KNOWLEDGE SERIES

BRITISH MOSSES

BY

THE RT. HON. LORD JUSTICE FRY

To

F. Davey

with kind regards.

21

BRITISH MOSSES.

BY

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E. F.

May, 1892.

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British Mosses.

Introductory.—Lord Bacon thought that a Moss was "but a rudiment between putrefaction and a herb." Mr. Ruskin thought, and perhaps thinks (he is at war, he tells us, with the botanists), "that the pineapple is really a Moss." People popularly talk of Club-Mosses and Stag-Mosses. Now all these usages of the word may be useful to us when we begin to think about Mosses, if we will make the right use of them, *i.e.*, if we will absolutely reverse them. A Moss is not a rudiment between a putrefaction and a herb, but a delicately, exquisitely organized plant. No possible stretch of the conception of a Moss can make it include a pineapple any more than an elephant; and the Stag and Club-Mosses of popular speech belong to a group of plants quite different from the Mosses, and of a far higher organization.

What then is a Moss? This is a question not to be hastily answered, and will I think be best answered at the end and not at the beginning of this paper. If you are working deductively, your definitions may come at the beginning; but if by patient investigation into natural facts, beware of starting with definitions—they ought to be the ripest fruit of your longest labour.

Classification. — Vegetable productions are commonly divided into two great groups: those which possess obvious blossoms, or Phanerogams, and those which possess no obvious blossoms, or Cryptogams. The Cryptogams are again divided into two great groups—those whose structure is built up of cells without regularly formed vessels, such as sea weeds, fungi and lichens, the cellular Cryptogams; and those which, like the ferns and the Club-Mosses, possess, in addition to cells, regularly formed vessels; these are known as Vascular Cryptogams.

This brief explanation will be enough to enable the reader to learn from the following table, which is arranged in an ascending rank, something as to the position of the Mosses in the vegetable kingdom, and the principal groups into which they may be divided :—

TABLE A.

		Series.	Orders.	Examples.
Vascular Cryptogams				
Muscineæ	i. Musci.	Pleurocarpæ		Hypnum
		Acrocarpæ	Stegocarpæ	Polytrichum
			Cleistocarpæ	Phascum
		Anomaleæ	Schizocarpæ	Andræa
			Holocarpæ	Archidium
	ii. Sphagnaceæ			
	iii. Hepaticeæ.	Jungermanniaceæ		
		Marchantiaceæ		
Algæ, &c.				

From this table it will be gathered that the Mosses, using that word in its wide signification, stand at the head of the cellular cryptogams, and that above them are the vascular cryptogams, of which, as I have already said, the ferns are one of the best-known groups. From these vascular cryptogams the Mosses are, however, separated by a distance which Goebel has described as a chasm "the widest with which we are acquainted in the whole vegetable kingdom." Perhaps, however, at some future time it may be found that even over this gulf Nature has thrown some slender bridge.

From the table it will be further seen that the larger group of the Muscineæ divides itself into three principal smaller groups: the Hepaticeæ or Liverworts, the Sphagnaceæ or Turf Mosses, and the Musci or true Mosses—Urn-Mosses, as they have been called, from the form of their

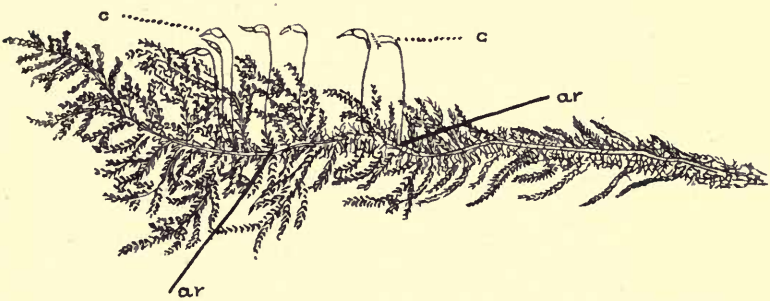


FIG. 1.—Hypnum: a Pleurocarpous Moss, after Dillenius. *ar.* Position of the Archegones. *c c.* Capsules.

capsule. These three divisions the Germans conveniently name as Leber-Moose, Torf-Moose, and Laub-Moose.

FIG. 2.—Polytrichum: an Acrocarpous Moss Female Plant, after Dillenius. *ar.* Position of archegone. *s.* Seta. *a.* Capsule and appendages. *c* and c^1. Capsule. *o.* Operculum. *cal.* Calyptra.

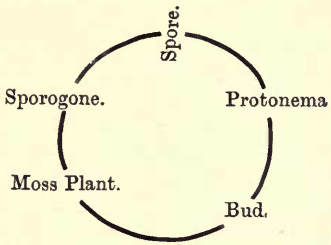
Now I will ask the reader to look at the column under the word "Series." The Pleurocarpæ or Pleurocarpous Mosses are those which carry their capsules on stalks proceeding from the sides of the axis of growth; the Acrocarpæ or Acrocarpous Mosses are those which bear these capsules on the top of their axis of growth. This distinction will be readily understood by comparing Fig. 1, which is a Pleurocarpous Moss, with Figs. 2 and 3, which represent an Acrocarpous Moss; in the former it will be seen that the axis, or line of growth, is horizontal, that the plant, in short, grows along the ground, whilst in the latter the direction of growth is vertical.

FIG. 3.—Polytrichum: Male Plant. After Dillenius. *a*. Male Blossom.

Again, in the former the capsules *c c* are seen carried on stalks originating from the principal stem, whilst in Fig. 2 the capsule *a* crowns the line of growth. This distinction in the mode of carrying the capsule is one of great importance in the classification of Mosses, and the student who desires to begin to learn them should pay early attention to it. Often it is perfectly easy of application, but intermediate forms occur which are puzzles, and go to show that the chasm between the two forms is bridged over in Nature.

Life-History.—I propose now to trace the life-history of a Moss in its most complete course of life, and I shall then show how, in many cases, this course is abbreviated. It

will be found that the full cycle of life may be indicated in the following circular form :—



so that, starting with a spore of one generation, and travelling to our right hand, we return to another spore which will give rise to a new circle of life.

(1) The spore is a simple cell; how produced we shall hereafter see. It is, I say, a simple cell, and not like the seed of a phanerogam, a highly complex organism. The spores are often seen to be emitted in vast numbers from the cases in which they are produced, and sometimes are brightly coloured—red, green, or yellow. Fig. 4 represents (highly magnified) the spore of a common Moss, the Funaria hygrometrica.

FIG. 4.—Spore of Funaria hygrometrica. After Schimper.

(2) From the spore proceeds the protonema, a line of cells, extending by transverse divisions, so that it comes to consist of single cells joined end to end to one another—an organism indistinguishable from the hypha of an Alga. At points this hypha throws off lateral branches, which are always of less diameter than the principal ones. There is thus produced a tangled mat of fibres, running on or near the surface of the ground, and often coloured by

chlorophyll. This is the green stuff so often seen in flower-pots which have been allowed to get too damp. At points in the primary hypha cells begin to divide in a new fashion—not by transverse septa as before, but by septa differently inclined, so as to produce the rudiments of leaves; and the direction of growth changes from horizontal to vertical. Thus is formed (3) the bud, which by growth gives rise to (4) the Moss plant.

FIG. 5.—Spore with young Protonema. After Schimper.

This course of development is illustrated by Figs. 5 and 6. Fig. 5 shows at *a* the remains of the cell which has burst in emitting the hypha, or cellular projection to the right. Fig. 6 shows the same plant further advanced

FIG. 6.—Protonema with, *a a*, young Moss Plants forming on it; *r*, Rhizoids or Rootlets. After Schimper.

in life; the hypha has been divided into numerous cells by the transverse septa or walls; lateral branches have grown. Two letters *a* will be observed on the diagram. At the left hand *a* the divisions of the cells have assumed a new inclination so as to cut the cells into rudimentary leaves, and we have the first promise of the Moss plant. At the right hand *a* we have another Moss plant in a far more advanced stage, showing distinct traces of leaves, and having thrown out rootlets (*r*) downwards. The Moss plant when mature assumes generally, but not universally, a form referable to one or other of the two types already described, either the pleurocarpous form shown by Fig. 1 or the acrocarpous form shown in Fig. 2. This Moss plant is a structure of very considerable complexity, and often of great beauty of form. Sometimes it assumes the likeness of some of the smaller and more delicate ferns; but very rarely would it be taken for a flowering plant, even by a casual observer.

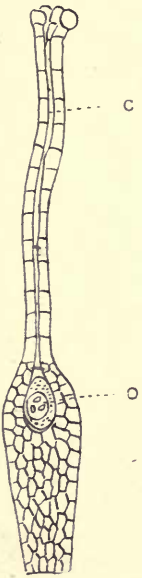


FIG. 7.—Archegone greatly magnified. *c*. Canal. *o*. Oosphere. After Berkeley.

The Moss plant produces organs with two distinct functions, comparable the one to the pistil and ovary, and the other to the stamens including the anthers of a flowering plant. The organ corresponding with the pistil is called the archegonium or archegone;

the organs corresponding with the stamens the antheridia or antherids. The archegone is a flask-shaped organ, which ultimately produces a specialized cell, known as the oosphere, at the bottom of the flask, the neck of which is perforated by a canal. This organ is usually surrounded by circles of leaves, often larger and almost always different in form from the ordinary leaves of the Moss. The ordered arrangement of these leaves produces something like a flower, and is known as the perichætium, *i.e.*, the surroundings of the couch. If the reader will turn to Figs. 1 and 2, and note the letters *a r*, they will indicate the situation of the archegone before it gave rise to the capsule.

Fig. 7 will show an archegone, with the canal, *c*, and the oosphere, *o*.

The male organs are known as antherids. Fig. 8 shows an antherid, a long bag-like cell, surrounded by filaments, sometimes club-shaped, called paraphyses. These are usually associated in groups, and surrounded by specialized leaves, often in the shape of a rosette, and when (as sometimes) they are highly coloured they present the aspect of small but beautiful flowers. Fig. 3 exhibits a male plant of one of our common Mosses, the Polytrichum, terminating in the rosette-shaped flower of a scarlet colour, composed of the antherids, the paraphyses, and the specialized leaves. The large beds of these short stiff male plants of Polytrichum, which may often be seen

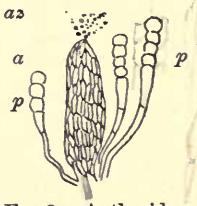


FIG. 8.—Antherid, *a*, with Paraphyses, *p*. *az*, Escaping Antherizoids. After Berkeley.

in the spring of the year, are objects of great, but, I fear, often neglected, beauty.

