. The rapidity with which the action takes place makes it very striking, but it is not particularly different, except in amplitude and celerity, from many other sensitive reactions. All plants are sensitive plants, if one watches them closely enough. The curious Venus's fly-trap of Carolina is another quickly-moving variety. Its leaf-blade may snap together along the pulvinus-like midrib, quite after the manner of a steel trap. The mere contact of an insect is enough to set off the irritable mechanism.

A tendril is a singularly ingenious contrivance. At first it is straight, or with the free end slightly bent. It sweeps about slowly with the growth-movement known as *nutation*, and when its tip encounters a resistant body, the tendril becomes bent around the object that it has found and fastens itself to it. Then the whole cylindrical organ coils into a spring, drawing the leaf or stem up against the support. Later the tissues of the tendril become woody, giving strength, while the coiled structure gives elasticity. Thus plants with these organs are the most perfect of climbers and support themselves lightly but firmly upon their trellises.

All the responses to stimulation that have just been reviewed would be classified as curvatures. When a gall-forming insect stings a plant, or when a witches'-broom fungus obtains a foothold upon it, there is, rather, as a result of the stimulation, an abnormal growth of tissue. Galls, in particular, are often very extraordinary structures. The huge purple root-galls of the wild rose, the spherical papery shells of the oak, the little hemispherical nodules on basswoods leaves, the cone-like grey bodies on willows and the great bushy tangles on black ashes are all familiar objects in Minnesota. In such galls special anatomical structures are called into existence by the virus injected with the insect's sting. Special gall-types characterize particular plants, and will not be found elsewhere. Between the specific virus and the specific character of the living substance of the plant a relation exists; and upon this depends the anatomical and physiological character of the gall.

Another type of induced irritability of organs is seen in the arrangement of skeleton-tissues, for the large leaf will have more strengthening material in the stem than will the small leaf of the same species. Such strengthening areas are found to lie very exactly in the regions of pressure or of tension, and may be regarded as having come into being by the response of cells to such stimuli. The cross-section of the familiar rhubarb leaf-stalk shows it to be half-cylindrical in form. The arched side is towards the ground and the calling into existence of the arched form of leaf-stalk depends upon the action of pressure, owing to the weight of the leaf-blade. All the beautifully accurate arrangements of strengthening beams and elastic tissues in stems and leaves may be regarded as possible only through irritability of the living cells, some of which, under pressure, thickened their walls to withstand it; while others, in a region of flexions, adopted elasticity of structure.

Summary statement. What has been brought forward upon the subjects of plant nutrition, growth and irritability, suffices merely to direct attention to a few of the paths along which investigation has proved profitable. No attempt has been made in so limited a space to present a complete outline of plant-physiology. In cursive manner, the existence of a living substance has been affirmed and it has been intimated that the physiological activity of the plant is in fact the physiological activity of living substance. For this reason, advanced research must be with aid of the microscope and all the other appliances of the modern laboratory. The secret of the plant lies very deep and is not to be wrested from it by superficial examination or analysis.

Self defense. Not only must the plant utilize the materials and forces about it and adapt its structure and behavior to the environment, but it is also often called upon to defend itself against unfavorable conditions. Two of the common animal types of defense are but sparingly employed by plants. These are *active opposition* and *flight.* Not being provided with muscles, the plant can rarely run from threatening dangers, nor can it often combat them by an active display of force. Among the lower plants flight is of defensive value for diatoms and other motile varieties. They swim away from undesirable localities and seek those where they can best maintain their existence. Motile cells, such as spermatozoids and swimming spores, may also protect themselves in this manner. Active opposition is very rare, but is practiced, perhaps, by such a plant as the Venus's fly-trap when it snaps at the insect that may have approached it with some notion of feeding upon its tissues.

Most plants maintain a passive defense against unfavorable or harmful influences. A great variety of such defenses are practiced. Some are structural, while others are physiological. The principal dangers to which plants are exposed are these: desiccation, inundation, fracture by wind or water, poisoning by salts, over- or under-illumination, over-heating, cold, and attack by other plants or by animals. The defensive adaptations against the various inanimate harmful influences have already been discussed in Chapter XL; but there remain a few words to be said concerning defense against other plants and animals. The most universal method is by producing distasteful or poisonous substances in the tissues. Among such should be counted the acids, alkaloids, tannins and resins that are characteristic of many plants. By means of these substances, dissolved in their juices, they make themselves objectionable to grazing animals, to insects and snails, and even to parasitic fungi. Sometimes the poisonous materials are projected to a distance, as is true of the poison-ivy and poison-dogwood. In such instances the animals are dissuaded even from approaching the plant.

