CHAPTER 1

HOUSEHOLD AND PERSONAL USES

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Figure 1. Mosses being sold along with fruits and vegetables in a marketplace in China. Photo courtesy of Eric Harris.

Household Uses

I think every bryologist must have been asked "what good are they?" The small size, difficult taxonomy, and inconspicuous position in the ecosystem of bryophytes have caused most people to ignore bryophytes. Nevertheless, the rate at which bryophytes are being harvested from some of our national forests in North America and elsewhere suggests they are useful for something. In the high mountains of Malaysia, simply collecting mosses as a novel pillow filler (Kuen 2002) has caused vast areas of bryophyte destruction in a pristine forest. In New Zealand the small number of peatlands is diminishing from horticultural usage. In the southeastern United States, sheet mosses are removed by the truckload, and in the Pacific Northwest epiphytes are disappearing from old growth forests.

Although ***Sphagnum*** (Figure 3) seems to be the most commonly used bryophyte, it is not the only moss with endearing, and enduring, qualities. Including all the known uses of bryophytes, Harris (2008) found that the most commonly mentioned uses of bryophytes are those of ***Marchantia*** (Figure 2), ***Sphagnum*** (Figure 3), and ***Polytrichum*** (Figure 10). Other genera used in more than two countries are ***Conocephalum*** (Figure 4), ***Climacium*** (Figure 64), ***Hylocomium*** (Figure 16), ***Hypnum*** (Figure 5), ***Rhytidiadelphus*** (Figure 17, Figure 118), ***Thuidium*** (Figure 22, Figure 42), ***Antitrichia*** (Figure 104, Figure 111)**,** ***Bryum*** (Figure 6)**,** ***Dicranum*** (Figure 13)**,** ***Fontinalis*** (Figure 75)**,** ***Funaria*** (Figure 89), ***Philonotis*** (Figure 7), ***Pleurozium*** (Figure 45-Figure 46), and ***Rhizomnium*** (Figure 8).

Durability and elasticity may have contributed to the Japanese use of ***Hypnum*** (Figure 5) to stuff balls and dolls (Pant & Tewari 1990). Others have used them for stuffing upholstery and hassocks (Thomas & Jackson 1985).

Figure 2. ***Marchantia polymorpha***, a species put into wine where it soaks up the wine and makes a tasty treat. Photo by Michael Lüth, with permission.

Figure 3. ***Sphagnum capillifolium***, on of many members of the genus with various human uses. Photo by Michael Lüth, with permission.

Figure 4. ***Conocephalum conicum***, a liverwort used in more than one country. Photo by Robert Klips, with permission.

Figure 5. ***Hypnum cupressiforme***, a commonly used moss around the world. Photo by Dick Haaksma, with permission.

Figure 6. ***Bryum argenteum***, member of a genus that is used in more than two countries. Photo by Michael Lüth, with permission.

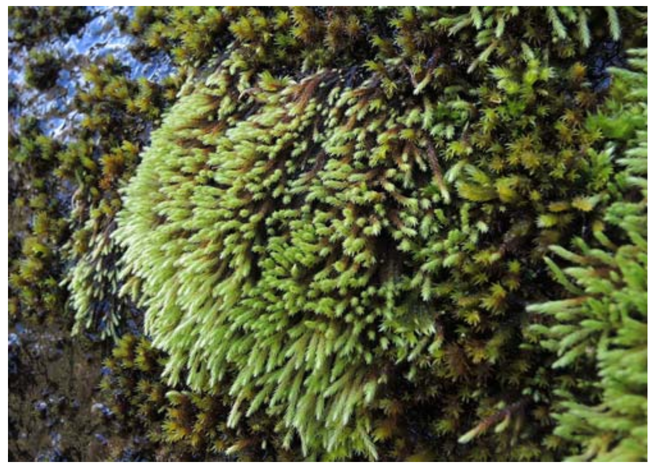

Figure 7. ***Philonotis fontana***, member of a genus that is used in more than two countries. Photo by Michael Lüth, with permission.

Figure 8. ***Rhizomnium magnifolium***, a moss in a genus used in more than two countries. Photo by Janice Glime.

Robin Stevenson (pers. comm.) shared his surprise at finding a reference to moss use in the "Rough Guide to Moscow. "One of the main roads in central Moscow, which runs parallel to the Kremlin Gardens, separating them from the Lenin Library and the Arbat district, is Mokhovaya ulitsa or Moss Street. So named, apparently, because this is where moss (mokh) was formerly sold. This moss was used as a caulking material for filling in chinks in wooden buildings, a use which is pretty well documented. However, it was also sold to put between the panes of glass in double-glazed windows."

Clearly, the use of mosses is not just a tale from the past (Welch 1948; Ando 1957, 1972). In the USA today, there are about 200 "mossers" (moss growers) (Epstein 1988), a testimony that the industry has not outlived its usefulness. The Chinese continue their tradition of using mosses and other herbals in medicines and food (Figure 1).

Furnishings

Imagine yourself in a remote village where there are no grocery stores and the nearest mall is 100 miles away by horseback. Villagers carry water on their heads, cushioned by a sirona, and bags of fruits wrapped in native moss. In your hut, you protect a fragile souvenir in a gentle bed of moss. Your mattress and pillow are stuffed with mosses. Mosses collect urine from pigs in the stall. And your child plays with a hand-made doll stuffed with moss. In these conditions, mosses take on an important role in your daily life.

In fact, mosses seem to be useful in maintaining structural integrity in a variety of materials. Siberian Eskimos roll up skins and freeze them into the shape of a sled runner (Figure 9), which they cover with a moss/water mix to protect the skins, smoothing them as they shape them onto the runners (R. Seppelt, pers. comm., based on "Man on the Rim" documentary; Wikipedia 2017). This makes a smoother ride.

Figure 9. Qamutiik with moss and ice on runners. Photo by Adolphus Greely, through public domain.

In India, mosses are used for door covers and smoke filters (Pant 1989) and the pharki – a door mat (Glime & Saxena 1991). In Sweden, ***Polytrichum commune*** (Figure 10) has likewise been used as a doormat (Hedenäs 1991). Their use as kindling is surely still valuable to campers (Thomas & Jackson 1985). Both ***Neckera crispa*** (Figure 11) and ***N. complanata*** (Figure 12) have been used as bedding in Europe (Dickson 2000).

Figure 10. ***Polytrichum commune***, a large moss used in making doormats, brooms, clothing, and other items. Photo by David T. Holyoak, with permission.

Figure 11. ***Neckera crispa***, a species that has been used in bedding in Europe. Photo by Malcolm Storey, through DiscoverLife.

Figure 12. ***Neckera complanata***, a species that has been used in bedding in Europe. Photo by Michael Lüth, with permission.

In some places, the past mixes in strange ways with the present. Among the Inuit at Pangnirtung in the Canadian North, electrical lines run to summer tents to power electric guitars while the tent is heated by ancient kudliks that burn with a wick of moss (Crowe 1974). A number of mosses make ideal lamp wicks: ***Dicranum elongatum*** (Figure 13) by the Cree Indians, ***Racomitrium lanuginosum*** (Figure 14) by Labrador Eskimos (Bland 1971), and, of course, ***Sphagnum*** (Figure 3) (Crum 1988).

Figure 13. ***Dicranum elongatum***, a moss used as a wick by the Cree Indians. Photo by Michael Lüth, with permission.

Figure 14. ***Racomitrium lanuginosum***, a species used by the Cree Indians as a lamp wick. Photo by Janice Glime.

A rather unique new use is to create tables using mosses as photovoltaic cells (Figure 15) (Chandler 2012). Bio-Photo-Voltaic (BPV) technology strives to make use of biological materials to trap light energy and convert it to a usable form. The table has a futuristic look with more than 100 round cells with growing mosses in them and a lamp at the edge. The moss is not yet able to power the lamp, but it can power a small clock. Currently it can produce about 520 Joules (J) of energy per day – enough to power a laptop for 20 seconds!

Figure 15. Moss pots as photovoltaic cells. Photo from The hidden power of moss, through Creative Commons.

To create the power in the table, the mosses convert carbon dioxide, using sunlight, to create organic compounds (Biophotovoltaics 2015). Some of these compounds are released into the soil where bacteria break them down and free by-products, including electrons. Conductive fibers inside the moss table capture these electrons and can use them, generating a potential of 0.4-0.6 volts (V) and a current of 5-10 microamps (μA).

Padding and Absorption

The absorbent properties and abundance of ***Sphagnum*** (Figure 3) make it the most used taxon among the bryophytes (Densmore 1928). The Chippewa Indians in North America used it as an absorbent. It serves as an insulator, as pillow, mattress, and furniture stuffing, to keep milk warm or cool, to stuff into foot mats for cleaning shoes, to weave welcome mats, and in Lapland to line baby cradles, keeping the infant clean, dry, and warm (Stark 1860).

Mosses were sold on Moss Street in Moscow to put between the panes of glass in double-glazed windows, to absorb condensation (Robin Stevenson, pers. comm.). A colleague of mine used lichens (*Cladina*) similarly between the inner window and the storm window for the same purpose.

And Anders Hagborg (Bryonet 11 June 2016) shared his experience with that very use. He remembers in his childhood in Sweden it was common practice to put mosses between the storm window and inside window to absorb the moisture from condensation on the cold glass in winter. He thinks this moss may have been ***Sphagnum*** (Figure 3).