The antherids burst and give out swarms of small bodies, known as antherizoids, consisting of roundish cells containing in the interior a spiral thread, which produces a rotatory movement in the containing cell. Fig. 9 represents such antherizoids. These little bodies find their way to the canals of the archegone, pass down it, and enter the oosphere, and so effect that union of two independent cells which produces fertilization.

FIG. 9. Antherizoids, showing spiral threads. After Schimper.

In the account which we have given of the life-history of a Moss it will be remembered that we started with a single cell in the shape of a spore, in which was wrapped up the whole future of the life of the plant; that from that single cell all the successive developments which we have been tracing have had their origin; and that we have then got back again to another cell, the fertilized oosphere, in which are again involved all the future life of the plant. We have travelled from cell to cell; the first part of the history of the plant, the so-called oophytic generation, is complete, and a new part of the history is to begin.

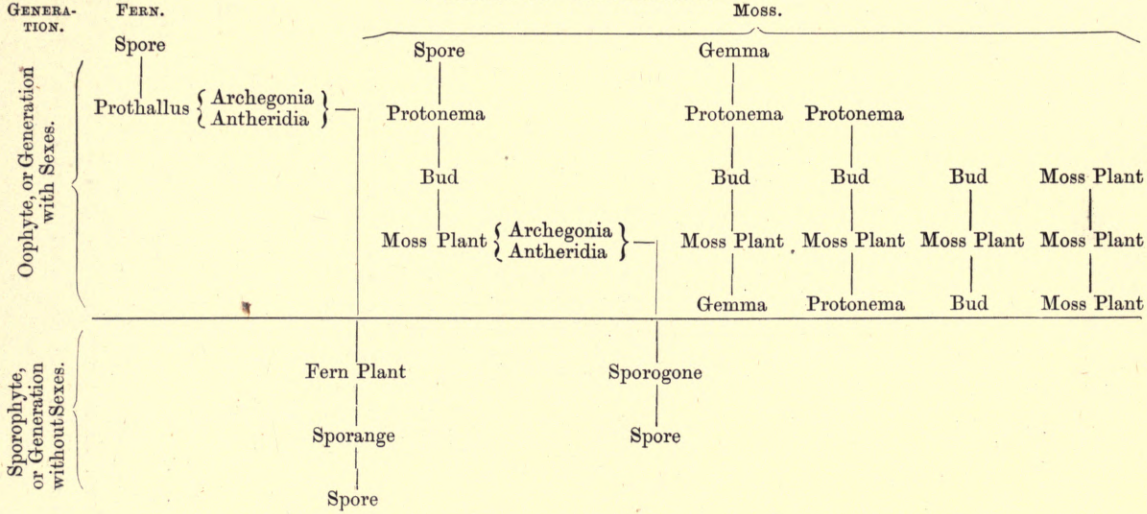
Now, what does the fertilized oosphere do? It begins a new career. It enlarges; it produces what is known as the *sporogone:* it sends up a stalk, often of considerable length and tenuity. This bursts the archegone and carries up with it the upper part of the cell, which forms the

veil of the capsule; it gradually swells at the upper end till it produces the capsule. In this capsule, without any fertilization or union of cells, is produced a mass of spores of the kind with which we began our life-history. We have now completed the second part of this history, and have come round to the spore with which we started. The plant has thus began with the spore, an asexual cell, reached the point where its whole future is gathered up in a sexual cell, which has produced an organism again producing an asexual cell. We started with a spore, and have returned to a spore; we have travelled round a circle, divisible into two parts or generations, one sexual, the other asexual, and we have therefore a case of alternation of generations. To make this statement more clear, it may be observed that a generation is here spoken of as that part of the life of an organism which intervenes between the two points at which its whole future is gathered up into one cell; that such a cell is sexual when it is the result of the combination of two previously existing and independent cells; that such a cell is asexual when it is not the result of such combination; that an alternation of generations exists whenever in the complete cycle of existence or life-history there are two points at which the whole organism is reduced to a single cell, and when the forms of the organism in the two intervals of its development are different. In the Mosses, where the sporogone co-exists with and is organically connected with what I have called the Moss plant, it is evident that the two generations are not such, according to the more popular notion of that word—they are not independent nor necessarily successive.

Such in outline is the course of the life of a Moss in its fullest and most complete circuit: like every other history of the growth and change of an organism, it fills one with wonder and amazement. Think of all the promise and potentiality which is wrapped up in every little spore of every little Moss, and we can no more account for it or understand it than we can for the creation of the starry host or of the infinite wonders of the human mind.

In the table following, the life-history, as I have already traced it, is represented by the first column under the head of Moss:—

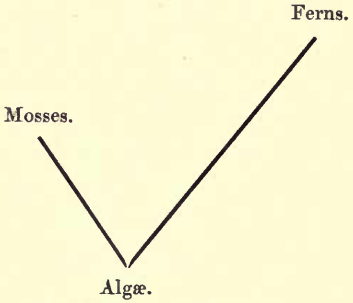
TABLE B.—LIFE-HISTORY.



The column under the head "Fern" in like manner epitomizes the course of development of a fern, and a comparison of these two columns reveals at once the likeness and the unlikeness of the life-histories of the Moss and of the fern. In each case the spore produces a growth of a form and nature entirely unlike the mother-plant—in one case a hypha, in the other a thallus, *i.e.*, a flat leafy cellular plate. But whilst in the Moss the protonema produces the Moss plant, in the fern the prothallus itself is the home of the male and female organs, and of the sexual process, so that the fern plant belongs to the sporophytic, and the Moss plant to the oophytic generation; the fern plant is the result of the sexual union, whilst the Moss plant is produced from the asexual spore; the fern plant produces spores asexually, the Moss plant produces the sporogone as the result of the sexual union.

The observations which arise in connection with this comparison are numerous. (1) It is the belief of botanists, ever since the investigations of Hofmeister, that not Mosses and ferns only, but all the phanerogams, go through an alternation of generations consisting of the oophytic and sporophytic generations. (2) It appears that the Mosses and the Characeæ are the only groups of plants in which the conspicuous and vegetative organism—the plant, in ordinary parlance—belongs to the oophytic generation. (3) That, in consequence, the plant of the Moss is in no sense the ancestor of the plant of the fern, or of the phanerogams, but belongs to a different generation from these; and further, that the leaves, the stem, and the epidermis of the Moss have no genetic connection

with the leaves, the stem, or the epidermis of our flowering plants, whilst the fibro-vascular bundles of the sporogone of the Polytrichum, and the stomata on the apophyses (or swollen bases of the capsule) of some Mosses will belong to the same generation which, in the vascular cryptogams and phanerogams, produces similar organs. (4) That the great chasm in the systematic arrangement of the vegetable kingdom between the Mosses and the ferns is thus accounted for by their belonging to different generations, so that the ferns are not in any sense descendants of the Mosses, but only collateral relatives, as thus:—



(5) That, consequently, the Mosses not only represent the highest development known of the cellular cryptogams, but the highest point in one line of development, in which the oophytic generation took the lead in importance; whilst the vascular cryptogams and phanerogams are the results of another and more successful line of development, in which the sporophytic generation took the lead as the prominent part in the life-history.

The appearance of similar organs in two independent lines of development—*i.e.* of the leaves, stem, and epidermis—in the Mosses, and then in the ferns, without any relation of descent, is a thing well worthy of being pondered over by those who study evolution: it may suggest that the two lines of development, though independent, are governed by some common principle which brings about such like results: it may be compared with the parallelism of the stages of evolution which are reached independently by the placental and marsupial mammals.

Such are some of the reflections and conclusions which follow from the adoption of that doctrine, current amongst botanists, of the presence of two alternative generations in what appears at first sight to be the history of a single generation. It would be presumptuous in one who makes no claim to any other position than that of a learner to assail the conclusions of great authorities; but it may be allowable to observe that I have sometimes asked myself whether the theory can stand the strain of all the conclusions which arise from it; that at any rate these conclusions are such as to seem to demand that the foundations of the theory should be very firmly laid in indubitable facts; that the approach of some ferns, especially the filmy ferns, to the Mosses is, on the theory we have been adopting, merely phenomenal and delusive; that the facts we are about to consider show that Nature can suppress one whole so-called generation without imperilling the life of the organism, and that the facts known as apospony and apogony produce the same results in the case of ferns. Perhaps in future years, and with fuller

knowledge, the different parts in the cycle of the life-history of the Moss may be expressed by other terms than those of alternative generations, and some larger generalization may be arrived at which will remove the difficulties which seem to stand in the way of the received doctrine.

One observation must be made to correct the generality of some of the language I have already used. I have spoken of the growth from the spore of the Mosses as a thread-like protonema : that from the spore of the ferns as a prothallus. This statement is generally but not universally true. The true Musci always, so far as is known, produce a protonema. The sphagnum produces protonema when the spore develops in water, but a prothallus when on the ground: the Hepaticæ produce sometimes a protonema, sometimes a flat plate of cells, or a mass of tissue. On the other hand, in the Ferns, whilst the ordinary first produce of the spore is a prothallus, in the filmy ferns, this is, so far as has been observed, a thread-like protonema closely resembling the like structure in Mosses. These facts show an approximation between the two great groups of cryptogams, the Ferns and the Mosses, and may hint to us the possibility of some direct genetic relation between them.

Modes of reproduction.—The remaining columns of the foregoing table B are epitomes of other modes of reproduction than the one which we have already described.

Hitherto our whole attention has been addressed to the reproduction from a spore produced in the special organ for their production—the spore capsule. But so far is this from being the only form of generation, that, in fact,

one of the most striking peculiarities of the Mosses is the vast variety of their modes of reproduction.

Fig. 10 represents the upper part of the leaf of a small Moss—the *Orthotrichum phyllanthum.* It is a Moss which grows on some of our coasts. I have gathered it in abundance amongst the nests of the sea-fowl on the Farne Islands, and again on the basalt rocks under Dunstanborough Castle, also on the coast of Northumberland. It affects great elevations as well as the sea level. It has been found high on Chimborazo, though Mr. Whymper did not meet with it there; it grows in great size on Cape Horn; it does not despise trees near the sea-shore as a home. This world-wide little plant rarely produces capsules, so rarely that they have only once or twice been seen, and that only quite recently; but in lieu of spores, it is reproduced by articulated cells or gemmæ, which cluster round the ends of its leaves; these drop off and produce protonema, from which the plant grows just as if the protonema had arisen from a spore.

FIG. 10.—*Orthotrichum phyllanthum*, with gemmæ, after Schimper.

Now, except in the very rare case of this plant producing a cell, the life-history of the plant differs widely from the one we have already considered—the Moss plant. The vegetable with its stalk and leaves is there, but there are no archegones, nor antherids, no fertilized oosphere, no sporogone, no capsule, and no spore; the whole sporophytic generation is excluded; the life is a short circuit which

never enters upon that generation at all. This is epitomized in the second column, under the head "Moss," of table B.

