How Ferns Grow

HOW FERNS GROW

MARGINAL SHIELD FERN.—*Frontispiece*

HOW FERNS GROW

BY

MARGARET SLOSSON

WITH FORTY-SIX PLATES BY THE AUTHOR

NEW YORK
HENRY HOLT AND COMPANY
1906

PREFACE

INNUMERABLE books have been written about ferns in their mature stages of development, and many accounts exist of their earliest stages, which end with the formation of the young fern-plant, but very little respecting the intervening stages seems to have been recorded. Although in these stages the fern-plant's development takes place, including the leaf-development, the literature of the subject consists of a few scattered papers only. These papers, moreover, deal mostly with individual species, and chiefly with the subject of cell-growth and kindred phenomena. They scarcely touch upon the development of the form and venation of the leaf in each species, and in its individual aspect only, without reference to its relation to such development in other fern species.

For these reasons, and in view of the important part that the form and venation of the species' leaf play nowadays in the classification of fern species, and of the fact that both often differ widely in the early stages of the leaf from their characters in the later, it is thought that to point out in this book the principal features of the development of form and venation in fern leaves, as seen in the species of the northeastern United States, will be useful, and may serve to throw light upon such development in fern species in general.

In order to give a clearer understanding of the leaf-development, in each chapter containing an account of this development in a single species, the account is preceded by a synoptical description of the fern-plant in its mature stages.

The distribution of the species is mostly quoted from Mr. William R. Maxon's "List of the Ferns and Fern Allies of North America, North of Mexico, with Principal Synonomy and Distribution."* Most of the spore characters cited are quoted from Prof. D. C. Eaton's "Ferns of North America." With these exceptions, and a few others noted as they occur, all descriptions have been drawn from or verified by specimens examined by myself. I have personally collected in the field or raised from spores nearly all the young leaves figured and described.

The illustrations of leaves, throughout the book, excepting where otherwise stated, are life size.

The nomenclature is in accordance with the American code. Sufficient synonomy is cited to include the more important synonyms.

I wish to render acknowledgments to all who by their courtesy have aided in any way the preparation of this book. To Dr. Lucien M. Underwood I am under obligations for kindly examining the synoptical descriptions of the species, for valuable suggestions, and for very many kindnesses and courtesies, including the privilege of access to important books and specimens. I wish to express likewise my indebtedness to Mr. George E. Davenport, for kindness in connection with numerous specimens. To Dr. Henry F. Walker I am indebted in many ways, which it gives me much pleasure to acknowledge. Miss Katherine Foot also should be especially mentioned. Mrs. N. L. Britton and members of the American Fern Society have kindly furnished me with certain notes and specimens.

*Proc. U. S. Nat. Mus. 23: 619–651. 1901.

CONTENTS

ILLUSTRATIONS

CHAPTER I

DEVELOPMENT OF THE FERN LEAF

AMONG the reasons for which study of the development of form and venation in fern leaves appears desirable, the following are conspicuous.

In many cases, leaf characters supposedly specific are features of only comparatively late stages of development of the species' leaf. As might be expected from that fact, this development sometimes, by exceeding its usual limits, partly or wholly obliterates such characters. In any delimitation of fern species, it is thus necessary to take into consideration the leaf-development of each species. In order to do this, and sometimes also in order to distinguish between what is due to this development and what is due to subspecific or other variation, it is necessary to know something of the modes of development of the form and venation of the leaf of each species in question. Instances are not wanting in which failure to understand the phenomena of such development has misled fern students into interpreting different stages of one species' leaf as leaves of different species or of different varieties of the same species.

It is evident that in many cases a clearer conception of the genetic affinities of fern species can be formed with knowledge of the sum of the stages of development of the form and venation of the leaf in each species, than with knowledge of isolated stages, however advanced, alone. This is especially true if, as there seems reason to believe,* traces of each of these plants' descent are to be seen in phases of the plant's leaf during its development.

Most fern students, however, cannot easily obtain more than isolated and, usually, mature stages. It seems, then, worth while to ascertain, if possible, both the various modes of development of form and venation in fern leaves, and the various effects produced by these in the leaves, in order that the modes of this development in any species' leaf may be recognized from isolated stages of the leaf, and a working knowledge of the missing stages thus gained.

It is proposed to outline in this chapter the different modes of this development, as shown in the fern species of the northeastern United States, and to point out in succeeding chapters various effects produced by these in the leaves of certain of the species. Such species have been included as serve to represent a wide diversity of effects. While the account contained in this chapter is based principally on specimens of the species of the northeastern States, it has been confirmed on examination of very many specimens of other species.

The development of the fern species' leaf from the first to the adult stage is exemplified, as fern students know, not in a single leaf, but in a series of leaves. This series is borne by the fern-plant, which is technically known as the sporophyte. The leaves of the series, which begins with the first leaf produced by

* See p. 8.

the young plant as it arises from the prothallus, portray successively the successive changes that the species' leaf undergoes in its development. After the mature stages of leaf-development are reached, leaves continue to form on the plant, but, at least as a rule, portray only the mature phases of the species' leaf.

The degrees of development shown by the individual leaves of the series illustrative of leaf-development vary in different plants of the same species. The degree shown by any one leaf of the series borne by any one plant is commonly more or less greater than that shown by any one of the leaves preceding this leaf in the series, and more or less smaller than that shown by any one of those following, but bears no other relation to the degree shown by any leaf of the series. The discrepancy between the degrees shown by any two consecutive leaves of any series may be minute or larger or even great. The number of leaves composing the series of any one plant of a species is thus not necessarily the same as the number composing the series borne by any other plant of that species.

The development of the species' leaf as a whole commonly advances steadily, but the development of its parts often fluctuates. For example, given two consecutive leaves of the series of leaves illustrative of leaf-development, the degree of development of the second leaf as a whole is commonly greater than that of the first, but the degree of development of one of its parts is often less than that of the corresponding part of the first, while the degree of development of the corresponding part in the leaf next succeeding these two leaves in the series may or may not be greater than that of the corresponding part in either of the two. Even after the mature stages of leaf-development have been reached, while two leaves of the same plant may as wholes agree approximately in point of development, the degrees of development of similar parts in these leaves may or may not be uniform: but this is almost equivalent to saying merely that no two leaves are likely to be exactly alike.

It is evident that under the above conditions, if we want a complete series of leaves illustrative of the gradations of change that a species' leaf undergoes in its development, we shall probably not be able to find it in the series of leaves borne by any one plant, but we may be able to select the leaves necessary to form it from the series borne by different plants of the species.

It is also evident that, while there is apparently no certainty that any one of the leaves of the series borne by any one plant shall match in points of development any leaf of the series borne by any other plant, instances may occur in which one does. It will also be seen that instances may occur in which leaves portraying certain stages of development usually or always appear, under normal conditions, in the series borne by each plant of a species, however the leaves preceding or following them may vary in degree of development in the cases of the different plants. I have found, on examining a large number of young plants of each of certain species, taken from different localities, that nearly all the first leaves produced by the plants of each of these species portrayed the same stage of development.

It is often difficult to say at what stage of development the species' leaf becomes mature. We can scarcely say at the stage when it first bears sori, for in some species this stage appears to be different with different plants, and in some the leaf bears sori at an extremely early stage. Nor can we say at the ultimate stage only of normal development, for this stage, as will be seen farther on, is apparently attained, in the cases of at least some species, under particularly favorable conditions only, so that the leaves of many plants of a species may never portray it, that nevertheless reach a fair size, compared with the more highly developed leaves, and bear sori freely. For practical purposes we may, however, regard as mature both those leaves that have attained the latter state of development and those more highly developed.

The species' leaf on becoming fertile often becomes modified in character. The change is sometimes very great, as in *Onoclea sensibilis*. It is often slight. When it occurs, often only those leaves that portray the two extremes of the transition are to be seen on some plants, or on those plants at certain times, but in such cases it sometimes, if not always, happens that leaves portraying the intermediate stages are to be seen either on the same plants at other times, or on other plants. A series of leaves illustrative of the transition can thus be collected in the same manner that a series of leaves illustrative of the leaf's development can be collected.

The degree of development and the size of each successive leaf of the series illustrative of leaf-development borne by the individual plant seem to be governed to some extent by the plant's degree of vigor. The leaves of the vigorous plant are apt to be considerably larger than the leaves of the weaker, even than such as happen to portray the same stages of development. In addition, if the plant is vigorous, the discrepancy between the degrees of development shown by any two consecutive leaves of the series is apt to be greater, so that the series consists of fewer leaves and the mature leaves in consequence appear sooner than if the plant is weak: the first leaf, also, produced by the plant often portrays a more advanced stage of development and the height of leaf-development attained is sometimes greater. The leaves of a sickly plant often portray minute gradations of change.

There is evidence which tends to show that if a plant's vitality be suddenly lowered, as, for example, by an injury, the first leaf the plant produces afterward may portray a lower stage of development than the last leaf it produced before, and it may or may not produce additional leaves before the height of leaf-development previously attained in its series of leaves is again attained. But more evidence is needed on this point. The most striking apparent case of the kind that I have seen is the following:

The series of leaves produced by a young plant of *Asplenium ebenoides* had passed the stage of leaf-development at which, in this species, the leaf is simple, and had reached the stage at which the leaf is deeply pinnatifid, when the flower-pot containing the plant was broken and only a little earth left on the roots. The plant was allowed to remain in this condition for some days before it was re-potted, and some of its leaves were cut off. It then produced simple leaves again, and then a series of leaves leading again to the pinnatifid stage. But as *A. ebenoides* is a hybrid, and as one of the parent species has simple leaves, the case can be called merely one of temporary partial reversion to a parent type.

It is evident that conditions of environment can lessen or increase a plant's vigor, and so indirectly lessen or increase the degrees of development shown by its leaves individually. Little is known of the various other ways in which it may be possible for conditions of environment to affect these leaves.

In the cases of some species the extreme height of leaf-development seems to be attained under certain conditions only. These conditions, whether of environment or not, apparently are often such as tend to produce extreme luxuriance and fertility in the plant. It will readily be seen that this is not remarkable; that if a species' leaf has a tendency to develop along certain lines, under conditions particularly favorable to the plant's growth, development of the leaf might easily be carried along those lines farther than usual, or sometimes farther than ever before. Among our northeastern ferns we have apparently, in *Polystichum acrostichoides*, at least one authentic case of a species in which the plants, under certain conditions of environment, produce leaves portraying a height of leaf-development far beyond the usual one, and lapse to their usual state when the conditions are altered in certain respects, producing then the usual mature leaves only.

It is a well-known fact that conditions of environment sometimes apparently induce changes in a species' leaf. Conditions of environment acting upon the plant, during the period of the leaf-development, or even upon the individual leaves of its series illustrative of this development, during their formation, cannot, however, be said to account, at least in the cases of certain species, for some of the changes that the species' leaf undergoes in its development; for these changes are seen to be the same under conditions of environment obviously widely different. For instance, I have seen the leaf of *Asplenium platyneuron* undergo the same changes in the series of leaves borne by plants growing in sand mixed with leaf-mold, on a bank near the sea, on Shelter Island, New York; in the series borne by plants growing on rocks, on an exposed hillside, in central Vermont; and in the series borne by plants raised in mixed soil in flower-pots kept under glass in a greenhouse.

There is, however, one hypothesis which offers a rational explanation of such changes; namely, that in the species' leaf during its development are indicated characters that the leaves of the plant's ancestry possessed. That is what we should expect to be true if we accept as true the alleged fact that in other living things traces of the individual's ancestry are to be seen in changes which take place in the individual during its development from the first to the adult stage.

The fact that, in the case of ferns, the changes in the leaf, which is a part of the fern individual, are exemplified in a series of successive ephemeral leaves rather than in one persistent leaf, need not militate against this hypothesis; which finds support in such facts as the following, difficult to account for on any other.

(1) In some species peculiarities are present in the early stages of the leaf which disappear in the later stages: in some peculiarities are absent in the first stages which appear and are gradually intensified in the later. For example, in the early stages of the leaf of *Nephrolepis exaltata*, according to Mr. A. A. Eaton,* the leaf's pinnæ are crisped and bristly at margin with excurrent nerves, but lose these characters as the leaf becomes mature. In the first stages of the leaf of *Polystichum acrostichoides* spinulose points on the leaf's margin are absent, but in later

* See Fern Bull. 11: 47, 1903.

stages they appear, first as one or two here and there, then gradually increase in number, and finally become extremely numerous.

(2) In the mature stages of the leaf of at least one species, appendages to the leaf are present which seem to be both out of place and a bar to the symmetry of the leaf, but which retain their positions in the preceding stages until an early stage is reached in which the leaf is so altered in form that they constitute an integral part of it. For example, in the mature stages of the leaf of *Adiantum pedatum* a single leaflet is present below the basal pinnæ on one half of the dichotomous rachis. There appears to be nothing about the leaf at this stage of development to account for its presence, and no corresponding leaflet on the other half of the dichotomous rachis; but this leaflet retains its position in preceding stages until a stage is reached in which the section of stalk that later forms the section of dichotomous rachis bearing the leaflet constitutes the base of the rachis of a pinnate branch, and the leaflet constitutes one of the basal leaflets of that branch.

Owing to lack of space, additional evidence tending to confirm the truth of the above hypothesis cannot be cited here, but it is believed that the reader will continually find such evidence, both in facts cited elsewhere in this book and in those that come under his own observation.

The development of the fern leaf, while characterized by other particulars as well in individual cases, may be said to be characterized in general by change in the leaf's form and by increase in the leaf's size and in the complexity of the leaf's venation. This is true whether the leaf is simple at first and remains simple throughout its development, whether it is simple at first and becomes compound later, or whether it is compound from the first.

The development of the form of the leaf that is simple at first and remains simple, while obviously differing in different species according to the phases through which the leaf passes and the ultimate form to be produced, need not be described here.

The development of the form of the leaf that is simple at first and becomes compound later, and of the form of the leaf that is compound from the first, can be best understood by ascertaining the various ways in which simple leaves become compound and compound leaves more so. In the following description of the ways in which this occurs in our northeastern ferns, for the sake of brevity, each of the various processes will be described as if continuous and taking place in a single leaf, but the reader will bear in mind that in reality each is exemplified in a series of leaves.

The student of actual specimens illustrating these processes will find it necessary to bear in mind also that, (1) as the complete series of leaves is not likely to be borne by any one plant, and (2) as it could scarcely be considered remarkable if some steps in any one of the processes, although portrayed at first, should in the course of time come to be partly or wholly obliterated, as a rule, in the series borne by the plants of a species, hence, (3) that failure to find some steps portrayed in the series borne by one plant, or even in the series borne by many plants of a species, which often occurs, does not necessarily mean that these steps are not portrayed at the time or have not been portrayed at some former time in the series borne by any plant of the species in question. The remarkable part of it is, not that we should find, as we do, some steps missing in the case of some species, but that we should find, as we do, so few steps missing in the case of many species. Often the gradations of change from a simple leaf or leaflet to a compound one are so minutely portrayed that the series can be likened to a series of photographs, taken by a kinetograph, of a single leaf undergoing actual enlargement and subdivision.

For a simple leaf or leaflet to become compound, and for a compound leaf or leaflet to become more compound, one or more incisions, according to the number of segments* to be formed, must occur in the leaf or leaflet. Often the appearance of such an incision is first indicated by a shallow sinus or small notch in the leaf's margin. This sinus or notch then deepens and so forms the incision.

If enlargement of the segments takes place (and it usually does), it may take place during, before, or after formation of the incision or incisions by means of which the segments are formed. Sometimes the portion of leaf that is to become a segment elongates in the direction its apex is to take before any incision that is to separate it from the remainder of the leaf is even indicated. In such a case, a more or less extended lobe is formed. We have examples of such lobes in some of those often seen at the bases of the divisions of the leaf-blade in *Pellæa atropurpurea.* In the latter plant the incisions setting free the lobes

* The term "segment" is used here and generally throughout this book, not in its restricted sense, in which it means "one of the lobes of a pinnatifid leaf or leaflet," but interchangeably with the term "leaflet," as meaning "one of the subdivisions into which a leaf or leaflet naturally divides." For example, the pinna of a pinnate leaf is a "segment" or "leaflet" of this leaf.

mostly appear, but in some plants development of the segments is arrested before incisions appear. A case in point is afforded by *Camptosorus rhizophyllus.* Lateral prolongations are sometimes seen at the base of the leaf-blade of this plant. These have never, so far as I know, been found separated from the main part of the leaf by incisions, yet their position and character show that they are to be regarded as partly formed segments.

The position of each incision that divides each leaf or segment of a leaf into segments depends largely upon the character of the leaf's venation; in what way will be seen from the following description of the different kinds of venation and their modes of development as seen in the leaves of the species of the northeastern United States.

These kinds of venation are:

Free { 1. Pinnate. 3. Flabellate. 4. Unilateral. } Anastomose { 2. Pinnate. }

In the leaf with free pinnate venation the leaf-blade, and each of the leaf's segments, if there are any, are entered at base by a vein that extends longitudinally through it in the form of a midvein which bears branches on both sides. These branches, each of which has its base attached to the midvein, are the midvein's "primary branches." They are usually either alternate or opposite, and are either simple or bear branches.

When the leaf or segment subdivides into segments, the incisions, by means of which the segments are formed, occur between the primary branches of its midvein. In our northeastern species the first incision between these branches that occurs on either side of the midvein usually occurs between the two lowest primary branches on that side, and each successive incision, except the first, occurring on either side, normally occurs between the two primary branches next above the last incision previously formed on that side.* Each new segment thus con-

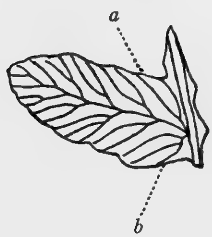


FIG. 1.

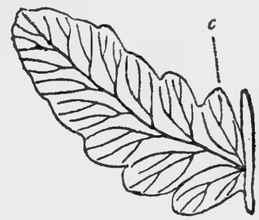


FIG. 2.

tains one of the midvein's primary branches, including its ramifications, if any, and this branch, unless its development be arrested first, develops into the segment's midvein, bearing branches on both sides. This will be readily understood from figures 1–4.

In figures 1–3 the partial subdivision of a primary segment,

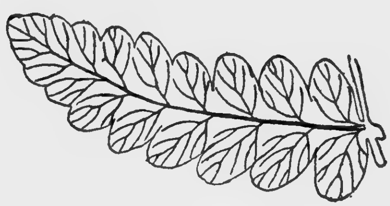


FIG. 3.

of a leaf with free pinnate venation, into secondary segments of the leaf, is shown. In Fig. 4, which represents a section of this primary segment, the ending of this subdivision and the begin-

* In some foreign species the incisions, while occurring between the primary branches of the midveins in such a way that each segment formed by them contains one of these primary branches, occur at wider intervals than as above described, some primary branches without incisions between them intervening between the new segments.

ning of subdivision of the secondary segments into tertiary segments is shown. In Fig. 1, the beginning of the incisions between the primary branches of the segment's midvein, by means of which the secondary segments are to be formed, is in some places not evident, and in others indicated by barely perceptible indentations of the leaf's margin. In Fig. 2 it is marked, and in Fig. 3 these incisions are pronounced.

In Fig. 4 some of these incisions have almost, and others quite, reached the midvein, so that the secondary segments are

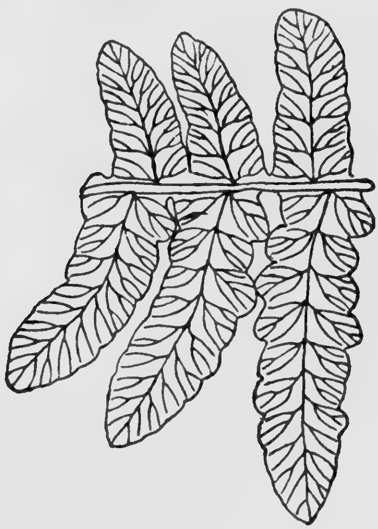


Fig. 4.

practically distinct, and the incisions, by means of which the secondary segments are to be divided into tertiary segments, have begun to form between the primary branches of the secondary segments' midveins.

In Fig. 1 the primary branches of the segment's midvein vary in degree of complexity. Those close to the apex of the segment are simple; those below, by lengthening and sending out branches, have begun to develop into the midveins that they finally become in the secondary segments, although these segments are not as yet formed. In Fig. 1 *a* this development of a primary branch into a midvein has but just begun: the primary branch may be described either as once forked or as an incipient midvein not developed beyond its two first (basal) primary branches, which are simple. In Fig. 1 *b* this development has been carried a step farther, in Fig. 2 *c* another step, and in other segments of Fig. 2, in some of Fig. 3, and in the secondary segments of Fig. 4, successively still farther. In Figs. 1 to 3 may be seen the early stages of the similar development of the primary branches of the newly-formed midveins into the midveins they are to become in the tertiary segments.

The development of the primary branch of one midvein into another midvein with primary branches is brought about, as may be seen from the above examples, by the primary branch repeatedly lengthening and sending out successive primary branches of its own on both sides. This development may begin before, during, or after the formation of the incision or incisions by means of which the segment that is to contain the new midvein is formed. At the same time the branches produced by the latter midvein may or may not begin to develop likewise. Within reasonable limits, there are apparently no bounds to the degree of complexity the primary branches of a midvein may attain before or during the formation of the incisions that set them apart to constitute midveins. On the other hand, the branches produced by a midvein's primary branch during its development into a midvein may, if appearing before the segment that is to contain the latter midvein is fully formed, *i.e.*, distinct, remain simple until this segment becomes distinct. There are also cases in which all the primary branches of each midvein and incipient midvein of a leaf are simple when first produced, and incisions, forming distinct segments, occur between them coincidently with their production: in these cases the segments appear to be made up of lobes containing each a simple vein. It is a question, however, if in the latter cases the venation can be called pinnate. It approaches closely the free flabellate type.

The depth to which the incisions between the primary branches of the midvein or midveins are carried in any part of a leaf determines whether the segments formed by them shall be partly formed or distinct, and if distinct whether adnate or not adnate to the rachis. For example, in Fig. 4 the incisions between the secondary segments are carried only far enough to render these segments practically distinct and adnate to the primary segment's midvein, which now constitutes a rachis. If these incisions had been extended, at the points where they cease in Fig. 4, along the edges of the rachis as far as the midveins of the secondary segments, these segments would have been sessile instead of adnate to the rachis. If the latter midveins had been lengthened at base, or the incisions had extended a short way upward beside them, these sessile segments would have been rendered stalked.

I have found that neither the primary branches of the midveins of a species' leaf nor the segments formed by incisions between these branches appear uniformly either opposite or alternate in all the leaves of any species with pinnate free venation that I have examined, although in some species they have appeared much more nearly so than in others. Occasionally two on one side of the midvein intervene between two on the other, but for the most part they appear to vary from opposite to alternate. The apparent positions, on the midveins, of the primary branches between which the incisions occur have been taken as criteria in determining the positions of the segments formed by these incisions, instead of the positions of the ends of the incisions, since the latter vary according to the degree of development of the segments. But the exact positions of these branches on the midveins can only be determined by examination of cells of the leaf, which I have not attempted.

It will be noted that in Figs. 1 to 4 the successive segments, whether partly formed or distinct, whether entire, cleft, or divided, continually elongate at apex, their midveins also lengthening and sending out new primary branches in succession above those previously formed. This and a similar lengthening of the leaf-blade at apex are common occurrences in the development of fern leaves. To one or both the long tapering tips of some compound leaves are due in many cases.

It will also be noted that the forms of the segment belonging to the primary series of segments of the leaf, shown in Figs. 1 to 3, are essentially duplicated by the forms of the segments belonging to the secondary series, shown in Fig. 4. Duplication of the forms of the segments of one series by those of succeeding series is often seen when, as in the section of leaf here figured, formation of the segments of one series upon those of another is not particularly evident until the latter segments have become fairly large, comparatively speaking. It is also often seen when

2

formation of each successive segment of each series is not begun until the segment preceding it on the same side of the midvein has become distinct. It is often absent when formation of the segments of one or more succeeding series is begun upon segments of one series while the latter segments are still in an incipient state. Instances of the latter kind are often seen in very young leaves: in such cases the effect of clusters of lobes is often produced. An analogous and particularly common case is the beginning of the formation of segments on a leaf-blade when the formation of the leaf-blade itself has barely begun.

From the above account some idea can be formed of the diversified results that may be produced in a leaf with pinnate free venation, by the simple occurrence of incisions between the primary branches of the leaf's midveins, with or without enlargement of the segments so formed and with or without development of a midvein from the primary branch, as a base, contained within each segment.

Anastomose pinnate venation differs from free pinnate venation in that the midveins bear, instead of free branches, branches that unite with one another, usually by means of their veinlets. Between the two kinds of venation all gradations exist, as the result of some veins uniting and others of the same leaf remaining free. The occurrence of an occasional areole in a leaf whose venation, as a rule, is wholly free is common

It is a curious fact that in all four of our northeastern species* whose leaves, when mature, possess pinnate venation more or less conspicuously anastomose, the venation in the first stages of the leaf is free.

* *Camptosorus rhizophyllus, Anchistea Virginica, Lorinseria areolata,* and *Onoclea sensibilis.*

In the leaf with pinnate anastomose venation, the incisions by means of which segments are formed occur, as in the leaf with pinnate free venation, between the primary branches of the leaf's midveins, and the midveins of each of these segments start, as in the latter leaf, from the primary branch, as a base, contained within the segment.

In Fig. 5 is shown the section of a leaf with pinnate anastomose venation in which segments have begun to form, with the midveins of these segments not yet evident. In Fig. 6 is shown a longitudinal section of the segment of a leaf with similar venation, partly formed segments on one side of the midvein, and the midveins of these segments evident.

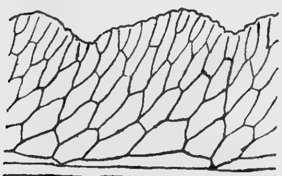


FIG. 5.

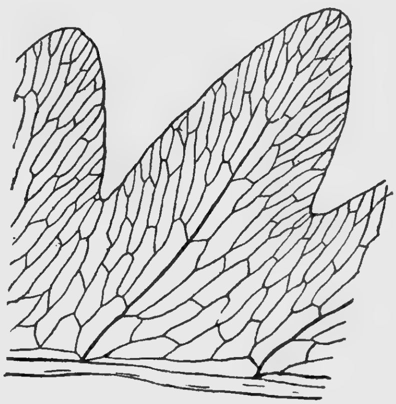


FIG. 6.

In the leaves with free flabellate venation, each simple leaf-blade and each segment of each compound leaf-blade is entered at base by a vein which, instead of forming a midvein, either forks once or is dissipated into forking veinlets: if the latter, the successive veinlets, excepting the two first, which are formed by the forking of the primary vein, are formed by the forking of the veinlets preceding them.

Each incision subdividing the simple blade or segment of a leaf with flabellate free venation into segments, occurs between the two vein-branches formed by the first forking of the vein entering the blade or segment. Each new segment thus contains one of these branches, with its ramifications, if any. If no ramifications exist, some may appear afterward, or, if some exist, more. There are also cases in which, coincidently with the forking of the vein that enters each segment, and before either of the two branches formed by this forking fork, an incision subdividing that segment into segments occurs. The latter cases are analogous to those in which the venation of the leaf is pinnate and incisions occur between the primary branches of the leaf's midveins coincidently with the formation of these branches and while they are still simple;

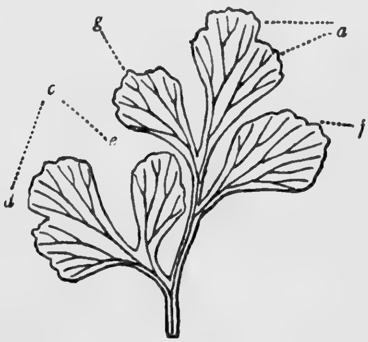


FIG. 7.

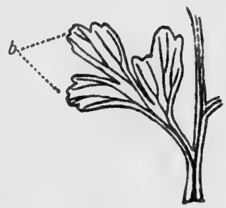


FIG. 8.

and in both sorts of cases the leaf-blade appears to be made up of lobes containing each a simple vein.*

In Figs. 7 and 8, segments of a leaf with free flabellate venation are shown in different stages of subdivision. In Fig. 7 *a* the beginning of the incision by means of which the segment is to subdivide is barely indicated. In Fig. 8 *b* the incision is pronounced. In Fig. 7 *c d e* the incision has extended nearly far enough to render one (*e*) of the two new segments distinct, and

* See page 16.

the other (*d*) of these two segments has begun to subdivide into segments.

Since, when a simple leaf or segment of a leaf with free flabellate venation subdivides into segments, the incision occurs between the two vein-branches formed by the fork of the vein that enters the simple leaf or segment, and since each of these branches thus becomes the vein entering one of the two new segments, this branch's starting-point—namely, the apex (point of forking) of the vein that entered the original simple leaf or segment—may be considered the starting-point or base of the segment this branch enters.* Any two segments formed by the subdividing of a simple leaf or simple segment of a leaf with free flabellate venation are thus situated at the apex (point of forking) of the vein that entered the original simple leaf or segment. Hence, if the part of the original simple leaf or segment that contains this vein becomes sufficiently attenuate it will constitute a stalk bearing two segments at apex. If, then, either one of the latter segments, which may be designated as *a*, becomes transformed in like manner into a stalk with two segments at apex, and the other, which may be designated as *b*, remains undivided, the latter stalk will have the same starting-point as *b*, since it is formed of the lower part of *a*, and since *a* and *b* had the same starting-points. This stalk will, therefore, separate the pair of segments at its apex from *b* by its length, which is the length of the vein occupying it, namely, the vein that entered *a*. This stalk will thus constitute a rachis. If *b* was the left one of the

* The end of the incision by means of which the two segments are formed cannot be held to determine the starting-points of these segments, for it varies in position in different stages of the segments' development.

segments *a* and *b*, *b* obviously will now be at the left side of the base of this rachis if the right one, at the right side.

If, now, of the two segments at the apex of this rachis, which may be designated as *c* and *d*, one (*c*) becomes transformed into a stalk with two segments at apex, in the same manner as the original simple leaf or segment and as *a* was transformed, and the other (*d*) remains undivided, the latter stalk will constitute a second section of rachis which will separate the latter pair of segments from *d*, while the first section of rachis will still separate *d* from *a*. If *d* were the left one of the segments *c* and *d*, *d* will now be at the left side of the base of this second section of rachis; if the right one, at the right side. *D* and *b* may, therefore, be either on the same side of the rachis composed of the two sections or on opposite sides. If on opposite sides, they will be alternate, since they will be separated by the length of a vein. This vein may, however, be so short as to be imperceptible to the naked eye, in which case they will appear opposite.