In Germany, ***Sphagnum*** (Figure 3) has been used in hospitals as neck and head rests, to support hips and backs, and to elevate the legs of wounded people (Hotson 1921). On the farm it is particularly good for absorbing urine from livestock and pets, a function shared with ***Hylocomium splendens*** (Figure 16), absorbing up to 55%, ***Rhytidiadelphus squarrosus*** (Figure 17) 33%, and ***Pseudoscleropodium purum*** (Figure 18) 6%. And even the Romans used it for toilet paper (Birks 1982)! In the laboratory ***Sphagnum*** prevents red-leg in frogs, in part by absorbing the urine. In the Philippines, the crocodile breeding station uses peat moss as a cushion or layering material for incubation of crocodile eggs (Tan 2003).

Figure 16. ***Hylocomium splendens***, a species used to absorb farm urine in Europe. Photo by Michael Lüth, with permission.

Figure 17. ***Rhytidiadelphus squarrosus***, a species used to absorb farm urine in Europe. Photo by Michael Lüth, with permission.

Figure 18. ***Pseudoscleropodium purum***, a species used to absorb farm urine in Europe. Photo by Michael Lüth, with permission.

Mattresses

Mosses have been used for sleeping for a long time. Dickson (2000) reported that mosses, especially ***Neckera crispa*** (Figure 11), were used for mattresses during the Bronze Age.

The Potawatomi Indians in North America used ***Sphagnum*** (Figure 3) species as fibers for rugs, mats, and bedding (Smith 1933). In the North Central States, USA, the Ojibwe Indians have used dried ***Sphagnum dusenii*** to make mattresses (Smith 1932).

In parts of the Malay Peninsula, ***Leucobryum*** (Figure 19) is used together with ***Campylopus*** (Figure 20) to stuff cushions and mattresses (B. C. Tan, pers. comm.). Burkill (1966) likewise reported that ***Calymperes*** (Figure 21), ***Campylopus*** (Figure 20), and ***Sphagnum*** (Figure 3) are used for stuffing mattresses in Malaysia.

Earlier uses of mosses to stuff mattresses are known from Carlisle, UK, where Woodward (1996) reported that 86 horseloads of moss were delivered to Council in 1584. One of the uses was for bedding as a form of down. Woodward contends that harvesting of mosses and other natural materials was more important in early modern society than we typically realize, providing significant employment for the poor of the land. A load of mosses brought 4 [old] pence.

Figure 19. ***Leucobryum sanctum***, a Malayan species in a genus used to stuff mattresses there. Photo by Niels Klazenga, with permission.

Figure 20. ***Campylopus introflexus***, a genus that has been used to stuff pillows. Photo by Michael Lüth, with permission.

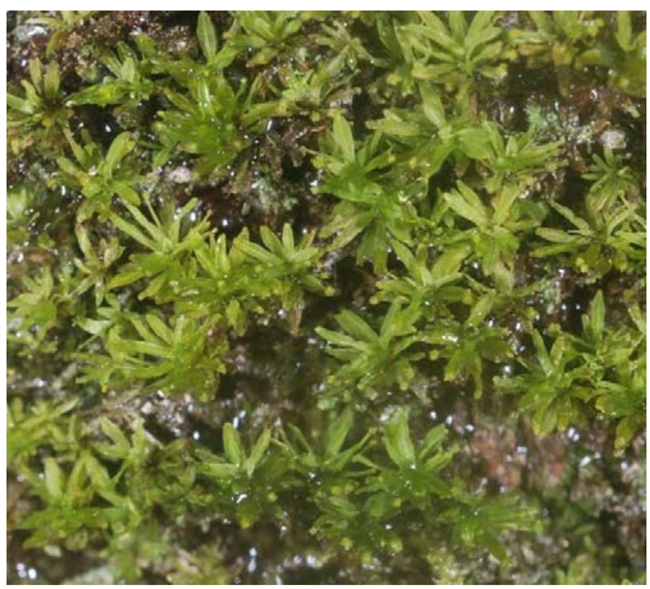

Figure 21. ***Calymperes*** sp, a genus used for stuffing mattresses in Malaysia. Photo by Niels Klazenga, with permission.

Table 1. Comparison of weight gain measured as wet weight to dry weight ratio of selected bryophytes (Horikawa 1952).

Atrichum	6.9
Barbula	8.3
Bazzania pompeana	4.0
Haplomitrium mnioides	12.0
Hylocomium cavifolium	9.8
Plagiomnium maximoviczii	6.7
Rhodobryum	10.0
Sphagnum	12.4
Trachycystis microphylla	3.2

In the Azores, ***Thuidium tamariscinum*** (Figure 22), ***Pseudoscleropodium purum*** (Figure 18), and ***Hypnum cupressiforme*** (Figure 5) were used to stuff pillows and mattresses (Allorge 1937). In fact, ***Hypnum*** was so popular as a pillow stuffing that Dillenius (1741) chose ***Hypnum*** as its name because of its association with sleep (sleep, from Greek *hypnos*). And Linnaeus copied the bears that sleep among mosses, choosing ***Polytrichum commune*** (Figure 10) for bedding (Crum 1973), stating that if a quilt could be made of it, nothing could be more comfortable (Black 1979). Both humans and domestic animals have enjoyed the comfort of a moss bed, with the absorptive ability serving an additional function for the animals (Ando & Matsuo 1984). And for all, mosses such as ***Brachythecium*** (Figure 23), ***Dicranum*** (Figure 13), ***Hypnum*** (Figure 5), ***Neckera*** (Figure 11-Figure 12), ***Papillaria*** (Figure 24), and ***Thuidium***, add the advantages of being insect-repellent and resistant to mold (Pant & Tewari 1989).

Figure 22. ***Thuidium tamariscinum*** with capsules, an insect-repellant moss used to stuff mattresses and pillows. Photo by Michael Lüth, with permission.

In 1868, Albert G. Morey applied for a patent for an "improved mattress." "Be it known that I, ALBERT G. MOREY, of Chicago, in the county of Cook, in the State of Illinois, have invented a new and useful Improvement in the Construction of Elastic Mattresses or Cushions…" The improvement appears to be the use of layers, with the bottom layer being moss, the middle layer of woody fiber or excelsior, and the top layer of elastic sponge. This sponge was not the synthetic sponge we know today, but the real animal, dead of course. "The object of my invention is to furnish an elastic mattress for beds, or cushion for seats, which, while possessing the peculiar qualities of the sponge mattress or cushion, shall yet be afforded at a less cost."

Figure 23. ***Brachythecium rutabulum***, in a genus of insect-repellant mosses used in bedding. Photo by Michael Lüth, with permission.

Figure 24. ***Papillaria nigrescens***, a suitable moss for packing fragile objects or making a bed. Photo by Michael Lüth, with permission.

Shower Mat

A modern use of mosses for absorption is that of Swiss artist/designer La Chanh Nguyen (Nguyen 2014; Telegraph.Co.UK 2009). She used 70 pieces of forest and island moss in cushions 6 cm in diameter to make a bath mat. Each piece is placed in a foam frame to prevent the moss from spreading. She reveres its softness underfoot and lack of unpleasant odor, claiming that it is relaxing and requires little care. Now she is looking for financial backing so she can mass produce it at less than the £220 it cost her to make her own.

But all may not be rosy with this special mat. Bryonetters (Bryonet-L@mtu.edu) quickly expressed their concern about conservation issues and the unlikelihood that the moss would survive indoors in low light. They suggested that most likely it looks alive, when it is really dead.

Such concerns aside, Winter (2014) shares her advice in **making a moss shower mat**. It is her perspective that these mats help you to make the transition from "insanely comfortable shower time" to "everything else you absolutely have to do with your life" by embracing the comfortable feel of a moss mat. Although these mats are available commercially, they are expensive, so she suggests making your own:

Materials needed:

- Substrate for the moss, such as high density foam, about 2.54 cm (1 inch) thick
- Sharp utility knife
- Silicone sealer, like caulk or cement
- Posterboard or cardstock for creating stencils
- Marker or grease pencil
- Spray bottle filled with water
- Moss (many kinds of moss can be used, just choose yours based on the amount of sunlight and average temperature of your bathroom)

How to do it:

- Choose the **size** of your mat. This can be as large or small as you need it to be, given the size of your bathroom. If using foam, be sure that you have enough to make two layers. Bamboo or wood trays will not work quite as well, given their tendency to produce mold and mildew under the conditions required to keep the moss alive.
- Choose the **shape** of your mat. You will need to create several cutouts for your moss. The shape of the cutouts and the edge of the mat are entirely up to you! Any shaping of the edges will need to be done to both pieces of foam, but the cutouts for the moss will only be on the top layer. Use the marker or grease pencil to trace the shapes onto the foam and use the utility knife to cut through the entire thickness. Use as many as you need to cover the mat with moss. Keeping small sections (as opposed to filling a tray with moss) will prevent it from growing excessively.
- **Seal the mat**. An adhesive like silicone caulk is recommended, because it will create a water-tight environment for the moss. Using a product like hot glue or certain other adhesives may melt the foam. Apply the adhesive to the underside of the top layer with the cutouts, making sure each section and the edge of the mat will be properly sealed. Press the top layer to the bottom layer, cleaning up any excess that may have squeezed out the sides. Use books or something heavy to weigh down the mat until the adhesive has dried.
- Prep the mat. Once the mat is ready for the moss, it will need to be properly prepped to ensure its survival. Use the spray bottle to mist the surface of the mat. Keep the spray bottle handy in the bathroom while the moss gets established.
- Plant the moss. Insert the moss into each cutout, until the mat is covered.
- Depending on what species of moss you have used, you might need to water it more than just the drips from your shower once a day. Use the spray bottle to mist the moss for the first couple of months while it gets established. This will keep it moist without over-saturating it.