The *Tetraphis pellucida* is one of our most lovely little Mosses; it grows in hollows in woods, and on damp and decaying stumps of trees, and produces capsules comparatively rarely—at least I have only once found the capsules growing—but relies mainly for its reproduction on gemmæ not much different from those of the Orthotrichum, but these it carries in cups at the end of its stem, formed of large, delicate and almost translucent leaves, which with their egg-like gemmæ are a very beautiful structure. A magnified drawing of this Moss forms our Fig. 11.

FIG. 11.—*Tetraphis pellucida*, with its cup containing gemmæ, after Schimper.

The *Aulacomnium palustre* is another British Moss which is reproduced sometimes by spores, sometimes by gemmæ, but in this case the gemmæ are borne, not on the ends of the leaves or in terminal cups, but in clusters growing at the ends of special supporting stalks growing out from the plant laterally. The two forms of the plant, the spore-bearing and the gem-bearing, are strangely unlike as regards their general appearance, and the casual observer would, I feel sure, take them for widely different plants. The question whether the plant shall adopt the one mode of reproduction or the other seems to depend, in part at least, on temperature, a high temperature tending

towards the production of the gemmæ, and a lower temperature towards that of spores. The two forms are shown in Figs. 12, 13 and 14. Fig. 14 shows the plant surrounded by its stalked heads of gemmæ (*g g*). The plant, as its name

FIG. 12. *Aulacomnium palustre.* Male plant of spore-bearing form, after Dillenius.

FIG. 13.—*Aulacomnium palustre.* Female plant of spore-bearing form, after Dillenius.

FIG. 14. *Aulacomnium palustre.* Gem-bearing form, after Dillenius.

indicates, affects marshy situations, and often grows amongst sphagnum, and as this is used for orchids, and often kept in considerable heat, this form of the Aulacomnium may sometimes be seen in orchid houses in great abundance and beauty, raising its delicate heads above the level of the sphagnum.

The other form of the plant is double, *i.e.*, the male and female blossoms are produced on different plants; the former is shown in Fig. 12, and the latter in Fig. 13. This is a very handsome and strong-growing Moss.

The great diversity in the general appearance of these two forms of the same Moss is very striking; it suggests the great influence of temperature on such forms, the warmer temperature in this case producing the more delicate plant and the colder temperature the more robust. Furthermore, it is an instance of the correlation of great difference of general form with differences of modes of reproduction.

Other Mosses produce gemmæ on other parts of their structure; some on the midribs of the leaves, and some in the axils.

In the case of the Tetraphis there is reason to believe that the cup that contains the gemmæ is a modification of a male flower, and from the drawing above presented of the male flower of the Aulacomniu m (Fig. 12), it would seem as if it had a tendency to produce the stalked heads of gemmæ. The drawing is a copy from one in Dillenius. I have never seen such a growth in Aulacomnium, but the drawing is probably accurate, and it suggests for investigation, as a

question of interest, the relation between these stalked heads and the inflorescence of the Moss.

We have seen that Nature has been practising a piece of severe economy in doing without the spore and the whole machinery adapted for the production of spores and substituting a gemma for a spore. We shall now see her going a step further in the same course of economy and doing without the gemma. She will produce protonema from the existing Moss plant without the intervention of spore or gemma.

Fig. 15 represents a leaf of *Orthotrichum Lyelli*, a Moss

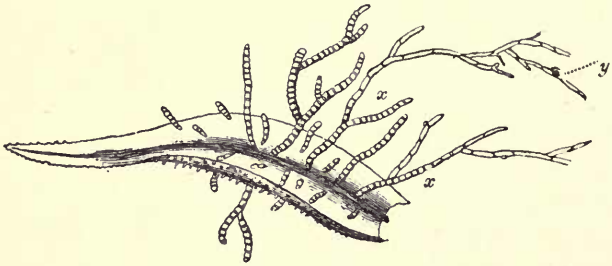


FIG. 15.—Leaf of *Orthotrichum Lyelli*, after Schimper.

found both in the old and the new world, on the trunks of trees: from this leaf, and especially from its midrib, are seen growths of protonema, and these gradually change into true roots, and on these roots buds are formed, which buds develop into true Moss plants. At *x* will be seen such a protonema divided into cells by transverse walls—further on the walls are oblique to the line of growth, and the growth then assumes the form of a root—and at *y* is seen a bud destined to produce a Moss plant.

Other species of Moss produce protonema from other parts of their structure; sometimes from the small roots or rhizoids, sometimes from the base or the margin of the leaf, sometimes from the stem and sometimes from the calyptra or veil. These modes of reproduction are referred to in the third column in table B, under the heading "Moss."

But Nature has not yet tired of economy, she will try a yet shorter circuit of life; she will reject the protonema, as well as the spore, and produce on the existing Moss plant itself a bud which shall produce a new Moss plant. Sometimes leafy buds are formed on the true rhizoids, sometimes on the root-like hairs which hang suspended in the air and are

FIG. 16.—*Sphagnum cuspidatum. a a*, young plants at ends of branches. After Schimper.

known as aerial rhizoids; sometimes bulbs are found on the stem, and from these buds and bulbs fresh Moss plants arise. A yet more direct mode of propagation may exist, viz., the direct production of a Moss plant from a Moss plant; whether, in this case, a bud is first formed or not I do not know, though I should suspect the affirmative. This curious mode of reproduction is shown in Fig. 16, which depicts a plant of *Sphagnum cuspidatum*, on the ends of the loose leaves of which (*a*, *a*) are seen numerous young plants directly arising and alike in all things but size to the parent plant.

The last-mentioned modes of reproduction are epitomized in the last two columns of table B.

There is one reflection which must almost have forced itself on every reader in considering this sketch of the development of Mosses, and of the economies of Nature in the process. The one object of her solicitude is the Moss plant—whatever else be left out, this is always present: Nature may strike off the spore, she may do without the gemma, she may avoid the protonema, but do whatever she may she always produces the Moss plant, the vegetable growth with its stem and its leaves. To the production of this all else is subordinate; it is the one thing needful.

On the other hand, the one thing which Nature seems desirous to avoid is the sexual reproduction by the concurrence of the two organs of the archegones and the antherids. This is found only in the one mode of growth; every other kind of reproduction by gemma, by protonema, by bud, all of course leave out the whole sporophytic generation.

In the following table, which is far from exhaustive, I have endeavoured to exhibit some of the modes of reproduction, dividing them into those cases in which it takes place with protonema and those cases in which it takes place without.

Table C.—Modes of Reproduction.

A.—*With Protonema.*

i. Spores	in capsule.	
ii. Gemmæ	on end of leaf	*Leptodontium gemmascens.* *Orthotrichum phyllanthum.* *Grimmia Hartmani.*
	on midrib	*Tortula papillosa.*
	in axils of leaves ...	*Bryum.*
	in balls	*Aulacomnion.*
	in cups	*Tetraphis.*
iii. Protonema ...	from zhizoids	*Phascum.* *Polytrichum.*
	from aerial rhizoids...	*Dicranum undulatum.*
	from terminal leaves.	*Oncophorus glaucus.*
	from base of leaf ...	*Funaria hygrometrica.*
	from midrib	*Orthotrichum Lyelli.*
	from margin	*Buxbaumia aphylla.*
	from stems	*Dicranum undulatum.*
	from calyptra	*Conomitrium julianum.*

B.—*Without Protonema.*

iv. Leaf-Buds ...	on rhizoids	*Grimmia pulvinata.*
v. Leaf-Buds ...	on aerial rhizoids ...	*Dicranum undulatum.*
vi. Bulbs	on stem...	*Bryum annotinum.*
vii. Young Plants.	at ends of branches...	*Sphagnum cuspidatum.*
viii. Leafy Branches.	becoming detached ...	*Conomitrium julianum.* *Cinclidotus aquaticus.*
ix. Rooting of main axis	... ...	*Mnium undulatum.*

Weismann's Theory.—The consideration of this table, and of the facts which are epitomized in it, is not without its interest in reference to Prof. Weismann's theory of the division of the cells and the plasma of organisms into two kinds: the germ cells and germ plasma endowed with a natural immortality, and the somatic cells and somatic plasma possessing no such endowment. That the Mosses are a difficulty in the acceptance of the theory as a universal

truth, the professor himself admits. The evidence of the Mosses seems to amount at least to this: that in this whole group, the highest in this line of development, where the oophytic generation produces the principal plant, and where there are highly specialized organs for the production of spores or germ cells—that in this whole group either there is no effectual separation between the two kinds of plasma, or that the germ plasma is so widely diffused amongst the somatic plasma that every portion of the plant is capable of reproducing the entire organism.

Comparison with Zoological Embryology.—The table will further offer us some points of comparison with animal embryology.

In that branch of physiology, one of the most remarkable facts is what has been called recapitulation, *i.e.*, the summary in the life of the individual of the life of the race, so that the development of the individual tells the development of the race—*e.g.*, the gills of the tadpole tell us of the descent of the Batrachians from gill-breathing animals.

So here we cannot doubt that the protonema of the Moss tells us of the descent of the whole group of Mosses from the Algæ.

Another remarkable fact in animal embryology is the co-existence in exceptional cases of the mature and the immature form: so the axolotl retains both gills and lungs throughout its life. In like manner some Mosses retain their algoid protonema throughout life.

The Phascum or Clay Moss is a conspicuous instance of this curious fact: it is depicted in Fig. 17. It is a Moss of a not very high organization. The leaves grow close to the

ground and the stem is very short. In like manner the sporangium (*a*) is almost sessile, and is seen almost enshrouded in the leaves, true rootlets or rhizoids (*r*) attach the plant to the ground, and the protonema (*p*) from which the plant has arisen survives and remains attached to it during the whole life of the plant. This protonema often exists in great quantity in the clay banks or fields where the Phascum dwells, and forms a sort of tangled mat.

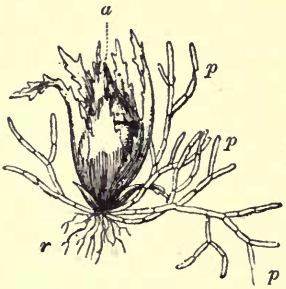


FIG. 17.—*Phascum cuspidatum. a*, capsule; *r*, rhizoids; *p*, persistent protonema. After Schimper.

Again, in zoological embryology, an attempt is often found, to use the language of Prof. Milnes Marshall, "to escape from the necessity of recapitulating, and to substitute for the ancestral process a more direct method."