If, instead of the segments subdividing in the above-described order, the original simple leaf-blade or segment becomes transformed into a stalk with two segments at apex, in the manner above described (*i.e.*, by subdividing into segments and becoming attenuate below these segments), and each of the latter segments becomes transformed likewise into a stalk with two segments at apex, a dichotomous rachis with two segments at each end of its fork will result; for this reason. The starting-points of the two segments formed by the subdividing of the original simple leaf-blade or segment will also be the apex of the stalk composed of the lower part of the latter; hence, when the lower parts of these segments shall have become stalks, the starting-points of the latter stalks will be the apex of the former stalk, and the three stalks will thus constitute a dichotomous rachis.

It is thus apparent that each section of rachis in a leaf with free flabellate venation consists of the part of some segment subdivided into segments that contained the vein entering the segment, and which has become attenuated. This attenuation of this part of the segment that becomes the section of rachis may take place before, during, or after the subdividing of the segment into segments. If before, the segment, until it subdivides into segments, will appear merely stalked, and if it be one of the two terminating a rachis or petiole of a leaf, will appear raised above the other by its stalk.

It is also apparent that whether the rachises of the leaf with free flabellate venation are simple, forked, or otherwise compound, and whether they bear segments on one or both sides, as well as at apex, or at apex only, depends upon which of the leaf's segments subdivide into segments and become attenuate below these segments in the course of the leaf's development.

There are certain cases in which the compound or partly compound leaf with free flabellate venation may resemble or be indistinguishable from that with free pinnate venation. For example:

(1) When in the flabellate-veined leaf segments are borne on both sides of the rachises, and attenuation of the parts of segments of which the rachises are composed has not been very complete, so that a small amount of leafy tissue forming a wing remains about the vein each of these parts contains, this leaf may resemble or may be indistinguishable from the pinnate-veined leaf in which the incisions between the primary branches of the mid-

veins (by means of which segments are formed), have not quite reached the midveins.

(2) When in the flabellate-veined leaf one of the two segments formed by the subdividing of a simple leaf or segment subdivides into segments coincidently with the occurrence of the incision by means of which it is formed, and before the lower part of it has become transformed by attenuation into a rachis, the same effect may be produced as when, in the pinnate-veined leaf, two of the incisions between the primary branches of the midvein of a simple leaf-blade or segment occur above the two lowest primary branches (one on each side of the midvein), before other such incisions occur and while the midvein is in an incipient state.

(3) When, in the pinnate-veined leaf, one of the incisions between the primary branches of the midvein of the simple leaf-blade or segment occurs above the lowest primary branch on one side of the midvein before any other such incision occurs, and while the midvein is in an incipient state, this leaf-blade or segment may appear to be cut more or less vertically in two, and thus like the simple leaf-blade or segment of the flabellate-veined leaf which is subdividing into two segments.

In the leaf with unilateral venation, each segment of the leaf is entered at base by a vein which extends through it at one side, in the form of a unilateral midvein bearing branches on one side only. These branches, each of which has its base attached to the midvein, are the midvein's primary branches, and may be simple or bear branches.

In Fig. 9 is shown the segment of such a leaf.

I have been able to study the development of the leaf with unilateral venation in one plant only, namely, *Adiantum pedatum.* The development of the venation of the leaf of this plant, and the occurrence of incisions, etc., in the leaf, are discussed in the chapter on *Adiantum pedatum*,* and so need only be touched upon here.

In the leaf of this species, incisions occur between most or all of the primary branches of the midveins. These incisions, with the exception of the basal one, do not deepen sufficiently to render the segments formed by them either distinct or nearly so. The

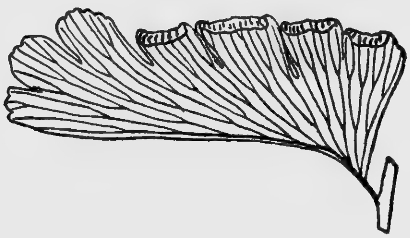


Fig. 9.

basal incision occasionally deepens sufficiently to render the basal one of these segments, distinct, and in this way new segments are added to the leaf. The basal primary branch of the midvein of the segment from which the basal segment is separated is thus included in the new segment and develops into its unilateral midvein. This development may become evident either before or after the basal segment becomes separated, and similar development of the midvein's basal primary branch is sometimes seen in segments from which the basal segment never becomes separated.

It will be seen that the ultimate form of the compound fern leaf depends chiefly upon the manner in which the leaf-blade, when first formed, and such of its successive segments as do so, subdivide into segments, upon which, if any, of the segments

* See pages 35-37.

subdivide, and upon the extent to which this subdivision is carried, in the course of the leaf's development.

Instances sometimes occur in which some part of a species' leaf that normally is undivided becomes subdivided into segments, and one, or repeated, series of segments may arise from these. Such development of the leaf may be characterized as monstrous. It sometimes produces most beautiful crested and ruffled effects in the leaf. Many so-called "varieties" are based upon leaves that are only monstrously developed.

Monstrous development may occur in any part of a leaf, and in one leaf only, or in more or in all of a plant's leaves. When it occurs in more than one of a plant's leaves, it often varies in degree in the different leaves, although it may affect similar parts in these leaves.

When the monstrously developed leaf is fertile, monstrous development similar to that which appears in it often appears in the leaves of any plants which may spring from its spores.

It is sometimes difficult to distinguish between monstrous development and normal development carried further than usual. The latter, however, is to be looked for in especially luxuriant, mature, fertile plants, and produces effects that appear the logical sequel to all that has gone before in the way of leaf-development; while the former, due to unknown causes, is often correlated with partial or complete sterility of the leaf, often produces freakish effects, and is apt to be visible from the first appearance of leaves on the plant.

CHAPTER II

WALL-RUE

Belvisia ruta-muraria.

Rootstock creeping, short, chaffy: scales minute, strongly striate-reticulate in blackish-brown, linear or linear-lanceolate, acuminate, entire or ciliate: leaves fascicled at end of rootstock: roots springing from bases of petioles, one to each petiole.

Leaves evergreen.

Petioles two to three inches long, usually as long as or longer than blades, more or less grooved on face, otherwise rounded or above faintly grooved on sides; at base deep brown or dark purple, slightly rigid, glandular, chaffless or bearing at base a few scales like those of rootstock; above green, herbaceous, glabrous, glands large, grayish, globose, unicellular: fibrovascular bundle solitary, flattened-cylindrical.

Blades two-fifths of an inch to two and one-third inches long, ovate or ovate-deltoid, below bi-tri-pinnate, above once pinnate: pinnæ alternate, oblique to rachis, the compound stalked: ultimate divisions alternate, one-twelfth to two-fifths of an inch long, roundish-obovate to cuneate-rhomboid or cuneiform, at base entire, upper margin crenate or dentate or incised or in young plants undulate: rachises green, channelled on face: surfaces glabrous: color bluish-green or olive: texture coriaceous or sub-coriaceous.

Venation flabellate, free or with occasional areolæ: veins repeatedly forked.

Sori short-oblong to linear, borne on veins near and opening toward centres of ultimate segments of leaf: indusia whitish, delicately membranous, ciliate-erose.

Spores ovoid-bean-shaped, minutely roughened.

Habitat. Seams, pockets, and ledges of calcareous rock: usually exposed to the sun or in partial shade. Growing in tufts.

Range. Vermont, southern Ontario, and Michigan, south to Alabama and Missouri.

Asplenium ruta-muraria. **Linnæus, Species Plantarum, 1081. 1753.**

The leaf-blade of *Belvisia ruta-muraria* is at first simple and more or less rounded, and somewhat truncate at base or soon becoming so (Pl. I, Figs. 1 *a*, 2 *a*, 3 *a*). It then develops into a blade consisting of a single leaflet-bearing rachis, in the following way.

A slight incision forms at the apex of the blade (Fig. 2 *b*), and gradually deepens until the blade is cut into two leaflets (Fig. 3 *c d c′ d′*). One of the two remains, temporarily, undivided (Figs. 3 *c′*, 4 *c′*). The other becomes at base elongate and narrow, forming the beginning of a rachis, and divides above into two leaflets (Figs. 3 *d′*, 4 *a′*, 5 *dd′*), as the simple leaf-blade divided. The rest is repetition: one of every two leaflets formed remaining undivided, and the other becoming transformed at base into an extension of the rachis and dividing above into two leaflets. Which of the two leaflets remains undivided depends in each case upon which of the two in the preceding case remained undivided: if the left leaflet in the one case, the right leaflet remains undivided in the following case, and *vice versa.* The leaflets remaining are thus rendered alternate on the rachis.

Almost coincidently with the formation of this primary rachis, similar development of leaflets upon it into secondary leaflet-bearing rachises is begun (Figs. 5 *e*, 6 *e*, and 7 *e g*). This is sometimes followed by similar development of leaflets upon the secondary rachises into tertiary leaflet-bearing rachises (Figs. 9 *h*, 10 *h'*).

It will be noted that in each instance development of the leaflets of each rachis into leaflet-bearing rachises begins with the leaflet lowest (first formed) on that rachis, and involves successively the leaflets above in the order in which they were formed; and that likewise the formation of the tertiary rachises begins on the lowest (first formed) secondary rachises, and involves successively the secondary rachises above in the order in which they were formed.

The venation is flabellate. In consequence,* each incision that transforms a leaflet or simple leaf-blade into two leaflets occurs between the vein-branches formed by the first forking of the vein that enters that leaflet or leaf-blade. Each branch thus becomes the vein entering one of the new leaflets; and the first forking of the one entering the leaflet that is in turn to subdivide forms the two branches between which the incision is to occur, while the part of it below its first fork is contained in that leaflet's base, which finally becomes elongate and forms a section of rachis. Sometimes the subdivision of a new leaflet takes place before it becomes fully separated from the old one, giving the old the appearance of being cut into three.

When a leaflet on one rachis subdivides in the beginning of

* See Chapter I, pp. 19 and 20.

the formation of another rachis, the base of this leaflet, containing the part of the vein that enters the leaflet below the first forking of that vein, becomes elongate and forms the part of the new rachis between its first leaflet and the old rachis.

The part in general taken by the venation in the leaf-development will be more readily understood by studying Pl. I, Fig. 2.

Many of the leaflets of the leaves of the older plants are more or less incised between the marginal veinlets. This incision, to which is due the peculiar toothed appearance seen so often in this fern's leaves, is not to be confused with the incision described above, employed in the leaf-development.

The plants bear sporangia when very young. The bifoliate leaf is sometimes fertile.

A. ruta-muraria has been included in the genus *Asplenium* by nearly all pteridologists. Newman, however, in 1844, separated it from *Asplenium*, to form, together with *A. septentrionale* and *A. germanicum*, a genus which he named *Amesium*. But *A. septentrionale* had already stood as the type of a genus of Mirbel's.* The affinity of *A. ruta-muraria* with *A. septentrionale* appears very marked, especially on comparing the leaf-development of the two species, and, taking into consideration the flabellate venation and other peculiarities which characterize these two species, they appear sufficiently distinct to warrant restoring Mirbel's genus *Belvisia* and including *A. ruta-muraria* in it.

* *Belvisia* Mirb. in Lam. & Mirb. Hist. Nat. Veg. 3: 405. 1802.

EXPLANATION OF THE PLATE.

PLATE I.—WALL-RUE. *Belvisia ruta-muraria.* 1–10. Plants and leaves in different stages of development. 1. Young plant attached to prothallus. 9, 10. Mature leaves. 11. Fertile leaf, × 2½.

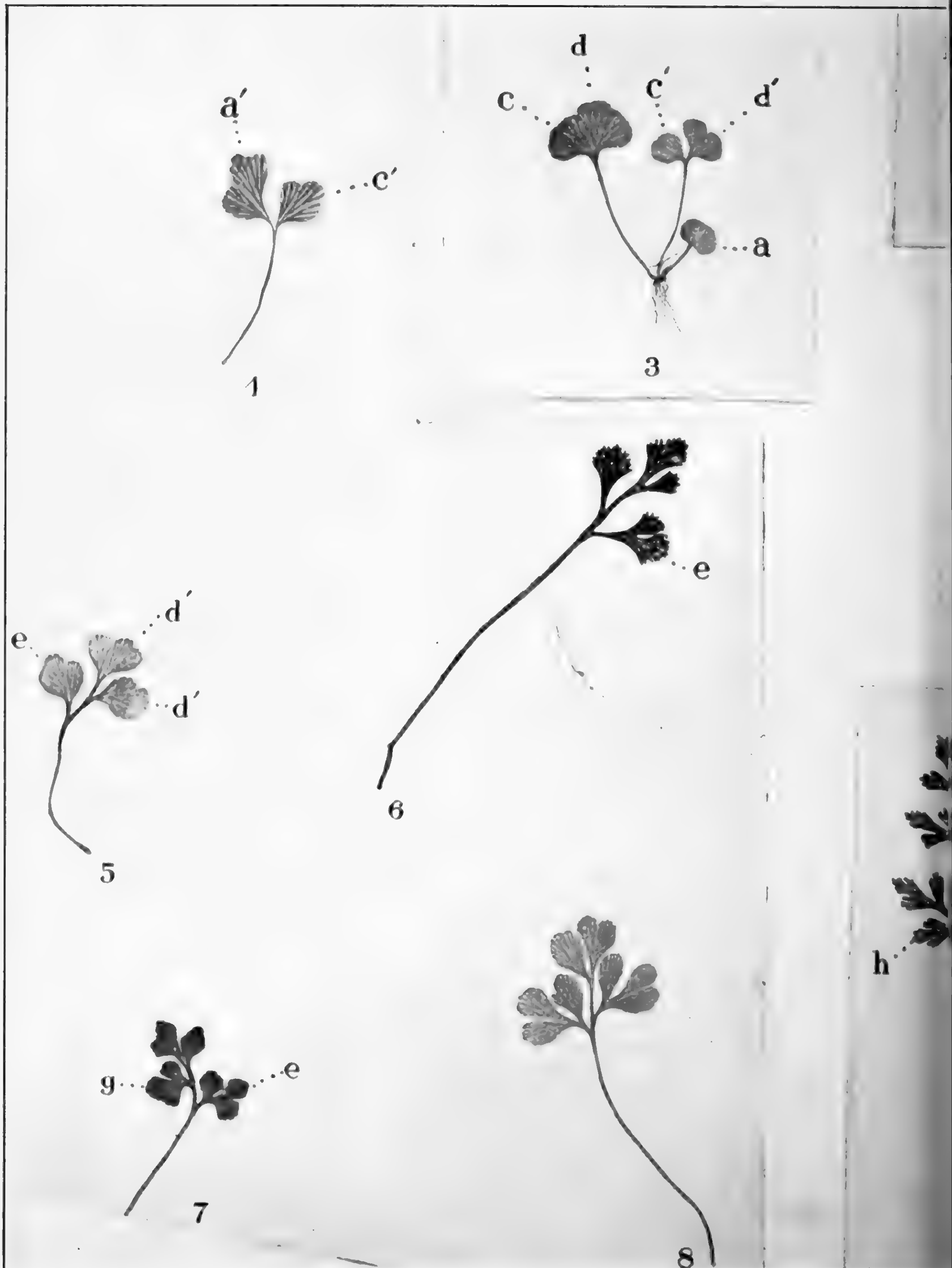


PLATE I.—

LL-RUE

CHAPTER III

MAIDENHAIR

Adiantum pedatum.

Rootstock wide-creeping, branching, brown, slender, clothed with numerous small, brown, glossy, imbricated, oblong, acuminate, entire scales: leaves approximate, rising alternately from right and left sides of rootstock: roots irregularly scattered, springing from rootstock.

Leaves erect; sporophylls withering in autumn; sterile leaves sometimes persisting into winter.

Petioles eight to eighteen inches long, slender, glossy, wiry, dark-reddish-chestnut to purplish-ebeneous or ebeneous, slightly angled at sides, convex at back, flattish-convex on face or furrowed when dried; clothed at base with imbricated scales similar to scales of rootstock, the uppermost two to three times larger; scales above few, scattered, deciduous: fibrovascular bundle solitary, at base of petiole U-shaped, becoming above V-shaped in section.

Blades imperfectly circular, somewhat funnel-form in centre, flattened toward edge, eight to eighteen inches broad, dichotomous: rachises wiry, glossy, chestnut-brown to black, sometimes purplish, tapering; the halves of the primary rachis diverging at an acute angle, curving outward and upward and bearing at apex two pinnæ and, except in very small leaves, on upper side about two to twelve radiating pinnæ interspersed with single pinnules, a single pinnule also borne on rachis below one of basal pinnæ: pinnæ lanceolate or linear-lanceolate or the smaller oblong or suboval, obtuse, pinnate, the basal six to ten inches long, the outer successively shorter: pinnules numerous, two-fifths of an inch to one inch long, alternate, stalked, oblong or oblong deltoid, the apical cuneate, the lower mostly becoming cuneate or transversely oblong, attached at acute lower corner, other corners rounded; entire on sides next footstalk, otherwise dentate and on upper side or both upper and outer sides cut into oblong often oblique lobes; apical pinnules, and outermost basal pinnules of outermost pinnæ, sometimes bifid: surfaces glabrous; the upper repelling water, bright green or darker; the lower paler; texture elastic, membranaceous.

Venation conspicuous, free: principal vein of each pinnule dividing at base of pinnule into two branches: in oblong or deltoid-oblong pinnules, the outer branch forming a unilateral midvein next pinnule's lower margin, bearing branches on upper side; the inner branch appearing as basal primary branch of the outer, little, if any, more complex than primary branch next it: in cuneate or transversely oblong pinnules both branches forming unilateral midveins, one each side of pinnule's footstalk, next pinnule's margin, bearing branches on upper side: primary branches of midvein three to four times forked at midvein's base diminishing to once-forked or simple at midvein's apex, pinnule's lobes each occupied by one.

Sori borne at apices of veinlets on under side of indusia: indusia consisting of reflexed altered portions, chiefly ends of lobes, of pinnule's upper margin, transversely oblong or linear or the smaller sublunulate, yellowish-brown, slightly striate; at margin whitish, thin, membranaceous, somewhat erose or slightly denticulate.

Spores spheroid-tetrahedral, the three radiating angles marked with slender vittæ or bands.

Habitat. Rich woods, shaded banks, etc.

Range. Nova Scotia to British Columbia, south to Georgia, Mississippi, Arkansas, Kansas, Utah, and California. Also in Alaska.

Adiantum pedatum. Linnæus, Sp. Pl. 1095. 1753.

THE petioles and rachises of *Adiantum pedatum* are dark-colored in all stages of development. In the earliest stages they are hair-like.

The leaf-blade is simple at first (Pl. II, Fig. 1 *a*, *a*). It soon develops into a blade consisting of a single rachis leaflet-bearing at sides and apex (Figs. 2–6). First one and then the other of the two basal leaflets on this rachis then develop into a branch, which consists of a similar leaflet-bearing rachis (Figs. 7 *b*, *c*; 8 *b′*, *c′*). The outer basal leaflet (Fig. 8*d*) of the first branch (Fig. 8 *b′*) then develops likewise into a branch (Pl. III, Fig. 9*d′*). In this way the earliest dichotomous leaf-blade is formed (Pl. III, Fig. 9). This may be said to consist of a dichotomous rachis (Fig. 9 *e′ o′ j′*) bearing two pinnæ at each of its two apices.

The leaflet that was formerly the inner basal leaflet *g* of the branch *b′* in Fig. 8 (Pl. II), becomes, when the outer basal leaflet *d* in Fig. 8 develops into the branch *d′* in Fig. 9 (Pl. III), the leaflet *g′* on the section *e′ o′* of the dichotomous rachis *e′ o′ j′* in Fig. 9, since *e′ o′* in Fig. 9 corresponds to *e o* in Fig. 8. As no leaflet occurred on the part of the rachis *o j* in Fig. 8, no leaflet is seen on the corresponding section *o′ j′* in Fig. 9. This explains why, in mature leaves of *A. pedatum*, a leaflet is seen on one side of the dichotomous rachis below the first (central) pinna and not on the other.

The dichotomous leaf-blade (Fig. 9) having been formed, the dichotomous rachis is prolonged and pinnæ and pinnules are added to its upper side by the development, repeated in successive leaves, of the outer basal leaflet of the outermost pinna at each end of the dichotomous rachis into a branch. For instance, by the development of the outer basal leaflet *h* of the outermost pinna *i* in Fig. 9 into a branch, Fig. 9 becomes, essentially, Fig. 10. The leaflet *h* in Fig. 9 becomes the outermost pinna *h′* in Fig. 10, the part of the pinna *i* above the leaflet *h* in Fig. 9 becomes the pinna *i′* in Fig. 10, the part of the pinna *i* below the leaflet *h* in Fig. 9 becomes the part *j′ j′* of the dichotomous rachis in Fig. 10, and the inner basal leaflet *k* of the pinna *i* in Fig. 9 becomes the leaflet *k′*, on the dichotomous rachis in Fig. 10. It is evident that if in Fig. 9 the inner basal leaflet *k* of the pinna *i* had been higher on the stalk of that pinna than the outer basal leaflet *h*, instead of lower, the corresponding leaflet in Fig. 10 would appear on the pinna *i′* instead of on the dichotomous rachis. Since there seems to be no reason why the outer rather than the inner basal leaflets of the outermost pinnæ of the dichotomous leaves, or of the basal pinnæ (*b′*, *c′*) of the leaf shown in Fig. 8, should be the higher, we should expect to find in some leaves of this plant, and do find, leaflets missing from the dichotomous rachis that are present in others.

Fig. 11 represents a leaf in a later stage of development than Fig. 10.

Development of a leaflet into a branch is brought about in the following way. An incision forms between the two vein-branches formed by the first forking of the vein that enters the leaflet, and cuts the leaflet into two leaflets. One of the two thus formed remains, at least temporarily, undivided. The base of the other leaflet becomes elongate, attenuate, and dark-colored, forming the beginning of a rachis, and this leaflet, which may be called the apical one, divides into two as the original leaflet divided, the incision occurring, as in the latter, between the two vein-branches formed by the first forking of the vein that enters the leaflet. The rest is repetition, one of every two leaflets formed remaining undivided, and the other becoming transformed at base into a continuation of the rachis and dividing above into two leaflets. Which of the two leaflets remains undivided depends in each case upon which of the two remained undivided in the preceding one: if the left leaflet in the one case, the right leaflet remains undivided in the following case, and *vice versa.* The leaflets remaining on the sides of the branch are thus rendered alternate.*

The apical leaflets are cuneate. Most of the leaflets left on the sides of the rachis lengthen at right angles to the rachis, becoming more or less oblong, although the lower ones, which may lengthen in the opposite direction also, are apt to become more or less cuneate.

In the earliest leaves the unilateral midveins of the leaflets are little developed, sometimes barely developed beyond their superior basal branches. As a result, the venation at this stage of development can scarcely be called anything but flabellate.

* It will be noted that the development of leaflets into branches is here essentially the same as in certain leaves with flabellate venation. See pages 21-22.

A curious analogy exists between the development of the venation and the development of the form of the leaf-blade. As, in the course of development, each successive outermost pinna of each half of the dichotomous rachis becomes forked (by the transformation of its outer basal leaflet into a branch), the part below the fork becoming a continuation of the dichotomous rachis, one of the two parts above the fork a pinna upon that rachis, and the other part the new outermost pinna; so each successive outermost veinlet of each unilateral midvein becomes forked, the part below the fork becoming a continuation of the unilateral midvein, one of the two parts above the fork a primary branch upon that midvein, and the other part the new outermost veinlet. In this way the incipient unilateral midveins are developed and primary branches are added to their upper sides.

In some leaflets, notably the apical and some of the lower, the basal primary branch of the unilateral midveins of each is developed in a similar way into a unilateral midvein, and the two unilateral midveins taken together may be said to constitute a dichotomous midvein with primary branches springing from its upper side. The analogy between this and the plant's dichotomous rachis with branches springing from its upper side is apparent. In those leaflets that possess only one unilateral midvein, or one half of a dichotomous midvein, the latter may be likened to one half of the dichotomous rachis. But here the analogy ceases, for the branches that spring from the upper sides of the midveins, unlike the branches that spring from the upper side of the dichotomous rachis, fork repeatedly. They are less complex in the early stages of leaf-development than in the later.

Incisions, cutting the leaflets into shallow lobes, occur between the primary branches of the midveins.* By a deepening of the one next the basal primary branch, which brings its base between this branch and the midvein itself, the incision described above, that divides the leaflets into two in the development of the leaf, is formed; since that incision occurs between the vein-branches formed by the first forking of the vein that enters the leaflet, and since the basal primary branch of a unilateral midvein and the midvein itself represent those branches. This applies both to those leaflets possessing only one midvein and to those possessing two midveins, since in the latter case either of the two may be regarded as the basal primary branch of the other.

The incisions between the primary branches of the midveins suggest the lines along which future development, normal or monstrous, of this plant's leaf may follow. The lobes which the incisions form can be regarded as partly formed leaflets, and it would not be surprising if at any time the incisions should deepen sufficiently to render these leaflets distinct. It has been seen that the basal incision already deepens at times (in the development of the leaf's form), sufficiently to render the basal one of these leaflets distinct.

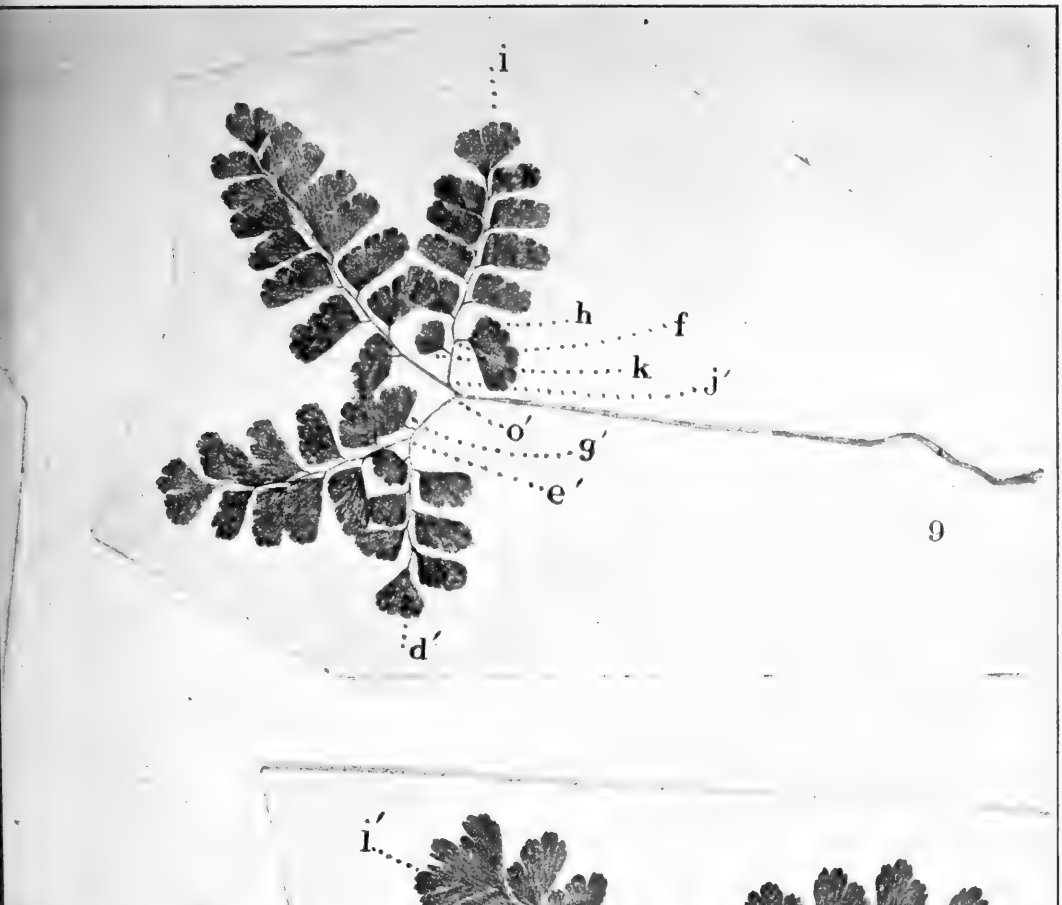
* This is best seen in the sterile leaves. In the sporophylls an indusium occasionally extends over the tops of several primary branches, so that no incisions occur between those branches.

EXPLANATION OF THE PLATES.

Plates II–III.—Maidenhair. *Adiantum pedatum.* Plate II.—1. Young plant attached to prothallus. 2–8. Young leaves in early stages of development. Plate III.—9–11. Leaves in later stages of development. 12. Fertile leaflet of mature leaf, × 2½.

PLATE II.—MAIDENHAIR

Plate III.



DENHAIR

CHAPTER IV

HART'S-TONGUE

Phyllitis scolopendrium.

Rootstock caudiciform, somewhat chaffy: scales hyaline, pale brown, usually reticulate or striate-reticulate in reddish-brown, lanceolate, acuminate, entire: leaves in a crown: roots springing singly or in clusters from bases of petioles or from rootstock.

Leaves ascending, the larger drooping, eight inches to two feet long, four-fifths of an inch to two and one-third inches broad, usually evergreen unless unduly exposed to cold.*

Petioles two to six inches long, shorter than blades, toward base brown, slightly turgid; above green; somewhat flattened on three sides and two-ridged above, traces of groove on face, or subterete, chaffy: scales pale brown, delicately reticulate in brown or reddish-brown, lanceolate to narrowly elongate-linear from a broader base, acuminate, entire or below ciliate, those near base of petiole broadest; fibrovascular bundles two, curved and finally forming an X.

Blades lanceolate or oblong-lanceolate or linear-lanceolate, acute or obtuse, cordate or auricled at base, entire or undulate or abnormally variously incised, finely and more or less ob-

* W. R. Maxon.

CHAPTER IV

HART'S-TONGUE

Phyllitis scolopendrium.

Rootstock caudiciform, somewhat chaffy: scales hyaline, pale brown, usually reticulate or striate-reticulate in reddish-brown, lanceolate, acuminate, entire: leaves in a crown: roots springing singly or in clusters from bases of petioles or from rootstock.

Leaves ascending, the larger drooping, eight inches to two feet long, four-fifths of an inch to two and one-third inches broad, usually evergreen unless unduly exposed to cold.*

Petioles two to six inches long, shorter than blades, toward base brown, slightly turgid; above green; somewhat flattened on three sides and two-ridged above, traces of groove on face, or subterete, chaffy: scales pale brown, delicately reticulate in brown or reddish-brown, lanceolate to narrowly elongate-linear from a broader base, acuminate, entire or below ciliate, those near base of petiole broadest; fibrovascular bundles two, curved and finally forming an X.