Another common method of defense, especially against animals, is the wearing of armor. This ordinarily takes the form of prickles, spines, or thorns, though it may rarely appear as hard scales or plates. Armor is not limited to the plants of any particular region or of any adaptational group. The aquatic water-fern, *Salvinia*, has its sharp-pointed hairs to deter small insects from feeding upon its fruiting areas; the mesophytic hawthorns, roses, and brambles are bristling with prickles and thorns, while the xerophytic cacti and spurges are unapproachable in the effectiveness of their defense. Armor is particularly useful to desert plants, for they are most exposed to attack by hungry animals. Less ordinarily in mind, when plant-armor is mentioned, is the skin on leaves and green twigs. This, while not defensive against animals of large size, is sufficient, perhaps, to puzzle some of the smaller insects, and often suffices to prevent the infection-tube of a fungus from obtaining an easy entrance to the soft inner tissues of the leaf or stem.

Mimicry is a peculiar method of defense adopted by some plants. Thus, an innocuous plant by its resemblance to a poisonous variety often escapes injury. In deserts some kinds of plants are gray in color, irregular and massive in shape, and, in short, so much like stones that they are likely to be passed over as members of the mineral kingdom. Such an appearance must help them just as its green color helps the tree-toad by making it inconspicuous. Another kind of mimicry has been thought to characterize certain tropical herbs with mottled leaves. Some begonias and aroids suggest themselves as examples. It has been supposed that by their resemblance to snakes they may avert danger to themselves, from grazing animals. The sensitive plant, which at a slight shock drops into an apparently shriveled and dry condition, may by this behavior startle or deceive animals that would otherwise feed upon its foliage.

Utilization of allies is a not uncommon method of defense. Thus, plants growing in hedge-rows obtain protection because the thorny or impenetrable vegetation about them is sufficient to withstand the attack of animals. Some plants may obtain defense by hiding themselves in out of the way places, but this is scarcely a calculable matter. A peculiar alliance is that which exists in the tropics between certain trees and ants. In these regions leaf-cutting ants are abundant and some trees, by the secretion of sweet liquid on the twigs, attract large numbers of warrior ants that feed upon the honey. The plants even develop shelter for such ants and when leaf-cutting ants attempt to ascend the tree the honey-eaters swarm out and offer battle. An ant-defended tree, such as a *Cecropia*, is an extraordinary object. A slight blow upon the trunk calls out thousands of angry ants from every crevice. By keeping such a body-guard of insects, the plant undoubtedly protects itself. Many other such alliances might be mentioned but one further example must suffice.

Seedlings of trees are particularly exposed to harm. As in man, so in plants, the expectation of life is at first decidedly low. Most seedlings perish before they are firmly established and those that are fortunate enough to persist and finally to mature into sapling-trees have generally been nursed along by surrounding plants which have happened to be of kinds not unfavorable to the seedling itself. Thus the young red pine plants make excellent nurses for the seedling of the white pine, and if the former are abundant on the forest floor, the white pines are more likely to obtain a foothold.

The maintenance of a plant, like that of an animal, depends, in the words of Herbert Spencer, upon a continuous adjustment between internal and external conditions. If this adjustment ceases to be made, death is the result. Every fundamental problem of life that confronts the animal, confronts also the plant. The solution may be by different processes, but solution there must be in the one instance as in the other. Structurally and physiologically the living substance of plants and of animals shows many resemblances, and it is not at all erroneous to say that plants and animals are but different manifestations of the organizing power of living substance. In plants the constructive processes preponderate, in animals the energy-producing; but fundamentally the two kinds of creatures are much more decidedly alike than different.

Chapter XLV.

Maintenance of the Plant Species.

The methods by which individual plants are maintained as units in Nature may be regarded as methods, also, for maintenance of the species. A species consists of all the individuals, living and extinct, that are judged to form a single and definite line of inheritance and are of practically identical structure. Thus, one speaks of the human species, meaning not only the men and women of to-day, but also their ancestors. In the same manner one may take into the mind the conception of a plant-species, such as the dandelion, or the white pine. While the lives of individuals are comparatively brief, the life of a species may be of long duration, varying, perhaps, from a few hundred to many millions of years. Most species are more than ten thousand years old—at least this is the belief that has been strengthened by researches in geology and in the history of development.

In order to continue the chain of individuals that constitutes a species, the living substance both among plants and animals has the universal habit of separating portions, usually single cells, from the mature body, and these, if properly situated, will build up new bodies from the organic or inorganic world by which they are surrounded. Such a process is termed *reproduction*. It is analogous to growth and may be regarded as a function of living substance that has become specialized owing to the establishment, for each kind of living thing, of a *life-period*. The normal life-period may vary in different organisms from a few days to many hundreds of years. Some individuals are comparatively ephemeral, while others are able to maintain themselves over periods almost as long as that of human history. Whatever is the duration of the life-period, it may always be considered as expressing a ratio between the bodily vigor of the organism and the average sum total of unfavorable chances against it, in the outer world. Thus, for each kind of living thing an hereditary rhythm comes to be established.