Urinal Absorption

It seemed unlikely that the desert moss ***Syntrichia caninervis*** (Figure 25) would have any commercial potential. But it is great at absorbing water. Hence, Williams (2016) suggested its potential use to make bathroom urinals "less disgusting." It is able to take water from fog, dew, snow, and of course rain, very efficiently (Pan *et al.* 2016). Having this moss in the urinal would seem a good way to prevent the splashback, according to Tadd Truscott, Assistant Professor of Mechanical Engineering at Utah State and one of the study's authors (Hurd *et al*. 2015). But being the technology-oriented society we are, it is likely that the moss will only be a model, with an artificial moss serving the function. Good luck!

Figure 25. ***Syntrichia caninervis***, a highly absorbent moss with the potential to prevent backsplash in urinals. Photo by John Game, through Creative Commons.

Cleaning

The absorptive property, and often crunchy texture when dry, makes mosses useful for cleaning pots when camping (Gould, pers. comm.), while the remaining mosses can be used to keep the fishing worms alive. In India villagers use mosses mixed with burned ashes to clean household utensils (Pant 1989).

Brushes and Brooms

Polytrichum, with its long, stiff stems, makes good brooms for dusting curtains and carpets (Crum 1973) and apparently ***P. commune*** (Figure 10) is still in use for brushes in southern Sweden today (Hedenäs 1991). Stems are stripped of their leaves to make a broom 30-45 cm long (Thieret 1954).

Robin Stevenson (pers. comm.) reminded me that mosses have been used to make brushes.

Oily Humans

Imagine yourself all greasy and dirty, far from any source of soap or hot water. Your clothes are dirty and your hands are encrusted with grime. Fridtjof Nansen (1897) recounts an experience that is best told in the original language: "Fancy being able to throw away all the heavy, oily rags we had to live in, glued as they were to our bodies. Our legs suffered most; for there our trousers stuck fast to our knees, so that when we moved they abraded and tore the skin inside our thighs till it was all raw and bleeding. I had the greatest difficulty in keeping these sores from becoming altogether too ingrained with fat and dirt, and had to be perpetually washing them with moss, or a rag from one of the bandages (Figure 26) in our medicine-bag, and a little water, which I warmed in a cup over a lamp. I have never before understood what a magnificent invention soap really is. We made all sorts of attempts to wash the worst of the dirt away; but they were all equally unsuccessful. Water had no effect upon all this grease; it was better to scour oneself with **moss** and sand. We could find plenty of sand in the walls of the hut, when we hacked the ice off them. The best method, however, was to get our hands thoroughly lubricated with warm bears' blood and train-oil, and then scrub it off again with moss. They thus became as white and soft as the hands of the most delicate lady, and we could scarcely believe that they belonged to our own bodies. When there was none of this toilet preparation to hand, we found the next best plan was to scrape our skin with a knife." (Contribution from Robin Stevenson, pers. comm.)

Figure 26. ***Sphagnum*** for surgical dressings. Photo by National Museum of American History, with online permission.

Soaps

Stevenson (2012) recalls his recent visit to an antique shop. There he was surprised to find a new use for ***Sphagnum*** (Figure 3) – Sphagnol Soap – produced by a British company called Peat Products (Sphagnol) Limited (Figure 27-Figure 28) (see also Richardson 1981; The Science Museum 2012). A search on the web produced several useful references to this company and its various products. Each bar contains 15% pure Sphagnol, which is said to consist of 'Emollient Vegetable Tars and Oils.' The 'active ingredient,' Sphagnol, appears to have been a distillate of peat, prepared by the calcination of the peat itself. Details of the chemistry of this mysterious distillate are not available, leading one to the suspicion that a certain amount of scientific mumbo-jumbo may have been involved. The product was, however, said to be 'delightful in use'. The company was in existence at least as early as 1899, since a testimonial of that date from Dr. Carl Peters, wrapped around each bar, states that it not only helped prevent prickly heat on his expedition to the Zambesi district, but also cured one member of the expedition of piles! (Carl Peters was a German explorer and journalist).

Figure 27. Sphagnol soap ad. Photo courtesy of Robin Stevenson.

Figure 28. Sphagnol soap on display in an antique shop. Photo courtesy of Robin Stevenson.

Kai (1919), in a New Zealand nursing journal advertisement, lists Sphagnol soap, but also ointment, suppositories, and shaving soap made with ***Sphagnum*** (Figure 3). The claim was that all these products were awarded a "certificate of purity, quality and merit by the Institute of Hygiene."

Pools and Spas

If you are guessing that ***Sphagnum*** (Figure 3) might be the moss of choice here, you are right. But Dick Andrus warns that not all ***Sphagnum*** species are created equal. Ecology is important. The "aquatic" species like ***S. cuspidatum*** (Figure 29), ***S. torreyanum*** (Figure 30), ***S. majus*** (Figure 31), and ***S. macrophyllum*** (Figure 32) appear to have little or no cation exchange capacity. Rather, hummock species like ***S. fuscum*** Figure 33), ***S. capillifolium*** (Figure 3), and ***S. rubellum*** (Figure 34) should work well.

Figure 29. ***Sphagnum cuspidatum***, an aquatic species with little cation exchange capacity. Photo by Michael Lüth, with permission.

Figure 30. ***Sphagnum torreyanum***, an aquatic species with little cation exchange capacity. Photo by Janice Glime.

Figure 31. ***Sphagnum majus***, an aquatic species with little cation exchange capacity. Photo by Michael Lüth, with permission.

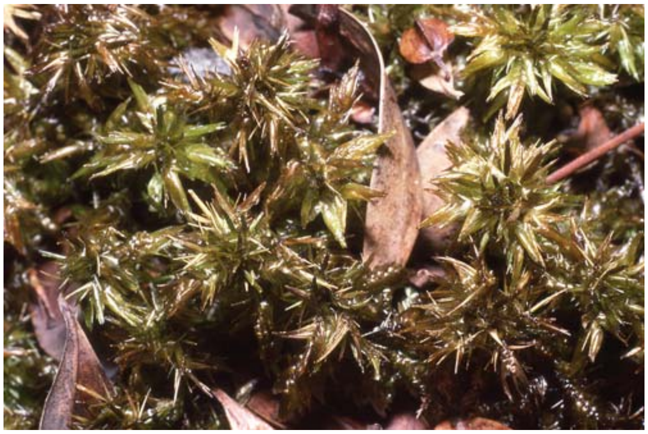

Figure 32. ***Sphagnum macrophyllum***, an aquatic species with little cation exchange capacity. Photo by Janice Glime.

Figure 33. ***Sphagnum fuscum***, a species with good cation exchange capacity. Photo by Jutta Kapfer, with permission.

Figure 34. ***Sphagnum rubellum***, a species with good cation exchange capacity. Photo by Michael Lüth, with permission.

For those of you who are new to the wonders of ***Sphagnum*** (Figure 3), it has two huge advantages as an absorbent of such things as heavy metals and other contaminants. It has large hyaline cells (Figure 35), especially in dryer habitats, that permit it to absorb large quantities of water. And it is able to exchange hydrogen ions (Figure 36) on its cell walls for other ions with a positive charge, hence removing them from the surrounding water.

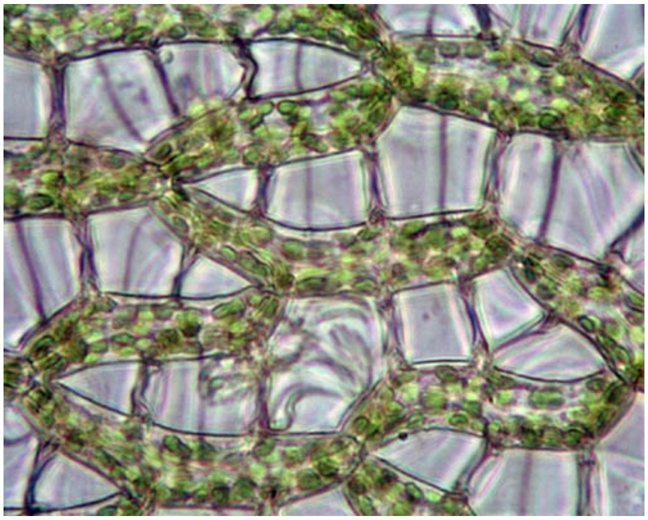

Figure 35. ***Sphagnum palustre*** leaf cells showing green photosynthetic cells and hyaline cells with bars. Photo by Malcolm Storey, through Creative Commons.

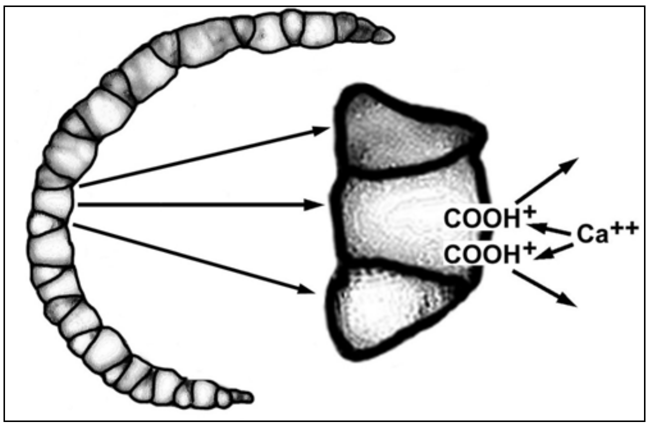

Figure 36. View of leaf cross section of ***Sphagnum*** (**left**) with two enlarged chlorophyllous cells and hyaline cell on **right**. Enlargement shows **carboxyl groups** ($COOH^+$) of the **polyuronic acid** and one Ca^{++} that will exchange for two H^+ ions in cation exchange. Drawing by Janice Glime.