In like manner we have already seen to how great an extent Nature has adopted the system of short-circuiting in the reproduction of the Mosses; for in every mode of reproduction, except that through sporogone and spore, a shorter circuit is travelled. We have seen how in every case Nature seems to leave out the sexual reproduction if she can help it, and directs her whole attention to the production of the vegetative organism—the Moss plant in the popular sense—which she never omits.

Another point of comparison arises, but this time it is one of contrast between the embryology of the two kingdoms.

In animals, to again quote Prof. Milnes Marshall, "recapitulation is not seen in all forms of development, but only in sexual development, or at least only in development from the egg. In the several forms of asexual development of which budding is the most frequent and the most familiar, there is no repetition of ancestral phases, neither is there in cases of regeneration of lost parts."

In Mosses, on the contrary, the table last given shows that in most of the modes of reproduction the ancestral form, the algoid protonema, is retained and reproduced, whereas in the growth from a sexual cell, *i.e.* in the sporogone, the ancestral form entirely disappears.

Organization.—I now propose to describe somewhat more in detail certain parts of the structure of a Moss.

The *stem* of Mosses is, as we have already seen, very variable in size. Sometimes, as in the Phascum (Fig. 17), the whole plant is almost sessile; in other cases, as in the Polytrichum (Fig. 2), it attains to a very considerable length. In some Mosses inhabiting water, the length of the plant reaches to feet. In our flowering plants the stem is supported by the presence of fibro-vascular bundles, *i.e.*, fibres arranged in combination with tubes along which fluids can and do pass. But with the exception of one family, the stem of the Mosses, like all the other parts of the plant, is constituted of cells alone, and consequently the circulation of fluid in them appears to result entirely from the passage of fluid through the walls of the cells. Hence their close dependence on the presence of moisture; hence in dry weather they fade and droop, and with the return of moisture assume their wonted appearance.

The exception to which I have referred exists in the family of the Polytrichaceæ, of which the genus Polytrichum is the foremost (Figs. 2 and 3). In that kind of Moss the stem of the plant and the stalks that support the capsules are of a firm, almost woody, structure, and give to the whole plant a different character to that of most of the Mosses. This peculiarity of the Polytrichum has, so to speak, enabled it to play a greater part in the world than most Mosses. Gilbert White tells us that the foresters of his neighbourhood made "neat little besoms from the stalks of the Polytrichum, common or great golden maiden hair, which they call silkwood, and find plenty in the bogs. When this Moss is well combed and dressed, and divested of its outer skin, it becomes of a beautiful bright chestnut colour, and being soft and pliant is very proper for the dusting of bed curtains, carpets, hangings, &c." But long before the dwellers in Wolmer Forest discovered this use for this Moss, it had been known to the pre-historic dwellers in our island, and had, it appears, been used by them to adorn themselves or their wives (themselves most likely). Curious fringe-like objects plaited of the stems of this Moss have been discovered in a crannog, or island fort, at Lochlee, in Ayrshire, attributed to that pre-historic period which has been called the late Celtic period. Furthermore, it is perhaps due to this fibrous character of the class that the earliest Moss of which we have any record in the strata of the earth appears to be one of the Polytrichaceæ.

The roots or rhizoids of the Mosses are distinguished by the minuteness of their growing ends, by their pliancy, and

by the presence on their exteriors of a balsamic or glutinous deposit. To these points of structure they owe their capacity to insinuate themselves into the minutest crevices of rock, to get, for instance, amongst the particles of the oolites, and also to fix themselves in the shifting sands of the sea-coast, and by so fixing themselves to give fixity in return to the sand, and so tend to produce the sand-dunes in many parts of the coast. At some parts of the Northumbrian coast the *Racomitrium canescens* may be found buried deep in the sand, from which it can scarcely be detached; and in like manner the sand-dunes of Holland and the west of France have in many places been fixed by Mosses. The forests of firs on the North Sea and the Bay of Biscay thus owe their place of abode to humble Mosses.

Leaves.—When we examine the leaves of Mosses and compare them with the more familiar forms presented to us by the phanerogams, we find ourselves in a new world, and the interest with which we view them is increased when we remember that, according to the view usually accepted, they are, so to speak, a unique phenomenon; they are not the descendants of any earlier leaves nor the ancestors of any later ones; they appear thus once, as it were, in the history of the vegetable kingdom, and advance no further. They possess something of the charm which an ἅπαξ λεγόμενον exercises over the mind of a philologist.

We may first note what they are not. They are never opposite, never whorled, never on leaf-stalks, never truly veined, never lobed or compound, never furnished with epidermis or stomata.

When we turn to consider affirmatively what Moss leaves are, we find them in some cases characterized by an extreme simplicity of form. They are single plates of similar cells without midribs, without veins, and without border.

The accompanying Fig. 18, representing a leaf of the

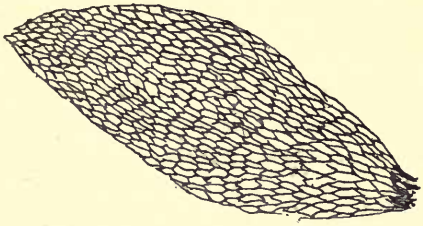


FIG. 18.—Leaf of *Hookeria lucens*, magnified, after nature.—A. F.

beautiful Moss, the Hookeria lucens, is an illustration of this form of leaf, and the Figs. 19 and 20 will show more

FIG. 19.—Cells of young leaf of *Hookeria lucens*, after nature.—A. F.

FIG. 20.—Cells of old leaf of *Hookeria lucens*, after nature.—A. F.

highly magnified the structure of the component cells in a young and old leaf, and the grains of chlorophyll in the cells. In the old leaf a tendency will be observed in these grains to place themselves along the walls of the cells so as to produce the effect of thickened walls.

The leaves of Mosses stand in immediate connection with the atmosphere, absorbing moisture from it when moist, and shrinking and shrivelling when the air is dry. In some cases they are characterized by a marked difference in the form of the cells in the different parts of the leaf, and again in other cases by the unequal distribution of chlorophyll; in other cases we come across strange forms, the like of which we hardly know in the phanerogams; such are the thick border and double rows of teeth in some of the genus Mnium, the parallel plates in Polytrichums and, stranger still, the third flange of the leaf in Fissiden; the true homology of which has proved a *crux* to bryologists.

A drawing of the leaf of *Fissidens adiantioides* is shown in Fig. 21—a thickened line of cells down the middle of the leaf assumes very much the appearance of a midrib, and on the right hand side occupying the lower half of the leaf is seen a third flange to the leaf, attached at its upper part to the leaf in an oblique line and after that to the vein or midrib of the leaf, so that in that part of the

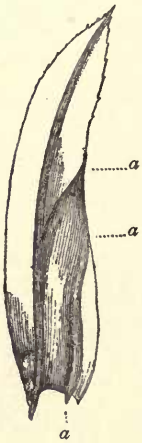


FIG. 21.—Leaf of *Fissidens adiantioides*, showing *a a*, the third flange. After Schimper.

leaf there are, as it were, two sheets or plates instead of one. Various theories of the homology of this part of the leaf have been suggested. By some it has been thought to result from a vertical splitting of the leaf; but each of the two plates where they are doubled is of an equal thickness to the rest of the leaf. Some have suggested that the double portion is alone the true leaf and the rest an outgrowth, but this seems a violent assumption. Others, again, have suggested that the additional lobe is a stipule arising on the opposite side of the stem, which has become adnate with the leaf. Some of these suggestions carry conviction with them.

In some cases the leaf is produced into a long thread or beak, devoid of chlorophyll, and often with indented or toothed edges. This structure is found chiefly in Mosses living on stones and rocks, and in dry situations, such as Grimmia and Racomitrium, and the presence of these long white threads or beaks gives a grey tint to the whole Moss, and in places where the Moss is predominant (as, for instance, some parts of Dartmoor and North Wales, where Racomitrium abounds) a grey tint to the whole landscape. These long hairs and prominences, especially when armed with lateral teeth, no doubt retain the moisture which is necessary not only for the vegetative life of the Moss, but also for the process of reproduction by archegones and antherids; hence it probably is that this form of leaf prevails in Mosses living in dry situations, just as the thick leaves of succulent plants are found in similar situations.

The capsule.—Of all the organs of a Moss plant, the

capsule which produces the spores is, perhaps, the most peculiar and characteristic. If the reader will refer back to Figs. 1 and 2, he will see the capsules (*c* in Fig. 1, *a* in Fig. 2) borne on the end of the long stalks (*s*). The capsule, as is shown in Fig. 2, is covered with a delicate veil or calyptra, which is shown as removed at *cal*. This veil is the remains of the archegone, borne up by the stalk or seta in its upward growth. In the case of the Polytrichum, it is covered with a thick coating of depending hairs, a circumstance which gives its name to the genus. When the veil is removed, the capsule itself is disclosed (*c* in Fig. 2), surmounted by an operculum or lid (*o*), which fits on to the top of the capsule like the lid on a box. The capsule with the lid removed is shown at the letter *c'*.

If the reader will refer back to table A, he will find that the Acrocarpous Mosses, *i.e.*, those which produce their capsules at the end of the axis, are divided into Stegocarpæ and Cleistocarpæ. We are now in a position to appreciate this distinction. In the Cleistocarpous Mosses, the capsule is never differentiated into the two parts of the true capsule and lid; it remains always as a closed capsule until the walls decay or break, and so emits the spores which it contains. Of this class, the clay Moss or Phascum (Fig. 17) is a familiar example. As a whole, this class is less highly organized than the Stegocarpous Mosses—such as the Polytrichum—where the capsule, originally a single organ, becomes differentiated into the two parts already described, and the spores are retained in the capsule dry and snug until the ripened lid falls off and allows their escape.

In some cases, the orifice of the capsule is formed by a smooth edge or lip; but in other cases this orifice is surrounded by a girdle of teeth of varying number, form, and colour, so that the study of the peristome, as this girdle is called, presents a continued variation of objects of beauty and interest. Fig. 22 exhibits the peristome of the beautiful little Moss the *Tetraphis pellucida*, to which I have already referred. No simpler form of peristome can be found than this, exhibiting four teeth in a single ring. Fig. 23 is part of the peristome of the *Fissidens adiantioides* magnified, and shows two phenomena common in

FIG. 22. Peristome of *Tetraphis pellucida*, after Schimper.

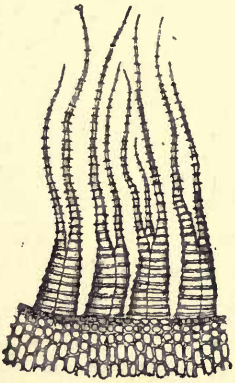


FIG. 23.—Part of peristome of *Fissidens adiantioides*, magnified. After Schimper.