At first the number of individuals in a species may be few; later, a climax may be reached in the maintenance of the species, and following this the number of individuals may dwindle until finally the species becomes altogether extinct. There is, therefore, a "life of the species" distinct from the life of the individual. For a species to maintain itself through the centuries it must be strong—that is, composed of strong individuals, each able to hold its own in the battle with other types of life and with the forces of Nature. For this reason the "instinct of self-preservation" characterizes every living thing. A species composed of negligent, apathetic or suicidal individuals could not continue in competition with others in which the opposite qualities were developed. Nevertheless, although the instinct to live is universal among living things, the necessity of death is equally universal and here one faces an extraordinary dilemma. For the interests of the species, each individual is placed in a contradictory position. Yet the apparently irreconcilable situation is understood when it is observed that while the passion for life, in an animal, serves to keep the species strong, the death, also, of the animal, at the end of a definite life-period, serves precisely the same end; since in this manner the species may consist always of fresh, young and vigorous organisms rather than in large part of those old, decrepit or shattered. While in the sphere of the individual there is no solution of the problem of life and death, it is illuminated in the sphere of the species. Thus, death at the end of an appointed life-period has been described by Weismann as an "acquired physiological trait," developed for the advantage of the species as a whole and no less useful than the instinct to live which characterizes each individual.

With these conceptions in mind it may be understood how a plant or animal species may be regarded as a continuous, very long-lived organism in which, in a rhythmical succession, individuals constantly form and disintegrate. Possibly the living substance of the species as a whole might be conceived of as a sea in which that of the individual organisms was as the waves rising and falling through the whole period in which the sea existed. Even an ocean, however, as taught by geological science, may disappear; and in the same manner many species, after existing perhaps for thousands of years, have become extinct. Schopenhauer beautifully illustrates this thought by his figure of the waterfall, in which he compares the lions of the desert to the drops of water that hurry to the brink of a cataract, are poised there for a moment, and then plunge into the abyss below. The *lion species* continues, like the fall, and the *lion quality* persists—just as the rainbow crowns the spray so long as water flows and rocks are strong.

Reproduction in its broad sense may, therefore, be defined as that form of growth in which a species bridges the gap from individual to individual. It is not a process by which new organisms are *created*, but one by which the immortal and underlying living substance may keep intact the chain of individual bodies that constitutes the species.

Propagation. It is customary to classify reproductive phenomena as *propagative* and as *reproductive in the narrower sense.* Propagation is a term applied to all processes by which new individuals come into existence through divisions of the parent body other than in the formation of special reproductive cells. Thus the growth of new potato plants from the buds or "eyes" on the tubers, the multiplication of house-plants or trees by cuttings, buds or grafts, the development of blackberries from bent-over canes, of strawberries from runners, of onions from aerial bulbs, are all classified as forms of propagation. Such processes are indicative of strong regenerative power in plants, but it should be noticed that considerable difference exists among different plants in their ability to propagate. Some, like the willows, propagate very easily, others, like the castor-oil plant, with difficulty. Propagative or regenerative power may exist in most of the vegetative organs, and sometimes in true reproductive areas like spore-cases, spermaries or egg-organs. Generally speaking, however, propagation is a function of the vegetative tract and is most common in the least specialized portions. Roots and stems, for example, much more frequently give rise to new individuals than do leaves, flower-stalks, petals or seed-coats. In some groups of plants, such as the mosses, propagation is abundant; in others, such as the mustards, it is rare or unusual. Special propagative bodies, like the gemmæ of the umbrella-liverwort, the bulbils of ferns or of tiger-lilies, and the brood-cells of many mosses and fungi are not uncommon. When they are one-celled they are difficult to distinguish from true spores.

Of important propagative organs among higher plants should be mentioned the rootstocks, tubers, bulbs, corms and trailing stems of many varieties of herbs. Here, too, should be included certain buds, such as the separable buds of pondweeds and bladderworts; and the offsets, stolons, suckers, runners, and other branches with propagative tendencies. The leaf of the walking-fern, and the leaves of some begonias have strong propagative power. In mosses almost any portion of the body, if isolated, proceeds to develop a new individual.

Reproduction. Reproduction in the narrower sense, as it takes place in organisms that have developed the cell habit, begins by the formation upon the parent body of special reproductive cells. These are either *perfect* or *imperfect*. Perfect reproductive cells are those that, after separation from the parent body will, if conditions are favorable, develop into new organisms. Such cells are called *spores*. Imperfect reproductive cells are those that will not normally at once develop into new organisms, but will fuse together in pairs as a preliminary to development. Such fusing cells are called *gametes*, and ordinarily a division of labor exists among gametes in view of which some, in a species, are motile, or at least mobile, and active, while the others are quiescent or passive. The motile gamete is called a *spermatozoid* and the quiet gamete is called an *egg*. In certain lower algæ, such as the water silk, both gametes are provided with swimming lashes and are consequently motile. In higher types, however, one gamete retained the motile character while the other lost it and as a consequence of its quiet life, grew larger. Thus arose the distinction between male and female cells, a distinction that lies almost as deep as that between plant and animal cells. In both kingdoms similar conditions have arisen, and in both, the formation of eggs and sperms is a normal and constant character in all species above the very lowest in the scale. In both kingdoms the sperms are generally provided with swimming lashes, or their vestiges, though, sometimes, as in red algæ, these are altogether lost and the sperms depend upon water currents for their transfer to the eggs.

