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ROCKY MOUNTAIN MOSSES WITH A HAND MAGNIFIER
A MOSS PRIMER FOR AMATEURS

By William A. Weber and Ronald C. Wittmann

Sir, said he. *there is nothing too little for so little a creature as man. It is by studying little things that we attain the great knowledge of having as little misery and as much happiness as possible.* Samuel Johnson to James Boswell, recorded in Boswell s Journal, 16 July 1763

PREFACE

In 1934, when I was still in high school, I entered a competition at the American Museum of Natural History, I won a prize of $25.00 for building a terrarium containing, among salamanders and tree frogs, some mosses and lichens. With the money I was able to purchase four books: *The New York Walk Book; Out Of Doors,* by William B. Mann, a well-known biology teacher; *Ferns of the New York City Region,* by John Kunkel Small, and *Mosses With a Hand Lens*, by Abel Joel Grout.

Mr. Grout was a high school teacher on Staten Island, and an associate of the New York Botanical Garden. He spent a lifetime becoming a specialist on mosses, and eventually produced a classic three-volume work entitled *Moss Flora of North America*, written with the aid of as many specialists as he could muster. *Mosses with a Hand Lens* was written from the standpoint that Grout felt that, with proper attention and guidance, a person could learn to recognize most of the common mosses of the New York City Region with the use of only a hand lens and his book. This book was so popular that people began to be fairly proficient but needed more. To meet the demand, Grout then wrote *Mosses with Hand Lens and Microscope*. This required more diligent and critical study, and the area covered was greater. Most professional biologists of my generation in America owe their starts to this remarkable man.

Grout's little moss books, now sadly out of print, were extremely useful in the Eastern United States, and have been followed by many useful books currently available there. One of the very successful ones based on Grout's philosophy was *How to Know The Mosses*, by Henry S. Conard 1956), one of the most beloved of teachers of budding bryologists. He was professor at Grinnell College, Iowa. Unfortunately, Conard's book was also designed for use in the eastern U. S., and did not help me at all in 1944 when I was collecting mosses as a hobby in the Columbia River Gorge. However, this fact was not too tragic, because it resulted in my corresponding with Dr. Conard, who helped me identify my mosses. Perhaps it was through helping people like me that he realized that he had to publish an expanded version that covered the entire United States. The latest edition is co-authored by one of Conard's protegés, Paul Redfearn, who has just now retired.

One of Grout's disciples was Seville (Bill , or to most of his students, Doc) Flowers, a long-time professor of all sorts of biology and botany at the University of Utah. Bill Flowers, over the years, emulated Grout in producing mimeographed outlines of keys to mosses, liverworts, and ferns, of Utah. He wrote very useful mimeographed class materials for students of bryophytes. He amassed a large collection as well, and painstakingly produced marvelous pen-and-ink illustrations for a book on the mosses of Utah. He did not live to see this published, but after his death, Howard Crum, bryologist at the University of Michigan, edited it and it was published under the name *Mosses: Utah and the West*. For Colorado bryologists this book has excellent descriptions and illustrations of nearly all of our Colorado species. The book also has one of the best introductions to moss morphology ever written in America.

I had a few early brushes with the world of mosses without being aware of them. At the age of twelve and getting interested in bird-watching, I used to roller skate from my home in Washington Heights over to Bronx Park, getting up very early in order to reach the botanical gardens at sun-up. There I used to tag along with an elderly

gentleman who had a white goatee, and who stood up very straight. He had a small binocular and when a good bird showed up he let me look at it through it. He showed me my first and only Prothonotary Warbler in the thickets below the middle of Boulder Bridge. We were told that Mr. Williams had been a Pony Express Rider, and one day he took me and my friends to his house on Webster Avenue and showed us his collection of South American hummingbirds and his real ebony Irish shellalagh. Years later I learned that this man was Robert Statham Williams, who as a business man had gotten interested in mosses and collected them, first in Montana and later in South America. The Pony Express story must have been a mistake, because it never ran in Montana, and for a very short time; he would have had to be about nine years old to ride the Pony Express. Perhaps he did carry the mail for some outfit in Montana. Who knows?

My second brush with bryology happened in Bronx Park one afternoon. I walked a few yards off the path to pick a leaf of Skunk Cabbage to show my friends. An elderly lady wearing a flouncy dress and wielding a parasol chased after us. This apparition, I was told, was Mrs. Gertrude Britton, wife of Nathaniel Lord Britton, the Director of the New York Botanical Garden. We used to call her the old witch of Bronx Park, and for a long time I never ventured into the herbarium building for fear that she would be there and recognize me. I learned many years later that Mrs. Britton was probably the most famous living Bryologist in America, who encouraged A. J. Grout to write his important books on the North American mosses. Mrs. Britton was herself a specialist in the mosses of the Caribbean region.

My high school biology teacher, Grace Esternaux, had me over to her house one day, and showed me her notes from a course she had taken about mosses at Cornell University. Besides the notes and drawings, she showed me her little collection of mosses, Some biological supply company sold sheets of paper, composed with borders and a space for writing labels at the bottom, noting the name of the moss, with the place and date of collection. She suggested that this would be a good hobby for me and told me how to order the sheets. So, beginning in about 1933, before I finished high school, I collected mosses, and now, with Grout s book, I found I could identify his selection very nicely, and all I needed was a hand lens, my eyes, and nickels for the subway ride to interesting localities.

The first moss I learned was *Dicranella heteromalla*, for this was the moss that grew in the cracks in the sidewalks in upper Manhattan where I lived. (in Boulder, one would undoubtedly start with *Bryum argenteum,* which fills the cracks in our sidewalks). I also collected in Camp Ranachqua, the Bronx Boy Scout Camp near Ten Mile River, Sullivan County, at a camp in Maine, and a camp in western Massachusetts for underprivileged kids, sponsored by the American Museum of Natural History. As I became more moss-conscious I began to collect many things that were not included in *Mosses with a Hand Lens*, and to find out what they were, I had to wait until 1937, when I was able to break out of the city and go to Iowa State College. By that time, Grout had published a second book, *Mosses With Hand Lens and Microscope*, and the first two volumes of his *Mosses of North America.* I spent many happy evenings in the herbarium, working out my unknowns.

My interest in mosses grew apace, and during my first year of graduate work, a summer field course took me to the Canadian Rockies, where there were all sorts of new mosses of a more northern persuasion. There I had me first and only personal acquaintance with Mr. Grout. I had collected a moss belonging to the genus *Splachnum*, but had difficulty running it down to species. I sent a bit of it to Grout, asking Could this be *Splachnum vasculosum?* He replied with a postcard saying Why not *Splachnum vasculosum?* From that moment I was a member of the growing host of amateur bryologists!

During World War II, I was an internee in the Conscientious Objector camp at Cascade Locks, Oregon. While not doing work of national importance, which involved, among other forest service chores, hand chopping ice from the main highway, I discovered a moss paradise. My comrades, who lived lives of desperation, would say, Well, he ll always have his mosses! This was very true. My collections grew and grew, but there was little literature available except a little paper-back book lacking illustrations, written by George Neville Jones, who started his college career at Pullman and wrote a thesis entitled *Mosses of Southeastern Washington and adjacent Idaho.* A gentleman named Barnes had also written an atrocious key to the genera of mosses of North America, which I had at my disposal.

Becoming frustrated at my inability to cope with this marvelous Pacific Northwest flora, I wrote in desperation to Dr. Henry S. Conard, a professor at Grinnell College in Iowa. I had met him once or twice at meetings of the Iowa Academy of Science when I worked at the registration table. He had written a little booklet of local Iowa mosses. Dr. Conard responded in a friendly way. He assumed at first that I was a forester who wanted to use mosses as indicator species in forest ecology. But when he learned what my situation was, he really opened up for me; he was a Quaker himself and sympathized with my position. He offered to identify my mosses, and sent me a small check so that I could join the American Bryological Society, and buy a pair of socks if there was money left over.

Many years later I became Secretary-Treasurer, Vice President, and President of the Society and presided at the meeting when the name was changed to The American Bryological and Lichenological Society. I never met Dr. Conard again. He had been invited to the University of Iowa upon his retirement. But I came across him once again when I was returning from Finland after an International Phytogeographical Excursion. I happened to be sitting in a waiting room at the airport and got to talking with a couple who asked me what I had been doing and what my interests were. I mentioned mosses, and their eyes lit up. We live in Florida, and there is a gentleman on our street who is also interested in mosses. His name is Dr. Conard! He had retired to Florida, and lived to a very ripe old age, one of our revered bryological ancestors.

Although I used to burn the midnight oil in the herbarium at Iowa State College trying to name all the mosses I had collected over the past decade in New England, I was frustrated because only two of the three volumes of Grout s Moss Flora of North America had been published. Of course, Grout had left the most difficult groups to the last, and struggled long and hard but so many of my collections remained unidentified. And besides, I had always been getting along with the flowering plants. In High School, Mr. Mortenson, one of my biology teachers, was required to buy a copy of Gray s *New Manual of Botany,* but since he never even cracked it, he gave it to me, and that s how I started on learning the New England flora. My classmates thought I was crazy to be carrying around, and actually *reading* what looked to them to be a facsimile of the Bronx telephone directory.

But before that happened I got a better start. I used to walk in Van Cortlandt Park on week-ends to see birds, and one day I met a young fellow who was taking a course at Columbia University. His name was José Antonio Jove, a Venezuelan boy whose family emigrated to New York from Caracas (his father had been an army general on the wrong side of things). José was carrying a little book that was a guide to the woody plants of the New York City parks in winter condition, and I tagged along with him and learned what I could. This was excellent training for anybody starting out in learning plants, simply because in winter time you only had the characteristics of the twigs and bark to worry about; the terminology needed to memorize was minimal. There were the gross characters of the bark: furrowed or smooth, corky or not, gray or black or white. Is the pith white or brown, is it solid or chambered? Is it terete or triangular? When the leaves fell off in the fall the petiole left leaf scars, so I had to learn to discriminate between different shapes of leaf scars, were they triangular, crescentic, did they completely circle the bud of next year? I learned to count the vascular bundle traces, discover the differences between surface features: hairs, lenticels, and glands. Are the buds (hence the leaves) opposite, alternate or whorled? Do they have several scales, like poplar, or a single one, like willow? Are there buds below the regular leaf bud?

I remember how useful this training was to me when I began to study the flowers and fruits of plants. Shortly after I met José, I came under the wing of a lady whose job it was to supervise a lot of other ladies who were involved on the W.P.A. project of re-mounting all of the specimens of plants at the New York Botanical Garden. One of the ladies rented a room in our house, and later on Miss Helene Lunt did too. On Sundays and holidays, Miss Lunt took me to an interesting botanical place and sat me down in a meadow and under her supervision I learned to key out the plants by using Gray s Manual. I had no idea there might be some simpler way (actually there was not, unless you wanted to carry around the three volume illustrated Britton and Brown.

All this to convey to you that if you want to become proficient you need to apply yourself, not be afraid to learn new terms, increase your general vocabulary, work directly with the plants in nature and not in a dusty schoolroom, and, most of all, try to be lucky enough to find someone who knows more than you do and is interested in you and willing to spend time as your mentor. The word mentor is one of the most important words in a budding

scientist s vocabulary. I was very lucky to have so many mentors.

Having said this, I must confess that I first learned about mosses without having at hand all of these appurtenances, and nevertheless feel I got a very sound grounding my moss studies. When I was in High School I built a small terrarium with mosses and lichens in it, and entered it in a contest (this was before the days of Science Fairs) at the American Museum of Natural History. With the $25.00 I won as first prize, I was urged by my biology teacher to buy a small book by A. J. Grout, *Mosses with a Hand Lens*. Thus, I acquired my first moss textbook on Christmas Day, 1934, and still find it useful over fifty years later!

Our (Ron Wittmann and I) guides to the Colorado mosses are patterned after the excellent series of little books written by the late Prof. Helmut Gams of Innsbruck, Austria, entitled *Kleine Kryptogamenflora von Mittel-europa*. They are *Excursion-floras* field guides to mosses, lichens, ferns, fungi and algae of Central Europe, and their author was one of the keenest field men in Europe. I remember following him in the field and listening and looking as he pointed out (*sotto voce* to himself) all of the various species he saw as he passed by. This is only one of the many ways one learns the lower plants.

As a compromise owing to the desirability of having an easily carried field manual, an Excursion Flora contains only keys and ecological notes. For more detailed descriptions and illustrations they presume the availability of more comprehensive literature. They also expect a certain amount of general biology background on the part of the user.

In order to make good use of this little primer, the reader should have access to one or more introductory books giving the basic information about the life histories and anatomy of mosses and liverworts. The very best one for mosses, I believe, is Seville Flowers, *Mosses, Utah and the West*. It contains some of the most elegant line drawings of mosses anywhere. Some common Colorado mosses are not covered.

At the moment, there is no book available that covers all of the mosses of Colorado. We are working on this. My *Guide to the Mosses of Colorado*, Occasional Paper No. 6, Institute of Arctic and Alpine Research, Univ. of Colorado, 1973, is long out of print, as is the punch card key to the genera of Colorado mosses, by Patricia Nelson. An electronic version of the latter has been made for our use, but it needs to be updated. Fortunately for you, our new manuscript (Weber & Wittmann) can be downloaded from my website, <spot.colorado.edu/~weberw>

The liverwort flora of Colorado is still imperfectly understood. We have found indispensable R. M. Schuster, *Boreal Hepaticae, A Manual of the Liverworts of Minnesota and Adjacent Regions.* 1953, American Midland Naturalist 49:257-684, reprinted as a single volume by the University of Notre Dame Press. Won Shic Hong, University of Great Falls, Montana, is publishing monographs of the liverworts of the Western United States in the journal, *Bryologist*. T. C. Frye and Lois Clark, of the University of Washington, published two volumes, *Hepaticae of North America*. University of Washington Publications in Biology, Vol. 6, 1937-1947. This is difficult to obtain except in libraries, and is not really suitable for amateurs. We are including the liverworts in our new manuscript.

In the meantime, the following volumes must be used for the identification of Colorado s mosses, although none of these deal with some of our rare alpine/arctic species.