The folks at Creative Water Solutions have been very helpful in telling me about their use of ***Sphagnum*** (Figure 3, an aquatic species with little cation exchange capacity. Photo by) absorbents. They were concerned with removing biofilms in various water systems (including pools). Research shows that the chemicals typically used actually bind to the biofilms, making the chemicals less effective. Furthermore, the biofilm itself provides an environment that is protective of the bacteria. They can only be attacked by the chemicals when they are freed from the biofilm, causing managers to add more and more chemicals to the water. Enter ***Sphagnum***. This moss has permitted them to reduce the need for chemicals by as much as 90%.

Toiletries and Toilets

I have learned from Susana Rams Sánchez that mosses are sold, mixed with a variety of other plant items (Figure 37), and sold in Morocco for washing one's hair. I have to wonder what their role is – antibiotic perhaps? Other items in the mix include fresh flowers, presumably for their sweet odors.

Figure 37. **Upper:** Market place in Azrou, Morocco, where bags of herbals comprise the ingredients for washing hair. **Lower:** Bag of herbals mixed and ready for sale for washing hair. Photos by Susana Rams Sánchez, with permission.

Dillenius (in Crum 1973) stated that ladies of his time used an oil extract of ***Polytrichum*** (Figure 10) for their hair, applying the Doctrine of Signatures because of the hairs on the calyptra.

One use that will probably remain forever among field personnel is that of toilet "paper" (Open-Air 2007). ***Sphagnum*** (Figure 29-Figure 34) is particularly suitable, both for its absorptive properties and its antibiotic properties. Use as toilet paper is most likely ancient. Rösch (1988) reported the use of ***Neckera*** (Figure 11-Figure 12) species for toilet paper. Dickson (2000) reported eleven species of forest mosses mixed with human excrement, indicating their use for toilet paper. Among these, species of ***Neckera*** were prominent.

The German peat closet is one step further in toilet use. This is a toilet in which peat is used instead of water (Turner 1993). The peat was thus mixed with the human excreta (both feces and urine) and the mix was disposed into a mobile cart.

Pesticides

We have known about the ability of bryophytes to discourage insect pests for centuries. Whereas tracheophyte herbaria require ill-smelling moth balls to protect them from destruction by tiny beetles, bryophytes store safely with no such protection. Such safety suggests that bryophytes may contain some sort of natural pesticide (Yepsen 1984), or simply be unpalatable. In nature, it is not unusual for capsules to be grazed by slugs – not a common organism in a dry herbarium, but the leafy portion of the same plant is often ignored.

Davidson and coworkers (1989) isolated the antifeedants ferulic and possibly m- or p-coumaric acid from a wall-bound fraction of the leafy shoots of ***Brachythecium rutabulum*** (Figure 38) and ***Mnium hornum*** (Figure 39), parts ignored by slugs that readily grazed the capsules. Asakawa has devoted his life to finding a wide variety of phenolic and other ill-tasting or lethal compounds in liverworts. For example, the liverwort ***Plagiochila*** (Figure 40) contains the sesquiterpene hemiacetyl plagiochiline A (Asakawa et al. 1980b) that inhibits the feeding of an African army worm (Asakawa *et al.* 1980a) and is an extremely potent poison to mice (Matsuo *et al.* 1983, unpublished data).

Figure 38. ***Brachythecium rutabulum***, a large pleurocarpous moss that produces antifeedants such as ferulic acid. Photo by Michael Lüth, with permission.

Figure 39. ***Mnium hornum***, a species that is endowed with antifeedants such as ferulic acid. Photo by Michael Lüth, with permission.

Clearly not all bryophytes are so inhospitable to hungry herbivores. My students and I have found that pillbugs (***Porcellio*** spp.; Figure 41) will readily consume ***Thuidium delicatulum*** (Figure 42) plants and ***Polytrichum juniperinum*** (Figure 43) leaves while preferring starvation or paper towels to ***Polytrichum*** stems, ***Dicranum polysetum*** (Figure 44), or ***Pleurozium schreberi*** (Figure 45-Figure 46). However, this avoidance is not always the case, suggesting that seasonal differences may occur (Hribljan 2009).

Figure 40. ***Plagiochila sciophila***, in a liverwort genus that contains the sesquiterpene hemiacetyl plagiochiline A. Photo by Yang Jia-dong, through Creative Commons.

Figure 41. ***Porcellio scaber*** on bryophytes, a species that consumes mosses. Photo by Bernard Dupont, through Creative Commons.

Figure 42. ***Thuidium delicatulum***, a species eaten by pillbugs (***Porcellio*** spp.). Photo by Janice Glime.

Figure 43. ***Polytrichum juniperinum***, a species for which leaves, but not stems, are eaten by pillbugs in the genus ***Porcellio***. Photo by Paul Slichter, with permission.

Figure 44. ***Dicranum polysetum***, a species not eaten by pillbugs (***Porcellio*** spp.). Photo by Janice Glime.

Figure 45. ***Pleurozium schreberi***, a species sometimes eaten by pillbugs (***Porcellio*** spp.) and sometimes avoided. Photo by Janice Glime.

Figure 46. ***Pleurozium schreberi*** eaten in its forest home by ***Porcellio scaber*** (see upper left). Photo by courtesy of John Hribljan.

L. Russell found that one insect readily devours ***Porella navicularis*** (Figure 47) until it eats a species of ***Porella*** that has a peppery taste (D. H. Wagner, pers. comm.). After eating the peppery species for a few minutes, it stops eating it and henceforth refuses to eat either ***Porella*** species. (How is it these creatures are such good taxonomists!?)

Figure 47. ***Porella navicularis***, in a genus with some edible species and some with an unpalatable peppery taste. Photo by Kent Brothers, Botany Website, UBC, with permission.

It appears that exploration of antiherbivory compounds in bryophytes could prove quite profitable for moving genes to crop plants. But I must ask, if insects don't eat them, what is the reason? Doesn't that mean that the ones that ate them didn't pass on their genes? And do I really want the lethal products of those bryophyte genes in **my** food? Certainly a long regime of testing stands between us and widespread use for this purpose, I hope!

Fortunately, so far moss genes are only being considered for a commercial level of transplantation into tobacco (Comis 1992) – a step that has already been accomplished. Oliver and colleagues, working at the United States Department of Agriculture in Lubbock, Texas, have isolated (Scott & Oliver 1994) and transplanted (Oliver *et al.* 2000) several genes from ***Syntrichia*** (formerly in ***Tortula***; Figure 48) that are specific for recovery from desiccation. Antiherbivory genes are being considered as well. But will tracheophytes be able to express these genes in meaningful ways? And what will they do to the safety of our food?

Figure 48. ***Syntrichia ruralis***, a moss being studied for possible transfer of genes for drought tolerance and antiherbivory into tobacco. Photo by Michael Lüth, with permission.

Kenneth Adams (pers. comm. 1 November 2013) reports that ***Pseudoscleropodium purum*** (Figure 18) has been used in tobacco tins for cleaning up maggots for fishing.

Clothing

Can you imagine wearing mosses? In some parts of Germany, wool was woven with ***Sphagnum*** (Figure 29-Figure 34) to make a good, cheap cloth (Hotson 1921), whereas in Mexico, the dark-colored extract of a rock-inhabiting moss is used to color it (Delgadillo, pers. comm.).

In the Philippines, the tall moss ***Spiridens reinwardtii*** (Figure 49) is used by some of the natives to decorate head gear and clothing (B. C. Tan, pers. comm.). Likewise, in the area around Mount Wilhelm in Papua New Guinea ***Dawsonia*** (Figure 50) is used together with other bryophytes to decorate head gear and body wear (Dickson 2000; Tan 2003). In Malaysia, the large mosses ***Dawsonia***, ***Pogonatum*** (Figure 51), and ***Spiridens*** are used for body decoration and to ward off evil spirits.

Figure 49. ***Spiridens reinwardtii***, a moss used to decorate head gear in the Philippines. Photo by Daniel Nickrent, with online permission.

Figure 50. ***Dawsonia superba***, a moss used to decorate head gear and clothing in New Guinea. Photo by Jan-Peter Frahm, with permission.

Figure 51. ***Pogonatum cirratum***, member of this genus in Malaysia where ***Pogonatum*** is used for body decoration and to ward off evil spirits. Photo by Li Zhang, with permission.

Several cultures have used ***Sphagnum*** (Figure 29-Figure 34) (Bland 1971; Carrier Linguistic Committee 1973; Turner 1983; Compton 1993; Smith 1997; Moerman 1998; Marles *et al*. 2000) and ***Dicranum scoparium*** (Figure 52) for lining diapers (Adelson 2002; Kimmerer 2003), and even modern diapers from Johnson & Johnson in the U.S. and Canada can have ***Sphagnum*** liners (Johnson Gottesfeld & Vitt 1996). ***Sphagnum*** is also used for diapers by the Maori of New Zealand (Macdonald 1974; Harris 2008). Alaskan Native Peoples have used blades of grass, rubbed together until soft, mixed with peat moss and squirrels' nests to line a cradle as a diaper (Kari 1985).