After a sperm and egg have fused—by a complex process entailing a profound rearrangement and combination of parts—the resultant cell, known as the *fecundated egg*, becomes capable of elaborating a new organism.

There are, then, in the plant world, four types of reproductive cells: 1, the *originally* perfect cell or spore; 2, the imperfect motile, male cell or sperm; 3, the imperfect quiet, female cell or egg, and 4, the *secondarily* perfect cell or fecundated egg. The story of plant reproduction concerns the formation, structure and behavior of each of these four types of cell and the interrelations that arise between them, their products and the mature areas of the individual upon which they are produced.

Production of spores. Almost all spores are of microscopic size. In quantity, they appear as a dust. The spores of a puff-ball or the pollen of an Easter lily will illustrate this. There are two principal methods of spore production. They may be formed either from superficial cells of the body, by *abstriction*, or from the contents of special cells known as *spore-mother-cells*. The former method is illustrated by the blue moulds, mushrooms, red algæ and related plants, in which certain superficial cells pinch off their free ends as one or more special spore-cells. The latter method is much more universal, and characterizes mosses, ferns and all higher plants. Furthermore, it is the method common in many types of algæ, such as the brown seaweeds, and in many fungi, such as the black moulds, fish-moulds, and sac-fungi. Spore-mother-cells may produce, in different types, from one to many hundreds of spores. Large numbers arise in the mother-cells of the giant kelp, the fish-moulds and the black moulds. In many sac-fungi the number is commonly two, four or eight, while in liverworts, mosses, ferns and the higher plants four spores are ordinarily produced from each mother-cell, except in the instance of embryo-sacs.

Spore-producing areas are often aggregated as definite organs. Examples of such are the gills of mushrooms, upon which the spores form a superficial layer, and the various capsules containing numerous mother-cells—such as those of mosses and ferns, or the pollen-sacs of flowering plants. Another aggregate body is seen in the fruit of the cup-fungus, where the lining consists of numerous sacs in each of which a definite number of spores is formed.

In any case, spores arise by the division of preëxisting cells of the body and, after formation, they are either distributed to a distance or retained upon the body and permitted to germinate near the point where they arose. The first is the primitive and ordinary treatment of spores, but certain special types, such as the large-spores (embryo-sacs) of seed-producing plants, are retained in the rudimentary seeds where they were formed and go through their germination processes without distribution to a distance. While maturing, spores are protected, moistened and nourished by various devices.

Distribution of spores. If spores are to be removed from the body of the plant producing them, some method of separating them from their point of origin must be devised, and some agency must be found that will transport them to a spot where they may be able to germinate. Of abstricted spores, such as those of mushrooms, the separation is little different, in most instances, from a mere falling off the support. Yet in certain cluster-cup fungi special wedges of cell-wall-substance are produced between the successive spores of a chain and by means of these they are loosened from each other. And in the fly-cholera fungus the terminal spore is projected from its stalk by an explosive mechanism that not only separates the spore from the body of its parent, but throws it some little distance from its point of origin.

In order that spores formed internally, within spore-mother-cells, may be distributed, the walls of the spore-mother-cells must be broken or dissolved. Sometimes only the ends of the sacs break down to release the spores, as in cup-fungi and disc-fungi, and in such the release is sometimes of an explosive character. Again the whole wall of the spore-mother-cell may dissolve. This is true of mosses and ferns, of club-mosses and higher plants. In these instances the spores come to lie freely, in the form of a dry powder, within the capsules where the spore-mother-cells were developed.

Having been liberated either from the stalk to which they were attached or from the chamber in which they were confined, spores become units for which various distributional devices have arisen. They are borne away by gusts of wind, by currents of water, or by insects or birds that have picked them up either by accident or design. Sometimes special assistance is given them by the parent plant—directly, as when a liverwort produces, in its capsule, writhing cells or *elaters*, by the struggling movements of which the spores are scattered; indirectly, as when the flowering plant secretes honey near where its pollen spores are formed, thus attracting insects that may act as carriers. A great many structures in the plant world have arisen to assist in the distribution of spores. Among these may be mentioned the erect stems of moss capsules, serving to lift the spores into the wind, the teeth at the margin of a moss capsule, serving to sift out the spores at favorable times, the spring-back of the catapult-like spore-case of true ferns, and the explosive pollen-sacs of some flowering plants; but no adequate idea of the variety that exists can be given in a limited space.

Sometimes spores attend to their own distribution by the development of motile organs, such as swimming threads, as in fish-moulds or green felts, or by the production of gas bags by which they float more easily in the wind—a condition that exists among the spores of the pines. Many pollen-spores have viscid or spinous surfaces that facilitate their attachment to the bodies of insects, and in general, the surface of the spore is commonly adapted to aid in distribution.