Crum, H., & L. E. Anderson, *Mosses of Eastern North America* (2 volumes). Columbia University Press.
Flowers, Seville. *Mosses: Utah and the West.* A beautifully illustrated manual, recently re-issued as a reprint.
Lawton, Elva, *Moss Flora of the Pacific Northwest.* Hattori Botanical Laboratory, 3888 Honmachi, Nichinan-shi, Miyazaki-ken, Japan
Malcolm, Bill & Nancy. 2000. *Mosses and Other Bryophytes: An Illustrated Glossary*. Micro-Optics Press, Nelson, New Zealand. This is a very fine color-illustrated glossary of moss terminology.
Sharp, Aaron J., Howard Crum, & Patricia M. Eckel. *The Moss Flora of Mexico* (2 volumes). N. Y. Bot.. Garden; ;

There are a number of web sites that can be used to look up moss genera and species and to find drawings of photographs. Just find GOOGLE on the Internet and ask for mosses, bryophytes, or liverworts, and especially images.

The Flora North America Project deals with bryophytes, and the keys, descriptions, and illustrations of the genera and species. As they are completed they are available on the Web.

WHAT ARE BRYOPHYTES, REALLY?

The most succinct statement is a most recent one by Pederson, Cox, & Hedenäs (2003) and deals only with mosses:

> With an estimated 13,000 species (Crosby et al 1999), mosses are the second largest land plant group after the angiosperms. Mosses, like liverworts and hornworts, are characterized by a life cycle that is dominated by the gametophyte, with the sporophyte attached to the gametophyte throughout its whole existence. Spores are produced in a single sporangium which is attached to the apex of an unbranched axis called the seta. In most mosses, spores are released through the mouth of the capsule after dehiscence of a lid. The mouth of the capsule is lined by one or two concentric rows of teeth, which compose the peristome. When two rows of teeth are present, the outer row is called the exostome and the inner the endostome. Within the true mosses (i.e., class Bryopsida), two major groups are traditionally recognized based on sporophyte placement. These groups are the pleurocarps with extensively branched gametophytes bearing sporophytes on lateral branches, and the acrocarps characterized by sparsely branched gametophytes producing terminal sporophytes.

Brent Mishler (2001), in a recent review of an important new book on bryophytes (Shaw & Goffinet, eds., 2000), presents A radical view of bryophyte biology, or, Mosses are from Mars, Vascular Plants are from Venus. He makes a strong plea for the study of bryophytes: The bryophytes are clearly a key to understanding how the embryophytes are related to each other and deciphering how they came to conquer the hostile land environment from their primitive home in fresh water habitats still occupied by relatives of the land plants, the green algae. Yet despite their diversity, phylogenetic importance, and key roles in the ecosystems of the world, study of many aspects of the biology of bryophytes has lagged behind that of the larger land plants, perhaps because of their small size and the few scientists specializing on the group. This is unfortunate because of the intrinsic scientific interest of these plants. The bryophytes contain some of the most species-rich lineages of land plant, presenting a challenge (as well as opportunities) for understanding processes of evolutionary diversification.

In a summary, he lists nine differences between bryophytes and vascular plants that are important for anyone interested in bryophytes to understand. This essay was published in a professional journal that would not be seen by most amateurs, so I am quoting these nine points in full.

> 1. *Haploid dominance in the alternation of generations.* The green, vegetative part of the life cycle in bryophytes is haploid. Without the genetic benefits of dominance, genes acting in the gametophyte are presumably subject to relatively severe selection.
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> 2. *Extensive phenotypic plasticity.* Studies have shown that bryophytes tend to have very high amounts of morphological and physiological plasticity. This may compensate for their low levels of ecotypic differentiation (perhaps due to haploidy).
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> 3. *Poikilohydry and dessication tolerance.* Poikilohydry is the rapid equilibration of the plant s eater content to that of the surrounding environment, while dessication tolerance is the ability of a plant to recover after being air-dry at the cellular level. All bryophytes have these abilities to some extent, but, as discussed above, this was lost in the larger, more complex, and endohydric tracheophytes.

4. *Need for free water for sexual reproduction.* A residual feature of the early land plants is the constraint imposed by the swimming sperm. Swimming gametes have short dispersal distances that leads to frequent inbreeding in monoicous species and lack of sporophyte production in dioicous species.

5. *The clump as a super-organism.* Many mosses and some liverworts are essentially social organisms. This results from the combination of clonal growth, poikilohydry, and external water conduction. The plants in a clump are subject to natural selection as a group. Intimate contact of each vegetative cell with the environment, due to poikilohydry, lends itself to inter-plant chemical communication via pheromones.

6. *Heavy reliance on asexual reproduction.* Due to the difficulty of achieving fertilization, many bryophytes have evolutionarily lost functional sexuality. Since bryophytes grow from an apical cell, somatic mutation allows genetic variation even within clones.

7. *Small stature and the occupation of microhabitats.* Small size, lack of roots, and poikilohydry means that bryophytes are in a close relationship with only their immediate micro-environment. Over geological time, they may be less influenced by climatic change, and linger in refugial habitats.

8. *Less selection pressure from the biotic component of the environment than from the physical component.* Vagility [ability to spread] and establishment abilities of bryophytes are relatively poor. Available substrates are not filled in most metic and xeric environments (although they may be in some hydric environments). The presence of other bryophytes nearby often appears beneficial to growth.

9. *Relatively slow evolutionary rates in morphology.* The fossil record of bryophytes indicates their ancient forms are very similar to modern ones. Biogeographically, bryophytes tend to follow the same historical patterns of disjunction as tracheophytes, but at a lower taxonomic level. This may indicate that developmental constraints play an unusually important role.

The evolutionary effect of these features on the evolutionary ecology of bryophytes makes them profoundly different. By studying bryophytes and comparing their life style to that of tracheophytes, the student can learn to observe structure closely, think critically about evolutionary inferences, and comprehend how different lineages can take different functional paths in response to the same stimuli. Let us hope that this book [Shaw & Goffinet] will lead more students to study and enjoy this most wonderful group of plants.

WHY BE CONCERNED ABOUT MOSSES?

My friend Alan Crundwell, the Scottish bryologist (Perry & Long 2001), is quoted as saying, Bryophytes. . . are the wrong size. Bryophytes are of little economic use. . .There is no money in them!

Mosses are extremely sensitive indicators of environmental nuances, and they occupy, for the most part, very precisely delimited habitats. These habitats are often small, and few mosses rapidly colonize large virgin areas. Their distribution patterns, on the world-wide as well as on the local scale, reflect relictual or vanishing microhabitats. This is especially true in the Rocky Mountains, where aridity is the rule. The habitats of our mosses, except for a few pioneering species on recently disturbed, particularly burned, sites, are sites that have remained stable for extremely long periods of time. The presence of certain moss colonies can be used to indicate the presence of certain chemical ions or relative soil acidity, local anomalies of relative humidity, duration of snow cover, the occurrence of intermittent or seasonal water seepage, and other environmental variables that exist on almost too local a scale the justify the use of continuous sensitive recording devices for obtaining comparable data.

Mosses and erosion control

When you are sensitive to the presence of mosses in the field, you will see that they colonize well-trodden

surfaces, preventing them to erode further. They colonize cliff faces and sloping rock, preventing rapid of water flow down-hill. In early spring, if you dig up a tuft of a moss such as *Dicranum*, you may find that the part of the moss that is below the soil level is a solid chunk of ice! Old growth forests and healthy ones generally have a moss cover. Wet stream-sides have mossy banks. Even barren steppe soils may have mosses that you can only see after a shower. There is no question; mosses are more important vegetational protection from soil erosion than any other plants.

There is every reason, therefore, why ecologists should begin to pay serious attention to mosses, because they are able to tell us more about local environments than the more conspicuous trees and herbs. In Europe, mosses have long been used in forestry research and applied forestry. But identification tools are slow to reach a wide audience because the path to understanding these plants is tortuous, requiring critical and tedious research and attention to minute details, thorough experience in the field and the availability of excellent herbaria, long hours at the microscope, comprehensive libraries of the world literature and the development of special skills of dissection that are foreign to the work habits of most plant taxonomists.

Mosses as endangered plants

We who live in Colorado can hardly visualize that mosses in many parts of the world are a wild crop ripe for harvesting. But this is a real problem in eastern and western North America and in parts of Europe. In South Park,, drainage of the wetlands and the harvesting of a thin layer of peat, Colorado has already lost much of the local ecosystem. *Sphagnum* moss is no longer legally sold in Colorado, and the supplies come from northern Canada. Other mosses are rarely abundant enough to encourage harvesting, so we don t need to carry banners Don t Trod On These! in Colorado. But for the rainy regions of America, there is a crisis. Joshua Tompkins wrote the following account of this in the New York Times, Tuesday, November 30. 1004. I am deliberately omitting some paragraphs that contain misinformation concerning moss origin and evolution.

> While a rolling stone may gather no moss, what Dr. Robin Wall Kimmerer wants to know how quickly a stationary stone can collect it. Specifically, how quickly moss, when stripped from boulders or tree tunks or the forest floor, will grow back.
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> Dr,. Kimmerer, a professor of environmental and forest biology at the State University of New York College of Environmental Science and Forestry, is one of a growing number of researchers Ans land managers who are worried about the effect of commercial moss gathering. She has seen the aftermath of such gathering first-hand, having once bushwhacked her way up a muddy hillside in western Oregon, following the trail of harvesters to a grove of maple trees hiding in the mist.
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> Winded by the climb and bloody from thorn scrapes, she took on the scene described in her book, *Gathering Moss*. On the far side of a stream, the trees were swaddled in moss, its lush fabric wrapped around the trunks in woolly pelts and hanging from the branches like green gossamer beads.
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> But on her side of the water, the maples were bare. Their moss had been torn off, stuffed into burlap sacks, and hauled back down the hill. Frowning at a cigarette package left by one of the harvesters, Dr. Kimmerer marveled at how they had gotten their heavy prize through the salmonberry bramble and wondered if they knew what they had plundered. What it was, of course, is a living carpet that might have been a hundred years old, she said recently in a telephone interview.
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> Her frustration stresses the contradictory relationship humans have with moss, an ancient, primitive [sorry, while I agree that they are ancient, I don t agree that mosses are primitive at all!] plant whose role in the forest ecology is still just partly understood. Overlooked in its habitat or even mistaken for a blight moss is nevertheless sought for its aesthetic value in nurseries, craft stores and floral shops around the country, lining baskets and adorning wreaths.
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> With gatherers roaming public and private property for fresh pickings, the loosely regulated industry faces

scientific scrutiny as biologists and businesses clash over research findings, and land managers struggle to enforce collection policies across huge tracts with scarce personnel. Last year, harvesters in the United States bagged as much as 17 million pounds of moss, according to an estimate by Dr. Patricia Muir, a professor of botany and plant pathology of Oregon State University. Most of the moss is from the Pacific Northwest and Appalachia, where moderate winters and abundant rain allow moss to thrive.

Gatherers favor a few popular species, none of them endangered or threatened (no mosses are), pulling them from rocks and logs in the East and hardwoods in the West. Harvesters use bare hands and an occasional rake or ladder, but sometimes they get brazen: Oregon officials once saw harvesters who had strung a cable down a small valley and strapped a shopping cart to it to hoist moss up to the road.

The question is how soon new moss can take its place. A tree shrouded in moss may have needed decades or longer to get that way, and after harvesting, regeneration is even slower. Dr. Kimmerer s study of an experimentally harvested area found in some cases a recovery rate of only one percent per year. You re looking at a hundred years to get back to the initial volume, she said. Yes, it s a renewable resource, but not on any meaningful time scale.

Land managers in the Pacific Northwest and Appalachia are trying to curtail legal and illicit gathering. The Monongahela National Forest in West Virginia has ceased issuing collection permits, and the Siuslaw National Forest in Oregon limits the amount of moss that can be taken each year a few thousand pounds in some districts but many gatherers flout restrictions. It s a continuous problem, said Rich Babcock, the special forest products coordinator for the Hebo District in Siuslaw, the busiest collection area. You see a lot of moss going down the road in the late evening, and you don t really know where it s coming from.

At Washington s Olympic National; Park, where no commercial harvesting of any forest product is allowed, Dan Pontbriand, a ranger, said moss poachers were venturing farther and farther onto the property for their quarry. Gatherers will often pile bags of mosses in a secluded location and haul it away under cover of darkness. He estimates that for every arrest forest officials make, confiscating the crop and issuing a $250 fine, another ten harvests go unnoticed.

For years, the moss industry itself went largely unnoticed as well. Last spring, Dr. Muir finished the first comprehensive survey of the American moss harvesting industry in a report to the Fish and Wildlife Service and the United States Geological Survey. Questioning dozens of botanists, land managers, and moss dealers, she calculated that 10 million to 40 million pounds of moss had been collected annually nationwide in recent years. Accurate figures are impossible because many land managers still allow unlimited harvesting. Furthermore, Dr. Muir said: You ve got as permit, let s say, for 200 pounds. Nothing s going to stop you from harvesting ten times that much.

Laws in some states say otherwise. In Washington and Oregon, the small store-house operations and larger forest-product distributors that buy moss from harvesters are require to check the seller s permit for each haul. Yet whether or not the moss came from the area designated by the permit is practically impossible for buyers to know.

The Forest Products Packaging Company of Independence, Oregon, buys more than 300,000 pounds of moss from harvesters every year. Its owner, Dick Reinhard, said the burden of obtaining permits and avoiding prohibited areas has forced many smaller gathering outfits out of the business. He also says he believes moss grows back faster than scientists claim. After an area is picked clean, with adequate shade and moisture it will be regrown within five years to the pont where you can t tell, he said.

At retailers, moss can fetch as much as $5 for a four-ounce bag, and much of it is sold on the Internet. Moss export figures are compiled by the United States Department of Commerce, but domestic sales are not. Dr. Muir puts total annual sales anywhere from $6 million to $165 million. The market has fluctuated sharply in

the last decade, dropping off in 2001 but doubling last year.