Blades lanceolate or oblong-lanceolate or linear-lanceolate, acute or obtuse, cordate or auricled at base, entire or undulate or abnormally variously incised, finely and more or less ob-

* W. R. Maxon.

scurely chaffy or paleaceous, especially below along midrib: scales colorless or bronze-colored, often with bronze-colored cross-barred centres, narrowly lanceolate or linear-acuminate: color bright or deeper green: texture subcoriaceous.

Venation pinnate, free or with occasional areolæ: primary branches of midrib, excepting the basal, once to three times forked or in apex of blade simple; the basal more complex, repeatedly branched.

Sori linear, contiguous and faced in pairs on adjoining veins, commonly one sorus of each pair extending along more or less of the inferior veins of a primary branch of midrib and the other similarly borne on the superior veins of the next adjoining primary branch, occasionally both on veins of the same primary branch: the opposed indusia at first flat and overlapping, entire or subentire.

Spores reticulate, verrucose.

Habitat. Crevices of limestone rocks or earth upon limestone. On hummocks in dark, moist, rocky woods, on talus, and in or about the mouth of open chasms, particularly in shaded cold places near water.*

Range. Central New York, Tennessee, New Brunswick, Grey and Simcoe counties, Ontario. Also in Alaska (?).

Phyllitis scolopendrium (L.). Newman, Hist. British Ferns, ed. 2, 10. 1844.

Asplenium scolopendrium. Linnæus, Sp. Pl., 1079. 1753.

Scolopendrium vulgare. J. E. Smith, Mém. Acad. Roy. Sci., Turin, 5: 421. 1793.

Scolopendriu mscolopendrium. Karsten, Deutsch Fl., ed. 1. 278. 1880–83.

* W. R. Maxon. See Fernwort Papers, 30–46. 1900.

In the development of the leaf of *Phyllitis scolopendrium* the blade assumes successively the following forms: spatulate; spatulate-oval or suborbicular; suborbicular or roundish-ovate or ovate-oblong, becoming cordate; ligulate-cordate; and oblong-lanceolate or lanceolate or linear-lanceolate with cordate or auriculate base.

The spatulate leaf contains either a simple vein or an incipient midvein which does not extend beyond two basal primary branches. The midvein is evident in succeeding leaves. It gradually lengthens and sends out successive primary branches, and is finally contained in a midrib.

The basal primary branches of the midvein may be once forked or even occasionally simple at first. They vary, but are mostly more complex than the primary branches above them. As development of the blade progresses they branch more and more, and in the mature leaves are markedly complex.

The primary branches above the basal mostly vary at first from simple to once forked, but gradually become more complex. In the mature leaves they vary from once to three times forked, excepting the extreme uppermost, which, appearing later than those below, sometimes do not develop beyond the simple stage.

The veinlets are mostly clubbed at apex. They end near the leaf's margin: the veinless border is often pronounced.

Occasional areolæ occur in the mature leaves. I have seen only one areole, near the midvein of a very small leaf, in the young leaves.

At first the leaf-blade is decurrent on the petiole—so much so in the narrower of the spatulate leaves that the petiole resembles a winged midvein.

EXPLANATION OF THE PLATE.

PLATE IV.—HART'S-TONGUE. *Phyllitis scolopendrium.* 1–6. Young leaves and plants in different stages of development. 1. Plant attached to prothallus. 7. Mature fertile leaf. 8. Section of fertile leaf, $\times 2\frac{1}{2}$.

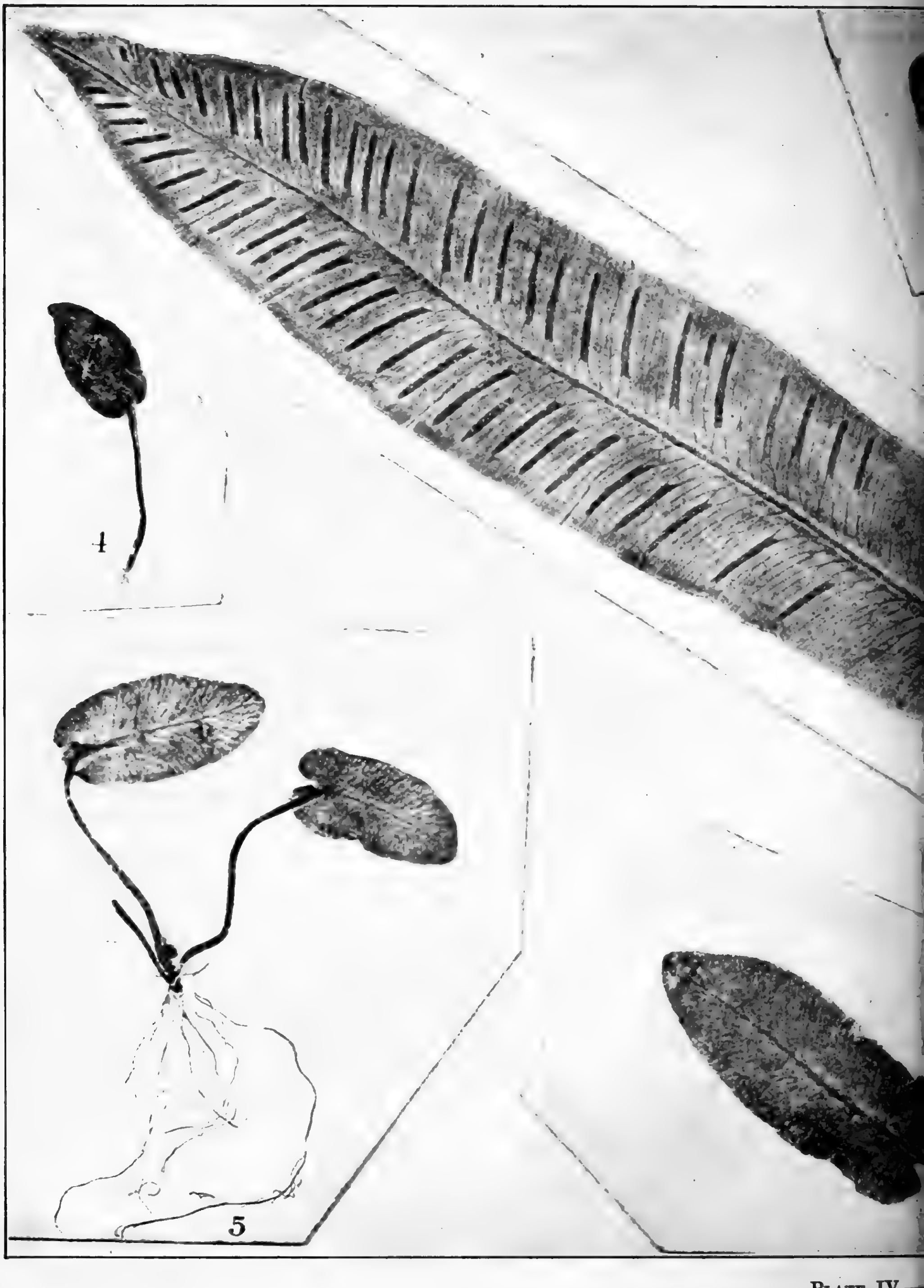
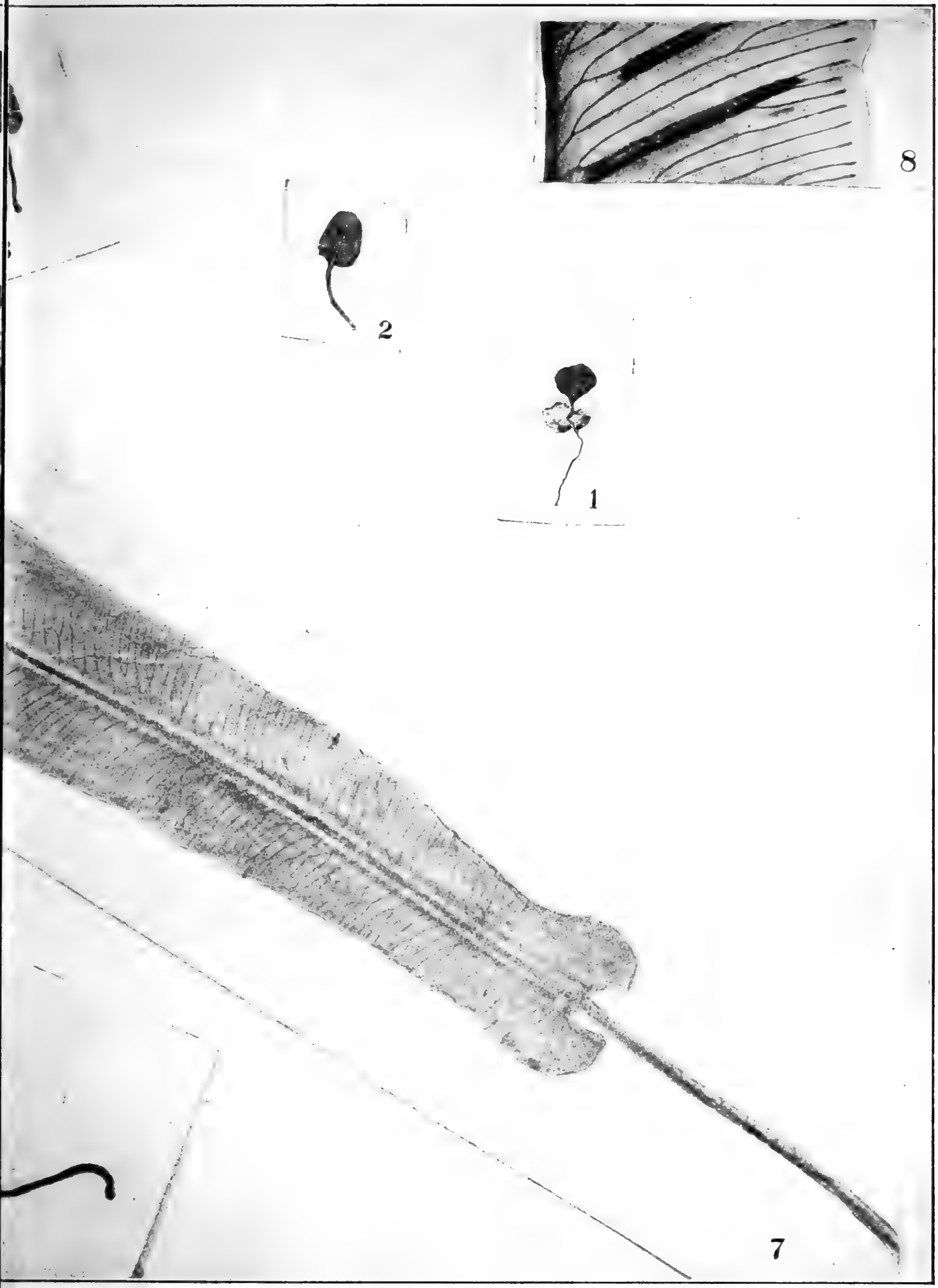


PLATE IV.—



T'S-TONGUE

CHAPTER V

POLYPODY

Polypodium vulgare.

Rootstock slender, creeping, branching, brown or, at tips, green, chaffy: scales numerous, small, brown; under a lens yellow or orange, or margins subcolorless, the centre often banded lengthwise in yellow or orange or reddish-orange-brown; ovate or lanceolate, acuminate, cordate* and often dilated at base, ciliate-erose: leaves approximate, borne alternately on right and left of top of rootstock, articulated to rootstock: roots springing from sides and base of rootstock, paleaceous.

Leaves ascending or suberect, four and one-half to sixteen inches long, two-fifths of an inch to four and two-fifths inches broad, evergreen, not prostrated in winter; in icy or dry weather drooping forward, the segments curving horizontally and becoming connivent over face of blade.

Petioles shorter to longer than blades, green or, when dried, greenish-stramineous, on face convex or below flattened or slightly hollowed, at back convex, on sides narrowly winged or below angled, or at extreme base subterete, glabrous or bearing

* D. C. Eaton says "scales peltately attached," but I find a sinus leading from the base to the point of attachment. An overlapping of the sides of this sinus often makes the scales appear peltately attached.

an occasional scale: scales next rootstock similar to those of rootstock; those above pale brown, small, lanceolate or linear or oblong, pointed, subciliate: fibrovascular bundles three to four in base of petiole, the two anterior largest, uniting higher up into one wedge-shaped in section or roundish and furrowed on face.

Blades ovate-oblong or narrowly oblong or rarely lanceolate-deltoid, pinnatifid or divided, gradually or abruptly narrowing at apex; apex crenate or serrate or at base pinnatifid or at tip undulate, obtuse or acute or acuminate, often elongate: segments about ten to twenty-three pairs, alternate or opposite, mostly separated by acute or rounded sinuses, oblong or oblong-linear or oblong-lanceolate, usually obtuse, rarely acute or acuminate, usually undulate or obscurely serrulate or crenate, rarely and abnormally coarsely serrate or variously lobed or pinnatifid: a few minute, pale brown or partly colorless, hyaline, linear or oblong, acuminate, ciliate or subciliate scales occasionally borne on under surface along rachis and midveins of segments, upper surface glabrous or an occasional scale along rachis: rachis green or greenish-stramineous, convex on face and back: color otherwise olive-green, the under surface pale: texture subcoriaceous.

Venation pinnate, wholly free or with occasional areolæ: primary branches of midveins of leaf's segments commonly once-forked or at apex simple with two simple branches below, the lowest branch on upper side sometimes, especially in large segments, bearing a few simple or once-forked branches or in apices of segments simple: apices of veinlets dilated, oval or roundish, visible as straw-colored spots on face of leaf.

Sori round, borne singly on simple superior basal branches of primary branches of midveins of leaf's segments and apex, commonly covering, sometimes below, apex of veinlet, often becoming confluent.

Spores rather large, yellowish, oblong-reniform, minutely areolated or reticulated, a single vitta or band along the concave side.

Habitat. Flat or slightly sloping surfaces of rocks, woodland banks, stone walls, etc.

Range. Labrador and Newfoundland to Georgia, Alabama, Missouri, Manitoba, and Keewatin. Probably has a wider range toward the northwest.

Polypodium vulgare. Linnæus, Species Plantarum, 1085. 1753.

THE young leaves of *Polypodium vulgare* described here have been mostly taken from offshoots of rootstocks of the older plants: young plants attached to prothalli have not been seen.

The forms of the leaf-blade at different stages of development may be seen from Plates V, VI, and VII.

Small notches, often obscure, occur between the primary branches of the leaf's midveins and often between the veinlets as well. By a deepening of the notches between the primary branches of the primary midvein, the leaf's primary and, normally, only segments are formed. Almost, if not quite, coincidently with this deepening, the section of leaf that goes to form the segment lengthens at right angles or obliquely to the primary midvein. The segments begin to form at the base of the leaf-blade, and segment after segment are successively separated from the part of the blade above, which continually lengthens at apex. To a marked lengthening of the segments below the leaf's apical section before the segments forming next above them have become especially lengthened, or perhaps more than mere lobes, is due the abruptly narrowed appearance of the leaf-blade at apex, common in this fern's leaves.

The blade at first is obtuse at apex, but as it grows large and long it becomes acute or acuminate. Sometimes, although rarely, the segments also become acute or acuminate. Acute or acuminate apices in the segments are often correlated with monstrous development of the leaf, but occur also in leaves otherwise typical, particularly in unusually large ones. Their occurrence in the latter leaves is in accordance with a tendency, common in many ferns with pinnate venation, to lengthen and point the leaf-blade and its segments, as these enlarge in developing, and such leaves are at best doubtfully abnormal, although undoubtedly unusual in *P. vulgare*.

The primary branches of the leaf's primary midvein develop, while the segments are forming, into the segments' midveins. Their branches are usually simple in the young very small leaves. In the large, or at least in the older leaves, these branches bear branches, and when the segments become incised in monstrous development of the leaf, often appear as well-defined midveins in the segments' lobes.

The superior one of the two basal primary branches of the primary branches of the leaf's midveins is usually lower but sometimes higher than the inferior, and sometimes opposite it.

On a superior one each sorus is borne. What seems at first an exception to this occurs sometimes near the leaf's apex, where the primary midvein, emerging from the rachis, appears as a midvein in the leaf's apical section, and the series of sori belonging to it consequently appear. Here the superior basal primary branch of the midvein of some one of the leaf's segments sometimes is once-forked and bears a sorus at each of its two apices. The presence of both these sori can, however, be accounted for. The presence of the sorus on the veinlet nearest the segment's midvein is explained, if that veinlet is regarded as the superior basal primary branch of the primary branch of the segment's midvein. The presence of the sorus on the other veinlet also is explained, if this veinlet is regarded as merely an extension of the superior basal primary branch of the segment's midvein, and so (since the segment's midvein is a primary branch of the leaf's primary midvein), as a part of the superior basal primary branch of a primary branch of the primary midvein. Occasionally the two veinlets become connivent at apex, and the two sori coalesce, forming one, which is borne on the veinlet's connivent apices.

Sometimes occasional areolæ occur in the leaf at various stages of its development.

The veins are clubbed at apex and appear to pierce the face of the leaf: their tips are visible as stramineous spots on the leaf's upper surface at every stage of leaf-development.

The leaf often becomes monstrously developed. "*Var. Cambricum*" Moore, and many other so-called varieties of this species, are based upon monstrously developed forms of the leaf.

EXPLANATION OF THE PLATES.

PLATES V–VII.—POLYPODY. *Polypodium vulgare.* Plate V.—1–6. Young leaves and plants in early stages of development. Plate VI.—1, 2. Young leaves in later stages of development. 1. Leaf with epidermis removed, showing venation. Plate VII.—1. Mature fertile leaf. 2. Fertile pinna, × 2½.

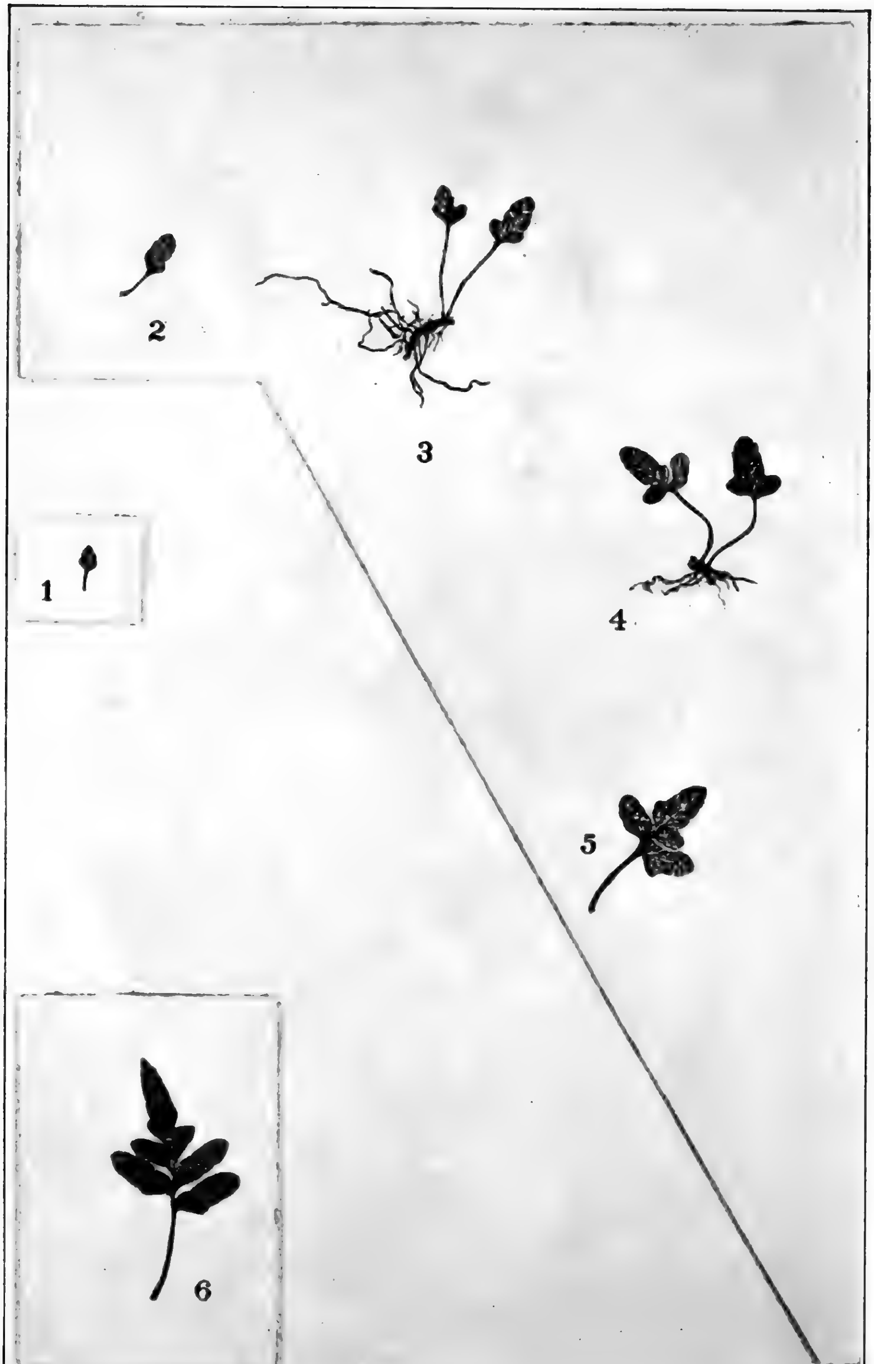


PLATE V.—POLYPODY

Plate VI.—Polypody

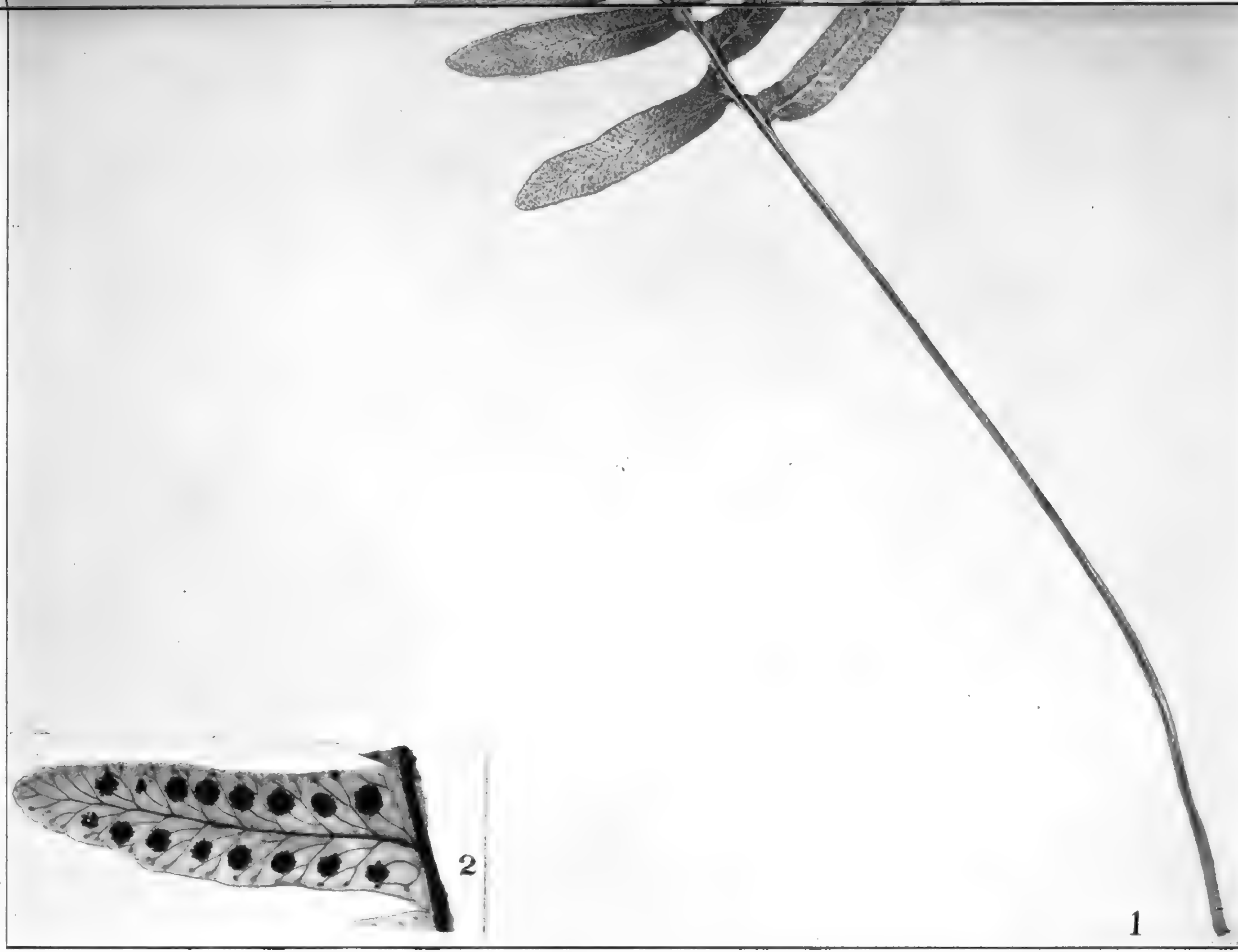


Plate VII.—Polypody

CHAPTER VI

PURPLE CLIFF-BRAKE

Pellæa atropurpurea.

Rootstock creeping, short, stout, usually nodose, thickly clothed with soft, lustrous, cinnamon or orange-colored or whitish, hyaline, linear, acuminate, entire scales: leaves clustered at apex of rootstock: roots springing from rootstock, sometimes paleaceous.

Leaves two and one-third to twenty inches long; ultimate divisions persistent during winter, falling off in spring,* petioles and rachises persistent.

Petioles two to six inches long or longer, wiry, purplish-ebeneous to blackish-red, rigid, terete; at base slightly turgid, bearing a few scales similar to scales of rootstock; above usually paleaceous: fibrovascular bundle solitary, U-shaped.

Blades about two to six inches broad, oblong-lanceolate or ovate, above once, below twice pinnate: pinnæ alternate or opposite: ultimate divisions three-tenths of an inch to two inches long, two-fifths of an inch or less broad, alternate or opposite, obtuse or obscurely mucronulate; at base cordate, truncate, or obtuse, sessile to short-stalked; the sterile oval or ovate; the fertile linear or linear-oblong or the smaller elliptical; the apical long-

* H. H. Swift.

est, often elongate, often connate at base with segment next below on one or both sides: margins thin, whitish, crenulate, and very minutely and obscurely denticulate: upper surface of ultimate divisions deep bluish-green, glabrous, lower surface pale, minutely paleaceous along midveins: texture coriaceous: rachises and footstocks of ultimate divisions purplish-ebeneous or blackish-red, usually paleaceous.

Venation pinnate, obscure, free or with occasional areolæ: primary branches of midveins once to three times or the basal four times, those above the basal mostly twice forked.

Sori intramarginal on upper part of veins, becoming confluent laterally: indusia formed of reflexed margin of ultimate divisions of leaf, continuous around sides and apex of division or interrupted at apex: at margin minutely denticulate or undulate, often finely fluted.

Spores obscurely tetrahedral, or trivittate.

Habitat. Dry rocks, especially limestone, exposed to the sun or partly shaded. Often near the tops of cliffs, projecting in masses from cracks in the rock or growing in partly caked sand on the ledges; or on surface rock on hillsides.

Range. Massachusetts, Vermont, and Ontario to British Columbia and Mackenzie, south to Georgia, Mississippi, Texas, Arizona, and California.

Pellæa atropurpurea-Linnæus-Link, Fil. Sp. Hort. Berol. 59. 1841.

Pteris atropurpurea Linnæus, Sp. Pl. 1076. 1753.

The young leaf-blade of *Pellæa atropurpurea* is simple and roundish or reniform at first (Pl. VIII, Fig. 1). It then elongates and two lobes develop, either simultaneously or successively, at its base (Pl. VIII, Fig. 2–5). These lobes are the blade's incipient basal primary pinnæ. In Fig. 6 they are shown fully separated from the part of the blade above them. In later leaves additional pairs of primary pinnæ are formed, and in time a series of secondary pinnæ (Pls. IX, X).

Each pinna becomes distinct from the part of the leaf beyond it before its subdivision into segments, if occurring, is begun, and nearly always before formation of any pinna beyond it is begun: before or during the formation of the incision that renders the pinna distinct from the part of the leaf beyond it, the part of the leaf that is to form the pinna usually elongates in the direction that the pinna's apex is to take. As a result, at any stage of the leaf's development each of the leaf's ultimate divisions or apical sections, excepting the microscopic irregularity of the margins, either with rare exceptions is entire (Pl. X, *a*), or has merely a single, often extended, lobe at base on one or each side (Pl. XI, *a*), from which it is sometimes partly separated by an incision (Pl. X, *c*).

The venation is pinnate. The blade's primary midvein is so little developed in the earliest form of the blade that the venation at this stage of development may be called pseudo-flabellate, but this midvein becomes evident while the blade is still simple. A midvein is evident in all but occasional, very small, newly formed, ultimate divisions of the later leaves. The two basal primary branches of each midvein are usually much more complex than the others. In the lobed leaf-sections one or each of the two constitutes the venation of a lobe, according to whether there is a lobe on one or on each side of the section. The development of the branch into a midvein in the lobe is evident either before or, if the lobe be very small, soon after the lobe has become distinct from the leaf-section, and in any case before the lobe, as a distinct pinna, becomes, if ever, lobed.

When the blade becomes fertile, its segments, if any, narrow, and its margins recurve. It becomes fertile at a very early stage of development; a tendency to recurve is sometimes visible in the margin of the simple leaf-blade, although apparently no sporangia appears at this stage.

EXPLANATION OF THE PLATES.

PLATES VIII–XI.—PURPLE CLIFF-BRAKE. *Pellæa atropurpurea.* Plate VIII.—1. Young plant attached to prothallus. 2–5. Young leaves in early stages of development. Plate IX.—1, 2. Young fertile leaves. Plate X.—Mature highly developed sterile leaf. Plate XI.—1. Mature highly developed fertile leaf. 2. Fertile pinnule, × 2½.