FIG. 24.—Peristome of *Tortula ruralis*, magnified. After Schimper.

peristomes, (1) the division of the teeth at their free ends, and (2) the presence of transverse markings, generally of a darker colour than the intervening spaces. A tooth thus marked is said to be trabeculated, *i.e.*, marked by trabeculæ, or little beams.

In one considerable family of Mosses, some of which are very common on the tops of our walls, the teeth are hair-like in length and delicacy, and are twisted into a curious scroll like a lambent flame of fire. Fig. 24 represents one of these twisted peristomes, from which the genus especially characterized by it has received from some botanists the name of Tortula.

Again, in another form, which exists in Polytrichum, the teeth assume a very different appearance and connection. To make this intelligible I must refer to a portion of the structure of the capsule to which I have not hitherto referred, the columella, or little column, a central stem which occupies the very axis of the capsule; this, in Polytrichum, emerges from the mouth and expands into a tympanum or drumhead, and the teeth arising from the lip of the mouth join and support this drumhead, leaving interspaces between them something like long narrow windows under the flat roof of a circular tower, through which the spores escape. Fig. 25 is a representation of this singular structure, in which *p.* marks the place of the peristome or girdle

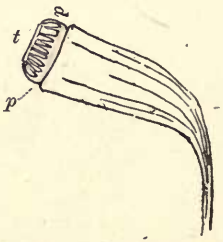


FIG. 25.—Capsule and peristome of *Polytrichum.* *p.* peristome, *t*, tympanum, after nature.—A.F.

of teeth: these are seen to be attached to *t.*, the tympanum, into which the column has expanded.

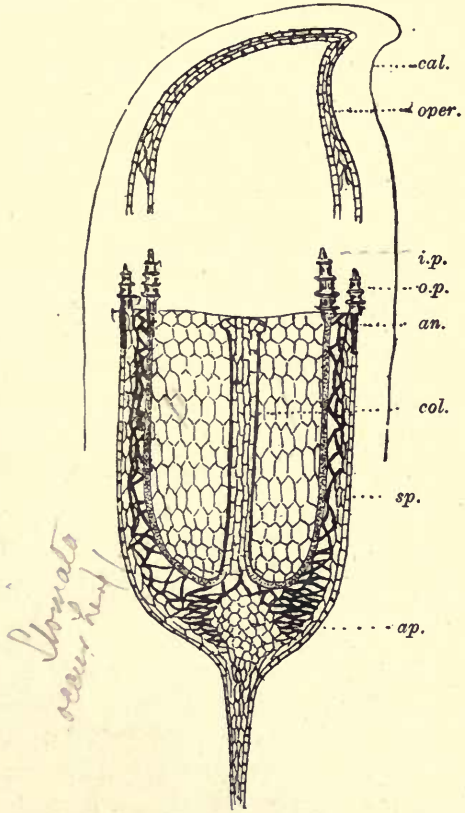


FIG. 26.—Diagrammatic section of a capsule. *cal.*, calyptra; *oper.*, lid or operculum; *ip.*, tooth of inner peristome; *op.*, tooth of outer peristome; *an.*, annulus or ring; *col.*, columella; *sp.*, wall of the actual spore sac; *ap.*, region of the aphyse.—A. F.

I have hitherto spoken of the peristome as consisting of one girdle of teeth; often it is double as in the great genera Hypnum and Bryum, and then the teeth often reach the number of sixty-four. In one foreign genus (Dawsonia) there are as many as four circles of teeth.

The accompanying Fig. 26 is a diagram intended to assist the reader in gaining a general notion of the structure of the several parts of a capsule with a double peristome : it is a diagram only of a section of an ideal capsule, and not a picture or representation of any existing capsule. The reader who will carefully inspect it will learn what to look for when he first holds a capsule in his hands, and may get some assistance as regards the technical language of bryology. He will see the calyptra, or veil (*cal.*), the remains of the original archegone; he will see the operculum, or lid (*oper*), severed from the capsule itself; he will observe the double peristome (*i.p.* and *o.p.*), the outer teeth consisting of a prolongation of the outer coat of the capsule, the inner teeth arising in like manner from the wall of the inner sack or spore case, or sporangium (*sp.*); he will observe an interspace between these two sacks filled with cellular tissue; he will observe in the interior of the sporangium the cells which become spores with the maturity of the growth; and in the middle of the diagram he will notice the columella or column. At the base of the capsule he will see the region (*ap.*) which, when swollen or enlarged, gives rise to the apophyse. All these parts are subject to a great range of variation, but this diagram may never-

theless, I hope, prove of some assistance to those beginning the study.

The object served by the complicated structure of the peristome is not, perhaps, very certain, but it seems to be intended to secure the retention or exclusion of the spores from the spore sac in such conditions of the atmosphere as will best conduce to their germination. In the Gymnostomous Mosses (*i.e.*, those without peristome) it is observed that the spores sometimes germinate within the capsule, an event which is probably adverse to the prospects of the race. The following table will illustrate, in a few cases selected as illustrations, the different behaviour of the teeth of the peristome under different hygrometric conditions, and suggests what is the probable advantage in each case :—

TABLE D.

Genus.	Condition of teeth		Reason suggested.
	in dry weather.	in wet weather.	
Bartramia ...	Erect ...	Convergent	That spores require *dry* weather when first emitted.
Orthotrichum	Erect or reflexed ...	Ditto ...	Ditto
Funaria ...	Reflexed ...	Ditto ...	Ditto
Bryum ...	Convergent...	Expanded	That spores require *wet* weather when first emitted.
Fissidens ...	Ditto ...	Ditto ...	Ditto

The motion of the teeth of the peristome appears to be due to the action of the annulus, a ring of specialized

cells which surrounds the mouth of the capsule at the base of the teeth: and the opposite ways in which these cells act in the same condition of moisture in different genera is a remarkable circumstance.

To anyone who studies the subject, the immense variety as well as beauty of the peristomes of Mosses becomes very impressive. If the sole end be the protection and extrusion of the spores in the proper weather respectively, why is there this infinite wealth and variety of form and of colour? The question can be asked, but hardly can be answered: and the mind of the beholder is left, as it so often is when contemplating the richness of Nature, in a state of admiration and wonder and ignorance. "Rerum natura tota est nusquam magis quam in minimis."

If the reader will now return to my table A, at the beginning of this article, he will see that I have given some account of all the Musci except the Anomaleæ; these are a somewhat heterogeneous group of plants, of great interest to the botanist, but with which I fear to detain my reader lest I should disgust him with apparently dry details.

Sphagnaceæ.—Next in order to the Musci in my table A will be found the Sphagnaceæ, or Turf or Peat Mosses, a natural group of comparatively few species and very marked organization. The general appearance of this class of Mosses may be gathered from the figure of one already given (see Fig. 16), and is well known to almost everyone who has had any interest in a hot-house.

Vast tracts of land in this country and throughout Northern Europe and America are covered with plants of this group, and large tracts which are now fertile agricultural land, where they have entirely ceased to grow, have in former times been occupied by them. The bogs of Ireland, which are mainly constituted of Turf Moss, were computed in 1819 by the Bog Commissioners to occupy 2,830,000 acres. No Moss has probably ever, at least in the present state of the globe, played so large a part as the Sphagnum or Turf Moss.

Structure.—It is to the peculiar structure of the Peat Moss that this great part on the theatre of the globe is to be attributed.

Leaves.—In the young leaves the component cells are all alike; then by a differential growth we are presented with large cells (sometimes of a square or rectangular shape) surrounded by narrower cells; then chlorophyll forms in these narrow cells, but is absent from the square cells; from these the contents disappear, and water or water-like fluid occupies the whole cell; subsequently annular and spiral threads develop on the walls of the square cells. The intimate structure of the leaf thus enables it to absorb great quantities of water.

But again, the shape of the leaves is in many species adapted to the retention of water. By a retardation of the lateral as compared with the mesial growth, the leaf assumes a boat shape. Often the edges of the leaves are turned over; the leaf thus affords means of holding water.

Figs. 27 and 28 will enable the reader to follow

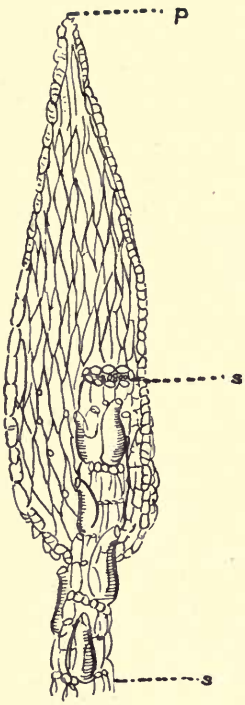


FIG. 27.—Leaf of *Sphagnum acutifolium*, magnified; *s s*, stem; *p*, point of the leaf. After Schimper.

the foregoing description. Fig. 27 shows a magnified leaf of the *Sphagnum acutifolium*—with a portion of the adjoining stem (*s s*), of which more hereafter. The edges of the leaf are turned over—as may be seen by looking at the extreme point of the leaf (*p*) where these foldings over cease. Fig. 28 exhibits a portion of a leaf far more highly magnified; the large cells free from chlorophyll bounded by the narrower cells charged with it will be at once observed as well as the spiral threads developed on the walls of the larger cells, a peculiarity of the leaf of this genus which enables one to detect the presence of its remains so long as any organic structure is retained; and at the points *o o* are seen orifices opening from the interior of the cell and admitting water.

A reference to Fig. 16 will show that the leaves of the Sphagnum are borne on lateral branches. These at the head of the plant form a thick and often widely extended tuft; but lower down the branches grow out laterally from the stem, generally in tufts of four branches,

of which, as shown in Fig. 29, two generally grow more out or less horizontally, and two are disposed in close proximity to the stem, round which in fact they fall (see again Fig. 16), so as to exert a great capillary attraction and keep a great mass of water in suspension even against the force of gravity.

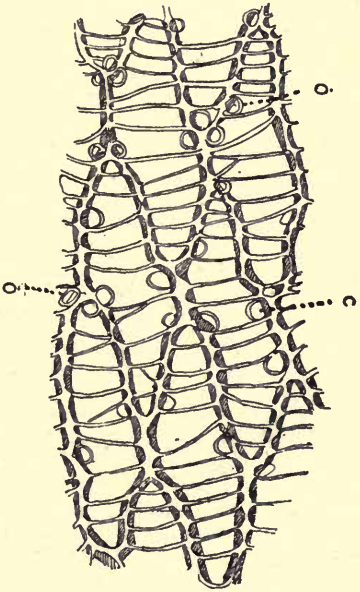


FIG. 28.—Portion of leaf of *Sphagnum acutifolium*, highly magnified; *o o*, orifices opening from interior of cells. After Schimper.