If harvesters and wholesalers regard moss as a commodity, many park visitors didn t notice at all. Flourishing in the shadowy boscage of old-growth forests, moss is nature s wallpaper, with all the lack of sexiness that implies. And though its perseverance can invoke a kind of meditative sympathy the poet and occasional gatherer Theorore Roethke wrote of the guilt he felt after pulling off flesh from the living planet the experts calling attention to the plight of moss realize it hardly possesses the majesty of a humpback whale or the pathos of a harp seal pup. :We conservation biologists think of those as the charismatic megafauna, Dr. Kimmerer said. I like to think of the mosses as charismatic microflora, but you have to look close.

Indeed, under the magnifying glass the seemingly featureless façade becomes a tiny forest unto itself, a microcosm of stalks and leaves. Without roots, seeds, or a vascular system, mosses work hard to build this infrastructure, enduring a two-stage reproductive cycle that sends millions of spores out a few inches to start new growth. Only a tiny fraction succeed, though mosses can also clone themselves with nearly any piece: a broken-off shoot or leaf can foster a whole new plant.

Harvesting removes more than just moss. The coral reef of the forest, it is the home of dozens of tiny creatures mites, springtails, microscopic rotifers, and others. Dr. Neville Winchester, an entomologist of the University of Victoria, has counted more than 300 species in some tree canopy moss colonies. And the marbled murrelet, an endangered sea bird, flies miles inland to nest on moss mats in the trees.

Concerns about the sustainability of wild moss lead to a question. Can it be raised instead? Though bryology has been around for centuries, virtually nothing is known about cultivation. It really is time that we start learning how to farm them just as we do corn and tobacco and everything else , said Dr,. Nalini Nadkarni, a forest ecologist at Evergreen State College in Olympia, Washington. Predicting that moss s low-key nature would be well suited to the prison setting, where horticulture has become a popular rehabilitation therapy, Dr. Nadkarni began a moss program last fall at the nearby Cedar Creek Correction Center in which about a half-dozen inmates experiment with differing growing methods. Despite promising results, Dr. Nadkarni realized that even a large commercial moss farm or two will barely dent the market. It might start out as a boutiquey thing , she said, hoping eco-conscious consumers may go for hand-tended moss the way they have flocked to cachets like green timber products and shade-grown coffee. If we don t come up with ways to provide an alternative, then we re stuck with naked branches.

Collections

This guide could not have been undertaken without the data bank consisting of collections in the University of Colorado Museum and all the other museums in which collections from Colorado have been preserved during the period of exploration of the nineteenth century. Many people do not realize the enormous value of these collections. Only two or three bryophytes were collected by the Lewis and Clark Expedition (1803-1806) but they are still as readily available for study as when they were picked up. These plants do not deteriorate with age, so long as they are kept dry.

The most important herbaria for the study of early collections of Colorado bryophytes are the New York Botanical Garden, which assumed the care of the collections of Columbia College, where John Torrey worked, and Harvard University, where T. P. James worked. The University of Colorado Herbarium was started, as noted above, by Geneva Sayre, and under my curatorship during the past fifty-odd years, it has grown through the efforts of those of us who as faculty or students have collected and contributed specimens, and through exchanges of duplicate specimens with herbaria allover the world. In 1953 the herbarium was able to receive on exchange an almost complete set (about 4,000 specimens of mosses and lichens) of the Exsiccati of the Naturhistorisches Museum of Vienna. During the administration of Oswald Tippo as Provost of the University of Colorado, we were able to purchase very important collections of European bryophytes. Later we were able to receive the collections of Seville Flowers, as well as his field notebooks and original plates for *Mosses: Utah and the West*, as a gift from the University of Utah, and Carnegie Institution of Pittsburgh s collections of hepatics.

In order for us to understand the bryophytes of Colorado we needed to have material from many other parts of the world, including Arctic America, Australasia, Japan, Europe, Africa, and South America. And we have needed to ask the advice and counsel of specialists from all of these places. One does not simply got into the field and use the available keys and descriptions. Writing a regional bryophyte flora is a major undertaking. It is obvious that the help of herbaria and professional bryologists is of paramount importance. But we want to give special credit to the collectors, casual, amateur, or otherwise, who have made our collections possible.

The importance of collectors

It is very unfortunate that collectors have never been given their due. Peter Raby, in *Alfred Russel Wallace: A Life. 1992*, writes:

> Working entomologists such as Wallace. . . were not accepted [into the ranks of the scientists] without a slight struggle. . . . Edward Newman, in his presidential address of January, 1854 [to the Entomological Society of London] had to underline the value of the actual collector , as opposed to the professional experts in the museums of London, and the connoisseurs of the rectories and country houses:
>
> > The monographer cannot say to the collector, he specified: I have no need of you. The very admission of such a thought is a stumbling-block. . . I wish to be understood as applying this last observation especially and emphatically to the case of the actual collector; to the man who, in whatever station in life, devotes his time, by night and by day, at all seasons, in all weathers, at home and abroad, to the positive capture and preservation of those specimens which serve as the objects for all our observations. He is the real labourer in the field, and if we could keep the lamp of our science constantly burning, it is to him alone that we can look for fuel to feed its flame. . . . Such men do great, permanent, and continual good. They render our science an unquestionable service, and their motives are no more to be called into question than those of the artist or the author, who receives the just reward for his well-directed labours.

Early in 1997 I was approached by my colleague, Dr. Uno Eliasson, at the Botanical Museum of the University of Göteborg, Sweden, asking if I would like to have as a gift for the COLO Herbarium of a large collection of moss and liverwort specimens. These were considered duplicates of what they already had, and my

friend thought that, since I am fluent in Swedish and calligraphy, I might be the best person to curate them. Since our collection of cryptogamic plants is one of the largest in the United States, he felt that this infusion of Scandinavian specimens would be useful to us. We already had a complete set of Swedish flowering plants assembled by Gunnar Samuelsson and distributed by the Riksmuseum in Stockholm, as well as an excellent collection of Scandinavian lichens, as well as my own collections from 1957-8.

The bryophyte collection that we received from Sweden has a very interesting history. During the nineteenth century there was a very active informal club of amateur and professional botanists interested in bryophytes (mosses and liverworts). They exchanged specimens through the good offices of the Botanical Museum of the University of Göteborg. These people, aside from the prominent professionals, were what we might call lay amateurs. They were teachers, lawyers, physicians, priests, accountants, bureaucrats, and others who had time and inclination to learn the flora. A member would send a quantity of a particular species to the exchange club, and he or she would be credited with that number. A master list was circulated once or twice a year from which members could select specimens deposited by other members. In this way an amateur could quickly build a representative set of Swedish bryophytes. The exchange club, called Flora , apparently began in 1824 and closed down in the 1940s. We were being offered the remainder of the club s holdings.

The number of specimens was staggering. The University of Colorado Herbarium contained up to the time of this gift about 100,000 specimens. The unicate set of the Göteborg collection numbers over 4,500 specimens, which will give us one of the finest holdings in America of Scandinavian mosses. Not only are there the common mosses of Sweden, but a remarkable collection of bryophytes from Spitzbergen, North Norway, and north Greenland, which were collected between 1861 and 1868 by Sven Berggren and A. J. Malmgren on voyages of rescue in the Arctic (*Plantae in itineribus succorum polaribus collectae*), which formed the basis of our knowledge of that flora..

There were, in fact, many duplicate specimens in the Göteborg gift; sets have been sent to the following institutions: Crakow, Poland (Ryszard Ochyra); University of California, Berkeley; Missouri Botanical Garden; New York Botanical Garden; the Australian National Herbarium, Canberra; and the University of British Columbia.

The names of the collectors are listed below. It seems incredible to an American that there should have been such a great interest in bryophytes among amateurs in Sweden or anywhere else, for that matter. However, bryophytes were not only a fad. Sweden, of course, was the home of Linnaeus, who is still greatly revered (despite the fact that he considered mosses and lichens the dregs of creation). And it was from the heavy metal residues captured by the mosses while they were alive that made possible the recent mapping of the march of the Industrial Revolution through Scandinavia! At the University of Lund there was a long-lived exchange club for mostly vascular plants and plant insect galls (zoöcecidia). My good friend Lewis Rose, of San Francisco, collected thousands of California plants, sent them to the Lund Exchange Club, and he donated the specimens he received over the years to the California Academy of Sciences. Lewis urged me to join, and for a few decades I, too exchanged with the club. When the Lund Exchange Club closed down the remaining members were invited to choose any or all items remaining on the accumulated list, free, and this set added materially to our world-wide holdings, for the club did not restrict its activities to Scandinavia.

Swedish collectors represented in the Göteborg exchange club, FLORA, 1824-1942
Given to the COLO herbarium, 1997, by Göteborg Botanisk Trädgården

Adlerz, E.	Andersson, A. A.	Arvén, A.	Baur, W.
Adlerz, Gotefried	Andersson, G. A.	Ångström, J.	Bäumler, J. A.
Ahlberg, F.	Andersson, L.	Asplund, Erik	Beckhaus
Ahlfvengren, Fr. E.	Areschoug, F.W,C.	Asplund, Martin	Bengtsson, L.
Ahtz,	Arnell, H. Wilh.		Bergner, Carl
Alfthin, A.	Arnell, Sigfrid	Barabas, V.	Bergström, C.A.
Allmandinger	Artaria, F. A.	Baumgartner	Bergström, Sixten

Berndes, Ulrik
Berndes, W. & E.
Bernet, D.
Bertram, Pastor W.
Besler
Binning, Axel
Binstead, C. H.
Birger, Selim
Björke, A.
Björkman, A. T.
Björling, E.
Björnström. F. J.
Blomberg, O. G.
Blumrich. Prof. J.
Bock, W. von
Boros, A.
Bottini, A.
Brockhausen
Brotherus, V. F.
Browa, Th.
Bryhn, N.
Buch, Hans
Bägenholm, G.

Calman, C.
Carlson, G.W.F.
Cash, F.
Cedergren, G. R.
Charrier, J.
Clemens, M. S.
Cleve, P. T.
Collinder, E.
Corbière, L.
Cornet, J.
Culmann, P.
Cypers, V. von

Dafones
Davidsson, O.
Dietzow
Ditmer, Dr.
Dupret, H.
DuRietz, G. Einar
Dusén, K. F.
Dusèn, Peter
Duterte

Eberhart, Dr.
Egler
Ekman, Erik L.
Ekstrand, E. V.
Ellingsen, Edv.
Elmqvist, Fr.
Eriksson, Joh.
Everken

Fagerlind, G. R.
Familler, Ignatz
Filarszsky, F.
Fleischer, Max
Forssell, Hans
Forssell, K.B.J.
Forster K.
Fristad, R. F.
Fritze. I.
Fröding, H. A.
Frymann, J.
Fryxell, Anders

Gardet
Geheeb, A.
Gjörffy, Istvan
Glowacki
Golinz, J.
Goradnova, E.
Göransson, Ant.
Görtze, And.
Graf, Hugo
Grane, A.
Graw, A.
Grossmann, H.
Groves, J.
Guillaumet
Gustafsson, John

Hagen, I.
Hager
Haglund, E.
Halle, T. G.
Hällström, E. af
Hamnström, C. O.
Hampus & Post
Hansen, August
Hartman, Carl
Hartman, Robert
Hayek
Hasslow, Olof J.
Heintze, August
Heldreich, Th. de
Hellsing, Gustaf
Helm, Fl.
Hester, G.
Hintze, F.
Hjärne, Carl E.
Hjertman, Ernst
Högman, Laura
Holler, A.
Holm, Oto
Hollmén, Hans
Holmgren, Hjalmar
Holst, N. O.
Hult, R.
Hulting, Johan
Hülphers, A.
Hunt, G. E.
Hurst, C.P.
Håkansson, T.
Hålmarsson, T.

Indebetou, Conrad
Issén, P. A.

Jahns
Jensen, C.
Johanson, C. J.
Johansson, K.
Johansson, Yngve
Jonas
Jörgensen, E.
Jungner, J. R.
Jäderholm, Elof

Karlström, P. O.
Kaurin, Christian
Keller, Dr. Robert
Kern, F.
Kindberg, N. C.
Kjellberg, G.
Kjellman, F. R.
Kleist, G.
Köpsch, A.
Kolbzig, E.
Kotilainen, Mauno
Krusenstjerna, E.
Kühlmann, A. Osc.
Kurek, C.

Lagerberg, I.
Landegren, Carl
Larsson, E. L.
LeJolis
Larsson, P. A.
Lehtonen, Lauri
Liljeholm, A. F.
Lindberg, Harald
Lindberg. S. O.
Lindgren, S. J.
Linnaniemi, W. M.
Ljungström, Ernst
Löfvander, C. L.
Löfvander, K.
Loitlesberger, K.
Lorentz, P. G.
Lundqvist, P.
Lübeck, W. O.,
Lund, Samsas
Lång, G.
MacFadden, F. A.
Magnusson, Axel
Malmgren, A. J.
Malmgren, G.
Malte, M. O.
Medelius, Sigfrid
Mihai, G.
Milde, J.
Möller, Hjalmar
Möller, Otto
Mönkemeyer, W.
Mosén, Hjalmar
Müller, F. von

Müller, H.
Nichols, G. E.
Nicholson, W. E.
Nilsson, Bror
Nilsson, Herman
Nilsson, O.
Nordstedt, O.
Nordström, K.
Nyholm, Elsa
Nyman, G. W.

Oldberg, R.
Olson, A. D.
Olsson, P.
Oslem, B. Wilh.
Österlind, F. O.

Palmér, J. E.
Palmgren, O.
Persson, John O.
Peterson, Bo
Podpera, Josef
Progre

Rancken, Holger
Rekstad, J.
Retzius, G.

Riehmer, E.
Ringselle, G. A.
Rosendahl, H. V.
Rostrup, E.
Roth, Georg
Ruthe, R.