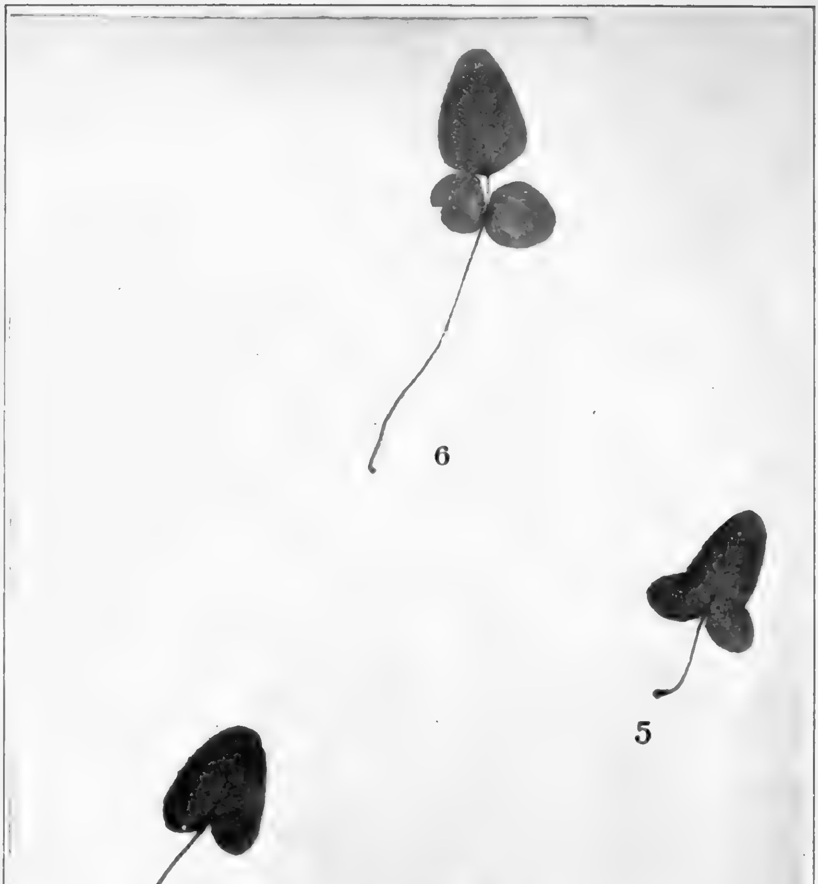


Plate VIII.—Purple Cliff-Brake

Plate IX.—Purple Cliff-Brake

Plate X.—Purple Cliff-Brake

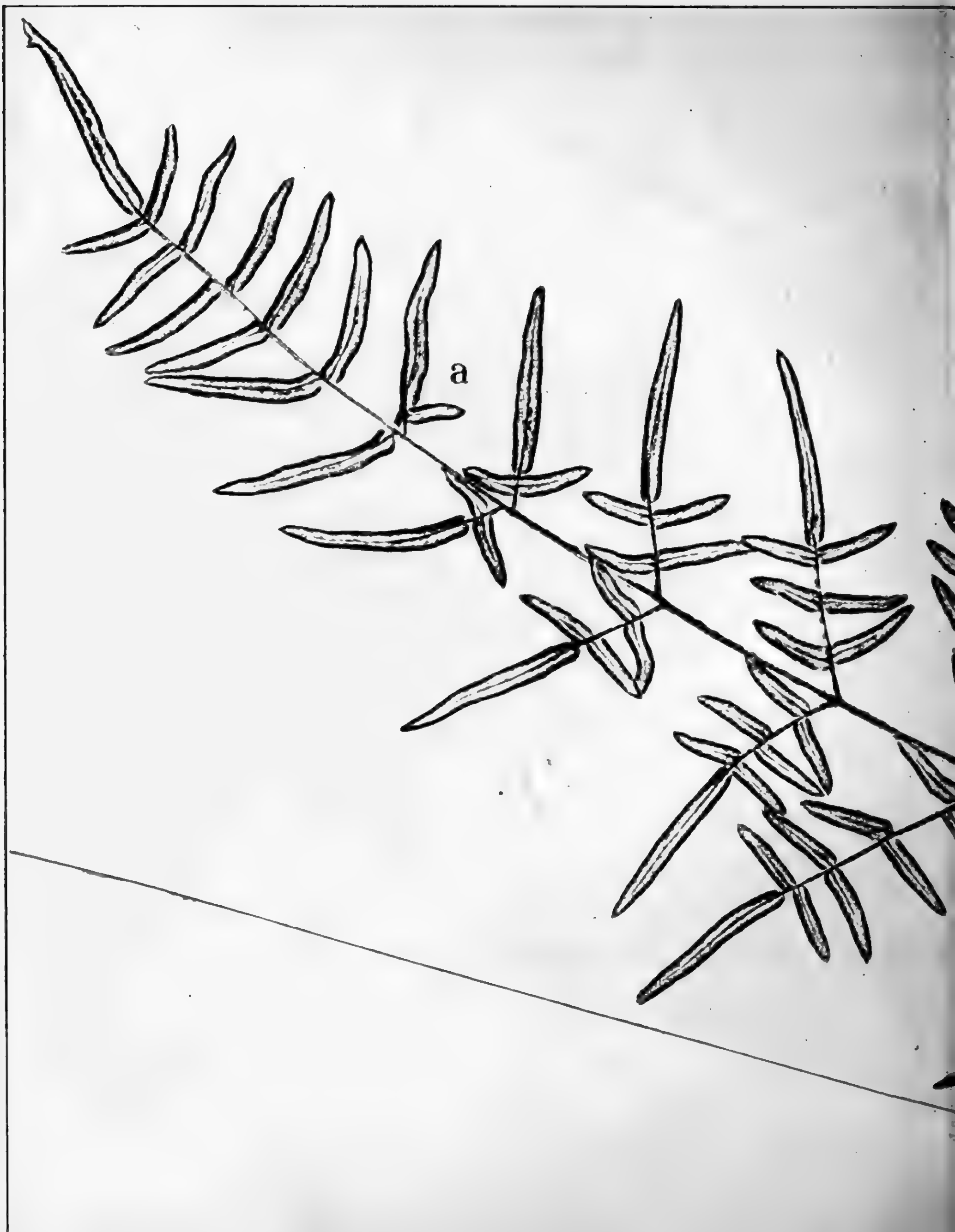


PLATE XI.—

LE CLIFF-BRAKE

CHAPTER VII

NARROW-LEAVED SPLEENWORT

Asplenium angustifolium.

Rootstock creeping, light greenish-brown, brown in age, a few, delicate, pale-brown, lanceolate-acuminate or broade, entire or slightly toothed scales: leaves clustered near apex of rootstock, springing from all sides of rootstock: roots numerous, light brown, coarse, springing from rootstock and bases of petioles, scattered or fascicled.

Leaves twenty to thirty-six inches long, three to eight and three-fifths inches broad, sensitive to frost, sporophylls usually longer and narrower, with narrower pinnæ, than sterile leaves.

Petioles shorter than blades, fleshy-herbaceous; at base brown, turgid-compressed; above green or, when dried, greenish-stramineous to bright stramineous often tinged with brown, narrow and furrowed on face, at back and on sides broader and flattish; bearing a few pale-brown scales: fibrovascular bundles two; in base of petiole strap-shaped or roundish strap-shaped, slightly furrowed on one or both sides; higher up more or less furrowed on outer broad side, convex in centre of opposite side, somewhat **3**-shaped in section; in apex of petiole uniting into one unevenly U-shaped in section.

Blades lanceolate, gradually or abruptly narrowed at apex, pinnate: apex long-acuminate, undulate to crenate becoming parted below: pinnæ approximate or distant, alternate or opposite, mostly very short-stalked or subsessile, at base truncate or wedge-shaped or rounded or, at least in sterile leaves, slightly cordate, linear-lanceolate, in sporophylls often somewhat falcate, acuminate; the basal reduced, often oblong-lanceolate or oblong-ovate or ovate and obtuse; the uppermost oblong-lanceolate or ovate-lanceolate, acute to obtuse, often passing into obtuse sometimes orbicular segments; subentire to undulate or crenulate, rarely slightly and coarsely crenate and at base cut, abnormally, into lobes: margins obscurely hyaline, very minutely and obscurely serrulate: rachis furrowed on face, very narrowly winged above, greenish-stramineous to bright stramineous when dried: lower surface, sometimes both surfaces, bearing a few obscure, minute, chaffy hairs: color grass-green or darker: texture thin, herbaceous.

Venation pinnate, free or with occasional areolæ: primary branches of pinnæ's midveins mostly simple in apices of pinnæ; the basal usually the most complex, once to three times forked; those between mostly once to twice forked.

Sori linear or oblong, or the smaller suboval; borne singly on primary branches, when these are simple of midveins of pinnæ and apex of blade, when they are compound extending along or wholly upon their superior basal branches, or when latter are compound sometimes extending along or in apex of blade wholly upon the veinlets next midveins, opening toward midveins: indusia arched, entire.

Spores ovoid, covered with anastomosing ridges.

Habitat. Rich soil in damp woods or ravines, sometimes near calcareous rock. Often with *Dryopteris Goldieana.*

Range. Northern New England and southern Quebec to Wisconsin, south to northern Georgia, Tennessee, and Missouri.

Asplenium angustifolium Michaux, Fl. Bor. Am. 265. 1803.

The young leaves of *Asplenium angustifolium* are translucent when dried. The venation can be seen distinctly by transmitted light, and the development of the vascular system easily observed.

At first only one fibrovascular bundle is present in the leaf's petiole: it may perhaps sometimes divide into two at the extreme base of the petiole. Soon two are seen, which merge into one some distance above the base. The mature petiole contains two, which coalesce to form the leaf-blade's primary midvein.

The venation is pinnate. The translucence of the young leaf reveals the fact that a pinna's midvein sometimes leaves the midvein (fibrovascular bundle) from which it springs some distance below the apparent node of the pinna.

The formation of the pinnæ is gradual. The pinnæ appear first as small lobes, on the lower part of the leaf's apical section in the older leaf and substantially at the leaf's apex in the younger. New lobes begin to form above those previously formed while the latter are separating to constitute pinnæ. This will be seen from Plate XIV, and it will also be seen that both the pinnæ and the leaf-blade itself are short and blunt at first, but gradually lengthen and become pointed more and more.

In some leaves of this fern, collected in Vermont by Miss Mary E. Bidwell,* there are small lobes on the lower parts of the pinnæ, indicating a tendency to produce secondary pinnæ. Some of the basal lobes in these leaves are distinct. This seems to be a case of monstrous leaf-development. Spores from these leaves

* See Fern Bulletin, 8: 61. 1900.

have been sown and have produced plants with some normal leaves and with other leaves showing, at a very early stage, similar abnormal lobes.

In this fern, as in other *Asplenii*, the sori are borne on veins that stand in certain relations to the midveins, each sorus opening toward a midvein. Some veins occur that stand in one of the required relations to each of two midveins, and, as a result, two sori (diplazioid sori) sometimes occur on these veins, one sorus opening toward each midvein.*

Each sorus is borne on a midvein's primary branch, or on this branch's superior basal branch, or on a veinlet of the latter next the midvein. The only veins that stand in one of these relations to each of two midveins, and, consequently, the only veins on which diplazioid sori occur, are the upper basal primary branches of the pinnæ's midveins. These branches stand both in the relation of primary branches to the pinnæ's midveins and (since the pinnæ's midveins are primary branches of the leaf's primary midvein), in the relation of superior basal primary branches of primary branches to the leaf's primary midvein. Diplazioid sori occur only on the upper part of the leaf, perhaps for the reason that the leaf's primary midvein, while showing its character as a midvein in that part of the leaf, apparently loses it below by becoming merged or concealed in the rachis.

Whether the sori which go to form the diplazioid sori are diplazioid for the whole or only for part of their length depends upon how far they extend. One may extend farther along the upper basal primary branch of the pinna's midvein than the other. At the upper end of this vein, if it divide into two veinlets,

* For instances of the occurrence of diplazioid sori in other *Asplenii*, see pp. 72, 89, and 90.

the two sori may continue, in which case they will diverge, each following the veinlet nearest the midvein toward which this sorus opens, as that veinlet is the only one of the two that stands in one of the required relations to that midvein. At the lower end, the sorus that opens toward the pinna's midvein cannot extend farther than that midvein, as no sorus in this fern extends at base farther than the midvein toward which it opens, but the other sorus may extend down the pinna's midvein to the leaf's primary midvein, toward which this sorus opens. It will be seen that only such parts of the sori are diplazioid as extend along the same part or the whole of the upper basal primary branch of the pinna's midvein.

EXPLANATION OF THE PLATES.

PLATES XII–XIV.—NARROW-LEAVED SPLEENWORT. ***Asplenium angustifolium.*** Plate XII.—1. Young plant attached to prothallus. 2–5. Young leaves in early stages of development. Plate XIII.—Young leaf in later stage of development. Plate XIV.—1. Mature sterile leaf. 2. Section of fertile pinna of mature leaf, × 2½.

PLATE XII.—NARROW-LEAVED SPLEENWORT

Plate XIII.—Narrow-Leaved Spleenwort

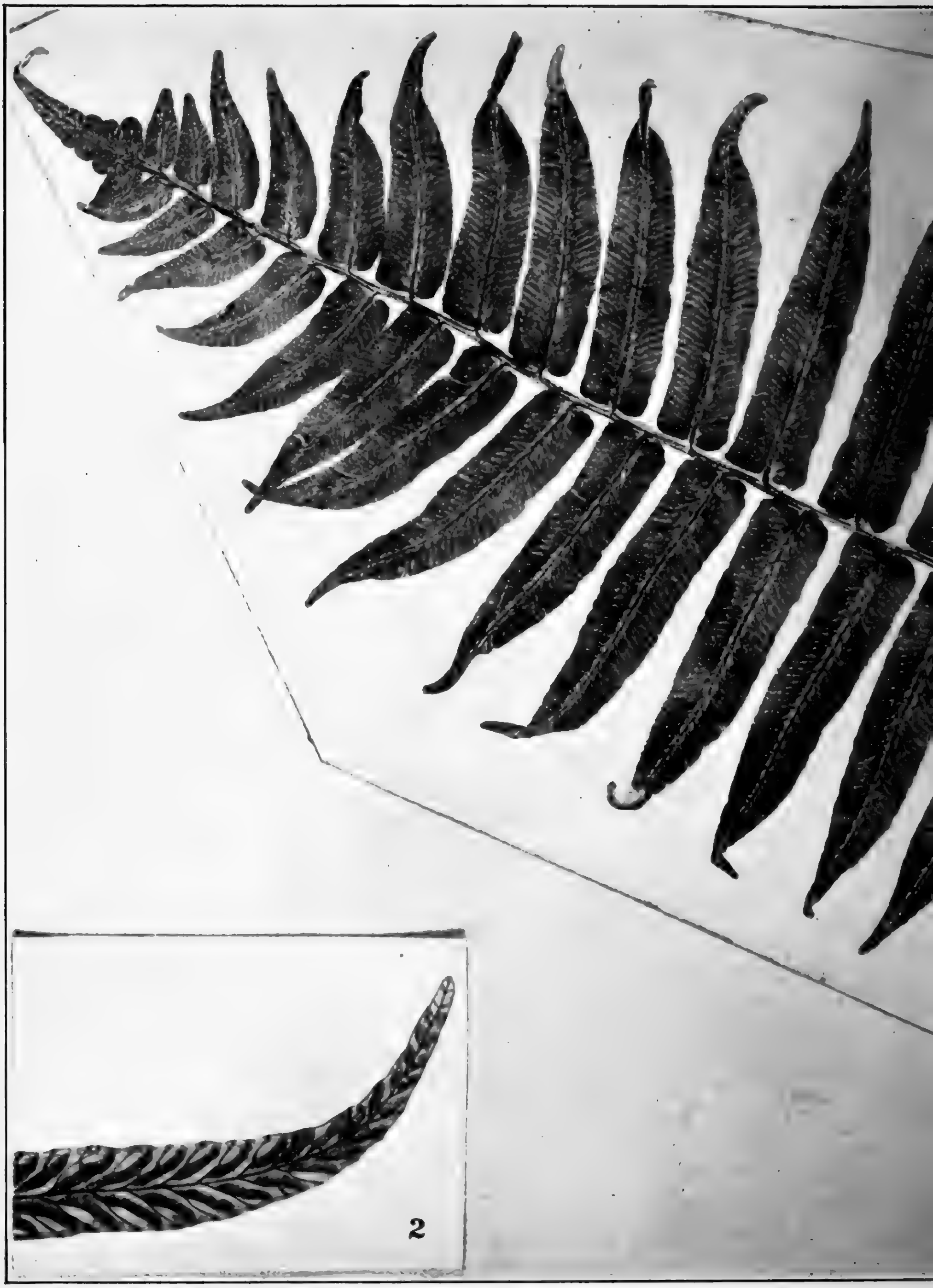


PLATE XIV.—NAR

Leaved Spleenwort

CHAPTER VIII

MAIDENHAIR SPLEENWORT

Asplenium trichomanes.

Rootstock caudiciform, slender, branching, chaffy: scales small, lance-linear, acuminate, entire or slightly ciliate, with subopaque, madeira-red or topaz-colored centres, otherwise hyaline or reticulate in similar color: leaves fascicled at rootstock's apex: roots springing singly from junctures of petioles and rootstock.

Leaves ascending or reclined, often in flattened tufts, two and four-fifths to eight inches long, two-fifths to four-fifths of an inch broad, imperfectly evergreen, the petioles and rachises more or less persistent, the pinnæ beginning to drop off in autumn.

Petioles four-fifths of an inch to four and one-third inches long, purplish or chestnut-brown, glossy, below terete or subterete; above flattened or slightly furrowed on face, narrowly winged on sides, wings light brown; bearing a few scales at base and sometimes above; scales lanceolate or linear, otherwise similar to scales of rootstock or subopaque centres reduced or lacking: fibrovascular bundle solitary, roundish or on face flattish.

Blades linear, obtuse or short-acuminate, pinnate: apex crenate, often lobed or pinnatifid at base: pinnæ alternate or opposite, approximate or the lower more distant, subsessile or the uppermost sessile, articulated at points of attachment; the lower reduced, roundish-oblong or roundish-oval or reniform, or roundish-fan-shaped with cuneate or truncate base; those above roundish-oblong or oval, obliquely wedge-truncate at base, inæquilateral, sometimes auricled on upper side; except at base somewhat crenate or sometimes more or less incised: surfaces glabrous: rachis purplish-brown, glossy, flattened or slightly convex on face, appearing furrowed from wings connecting pinnæ which are similar to and continuous with wings of petiole: foot-stalks of pinnæ purplish-brown: color otherwise deep green: texture firmly membranaceous.

Venation pinnate, free: primary branches of pinnæ's midveins, excepting the basal, mostly once-forked or the outermost simple, or a few bearing branches which are simple to twice forked: superior or both basal primary branches of midveins once to three times forked or bearing branches which are simple or bear branches.

Sori oblong or linear, each borne on a midvein's primary branch when this is simple, when it is compound extending along or wholly upon its superior basal branch or extending along or wholly upon a veinlet of the latter next the midvein, opening toward the midvein: indusia whitish, delicately membranous, subentire or undulate or irregularly crenate.

Spores marked with anastomosing ridges or verrucose or papillose with ridges reduced or lacking.

Habitat. Seams, pockets, and ledges of shaded cliffs, particularly limestone.

Range. Nova Scotia and eastern coast of Hudson Bay to Alabama, Texas, and Arizona, northwestward to Oregon, British Columbia, and Alaska.

Asplenium trichomanes Linnæus, Species Plantarum, 1080. 1753.

YOUNG plants of *Asplenium trichomanes* are apt to be confused with those of *A. platyneuron*, but can be easily distinguished by the dark petioles of the very young leaves.* The petiole is partly or entirely green in the young plant's first leaf, but becomes almost at once, in succeeding leaves, dark and lustrous, shading from stramineous-brown to dark purplish-brown.

Narrow membranous wings on the sides of the petiole, and of the rachis if there is one, are visible from a very early stage of leaf-development, if not from the first. At first the leaf-blade is roundish-spatulate, and contains a simple vein. It then becomes spatulate and obscurely notched at apex, next obcordate, and then cuneate-bilobed; and the vein sends out two branches at apex, each occupying one of the lobes. The leaf-blade then becomes slightly more complex, lobed, and crenate, and its primary vein (midvein) develops somewhat beyond the two first primary branches.

The parts of the leaf-blade that contain these two basal primary branches then separate from the upper part of the leaf-blade sufficiently to form two pinnæ, while the part of the leaf-blade remaining above them that contains the section of the leaf's primary midvein between the latter's first (basal) and second pair of primary branches becomes elongate and attenuate, forming a rachis, over which the dark color of the leaf's petiole spreads quickly. Additional pairs of pinnæ are added successively to the leaf in a similar way; by parts of the leaf containing the pair of primary branches of the leaf's primary midvein, next above the last pair of pinnæ previously formed, separating from the upper part of the leaf sufficiently to form a pair of pinnæ, while the part

* See page 71.

of the leaf containing the section of primary midvein between that pair of primary branches and the pair next above becomes a section of rachis. The primary midvein thus becomes merged in a rachis, remaining visible as a midvein in the leaf's apical section only. While pinnæ and primary branches of this midvein are separating from the base of the apical section, this section and this midvein lengthen at apex, the midvein sending out additional primary branches, but this takes place slowly; the apical section, therefore, is usually rather short. One or more pinnæ are usually to be seen in the process of forming on and of separating from it.

In the very young leaf the pinnæ newly formed are often, like the leaf-blade newly formed, obcordate, with their midveins not developed beyond two simple primary branches. Such pinnæ resemble the pinnæ of *Asplenium Clutei*, Gilbert.* The various forms of the early pinnæ can be seen from Plate XV. As the leaf develops, the pinnæ lengthen and broaden, gradually assuming their mature forms, their midveins lengthen and send out additional primary branches, and these midveins' primary branches mostly become more or less complex.

The pinnæ are usually crenately toothed or lobed, but, occasionally, incised. The so-called "var. incisum" is based upon monstrously developed sterile leaves with deeply incised pinnæ.

* See Fern Bulletin, 8: 62–63. 1900.

EXPLANATION OF THE PLATE.

PLATE XV.—MAIDENHAIR SPLEENWORT. *Asplenium trichomanes*. Young plant attached to prothallus. 2–5. Leaves in early stages of development. 6. Small mature plant. 7. Large fertile mature leaf. 8. Section of fertile leaf, × 2½.

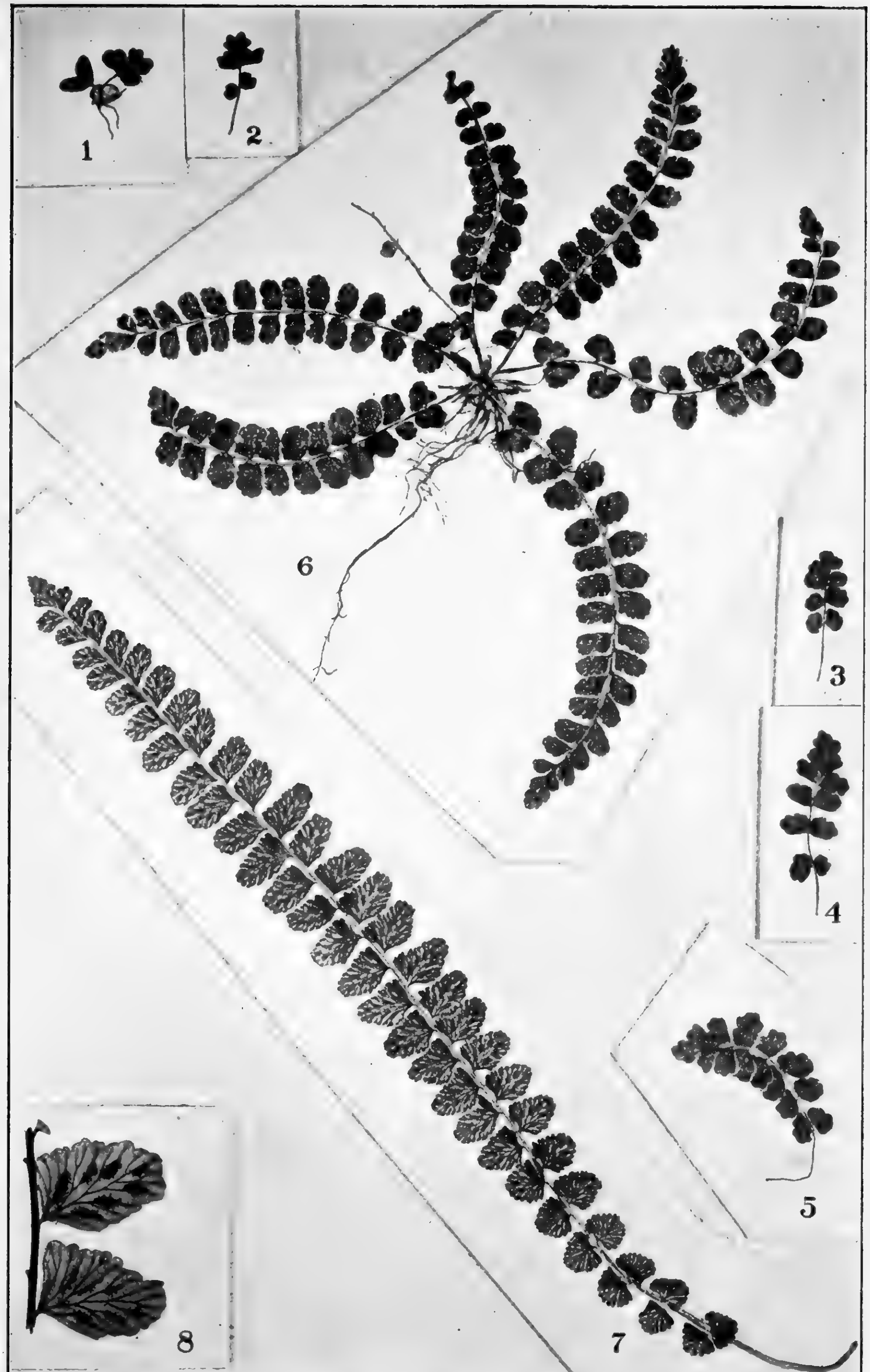


Plate XV.—Maidenhair Spleenwort

CHAPTER IX

EBONY SPLEENWORT

Asplenium platyneuron.

Rootstock creeping, chaffy: scales strongly reticulate in reddish-brown on a colorless or pale-yellow ground, lanceolate or rarely linear, acuminate, ciliate: leaves fascicled at apex of rootstock: roots springing from rootstock or junctures of rootstock and petioles.

Leaves more or less evergreen, sporophylls erect, six inches to two feet long, up to four inches broad; sterile leaves more or less reclined, much shorter.

Petioles four-fifths of an inch to four inches long, bright reddish or darker chestnut-brown to chestnut-ebeneous, sometimes tinged with green, a small light-colored spot, tawny in dried leaves, at the extreme base, glossy, subterete, turgid at base, bearing a few scales: scales at base of petiole lanceolate to linear, similar otherwise to scales of rootstock, passing above into obscure scattered palea commonly hyaline and colorless on sides with dark opaque reddish cross-barred centres: fibrovascular bundles two in base of petiole, roundish strap-shaped, uniting above into one roundish in section.

Blades linear-oblanceolate or linear-lanceolate, pinnate, pinnatifid below the serrate or crenate, acuminate or acute or obtuse apex: pinnæ alternate or rarely two opposite, crowded often imbricated in sterile leaves, approximate or sometimes crowded in sporophylls; excepting sometimes the uppermost, dilated at base and auricled on upper side or both sides, lanceolate or subfalcate or, especially the lower, oblong, the lowermost often unequally roundish-deltoid, obtuse or subacute or acute, subentire or undulate, or, especially the lower, slightly crenate, or serrate or, sometimes, obliquely cleft or pinnatifid, the lobes mostly serrate; beneath very obscurely, minutely and sparingly paleaceous, upper surface similar or glabrous: rachis reddish or light or dark chestnut-brown, glossy, terete or subterete below, above more or less furrowed on face, sparingly and obscurely paleaceous, palea similar to that of upper part of petiole; color of rachis in large leaves sometimes encroaching on under side of midveins of pinnæ: color otherwise olive green: texture firmly membranaceous.

Venation pinnate, wholly free or with occasional areolæ: primary branches of pinnæ's midveins, excepting the two basal, commonly once forked or at apices of pinnæ simple, or in highly developed, especially in lobed or pinnatifid pinnæ, often bearing simple or once-forked branches and each forming a midvein of a lobe or segment; superior basal primary branch bearing a few simple or once-forked branches and forming midvein of superior basal auricle; inferior basal primary branch once-forked or similar to superior one, forming midvein of inferior basal auricle when this auricle is present.

Sori oblong or linear, borne on branches of pinnæ's midveins and often on branches of midveins of pinnæ's auricles or other lobes or segments; each sorus on a primary branch of the midvein, partly below its superior basal branch, extending along or wholly upon latter branch or extending along the veinlet of the latter (when one is present), next the midvein, opening toward the midvein: indusia whitish, delicately membranous, the margin erose or slightly ciliate-erose.

Spores brown, covered with anastomosing ridges.

Habitat. Dry places exposed to the sun or partly shaded; usually near or on rocks. In old fields and pastures, among stones by the roadside, etc.

Range. Florida to Maine and southeastern Ontario, west to Texas and Colorado.

Asplenium platyneuron (Linnæus) Oakes; D. C. Eaton, Ferns N. Am. 1: 24. 1878.
Acrostichum platyneuros. Linnæus, Sp. Pl. 1069. 1753.
Asplenum ebeneum. Aiton, Hort. Kew. 3: 462. 1789.

The blade of the leaf first produced by the young plant of *Asplenium platyneuron* is usually either obcordate, or bilobed with each of the two lobes slightly bilobed. If the first, it contains a once-forked vein; if the second, a twice-forked vein, each of the four veinlets occupying one of the lobes. Another very young leaf is trilobed. It contains a vein which is simple at apex, occupying the central lobe, and which bears two simple branches below, each occupying one of the lateral lobes. The leaf-blade becomes next somewhat more complexly lobed and its midvein develops farther. Pinnæ are then gradually formed, in the same manner as in *A. trichomanes.** In *A. trichomanes*, however, the pinnæ are often opposite, whereas in *A. platyneuron* they are nearly always alternate.

The leaf's petiole is green at first but soon begins to change color, although not, at least noticeably, as soon as in *A. tricho-*

* See page 65.

manes. The color that replaces the green appears first at the petiole's base and spreads upward, involves in time the entire rachis, and, occasionally, in the larger leaves, encroaches also on the under surface of the pinnæ, along the midveins. It is straw-color at first, but gradually becomes chestnut-brown or darker, finally shading from brown to ebony and, occasionally, tinged with green.

Auricles at the bases of the pinnæ are absent in the first early stages of the leaf's development, but a tendency toward especial development at the places where they are to appear later is early noticeable. For instance, in many of the pinnæ of very young leaves the midvein's superior basal primary branch, which later forms the midvein of the superior auricle, is once forked, while the other primary branches are simple. The auricles gradually form as the leaf develops, sometimes at the inferior sides of the pinnæ as well as at the superior. They are in reality incipient secondary segments of the leaf.

Although the leaf-blade's margin is sometimes subentire or merely undulate, a greater or less degree of incision between the primary branches of the leaf's midveins, or at least a tendency to such incision, is noticeable in all stages of the leaf. It is obviously carried to its fullest extent in the production of the pinnæ. In the pinnæ themselves it is commonly shown merely by serration or crenation or undulation of the margin, but sometimes it is carried far enough to render the pinnæ cleft, more or less deeply, into segments.