Yet further, as it would seem, to add to the absorptive capacity of the leaves, Nature, in one or more species of the Peat Moss, has recourse to a further

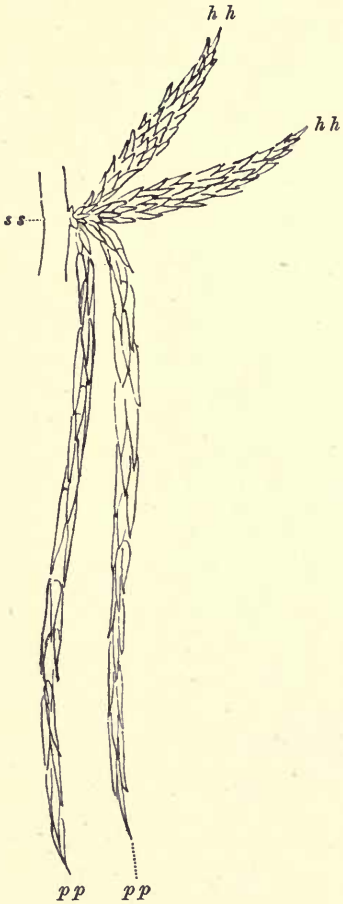


FIG. 29.—Lateral branches of *Sphagnum*; *s s*, stem; *h h*, horizontal branches; *p p*, pendant branches. After Schimper.

expedient. Round the base and sides of the leaf, clusters of half free cells, with spirally marked walls, are clustered, ready, like their sister cells in the leaf, to carry their full complement of water. Such a group is shown (magnified of course) in Fig. 30.

The stem of the Sphagnum in like manner is developed as a water-carrying instrument. Its appearance when examined by the microscope, as shown in Fig. 27 and in Fig. 31, is very singular, for it is surrounded not only with large transparent cells of more ordinary shape, but with large cells developed into the shape of flasks, with openings at their tops. Fig. 32 will enable the reader further to realize this structure. It is a highly-magnified section of a quarter of a stem.

Again, the mode of growth of the plant, abandoning its moorings on the soil and throwing out roots into the water, and growing successively year after year, enables it not only to attain great growth, but also when the occasion demands, to keep pace with the rise of the water in which it may be growing, "the individual thus becoming," it has been said, "in a manner immortal, and supplying a perpetual fund of decomposing vegetable matter."

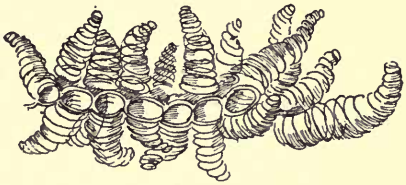


FIG. 30.—Cluster of cells at base of leaf of *Sphagnum acutifolium*. After Schimper

Physical Results from Structure.—The result of these peculiarities is that the entire plant of any species of Sphagnum is a perfect sponge. When dry it is capable (as may easily be found by experiment) of rapidly absorbing moisture, and carrying it upwards through the plant; and when growing in vast beds it acts thus on a great scale. Everyone who knows Scotland must know how on many a steep mountain-side, or on the bottom and sides of a gorge, these beds will hold up a great body of water against the force of gravity; and again, the Irish bogs are described as often ascending from the edges towards the interior, sometimes by a gradual and sometimes by a sudden ascent, so that at times the bog is so high that it reaches the height of the church steeples of the adjoining country, without any rising ground intervening.

These peculiarities in the structure of Sphagnum

have produced considerable physical effects.

(1) Everyone knows the different effects of rain falling on a land of bare rock or sand, like the Sinaitic desert, and on a porous soil. In the one case it produces a freshet or a flood, that leaves no water behind; in the other it is held for a while in suspense, and only gradually passes into the streams. The glaciers and the Sphagnum beds of the mountains of Europe alike act as compensation reservoirs—receive large quantities of moisture as it falls, and retain it till the drier season comes, when part of it gradually passes away; but for these reservoirs, many of the rivers would exhibit a far greater shrinkage in summer and autumn than is now the case. But (2) the Sphagnum beds have become peat, and have gradually filled up the ancient lakes and morasses, and turned water into dry land. It is true that peat appears under some circumstances to be formed by other vegetables than Sphagnum, and in all cases it has probably some other plants or roots growing amongst it. Mr. Darwin tells us that in Terra del Fuego and the Chonos Archipelago, peat is formed by two phanerogamous plants, of which one at least seems endowed with an immortality something like that of the Sphagnum; and the peat of the fens of

FIG. 31. — Stem of *Sphagnum mollus-cum*, magnified, showing *u u*, the utricles or flask-shaped cells. After Schimper.

Lincolnshire is formed mainly of *Hypnum fluitans*. But

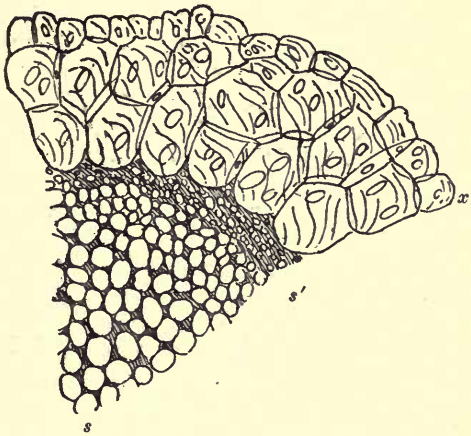


FIG. 32.—Magnified section of stem of *Sphagnum cymbifolium*. s s^1 stem; s^1 x, mass of spirally threaded cells surrounding stem. After Schimper.

Sphagnum appears to be the main constituent of peat in Ireland, Scotland, and, so far as my researches have gone, in England; the peculiar spiral threads of the cells of the Sphagnum leaf being easily detected in the peat so long as it retains traces of its organic origin.

Ancient Forests.—The Peat Mosses, and the sea-shores of our islands and of the adjoining mainland, reveal, as is very well known, traces of ancient forests. Many parts of England, nearly all the mainland of Scotland, the Hebrides, the Orkneys, and the Shetlands, Ireland, and Denmark, the shores of both sides of the English Channel, Normandy, Brittany, the Channel Islands, and Holland, and the shores of Norway, all bear evidence to the presence of these primeval forests;

and what is more, to the successive existence of forests, each in its order living above the buried remains of the earlier ones.

The following table will show the order of succession in the different species of trees in some of the places where this has been observed, the braces representing the co-existence of the trees :—

Island of Lewes.	Danes Moor, near Macclesfield.	Somerset.	Other parts of England.	Parts of Scotland.	Parts of Denmark.
1. Oak.	1. Scotch fir.	(Oak.	1 {Oak.	1 {Oak.	1. Scotch fir
2. Elder.	2. Larch.	1 {Ash.	Scotch fir	Scotch fir	2. Oak.
3. Birch.	3. Oak.	Yew.	2 {Birch.	2. Birch.	3. Birch.
4. Scotch fir.	4. Birch.		Hazel.	3. Hazel.	
	5. Hazel.		3. Alder.	4. Alder.	
	6. Alder.			5. Willow.	
	7. Willow.			6. Ash.	
				7. Juniper.	

In some Irish bogs fir, oak, and yew, and rarely elm, have been found.

What is the cause of the disappearance of these ancient forests one after the other? To this question various answers have been proposed.

The Romans, it has been suggested, in their inroads, cut ways through the forests and laid waste the land. But, wide as was the spread of the wings of the Roman eagle, the phenomenon in question is of far wider extension. They never conquered Denmark, or Norway, or Ireland, or the islands of Scotland: in Scotland, and even in England, their operations could never have covered the whole country; and as regards some of our Peat Mosses, we know that they must have existed long before the Roman invasion; for at least on the borders of Sedgmoor we have traces of their using peat for fuel as it is used there at the present day.

Still humbler agents have been invoked, in the supposition that the beaver and other rodents were the authors of the destruction of the forests. So far as I can judge, the cause suggested seems inadequate to the effect.

Again, changes in climate have been suggested. But, although there may be some evidence from the succession of the trees of a gradual amelioration in the climate, we know of no evidence of changes of so sudden and violent a character as would destroy the existing forests over large areas. Moreover, with few exceptions, the trees of the destroyed forests are such as are now found wild, or will grow easily in the spots where they lie buried.

The overthrow by storms has, again, been suggested as the cause of this wholesale destruction; and the fact that in some of the peat bogs of the west of Scotland the trees that have fallen lie to the north or north-east, and in some of those in Holland to the south-east, in the direction of the prevailing winds in those countries respectively, affords some reason to believe that wind has given the *coup de grâce* to the dying trees, and determined the direction of their fall. But it is much more likely that the work of the wind should be confined to this final overthrow of the decaying trees than that successive forests in full strength should have been swept from the face of vast tracts of Europe by the agency of wind alone. Moreover, in some cases the trunks as well as the bases and roots of the trees are found standing or buried in the bogs.

Allowing that some or all of these agencies may have had their part in the destruction of the forests, I believe that the growth of Sphagnum has been the greatest factor in the work of destruction. "To the chilling effect of the wet bog Mosses in their upward growth must be attributed," says Mr. James Geikie, "the overthrow of by far the greater portion of the buried timber in our peat bogs."

In a letter written by Lord Cromarty, in 1710, on Peat Mosses, and published in the twenty-seventh volume of the *Philosophical Transactions*, we get a curious account of the swallowing up of a forest by a peat bog. In 1651 the Earl saw in the parish of Lochburn (or, as Walker says, at Lock Broom, in West Ross), a plain

with fir-trees standing on it, all without bark, and dead. Of the cause of their death he says nothing. Fifteen years after he found the whole place a Peat Moss or "fog," the trees swallowed up, and the moss so deep that in attempting to walk on it he sank in it up to his armpits.

This same process of destruction is still found to be going on in the mountain districts in the Harz and in Thuringia. "Forestry in these highlands," says Graf zu Solms Laubach in his *Fossil Botany*, "is everywhere at strife with the peat bogs, which, left to themselves, are always growing, and by the advance of their margins eat their way into the adjoining forests, and make irregular gaps in them."

But, it will be said, assuming that this may be the case with one growth of forest, how about the successive destruction of successive forests? The answer is, I believe, to be found in the curious change which peat undergoes, and which converts it from a substance highly absorbent of water into one impervious to it.