Samuelsson, G.
Sandberg, Carl
Sandberg, M.
Sanio, C.
Schellenberg, G.
Schenk, Ferdinand
Scheutz, N. J.
Schiffner, Victor
Schimper, W. P.
Schlegel,
Schliephacke, K.
Schotte, Gunnar
Schumacher, A.
Seth, K.A.T.
Sheel, G.
Sillén, O. Leopold
Simmons, H. G.
Skottsberg, Carl
Sloumans, H.
Smith, Harry
Söderberg, Ivar
Söderström, C. E.
Spindler, M.
Spruce, Richard
Stenholm, Carl
Stenström, K.O.E.
Sterner, Rikard
Stolle, E.
Strandmark, J. E.
Suse, Theodor
Svanlund, J.F.E.
Svensson, Gösta
Szurák, J.

Tedin, V. H.
Thedenius, Hugo
Thedenius, K. F.
Trana, Erik
Trautmann, C.
Trautmann, W.
Trulsson, Åke
Tufvesson, Elsa
Tullberg, S. Axel
Tullgren, H. A.
Turner, C
Vetter, H.
Vetterhall, Erland
Vinge, Axel
Vrang, Erik Walther

Warnstorf, Joh.
Wegelius, Axel
Weimarck, H.
Westerberg, F.O.
Westergren, Tycho
Westling, F.
Westling, P. A.
Wheldon, J. A.
Wickbom, J.A.D.
Wilms, F.
Wirén, Erik
Wulfsberg, N.
Zetterstedt, J. E.
Zimmermann, F.
Åberg, G.

THE DETAILS OF CURATION

For those who may not be aware of the way that bryophytes are collected and stored as herbarium specimens, a few remarks are in order. Mosses and liverworts are collected in the field in paper bags or newspaper packets, and are allowed to dry naturally under gentle pressure so as th decrease their bulk but at the same time not to change their natural appearance. Usually the specimens are collected for one dominant species, although some hepatics, especially, grow in mixtures, so that while each species in a mixture is saved in its own packet, the name on the packet should be one of the species in the mixture. In these old Swedish collections, packets were made of various kinds and sizes of brown paper (ledger sheets, penmanship drills, book pages, etc.), some durable but others becoming strongly oxidized and brittle over time. A label was usually pasted on the packet with a small dot of mucilage, indicating the name of the plant, the province from which it came, the socken (parish), some brief ecological information, the date, and the collector s name. Some of the specimens had press-printed labels, but most of them were hand-written, with various abbreviations known only to Swedophiles. Dates on the specimens ranged from the 1830s to the 1940s.

Our job was to bring the specimens up to our standards of curation. The original packets were of odd sizes, and the paper was usually highly oxidized. The collection data, sometimes with old hand-written labels or hand-written on scraps of newspaper, had to be transcribed from Swedish script, and the nomenclature brought up to date. Then the specimens had to be transferred; each was placed on a numbered card corresponding to a numbered packet measuring about 4 x 6 inches folded from 8 ½ x 11 inch stock, New labels were typed on the computer to replace the hand-written ones, saving the original information and labels inside the packets. In doing all this, the specimens had to be separated from the collection data for some time. This operation was made possible because the herbarium staff generates packets and cards that are serially numbered. Packets are of two sizes, 4 x 6 inches, or, for oversize specimens, 8 ½ x 11 inches.

This process produced a huge bank of specimens on cards, organized in groups of eight, separated by sheets of newsprint, and temporarily stored in bundles marked by their contents. The labels were removed and placed with the respective packets (the old data stored inside the packets). The packets were returned to the herbarium mounting mill where their labels were pasted on them. The packets then were returned to me for collating specimens and packets. The specimens then had to be entered individually by name in the accession book, then alphabetized. Alphabetizing about 4,500 specimens is very slow work, so it was done in small groups, then merged into the larger ones. Finally the collection was ready to file.

To some, these details would be sheer drudgery, but it is a large part of what curation is: painstaking and tedious work, now made much easier by the computer, which can produce labels and enter accessions so much faster than before. It would have been wonderful to have had a computer 50 years ago, for curation is less romantic than discovery and identification of species. In this instance, no untrained clerk could have accomplished it, because special knowledge of the material is required, and the ability to read a myriad of different handwritings, variations in spellings of the geographic areas, and a scientist s ability to update nomenclature dating from over a century before. Nevertheless, it is always thrilling to us to see the individual collections as they appear and as we have to handle them, for it impresses upon us the presence or lack of variability within species as well as reinforces my knowledge of their geographic distribution. This experience may never be replaced by electronic scanners!

WHY BE CONCERNED ABOUT MOSSES?

Mosses are extremely sensitive indicators of environmental nuances, and they occupy, for the most part, very precisely delimited habitats. These habitats are often small, and few mosses rapidly colonize large virgin areas. Their distribution patterns, on the world-wide as well as the local scale, reflect relictual or vanishing microhabitats. This is especially true in the Rocky Mountains, where aridity is the rule. The habitats of our mosses, except for a few pioneering species, are sites that have remained stable for extremely long periods of time. The presence of certain moss colonies can be used to indicate the presence of certain chemical ions or relative soil acidity, local anomalies of relative humidity, duration of snow cover, the occurrence of intermittent or seasonal liquid water seepage, and other environmental variables that exist on almost too local a scale to justify the use of continuous sensitive recording devices in order to obtain comparable data.

There is every reason, then, why ecologists should begin to pay serious attention to mosses, because they are able to tell us more about local environments than the more conspicuous trees and herbs. But identification tools in this field are slow to reach a wide audience because the path to understanding these plants is tortuous, requiring critical and tedious research and attention to minute detail, thorough experience in the field and in excellent herbaria, long hours at the microscope, comprehensive libraries of the world literature, and the development of special skills of dissection that are foreign to the work habits of most plant taxonomists.

Mosses often have much larger or more widely disjunct distribution patterns than do flowering plants. The Southern Rocky Mountains draws its flora from the obvious migration pathway afforded by the immense north-south extent of the Western American Cordillera, and some of our species are here as a result of mountain connections which no longer exist. Every drainage system that radiates from the core of the range also serves as a highway of migration for riparian and lowland or desert species. An apt analogy is that of a great wheel, whose hub the Southern Rockies, preserves the most ancient survivors, and whose axle and spokes the Cordillera and the drainage systems, provide the pathways along which migration has taken place through time under the pressures of climatic shifts and orogenic movements.

At the present time the moss flora is predominantly oroboreal (circumboreal-montane), as testified to by the fact that all but a very small number of species are common to Colorado and Scandinavia. A residuum of desert and lowland elements enters along the drainage systems from the Southwest and East *(Crossidium, Aloina, Pterygoneurum)*. A very small number of world-wide disjuncts can be considered to be ancient relicts of Tertiary floras *(Anacolia, Leptodon, Leptoperigynandrum, Oreas)*. There is virtually no endemism in the moss flora of the Southern Rocky Mountains although certainly there are mosses endemic to the larger Cordilleran system.

MUST-HAVE LITERATURE

No single book or bibliographic source will be sufficient to satisfy anyone who becomes deeply involved with bryophytes. For the Rocky Mountain Region, especially, the following titles are almost indispensable. Complete citations of these books will be found in the bibliography.

Conard, H. S. 1956, 1979. How to Know the Mosses. For beginners, this is the only easy guide. Unfortunately, It

does not include enough of the western mosses to be of great value.

Crum, H. 1973. Mosses of the Great lakes Forest. Although this treats only part of Michigan, it treats many of our mosses, especially the forest, fen, and widely distributed circumboreal species, and is interspersed with delightful stories and unusual facts.

Flowers, S. Mosses: Utah and the West, This has probably the best introduction to the life history and anatomy of mosses available, written from the standpoint of a great teacher. Also, the pen-and-ink drawings are magnificent.

Malcolm, B. & N. 2000. Mosses and other bryophytes: An Illustrated Glossary. A dictionary that has the advantage of beautiful color photographs of the characteristics of bryophytes, The illustrations are chiefly drawn from specimens occurring naturally in new Zealand.

Rodgers, A. D. 1940. Noble Fellow: William Starling Sullivant.

Schofield, W. B. 2002. Field Guide to Liverwort Genera of Pacific North America.

Sharp, Crum, & Eckel. 1994. The Moss Flora of Mexico.

Zander, R. H. 1993. Genera of the Pottiaceae: Mosses of Harsh Environments.

A remarkable treatise on the ecology of bryophytes, unfortunately little advertised in America, is Olle Mårtensson s *Bryophytes of the Torne Träsk area, northern Swedish Lappland*. Since it deals with many of our high altitude species, it is a very important paper for Rocky Mountain botanists, and is the kind of a study that needs to be done here.

WHERE DO I START?

To learn mosses, the best way, in my humble opinion gleaned from very long experience, is **not** to start as you would in a college course by learning the characteristics of a hundred families. You ll just forget them like you would any other memorized list of things you have never seen for yourself. Instead, start by learning a few easy species. Then learn a few more. Soon you will have seen two or three species of a single genus and you will get a feel for that genus. Take someone with you who knows more than you do. After a few field trips you will have learned to recognize on sight about 25 species, and you will begin to understand that like oaks and maples., there are genera of mosses (for the time being, forget about families. They will come later (if ever).

You should be able to find several common, easily recognized mosses if your house has a yard and some sidewalks. If you don t have that luxury, look around you.

THE SIZES OF MOSSES

In our flora, I think we can safely divide our species into about four slightly overlapping sizes: **B:** big (to be measured in inches), **M:** medium (the leafy stem to be measured in a few centimeters); **S**: small (forming low tufts with rather short leafy stems but easily seen with the naked eye, and **T**: teentsy-weentsy. In this primer we are going to deal mostly with the first three. So the list below will begin with **B, N,** or **S**. Let s see if we can agree on this very rough classification! This is a trial run; it may not be possible to categorize these as well as I hope!

ACROCARPY, PLEUROCARPY AND POINTS BETWEEN

These terms refer to the growth and branching form of mosses, more particularly to where the sporophyte arises. Mosses are either erect or they creep. According to Crum & Anderson, mosses are **acrocarpous** if they

produce the sporophyte at the end of the stem or main branch . They usually grow erect in tufts rather than creeping mats, and are sparsely branched. They are **pleurocarpous** when they produce their sporophytes laterally rather than terminally; they are usually creeping, freely branched, and matted. In Colorado so many mosses rarely or never produce sporophytes that one commonly goes by the growth habit alone in using these terms.

However, there are transitional forms. One of our most abundant and easily recognizable mosses *Hedwigia* is obviously pleurocarpous if one considers only the branching system, but acrocarpous in that it has terminal sporophytes. But since one learns this species so readily, and it is so common, why worry about this question?

A few other genera might appear to be transitional. The very common wet seepage moss, *Philonotis*, certainly has terminal sporophytes, but very often the fertile plants have a whorl of widely spreading branches just below the sporophyte. Again, this is extremely easy to recognize, The genera allied to *Mnium* obviously are acrocarpous, but in the genus *Plagiomnium* the erect stems produce terminal sporophytes, but there are horizontal stolons that creep. You should get used to exceptions!

FAMILIES OF MOSSES

In a university class on mosses you probably can expect to learn fifty to a hundred families; this is the pedagogical way. But unless you begin your study in the field with the live plant you may go out of class with a grade but still not be able to recognize a moss when you see one. For mosses, forget it! Families are not easy pigeon-holes with neat characteristics. A good moss person does not learn the families of mosses from the top down, but by slow accretion from the bottom up. First you learn to recognize on sight some of the easy species, tem gradually you learn more species that are in the same genus. That makes very good sense. From then on you may start to get a vague feeling of the relationahip between genera. And let me tell you, that when you become a professional,. You begin to wonder where one family leaves off and the other begins! So be patient and be happy to learn well the common and easily recognized species first. After that yoyu will have to become accustomed to using two expensive microscopes, learn to cut sections of leaves and stems, dissect the sporophyte to examine the structure of the peristome, measure cells and spores. Let s face it, some folks will be happier with a little knowledge, but for anyone who persists, the detailed study of moss plants opens up a whole new world!

Have someone who knows the mosses take you in the field, have you collect some easy ones, and learn the subtle ways of recognizing them. They may look quite different wet or dry! Get some of the floras and study the illustrations. Brush up on your long forgotten Biology One information on the moss life cycle, and by all means get to see all of the features in the flesh that you have read about in the elementary textbook. This way tyou sill never forget them!

THE LEAVES OF MOSSES

or, Things are seldom what they seem!

Since so much of what we are concerned with in bryophytes is their leaves, we have to talk about them.

The word leaf does a lot of work in the English language, probably more than it does in most others. German, *Blatt*, French, *feuille,* Italian, *folio,* Swedish, *blad*, Russian, *leest*, The Latin word, *folium* stands for leaf and its many meanings. Shakespeare s plays appeared in a Folio edition. In English, a book has pages that are commonly called leaves. Gold, pounded into a thin sheet, is called gold leaf. An expandable dinner-table has leaves. Flowering plants have leaves and foliage. These meanings of the word are well understood and accepted by ordinary folks. But here s where we get into trouble. We never speak of moss leaves as foliage , for good reason. Mosses don t have leaves! Let us explain.

Most people seem to assume that the main function of leaves, as they know them, it the production of chlorophyll. This function, however, is not restricted, even to the leaves we usually talk about. Potatoes are to be

avoided when they are green because of the prussic acid they contain, but the green is chlorophyll. We distinguish between sepals and leaves although they are very close cousins. Peel the bark of an actively growing twig and you will find it is green inside the epidermis chlorophyll. Granny Smith apples are green chlorophyll.

It may come as a surprise even to many botanists that the leaves of mosses and liverworts have nothing much to do with the leaves of other plants save for their common production of cblorophyll. In fact, bryophyte leaves have many other functions, possibly the least of which is the production of chlorophyll. Moss leaves do not have stomates (isn t that odd?). The moss structure homologous to the leaves of flowering plants is the seta and capsule, which constitute the sporophyte. The moss leaf is part of the haploid gametophyte. The capsule, which is part of the diploid sporophyte, is also green and, believe it or not, it has typical stomates in its wall although they are very few, sometimes only one! So we have to shift gears when we talk about the leaves of mosses.