Not infrequently spores are distributed *en masse* rather than separately. Orchids and milkweeds furnish good illustrations of this when several hundred of their spores cohere in little club-shaped or saddlebag-shaped clusters and these are carried away as units upon the bills or legs of insects. Similar aggregates of spores are produced in many lower plants, as in the water-ferns, *Azolla* and *Salvinia;* and a somewhat related condition characterizes the green felts. In the latter each motile perfect reproductive body is covered with swimming lashes, indicating that it is equivalent to an undivided group of spores, each one of which, if separate, would have had its own pair of lashes.

It makes a difference, in the economy of the plant, whither the spores are carried, in the distribution. The chances against their finding spots favorable for germination are met either by their production in enormous numbers, or by highly accurate methods of distribution. Pines illustrate the former condition, while orchids, in the management of their pollen spores, illustrate the latter. Much depends upon the needs of the sporeling—the plantlet that arises from the spore, upon its germination—and many structures and habits of spores are determined by the special requirements of the new plant. Thus, it happens among scouring-rushes that certain spores will produce little male plants, while others will produce small females. It is important that these plants should not arise isolated from each other, for then it would be difficult for them to breed. Therefore, scouring-rush spores are provided with curious grappling appendages by which they cling together in groups. Again, in some ferns, many club-mosses and all flowering plants two kinds of spores are formed, differing in size. The large ones, containing more food material, are better suited to give birth to female plants of the species, while the small ones, not so well nourished, can produce only males. Females need generally to be larger than males, for they have to form and nourish the larger gamete-cells, the eggs. Such a difference in size of spores occasions difference in their distribution and since it is more economical to transport the smaller bodies it happens that in higher plants the large spores are not distributed at all, and the small ones are brought near them so that upon germination of both, the male and female plants will not be too far apart. Various devices are employed in the different families. Very remarkable is the behavior of the little water-fern, *Azolla*, in which a cluster of small spores, embedded in mucilage and furnished with barbed grappling appendages upon the group, is ejected from the spore-case and is carried by water currents to find an anchorage among slender, thread-like appendages of the large spore, provided for that purpose. Under such an adaptation the two sexes arise in close proximity.

In flowers all the extraordinary arrangements for distribution of pollen are associated with the peculiar habits of the males and females of the higher plants. The female originates, as a microscopic body, from the undistributed large-spore within the rudimentary seed. The male, therefore, has come to be a degenerate, cobweb-like organism that lives parasitically on tissues near the spot where the female is situated. Thus pollen spores must be distributed not haphazard, as may be the spores of liverworts, mosses and ferns, but to some particular spot—either to the end of the rudimentary seed, as in lower seed plants such as pines, or, as in higher seed plants, to a special area known as the *stigma*. Since, further, all enlargements of experience are generally valuable for a plant as for an animal species, it happens that very often pollen spores are carried from one flower to stigmas of another, perhaps on another plant. This is called *cross-pollination*—a very different matter from *cross-fecundation* with which it must not be confused. For generations a false analogy has existed in the minds of almost every one, botanists included, that there is some comparison between pollination and a breeding act. There is no comparison; the two processes are absolutely distinct. Pollination is merely a special type of spore distribution of which the "puff of smoke" from a puff-ball is a more general type. Fecundation,—the blending of sperm and egg,—is an entirely different matter. In flowering plant species, after pollination has occurred and small spores have been placed in a position where they can germinate, male plants come into existence and the breeding-act takes place between microscopic organisms living parasitically upon the tissues of the spore-producing individual of their species. To speak of the "sexes" of flowers, or to call stamens "male" structures, or to name one cottonwood tree a male and the other a female, is in every instance an indication of ignorance or sloth, or it is a concession to the ignorance assumed to exist among one's hearers.

The colors, forms, structures, perfumes, secretions, positions, divisions of labor, and succession of flowers are all intimately connected with pollen-distributing devices. To discuss them in detail would require not merely volumes but libraries. It must suffice here to remark that every special type of flower has its own particular mechanism for spore distribution. It may utilize currents of air or water, or more commonly insects. Thus, by their interrelations, the two groups of living things, flowering plants and insects, have come to be highly developed as a partnership, constituting, indeed, the most remarkable association of all those existing between plants and animals.

Germination of spores. When a spore enters upon the course of development through which a new plant comes into existence, it is said to *germinate*. Perhaps not quite all the cell divisions that are undergone by spores should be classed as germination-stages. In lichen-fungi, for instance, and in many others, spore-cells before they are separated from the parent plant divide once or more, even building considerable aggregates; but this behavior seems rather a multiplication of the spore-cells than true germination. Yet even among distributed spores germination sometimes begins before the spore leaves the body of its parent. This is true of the cone-headed liverwort, the spores of which become divided into internal compartments before they are scattered from their capsule. Such division seems to constitute a true germination, for later divisions, by which the liverwort first-stage plant is constructed, follow in unbroken sequence, after the spore wall has been fractured. Undistributed spores, such as embryo-sacs, germinate at the spot where they were produced.