Figure 52. ***Dicranum scoparium***, a moss used by several Canadian cultures for diapers. Photo by Michael Lüth, with permission.

John Steel provided me with an image of a fashion statement that appeared in the Otago Daily Times, New Zealand, 30 March 2012. It shows a sweater coat with mosses used to create the design.

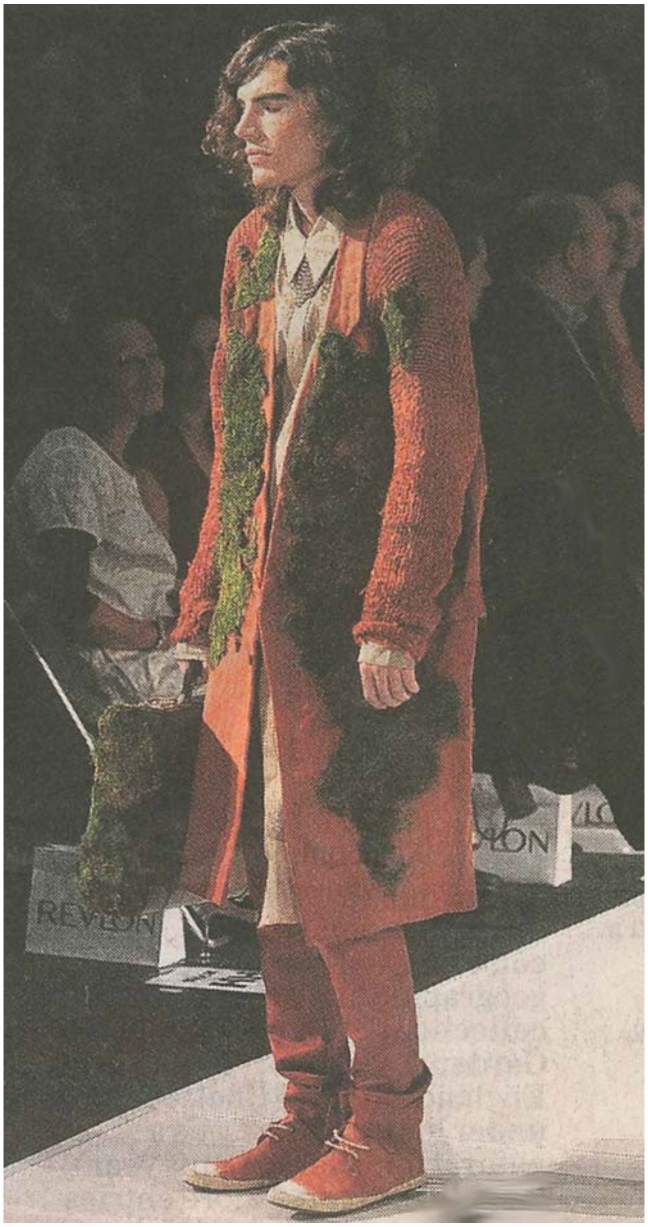

Figure 53. Moss used as design on clothing, modified fom Otago Daily Times, 30 March 2012, p 18 1b. Photo courtesy of John Steel.

Doug Elliott describes the benefits of using *Sphagnum* diapers in his Adventures website (Elliott 2012). The moss wicks the water away from the skin, acting much like talcum powder, and preventing diaper rash. This may be due to its acidity and antibiotic properties. One of its endearing qualities is that the baby's feces become covered with the ***Sphagnum*** (Figure 29-Figure 34) and are easy to remove and are kept away from the baby's skin. The soiled moss is easily discarded into compost or buried in the soil, even when hiking. Elliott prefers ***Sphagnum*** to other products for diapers, and he has tried a number of them. In Cree, the word for ***Sphagnum*** is *otaow*, and would translate to mean "protectively holds" or "embraces."

Elliott warns that the moss should be dried immediately for safe keeping. I would add that any discolored moss should be avoided because it could contain the fungus ***Sporothrix schenckii*** (Figure 54) that causes **sporotrichosis**. Elliott claims that the fungus can be avoided by gathering the moss in a tarp and spreading it so it dries quickly. That is probably sufficient to protect from adhering spores, but I wouldn't trust it against infected plants (Figure 55-Figure 57). When gathering the moss, care should be taken to minimize impact, gathering small clumps and moving around to avoid creating gaping holes.

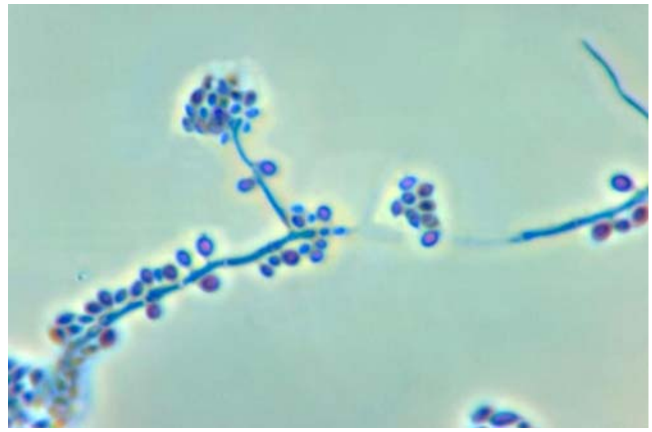

Figure 54. ***Sporothrix schenckii*** conidia, a fungus that inhabits ***Sphagnum***. Photo by USDHHS, through public domain.

Figure 55. ***Sphagnum*** with fungi causing the moss to lose color (left). Photo by Janice Glime.

Figure 56. ***Sphagnum*** infected with fungi. Photo by Janice Glime.

Figure 57. ***Sphagnum*** being used for diaper. Photo courtesy of Doug Elliott.

Elliott describes the diapering process: "Though some of our friends lay the ***Sphagnum*** (Figure 29-Figure 34) moss on a cotton diaper, we find that a moss-filled nylon diaper cover works best for us. To prepare for diapering, open the diaper cover and place it on a flat surface. Place a couple handfuls of the moss in the diaper cover and arrange it 'strategically' (more in front for boys). Examine the moss carefully to be sure it is free of leaves, pine needles and other potentially uncomfortable debris. (I press the moss into place with the back of my hand to be sure it is soft and free of projections.) Sometimes we use different 'grades' of moss. The softest moss is reserved for the inner layer and the rest is used as the 'backfill.' Sometimes we place a few sheets of toilet paper on top to cover the moss. Then we set the babe down onto the moss and fasten the diaper up as gracefully as possible. Since managing a squirmy baby on an easily scatterable pile of moss is not always easy, having an extra person helping usually makes it easier. (We call it 'tag team diapering.')"

Michigan's Chippewa Indians used ***Sphagnum*** for this purpose to keep the babies clean and warm (Crum 1973). In fact, Johnson Gottesfeld and Vitt (1996) learned that certain species were preferred and some avoided by the indigenous people of North America. The long, pink (not red) plants of ***Sphagnum divinum*** (Figure 58) were preferred, whereas short, yellow-green, and red plants (Figure 59) were considered unsuitable. Red ***Sphagnum nemoreum*** (Figure 60) caused irritation.

The New Zealand Maori have used ***Lembophyllum clandestinum*** (Figure 61) for diapers as well as for baby bedding (Cooper & Cambie 1991) – just think, a dual purpose moss! ***Sphagnum*** is even used in the modern world in mattress pads for infants (Turner 1993). In California, there is no ***Lembophyllum***, but ***Alsia*** (Figure 62) served the Native Americans for baby bedding (Thieret 1956).

Figure 58. ***Sphagnum divinum*** that is pink and suitable for diapers. Photo by David T. Holyoak, with permission.

Figure 59. ***Sphagnum divinum***, a species that is no longer suitable for diapers when it reaches this deep red stage. Photo by Michael Lüth, with permission.

Figure 60. ***Sphagnum*** (***capillifolium***) ***nemoreum*** illustrating the red colors that seem to be associated with diaper rash when used for baby diapers. Photo by Jan-Peter Frahm, with permission.

Figure 61. ***Lembophyllum clandestinum***, a moss used by the Maori in New Zealand for diapers and bedding. Photo by Tom Thekathyil, with permission.

Figure 62. ***Alsia californica*** in California, USA, a moss used by Native Americans for baby bedding. Photo by Michael Lüth, with permission.

In Germany and Nordic countries, ***Sphagnum*** (Figure 29-Figure 34)) has become popular to line hiking boots (Figure 63; Hedenäs 1991), not only cushioning the feet, but absorbing moisture and odors while discouraging bacteria. Thanks to Gillis Een, I have been enjoying the boot liners and can attest to their comfort.

Natives of the Philippines use mosses to decorate headwear and clothing (B. Tan, pers. comm.). In New Guinea, ***Dawsonia grandis*** (see Figure 50) is worn by natives in bracelets and hair (Van Zanten 1973) and to decorate ceremonial masks (Richardson 1981). The British in England used the moss ***Climacium dendroides*** (Figure 64), artificially colored (Clarke 1902), to decorate a lady's hat (Tripp 1888). And in Boston, the early cultural center of the United States, braids of ***Pseudoscleropodium purum*** (Figure 18) and cords of ***Neckera crispa*** (Figure 11) and bits of ***Dicranum*** (Figure 52) decorated ladies' hats and bonnets (Clarke 1902). These were woven into bands and sold for $0.10 per yard. In the villages of Kumaun, India, women stuff such mosses as ***Hylocomium*** (Figure 16), ***Hypnum*** (Figure 5), and ***Trachypodopsis*** (Figure 66) into cloth sacks to make the **sirona**, a head cushion, that both cushions the vessel carried on the head and absorbs water that splashes from it (Pant & Tewari 1989).