Evolutionarily speaking, the sporophyte of mosses is clearly a reduced structure that once was much more complicated, because its stomates evidently are no longer of much use in regulating gas exchange as they do in flowering plants. Mosses are not at all primitive but have a history during which the sporophyte was very likely to have been an independent plant that has become a reduced structure parasitic on the gametophyte. Leo Koch, who was a colleague back in the University of Illinois, suggested that we call moss leaves phylloids but no one in America has adopted the term. Nevertheless, in Spain, where bryology has recently come alive, the term filoidia is being used. Let s elaborate a little on this.

The leaf of vascular plants is totally different from a bryophyte leaf. It is defined as a structure on the stem that produces a bud in its axil. Structurally a leaf is complex. First of all, it is a diploid, sporophytic structure. It is a virtual sandwich, with an upper and lower epidermis enclosing an upper layer of cells (palisade layer) packed with chloroplasts, where the work of photosynthesis goes on. Below this is a layer of very loose tissue with few chloroplasts and many air spaces. The lower epidermis typically is a single cell layer that it pock-marked with stomata, which permit gas exchange. The stomates have guard cells which inflate and deflate, creating and closing holes in the leaf. These stomates are identical to those that are found on the moss capsule, never the moss leaves! And the leaf gets strength from a branching system of vascular bundles (veins) in which movement of water and photosynthetic products are transported into the stem and to the roots.

Moss leaves . On the other hand, are haploid structures. They lack layered structure and never have stomates. Most moss leaves are only one cell thick (rarely two). They lack hairs or glands. They do not have branched venation although some may be forked at the base. There is no conducting tissue. Moss leaves receive their moisture directly by imbibing vapor or moisture instantaneously (in most dry habitats) while some aquatic or wetland mosses resist wetting.

Moss leaves can remain dry for indeterminately long periods. They also can take advantage to slight traces of moisture. They do not grow continuously, so their cells do not need to be turgid all the time. Moss leaves usually have quite a different appearance when dry or wet. The leaves may be erect, wet or dry, or when dry they can be straight or twisted or curled. These changes in the shape of the leaf depends on the shapes and sizes of the cells, the thickness of their cell walls, their presence or absence of a differentiated border. the presence or absence, and thickness of a mid-rib (costa). The cells may differ in size, shape, and wall thickness in different parts of the leaf (basal , alar, mid-leaf, apical.

In Colorado, you will have to get used to the fact that you will have to learn to recognize moss leaves wet or dry. To delve deeply into the characteristics that make different mosses different you will naturally have to develop your skills in recognizing subtle differences. You should be able to recognize a great many moss species using no more than a 10X hand lens, but in order to get serious about mosses you will need to have two microscopes, one compound (at least 400 times magnification and one stereoscopic, with at least 100X magnification. You will also have to learn to use a pair of tweezers and bits of razor blades to make cross-sections of the leaves.

As amateurs you may be happy to learn the common larger mosses by their gross aspect, but you will not want to stop there. A whole new world will open to you once you have used the microscope.

ACROCARPOUS MOSSES

Andreaea

Andreaea rupestris is one of our rarest and most interesting mosses. It is only distantly related to the true mosses and forms a class of its own, the Andreaeobrya. The capsule is its distinctive feature, because it not only does not have the peristome mechanism of other mosses, but the capsule opens instead by means of four slits along the sides while still connected above and below. The capsule then collapses as if from downward pressure to form what resembles a Japanese lantern.

Andreaea plants form small tufts of very slender stems and extremely small leaves. They are black! The most frequent species occurs on granite rocks on the alpine tundra but also on outcrops in spruce forests of the upper subalpine. To find *Andreaea* one has to become well acquainted with *Grimmia*, the other dark green moss of alpine boulders, and look at hundreds of tufts of *Grimmia*, and as many times hoping to have found *Andreaea*. An *Andreaea* discovery is always an exciting event, especially so if there are any capsules!

Aulacomnium

Aulacomnium palustre is the most abundant acrocarpous moss of mountain wetlands of all types. The lowerr stems are conspicuously covered with red-brown rhizoids that tend to hold clumps together. Its lower leaves are brown and the leaves of the season are quite yellow-green. The leaves are characteristically lanceolate, tapered to the apex and twisted. At the stem tips there commonly is a naked, short stem terminated by a cluster of small flat gemmae. Capsules are rather uncommon, slender, with a conical operculum, and strongly ribbed.

The only other local species, *Aulacomnium androgynum,* is much smaller, with short, broad leaves, and almost always with gemmae-bearing stems. Its habitat is seldom in wetlands, but in moist forest gullies, where it commonly occurs on rotting wood.

Bartramia

Bartramia ithyphylla is a rock or cliff-dwelling moss forming tufts about an inch or so high with bluish-green, very narrowly linear leaves, and an almost spherically inflated, ridged capsule at the top of an erect stalk. It rarely grows more than a few tufts in any one situation and never grows massed like the next.

Philonotis

Philonotis fontana is the common moss that forms great yellow patches on seeping slope along the highways in the mountains. It is a most common plant, making deep colonies in very wet sites where springs arise along mountain paths. It is also common but not nearly so conspicuous when it grows directly along the wet banks of streamlets in the lower foothills.

Plants of *Philonotis* have stems that are erect, unbranched or with a rosette-forming cluster of branches at the summit of the stem. What look like reddish flowers in the center of the rosettes are the antheridial heads. The capsule is the balloon-shaped with a goiter, and terminates a long slender seta that arises from the apex of a stem of the previous season where dichotomous branches arose. The stems are usually red, and the lanceolate leaves often appear to be in three ranks, and are somewhat falcate. Under the microscope the leaf calls have a distinct papilla at one end, the marginal cells having terminal papillae meeting each other to form a double tooth.

Bryum

A great many common acrocarpous mosses belong to the *Bryaceae* family. They might be best characterized as short-stemmed mosses with oval leaves narrowed at each end, with a prominent costa, often leaf margins with a row or two of narrower, non-chlorophyllous cells, and variously pointed. A few are rounded at the apex; more of them have long attenuate apices. The leaf cells are longer than broad (*Mnium* species, in the related family Mniaceae) have more hexagonal or isodiametric cells),The leaves commonly, but not always, dry out without becoming very contorted. When the plants are fertile, the sporophyte usually has a nodding capsule that is plump, terete, and ellipsoid.

The genus *Bryum* is a very large and difficult one, partly because the leaves of the species are so similar, but also because they so often lack sporophytes, which contain the most important distinguishing features. But *B. argenteum* is unmistakable, at least the garden variety. Recently, our colleague, John Spence, has divided the genus up several that may be recognized vegetatively, which makes *Bryum* much less formidable.

Bryum argenteum. In my home town, New York City, the common moss of sidewalk cracks was *Dicranella heteromalla.* Here in Boulder and doubtless in other Colorado towns, particularly in places that are not right downtown, wherever a crack appears in the sidewalk it will soon be filled up with a very low, dense colony of *the* Silvery Bryum, *Bryum argenteum.*

In *Bryum argenteum*, the slender stems stand straight up, and are densely packed together. It is very easily recognized because the leaves are white rather than green, at least when they are mature. They are broadly ovate, with a short, slender tip, densely appressed to the rope-like, or what we call julaceous, stems and have very little or no chlorophyll. This is a common weed moss but it also occurs in natural habitats, often in cliff crevices. On the desert-steppe of the Western Slope, another species, *Bryum lanatum*, replaces this and differs in having long narrow leaf tips

This species very rarely produces sporophytes in our region. The exception was a colony that thrived around the base of an ornamental fountain in front of the Hamill House in Georgetown. There the plants fruited richly. The fountain was completely overhauled recently and now is surrounded by a concrete apron which will take some time to erode and crack. The bright red sporophytes of *Bryum* hang down from the end of the seta and resemble plump tubes. The operculum is rounded, often with a low nipple. In some species the capsule has a slender neck.

The Silvery Bryum is so different from the other species that now it is regarded as a completely different genus. Unfortunately it will take an act of congress to remove it and give it another generic name, because Mr. Britton decided that this should be the type species of *Bryum*! If this is the only one to which the name really applies, then all the other Bryum species would have to take a other generic name. In order to prevent this, a petition must be made to the International Botanical Congress to retain the name *Bryum* to all of the other species by choosing another *Bryum* to be the type species of the genus, and avoid all those name changes. If the petition succeeds, *Bryum argenteum* will take the name of *Anomobryum argenteum.* The genus *Anomobryum* already exists, so *Anomobryum argenteum* will simply find its correct place in the smaller genus.

Bryum (=Gemmabryum) alpinum. Although it is a rare plant in America, *Bryum alpinum* is worth mentioning. It forms large, golden-green or brownish-green patches whose stems do not stand erect but behave as if brushed downhill on granite slopes that seasonally run wet with snow-melt water. *Bryum alpinum* is not a common moss elsewhere in the world, but it is one of our most frequently encountered mosses in a narrow band along the Front Range. It rarely grows mixed with any other moss, and the cushions easily fall apart into loose groups of stems. It does not form capsules here.

Bryum (= Ptychostomum) caespiticium. This is one of the most abundant mosses on dry, open, disturbed places at low altitudes. The plant makes very dense, low tufts and fruits abundantly in late summer. The leaves are crowded at the top of the stem, and the stems are held together very tightly by masses of brown rhizoids. The leaves

are red at the very base, have very long slender tips, and have indistinctly margins. Sporophytes are very abundant. The pale, oblong capsules hang from the ends of long, slender setae. The outer peristome is pale yellow. The inner peristome has a high basal membrane, and the segments have gaping perforations along their mid-lines. Between the segments are long cilia that have very distinct lateral appendages. The spores are smooth. Sterile lowland Bryums that are very low and dense usually belong to this species.

Bryum calobryoides.. This species, though always sterile, produces abundant bud-like shoots in which the upper leaves are short, broad, and concave, resembling tiny cabbages. The leaves have a short costa ending below the apes, and the leaf apex is suddenly narrowed to a very short, often recurved, sharp point. We find it from the outer foothills to the subalpine. It seems to be best developed on north-facing cliffs of the canyons of the front Range. It was very recently discovered and described.

Bryum (= Rosulabryum) laevifilum. A common species in the foothill canyons and to some extent in the subalpine forest floors. It forms tufts in which the leaves, when dry, are arranged in a spiral around the stem. It never produces sporophytes here. Characteristically, there are thick filamentous green-brown gemmae in the axils of the leaves. In this species, the leaves are clustered at the top of the stem, the lower stem having only rudimentary leaves.

Bryum (= Ptychostomum) pseudotriquetrum. This is easily recognized in the field and common in any area of wetland from the piedmont valleys up to the subalpine. Almost any handful of moss muck that one grabs by the hand in a willow carr, fen, or marsh, is almost sure to contain stems of this species. It is sometimes, but not always, fertile. But the distinguishing feature of the moss is that the leaves are rather distantly spread along the stem and twisted when dry, and the base of the leaf is strongly decurrent (forming a narrow extension of the leaf base along the stem).

Bryum (= Ptychostomum) weigelii is a common moss in wet ditches and willow carrs in the subalpine; its stems are loosely clustered and the translucent, pinkish leaves are rather remotely spread along the stem and the bases are long-decurrent.

A number of additional species occur here, but their recognition is difficult without recourse to microscopic examination of the sporophyte. It is interesting that some of the easiest *Bryum* species to recognize seem to be those that never or rarely produce sporophytes.

There are a number of genera closely related to *Bryum*. Some of the easy genera easily recognizable without the microscope. Here are a few of the easy ones.

Pohlia

Pohlia nutans. The Bryaceae has a number of other genera in the Rocky Mountains. The most frequent one is *Pohlia*. *P. nutans* is one of the most common mosses in the forests and wetlands. Unfortunately *Pohlia* is not so easy to separate from *Bryum*. The best way to tell is that the leaf cells of *Bryum* are broad and relatively short and the leaf cells of *Pohlia* are long and narrow. Bryums are very rarely marginally toothed, and Pohlia is frequently serrulate distally. *P. nutans* usually fruits abundantly, and the seta is quite long, several times the length of the capsule. Unfortunately it has no easy field characters to separate it from other similar mosses. It is very common in somewhat wet ground and on rotting wood.

Most other *Pohlia* species often do not produce sporophytes. Nevertheless, these are often easier to identify than *P. nutans*. For example, *Pohlia cruda*, which grows on moist banks in the forest, has pale green leaves with a golden or iridescent cast. And *Pohlia wahlenbergii*, a moss of subalpine meadows and fens, forms very large polsters of stems with pale blue-green leaves.

Once you get a feel for recognizing *Pohlia*, you will see some with yellow-green leaves that grow on earth banks and lack sporophytes. However, in the axils of the upper leaves there are clusters of gemmae, some round,

others twisted or corkscrew-shaped. These are very much fun to analyze, but a microscope is needed.

Leptobryum

Leptobryum pyriforme. In moist places in the forests and meadows, and especially in places where are ashes from an old campfire you will see a moss that has the capsule of a *Bryum* except that it is pear-shaped, with a distinct narrow neck. Instead of having broad leaves, the leaves of *Leptobryum pyriforme* are narrowly linear. There is no danger of mistaking this for any other moss.

Roellia

Roellia roellii. This is a really giant *Bryum,* immediately recognizable by its huge leaves (for a moss) that are arranged mostly at the top of the stem in a spreading rosette. It might be mistaken for a large *Mnium* but the leaf cells are too narrow. One might mistake it for a large species of *Rhizomnium*, but *Roellia* has fairly short, simple stems not clothed with red-brown rhizoids. It grows in saturated soil along slow mountain brooks in the spruce-fir forests.

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Buxbaumia

Buxbaumia aphylla. A moss that hardly looks like one, *Buxbaumia* has no recognizable leaves. It consists simply of a short, stout seta, and an inclined brown capsule that is shaped like the body of a mandolin, rounded underneath, flat on top. The operculum is short and conical, and some refer say the capsule resembles a gnome s cap. There are extremely minute leaves at the base of the seta, but these are rarely noticed. I found this species first on greatly decayed (to the very ground!) stumps of conifers in old-growth forests near Gothic, and thought that this must be its habitat, for it was exceedingly rare there. However, recently, *Buxbaumia* has been found abundantly alongside a well-used trail in lodgepole pine forest near Frisco. So much for habitat preference!