The section exposed by a peat-cutting in, I believe, almost all cases exhibits two kinds of peat, the one known variously as red peat—or red bog, or fibrous bog, or in Somersetshire as white turf—which lies at the top, and the other a black peat, which lies at the bottom. The red peat retains visible traces of the Sphagnum of which it is mainly composed, and is highly absorbent of moisture; whilst the black peat has lost all, or nearly all, traces of the minute structure of the cells, and is not only unabsorbent of moisture, but is impervious to it. In fact,

it constitutes an insoluble substance which is said to be scarcely subject to decay, so that it is used in Holland for the foundations of houses, and is found unchanged after ages, and when the buildings have fallen into decay. It is even said to have remained unchanged after three months' boiling in a steam-engine boiler. The broad difference

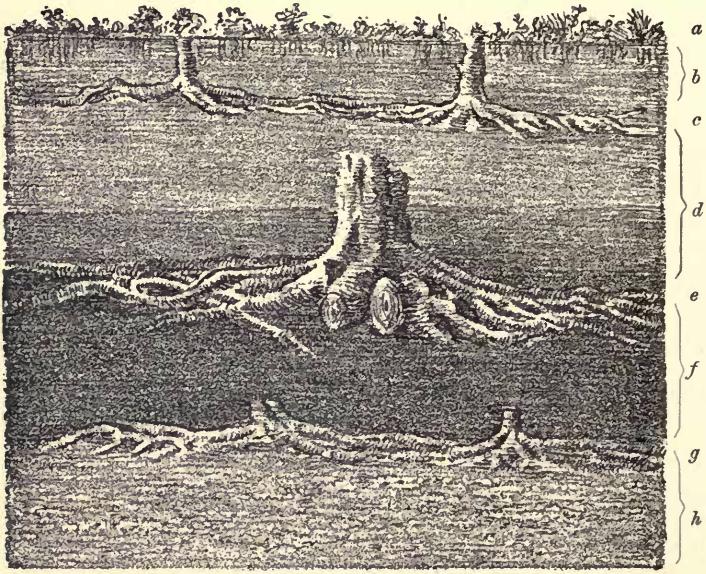


FIG. 33.—Section of Irish Peat bog, showing the growths of three successive submerged forests. (*From Third Report of Commissioners on Irish Peat Bogs.*) *a* Present surface with vegetation. *b* Third peat bog. *c* Third forest. *d* Second peat bog. *e* Second forest. *f* First peat bog. *g* First forest. *h* Limestone gravel at base of bog.

between these two kinds of peat may easily be ascertained by anyone who will, as I have done, subject the two kinds to the action of water.

In Fig. 33 will be found a section of a peat bog, copied from an engraving in the third Report of the Commissioners on Irish Bogs ("Parliamentary Papers," 1813-4), and exhibiting the remains of three forests anterior to the vegetation growing on the surface of the bog. The history of the formation will be, I believe, much as follows:—

(1) We must get a watertight bottom. In the section given it is said to consist of limestone gravel, but this probably had, at least in its lower part, got consolidated into a pan by the infiltration of insoluble iron oxides, themselves often due to decaying vegetable matter, or it rested on a subsoil of stiff clay. The necessity of this watertight bottom is well shown by the fact that in places in the Irish bogs where a pure limestone subsoil occurs the bog becomes shallow and dry.

(2) On this limestone gravel a forest arose and flourished for a considerable period, until the natural drainage of the area was stopped, whether by the choking up of the course of the effluent stream, or from the aggregation of vegetable matter, or from the fall in the course of nature of the trunks of the trees themselves. Everyone who will consider how much care our rivers require in order to make them flow with regularity to the sea—who thinks, for instance, of the works in the Thames valley, or in the upper valleys of the Rhine—will see how often and how easily, in a country in the condition of nature, stagnant waters will arise. In the morass thus formed the Sphagnum

has grown, years after years, and if it has not destroyed the old trees it has prevented the growth of young ones. The stools of the trees buried in the antiseptic waters of the Sphagnum pools have been preserved, whilst the fallen trunks have, except when preserved by the like circumstance, rotted, and added their remains to the peat which the Sphagnum has been producing. It has been observed in several places in Scotland, that the under side of fallen trees which would be protected from decay by the tannin of the Sphagnum is preserved, whilst the upper side has decayed or rotted away. Year by year the process of decay on the lower parts of the Sphagnum went on until the water grew shallower and at last disappeared, leaving the original morass choked and filled up by the Sphagnum and the plants which it has nourished. On the top of this soil have grown first the heath and bog shrubs which first succeed the Sphagnum, and in time, as the soil has grown more solid, forest trees. This is our second forest. This first peat deposit, or the lower part of it at all events, having been turned into the black peat impervious to water, plays the same part in the second stage that the clay or pan did in the first stage. Again, the drainage of this second level got stopped, and the forest bottom loaded with stagnant water, the home of the Sphagnum; together, the water and the Sphagnum killed the forest trees, which share the fate of their predecessors. The same history is gone through again—the Sphagnum filling up the morass and turning the water into dry land until it supports the third forest.

Decay of the Moss.—There comes, however, in many

cases a time when this process is arrested; the artificial drainage of the soil, or the physical position of the area, prevents the re-formation of a morass, and the Sphagnum dies away. So in many parts, if not universally, in Sedgmoor, in Somerset, it is almost impossible to gather a bit of Sphagnum, and the peat is well known to the turf diggers not to be reproduced. Here the regulated drainage of the level maintains the surface in the condition of meadows or agricultural land. But in many cases, especially on mountain sides or tops, when the Sphagnum has died, and the peat undergone its last change into black earth, a process of decay sets in under the influence of air and water. The water lies in holes or "hags," or flows in sluggish streams, wearing away the dead peat; and the surface of the soil is broken and uneven, small patches of green surface with a rough growth of sedge or grass being surrounded by wider spaces of black earth. Such is, or was some years ago, the condition of the peat on the top of Kinder Scout in Derbyshire; on the parts of Dartmoor around Cranmere Pool; and such also it is described to be on many of the Lowland hills of Scotland.

Sedgmoor.—In some cases the Peat Mosses have been originally arms of the sea, and the peat has only grown after the exclusion of the salt water. Such appears to be the history of Sedgmoor, the great plain of Central Somerset. Northward it is bounded by the Mendips; eastward lies Glastonbury with its Tor or hill; westward the Bristol Channel. The plain is intersected by the low line of the Pouldon Hills, once a long level-backed island or promontory in the estuary and afterwards in the morass; and

the way in which the villages lie and the moor is apportioned between them suggests that the Pouldon Hills and some other spots which slightly rise above the level of the Moss were the original seats of population. Originally this whole area appears to have been open to the Bristol Channel, of which it formed a bay or recess. The Burtle beds are a marine deposit well seen at the slight elevation on which the village of Burtle stands, which have been traced in various places along the borders of the moor and indicate the old line of beach. A curious confirmation of this geological fact is afforded by the presence—the one on Shapwick Heath, and the other near Glastonbury—of two plants (the *Rumex maritimus* and the *Vicia lutea*) which are shore plants, but which have until recently maintained their places as remains of the ancient marine flora, showing the retreat of the sea. The *Vicia lutea* has, I believe, recently succumbed in this interesting locality to the British collector. The description of Glastonbury as the Isle of Avalon, and the account of the bringing of the body of King Arthur from Tintagel to its resting-place at Glastonbury, are confirmations from tradition of the same fact.

Then a change came over the district, apparently by the formation of barriers of sand or mud along what is now the shore of the Bristol Channel, and along the sides of the overflowing rivers, and in that way the sea-water was shut out, and a depressed region left with a mud surface; on this there arose a forest of oak, ash, and yew, then the water stagnated, and in it the Sphagnum grew, and gradually filled it up, killing the growth of trees on the

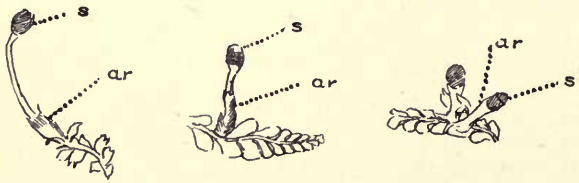
surface of the land, but leaving, down to historic times, spaces of fresh water from which the Abbots of Glastonbury formed their great fishing lake at Meare, by the side of which they erected the beautiful manor house and fish house which still remain. When the Romans occupied this part of England, they not only used the Burtle beds for plastic clay, but used the peat in their kilns, and the remains of the road which they constructed across the moor are now found some six feet below the present surface. In like manner, a pathway exists across part of the moor near Westhay consisting of slabs of birch, and perhaps alder laid crosswise, so as to form a kind of corduroy road. This has been found in one place at a depth of seven, at another of two feet only beneath the surface. The road bears the name of the Abbot's path, or way, and it may well, I think, have been a way by which the monks of Glastonbury passed from their abbey by way of Meare to Burtle, where they appear to have had a chapel which they served. Now, as I have already said, the system of drainage is so complete that the peat, when once cut, is not reproduced (though the lower soil is said to have a remarkable power of expansion and rises often to the old level), and the Sphagnum is to be found rarely, if at all, on many parts of the moor.

To the intimate structure of the Turf Moss are thus to be attributed great results in the history of the world. To look at our own island alone, but for it the primeval forests that once covered the land might still be standing; but for it large tracts of land would still be lake and mere; but for it every freshet in a Highland river would be a

flood; without it we should have had no Mosses on the confines of England and Scotland, and where would have been the border warfare and the border minstrelsy? where the Moss hags in which the hunted Covenanters sought for shelter and freedom of worship? To come southward, by force of its growth, the broad meadows of Somerset have been built up, and the dark waters on which the mysterious barge bore the dead Arthur from Tintagel to Avalon have been turned into the green pastures of Glastonbury and Meare and the battle-field of Sedgmoor.

Hepaticeæ. If my reader will once again refer to table A, he will see that the Hepaticeæ, the lowest group of Mosses, when that word is used in its wider signification, yet remain for some little notice. I am afraid that most people slight them greatly, and feel little inclination to examine them; and yet they possess a beauty of their own—a great diversity of form, and points of great interest and importance to the botanist.

Popularly these little plants would probably be considered Mosses, and it may be hard to say whether or no they deserve the name, and so botanists use two Latin words



FIGS. 34, 35, 36.—*Jungermanniæ.* *ar*, archegones; *s*, sporangium. After nature.—A.F.

for the one English one, and allow them to be Muscineæ, though not Musci.

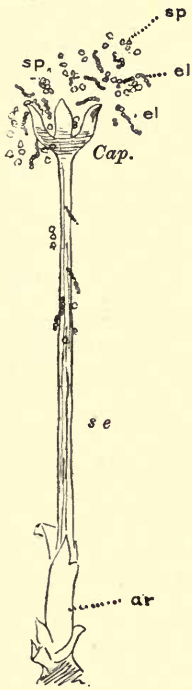


FIG. 37.—Part of a *Jungermannia*, magnified; *ar*, archegone; *se*, seta or stalk; *cap*, capsule of four leaves opening and emitting *sp*, spores and *el*, elaters. After nature. —A.F.