Figure 63. Advertisement for shoe lining made from ***Sphagnum***. Photo by Janice Glime.

Figure 64. ***Climacium dendroides***, a moss dyed and used to decorate ladies' hats in Great Britain. Photo by Michael Lüth, with permission.

The large size of ***Dawsonia grandis*** (see Figure 65) affords it more utility than most mosses. In New Guinea, it is stripped of its leaves, dried over a glowing fire, stripped of its outer layers, split in two, then plaited into a red rope to decorate net bags and other objects (Van Zanten 1973). In New Zealand, it was other members of the **Polytrichaceae** that proved useful. The shoots and leaves of ***Polytrichum commune*** (Figure 10) and ***Polytrichadelphus magellanicus*** (Figure 67) were used in making Maori cloaks, with alternating brown and black serving as decoration (Beever & Gresson 1995). The numerous air spaces, serving the moss for capillary movement and water retention, most likely provided an insulating warmth to the wearer.

Figure 65. ***Dawsonia superba***; ***Dawsonia grandis*** stems are used to decorate net bags in New Zealand. Photo by Velela, through Creative Commons.

Figure 66. ***Trachypodopsis serrulata***. Members of this genus are stuffed into sacks to make a sirona used to cushion water vessels carried on the head in India. Photo by Michael Lüth, with permission.

Figure 67. ***Polytrichadelphus magellanicus***, a moss used to make Maori cloaks. Photo by Phil Bendle, with permission.

Even buttons (Figure 68) can be made from bryophytes. In Europe, peat is pressed into disks and a design stamped into it to make an attractive button for clothing.

Figure 68. Button made of pressed peat. Photo by Janice Glime.

Archaeological evidence tells us that soft mosses such as ***Loeskeobryum brevirostre*** (Figure 69) were used to pad Mesolithic flint blades, protecting the user's hand (Dickson 1973; Figure 70).

Figure 69. ***Loeskeobryum brevirostre***, a moss used to pad Mesolithic flint blades to protect the hand. Photo by Bob Klips, with permission.

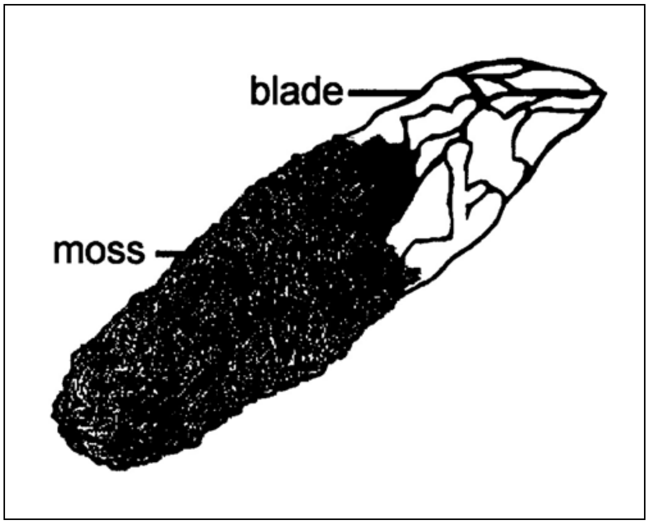

Figure 70. Mesolithic knife handles in Europe were sometimes wrapped with moss. Drawing based on photograph by Dickson 1981.

Figure 72. ***Pohlia nutans*** with capsules, member of a genus of the common mosses on the clothes of the Iceman. Photo by Malcolm Storey <www.discoverlife.org>, with online permission.

Tyrolean Iceman's clothes exhibit 30 species of bryophytes (Dickson *et al*. 1996), most likely as involuntary passengers. Nine of these would have been unable to grow at the high altitude where the Iceman was found. Two particularly notable mosses were the low altitude woodland species ***Neckera complanata*** (Figure 12) and ***N. crispa*** (Figure 11), indicating Iceman came from the south (now Italy) and not north (Austria). Most common in 30 samples were ***Polytrichum piliferum*** (Figure 71), ***Pohlia*** spp. (Figure 72), ***Andreaea*** spp. (Figure 73), ***Racomitrium lanuginosum*** (Figure 14), and ***Polytrichastrum sexangulare*** (Figure 74).

Figure 73. ***Andreaea rupestris*** with capsules, member of a genus of the common mosses on the clothes of the Iceman. Photo by J. C. Schou, with permission.

Figure 71. ***Polytrichum piliferum***, one of the common mosses on the clothes of the Iceman. Photo by Michael Lüth, with permission.

Figure 74. ***Polytrichastrum sexangulare***, one of the common mosses on the clothes of the Iceman. Photo by Hermann Schachner, through Creative Commons.

The Iceman had multiple uses for bryophytes (Dickson 2000). Among these was the use of ***Neckera complanata*** (Figure 12) for leggings and upper body clothing. ***Neckera crispa*** (Figure 105) was used in upper body clothing, leggings, aprons, twisted thongs, and hair decorations. In fact, ***N. crispa*** was the most abundantly used bryophyte in that part of the world. Ochsner (1975) reported its use by prehistoric Swiss.

Jewelry

A creative entrepreneur in Iceland is selling jewelry with a moss garden as the main attraction (HAF 2010). These items include a necklace with a small cup of mosses, a ring, and a knuckle garden that bridges four fingers. The included prices were 150€ for the ring and 180€ for the necklace.

Food Source

If even most insects won't eat the bryophytes, it is no wonder that they seldom have been used for human food. The Chinese consider mosses to be a famine food (Bland 1971). Their low caloric value (Forman 1968) and often abominable taste are efficient deterrents to herbivores of all sizes. Mizutani (1961) complained that it was necessary to gargle to get rid of the bitter liverwort taste, no doubt a result of the numerous phenolic compounds in a single species. Thus it is not surprising that the only country where any bryophyte seems to be a significant component of food is in the peat-rich Lapland where ***Sphagnum*** (Figure 29-Figure 34) was reportedly once used as an ingredient in bread (Bland 1971). However, Jim Dickson (Bryonet 20 February 2015) consulted a Swedish colleague who is an expert on the historic making and composition of bread and she has never heard of such a recipe including ***Sphagnum***. Even Linnaeus did not mention any use of ***Sphagnum*** in making 18th century bread [but then, Linnaeus put the aquatic flowering plant *Potamogeton* in the moss genus ***Fontinalis*** (Figure 75), so his understanding of mosses appears to be minimal]. John Lindley (1849) says ***Sphagnum palustre*** (Figure 76) is a "wretched food in barbarous countries." Native Americans used *Camassia quamash*, simmered in blood with moss, to make a soup (Hart 1992).

Figure 75. ***Fontinalis antipyretica***, a large aquatic moss. Photo by Michael Lüth, with permission.

Figure 76. ***Sphagnum palustre***, a "wretched food." Photo by Michael Lüth, with permission.

Weyrich *et al*. (2017) used DNA in dental calculus to infer the presence of bryophytes (***Physcomitrella patens***; Figure 77) in the diet of Neanderthals from El Sidrón cave, Spain. But Dickson *et al*. (2017) have taken exception to this as evidence of the use of bryophytes as food. They argue that bryophytes are neither palatable nor nutritious and that there is no conclusive evidence that people eat or have eaten mosses. They do not consider the presence of "forest moss" in the dental calculus on one Neanderthal to be an adequate basis to claim it as a dietary component.

Figure 77. ***Physcomitrella patens*** with capsules, a moss whose DNA was found in the calculus of the teeth of one Neanderthal man in Spain. Photo by Bob Klips, with permission.

Dickson *et al*. (2017) argue that fragments of DNA from a taxonomic group (bryophytes) that is under-represented in sequencing studies is a major limitation in interpreting diet. In the case of ***Physcomitrella patens***, it is not a forest moss as claimed, but lives on pool and river margins. It is furthermore so small that it is unlikely to be of interest for food.

On the other hand, Villarroel *et al*. (2007) described the use of ***Sphagnum*** in making cakes in Latin America. The recipe called for resistant starch, ***Sphagnum divinum*** (as ***S. magellanicum***; Figure 58-Figure 59), and defatted hazel nut flour (*Gevuina avellana*, Mol). The starch, HI Maize, and moss provided rich sources of dietary fiber (8.7%). With these ingredients, the product could be stored at refrigerated temperatures but not at 20ºC.

Mummified bodies give us clues into past uses of bryophytes for food. There is evidence that suggests the Iceman consumed bryophytes. ***Neckera intermedia***

(Figure 78) occurred in the eviscerated abdomen of a Guanche (aboriginal Berber inhabitant) "mummy" from the Canary Islands. And ***Sphagnum*** (Figure 29-Figure 34) is known from intestines of Danish and English bog bodies (Dickson 2000).

Figure 78. ***Neckera intermedia***, a species found in the eviscerated abdomen of a Guanche "mummy." Photo by Jan-Peter Frahm, with permission.

Scientists retrieved fragments of six moss species from the alimentary tract of the Tyrolean Iceman (5200 years BP) from the eastern Alps, including ***Anomodon viticulosus*** (Figure 79), ***Hymenostylium recurvirostrum*** (Figure 80), ***Neckera complanata*** (Figure 81), and ***Sphagnum imbricatum*** (Figure 82) (Dickson *et al*. 2009). The reason for having these in his gut remains unknown. Did he use the mosses to stop the bleeding of his wounded hand, then unintentionally ingest them along with his food? Or did they come with the drinking water? Were some of them used to wrap food, then get ingested with it? Or did these people use the mosses like the monkeys (Lamon *et al*. 2017), dipping them in water and squeezing the water into their mouths?