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Ceratodon

Ceratodon purpureus is one of the most abundant mosses worldwide. It occurs almost everywhere on usually level ground, in over-watered lawns, around the bases of cultivated pines, packed earth of trails and abandoned wagon roads, and even in the alpine tundra, a true weed moss found around the world. It loves being trampled upon.

It is the easiest moss to recognize if it has sporophytes, and a most difficult one if it is sterile and you are inexperienced. Many collections of small acrocarpous ground mosses that look interesting to a collector eventually turn out to be merely forms of *Ceratodon.* This is usually a very low species growing in dense clumps no more than a centimeter tall, but in very moist sites it may reach several centimeters tall. The leaves are narrowly triangular**,** more or less appressed when dry, and spreading when moist, often looking very different, because the leaves may be slender and long, or short and broad. The sporophytes begin to show in early spring, the setae arising as erect green lances in great numbers. Later on when they reach maturity the capsule is unmistakable. It is several times longer than wide, red-brown, slightly curved and distinctly furrowed! It is not erect but is distinctly bent from the base.

Recognizing *Ceratodon* when sterile is a different matter, and one really should see the leaf cells under the microscope to see how they are really different from other similar mosses. The leaf cells are neatly rectangular or quadrate, and have no pointed end walls, no papillae, and the costa is present but variable in length, sometimes exceeding the leaf lamina. Probably no other sterile moss is collected so many times because it simply looks interesting. It can be recognized more easily by its habitat.

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Dicranum and its relatives

Dicranum. The Dicranums are very common mosses of the forest floors, forming cushions of narrow leaves that are tapered from the base, bright green (no papillae), and usually curved but a few species almost straight. When they are in fruit the capsules are elongate and ether curved or straight, with a beaked operculum. The alar cells at the base of the leaf are usually enlarged and often orange. We have three very common species.

Dicranum scoparium is characterized by having leaves that are falcate-secund (curved in one direction as like a much-used broom (this is what scoparium means). Under the microscope the upper leaf cells are elongate. **Dicranum muehlenbeckii** is very much like *D. scoparium* but the leaves are not uniformly curved in one direction. **Dicranum rhabdocarpum** has leaves that are gently curved or almost straight, and has a capsule that is almost straight, easily distinguishing it from the last two. **Dicranum tauricum** is a very small species that only grows on rotting wood. It characteristically has broken leaf tips and very rarely is found with capsules.

Distichium

Distichium capillaceum is a very common moss of wet places and seeping cliffs in the subalpine and alpine. It is very easy to recognize because the leaves are in two ranks instead of being spirally arranged; they have a long-sheathing base and a widely spreading slender, linear blade. The capsules are pale, erect, and narrowly oblong-tubular. This moss grows in dense clumps among other mosses. The characteristic leaf arrangement is not always discernible unless a single stem is extracted.

Dicranoweisia

Dicranoweisia crispula is an extremely common species that grows on the surfaces and in cracks of granite boulders but occasionally on rotting wood. It has very narrow, curled leaves and usually has capsules that are straight and generally pale. It shares space with *Grimmia* species.

Paraleucobryum

Paraleucobryum enerve looks like a *Dicranum*, with falcate-secund leaves, but they are a curious pale, light color because they are very thick. Sometimes, however, the clump looks very dark, especially back from ther tip of the stem. The costa fills almost the entire leaf width. This is a moss of generally subalpine and alpine places. **Paraleucobryum longifolium** is similar in texture, but the leaves are very narrow and extremely strongly falcate-secund, curved almost in a closed circle. It grows generally at lower altitudes.

Encalypta

Encalypta vulgaris. Often called the extinguisher moss because the calyptra is unique, being cylindrical, completely covering the capsule, and terminating in a narrow tip resembling the end of a balloon that has not been quite fully inflated, *Encalypta* resembles an old-fashioned candle-snuffer. *Encalypta* usually forms small patches among other mosses on moist ledges and cliffs. The leaves are dark green and very papillose, opening up to form an oblong, flat lamina when wet, and a crumpled appearance when dry. But you will hardly ever be able to spot one of these mosses unless you first see the characteristic calyptra. The plants are not over a centimeter high.

Funaria

Funaria hygrometrica is a moss that tends to grow, like *Leptobryum*, on old moist ash heaps although it is common on many sorts of soggy places, often in disturbed places in the lowlands. It also happens to be abundant in the flower pots in greenhouses. It is distinguished by a unique form of capsule. The seta is long and slender, and the capsule is oblong and curved. The curious thing about the capsule is that its mouth does not appear to terminate the urn as it should be in most mosses, but lies more or less parallel to it. Of course, the mouth is really terminal, but the capsule makes a curious turn at its end so that the mouth seems to displaced to the side. There are very few species of *Funaria* in Colorado. The only common one is *F. hygrometrica*, so named because the slender seta moves around with changes in humidity (measuring water).

Grimmia and its relatives

This is a family that one really has to learn to recognize by what the Germans call Gestalt. Grimmiaceae have a distinctive Gestalt, or general aspect, at least until you know them better. We begin to learn to recognize the family because the plants are small, form mostly dark green or blackish tufts on rocks. They usually have a white hair-point. However! The genera listed below require us to add on to this general statement by significant departures. Nevertheless, with the exception of the unique *Racomitrium*, most of them have at one time been part of *Grimmia*. Read on.

Coscinodon

Coscinodon calyptratus forms dense rounded tufts on granite boulders. The hair-points are generally longer than in most of the true *Grimmia* species**.** This genus is unique for having a mitrata calyptra that completely covers the capsule. In Colorado one only finds this species in the outer foothills of the east side of the Front Range. The second species will be discussed in the larger Flora.

Grimmia

Most members of the family belong to this genus. There are several subgenera that can be distinguished on the basis of the leaf size and form, and the capsules. The capsules are with few exceptions exserted on a distinct seta, the calyptra is cucullate, the capsule is symmetrical, and the perichaetial leaves are not enlarged.

Racomitrium

For a member of the Grimmia family, *Racomitrium* sits, as we might say, way off in left field. Why this does not belong in a family of its own, I do not know. At least it is unique in the Grimmiaceae. The plants do not generally form tufts, but form loose mats. They branch repeatedly, usually to form short lateral branches. The capsules are produced on the lateral shoots, not at the apex of the main shoot, making these plants seem to be pleurocarpous. The leaves characteristically have wavy or irregularly thickened, what are called nodose or sinuous, cell walls. The leaves may be heavily papillose with simple or branched papillae. The plant may not anchor to rocks, but grow on soil. The peristome teeth, which are simple in *Grimmia*, are forked in *Racomitrium*! Huge areas of ground in the Pacific Northwest are covered with *Racomitrium*, something that never happens anywhere with *Grimmia*. But there we are; no one will agree to make a family of its own for these interesting mosses.

Racomitrium canescens is a yellow-green moss forming loose mats on soil in the high mountains. Its leaves are broad, and gray-green because of the curious thick-walled, papillose cells. The hair-point is white, and studded with coarse papillae. Once seen, it is not to be mistaken for any other moss. **Racomitrium sudeticum** is less obviously distinct, with smooth leaves and a variable and slender hair-point. It grows on moist vertical faces of cliffs and large boulders in the subalpine. It is commonly fertile, and the capsule is erect and tapered at each end. The calyptra is mitrate. The leaves are appressed with dry and widely spreading when wet.

Schistidium

Schistidium. This genus includes *Grimmia*-like plants that have sessile capsules in which the operculum falls with the columella attached to it (in *Grimmia* the operculum separates on its own). Hair points may not be well-developed. The characteristics separating the species are very small but very critical. We used to have only one *Schistidium* belonging to the *apocarpum* group. Now in Colorado, as a result of Blom's spectacular studies, we have over 18! It will be fun working them out, once we learn how to recognize them all!

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Hedwigia

Hedwigia ciliata. Named for Johannes Hedwig, father of bryology, published *Species Muscorum* in 1802. The specific epithet, *ciliata,* refers to the irregularly branched cilia on the margins of the perichaetial leaves. *Hedwigia* is one of the most abundant mosses in the Rocky Mountains and North America, as well as across the northern world. It almost always occurs here on granitic rocks in the foothills, where it forms patches of sprawling but not creeping stems, usually trending down slope. It is also the easiest to recognize of all our mosses. The leaves are ovate, opaque, and usually have a flat white point (occasionally this is short or almost lacking). There is no costa; in fact, the opacity of the leaves would make a costa almost invisible. The opacity of the leaves results from tightly packed papillae that cover the cells. I fact, it is our only moss with the combination: no costa, and papillose leaves.

The ability of the leaves to almost instantaneously imbibe water results in a dramatic change in the plant's appearance, from dry to moist. At one moment, the leaves are dull blackish-green with only the leaf tips curved slightly outward. At the moment of adding water, the entire plant springs to life; the leaves spread widely and become beautifully yellow-green! No other moss behaves like this although many mosses do assume more open appearances, but more slowly. The reaction of leaves to moisture has nothing to do with whether the plants are alive. I recently tried this out on a Swedish specimen of *Hedwigia* collected a hundred years ago. It comes to attention just as quickly as ever.

Sporophytes are not easy to see because they have no setae and are hidden by surrounding leaves at the stem tips. The capsule is goblet-shaped and wide open, with a red margin and no peristome. The operculum, which falls away as soon as the spores are ripe, is low plano-convex like the cover of a garbage can. The capsules occur on short shoots just below the terminal one. The perichaetial leaves have very broad hyaline tips.

Hedwigia rarely fruits in our region Even when it does, it is difficult to see the capsules, which are surrounded by the uppermost (perichaetial) leaves, which characteristically have long, crooked, variously branched hair points. It is surprising that there are no reports of this species from Utah. Possibly this is because there are few if any outcrops of the proper granitic substrate except at very low altitudes in the canyon bottoms. Nevertheless, it ought to be the subject of special searches.

Hedwigia would make an excellent show-and-tell for the children to take to school. It will fascinate the teacher as well as the classmates!

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Orthotrichum

Orthotrichum is very common on boulders. The various species may prefer granite, limestone, or sandstone, and seem to prefer vertical rock faces. They form loose patches and might when sterile be confused with *Grimmia* but the leaves never have hair-points. The young capsules have a mitrate calyptra (like a candle-snuffer) that is sparsely covered by appressed hairs. The most common species, **O. rupestre**, is the largest one and has

oblong capsules that protrude somewhat from the terminal leaf cluster. Orthotrichums are difficult to identify because one has first to determine whether the stomates (on the capsule! Remember, this is the sporophyte!) are flush with the surface of the capsule wall, or are sunken. However, with experience, some of the species can be recognized on sight. There is one species, **O. obtusifolia,** that only occurs on cottonwood and oak bark.

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Polytrichum and its relatives

The Polytrichaceae, or Hair-cap mosses, contain several genera that are found in a number of sites in the Rockies. This is one family that you can always recognize, because of the shared structure of the leaves. Characteristically, the leaves are like small conifer needles, rigid and thick-textured, spirally arranged around the erect stems. The easiest distinguishing feature is the calyptra, which is tubular, fitting over the capsule, and covered with straight hairs. The leaves are unique in having rows of longitudinal sheets of green cells that stand erect on the leaf surface. The height of these lamellae and the configuration of the terminal cell of each erect row of cells is very important in identification. A few genera and species are identifiable without examining the lamellae, but certain identification is assured by making a cross section of the leaf and/or scraping the lamellae off with a needle.

The leaves of Polytrichaceae are very special. They are adapted to very dry places, and to prevent evaporation from the leaves, they have a basic leathery texture to the leaf blade. But a number of plates of fragile cells arise from the upper (inner) surface of the leaf like pages of a book. These plates (lamellae) may be up to ten cells high, thin-walled and very green. But each standing row of cells making up the plate are capped by a cell that may be very thick-walled or of one of several shapes: indented, pear-shaped, or spherical. The lamellae are responsible for performing photosynthesis when the leaf is moist.

You can examine the lamellae very easily. Simply wet a leaf, take a needle and scrape along the upper side. The detached lamellae will float out on a drop of water on a slide. Take your hand lens and look at the slide in the light and you can easily make out the plates of cells. If you are very clever with your fingers and have a microscope handy. You can remove a leaf, lay it on the slide, holding it in place with a needle, and carefully slice the leaf with a sliver of a razor blade as if it were a loaf of microscopic bread. With practice you can get a slice thin enough to be only one cell thick. You can see a cross-section of the thick leaf blade (lamina) and the pillars of green cells of the lamellae. A cross section of the leaf will demonstrate the complex cell structure which makes the leaf stiff.

In the springtime you will find stems that are spread out at the top like a dinner plate, showing a yellowish or almost white surface. These are the structures that produce the sperm. If you find these plants at the right time, you can take some home and squeeze these tops or scrape them out with a needle onto a slide. You will see living sperm swimming around in the water, and perhaps see some undamaged antheridia as well! Another show-and-tell! The stems that contain the archegonia (female organs) and egg cells are not as easy to recognize.

The fruiting capsules are on long setae; when immature, they are simple spears covered by the calyptra, which does not loosen until the capsules are mature. The mature capsules are square in cross-section and have a rather short beak on the flat operculum. After the operculum has fallen, you can see with a hand lens that the capsule resembles a coffee-percolator. In the center there is a disk resembling a drum-head (the *columella*), which is attached by a central stalk to the bottom of the capsule. This disk is up-curved at the margin. The rim of the capsule has 64 very low teeth (peristome) which are incurved so as to engage the rim of the columella disk. Changes in humidity from wet to dry will shrink the columella and pull the teeth (also shrunken) to a horizontal position, forming a miniature salt-cellar through which the spores can escape slowly. Dry to wet reverses the process, causing the columella and the teeth to expand, effectively making the capsule watertight!

Polytrichum

This is the largest and most common genus. Several are easily recognized without a lens. The genus name

means many hairs , referring to the hairs on the calyptra. There is a good deal to interest us about this group, and to explain, we shall begin with the most abundant species, *Polytrichum piliferum*.