The so-called "var. serratum" Gray is based upon leaves with such cleft pinnæ. These leaves are not uncommon in large, luxuriant, fertile plants, and represent, apparently, the height of normal development of this fern's leaf. They are somewhat analogous to the highly developed leaves in *Polystichum acrostichoides*.

The cleft pinnæ are mostly unusually long, and commonly occur in the more central part of the leaf-blade, which is, as a rule, the most highly developed part of any mature leaf of this fern. The primary branches of the pinnæ's midveins are mostly more complex in the cleft pinnæ than in the others, excepting those in the basal auricles of the latter, and constitute the segment's midveins. Series of sori occur along these midveins as well as along the pinnæ's midveins. In the uncleft pinnæ series of sori occur only along the pinnæ's midveins and the auricles' midveins. The auricles, which, as already stated, are incipient segments, become basal segments in the cleft pinnæ.

In this fern, as in *A. angustifolium*,* diplazioid sori, or diplazioid parts of sori, sometimes occur on veins that are both primary branches of one midvein and superior basal primary branches of primary branches of another.

In addition to the incision described above, employed in the leaf's development, slight incision, or a tendency to slight incision, between the leaf's ultimate veinlets is often noticeable in the leaf at various stages. When present it adds to the unevenness of the leaf-blade's margin, and in highly developed leaves causes the pinnæ's segments to appear toothed.

"Var. Hortonæ" Davenport is based upon monstrous leaves in which incision occurs in an extreme degree and is correlated, so far as known, with total sterility of the leaf.

* See page 60.

EXPLANATION OF THE PLATES.

PLATES XVI, XVII.—EBONY SPLEENWORT. *Asplenium platyneuron.* Plate XVI.—1. Young plant attached to prothallus. 4. Slightly older plant. 2–11. Young leaves in different stages of development. Plate XVII.—1. Mature fertile plant, slightly reduced. 2. Section of highly developed mature fertile leaf, slightly reduced. 3. Fertile pinna of less highly developed mature leaf, × 1¾.

Plate XVI.—Ebony Spleenwort

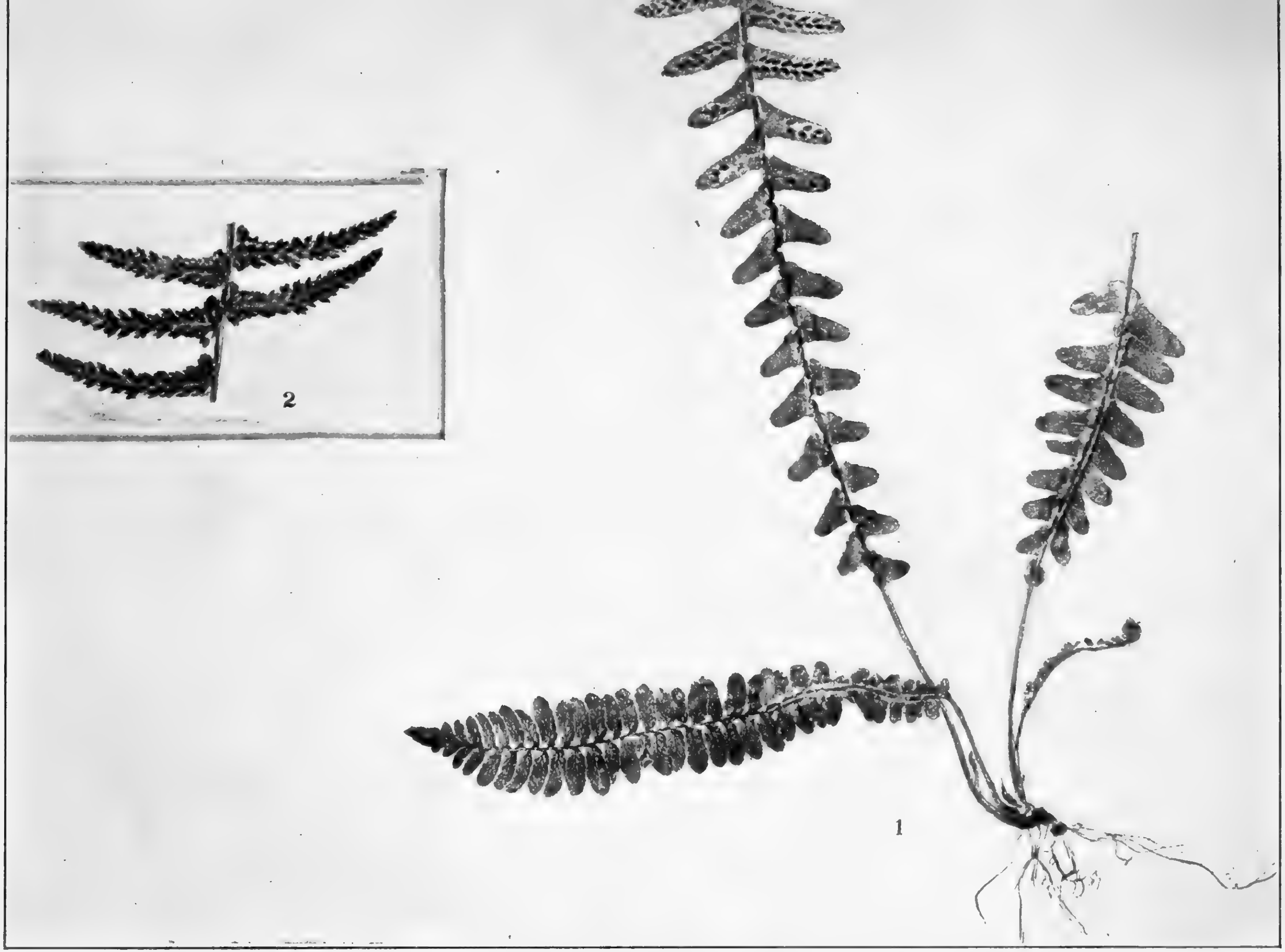


Plate XVII.—Ebony Spleenwort

CHAPTER X

CHRISTMAS FERN

Polystichum acrostichoides.

Rootstock creeping, chaffy: scales pale brown, lanceolate or ovate, acuminate, slightly ciliate: leaves clustered at apex of rootstock: roots springing from rootstock or extreme bases of petioles.

Leaves ascending, five to twenty-seven inches long, two and four-fifths to four and four-fifths inches broad, imperfectly evergreen; in autumn prostrated, the fertile parts of sporophylls usually withering.

Petioles shorter than blades, two to six and two-fifths inches long, toward base dark, often reddish or lighter brown, above green, somewhat flattened or furrowed on face, turgid at base, chaffy: scales numerous, pale brown, ovate or lanceolate, acuminate, ciliate: fibrovascular bundles four or five; the two anterior largest, ovate-wedge-shaped or suboval in section, or slightly hollowed on one or both sides; the others ellipsoidal or roundish in section.

Blades rigid, lanceolate, pinnate; apex pinnatifid, becoming serrate or serrulate at tip, subacute or acute or acuminate: pinnæ mostly approximate or in sporophylls distant, alternate or opposite, mostly subsessile or very short-stalked, obtuse or acute or sometimes short-acuminate, linear-lanceolate or oblong-lanceolate, often somewhat falcate, half-halberd-shaped at base, occasionally serrate or obliquely incised or pinnately parted into oval or ellipsoidal or roundish-oblong sometimes distant segments, which are often auricled on the upper side, only upper pinnæ of sporophylls, or in sporophylls with cleft pinnæ the tips or more of the lower pinnæ also, soriferous; soriferous parts of blade somewhat contracted: margins serrulate with appressed spinulose teeth: rachis chaffy with pale brown, lanceolate or linear or sometimes ovate, acuminate, ciliate scales: lower surface more or less paleaceous, especially along midveins, the upper somewhat so: color deep, lustrous green: texture subcoriaceous.

Venation pinnate, free or with occasional areolæ: primary branches of pinnæ's midveins mostly simple at apex with two simple alternate branches below, the basal one on upper side; or bearing a few branches which are commonly simple or, in basal lobes of pinnæ, once-forked or at apex simple with two simple branches below: primary branches of midveins of cleft pinnæ more complex; in pinnatifid pinnæ constituting midveins of segments, their branches simple or once-forked or the superior basal sometimes bearing a few simple or once-forked branches.

Sori small, apical or sometimes dorsal on the simple branches of primary branches of pinnæ's midveins, or on the inner or both of basal veinlets of the compound, mostly becoming confluent, an oval spot visible beneath each sorus: indusia orbicular, subentire or partly crenulate or suberose.

Spores ovoid or bean-shaped, with conspicuous, irregular, wing-like borders.

Habitat. Woodlands, especially open woods, wooded banks and stone walls: often among rocks.

Range. Nova Scotia and New Brunswick to Wisconsin, Iowa, Mississippi, and Florida.

Polystichum acrostichoides (Michaux) Schott, Gen. Fil. 1834.
Nephrodium acrostichoides Michaux, Fl. Bor. Am. **2**: 267. 1803.
Aspidium acrostichoides Swartz, Syn. Fil. 44. 1806.
Dryopteris acrostichoides Kuntze, Rev. Gen. Pl. **2**: 812. 1891.

THE simplest leaf-blade of *Polystichum acrostichoides* seen is obcordate (Pl. XVIII, Fig. 1). It contains a vein with two simple branches, one of which occupies each of the lobes. The leaf-blade becomes next more complexly lobed (Fig. 2 *a b*), and its midvein lengthens, and sends out additional primary branches. The formation of pinnæ is then carried out, and the venation develops in the manner usual in ferns with pinnate venation.

The pinnæ form gradually, appearing first as mere lobes.

At first the base of the leaf-blade is cuneate (Figs. 1, 2 *a b*). It is rendered truncate before the first pair of pinnæ become distinct (Fig. 4 *c*), and then cordate (Fig. 3), by a broadening of these two pinnæ.

In the early leaves the pinnæ are at first short and blunt, sometimes, in the very early leaves, even wedge-shaped or cuneate fan-shaped. They lengthen gradually, and become in highly developed leaves acute or sometimes acuminate.

When newly formed, the pinnæ in the very early leaves are apt to be cuneate at base and are sometimes nearly or quite equilateral, but a disposition to develop the upper side of the pinna at the expense of the lower is shown at a very early stage of the leaf-development. For some time this merely causes the pinna to appear one-sided, but finally it results in the production of the basal auricle seen in the mature leaves, which is an incipient pinnule, and is occupied by the superior basal primary branch of the pinna's midvein. This auricle sometimes, in very highly developed leaves, actually becomes a pinnule, as will be seen further on. The lower basal sides of the pinnæ mostly remain more or less oblique to the rachis.

The early leaves are crenately toothed or lobed, but one or more spinulose or at least apiculate lobes are usually to be seen before the first pair of pinnæ becomes distinct. More spinulose points appear in subsequent leaves, until the blunt teeth or lobes are almost or quite superseded. Each spinulose point occurs at the apex of a veinlet of the leaf, but one is not present at the apex of every veinlet. In the later leaves there is usually one or more to every primary branch of the pinnæ's midveins.

The leaf becomes fertile first above and the fertile pinnæ are contracted.

In some plants, some or all of the leaves become very highly developed, with the following results. In the fertile leaves the soriferous zone extends downward, forming a sort of triangle, the pinnæ, like the leaf-blade itself, becoming soriferous first at the apex, and their soriferous parts mostly becoming contracted. Incisions occur between the primary branches of the pinnæ's midveins and sometimes deepen sufficiently to render the leaf subbipinnate. These primary branches, constituting the midveins of the pinnæ's segments, are more complex than in the usual pinnæ.

The so-called "vars." "schweinitzii" Beck, and "incisum" Gray, are based on these highly developed leaves. These leaves are usually very large and densely soriferous, and, as Mr. A. A. Eaton has pointed out, appear to be the product of extreme luxuriance of the plant. From the following facts and from my

* See Fern Bulletin, 8: 13. 1899.

own observations, it appears that they are likely to be induced by anything acting as a strong stimulus to the plant, such as sunlight, or an unusual supply of food brought within the plant's reach by heavy rains. Mr. Eaton reports finding them late in the season in the second growth of vigorous plants, although fruiting lightly in such cases. They are often to be seen in plants exposed to the sun from the cutting down of surrounding woods. Mr. Eaton states that they are seldom found in plants growing in shade, and that they disappear in localities when surrounding trees that have been cut down are replaced by others. In short, we have here, apparently, the remarkable case of a plant often stimulated to a height of leaf-development far beyond the usual one, and lapsing to its usual state when the stimulus is withdrawn.

EXPLANATION OF THE PLATES.

PLATES XVIII–XX.—CHRISTMAS FERN. *Polystichum acrostichoides.* Plate XVIII.—1–6. Young leaves and plants in early stages of development. 2. Young plant attached to prothallus. Plate XXIX.—1, 2. Young leaves in later stages of development. Plate XX.—1. Mature fertile leaf. 2. Fertile pinna of same, × 2½. 3. Sterile pinna of same, × 2½. 4, 5. Sections of sterile pinnæ of more highly developed mature leaves, × 2½.

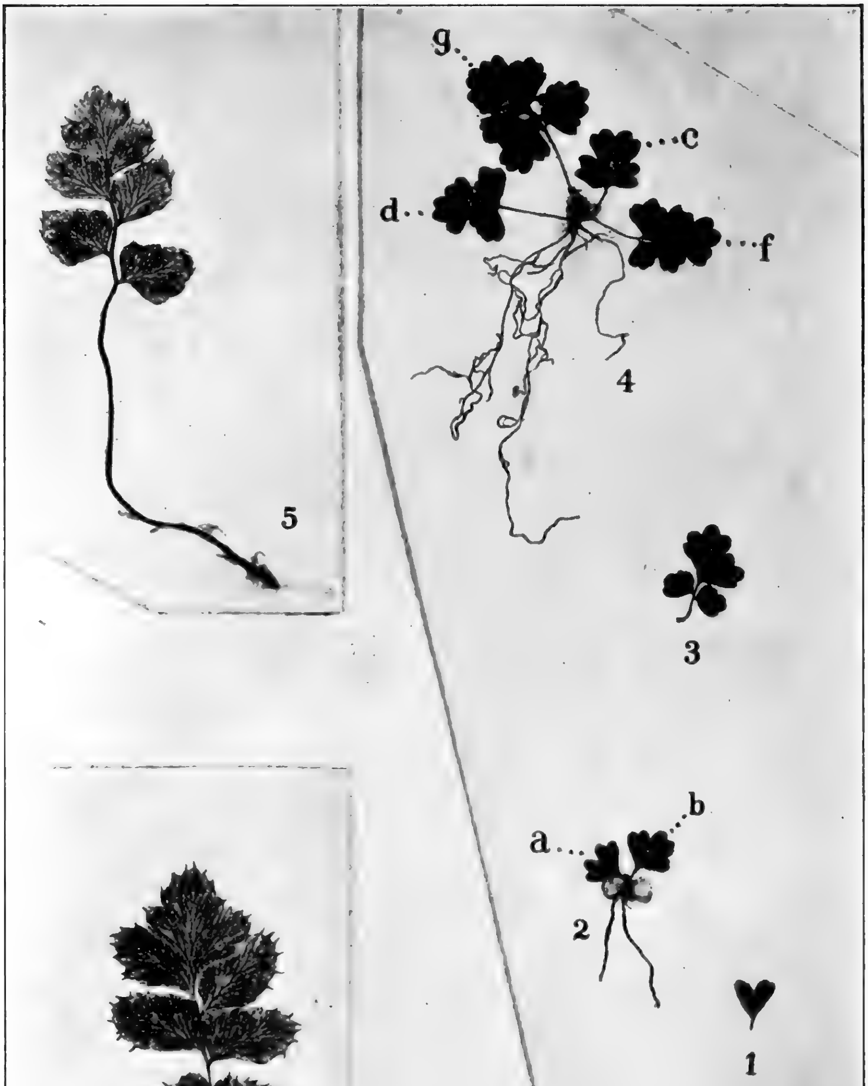


PLATE XVIII.—CHRISTMAS FERN

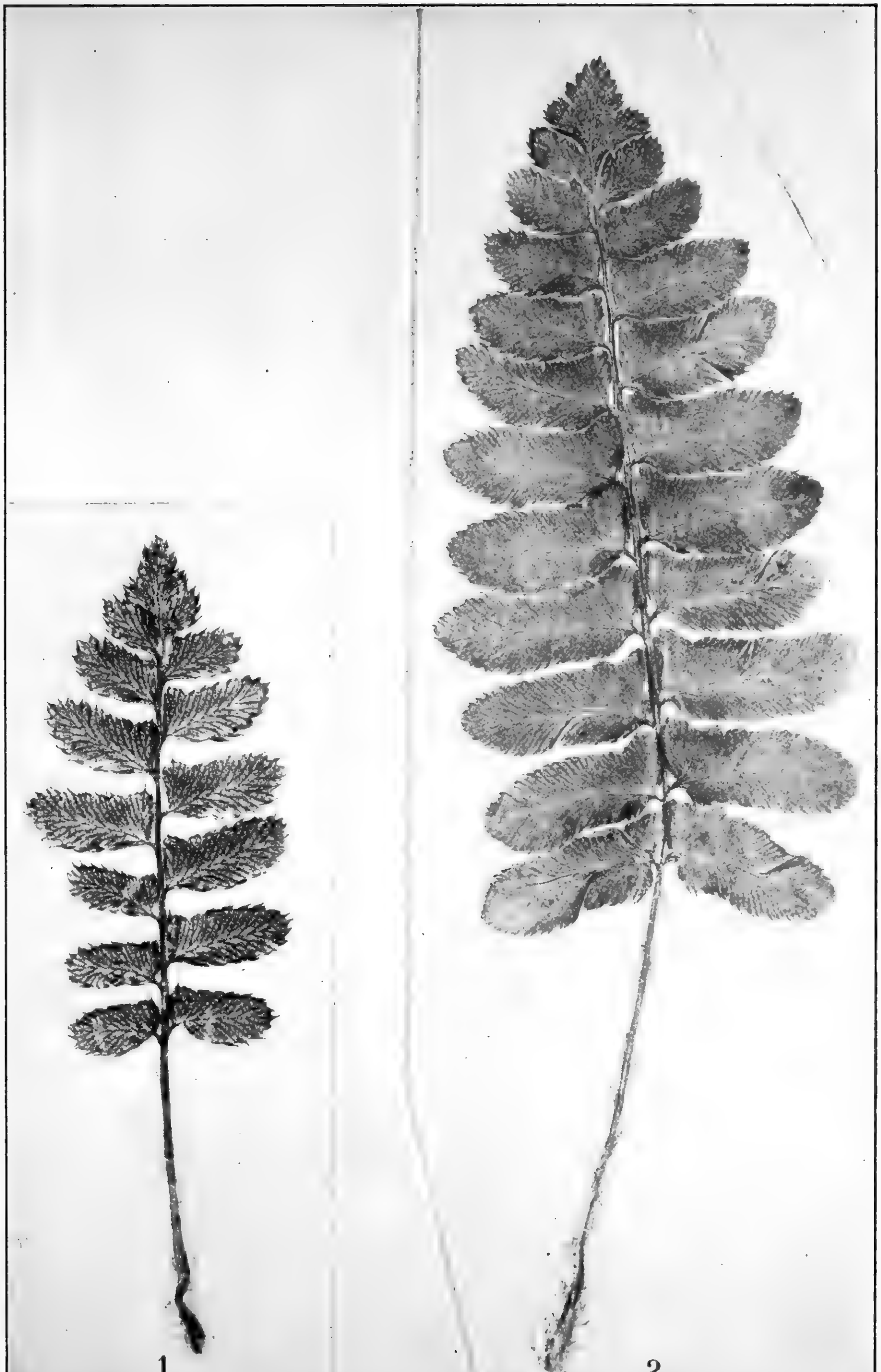


PLATE XIX.—CHRISTMAS FERN

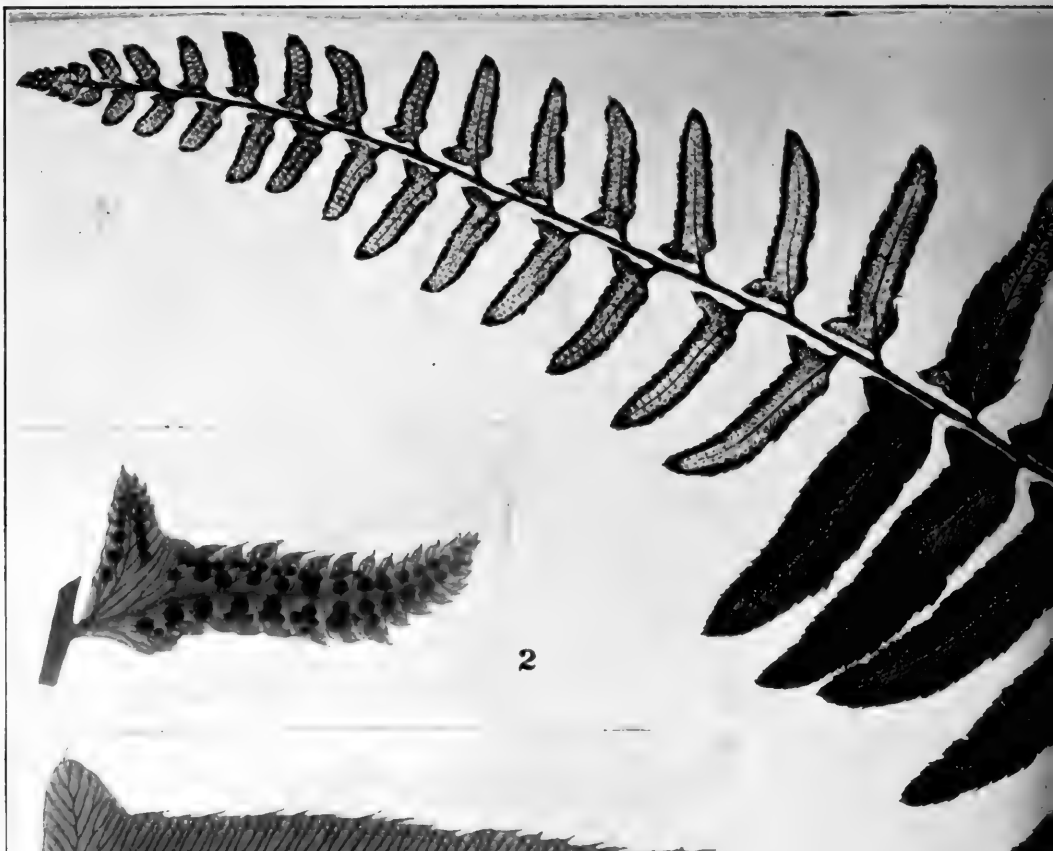
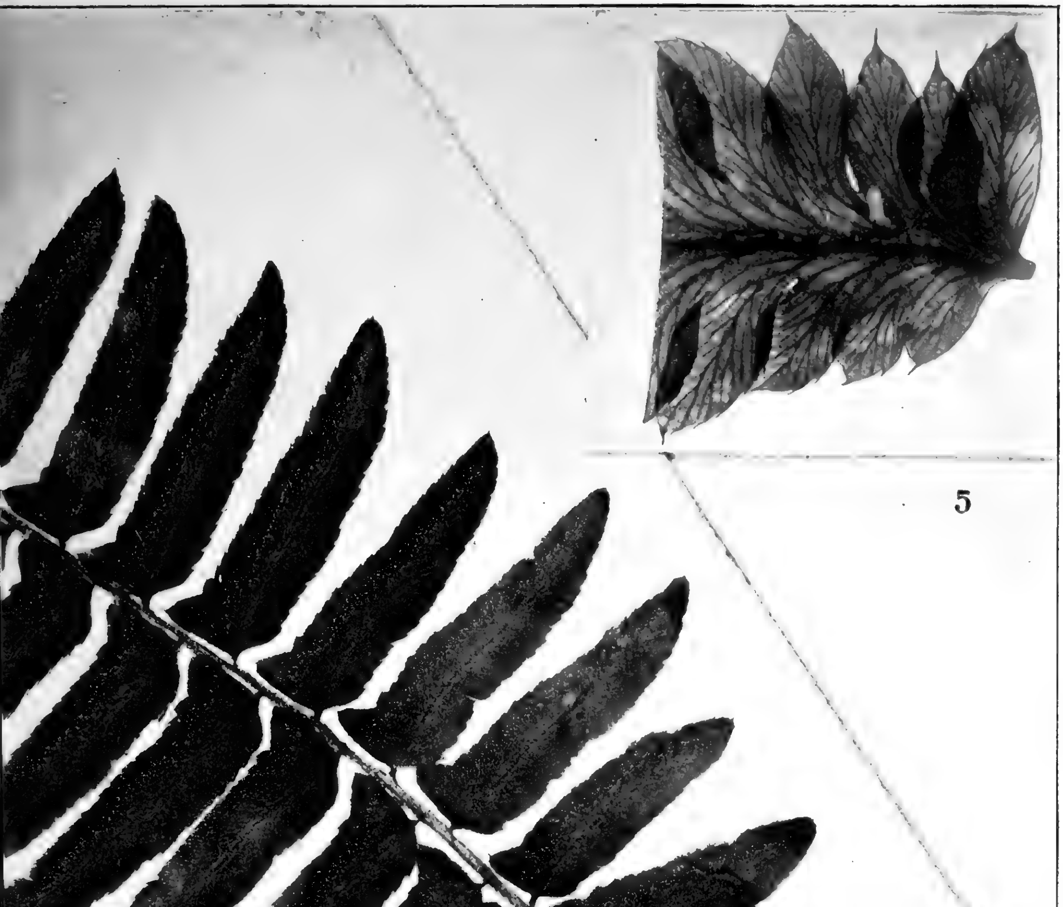


PLATE XX.—C



...TMAS FERN

CHAPTER XI

SLENDER CLIFF-BRAKE

Cryptogramma Stelleri.

Rootstock creeping, ivory-white or yellowish, slender, cord-like, sparingly furnished with minute, pale, appressed, ovate, acuminate, delicately reticulate scales with elongate cilia at margin: leaves scattered: roots few, capillaceous, springing from all sides of rootstock.

Leaves ascending, dimorphous, four to eight and four-fifths inches long, the sterile usually the shorter; tender, withering early, often before September.

Petioles slender, two to five inches long, usually longer than blades, straw-colored to brown, palest above, slightly polished, grooved on face and sides, the grooves less distinct below, bearing a few scales: scales broadly to narrowly lanceolate, otherwise similar to scales of rootstock: fibrovascular bundle solitary, more or less rolled up or folded at ends or sometimes barely curved.*

Blades ovate or ovate-oblong or ovate-deltoid, pinnate below, toward apex pinnatifid: pinnæ few, alternate or opposite, once or twice pinnatifid, in largest sporophylls sometimes pinnate below, becoming simple toward apex of blade, the lower often

* C. E. Waters.

short-stalked, the upper sessile and decurrent: sporophylls commonly more deeply cut than sterile leaves: ultimate segments adnate-decurrent, the inferior mostly longer than the superior; fertile segments lanceolate or linear-oblong on the smaller oval or roundish, obtuse or appearing acute or subacute from the reflexed margins; the apical mostly the longest; sterile segments obovate or ovate or roundish, crenately toothed or lobed, obtuse: rachis greenish or below brown, grooved on face: surfaces glabrous: color pale green: texture thin, membranous.

Venation conspicuous, pinnate, free: primary branches of midveins of fertile segments simple to twice-forked or rarely bearing several simple or once-forked branches, commonly simple or once-forked: primary branches of midveins of sterile segments varying as in fertile segments, the average more complex than average of latter: midveins sometimes not evident in small segments.

Sori clustered on upper part of veins: indusia consisting of reflexed altered margin of segments, extending along sides and often around apices of segments or in segments bearing few scattered sori sometimes present only at soriferous points, at length opening out more or less flat, delicately membranaceous, the margin more or less erose or minutely denticulate or entire.

Spores spheroid-tetrahedral, obscurely trivittate.

Habitat. Clefts and ledges of shaded moist calcareous rock, or on sandstone, mica-schist, or gneissoid rock;* particularly near streams and lakes in cold mountain glens and ravines.

Range. Labrador to Alaska, south to Massachusetts, Pennsylvania, Illinois, Iowa, and in the Rocky Mountains to Colorado.

* See Fern Bull. 10:56. 1902. Also Torreya, 2:176. 1902.

Cryptogramma Stelleri (S. G. Gmel). Prant, Engler's Bot. Jahrb. **3**: 413. 1882.

Pteris Stelleri. S. G. Gmel., Nov. Comm. Acad. Sci. Petrop. **12**: 519. *Pl.* XII, *f.* 1. 1768.

Pellæa Stelleri. Watt, Can. Nat. : **3** 158. 1867.

Pteris gracilis. Michaux, Fl. Bor. Am. **2**: 262. 1803.

Pellæa gracilis. Hooker, Sp. Fil. **2**: 138. Pl. CXXXIII. *B.* 1858.

I HAVE not been able to obtain leaves of *Cryptogramma Stelleri* portraying earlier stages of leaf-development than the leaves figured in Pl. XXI, but from the figures the general development of the form and venation of the leaf can be seen.

It will be noted that the venation is pinnate, and that when new segments form on the leaf, many duplicate to a certain extent the earlier segments. For instance, compare Figs. 1 *a*, 2 *a*, 4 *a*, 6 *a*, 8 *a* (Pl. XXI), and 2 *a* (Pl. XXII).

It will also be noted that the fertile leaf figured has no tertiary segments (Pl. XXII, Fig. 1). Tertiary segments are often lacking in the mature leaves.

The incision by means of which the first basal primary branch of the midvein of any one of the leaf's segments is set apart to constitute the midvein of a new segment sometimes occurs while the midvein of the existing segment is little developed, and before other incisions occur in this segment: which often gives the subdividing segment the appearance of being cut vertically into two nearly equal parts.

The midveins in newly formed segments are sometimes not developed beyond two simple primary branches. In segments in later stages of development they are conspicuously developed.

In the transformation of the sterile leaf into a sporophyll, the leaf's petiole lengthens, and the leaf-blade's margin recedes slightly and folds backward on the sides of the leaf's segments and winged midribs. The sporophyll thus is longer than the sterile leaf, and has slightly less complex veins and narrower and more distinct segments.

EXPLANATION OF THE PLATES.

Plates XXI, XXII.—Slender Cliff-Brake. *Cryptogramma Stelleri.* Plate XXI.—1–8. Leaves in different stages of development. Plate XXII.—1. Mature fertile leaf. 2. Mature sterile leaf. 3. Section of fertile leaf, $\times$ 2½.