Figure 79. ***Anomodon viticulosus***, a moss that occurred in the alimentary tract of the Tyrolean Iceman. Photo by Hermann Schachner, through Creative Commons.

In British Columbia, Canada, an ancient human body, 17-20 years of age, from a glacier likewise displayed bryophytes in the gut (Dickson *et al*. 2004, 2009; Mudie *et al*. 2005). At least twelve species of mosses were in the gut from the duodenum to the rectum. One of these was a member of the ***Acutifolia*** (Figure 83) section of ***Sphagnum***. But this circumstantial evidence does not tell us the reason for the ingestion.

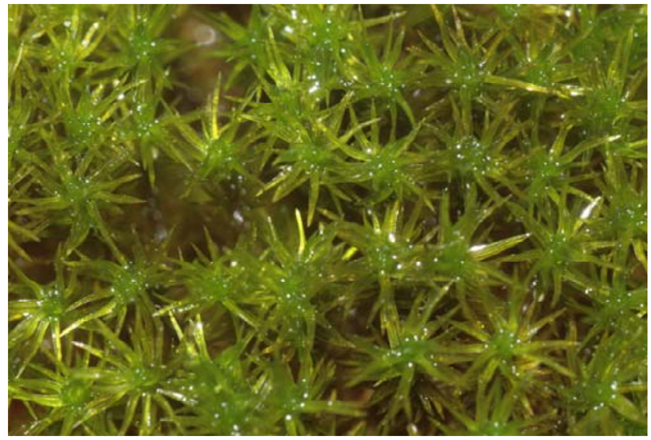

Figure 80. ***Hymenostylium recurvirostrum***, a moss that occurred in the alimentary tract of the Tyrolean Iceman. Photo by Hermann Schachner, through Creative Commons.

Figure 81. ***Neckera complanata***, a moss that occurred in the alimentary tract of the Tyrolean Iceman. Photo by Michael Lüth, with permission.

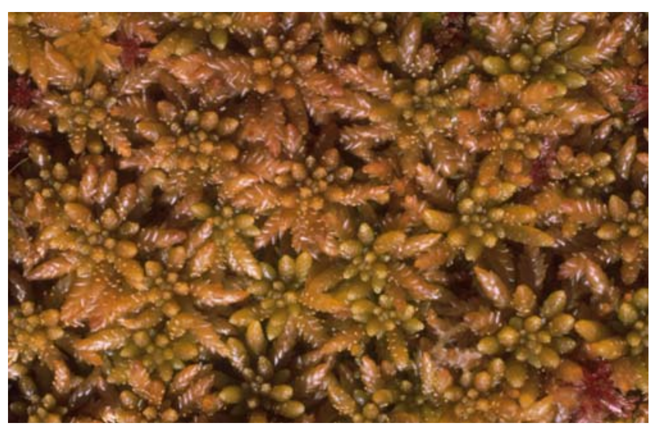

Figure 82. ***Sphagnum imbricatum***, a moss that occurred in the alimentary tract of the Tyrolean Iceman. Photo by Jan-Peter Frahm, with permission.

Figure 83. ***Sphagnum fimbriatum***, a member of the ***Acutifolia*** section of ***Sphagnum***. Photo by David Holyoak, with permission.

There is an interesting report of bryophytes being eaten by Neanderthal man, based on DNA evidence (Weyrich *et al*. 2017). In this treatise, pine nuts (*Pinus koraiensis*), a mushroom (*Schizophyllum commune*), and the moss ***Physcomitrella patens***, identified as "forest moss." Dickson *et al*. (2017) has published the same problems with this interpretation as I have. First, this moss does not grow in forests, but rather in mud flats in the open. Second, it is a tiny moss only a few mm tall, usually in small patches. And finally, this is the moss with its entire genome mapped; many mosses are not even in the database and those that are have been identified by only a small number of genes. On top of these factors making the consumption of this species unlikely, we don't know the reason for finding moss genetic material in the calculus on the teeth of this Neanderthal. Any number of reasons could be considered – perhaps mosses were a primitive tooth brush!

One historic note is that in the second edition of the Dictionary of Dates (Joseph Haydn, London, 1854), Peter, the Wild Boy, is described (C. R. Stevenson, Bryonet 27 November 2006). Peter was a savage creature who lived in the forest of Hertswold, electorate of Hanover, Great Britain. Peter walked on his hands and feet, climbed trees like a squirrel, and was found eating grass and moss in November of 1725. But even this recorded history of human consumption is in question because moss has many meanings to a lay person, and we cannot be sure it was truly a bryophyte being described.

A lot of drinks, especially teas, are made from a variety of odd plant substances with antibiotic properties. Some Native Americans have used ***Sphagnum*** (Figure 29-Figure 34) leaves to make tea (Carrier Linguistic Committee 1973).

Vitamins

Although bryophytes do not seem to be good candidates for food, some bryophytes may provide specific needs for animals both in the wild and on farms. For example, ***Neodicladiella pendula*** has a high content of vitamin B_{12} and causes no noticeable side effects when fed to puppies and chickens (Sugawa 1960). ***Sphagnum*** (Figure 29-Figure 34), as milled peat, provides a binder for iron and vitamins used to supplement the diet of anemic piglets.

Masanobu Higuchi (Bryonet 20 November 2006) reports being served a soup in southwestern Yunnan, China, ordered by his friend. He found something tough and hard to chew in the soup. On close examination, he identified it to be the moss ***Rhodobryum giganteum*** (Figure 84). He speculated that the chef may be including it as a medicinal herb.

Figure 84. ***Rhodobryum giganteum***, a medicinal herb and soup ingredient in China. Photo by David Long, with permission.

Flavoring

Mosses have, however, been used for flavoring, though not commonly. ***Sphagnum*** (Figure 29-Figure 34, Figure 85) contributes to the flavor of Scotch whisky. Scotch whiskies that contain peat include Ardbeg TEN, Highland Park, Octomore, Laphroaig, and Talisker <Whiskey.com>. First, the grains are steeped in water from a ***Sphagnum*** peatland during the malting stage, but this does not contribute to the smoky flavor (Miller 1981; <Whisky.com>). Drying the malt over a peat fire adds the smoke flavor to the barley grains <Whisky.com>. The degree of smokiness in the flavor depends on the length of time the barley grain is dried over the peat fire. Damp malt usually requires about 30 hours of drying.

Figure 85. Mined peat bog in Ireland. Peat like this is used in the fires used to dry the malt for making whisky. Photo by Amos, through Creative Commons.

In Germany one can buy "drinkable peatbog (Trinkmoor)" as a diet addition (Wolfgang Hofbauer, Bryonet 20 February 2015). This is a suspension made not from fresh ***Sphagnum*** (Figure 29-Figure 34), but from peat (Figure 85). ***Lunularia*** (Figure 86) and ***Plagiochasma*** (Figure 87) are used in preparation of maize beer (Franquemont *et al.* 1990).

Figure 86. ***Lunularia cruciata***, a liverwort used in making maize beer. Photo by Michael Lüth, with permission.

Figure 87. ***Plagiochasma appendiculatum***, a liverwort used in making maize beer. Photo by Michael Lüth, with permission.

In a drink of wine, ***Marchantia polymorpha*** (Figure 2) soaks up the wine and makes a tasty, crunchy treat with your drink. Hmm... are our favorite organisms only consumed with alcohol?

Vassilios Sarafis (Bryonet, 19 November 2006) reports having tried capsules of ***Polytrichum commune*** (Figure 10, Figure 88), finding them tasty. Amanda Hardman (Bryonet, 19 November 2006) claims to fancy eating ***Funaria hygrometrica*** capsules (Figure 89), but states that you must catch them at just the right ripeness. To her, they can taste "as good as yummy sweet peas." Nevertheless, Rod Seppelt (Bryonet, 19 November 2006) compares preparing bryophytes as a food to that of the recommended way to cook a Galah (otherwise known as a Rose-breasted Cockatoo) in Australia. You put a stone and water in the pot with the Galah, bring to a boil, and when the stone is soft, throw away the Galah and eat the stone! In the case of bryophytes, it is the phenolic compounds that make them unpalatable and of questionable safety for consumption.

Figure 88. ***Polytrichum commune*** immature capsules, a stage some might consider edible. Photo by Michael Lüth, with permission.

There have certainly been experimental uses of mosses for food flavoring. Stefan Rensing (Bryonet, 21 November 2006) reports that a group of ~50 botanists at a party sampled a newly created drink called "Psycho Physco." This drink contained a teaspoonful of protonemata from a bioreactor liquid culture of the prominent research moss ***Physcomitrella patens*** (Figure 90). Rensing reports that the taste was "quite interesting (not unpleasant)" and all 50 persons survived unharmed.

Figure 89. ***Funaria hygrometrica*** with capsules that apparently are suitable as human food. Photo by Hermann Schachner, through Creative Commons.

Figure 90. ***Physcomitrella patens***, the lab rat of bryophytes for which the protonema was tested for "taste" in a drink by a group of European botanists. Photo by Michael Lüth, with permission.

A well-known chef in Europe is looking for bryophytes to flavor his dishes, giving them a unique taste (Marta Infante & Patxi Heras, Bryonet, 18 November 2006). He plans to enter them in a gastronomical contest. So far he has tried ***Pseudoscleropodium purum*** (Figure 91) in tempura and made an infusion with ***Boletus edulis*** (Figure 92). But there are concerns about possible side effects and bryophytes to avoid.