If the outer wall of the spore is hard and brittle, as is usually the case, it must be broken by the expansion of its contents unless the sporeling is destined to remain principally or entirely within the confines of the spore. The latter condition actually obtains among many large-spores and is notably characteristic of the embryo-sacs of flowering plants. In them the female matures and produces her eggs without ever leaving the spore from which she arose. And in smaller club-mosses, quillworts and four-leafed water-ferns the male matures within the small-spore, the wall of which is finally broken open to liberate the spermatozoids. In all such instances the sporeling nourishes upon substances present in the spore and does no independent vegetative work. If, however, the sporeling is destined to gather nutriment from the outer world it very early establishes itself as a filament, plate or mass of cells, breaking or dissolving the original spore wall in the process. Thus, fern spores, when ejected from their capsules upon a sufficiently moist surface, soon crack open and a transparent-walled cell is protruded which undergoes rapid divisions, growth and differentiation, finally becoming a little green, prostrate, heart-shaped body with abundant root hairs and leaf-green granules. So, too, a fungus spore customarily protrudes, through a cleft in its wall, its first pale thread that nourishes upon whatever may be its proper food, ultimately divides, branches, grows and brings into existence a new fungus body. The pollen spores of flowering plants are not infrequently furnished with special thin places in their walls, through which the tubular sporeling may easily emerge. The necessary general conditions of germination are sufficient warmth and moisture and, in some instances, the chemical stimulus of a proper food supply outside the spore wall.

Care of sporelings. In all plants more or less provision is made for the protection and nourishment of the sporelings. The spore commonly contains food material, or mechanism for making it, and the supply of food is carefully adjusted to the needs of the new plant. For this reason in smaller club-mosses, quillworts and water-ferns the large spore is furnished with a comparatively generous stock of provisions, in the form of starch and aleurone grains, and consequently becomes as large as a grain of sand. Unlike most spores, these are distinctly visible without magnification. In the plants mentioned, the female, consisting of numerous cells, among which the egg is of prime importance, does little or no independent vegetative work, and must perforce have provisions enough reserved for her use to enable her to reach maturity. Sporelings with special necessities, such as pollen-tubes, have special food substances provided for them and are stimulated and directed in their growth by structural adaptations of the tissues around them and by chemical stimuli that guide them towards the eggs of their species.

Production of spermatozoids. All plants except the lowest algae and fungi produce gametes, or fusing cells. In a few lower algae the cells that fuse are alike, and in many fungi the fusing cells become blended into one body, in which it is difficult to distinguish the male and female portions. In most of the algae, in liverworts, mosses and ferns and in all the higher plants there are undoubted distinct and dissimilar sperms and eggs formed in special cells or organs.

Spermatozoids are typically small motile cells provided with two or more swimming lashes, by means of which they can progress in the water. The sperms of the water silk and some of its relations are pear-shaped, with the lashes on the smaller end. Those of the brown seaweeds are somewhat pointed, with the lashes on one side. Those of mosses, ferns and higher plants are commonly more or less corkscrew-shaped. In mosses and club-mosses two swimming lashes are formed, but in ferns, cycads and some other higher plants that have been studied the number of lashes is greater. In two high types of plants the lashes seem to have been lost, viz., in red algae and in most flowering plants. The size of spermatozoids is almost invariably below the limit of unaided vision, but sperms of cycads are plainly visible, without the assistance of a microscope, as tiny specks. As produced in some of the algae, sperms contain leaf-green and considerable living substance in addition to the portion termed the nucleus; but in brown and red algae and in flowering plants the substance is principally nuclear. Unlike many spores, spermatozoids are not formed as superficial cells, but originate from the divisions internally of mother-cells. Sometimes, as in the sphere-alga, enormous numbers arise from a single mother-cell, but more commonly only one sperm develops in each. The mother-cells may be superficial and aggregated, possibly, in exposed clusters, as among brown and red algae. On the other hand they may form the core of a solid organ, the *spermary*, as in mosses, liverworts and ferns. In the cone-headed liverwort, for example, thousands of sperm-mother-cells arise in each microscopic melon-shaped spermary, and, in the course of its life, a male cone-headed liverwort produces millions of such cells. In higher plants the males become greatly diminished in size and the number of spermatozoids that one can produce during its life is reduced to a score or less in water-ferns, to four in the quillwort, and to two in most seed-producing plants.

Distribution of spermatozoids. Each spermatozoid is carefully constructed within its mother-cell, and when the latter, by solution of its wall, opens to release the tiny male cell, this, in moss or fern types, swims rapidly away. It is carried in red algae types by water currents, and is liberated directly beside the egg in seed-plant types; for in them the pollen-tube containing the sperms grows into the immediate vicinity of the eggs produced by the female of the species. In its movements the spermatozoid is guided by chemical stimuli. The duration of its locomotion varies in different forms, but is rarely known to exceed a few hours.