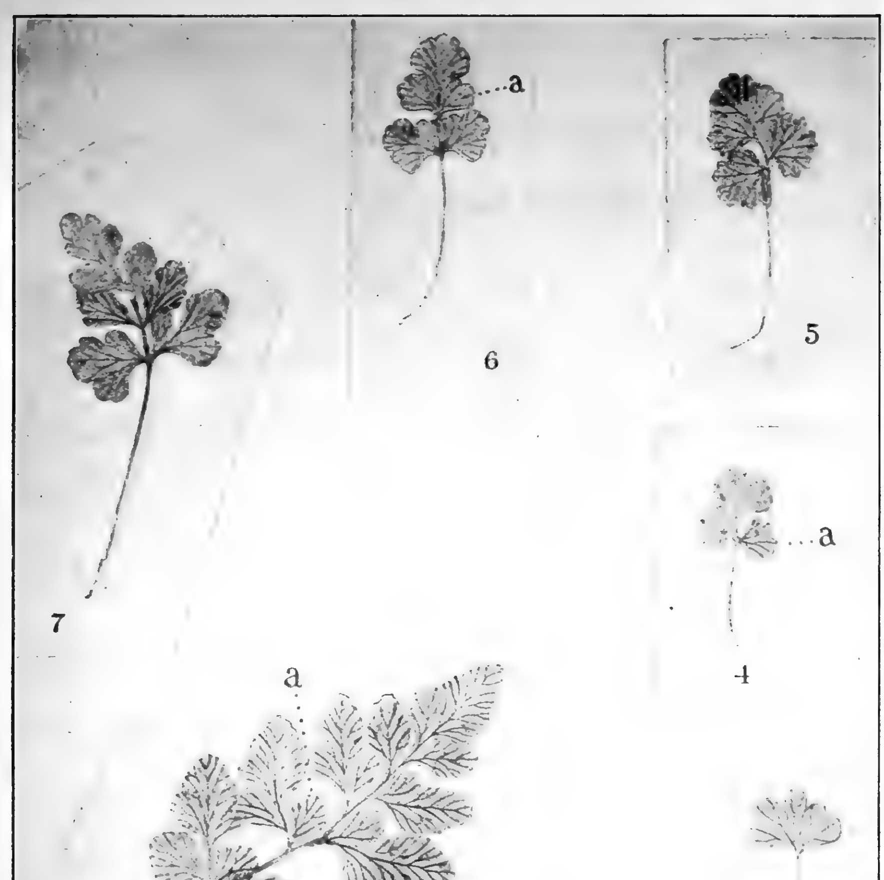


PLATE XXI.—SLENDER CLIFF-BRAKE

PLATE XXII.—

3

ER CLIFF-BRAKE

CHAPTER XII

SILVERY SPLEENWORT

Athyrium thelypteroides.

Rootstock creeping, forking, brown, green at tips, bearing delicate, pale-brown, lanceolate or ovate-lanceolate or ovate-deltoid, acuminate, slightly toothed or ciliate scales: roots brown, coarse, copiously branching, springing from rootstock and junctures of petiole and rootstock.

Leaves twenty to forty-seven inches long, five to twelve inches broad, sensitive to frost.

Petioles eight to twelve inches long, shorter than blades; at base dark-brown or at first partly green, turgid-compressed, angled laterally and toothed along angles; above greenish-straw-colored or straw-colored or brownish when dried, furrowed on face; somewhat scaly and pubescent: scales pale-brown, broadly ovate to lanceolate to linear, acuminate, entire, the linear often, at least the upper, articulated at apex: hairs articulated, marked at joints and sometimes lengthwise in brown or golden-brown: fibrovascular bundles two, strap-shaped, uniting below blade into one somewhat U-shaped in section.

Blades lanceolate or ovate-lanceolate, gradually or abruptly narrowed toward apex, somewhat narrowed at base, pinnate, pinnatifid toward apex: apex acuminate, undulate to serrulate or serrate: pinnæ sessile or very short-stalked, linear-lanceolate, acuminate, or the uppermost acute to obtuse, passing toward apex of blade into obtuse segments, deeply pinnatifid, the apices undulate to serrulate or serrate: pinnæ's segments oblong or ovate-oblong, obtuse or subacute, serrate or crenate, often obscurely so, or incisely serrate or lobed: rachis furrowed on face, at least above, toward base bearing a few scales which are articulated at apex and similar to those of upper part of petiole: surfaces studded, especially along rachis, midribs and veins, with articulated hairs marked at joints and sometimes tinged otherwise with golden-brown: color green: texture herbaceous.

Venation pinnate, free or with occasional areolæ: primary branches of midveins of pinnæ's segments commonly simple, sometimes once-forked, especially in the more deeply cut segments, or in latter bearing a few simple branches.

Sori borne each on a primary branch, when this is simple, of a midvein, when it is compound, extending along or wholly upon its superior basal branch, opening toward midvein; single and oblong or linear or the smaller suboval, or on veins that are both primary branches of one midvein and superior basal branches of primary branches of another, often opposed in pairs (diplazioid) for the whole or part of their length, one sorus of each pair opening toward one midvein, the other toward the other midvein, the two often connate at outer end forming an athyrioid sorus which is either hamate or hippocrepiform; indusia silvery and arched when young, often pointed at ends, entire or subentire.

Spores bean-shaped, irregularly and narrowly winged.

Habitat. Rich, damp woods and ravines, near banks of mountain streams, etc.; particularly in or on the outskirts of cold woodlands.

Range. Nova Scotia and New Brunswick to Minnesota, Illinois, Alabama, and Georgia.

Athyrium thelypteroides. Desvaux, Mém. Linn. Soc. Paris. **6**: 266. 1827.
Asplenium thelypteroides. Michaux, Fl. Bor. Am. **2**: 265. 1803.
Athyrium acrostichoides. (Sw.) Diels, Die Nat. Pflanzeuf. $\mathbf{1}^4$: 223. 1899.
Asplenium acrostichoides. Swartz, Shrad, Journ. Bot., 1800^2: 54. 1801.

YOUNG leaves of *Athyrium thelypteroides* can be easily recognized in the field by their peculiar specific texture and the short hairs studding their upper surface.

The venation is pinnate.

The early forms of the leaf are shown in Pls. XXIII, XXIV.

The early pinnæ are very short and blunt. In the course of development they, as well as the leaf-blade itself, lengthen more and more and become at last drawn out at apex into a long point.

In the mean time their segments, which at first are mere teeth or lobes or barely defined, and contain each a simple, once-forked or slightly more complex branch of the pinnæ's midveins, become well marked, oblong, slightly often obscurely toothed segments, in which the branches of the pinnæ's midveins have become well-defined midveins with simple branches which occupy the segments' teeth. At this stage of development the leaf appears as in Pl. XXV, Fig. 1. In Pl. XXV, Fig. 3, is shown an enlarged section of a pinna of a leaf at this stage.

Finally, in the most highly developed leaves, the pinnæ's segments lengthen and become slightly pointed, the segments' teeth enlarge and the incisions between them deepen, so that they become lobes rather than teeth, and the vein occupying each lobe often becomes an incipient or more developed midvein with simple branches (Pl. XXV, Fig. 2).

It will be seen that in one sense the last step is mere repetition of what has gone before, and that it accords with this fern's disposition to lengthen and point its leaf-segments as they develop, to enlarge teeth into segments, and to develop branches of midveins into midveins with branches. The leaves with the highly developed pinnæ are sometimes sterile, sometimes fertile. While less common than the leaves that do not represent the height of the leaf-development, they are to be looked for in any luxuriant mature plant, and are likely to occur on the same plant with less well-developed leaves as it advances in development: leaves also are likely to occur in which some of the pinnæ's segments are highly developed and others not. There is apparently nothing here to denote subspecific variation, or even monstrous development, or to entitle either the markedly highly developed leaves or markedly less well developed but mature leaves to a distinctive name. Yet the highly developed leaves have received at least two such names, and in one instance the less well developed have been interpreted as a variety of the highly developed.*

In this fern each sorus is borne on a vein which stands, or on

* "Var. serratum" Lawson is apparently based upon the highly developed leaves. See Canad. Nat. 181. 1864. "Athyrium acrostichoides thelypteroides" Gilbert is based upon the less well developed leaves. See Fern Bulletin, 8: 9–10, 1900. In his "List of North American Pteridophyta," 15. 1901, Mr. Gilbert apparently reverses this arrangement, calling the highly developed leaves the variety or "form," to which he gives the name "A. thelypteroides f. acrostichoides."

Swartz appears to have drawn his original definition of his *A. acrostichoides* from the highly developed leaves, judging from p. 82 of his Synopsis Filicum, where this definition is quoted and appears side by side with a short definition of Michaux's *A. thelypteroides*, which Swartz evidently considered distinct. The two definitions point respectively to the highly developed and the less well developed leaves of this fern.

two veins each of which stands, in the relation of a primary branch or of a superior basal primary branch of a primary branch to a midvein, the sorus opening toward the midvein. On such veins as stand in one of these relations to each of two midveins two sori are often borne, one opening toward one midvein, the other toward the other midvein. These sori are either distinct (diplazioid) or connate at the outer end (athyrioid). For instance:

The midveins of the pinnæ's segments are also primary branches of the pinnæ's midveins, hence diplazioid and athyrioid sori, or at least the opposed parts of such sori, often occur on their superior basal primary branches. Such sori are found particularly in the small uppermost pinnæ and the apices of the larger pinnæ, where the pinnæ's midveins are more distinctly midveins (are less merged in midribs), than elsewhere. In the pinnæ in which the primary branches of the midveins of the pinnæ's segments are simple, the only midveins are the midveins of the pinnæ's segments and the midveins of the pinnæ, hence such sori occur only as above described—*i.e.*, next the pinnæ's midveins or midribs, on the superior basal primary branches of the midveins of the pinnæ's segments, which in these pinnæ are the only veins standing in the required relation to each of two midveins (Pl. XXV, Fig. 3). In the pinnæ in which the midveins of the pinnæ's segments bear branches, and so represent incipient or well-defined midveins of the segments' lobes, such sori occur on their superior basal branches (Pl. XXV, Fig. 2).

In all the specimens of this fern that I have examined, I have not been able to find the opposed parts of any diplazioid or athyrioid sori on any vein that did not stand in such relations to two midveins as to lead one to expect two sori upon it, or either of the unopposed parts, if any, on any vein that did not stand in such a relation to one of the midveins as to lead one to expect a single sorus on it: judging from the positions of the single sori on the other veins of the specimens. The material examined comprise the collections of this fern in the New York Botanical Garden, two specimens typical of the highly developed and of the less well developed leaves kindly sent me by Mr. Gilbert, and a large number of specimens collected in Vermont.

Union in formation of otherwise normal asplenioid sori is thus, apparently, the explanation of the occurrence of athyrioid sori in this fern. It is evident that athyrioid sori are liable to occur in any *Asplenium* when, for any reason, two single sori are borne in juxtaposition on opposite sides of the same vein. That the union does not always occur when opportunity offers is seen by the presence of the diplazioid sori in *A. thelypteroides*.

Either of the two sori that make up the diplazioid or the athyrioid sori in this fern may or may not extend down the vein as far as the midvein toward which it opens. If, in the athyrioid sorus, the two extend an equal distance, we have a hipprocrepiform sorus, if an unequal, a hamate sorus, or one of the two may be so short as to be barely distinguishable. Since in the athyrioid sorus both are united at the outer end, one cannot extend at that end farther on the vein than the other, but one can and often does in the diplazioid.

By some botanists *A. thelypteroides*, *A. filix-fœmina*, and *A. cyclosorum*, the three representatives of *Athyrium* in the United States, are included in the genus *Asplenium*. All three ferns have a greater or less number of athyrioid sori on their leaves, but it appears from all the specimens that I have seen that the occurrence of the athyrioid sori is due to the same cause in all.

A. thelypteroides, *A. filix-fœmina*, and *A. cyclosorum* are undoubtedly congeneric. In habit and general character they are more nearly related to the group of *Dryopteris* of which *D. noveboracensis*, *D. thelypteris*, and *D. simulata* are representatives than to some species of *Asplenium*. *A. thelypteroides* is so named from its resemblance to *D. thelypteris*, and *D. simulata* from its simulation of a form of *A. filix-fœmina*. Shorten athyrioid sori sufficiently and we have *dryopterioid* sori: some of the short athyrioid sori often seen, on leaves of *A. cyclosorum* and *A. filix-fœmina* particularly, are not distinguishable from sori of *Dryopteris*.

The evolution of *Dryopteris* from an ancestor with asplenioid sori, and also the manner in which the change in the sori may have come about, is thus suggested. For instance, let us suppose that athyrioid sori were produced first in some *Asplenium* by casual union of otherwise normal asplenioid sori, as they are apparently produced in *A. thelypteroides*, *A. filix-fœmina*, and *A. cyclosorum;* a tendency to produce such sori might be inherited by the descendants of that *Asplenium* and augmented until these sori came to be produced not only on such veins as at first, but on other veins as well, and finally to supplant the asplenioid sori.

EXPLANATION OF THE PLATES.

PLATES XXIII–XXV.—SILVERY SPLEENWORT. *Athyrium thelypteroides.* Plate XXIII.—1. Young plant attached to prothallus. 2–6. Young leaves in early stages of development. Plate XXIV.—Young leaves in later stages of development. Plate XXV.—1. Mature sterile leaf. 2. Section of fertile pinna of highly developed mature leaf, × 2½. 3. Section of fertile pinna of less highly developed mature leaf, × 2½.

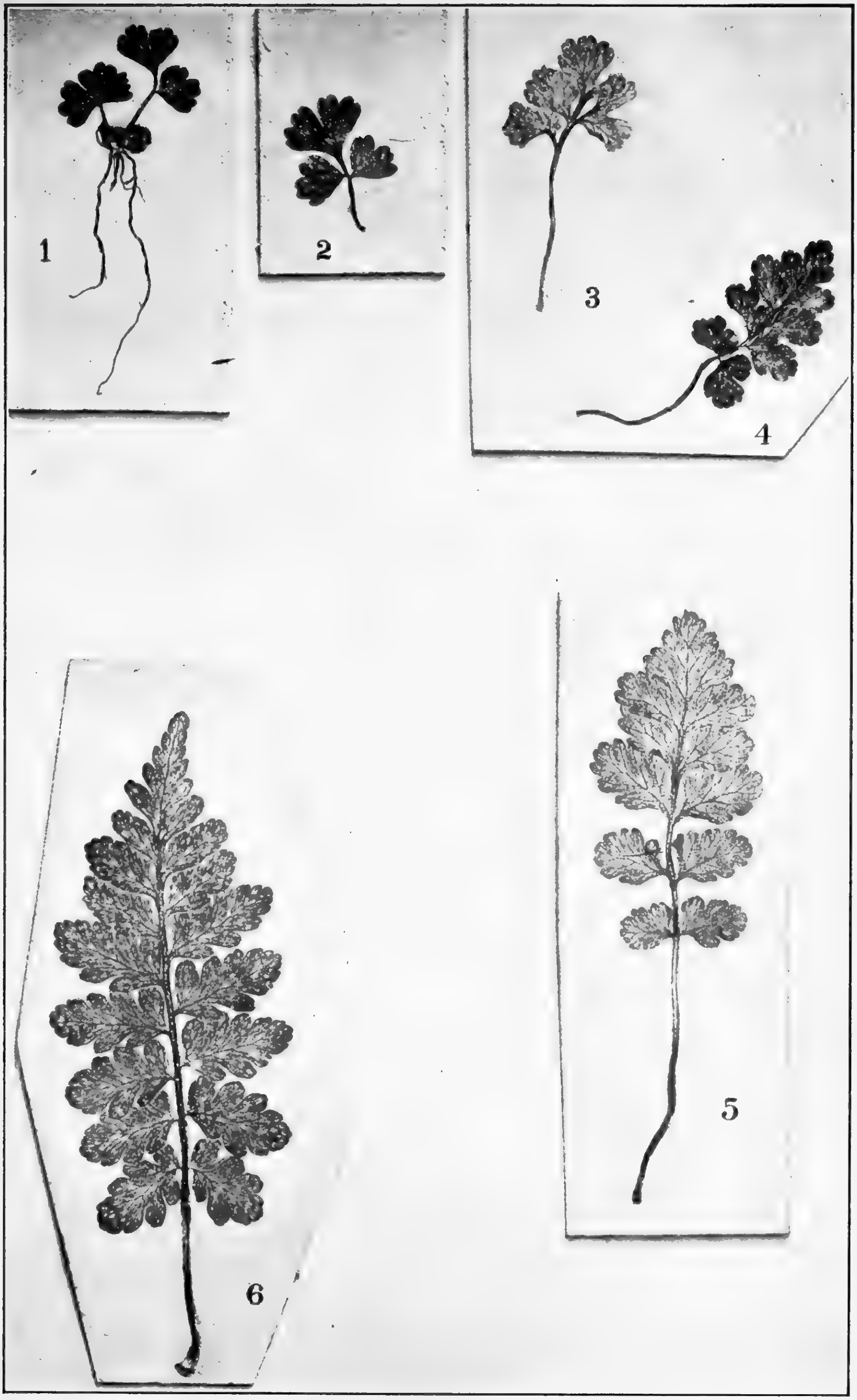


Plate XXIII.—Silvery Spleenwort

PLATE XXIV.—S

ERY SPLEENWORT

2

PLATE XXV.—

3

1

ERY SPLEENWORT

CHAPTER XIII

NEW YORK FERN

Dryopteris noveboracensis.

Rootstock wide-creeping, forking, brown, slender, bearing a few minute, pale-brown, ovate-deltoid, acuminate scales; leaves scattered along extensions of rootstock, forming cæspitose crowns at its growing ends: roots few, springing from rootstock.

Leaves ascending or suberect, withering in autumn, six to twenty-nine inches long, sporophylls usually longer and narrower than sterile leaves.

Petioles about one-fifth to one-third as long as leaves, slender, brownish-straw-colored, furrowed on face, bearing a few small, pale-brown, ovate, acuminate scales: fibrovascular bundles two, flattish.

Blades lanceolate, tapering both ways, two and one-half to seven and one-half inches broad, pinnate: apex pinnatifid, long-acuminate: pinnæ about nineteen to thirty pairs, sessile, alternate or opposite; principal pinnæ deeply pinnatifid, acuminate: upper and lower pinnæ acute to obtuse, the lower more or less distant and gradually reduced to mostly toothed or simply auriculate lobes: segments oblong or oblique, obtuse to acute, entire or crenately toothed: margins ciliate: rachis and midribs pubescent: surfaces otherwise sparingly pubescent along veins:

pubescence and cilia consisting of minute straight whitish hairs: texture thin, herbaceous: color light subdued green.

Venation pinnate, free: primary branches of midveins of pinnæ's segments simple or a few, especially in toothed segments, once-forked or bearing several branches.

Sori minute, mostly submarginal, variously placed on veinlets: indusia delicate, whitish, bearing on margin, and sometimes sparingly on surface, minute yellowish globules or glands, often also a few short, straight, whitish hairs.

Spores ovoid-reniform, muricate, with more or less of a semi-transparent border or wing along the slightly hollowed side.

Habitat. Woodlands and copses.

Range. Newfoundland to Ontario and Minnesota, south to northern Georgia, Alabama, and Arkansas.

Dryopteris noveboracensis (L.). A. Gray, Manual, ed. 1. 630. 1848.
Polypodium noveboracense. L. Sp. Pl. 1091. 1753.
Nephrodium noveboracense. Desv. Ann. Soc. Linn. **6**: 257. 1827.
Aspidium noveboracense Swartz, Schrad. Jour. Bot. 1800^2. 38. 1801.

The development of the form of the leaf of *Dryopteris noveboracensis* can be readily seen from Pls. XXVI, XXVII. It will be noticed that the tapering of the base of the leaf-blade, which is so marked a characteristic of the mature leaf, is lacking at first, and is produced later by a combination of extreme although gradual development of the principal pinnæ and very slight development of the lower. In the leaf-development of the nearly related *Dryopteris simulata*, the development of the principal pinnæ and the lower pinnæ is more uniform and a different shape is thus given to the leaf.

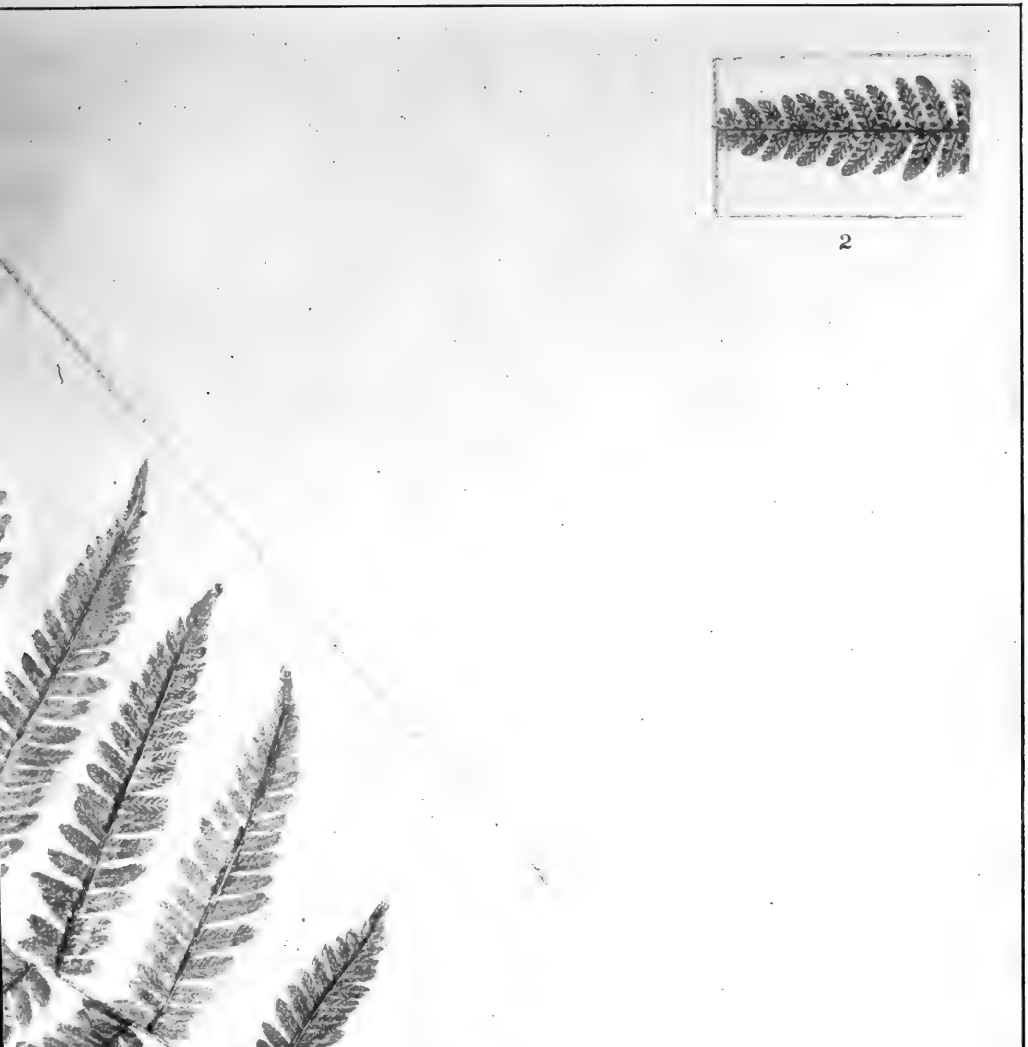
EXPLANATION OF THE PLATES.

PLATES XXVI, XXVII.—NEW YORK FERN. *Dryopteris noveboracensis.* Plate XXVI.—1–7. Young leaves in different stages of development. Plate XXVII.—1. Mature sterile leaf. 2. Section of fertile pinna, × 2½.

PLATE XXVI.

y York Fern

Plate XXVII.



·w York Fern

CHAPTER XIV

MASSACHUSETTS FERN

Dryopteris simulata.

Rootstock wide-creeping, forking, cordlike, brown, sparingly furnished with small, pale-brown, ovate-deltoid, reticulate scales: leaves clustered or approximate, springing from all sides of rootstock: roots few and coarse, clothed with mustard-colored wool, springing from rootstock.

Leaves erect or ascending, withering in autumn, twelve to forty-eight inches long or longer, sterile leaves the shorter, sometimes only half as long as sporophylls.

Petioles six to twenty inches long, slender, stramineous, furrowed on face, bearing a few pale-brown, ovate-acuminate scales; at base dark brown, slightly compressed: fibrovascular bundles two, flattish.

Blades six and four-fifths to twenty-two inches long, two to seven and one-half inches broad, oblong-lanceolate, occasionally oblong-deltoid, pinnate, gradually or abruptly narrowed toward apex: apex pinnatifid, long-acuminate: pinnæ twelve to twenty-one pairs, alternate or opposite, sessile, parting readily from rachis, elliptic-lanceolate, acuminate, deeply pinnatifid, the lower sometimes pinnate at base, basal pair usually introse: segments oblong or oblique, obtuse, entire or sometimes toothed:

margins ciliately pubescent, in sporophylls slightly revolute: surfaces finely pubescent, lower surface studded with minute yellowish glands: rachis stramineous, narrowly furrowed on face, texture herbaceous: color light or deeper green, rather bright.

Venation pinnate, free: primary branches of midveins of pinnæ's segments simple, or a few forked.

Sori rather large, submarginal or medial: indusia finely glandular on margin.

Spores red-brown, under a lens yellow, roughened with irregular ridges.

Habitat. Woodland swamps; sphagnous thickets, roadsides and pastures; wet banks of streams, etc.; most luxuriant in shaded swamps. In plants exposed to the sun the pinnæ are usually conduplicate and the leaf-blade somewhat contracted, suggesting a narrow form of *Athyrium filix-fœmina.* Often accompanied by *Lorinseria areolata.*

Range. Maine to Maryland. Also Vermont and New York, and reported from Indian Territory and Missouri. Probably of wider range.

Dryopteris simulata. Davenport, Botanical Gazette, **19**: 497. 1894, as syn.
Nephrodiums imulatum. Davenport, Botanical Gazette, **19**: 497. 1894, as syn. Also Rhodora, **4**: 10. 1902.

The development of the form of the leaf-blade of *Dryopteris simulata* needs little explanation beyond that given by the figures.* From these may be seen the manner in which the lateral primary segments of the early leaves become the pinnæ with small lobes of later, and these lobes lengthen into the segments, sometimes in turn becoming lobed, of the pinnæ of the mature leaves.†

* Plates XXVIII, XXIX, XXX.

† For comparison of the leaf-development in this fern and in *D. noveboracensis* see page 94.

The delicate pubescence of the leaf-blade and the dark color at the petiole's base are to be seen in the leaf at most if not all stages of development.

The yellowish glands have been found on the leaf-blades of all the leaves examined, excepting one or two extremely young ones, and offer the simplest means of distinguishing this fern from *D. noveboracensis* and *D. thelypteris* at any stage of leaf-development at which they are likely to be confused.

It is often said that the venation offers an easy means of distinguishing *D. simulata* from *D. thelypteris*, and this is true of the venation in the mature leaves. In these, the primary branches of the midveins of the pinnæ's segments are mostly once forked in *D. thelypteris* and simple in *D. simulata*, except in large, often toothed segments, which are examples of leaf-development carried slightly further than usual and in which, consequently, they are more complex. But in the early leaves of both plants the degree of complexity of any of the venation of the pinnæ's segments is changeable, depending upon the segment's state of development, and is not to be relied upon as a distinguishing characteristic until a fairly advanced stage of leaf-development is reached. As the venation in both is pinnate, the entire venation of the segments is formed by the lengthening and branching of the branches of the midveins in the early pinnæ, which takes place during the leaf-development.

EXPLANATION OF THE PLATES.

PLATES XXVIII–XXX.—MASSACHUSETTS FERN. *Dryopteris simulata.* Plate XXVIII.—1, 3–7. Young leaves in different stages of development. 2. Very young plant. Plate XXIX.—8. Young leaf in later stage of development. Plate XXX.—1. Mature sterile leaf. 2. Section of fertile pinna of mature leaf, × 2½.

Plate XXVIII.—Massachusetts Fern

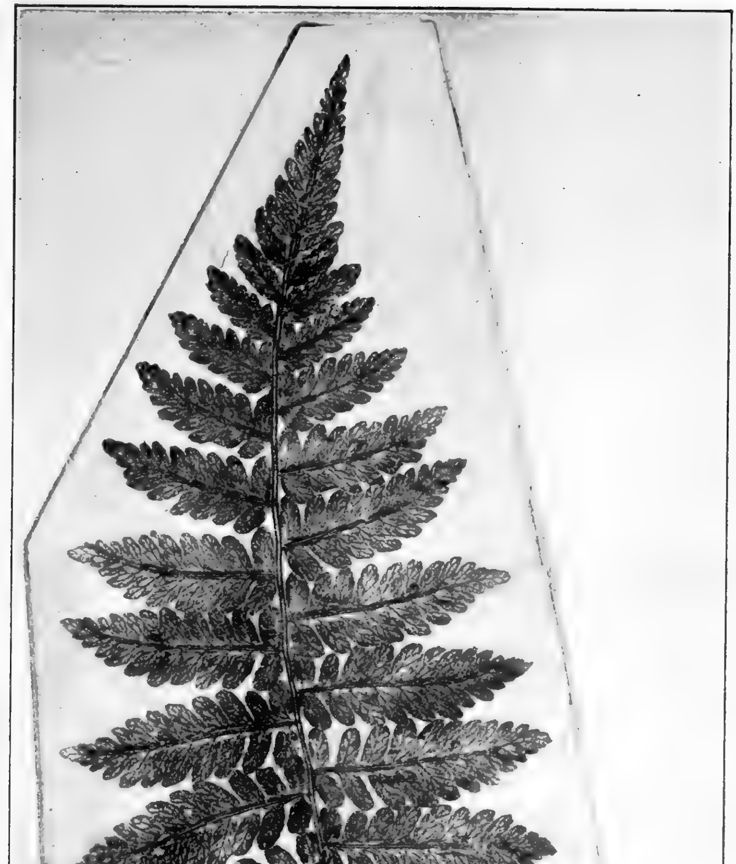


PLATE XXIX.—MASSACHUSETTS FERN

PLATE XXX.

…chusetts Fern

CHAPTER XV

MARGINAL SHIELD FERN

Dryopteris marginalis.

Rootstock caudiciform, stout, densely chaffy: scales large, light golden-brown or brown or rust-colored, lance-linear, acuminate, entire or near apex slightly ciliate-toothed, sometimes appearing articulated from a transverse contraction: leaves in a crown: roots springing from rootstock or junctures of rootstock and petioles, singly or by twos.