Polytrichum piliferum. *Piliferum* means having hairs , but this word refers to a long white hair-point at the tip of the leaf. *P. piliferum* is abundant on dry, gravelly places from the outer foothills up to the alpine tundra. It especially favors the packed earth of mountain trails. The small, erect stems, about a half inch high, are naked below, with a closely packed bunch of leaves at the top. The white hair-points are easily seen with the naked eye. When sporophyte are not present, people commonly mistake the moss for *Selaginella densa*, although it soon becomes obvious on examination that the *Selaginella* creeps along the ground.

Polytrichum juniperinum (resembling juniper). Unlike the previous species, in which the leaves are flat, this species has the thin margins folded over lengthwise, to cover the lamellae. The plants are taller, and the leaves do not have white hair points. *P. juniperinum* likes slightly more moist places, but the two species are often found nearby within a small area. A close relative, *Polytrichum strictum* (straight) is a species of peaty fens at high altitudes. The only feature that we have found to separate it is that the lower stems are covered by a dense white felt of rhizoids.

Atrichum

Atrichum, B. *Atrichum* means lacking a hairy calyptra. This genus used to be called *Catharinea*, after the empress Catherine the Great of Russia. *Atrichum undulatum* occurs on the ground in moist ravines of the outer foothills. In contrast to *Polytrichum*, the leaves are thin textured, drying contorted (crisped), and the lamellae are few and do not cover the leaf beyond the costa. The capsule is slender, slightly curved, and has a long, slender beak; the calyptra is naked or with only a few hairs. The peristome has only thirty-two teeth.

Pogonatum

Pogonatum is a plant of gravelly slopes and cliffs in the alpine tundra. The stems are not closely grouped, and are only about a centimeter high. The leaves are very thick and stiffly erect, glaucous-green, neither hair-pointed nor folded marginally. The capsules, unlike those of *Polytrichum*, are cylindrical, not square-sided, straight and erect, and the beak is very short. We have one species, *P. urnigerum.*

Meiotrichum

Meiotrichum lyallii is very similar to *Polytrichum* but here the leaves are more widely spreading than those of most *Polytrichum*, and the capsule, instead of being square-sided, has two of the four ribs much closer together. Sterile specimens need microscopic study of the lamellae. This is quite common in the dry subalpine forest. We have one species, *M. lyallii*.

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Mnium and its relatives

The Mnium family, Mniaceae, has three genera in Colorado. They have fairly large, oval leaves with large hexagonal cells that I think resemble the panes in a leaded glass window. The capsules are pendulous, as in Bryum, but the plants are larger than in most species of *Bryum*. Most species like to be in moist places, streamsides, and fens.

Mnium arizonicum is the most common species, growing (unlike the other species) on fairly dry sites on the forest floor. When dry, the leaves are beautifully spiraled around the stem

Plagiomnium

Plagiomnium is distinguished from *Mnium* because the plant produces runners that arch over and root. The species are best distinguished by microscopical examination.

Rhizomnium

Rhizomnium. This wonderful moss has stout stems and very large spreading round-oblong leaves, and the stem is clothed with red-brown rhizoids of two sizes – macronemata and micronemata. It is common in wet subalpine forests. There are two species with different leaf sizes.

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Syntrichia

Syntrichia is a very easily known genus. The plants are called star mosses because when the stems are wet, the leaves of most species open up wide and arch out and down. Most the the species have well-developed hair points. You will probably get to know two of three of the most common ones. **Syntrichia ruralis** has white hair-points and grows mostly on the forest floor. **S. norvegica** has hair-points that are reddish at the base, is a more slender plant, and likes to grow in cliffs. **S. calcicola** is a very small version with leaves that do not strongly recurve when wet.

The leaf anatomy of *Syntrichia* is very interesting. While most of the leaf cells are very small and studded with papillae, the base of the leaf has windows of large clear rectangular cells. These probably a great deal to do with the rapid swelling of the leaf when wet. Syntrichia belongs to the Pottiaceae, which is probably the most diverse and largest family in the Colorado flora. Many of the genera present the Dickens of a problem in identification.

Tetraphis

Tetraphis pellucida. The genus name comes from *Tetra-fid*, four-divided. A genus characterized by the unique peristome, which consists of only four teeth, each of which consists of a solid mass of tissue rather than the partial walls of several cells (see Introduction). The leaves are broadly oval and not curled or rolled, and the capsule and seta are stiffly erect. Formerly called *Georgia*, after King George III of England, *Tetraphis* is almost wholly restricted to the tops of stumps of conifers in the moister parts of the subalpine forests. The plants are reddish-brown, with rather distant, oval, leaves. The leaf cells are rounded and clear (pellucid). Sometimes colonies produce gemmae. These several-celled globular structures occur inside a terminal cup that has very broad, rounded leaves, resembling a rose blossom. We have one species, *T. pellucida*.

Timmia

Timmia austriaca. The leaves of *Timmia* resemble those of *Polytrichum* but they are thin, lacking any lamellae. They have a prominent sheathing base that circles the stem. When fertile, the calyptra frequently does not follow the growth of the capsule to sit at the top of the urn as in most mosses, but because the base of the calyptra clasps the seta, it is left behind and some people feel that it resembles the feather fixed to the back of the head of an Indian brave.

PLEUROCARPOUS MOSSES

It is no accident that most of the pleurocarpous mosses were long thought, in North America at least, to belong to a single family, the Hypnaceae. Even now, some of them bounce around from family to family, depending on what characteristics are emphasized, those of the vegetative stem or those of the sporophyte.

Abietinella

Abietinella abietina. A stiffly pinnate creeping moss with dark green short, broad incurved leaves, common on steep slopes in the forests of the lower altitudes.

Brachythecium

Brachythecium. Small to large green, creeping mosses with ovate, often slender-tipped leaves with a prominent costa. When fertile, the capsule is plump and curved, with a conical operculum on an elongate seta. The laminal cells are long and narrow, not at all papillose. The alar cells are quadrate, in a small group, the basal cells are not differentiated or only one row of short cells at the very base. The genus is very common and usually produces large yellow-green mats on forest soils. Our most common species is **Brachythecium erythrorrhizon**. making loose mats on the forest floor. The ends of the branches tend to be slightly curved.

Climacium

Climacium dendroides. *Climacium* has its own family, and is a fairly large moss growing on the edges of mountain streams , lakes, and willow tarns. It is unique among our mosses, because it has a creeping, mostly leafless, stem from which erect stems arise at intervals, crowned with several leafy branches with briadly ovate, toothed, leaves with a merely acute or rounded apex.. The best likeness of this moss is to a small palm tree! It color is usually brownish-yellow.

Drepanocladus

Drepanocladus aduncus. This may be the most common moss with falcate leaves in any wetlands. It is less common in fens than in ordinary wet meadows and in still water swamps. It is a slender moss with always green leaves and stems, without any hint of red coloring.

Fontinalis

Fontinalis novomexicana. A handsome, moss of running streams. The stems are very long and attached to rocks. The leaves are folded and imbricate in three ranks, so this is a moss with a very obviously triangular form.

Helodium

Helodium blandowii. A beautifully yellow-green and brown, pinnate moss growing in dense, erect tufts generally at the bases of willows in wet sedge meadows. The broadly ovate stem leaves have many branched paraphyllia growing out from the basal angles, and the stems have numerous paraphyllia as well. The stems are quite brittle when dry.

Hylocomium

Hylocomium splendens. Called feather-moss in the far north, This moss is beautifully pinnate forming a flat surface and then the branches are again pinnate. It should form branches that form stair-steps, the branch of the next season arising from the old branch by climbing up and going forward. However, in Colorado, this character is not pronounced as it is in the East.

Hypnum

Hypnum cupressiforme. This is recognized by the fact that the leaves, while falcate-secund, are concave, like shells, and the margins are not at all recurved. Robust forms are very easy to recognize, but depending on the local environment, it can become almost thread-like. It likes wet cliff-faces.

Hypnum revolutum. This is the most abundant moss on the face of Colorado rocks.It is everywhere in forested areas, and forms great masses over rocks and cliffs. It is also very variable. Small forms can be so different that he hesitates to believe they can be the same plant. *H revolutum* forms a beautiful braided pinnately branched plant. If you turn it over and look at the large leaves on the main stem you can see that the margins are recurved, hence the name. It seems a shame that it is so awfully common!

Neckera

Neckera pennata. A plant of deeply shaded grottoes, under-hangs of cliffs and talus slopes. The leaves are in two ranks, overlapping in one plane and rounded at the apex. The stems are flat and the leaves spread out widely so that the stems with their leaves are ribbon-like.

Paludella

Paludella squarrosa. A rare plant of fen pools. The stems are elongate and hardly branched, while the unique leaf arrangement is known in no other moss. The leaves are broadly ovate, standing out from the stem. and are strongly recurved, We have this from only two places in Clear Creek County, and anyone who finds more of it will be rewarded with the thrill of his bryological life!

Palustriella

Palustriella falcata. A very common golden or reddish plant that makes huge, deep patches on roadside seeps in the forested areas. The leaves are falcate, and the leaves are conspicuously provided with branched paraphyllia.

Pleurozium

Pleurozium schreberi. A rare moss so far found in the Front Range, Middle Park, and the San Juans. A lanky, little- branched plant with oblong concave leaves with rounded tips. The clincher is the contrast between the green or brown leaves and distinctly red stem.

Pseudoleskeella

Pseudoleskeella tectorum. This is a tiny moss that makes very broad mats, generally very darjk green or black, growing on slabs of rock in the timbered areas. The stems are very slender and the short, broad leaves are curved in towards stem, chain-like-wise. It is really one ov the very common mat-forming mosses.

Rhytidium

Rhytidium rugosum. A rugged-looking coarse, irregularly pinnately branched brownish moss of fairly steep slopes in the foothills forests. The leaves are rugose (wrinkled cross-wise), so it is an easy one to learn.

Sanionia

Sanionia uncinata. A common falcate-leaved moss growing in less than soggy places in the subalpine forests. The leaves are plicate and the margins serrulate distally. It has been called *Dropanocladus uncinatus*. It is usually found very richly fruiting.

Scorpidium

Scorpidium scorpioides. A very large and coarse, blackish moss with fairly broad falcate leaves, growing

in lax patches submerged in fens and willow carrs. Usually this occurs together with *Helodium* and *Climacium* at the bases of wilows in sedge meadows..

Tomentypnum

Tomentypnum nitens. A common moss in wetlands in the ,mountains. The stems are not regularly pinnate, the leaves are very slender and straight, and the hallmark of the species is that the stems are densely felted with brown rhizoids, especially when viewed from the underside.

THE SPHAGNUM MOSSES

Sphagnum

Sphagnum mosses are different from all the others! They are wetland plants, of willow carrs and fens. Web have no real bogs in Colorado because we don t have oligotrophic conditions (the only water received by the mosses coming from rain water). Our Sphagna are autotrophic types, living in places where water runs to them from a source and passes beyond them. For the good of our dispositions, we have not very many kinds of *Sphagnum* in Colorado!

Sphagnums are large mosses. They are unique in having a main stem with side branches in clusters of two or more at a node, and a terminal head of short branches. The plants are bright green or pale green, sometimes reddish. Their stems and leaves are very special. The leaves are like leaded glass panes, consisting of very large, elongate cells that are empty and hollow, with openings in the walls called pores; these pores can extend the width of the cell and show up as circles under the microscope. Forming a lattice between these cells a row of tiny green cells forms the lead between the panes. The leaves of the main stem are different in shale than the branch leaves; they are flat rather than concave. The empty cells or leucocysts fill with water and cause the plant to be very spongy. You can squeeze the plants dry without hurting them. Sporophytes are spherical, black, on a stouter seta, and they are of vitrually no value in identification, thank goodness!

Identification of *Sphagnum* can be very tough. When I began to study them I had to learn to make cross sections of those strange thin leaves and to determine whether the green cell is on a line with the surface of the leaf or whether it is situated half-way between the top and bottom surface., and whether the cell is broader on one side than on the other. I also had to learn how to find the stem leaf and to dissect it away.

However, if you go to Scandinavia you find that any good field bryologist can identify the species by looking at them! This doesn t mean that the old characters are useless, but it does mean that recognizing species can be done much of the time by becoming very sensitive to small differences that are not microscopic. It s amazing to see these people work. Of course, they may guess wrong sometimes, but all of us are guilty of that with most any other mosses.

CHARACTERISTIC MOSSES OF SPECIAL HABITATS

Main highway cut-banks. Most of the mosses one sees from a moving car will be on steep banks with water seeping over them. Usually drivers are attracted to bright yellow-green masses of mosses, Unfortunately, the mosses characteristic of these are usually very common and not typical of the richness of our floras. The chief inhabitants of these banks will be *Philonotis fontana* and *Palustriella falcata*. There may also be beds of *Bryum weigelii* and *Pohlia* species. Banks on unpaved forest roads also have similar moss communities, but with the added luxuries of less sun, more shade, and soil washing down the slope, the assemblages are richer in species.

Sagebrush flats and greasewood flats. Rolling sagebrush hills seem to be very low in moss populations, possibly because of too much movement of the soils downhill, but greasewood and alkaline flats support a few species, mainly of the Pottiaceae. In the Gunnison Valley near Delta, for example, the alkaline flats have *Syntrichia,*

Crossidium, and *Tortula* species. They are rarely seen except just after a rain when the leaves are green.

Soil crusts in piñon-juniper. Well-developed soil crusts, besides being held together in part by algae, typically have a number of species of lichens and a few mosses, especially in shade around the bases of shrubs. *Syntrichia* and *Pterygoneuron* are characteristic of such places.

Willow carrs along slow-flowing streams with sedge meadows characteristically support colonies of *Helodium blandowii* and *Climacium dendroides* around the slightly raised hummocks at the bases of the willow shrubs.

Sandstone tables or rim-rock. Very few types of moss occur on the surface of this kind of site; the most typical one is *Grimmia plagiopodia.*

Gypsum/salt domes. In Paradox Valley this is a very special habitat. Here you will find *Syntrichia caninervis*, and *Didymodon nevadensis.*

Now these are the distinctive habitats and not necessarily the richest ones. The richest moss habitats are the wetlands, mostly mountain fens, and the forested areas. Here there are a variety of microhabitats. Steep north-facing slopes and cliffs provide mosaics of soils, boulders, fixed outcrops, rocks of different lithologies, and running streams of various depths and extents. Such places train your eyes to see slight variations of habitat. There is not enough space to discuss this here in detail, but you will find that while walking the mountain trails you will soon discover that granite boulders usually have a small number of easily recognized species. Cliffs, with their seepage areas, crannies, and overhangs, support the richest floras of rock-loving mosses. Most of the excitement of discovery will take place in the vast areas of forested lands.