Production of eggs. Plant eggs occur in all species that produce sperms, for the two kinds of cells are complementary. In lower forms eggs may be motile and very much like sperms in appearance. They are distinguished, however, by tiring more quickly or by their slightly larger size. Typically, however, eggs have no swimming lashes and are quiet, passive cells, containing leaf-green bodies or their rudiments, in such plants as produce leaf-green; and they are much larger than the spermatozoids of their species. Yet plant eggs never reach the size of similar cells in animals, and the largest, among which should be counted the eggs of pine trees, are little ovoid, whitish bodies that may be dissected out of the rudimentary seed where the female lives and produces them, and may be picked up on a needle point for examination by the unaided eye. Most plant eggs are microscopic.

Eggs, like sperms, may be produced in mother-cells, sometimes several from each, but more often only one. In the sphere-alga a row of almost spherical eggs is produced in each of certain tubular cells of the filamentous plant-body. But occasionally eggs arise as the terminal cells of filaments, as in bass-weeds, where they are protected by a sheathing layer. Since the egg is a very important cell in the plant economy, it is protected from harm, in all higher plants, by surrounding cells; and thus in the series of plants extending from the liverworts to the pines, eggs arise in flask-shaped organs, one egg at the bottom of each flask. Clusters of such microscopic flasks are found at the end of the stem of a female moss plant, on the under side of fern sexual plants, and embedded in the surface of the enclosed female plant of rudimentary pine seeds. The egg organ serves the double function, in such plants, of producing the egg and protecting the young embryo during its early stages.

In a few plants eggs are ejected from the body of the female, as among many animals—for example, fish; but generally the egg is not ejected and remains in the organ where it was formed, awaiting fecundation. Certain brown seaweeds illustrate the first condition. The sperms and eggs are ejected into the sea water, where they find each other and pair. The second condition is that of the red seaweeds and of the whole series from mosses to seed-plants. Moreover, it essentially characterizes the fungi and many of the bright-green algae. In the management of their eggs plants remind one somewhat of the mammals. Because of the small size and concealment of plant eggs they are not familiar objects like those of insects, fishes and birds.

On account of their motile character, sperms are much more likely to be lost than eggs, consequently plants produce them in much greater numbers. Ordinarily many thousand sperms are constructed for one egg that is fecundated. But in seed-plants where the male grows as a parasite upon tissues close to the location of the female, only a pair of spermatozoids are needed, one for each egg produced by the female. In such forms the cells that are peculiarly in danger are the pollen-spores and these are commonly formed in extraordinary profusion.

Fecundation. The fusing of sperm and egg is known as *fecundation.* After fusion the egg is said to be fecundated. Exactly the meaning of the process is not clear. It is known that by it the offspring derives the benefit of a double line of inheritance, thus enabling it to make favorable variations, and perhaps accommodating it more precisely to its surroundings. But a single sperm fuses with each egg, and after this has taken place the egg commonly secretes a membrane which before was absent, and thus shuts out later sperms that might attempt a fusion. The cell mechanics of the fecundation process are decidedly complex, for this is by no means a mere blending of two masses of living substance, but is an orderly reorganization of the two structures into one. Not every portion of the egg is fitted to receive the sperm. There is generally a particular spot on the egg surface at which the fusion takes place. This is known as the "receptive spot," and in some forms it differs in color and texture from the rest of the egg. The swimming lashes of the sperm seem always to blend with that portion of the egg outside the nucleus, while the head of the sperm fuses directly with the nucleus of the egg. In cycads the swimming lashes of the sperm are separated from its body immediately after entering the egg and may be seen lying isolated in the living substance around the nucleus.

Behavior of the fecundated egg. After fecundation has been completed the fused body is regarded as a single cell, so perfectly have the two components merged their identity in their common product. This single cell is the fourth and last, as here classified, of the important types of reproductive cells formed by plants. After a period of rest it normally segments and grows, and by the continuation of this process a new structure is brought into existence. This organism is known at first under the general name of *embryo*, and matures into one or another type of body, as may be determined in the species of plant to which it belongs. Upon the whole, the behavior of plant eggs is more various than that of animal eggs. Among animals it is customary for the egg to mature into an organism similar to one of those which, by the production of sperms or unfecundated eggs, coöperated in the formation of the egg itself. This is also true in certain groups of plants, as, for example among the brown seaweeds, but is by no means the general rule. In all higher plants, including the red seaweeds, the higher fungi and the entire series from liverworts to seed-plants, the egg does not grow into an individual capable of producing sperms or eggs, but invariably into a spore-producing organism or its homologue. There are, therefore, in the plant world two main types of egg segmentation, known respectively as the *direct* and the *indirect*. When an egg segments directly it forms an embryo that gradually matures into a sexual plant or its homologue. When an egg segments indirectly it forms an embryo that matures into an asexual spore-producing organism or its homologue. From the spores of the asexual plant new sexual plants may arise, thus establishing the phenomenon known as "alternation of generations."