Leaves ascending, six to thirty-eight inches long, two to nineteen inches broad, prostrated in autumn, gradually withering more or less during winter.

Petioles shorter than blades; at base dark or reddish-brown, sometimes tinged with plum color, turgid; above more slender, pale-green or reddish-brown, stramineous when dried, furrowed on face, chaffy: scales thickly clothing base of petiole, those above fewer, light golden-blown or shining rust-colored, large and small mixed, lanceolate to linear, acuminate, subentire or ciliate-toothed, sometimes contracted like those of rootstock: fibrovascular bundles five to nine in base, five in apex, of petiole, roundish-strap-shaped; the two anterior largest, furrowed on sides or roundish-wedge-shaped in section.

Blades ovate-oblong or ovate-lanceolate, bipinnate or subbipinnate: apices pinnatifid, becoming dentate or crenate or subserrate or near tip undulate or entire, long-acuminate: pinnæ alternate or opposite, approximate or distant, short-stalked, the uppermost subsessile to sessile, lanceolate or ovate-lanceolate, or the basal unequally lanceolate-deltoid; mostly broadest above the base or below the middle: pinnules mostly approximate, the innermost largely subsessile to short-stalked, otherwise mostly adnate to rachis and somewhat decurrent, oblong or oblong-lanceolate, often oblique, sometimes slightly falcate, obtuse or subacute or rarely acute, entire to dentate or crenately toothed or lobed, or pinnatifid on the inner side or both sides: margins minutely paleaceous at or near nodes of pinnæ's lobes to glabrous: surfaces somewhat chaffy along or near rachises: scales minute or larger, lance-linear or linear, acuminate, ciliate-toothed: rachises furrowed on face: color dark-bluish-green or sometimes yellowish: texture subcoriaceous.

Venation pinnate, free: veinlets mostly curved: lobes of pinnules each occupied by a primary branch of the pinnule's midvein: primary branches of pinnules' midveins mostly once-forked or bearing branches which are simple or once-forked or in the larger lobes bear simple branches, or in smaller pinnules and apices of pinnules simple.

Sori submarginal, borne on the simple superior basal branches of primary branches of pinnules' midveins or on superior basal branches of the compound, below or more rarely on apices of veinlets: indusia at first white, becoming lead-colored, finally brown, orbicular-reniform, convex at first, entire, glabrous.

Spores ovoid-reniform, with a narrow crenulate wing.

Habitat. Woods, roadsides, and stone walls: particularly on or near rocks, or on old logs or stumps in wet woods and swamps.

Range. Nova Scotia to British Columbia, south to Indian Territory, Arkansas, Alabama, and Georgia.

Dryopteris marginalis (Linnæus). A. Gray, Manual, ed. 1, 632. 1848.
Polypodium marginale. Linnæus, Sp. Pl. 1091. 1753.
Nephrodium marginale. Michaux, Fl. Bor. Am. 2: 267. 1803.
Aspidium marginale. Swartz, Syn. Fil. 50. 1806.

THE venation of the leaf of *Dryopteris marginalis* is pinnate.

The development of the leaf's form can be seen from Pls. XXI, XXXII.

It will be seen that the development of the leaf's segments is, on the whole, gradual. Excepting the development of the basal primary segments (pinnæ), whose segments begin to develop almost coincidently with the pinnæ themselves, the segments mostly become fairly well formed before their subdivision into segments is more than obscurely indicated, although it is early suggested by minute notches occurring between their midveins' primary branches. The segments of each successive series following the primary series start with much the same form and venation, and undergo, so far as their development extends, substantially the same changes in form and venation as those of the preceding series: since they are a part of those, they obviously cannot reach the same height of development. In addition, the formation of each series following the primary one begins on the segments first formed (lowest on the leaf's stalks) of the preceding series, and involves successively the segments successively next formed (next lowest). As a result:

In the older leaves, segments in all stages of development can be seen. For instance, tertiary segments are often to be seen at the base of the leaf while some of the primary segments (pinnæ) near its apex are still in the subentire state. Also, segments at similar stages of development but belonging to different series are more or less alike. For example, compare the primary segment, Fig. 7*a* (Pl. XXXI), with the secondary segment, Fig. 8*a*; and the secondary segment, Fig. 6*b* (Pl. XXXI), with the tertiary segment, Fig. 2*b* (Pl. XXXII).

As stated in the synoptical description of this fern, leaves sometimes occur with the tertiary segments more highly developed than in those figured. The scope of the leaf's development and the fact that sori appear, at least sometimes, on the leaf at an early stage of its development, have occasionally misled fern students into giving different, distinctive names to the plants at different stages of the leaf-development.

It will be seen from the figures that the long acuminate apices of the leaf-blade, which are so conspicuous a feature of the mature leaves that they have almost come to be looked upon as an integral part of the plant's makeup, are lacking in the early stages, and are gradually formed later in accordance with a tendency of the leaf-blade itself and the segments of its successive series to lengthen and become more and more pointed at apex as they become more and more complex. This tendency, so marked in this fern, is common in many others, and especially in those with pinnate venation.

EXPLANATION OF THE PLATES.

PLATES XXXI, XXXII.—MARGINAL SHIELD FERN. *Dryopteris marginalis.* Plate XXXI.—1. Young plant attached to prothallus. 2–8. Young leaves in different stages of development. Plate XXXII.—1. Mature sterile leaf. 2. Fertile pinnule of mature leaf, × 2½.

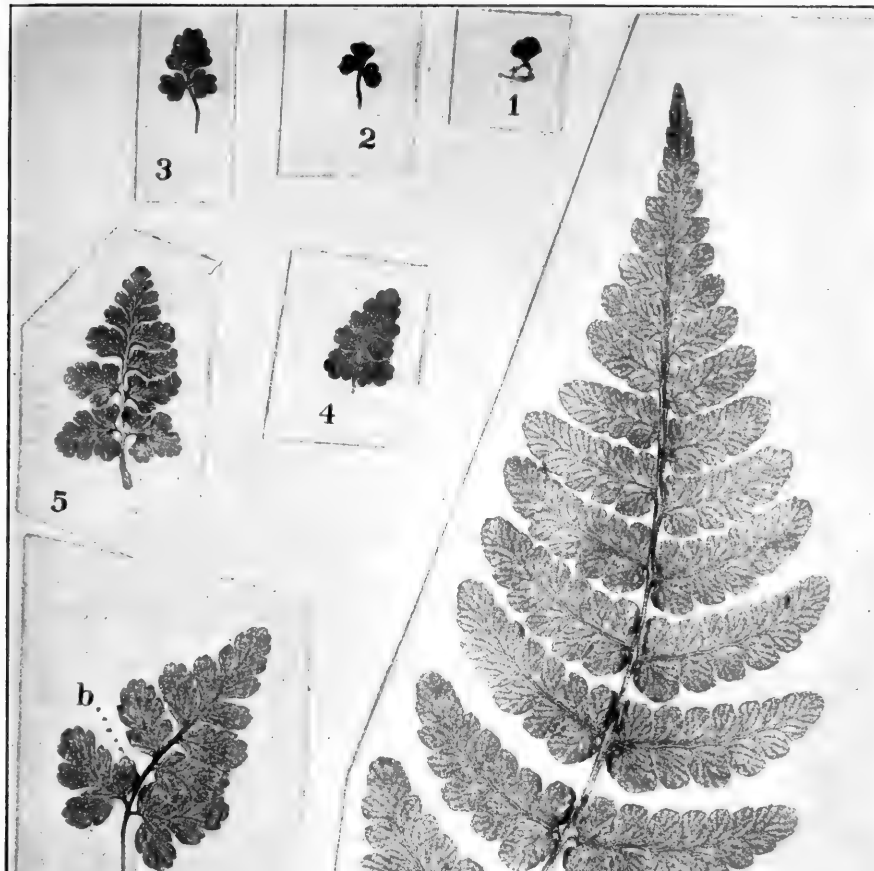


Plate XXXI.—Marginal Shield Fern

PLATE XXXII.—MA

. Shield Fern

CHAPTER XVI

SPINULOSE FERN

Dryopteris spinulosa intermedia.

Rootstock creeping, stout, chaffy: leaves clustered slightly back of or partly encircling terminal leaf-buds: roots springing from rootstock, often two or three to a petiole.

Leaves ascending or suberect, five inches to three feet long, three inches to one foot broad, imperfectly evergreen.

Petioles two inches to one foot long, commonly shorter than blades, chaffy: at base dark fuscous, turgid; above more slender, green or at back slightly brownish or when dried greenish-straw-colored, deeply channelled on face, slightly furrowed on sides: scales tawny with darker centres or darker at points of attachment only, ovate, acuminate, entire, when removed leaving minute rigid points; the lower numerous, rather large; the upper fewer, smaller: fibrovascular bundles five to seven in base, three near apex, of petiole, the two anterior largest; somewhat roundish-strap-shaped, on broader sides sometimes slightly hollowed or furrowed.

Blades oblong-ovate, bi-tri-pinnate: apices pinnatifid, acuminate: pinnæ spreading, diverging from rachis at angle of about sixty to ninety degrees, crowded or approximate or more distant, alternate or opposite, the lower short-stalked, the upper subsessile to sessile, oblong-lanceolate, basal pair unequally deltoid-ovate: pinnules diverging from secondary rachis at angle of about sixty to usually a trifle less than ninety degrees, crowded or more distant, alternate or opposite, mostly short-stalked or subsessile, ovate-oblong, obtuse to acute, commonly subacute, pinnatifid or pinnately divided, usually minutely, obscurely, and very sparingly chaffy on under surface along midveins; the inferior mostly longest, in basal pinnæ moderately elongate with the basal one commonly shorter than the next: segments adnate-decurrent, oblong or at least the larger ovate, on sides and apex serrately toothed or lobed; teeth and lobes spinulose entire or spinulose-toothed: rachises channelled on face, furnished, especially at nodes of pinnæ, sparingly with small or minute, linear or ovate, acuminate, entire scales, secondary rachises very narrowly winged: color commonly dark green: lower surface slightly paler than upper, minutely glandular: glands unicellular, capitate or cylindrical: texture firmly membranaceous.

Venation pinnate, free, marked on face of blade by depressed lines: each tooth of blade occupied by a veinlet: primary branches of midveins of pinnules' segments each, excepting sometimes the superior basal one, occupying a primary lobe or tooth of the segment, in the entire one simple, in the toothed bearing simple branches equal in number to the teeth: veinlets clubbed at apex.

Sori usually small, borne on primary branches, when these are simple, of midveins of pinnules' segments; when these branches are compound, borne on their superior basal branches, dorsal or subapical, the fertile veinlet mostly projecting beyond radius of sorus: indusia whitish, delicately membranous, round-reniform, bearing stalked and sessile glands, denticulate at margin.

Spores muriculate.

Habitat. Woods, dry or damp, swamps, stone-walls, and shaded hillsides. Often on crumbling logs or beneath evergreens.

Range. Labrador to Alaska, south to North Carolina and Tennessee.

Dryopteris spinulosa intermedia (Muhlenberg). Underwood, "Our Native Ferns," ed. 4. 116. 1893.

Aspidium intermedium Muhlenberg. Willdenow, Sp. Pl., **5**: 262. 1810.

Dryopteris intermedia. A. Gray, Manual, ed. 1. 630. 1848.

Aspidium spinulosum var. *intermedium.* D. C. Eaton in A. Gray, Manual, ed. 5. 665. 1867.

Nephrodium spinulosum var. *intermedium.* Davenport, Rhodora, **4**: 53. 1902.

YOUNG plants of *Dryopteris spinulosa intermedia* are often to be seen on old logs and stumps in wet woodlands.

The leaf is often deltoid at an early stage of development, but usually changes in shape later; in what way can be seen from Pls. XXXIII–XXXV.

The venation is pinnate. With rare exceptions each tooth or simple lobe of the leaf-blade contains a veinlet. For instance: in a leaf-blade consisting of two simple lobes, such as Pl. XXXIII, Fig. 1, represents, the primary midvein of the blade does not extend beyond two simple basal primary branches, each of which occupies one of the lobes: in a blade consisting of three simple lobes, a simple veinlet from its midvein occupies each of the lobes: if a lobe is two-toothed, which is often the case in different stages of the leaf's development, the vein belonging to that lobe has two simple branches, each of which occupies one of the teeth.

It cannot be said, however, that with rare exceptions each veinlet of the leaf-blade ends within a tooth or simple lobe. For instance, in the mature leaves the incisions, by means of which the pinnules' segments are formed, are not always deep enough to reach or pass the tips of the superior basal primary branches of the segments. Consequently, these branches, whether simple veinlets or not, may end within the unincised part of the pinnule and not within teeth or lobes.

EXPLANATION OF THE PLATES.

PLATES XXXIII–XXXV.—SPINULOSE FERN. *Dryopteris spinulosa intermedia.* Plate XXXIII.—1–7. Young leaves and plants in early stages of development. 1–3. Plants attached to prothalli. Plate XXXIV.—1, 2. Young leaves in later stages of development. Plate XXXV.—1. Mature sterile leaf. 2. Section of fertile pinna of mature leaf, × 2½.

PLATE XXXIII.—SPINULOSE FERN

PLATE XXXIV.—SPINULOSE FERN

PLATE XXXV.—

ULOSE FERN

CHAPTER XVII

WALKING LEAF

Camptosorus rhizophyllus.

Rootstock ascending, short, slender, somewhat chaffy: scales minute, strongly reticulate in reddish-brown, lanceolate or narrowly lanceolate-deltoid or, apparently abnormally, ovate, acuminate, entire or with a few short cilia: leaves fascicled at apex of rootstock: roots springing from outer sides of junctures of petioles and rootstock, one to each petiole.

Leaves two to fifteen inches long, decumbent or ascending, imperfectly evergreen.

Petioles four-fifths of an inch to six inches long, slender, flaccid; below chestnut-brown about one-eighth to one-third of length; above green; laterally narrowly winged for more or less of length from apex downward; at base bearing a few scales similar to scales of rootstock, sometimes an occasional narrow scale above: fibro-vascular bundles two in lower part of petioles, roundish, uniting above into one roundish-deltoid in section.

Blades lanceolate with flagelliform apex proliferous at tip, or lanceolate or ligulate with obtuse or acute non-proliferous apex; at base auricled, cordate, hastate, or, rarely, acute; auricles sometimes prolonged laterally and obtuse to flagelliform, occasionally proliferous at tip of prolongation: margins entire or undulate or irregular or rarely incised: midribs prominent beneath: surfaces glabrous: color deep, lustrous green, or yellowish-olive in age or in plants exposed to the sun: texture coriaceous or subcoriaceous.

Venation pinnate, anastomose: marginal veinlets largely free.

Sori linear, straight or curved, variously placed along veins, some solitary, some confluent with ends of others, some connivent, usually outwardly, or simply faced in pairs: indusia whitish, delicately membranous, undulate at margin, attached at sides or around outer ends of areolæ or at leaf's margin to free veinlets, those next midrib opening toward it, many of the outer opening toward each other in pairs.

Spores ovoid, with winglike pellucid crenate margin.

Habitat. Limestone, gneiss, granite, quartzite, sandstone, shale, and serpentine.* On cliffs, boulders, etc.,† usually on shaded sloping rock coated with mossy earth. Over this the leaves stretch, crossing one another: in the interstices the proliferous tips of new leaves are inserted.

Range. Maine and southern Quebec to Minnesota, south to Georgia, Alabama, and Kansas.

Camptosorus rhizophyllus (Linnæus). Link, Hort. Berol. 2: 69. 1833.
Asplenium rhizophylla. Linnæus, Sp. Pl. 1078. 1753.

The leaf first produced by the plant springing from the proliferous tip of a mature leaf of *Camptosorus rhizophyllus* often, if not always, represents a higher degree of leaf-development than the first produced by the plant springing from the prothallus. The blade of the latter leaf is either spatulate, obcordate, or obreniform: if spatulate, a leaf with an obreniform

* See Fern Bulletin, 8:92, 1900. Also D. C. Eaton, N. Am. Ferns, 1:56. 1878.

† In the limestone region of Vermont I have seen this plant lining the mouth of an old well.

or obcordate blade usually follows it. The order of forms of the blade in the scale of leaf-development is as follows: Spatulate, obcordate or obreniform, cuneate and trilobed or broadly cuneate-rhomboidal, roundish-ovate with truncate base, ovate, ovate-oblong, ligulate, and lanceolate. The blade's apex changes from obtuse to flagelliform; and its base from truncate to cordate, auriculate or hastate, and finally, although rarely, becomes developed laterally into long-drawn-out lobes, which are similar to the flagelliform upper part of the leaf, and sometimes, like it, proliferous at apex.

Although connate at base with the main part of the leaf-blade, these lateral lobes are in reality partly formed pinnæ.* In them, as well as in the flagelliform upper part of the leaf-blade, is shown the tendency of this fern's leaf to become attenuate and proliferous at its apices, whether primary or secondary.

The spatulate leaf-blade contains a simple or once-forked vein. The obcordate and the obreniform each contain a once- to twice-forked vein, and the trilobed and the rhomboidal each a midvein with two simple or once-forked branches at apex and two below. The development of the midvein continues in the succeeding leaves. The midvein is contained finally in a midrib.

The veins are free at first.† The formation of areolæ apparently begins as the blade becomes truncate at base, when two or more of the midvein's branches unite next the midvein. In succeeding leaves the midvein's branches become more and more anastomose until they form a network that extends nearly to the leaf-blade's margin. They are united in such a way that the veinless border of the blade seems to cut the network; appar-

* See page 12 † See page 18.

ently only such marginal veinlets are free as would be if it actually did so.

Each of the lateral lobes of the leaf, if at all pronounced, contains more or less of a distinct midvein, which starts from the starting-point of the basal areole next the leaf's midrib. These midveins are formed by the areolæ through the centre of each lobe gradually straightening in such a way as to form a double row of areolæ, the veinlets that form the side in common of the two single rows making up the double one, thickening and constituting a midvein.

EXPLANATION OF THE PLATE.

PLATE XXXVI.—WALKING LEAF. *Camptosorus rhizophyllus.* 1–11. Leaves and young plants in different stages of development. 1, 2. Young plants attached to prothalli. 9. Mature fertile proliferous leaf uncoiling at tip. 10. Mature fertile proliferous leaf, with young plant springing from tip and extended auricles at base. 11. Mature fertile non-proliferous leaf. 12. Section of fertile leaf, showing extended auricle, $\times 2\frac{1}{2}$.

4
3
2
1
5
a
6

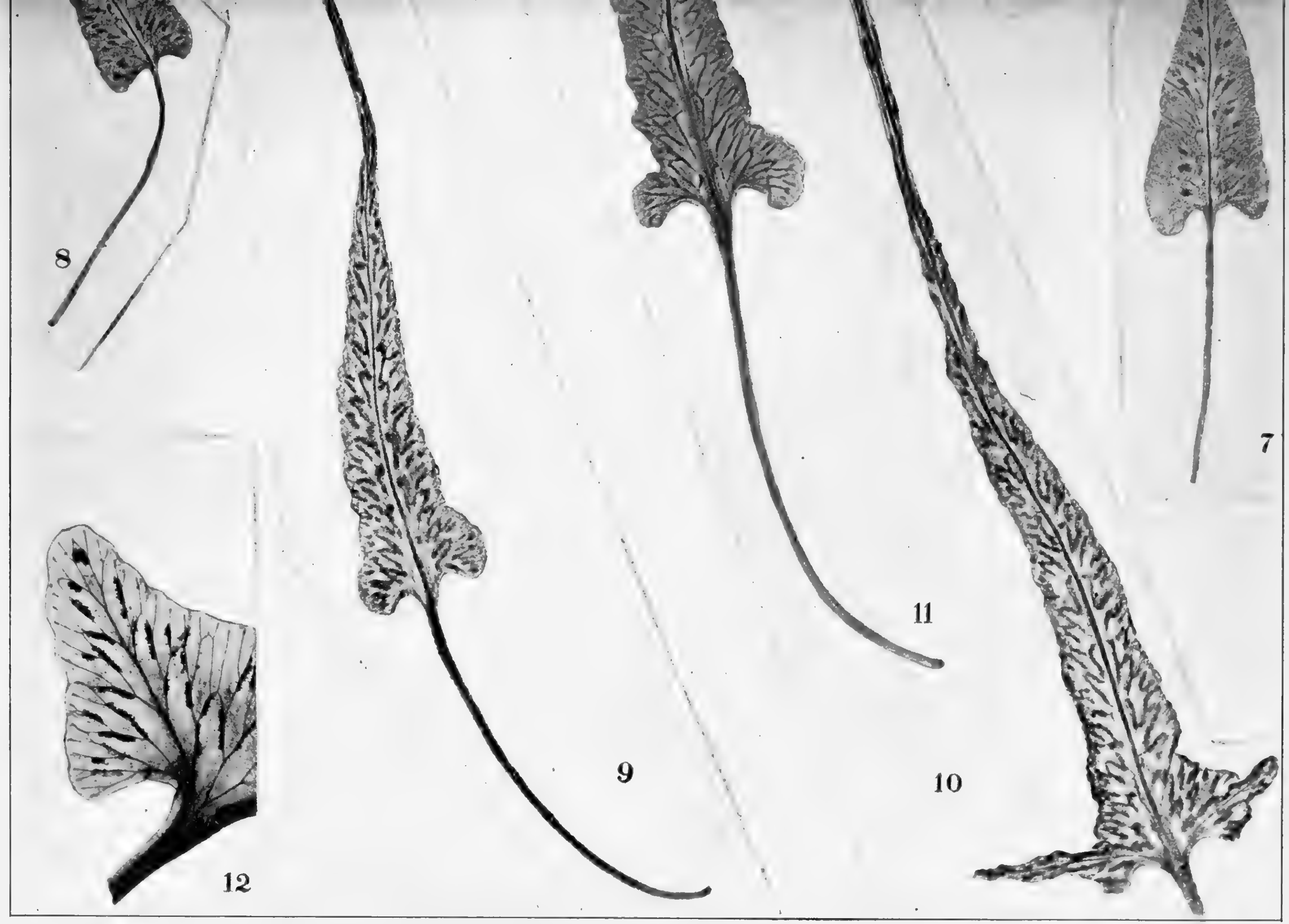


PLATE XXXVI.—WALKING LEAF

CHAPTER XVIII

NARROW-LEAVED CHAIN-FERN

Lorinseria areolata.

Rootstock wide-creeping, forking, dark brown, at least when dried, furnished with light brown, concolorous, ovate, acute, entire scales: leaves scattered, distant or approximate, borne on all sides of rootstock; roots springing from rootstock, equalling or slightly exceeding the petioles in number.

Leaves dimorphous, somewhat sensitive to frost; sporophylls erect, twelve to twenty-eight inches long; sterile leaves shorter.

Petioles compressed at base, somewhat chaffy, bordered on each side for some distance from apex downward by a fine ridge: in sterile leaves longer to shorter than blades, slender, chestnut-brown below, often furrowed on face and sides, at least when dried, the lateral furrows containing the lateral ridges: in sporophylls stouter, elongate, rigid, light chestnut-brown to purplish-ebony, subterete: scales hyaline, ovate, acuminate, entire or subciliate, thinly clothing base of petiole, upper scales few and scattered or absent: fibrovascular bundle solitary, arched at back, more or less channelled on face.

Blades of sterile leaves ovate-deltoid, below pinnate or sub-pinnate, above parted, gradually or abruptly narrowing to the often sinuate or sinuately lobed base of the ovate-lanceolate or lanceolate usually undulate apex: segments about eight to thirteen pairs, connected by a costal-wing or below by a fine ridge, oblong-lanceolate or lanceolate, largely undulate or sometimes sinuate, the basal narrowed at base, those above gradually widening, third or fourth pair usually longest: apices acute or acuminate; margins serrulate, or entire in and near costal-wing: rachis and midribs furnished along the sides beneath and sometimes very sparingly above with small, ovate, acuminate, entire or subciliate scales; midribs often brownish or olive, at least when dried: surfaces otherwise glabrous, the upper deep glossy green, the lower paler: texture softly membranaceous.

Blades of sporophylls ovate-oblong, below pinnate, above deeply pinnatifid, abruptly narrowing to the often lobed base of the elongate linear apex: divisions narrowly linear, alternate or opposite, connected by a costal-wing or ridge: apices acute, margins entire in costal-wing, otherwise undulate or denticulate, usually slightly revolute: rachis colored like petiole or above greenish: scales small, ovate, acuminate, subciliate, borne as in sterile leaves: surfaces glabrous otherwise, the upper dark green, the lower paler: texture firmly membranaceous.

Venation of sterile leaves pinnate, anastomose; marginal veinlets mostly free, simple or once forked: paracostal areolæ elongate, parallel or subparallel to costa, those next the rachis giving rise successively at ends to midribs of the segments, those next the midribs to midveins (when present), of the segments' lobes; in very narrow parts of costal-wing contracted to vanishing point or veinlets forming their outer edges alone visible, in form of fibers coherent with costa: outer areolæ shorter, oblique or in costal-wing subparallel or parallel to costa, oblong, hexagonal or pentagonal: midveins rarely present in lobes of segments.

Venation of sporophylls pinnate, anastomose: paracostal areolæ as in sterile leaves, mostly sending out to margin of blade veinlets which either are short with free, almost exsected apices or, especially near nodes of pinnæ, prolonged and form a few areolæ.

Sori sausage-shaped, linear or the smaller oblong, each borne on a veinlet forming the outer edge of a paracostal areole and contained in a depression of the leaf: indusia subcoriaceous, at first enwrapping sporongia, the free inner margin somewhat crenulate.

Spores ovoid-spherical or obscurely spheroid-tetrahedral, apparently smooth.

Habitat. Woodland swamps or damp thickets: usually in shade. In plants exposed to the sun the texture of the leaves becomes thickened and the venation somewhat obscure. Often accompanying *Dryopteris simulata.*

Range. Maine to Florida, Louisiana, and Arkansas. Also in Michigan.

Lorinseria areolata. Presl, Epim. Bot. 72. 1849.
Acrostichum areolatum. Linnæus, Sp. Pl. 1069. 1753.
Woodwardia areolata (L.). Moore, Index Fil. XLV. 1857.
Woodwardia angustifolia. J. E. Smith, Mem. Acad. Roy. Sci. Turin, 5: 411. 1793.

As elsewhere stated,* the plants of *Lorinseria areolata, Onoclea sensibilis* and *Osmundia spectabilis* when very young are liable to be mistaken for one another, but can be easily identified. *L. areolata* and *O. sensibilis* are closely allied, but bear only the most distant relationship to *O. spectabilis.*

In *L. areolata* the young leaf-blade is at first roundish-cune-

* See page 124.

ate, next oblong or obovate with cuneate or truncate base, then elliptical or oblong-ovate or oblong-lanceolate and early lobed below. From Pl. XXXVII can be seen how, in subsequent leaves, the lobes enlarge, and more and more lobes are formed, from the part of the blade above the first lobes, which enlarge also; until the lobes become the primary segments and the part of the blade left above them forms the apical section of the mature leaf. These segments sometimes in turn become lobed. Their lobes are rounded, and, so far as I have seen, are less deep than the lobes of the primary segments in *O. sensibilis*.

The margin of the blade, except at base, is more or less crenulate at first. Later the crenulation becomes serrulation. The number of teeth mostly corresponds with the number of marginal veinlets: except near the rachis, each marginal veinlet usually terminates within a tooth.

The veins are free at first. The leaf's primary midvein, if not evident at the beginning, becomes so before areolæ appear. One or two areolæ form first in the upper part of the blade while the blade is still simple. Others follow in subsequent leaves, forming downward on each side of the primary midvein, and thence outward until the margin of the blade has the appearance of cutting the network of veins: the marginal veinlets are mostly free. The primary midvein is finally more or less hidden in the rachis of the mature leaf.

The midveins of the leaf's primary segments (secondary midveins) are formed in the same way as in *O. sensibilis*, and start, as on that plant, from the ends of the paracostal areolæ next the blade's primary midvein. In the mature leaf they are more or less concealed in the segments' midribs. The areolæ between them, as in *O. sensibilis*, have the appearance of being stretched as the leaf becomes large, sometimes, the lower especially, to the vanishing-point.

Midveins are rarely evident in the lobes sometimes present on the blade's primary segments, but when evident are formed in the same manner and start from such veins as in *O. sensibilis*.

In the early leaves, the petiole, or at least its upper part, is narrowly more or less winged laterally. Later the wings contract, becoming mere ridges. The contraction apparently begins below, extends upward, and involves the basal part of the blade; either before or soon after the formation of one or both of the two basal primary lobes (whose midveins, if evident, would start from the starting-points of the two basal paracostal areolæ next the blade's primary midvein). These lobes thus apparently are sometimes never formed and sometimes aborted early. The parts of the blade that contain the two basal paracostal areolæ next the primary midvein appear to shrink into extensions of the petiole's lateral ridges. The contraction finally involves the wings between the blade's lower primary segments, these wings also, in the sporophyll especially, becoming more or less ridges.

In the transformation of the sterile leaf into a sporophyll (Pls. XXXIX, XL, XLI), the entire blade contracts, and the blade's margin recedes sufficiently to nearly reach the paracostal areolæ but not, as in *O. sensibilis*, sufficiently to cut them. The effect produced is the same as if the part of the leaf-blade containing most of the areolæ outside the paracostal areolæ had been cut off the leaf, and the few veins remaining outside the paracostal areolæ had thus been rendered mostly free. The veins forming the outer edges of the paracostal areolæ become soriferous. The petiole lengthens, and both petiole and rachis become stouter and dark-colored.

This fern is usually included in the genus *Woodwardia*, at least in America, but appears sufficiently distinct to warrant the restoration of Presl's genus *Lorinseria*, of which it is the sole representative.

EXPLANATION OF THE PLATES.

PLATES XXXVII–XLI.—NARROW-LEAVED CHAIN-FERN. *Lorinseria areolata.* Plate XXXVII.—1–7. Young leaves and plants in different stages of development. 1. Young plant attached to prothallus. Plate XXXVIII.—1. Mature sterile leaf. 2. Section of pinna of mature sterile leaf, $\times 2\frac{1}{2}$. Plates XXXIX, XL.—Leaves intermediate between the mature sterile and fertile leaves. Plate XLI.—1. Mature fertile leaf. 2. Section of fertile pinna, $\times 2\frac{1}{2}$.