Travertine deposits. Not many kinds of mosses (two or three) are restricted to traverttine, which is a calcareous rock that forms by drip and congealing. Mosses are often important in facilitating the formation of travertine because they become embedded in the material. There are not many species that make travertine, but most of them grow nowhere else.

MOSSES, WET OR DRY?

One of the most remarkable features of mosses are the various degrees that different genera react to becoming moist. *Hedwigia* is probably the most startling wit its instantaneous change of aspect. A great many mosses, but particularly the Pottiaceous mosses of desert habitats react just as quickly, but the plants are so small they are not noticed, although after a rain one can see mosses on ground that ordinarily is quite uninteresting.

On the other hand, mosses that grow in running water will not react to wetting, and to restore them to their natural condition (any conditions are really natural!) once they are dry one has to put a stem in some water drops on a slide and gently warm it with a match. Once warmed, it immediately changes its shape.

Mosses are finicky about how much water they can stand. In the mountain fens there are many pleurocarpous mosses that float free under the surface of the water. Some of these are very easy to recognize, but there are more that are very difficult to learn without having the help of an experienced field botanist. In rapidly flowing streams mosses distribute themselves according to whether they are accustomed to splash, or inhabit the downstream ledges of the stream boulders, or grow on the stream-sides just above the high water mark of flood stage.

Developing an awareness of the niceties of local moss distribution with respect to water, especially in a place like Colorado where water is so limited, is an exciting and little exploited field of knowledge.

HOW MANY MOSSES CAN I LEARN?

When we ask this question, we have to consider two other words: should , and could. How much time do you have? A lifetime will help. Does your work demand that you know all of the bryophytes of an area, or can you get by with the easy ones? Are you going to study mosses to increase your vision of the world of nature?

If you are involved with forest and range studies, you should at least get to be able to recognize the easy lichens in the field even some of the difficult ones may be so important to your study area that you will need someone who knows the mosses train you to recognize the species by aspect alone. Don t be afraid to ask for help; there will be someone who can and will help you!

Do you feel you want to know all of the mosses of your region? This is quite another matter. You should again do best to find someone who can help you in the field, or at least identify your collections and give you pointers on recognition in the field or at least with a hand magnifier. To go farther than learning those mosses that are easily recognized at this level you will need money and time! One or more mentors will always be needed (you may get involved with many specialists, and that is a great learning experience). For field work you must have a hand lens of no less than 9X power, hanging from a nylon cord around your neck at all times. For laboratory study you will need a compound microscope (maximum magnification would involve low to high dry lenses, a good stereoscopic microscope and a fiber optic illumination system.

TDA Cockerell wrote, in *Recollections of a Naturalist:*

> The saying, study nature, not books should not be interpreted to mean that books are to be ignored, but it is wise counsel for the beginning student who should learn to see things and to know their characters, instead of merely following what has been written. It may be actually detrimental to a young student to have his insects all named for him by experts. He is thereby excused from studying their characters, and unless he has a good deal of originality and initiative he may lose the chance of becoming competent. On the other hand, of course, if he lacks these qualities, he is likely to quit altogether when he runs into difficulties, and this may not always be a misfortune to science.

MAKING A COLLECTION

Before going into the field, sit down at the table and take a pile of second sheets (this is good recycling technique) and fold a lot of field packets. We take standard 8 1/2 X 11" paper and fold a small pile (about 10-15) up about 4 inches (together, to save having to do it one by one). Then fold the sides of each sheet forward 1 ½ inches (or so), and then fold the three inch flap over the folds to make a packet. We bundle about a dozen packets in rubber bands and carry a bunch of them into the field to use when necessary.

In the beginning, try to collect only one kind of moss in a packet. Later on you will find that some mosses may only occur in mixture with others, but these are not the easy mosses. With more experience, you will want to carefully examine every thing in a packet, and you will often find that there are mixtures of several species that are difficult to separate out; often a rarer moss will be represented by only a few stems, and those have to be carefully picked out and transferred to another packet. But don t worry about it when you are just beginning.

If there are only a few plants with sporophytes, set them aside and place them in small packets inside the large one so that they don t get lost. If you have collected a mixture, don t try to separate everything out, but take a few of each species and place it in small packets. It s easier to do this when they are fresh and not brittle.

Dry specimens should be placed in the packet in a non-bulky form; tufts may be squeezed in order to spread them out a bit, and to discard some of the soil. Some dense tufts may be divided with a knife . Wet mosses may be gently squeezed our to remove most of the water. and separated so a to make it easier for them to dry.

Let the specimens dry naturally in their packets. Stacking the packets upright and not applying extra pressure results in the best specimens. DO NOT EVER PRESS MOSSES IN A PLANT PRESS! Pressing distorts the natural appearance of the dry moss. Naturally dried mosses are easy to restore to their living form by gently

heating a stem on a slide with the help of a match.

Since you will often want to send the moss to an expert for naming, collect enough of it so that you can divide it and have plenty left.

How shall you number your collections? In the field we often do not use numbers, but instead mark each packet a collected with a symbol indicating the collecting site. Give each site a number, and write the details of the locality and its ecology, substrate, etc., on one of the packets. If you collect more than one packet of the same thing, simply write extra , or duplicate on the packet. Don t trust to memory for the details of the substrate.

How much data to use for a label? Do not add extraneous information, like found on . Simply say, on punky wood, on bark, on soil; don t say, on wet ground, unless it is really wet ground and has not just been rained on! Don t say the substrate is granite or limestone unless you are sure. Altitude should not be too precise; within 500 feet is usually enough; 5,254.4 feet is too much! Numbers are cheap, so give every specimen a different number; keep them simple, start with 1 and go on from there. Don t invent silly number systems that combine the specimen number with the date. The importance of the specimen number is so that the person you send a duplicate to can keep the specimen (this is a courtesy you extend for the help you get) and reply to you with the number. Don t forget to include the date on your label, but not as part of the number.

Your field packets will get dirty and out of shape, so replace them with fresh packets of good acid-free 20-pound bond. You may use padding to keep the specimen from sliding around, but don t use cotton batting; the fibers stick to the moss stems.

Make a specimen label; we suggest the following standard, that can be set up on your computer:

Select FORMAT
Select PAGE
Page Setup:
Margins: left, 0.313", right: 0.32". Top: 0.25", Bottom: 0.25"

Select FONT: 10 point

Select Columns: 2 (newspaper)
Space between: 0.500"
Width: column I: 3:69"
column 2: 3.68"
(Fixed)

B-111929 **COLORADO, U.S.A.**

Orthothecium strictum Lor. **Brachytheciaceae**

San Juan Co.: Deadwood Gulch, Hwy 550, SSW of Silverton, 2.2 mi., 2850 msm, N37°47 06 W107°40 21 . At the bottom of a narrow cascade, on cliffs and on rocks at the water s edge. Not granite as claimed by Hermann, but some layered volcanic rock: mixed with *Campylophyllum halleri.*

21 July 2001 W. A. Weber & R. C. Wittmann

Housing the collection: The cheapest way to house a bryophyte collection is to place the specimen packetsd upright in a men s shoe box, which is just about 4 x 6 inches.

MISCELLANEOUS BRYOLOGICAL CHIT-CHAT

Lumping and Splitting

Dana Griffin once wrote to me: Could I share pieces of a conversation I had several weeks ago with a Swedish bryologist who was visiting here for a while? The matter of taxonomic splitting came up. He allowed as how European botanists are infamous for their devotion to splitting (recognizing species as things that the rest of the world might raise an eyebrow over). Of course, like all stereotypes, this one is flawed through and through. Jan Peter Frahm, a German bryologist, has been an enthusiastic lumper (the reverse of splitter) in the genus *Campylopus*, but his reason for this state of affairs fascinated me. He said that botanists based in Europe are dealing with an essentially depauperate flora, ravaged by four glaciations. To keep things interesting (the boredom factor in taxonomy), they have taken to elevating small differences and writing paper upon paper on the significance of these differences. We now have a Polish bryologist who is rampaging through the Amblystegiaceae, finding new genera under every bush. He is an excellent example of this school. Of course, Howard Crum had a critical word for lumpers. He maintained that they hadn t done their homework. This from a *Sphagnum* authority!

The Higher Categories; Why worry about them?

Recently there was an interesting argument that developed among subscribers of the electronic internet called BRYONET. Someone collected an extremely rare and little-known *Sphagnum* in Michigan, and reported it over the net. This got a bunch of senior and amateur bryologists to wrangling over whether or not *Sphagnum* mosses should considered a group separate from all the other things we call mosses. According to some, this is very much justified, but then what to do about the other crazy groups that we include in mosses and liverworts. What to do with the Andreaeaceae, the hepatics, the Anthocerotes, and the Takakiales? Should these be classes parallel to the Bryopsida (bryophytes)? Orders? Aren t these so far removed from each other that they should be called Phyla or Divisions? Molecular biology raised its ugly, confusing, or enlightening, head in the debate. No conclusion was reached.

The delight of some taxonomists is to try to establish the proper expressions for the actual evolutionary status of the higher categories, to decide once and for all what came from what, and when, and where. I would suggest for beginners that it is far better for the time being to get to know some of the things we call bryophytes, mosses, or liverworts, and let the other folks count how many angels could fit on the top of a pin head and leave us to enjoy the wonders of nature. For me., the proper way to study biology is to start with the specific and defer the temptation to generalize until one has more experience precisely the reverse of the method used in university curricula!

A glimpse into the History of Bryology

We stand on the shoulders of bryologists who have gone before us in the past two hundred years. This is not a long time in human history. Bryological study really started in Germany. Frahm and Eggers (1995, 2001) lay out the story succinctly in their massive volume, *A lexicon of German-speaking Bryologists.* Since it is in German, I give my free translation for the benefit of English-speaking students..

Along with moss students of other countries, German bryologists, especially of the 19th century, were not only numerous but also very productive. The following collection includes the life histories of bryologists, some of whom naturally were only active and known regionally, others known and esteemed nationally. Among the latter belong Dillenius, the most famous Pre-Linnean bryologist, Hedwig, whose work, the *Species Muscorum,* rightly became the starting point of moss nomenclature, Schwägrichen, Bridel, Funck, Nees von Esenbeck, Hofmeister (who described the life cycle of mosses), Bruch, Schimper, and Gümbel (the authors of the *Bryologia Europaea*), Gottsche, Lindenbery, and Stephani as the most famous hepaticologists of their time, Schimper, Hornschuch, Hampe, Carl Müller, Limpricht, and Mönkemeyer as the contributors to the mosses of Rabenhorst s *Kryptogamenflora,* Roth as the author of *Mosses of Europe*, Warnstorf, the author of the only overview (up till recently) of the peat-mosses of

the world, Karl Müller as quite the best known hepaticologist of the first half of the twentieth century, Herzog with his (richtung-weisenden) *Geography of Mosses,* von Wettstein with his trail-blazing cytological studies. Altogether these constitute a Hall of fame that declined since 1930 and ended with the death of Herzog and Karl Müller.

The contributions of German botanists eclipses that of any other national group. Other continents have had their minor bursts of energy, and, indeed, it appears that in the last half of the twentieth and the beginning of the twenty-first century a great period of synthesis has begun in earnest. Scandinavia led with volumes on mosses by Elsa Nyhom (now in a second edition), and Hepatics by Sigfrid Arnell. Japan has been a strong leader, especially through Dr. Sinske Hattori, founder of the Hattori Botanical Laboratory. who has spawned a generation of excellent bryologists. The United Kingdom has strong voices in research and education. Spain has awakened from its long slumber and is producing a group of young scientists in all groups of systematic botany, publishing a moss flora of Spain. In Italy, Dr. Carmela Pedrotti has published the first volume of the bryophytes of Italy. Australia is working on a bryophyte flora, begun by the young, unfortunately recently deceased bryologist Heinar Streimann. Antarctica has a flora of mosses and hepatics published by the husband and wife team of Ryszard and Halina Ochyra. A team of bryologists of the Botanical Museum of Helsinki, headed by Timo Koponen published a series covering the flora of at least part of Papua-New Guinea. An African Bryophyte Flora is now being spearheaded by Bob Magill of the Missouri Botanical Garden. The bryophyte Flora of China is being published by teams from China and the Missouri Botanical Garden. The New York Botanical Garden is carrying on a Bryotropica program for South America. Mexico has a new two-volume flora published by the New York Botanical Garden. And the United States is well along in the Bryophyte Flora of North America, with many contributing bryologists, and directed through the Missouri Botanical Garden. Truly the twentieth century is going to be the century of Bryophyte Floras!

Sullivant and Lesquereux

William Starling Sullivant is the father of bryology in North America. Leo Lesquereux was his assistant and the father of Americna paleobotany. I pl;an to talk about these men in some detail in our short course so will not develop this story here except to urgently request that you read the biography of these two people in Andrew Denny Rodgers III, *Noble Fellow: William Starling Sullivant.* This book will give you real insight to the lives, personalities, and the history of our science.

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Lastly, we can say that the moss flora of Colorado still is not complete. In 1976 I reported about 200 species. As of march 2004 we have a list that totals 390 species, most of the additions having been recorded in just the past three or four years! It takes experience to discover the novelties, and it takes more than a good eye for differences, and the happy accident. You must know what is already there and anticipate the novelties.

And, as Sullivant wrote in a letter To Asa Gray on April 11th, 1845: Business and the Musci have kept me so under whip and spur that I have entirely omitted all correspondence. The unfortunate Musci not ready yet pretty much the old story over again I have this winter been overwhelmed with business, but notwithstanding have worked a great deal at them and have accomplished a great deal but the more you do the more you see is yet to be done. But of the endless labour, the time and patience in doing them up *in the right way*, it is not worth while to tell you for you can t believe it until you try it.