The extraordinary significance of alternation has already been discussed in Chapter XIV, and need not again be elucidated. In the simpler alternating life histories it would seem that the first few cells of the young embryo become separated from each other, and each then builds up a new sexual plant. Thus the phenomenon is equivalent to true twinning among animals. It is extremely difficult to grasp this conception without long familiarity with all the facts involved, but it is regarded as very certain that the ordinary plants of forest and field are really *interpolations* between the successive sexual plants of their species. One might say, indeed, that the real fundamental *plants* are, in such species, only those that form sperms and eggs, while the great spore-producing organisms are "structural afterthoughts." In such types as the seed-plants or some ferns, the sexual plants are inconspicuous and even microscopic. This adds to the difficulty of comprehending the true state of affairs, and it is still further obscured by the false nomenclature and wrong significance that has been applied to the parts of the flower. It must be remembered that in a wilted Easter lily there are living numerous tiny organisms, some male and others female. *These are the real, primitive lily plants.* It is they that have the ancestral line reaching back into the remotest past. The male plants are cobweb-like tubes buried in the tissues of the rudimentary fruit. The female plants are exceedingly minute organisms hidden one at the center of each rudimentary seed. The great leaf-bearing, flower-producing organism, rooted in the soil is an "afterthought" in the species. When this conception is taken into the mind, then and then only is it possible to institute proper structural comparisons between plants and animals.

Very remarkable divisions of labor come to exist among embryos in higher seed plants. In this group each female produces two very minute eggs, with each of which a sperm from the pollen-tube may fuse. One of the eggs forms an embryo that can go on and develop into a plantlet, and, as such, constitutes an essential portion of every seed. The other egg forms a degenerate embryo, known as the *albumen,* that fulfills its function in the species when it is consumed by its stronger twin. This truly astonishing cannibalism goes on in the seeds of all higher flowering plants, but not distinctively in the seeds of cycads, pines and their allies. In them the so-called albumen is the body of the mother-plant, and while more than one egg is formed in pines the embryos that arise are none of them essentially subordinated. Each and any may grow into an independent plant.

When embryos are young they often have special nursing organs that do not characterize their maturer stages. Remarkable structures of this sort are found in the embryos of nasturtiums, orchids, and madders, as well as in many others. They may be compared physiologically with the embryonal organs of birds and mammals.

Care of the young. The instinct of maternity so characteristic of the higher animals is not wanting among the higher plants. The brown sea-weed, like a fish, ejects its eggs into the sea, leaving them to be fecundated and to develop and shift for themselves; but higher plants have devised a multitude of structures for the care, protection and suitable establishment of their progeny. The industry and pugnacity of a hen with chickens is well known. Her cluckings, rufflings and scratchings are to be interpreted as indications of her motherly instinct to protect and nourish her young. Not otherwise in a plant species, such as an apple, must the greenness of the fruit be interpreted as a device for nourishing the young seeds by the aid of sunlight, the sourness as a method of defending them from attack, and the subsequent sweetness, flavor and aroma as adaptations for securing their distribution through the agency of animals. While ripening its seeds the lady's-slipper is peculiarly poisonous to the touch. Many seeds contain deadly poisons, making them secure from the attack of hungry animals or birds. By thorns, secretions, warning colors, hard walls and distributional contrivances such as burs, wings, bristles, and pulp, seeds and fruits show the care lavished upon the young of the plant species. The moss mother, with her green leaves and root hairs collects and elaborates food for her progeny, the capsule. The Russian thistle covered with fruits, breaks loose from the soil and rolls over the prairie, scattering the seeds along its path. Innumerable structural and physiological adaptations have in view the one end of assisting the young, and in their sphere of life plants, like animals, subordinate the needs of the individual to the necessities of the species. Thus, when germination has begun, female pine plants are altogether consumed by the young plantlets in the seed. This protective instinct extends back over more than one generation, and not only does the mother plant assist the young, but the spore-producing plant, from the spores of which the mother-plants arose, helps the young, forming for them seed-coats and holding the seeds upon the scales of its cones, thus protecting them until ready for distribution to a distance.

In the care of the young, other plants and even animals are utilized. Thus certain seedlings are nursed along by neighboring plants that protect them from winds, drought or too brilliant sunshine. And animals carrying about upon their feet or fur the burs and sticky seeds of various species serve also as illustrations of the interdependence between different kinds of living things.

Words in conclusion. My labor is now at an end, and if I have succeeded in portraying the vegetation of Minnesota as an assemblage of living creatures, as a world of infinite variety yet with a fundamental unity of plan, as forms linked together in structure, function, and adaptation, and as a field worthy of study and enthusiasm, I shall feel content. Much has been left unsaid. In the words of Newton, but a few pebbles have been collected on the far-stretching strand of truth. The whole story will never be told.

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