In the springtime, anyone who carefully looks may find, in woods or on shaded banks, little plants, in such forms as those shown in Figs. 34, 35, and 36. These show two species of Jungermannia—of the family Jungermanniaceæ of my table A. The genus bears a somewhat uncouth name, and one wishes it had a pleasanter one than this, which was bestowed upon it in honour of a worthy German botanist. It has been said that the unpronounceable names of the Mexican kings before the conquest rob them of the fame which their merits deserve ; and so long as these little plants bear this name, I see no hope that they should ever attain popularity.

That these little plants have great likeness to ordinary Mosses must be conceded, but the student who looks at them attentively will soon see something different about their general appearance. This is partly due to the peculiar way in which the leaves are inserted—the lines of attachment of the leaves to the stem generally forming an angle like a V. But other differ-

ences will be apparent from the figures. The sporangium, as in the Mosses, takes its rise from an archegone. In the Mosses this organ is concealed in modified leaves, and is generally speaking not easy to detect. In these Jungermanniaceæ the archegones form conspicuous green organs (*ar*) in which, in the earlier stages, the dark-coloured sporangia appear to rest (Fig. 36, *s*). They are subsequently raised on a seta or stalk, generally of a perfectly white cellular structure. The sporangium is not divided into capsule and lid, but opens as shown in Fig. 37, by the springing backward of the four leaves which constitute it, and emits large quantities of spores (*sp*), interspersed with very curious structures, known as elaters (*el*). These elaters, with some attached spores, are seen more highly magnified in Fig. 38. The elaters are endless threads, twisted

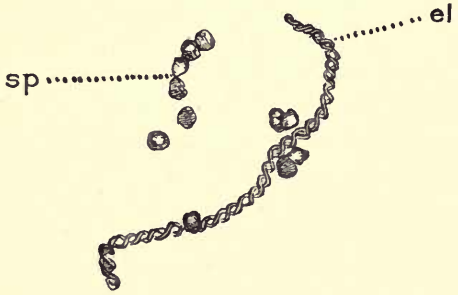


FIG. 38.—Spores and elaters of *Jungermannia* magnified. *sp*, spores; *el*, elaters. After nature. —I.F.

into spirals, and when liberated the spirals rapidly twist and twirl about, and in so doing, aid in dispersing the

spores. The spectacle of an opening orspangium of a Jungermannia is a very interesting one.

It is remarkable that in the true Mosses, with their much more highly organized capsules and spore cases, these elaters have disappeared.

If the patience of my reader hold out, I will ask him, for the last time, to refer back to my table A, where he will find that last of all in the series come the Marchantiacæ, so named from the best known species of the group, the *Marchantia polymorpha*, a plant so remarkable and so worthy of full consideration, that I fear that if I embarked on it I should weary my reader beyond endurance, so I leave it, at least for the present.

Distribution in Time.—It will be interesting now to enquire how long the present Moss flora of England has existed. How far back can we carry our knowledge of the existence on the world's surface of these delicate organisms? It is evident that they have had but a small chance of leaving evidence of their existence as fossil remains, because whilst the strong, almost wiry, vessels of the ferns have a great power of resisting decay and so getting preserved, the delicate cellular structure of the Mosses offers little or no resistance to that process. Hence it is that the fossil remains of Mosses are not very numerous, or for the most part very ancient. Yet we have some materials to answer the enquiry. Three ancient collections of Mosses enable us to throw some light upon it. In an interglacial bed near Crofthead, in Renfrewshire, eleven species of Moss were discovered, and with one possible exception all are

well-defined British species of the present day. If we take Mr. Wallace's chronology, and hold that 80,000 years have passed since the Glacial epoch disappeared, and 200,000 years since the Glacial epoch was at its maximum, we may perhaps give from 100,000 to 150,000 years for the age of this little collection. Out of the eleven Mosses discovered, seven belong to the genus Hypnum, or the family Hypnaceæ. This collection, then, is evidence, so far as it goes, (1) that the existing Moss flora is as old as the inter-glacial epoch; (2) that the Hypnaceæ were as dominant then as now; and (3) that the specific forms have remained constant since that epoch.

Another collection of fourteen Mosses has been discovered in a drift in the Clyde valley above the Boulder drift, and tends to confirm the previous conclusions; as all the species are existing, all now inhabit the valley of the Clyde, and the Hypnaceæ are still predominant, though not in so great a proportion as in the Renfrewshire bed.

A third collection has been found at Hoxne, in Suffolk, in a lacustrine deposit, probably resting in a hollow in the boulder clay. Together with phanerogams of an arctic habit, have been found the remains of ten Mosses, which are described by Mr. Mitten as looking "like a lot of bits drifted down a mountain stream." They are all still dwellers in our island, and exhibit, like the other collections, a preponderance of the family of Hypnaceæ.

But we can give some evidence of more ancient date. Heer inferred the existence of the Mosses in the Liassic period from the presence of remains of a group of small Coleoptera, the existing members of which now live amongst

Mosses—an inference which seems not very strong. But recently the remains of a Moss have been found in the carboniferous strata at Commentry, in France. It appears to be closely allied to the extant Polytrichum, the most highly-developed genus of Mosses; so that we have here a phenomenon like that which occurs in reference to the Equisetacæ and Lycopodiaceæ, viz., that the earliest fossil species known belong to very highly-developed forms of the group.

Distribution in Space.—If we turn, now, from the distribution of this family in time to its distribution in space, we shall observe some curious phenomena. Of our English Mosses some are of almost world-wide distribution; some are found here and in spots far removed from our shores; some are believed to be peculiar to our island. One observation should be borne in mind in considering the following statement, viz., that Mosses are often small and inconspicuous plants; that they are often neglected where flowering plants have been collected and studied; and that consequently the statements as to their non-existence must always be accepted with this proviso, that they may mean the non-existence or the non-discovery, or non-observation of the plant in question.

Of our Mosses I have said that some are cosmopolitan in their extension. Our common *Funaria hygrometrica*, our *Bartramia pomiformis*, and, amongst the Hepaticæ, our Marchantia are a few amongst many that are denizens alike of the Old and of the New World. Of the New Zealand Mosses about one-fifth are British, or at least European, species; of the Tasmanian Mosses about one-third.

But whilst there are instances of this wide dispersion, there are instances too of the opposite kind. Amongst the British Mosses and Hepaticæ (as we learn from Mr. Wallace on the authority of Mr. Mitten) seventeen Mosses and nine Hepaticæ are said to be peculiar to the British Islands, and of these, three genera of Mosses and three of Hepaticæ are also non-European (*i.e.*, not known on the Continent of Europe). The three non-European genera of Mosses have their greatest development in the Andes; the three non-European genera of Hepaticæ have their greatest development in the temperate regions of the southern hemisphere. Let me take one of the Mosses of which the genus is non-European—Streptopogon. This genus is thus distributed: Seven species in the Andes; one in the Himalayas; three in the south temperate zone; one in Sussex. Take, again, one of the Hepaticæ, *Acrobolbus;* its species are confined to New Zealand and the adjoining islands, with one species in Ireland.

There are other noteworthy but isolated facts about the distribution of Mosses to which I may here refer: one is, that the great boulders of the plains of the centre of Germany are found to bear alpine species of Moss as if brought from some distant or elevated region; is this due to the actual transport of the boulders on which they live or to the retreat of the northern flora in the tail of the ice as it retreated northward as the glacial period disappeared? In any event it reminds one of the scattered patches of alpine gentians, which are to be found in the great stretch of moorland south of the Danube, and between that river and the Tyrolese Alps.

I have reason, furthermore, to believe that if the Mosses of some parts of the south-west of England were worked out carefully, northern forms would be found to prevail in a way which would require, if possible, some explanation.

The facility with which the wind can carry the small spores of the Mosses probably accounts in some cases for the wide distribution of the organisms. The very small area occupied by some species suggests great susceptibility to local surroundings.

Conclusion.—I can cordially recommend the study of the Mosses to any, old or young, who really love Nature : I have found in it a great source of pleasure during the last few years. The tops of walls, the banks of lanes, the slopes of woods, the mountain passes, each inhabited by different classes of Mosses, are as distinct in their vegetation as the oak or elm or beech counties of England, or the pine-clad slopes or the birch groves of the Alps. A square foot, in some situations, will contain a large number of species of different forms and modes of growth. The long arms of the Hypnum may stretch along the ground, whilst the Tortulas raise their spires of rich brown from out rosettes of verdant leaves, and the Bryums with their pendant capsules vie with them in beauty. One stone or bit of boggy land may be a study in colours—greens, browns, reds, greys, and gold—which my pen would fail to describe. A wall-top may show

> "A stubble field, or a canebrake; a marsh
> Of bulrush whitening in the sun."

Another may present a mimic forest, built up of varied forms, as different from one another as were the huge vegetables

of the Coal period from our trees. In a word, I find myself, whenever in the country, surrounded by a world of beauty and interest which I only dimly perceived before I entered on the study, though I have never, I hope, been entirely unobservant of things around me. More than ever I can say—

> "In small proportions we just beauties see,
> And in short measures life may perfect be."

"But how shall I begin the study?" some may say. Gather the first moss you come across, examine it with the naked eye, and then with a microscope, and you will have made some advance. If the British Museum be accessible to you, go to the Botanical Department and examine the collection beautifully arranged and exposed in one of the rooms upstairs. But books—you must have books to aid you, and therefore I will suggest a few. Bagnall's "Handbook of Mosses" will, I believe, be found a very useful first book, and is very inexpensive. "The Handbook of Cryptogamic Botany," by Bennett and Murray, will be a very good one with which to begin the study of the organization of the Mosses. Berkeley's "Handbook of British Mosses" may serve as the second book on classification. Wilson's "Bryologia Britannica" is a more advanced book of the same description, and difficult to get. Dr. Braithwaite's "British Moss Flora," which is in course of publication, is a more elaborately illustrated and expensive book. Two works of Schimper's—"Recherches sur les Mousses" and "Entwickelungsgeschichte der Torfmoose"—are admirable, and his "Synopsis Muscorum Europæorum" is very helpful, especially for finding

European species not found in Britain. The work of old Dillenius ("Historia Muscorum"), though of course out of date, is very delightful, and contains many excellent plates, worthy of study even in the present day.

One pleasant duty remains to be performed. Figures 4, 5, 6, 9, 10, 11, 15, 17, 21, 22, 23, 24 have been copied from Schimper's "Recherches sur les Mousses"; Figures 16, 27, 28, 29, 30, 31, 32, from the same author's "Entwickelungsgeschichte der Torfmoose"; Figures 7, 8, from Berkeley's "Handbook." For permission to use these sets of figures I beg to thank respectively Messrs. Freutel and Weitz, Mr. Schweizerbart, and Messrs. Lovell Reeve and Co.; nor can I omit to add my thanks to my daughter, Agnes Fry, from whose drawings, partly original and partly copies, most of the foregoing illustrations have been taken.