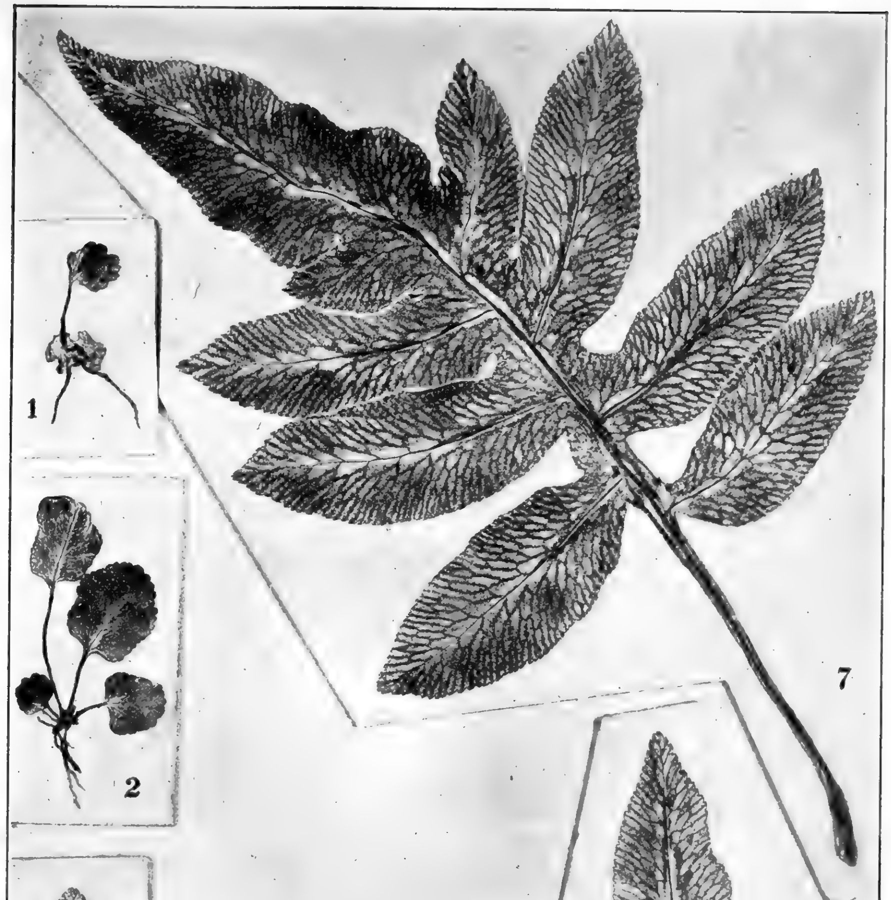
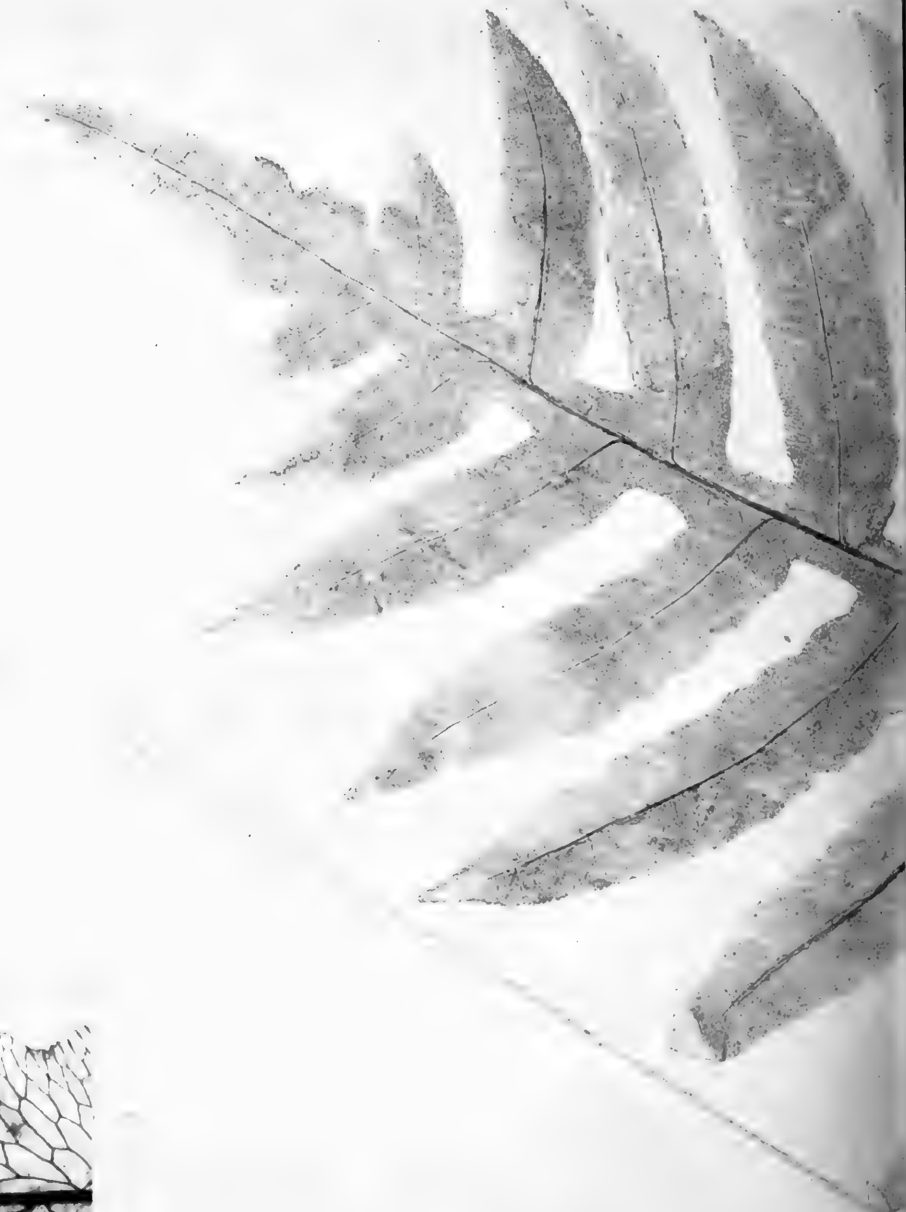
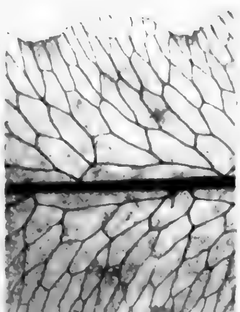


Plate XXXVII.—Narrow-Leaved Chain-Fern





2

PLATE XXXVIII.—NAR

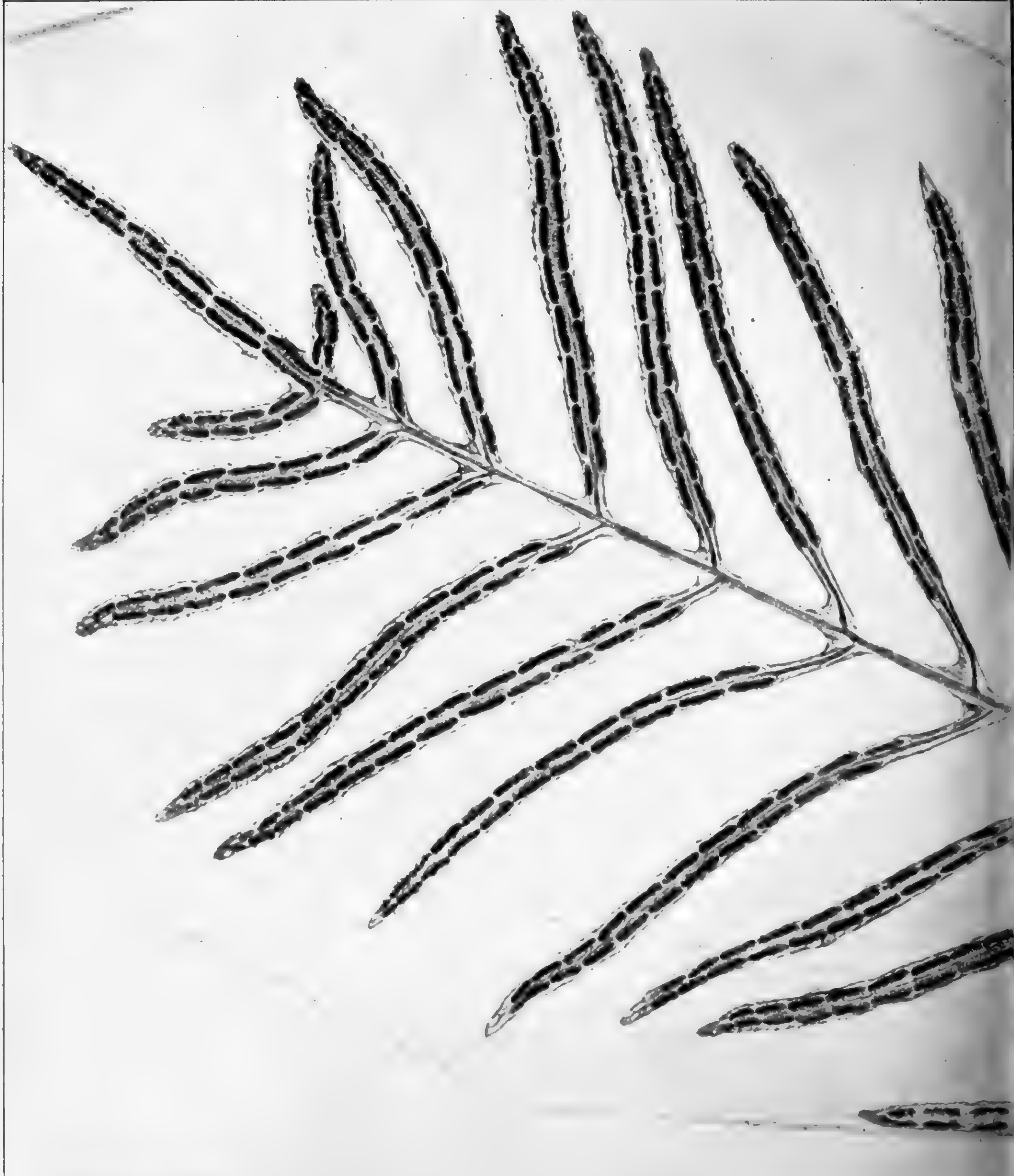
-Leaved Chain-Fern

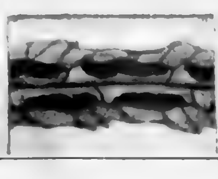
PLATE XXXIX.—NARRO

EAVED CHAIN-FERN

PLATE XL.—NARRO

-EAVED CHAIN-FERN





2

PLATE XLI.—NARRO

1

EAVED CHAIN-FERN

CHAPTER XIX

SENSITIVE FERN

Onoclea sensibilis.

Rootstock wide-creeping, forking, greenish-brown to cherry-colored, black in age, hollowed beneath bases of petioles, smooth or bearing an occasional large pale-brown scale: leaves scattered, borne on all sides of rootstock: roots copious, densely matted, springing from edges of hollows, also often continued backward or forward in lines from edges.

Leaves erect, dimorphous: the sterile twelve to fifty-four inches long, leaf-like, sensitive to frost: sporophylls shorter, contracted, rigid, paniculate, persisting into second season.

Petioles usually as long as or longer than blades, sparingly furnished with pale brown, concolorous, hyaline, ovate, acute, ciliate, often deciduous scales, at base similar in color and parallel to rootstock, compressed, often elongate or cochleariform: above erect, rounded; in sterile leaves slender, slightly furrowed on face, green or in spring wine-red, straw-colored in age; in sporophylls stouter, slightly flattened or furrowed on face, especially near the base, when dried greenish-straw-colored or in age pale brown: fibrovascular bundles two, strap-shaped, uniting below blade into one U-shaped in section.

Blades of sterile leaves deltoid or ovate-deltoid, below sub-pinnate or pinnate, above successively less deeply pinnatifid, gradually or abruptly narrowing to the undulate or sinuate apex: segments two to thirteen pairs, basal or second pair longest, connected by a costal-wing or the lowermost distinct, lanceolate or oblong-lanceolate, often narrowing both ways, the lower, especially, narrowed at base, very minutely serrulate, the uppermost otherwise entire or undulate, the lower more or less sinuate or, especially the lowermost, deeply sinuous-pinnatifid; the lobes oblique, obtuse or a few subacute: apices obtuse or subacute: rachis and midribs prominent beneath, smooth or bearing a few minute, pale-brown, ovate or lanceolate, acuminate, ciliate scales: surfaces glabrous otherwise, the upper grass-green; the lower paler, slightly glaucescent: texture herbaceous.

Blades of sporophylls contracted, oblong, secund, bipinnate; apex pinnate: pinnæ bent backward and upward, appressed, alternate or opposite, short-stalked or the uppermost sessile: pinnules small, dark green, fleshy or cartilaginous, subglobose, alternate or opposite, sessile or subsessile, reflexed, pinnatifid: segments four to six, slender, oblong or deltoid, recurved and connivent over sporangia, finally spreading apart, inferior basal segment of pinnule often dichotomous: rachis when dried more or less angled or grooved obscurely or partly subterete, glabrous or sparingly chaffy as in sterile leaves.

Venation of sterile leaves conspicuous, pinnate, anastomose: marginal veinlets largely free, simple or once forked: paracostal areolæ parallel or subparallel to costa, elongate, those next rachis giving rise successively at ends to midribs of segments, those next midribs to midveins of segments' lobes, in very narrow parts of costal-wing contracted to vanishing point or veinlets forming their outer edges alone visible, as fibres coherent with rachis:

outer areolæ much shorter, mostly oblong, hexagonal or pentagonal, oblique, or those nearest parallel or subparallel, to costa.

Venation of sporophylls pinnate, free, a simple or in forked segments a once-forked veinlet occupying centre of each segment of pinnules.

Sori medial on veinlets, blackberry-shaped: sporangia numerous, borne on a cylindrical receptacle: indusia delicate, whitish, coherent at inferior side of and partly surrounding each sorus, opening toward apex of segment, at first almost completely covering sori, later thrown back or torn, the sporangia becoming confluent.

Spores very dark colored, ovoid.

Habitat. Grassy banks, roadsides, the outskirts of woods and thickets, low-lying meadows, etc. In damp soil exposed to the sun or partly shaded.

Range. Newfoundland to Saskatchewan, south to Nebraska, Louisiana, and Florida.

Onoclea sensibilis. Linnæus, Species Plantarum, 1062. 1753.

THE young plants of *Onoclea sensibilis* and *Lorinseria areolata* are liable to be confused with each other, and before their venation becomes anastomose, with *Osmunda spectabilis* Willdenow,* but can be distinguished from the latter by the absence of stipuliform appendages from the bases of the petioles, and from each other by a difference in the shapes of their leaf-blades. The resemblance to the young plants of *O. spectabilis* is seen only in the very first stages of development, is superficial merely, and quickly disappears, but *O. sensibilis* and *L. areolata* are closely related.

* The American species better known as *Osmunda regalis*, but separated from the European species of that name by Willdenow.

In *O. sensibilis* the margin of the sterile leaf-blade is very minutely and obscurely more or less serrulate in all stages of development. Aside from this, the blade is at first imperfectly semi-orbicular, and sometimes obscurely trilobed, with subtruncate entire base and crenate or dentate upper margin. It then becomes successively reniform or reniform-orbicular, with undulate or crenate upper margin, reniform-deltoid becoming crenately trilobed, and deltoid trilobed with deep often squarish sinus at base. As development progresses, the central lobe becomes sinuate or lobed, and at length cut into segments, which form all but the basal segments of the mature leaf and which, as they develop, become in their turn undulate, sinuate, or pinnatifid. The two lateral lobes develop into the basal segments of the mature leaf and become sinuous-pinnatifid. At this stage the segments above them range upward from sinuous-pinnatifid to undulate or entire. Development of the sterile leaf as such then ceases. Further change lies in its transformation into a sporophyll.

The veins are branched and free in the first stages of the leaf-blade's development. They become anastomose before a midvein shows in any very distinct fashion. One or two areolæ form first in the centre of the reniform or reniform-orbicular blade, and others quickly follow, forming outward until the margin has the appearance of cutting the network of veins. The marginal veinlets are mostly free.

When the blade becomes trilobed the areolæ through the centre of each lobe are straightened in such a way as to form a double row, the inner common side of the two single rows that make up the double one forming the midvein. Thereafter every well-defined lobe or segment of the blade possesses more or less of a midvein, similarly formed.

The midvein of the central lobe of the trilobed blade is the blade's primary midvein. As the lobe lengthens and is cut laterally into segments, this midvein lengthens gradually and becomes merged in the mature leaf's rachis.

The midveins of the two lateral lobes of the trilobed leaf, since these lobes are the incipient basal primary segments of the blade, are the two basal secondary midveins of the blade. In the mature leaf they, as well as the midveins of the primary segments later formed, become more or less merged in the segments' midribs.

The ends of the paracostal areolæ next the blade's primary midvein form the bases of the midveins of the primary segments. The ends of the paracostal areolæ next the midveins of these segments form the bases of the midveins of the segments' lobes.* Thus every paracostal areole next the rachis and between midribs of the primary segments reaches from midrib to midrib, and every paracostal areole next a midrib of a primary segment and between midveins of the segment's lobes reaches from midvein to midvein. As the segments grow larger and the ends of these areolæ are consequently drawn farther and farther apart, these areolæ appear to be stretched while the rachis-wings containing them appear to shrink toward the rachis, until, in the base of a very large blade, they are drawn out to the vanishing-point and the veinlets that formed their outer edges are more or less coherent with the rachis, if not contained within it.

The transformation of the sterile leaf into a sporophyll can be clearly seen from the transitional leaves which sometimes occur (Pl. XLV). In these, such parts of the blade's apical

* See page 119.

section and primary segments as are not lobed already become lobed, and contraction of the blade and recession of its margin are begun and carried far enough to produce the following results. The outermost part of the blade, containing most of the veins, disappears; a few free veinlets, remnants of the innermost areolæ, are left next the lobes' midveins; the lobes are disconnected, narrowed, shortened, and recurved until subglobose, finally splitting into segments and becoming soriferous; and the contraction eventually draws the blade's primary segments, now pinnæ, backward and upward, and reflexes the subglobose soriferous lobes, now pinnules. Indusia occur on the transitional leaves as well as on the sporophylls.

The transitional leaves constitute the so-called "var. obtusilobata" Torrey. As they represent merely the transition from the usual sterile leaf to the fully fledged sporophyll, it is scarcely necessary to say that to give them a distinctive name is absurd.

The affinity of this plant with *Lorinseria areolata* is marked. Both plants are essentially akin in habit, have scattered leaves rising from a creeping rootstock, sterile leaves similar in character and texture, and venation of the same type.

As already stated, in *O. sensibilis* development of the blade's two basal primary segments is peculiarly rapid, while in *L. areolata* contraction overtakes the corresponding part of the blade at an early stage of the leaf's development.* This gives different aspects to the early leaves of the two plants, but by comparing the accounts of the development of their leaves it will be seen that development, while carried further in *O. sensibilis* than in *L. areolata*, is along similar lines in both.

The transformation of the sterile leaf into a sporophyll is in

* See page 125.

both, aside from the production of sori, largely a matter of contraction of the blade and recession of its margin. The difference in the venation of the sporophylls of the two is due to the fact that in *O. sensibilis* the venation is more highly developed, since midveins are evident in the lobes of the primary segments, before transformation of the sterile leaf into a sporophyll begins, and that the recession of the margin and the contraction are carried further than in *L. areolata*.

It seems probable that if this contraction and recession were carried in *L. areolata*, as in *O. sensibilis*, to the extent of cutting the veins that form the outer edges of the paracostal areolæ, shortening the free veinlets thus formed, and so reducing the sori, which in *L. areolata* are borne on these veins, to a minimum, the sori would present much the same appearance in *L. areolata* as in *O. sensibilis*. In the leaves of *O. sensibilis* intermediate between the usual sterile leaves and the sporophylls, in which the contraction and recession have obviously been carried less far than in the sporophylls, indusia of varying lengths are seen. Some of these indusia are prolonged, extend along a vein, and are attached to it by the upper margin, as the indusia are in the sori of *L. areolata;* and it is apparently as the indusia shorten in these leaves, approaching their form in the sporophylls, that the line of attachment shortens and they become detached from the vein everywhere but at the lower end, as they are in the sporophylls. The indusia in these transitional leaves may be vestigial sori, and the prolonged indusia may be evidence of a time when the sori had the same form and were attached in much the same manner in the ancestors of *O. sensibilis* as they are in *L. areolata*.

This species is apparently very old. *O. sensibilis fossilis*

Newberry * is said to differ from it only in possessing a more robust habit. Specimens of the fossil fern are said to practically duplicate both the mature sterile and fertile leaves of our fern, and the transitional leaves as well. According to Dr. Knowlton, the fossil fern has been found only in the Fort Union Beds at the mouth of the Yellowstone, and in the Canadian Upper Laramie.

* *O. sensibilis fossilis* Newberry, Ann. N. Y. Lyc. Nat. His. **9** : 39. 1898. See Lesquereaux, Ill. Cret. and Tert. Plants, Pl. VIII., Figs. 1–9, Figs. 1–5. 1878. Newberry, Later Extinct Floras, **8**: Pl. XXIII., Fig. 3; Pl. XXIV., Figs. 1–5. 1898. Knowlton, Bull. Lon. Bot. Club. 705–706, Pl. XXVI., Figs. 1–4. 1903.

EXPLANATION OF THE PLATES.

PLATES XLII–XLV.—SENSITIVE FERN. *Onoclea sensibilis.* Plate XLII.—1. Young plant attached to prothallus. 2–6. Young leaves in early stages of development. Plate XLIII.—Young leaf in later stage of development. Plate XLIV.—1. Mature fertile leaf. 2. Mature sterile leaf. 3. Section of pinna of fertile leaf, × 2½. 4. Section of pinna of sterile leaf, × 2½. Plate XLV.—Leaves intermediate between the mature sterile and fertile leaves.

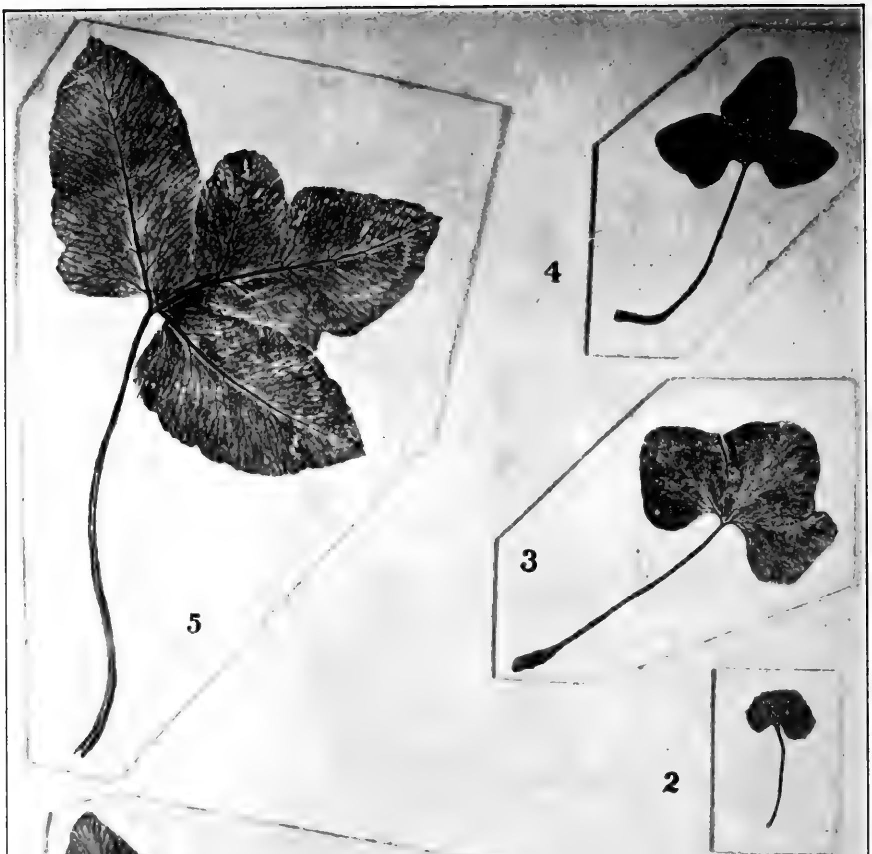


PLATE XLII.—SENSITIVE FERN

Plate XLIII.—Sensitive Fern

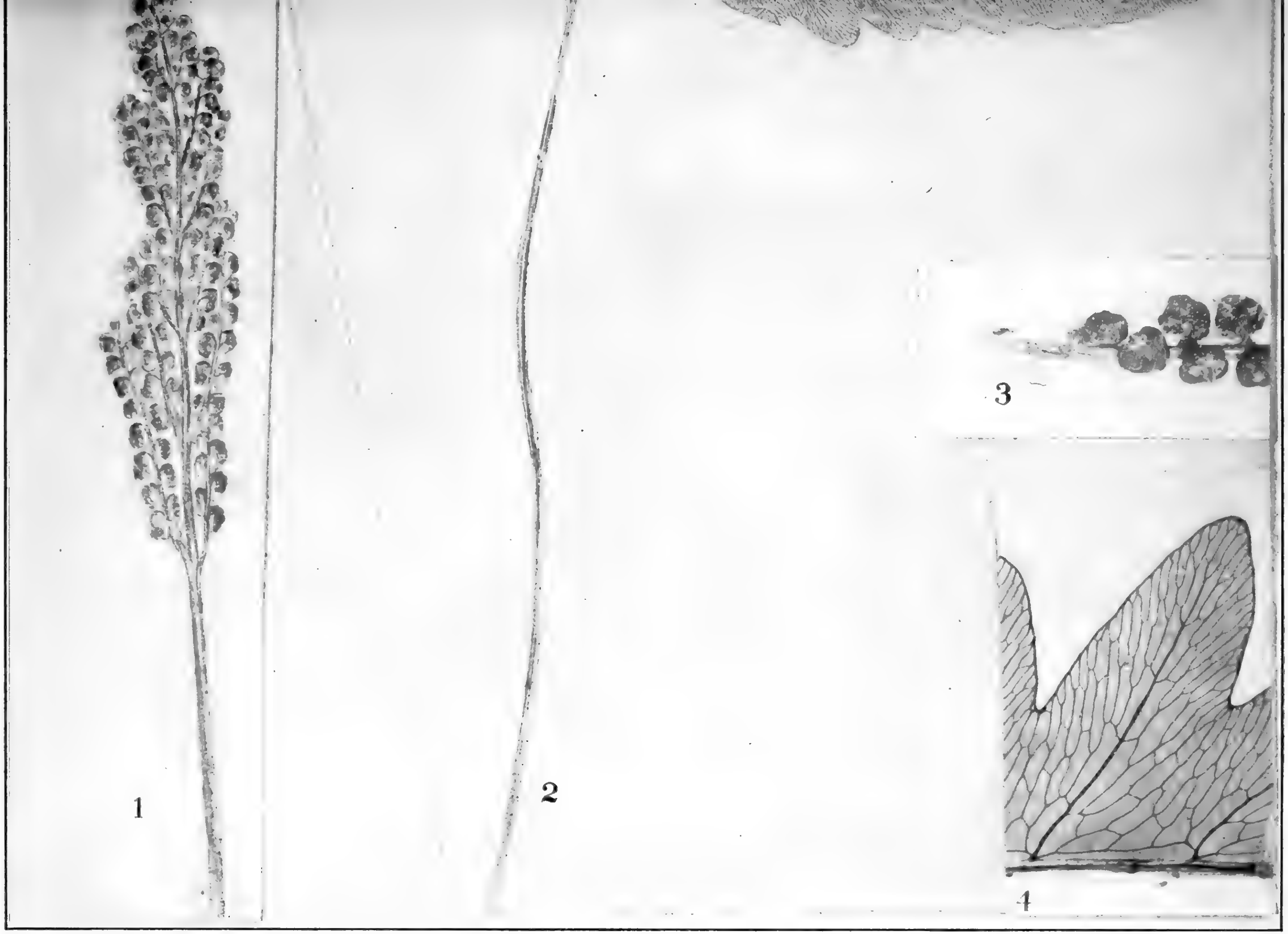
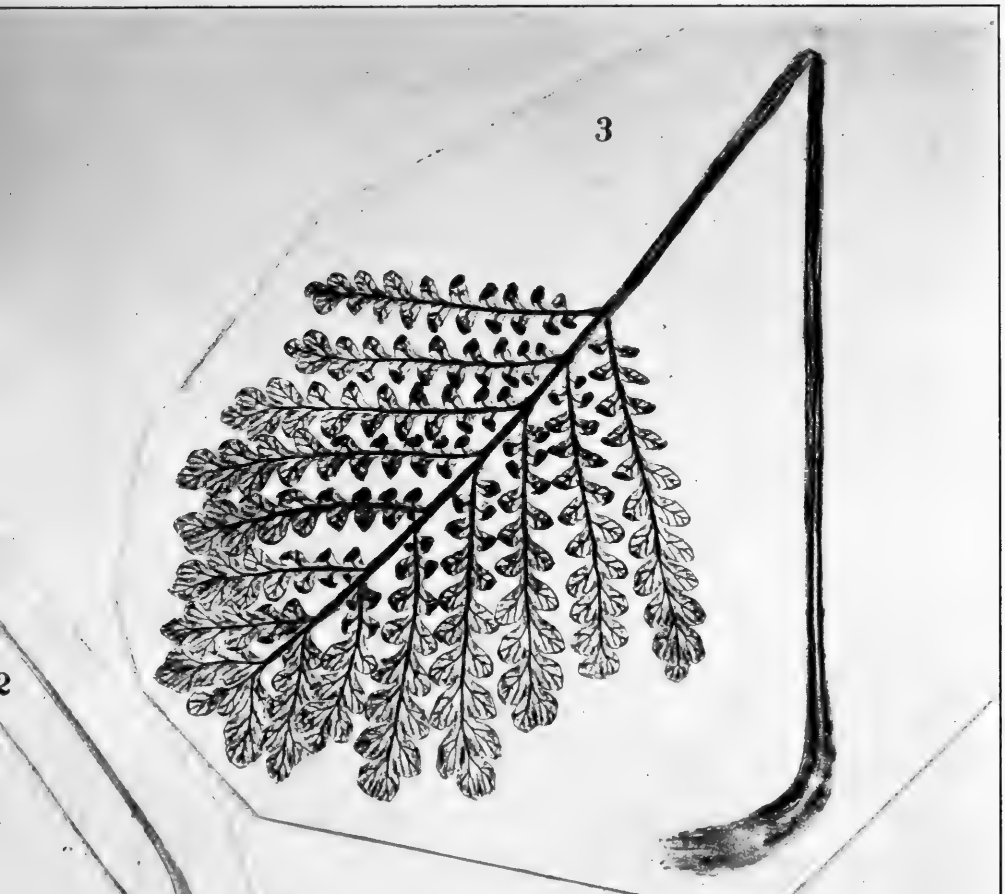


PLATE XLIV.—SENSITIVE FERN

1

PLATE XLV.—



TIVE FERN

INDEX