Figure 91. ***Pseudoscleropodium purum***, a large moss being explored for taste contributions to food and still being used in shipping plants and fragile objects. Photo by Michael Lüth, with permission.

Figure 92. ***Boletus edulis*** with moss, a mushroom cooked with ***Pseudoscleropodium purum*** by a European chef. Photo by H. Krisp, through Creative Commons.

Chinese Gallnuts

Perhaps the most important use of mosses in the food industry is indirect. Several mosses, especially species of ***Plagiomnium*** (Figure 93), are winter hosts to the Chinese gallnut aphid (*Schlechtendalia chinensis*), the insect that provides those gallnuts (Figure 94-Figure 96) that are both a delicacy and important medicine in China (Horikawa 1947; Wu 1982; Ando 1983). The gallnuts, formed on the leaves of *Rhus javanica* (Figure 94-Figure 96) are used as pain killers, antiseptic and antidiarrheal agents, and as expectorants, astringents, and preservatives (Min & Longton 1993), and in industry as a source of tannic acid.

Figure 93. ***Plagiomnium undulatum***, one of the overwintering host mosses for the Chinese gallnut aphid. Photo by Michael Lüth, with permission.

Figure 94. Leaves of the summer gallnut host, *Rhus javanica*. These plants must be near suitable mosses for the gallnut aphid to survive the winter. Photo by Kenpei, through Creative Commons.

Figure 95. These gallnuts of the aphid *Schlechtendalia chinensis* occur on the branch of the sumac, *Rhus javanica*. Photo by Yingdi Liu, with permission.

Figure 96. These harvested gallnuts are used for eating and medicinal purposes in China. Photo by Yingdi Liu, with permission.

The gallnuts were so important that Takagi (1937) proposed the culture of suitable mosses in order to increase gallnut (Figure 96) production. In China, the aphids are now reared agriculturally on mosses (Tang 1976). In Yunnan the host tree and the most common host mosses (species of ***Plagiomnium***, Figure 93) do not have large overlapping distributions, making establishment of the gall aphids difficult. The aphids lay their eggs on the moss and the young nymphs survive during winter using the moss as food. In some areas, mosses are reared in bowls that are placed under the trees for several weeks during autumn until the aphids locate them (Min & Longton 1993). Then the bowls are moved into sheds for the winter. In April the moss is removed from the bowls and placed back under the trees. The bowls are supplied with fresh soil and kept in a more suitable place where the remaining moss fragments regenerate. By October these mosses are sufficiently large to use the same bowls to gather the next winter's crop of aphids.

Food Improvement

There seems to be little interest in cultivating bryophytes themselves for agricultural purposes. However, they do contribute peripherally to our food. They are used as a carrying medium for the nitrogen-fixing *Rhizobium* (Figure 97) inoculants for legume production (Turner 1993). And currently there is research to try to encourage the **Cyanobacterium *Nostoc*** (Figure 98) to grow on roots and stems of plants. This photosynthetic bacterium, once known as a blue-green alga, is able to convert atmospheric nitrogen into ammonia, making is usable for plants. But what has this to do with bryophytes? Well, there has to be a source of the ***Nostoc***, and this should be a species adapted to living in association with a plant. A number of liverwort taxa are known for cyanobacterial partners. In this case, it is ***Anthoceros*** (Figure 99) that has contributed the ***Nostoc***, which Gantar and coworkers (1995) are trying to persuade to live and fix nitrogen on, of all things, wheat roots! That would go a long way toward solving fertilizer problems! And Rao and Burns (1990a, b) have suggested the use of ***Anthoceros*** as a living agricultural fertilizer because of its ***Nostoc*** partners. That might even work, since ***Anthoceros*** likes disturbed areas.

Figure 97. ***Rhizobium*** nodules on the roots of a legume. Photo by Terraprima, through Creative Commons.

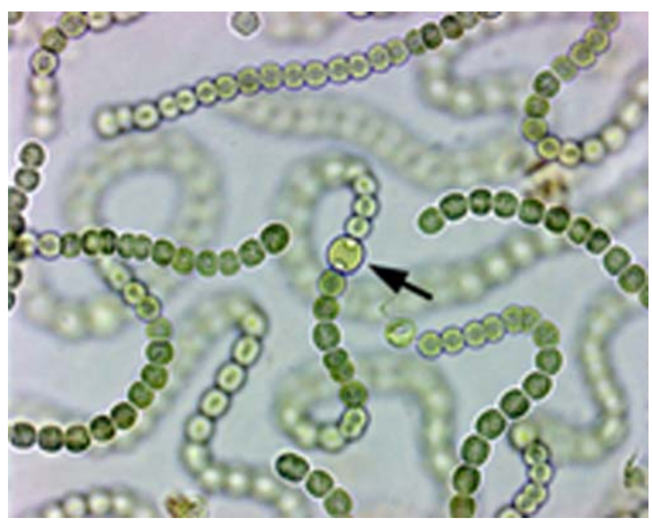

Figure 98. ***Nostoc*** sp., a nitrogen fixer that is often found on mosses, especially ***Sphagnum***. Photo from <vle.du.ac.in>, through Creative Commons.

Figure 99. ***Anthoceros agrestis***, a hornwort with Cyanobacterial partners that fix atmospheric nitrogen. Photo by Michael Lüth, with permission.

Use of peat mosses for culturing certain foods is common. One environmentally friendly use is the combination of extracts from fisheries by-products with peat compost (Martin 1992). This is especially true in coastal areas where the more usual by-products are limited in availability. Products of this fermentation process can be used successfully to feed, of all things, more fish! Then there are the agricultural uses – growing mushrooms, salad greens, and other specialty crops (Turner 1993) that will be discussed in the sub-chapter on commercial uses.

Peat water is typically brown and looks unfit to drink, but for sailors going on a long journey, it has provided a safer alternative (Dente 1997). It stays free of algae longer than well or spring water.

Extracts from the leafy liverwort ***Porella platyphylla*** are able to inhibit "radice" (root) seedling growth (Beike *et al*. 2010). On the other hand, extracts of the moss ***Brachythecium rutabulum*** promote their growth, demonstrating the individuality of the bryophytes.

A major threat to crop plants in many parts of the world is drought. Many kinds of bryophytes are very tolerant of drought, so enterprising scientists endeavored to identify the genes in bryophytes that endowed them with their unique ability to recover from drought. Among these, the model system created with the moss ***Physcomitrella patens*** (Figure 90) had a high tolerance to such abiotic stresses as salt and osmotic stress (Frank *et al*. 2005b).

Physcomitrella patens (Figure 90) is an ideal laboratory culture organism. Hence, Frank *et al*. (2005a) have developed molecular tools to identify its genes and their roles. Reski and Frank (2005) have identified the genes it uses for drought protection and other stress response genes. Not only does it produce plant metabolites, but it also produces animal, fungal, and algal metabolites, suggesting they might be useful for therapeutic and diagnostic purposes.

One important use of the bryophytes has been to identify the genes involved in drought tolerance and apply this knowledge to other organisms. At the University of Freiburg, 40 scientists and technicians collaborated on identifying genes from ***Physcomitrella patens*** (Figure 90) that could potentially be used to improve crop plants (Schiermeier 1999). The complete genome was enumerated in 2007 (Anonymous 2007; Rensing *et al*. 2008).

Following this elucidation, Richardt *et al*. (2010) were able to recognize the vegetative osmotic stress tolerance genes in the moss ***Physcomitrella patens*** (Figure 90) that were identical to those in maize. Na^+ pumps existed in such early land plants as ***P. patens***, but these seem to have been lost as the tracheophytes evolved (Benito & Rodríquez-Navarro 2003; Horie & Schroeder 2004). This discovery led to studies on feasibility of moving stress tolerance genes from ***P. patens*** into crop plants (Reski & Frank 2005). In 2007, the sequencing of the complete genome of ***P. patens*** was completed (BIOPRO 2011).

A group of Spanish researchers have identified a Na^+ pump in ***Physcomitrella patens*** (Figure 90) and Australians have transferred it into maize to make those plants more salt tolerant (Ralf Reski, pers. comm. 14 August 2017).

By now, moss genes have found their way into our food (Ralf Reski, pers. comm. 14 August 2017). The patent <http://patents.com/us-8835715.html> for creating unsaturated fatty acids has just been approved:

"Abstract: The present invention relates to an improved process for the preparation of unsaturated fatty acids and to a process for the preparation of triglycerides with an increased content of unsaturated fatty acids. The invention relates to the generation of transgenic organism, preferably of a transgenic plant or of a transgenic microorganism, with an increased content of fatty acids, oils or lipids with .DELTA.6 double bonds owing to the expression of a **moss** .DELTA.-6-desaturase [sic]. The invention furthermore relates to transgenic organisms comprising a .DELTA.6-desaturase gene, and to the use of the unsaturated fatty acids or of the triglycerides with an increased content of unsaturated fatty acids prepared in the process."

"The genomic .DELTA.6-acyllipid desaturase from ***Physcomitrella patens*** was modified, isolated and used in the process according to the invention on the basis of the published sequence (Girke *et al*., Plant J., 15, 1998: 39-48) using a polymerase chain reaction and cloning. To this end, a desaturase fragment was first isolated by means of polymerase chain reaction using two gene-specific primers, and inserted into the desaturase gene described in Girke *et al*. (see above)." Permission was granted for "A process of preparing an unsaturated fatty acid, which comprises introducing, into an organism being a yeast or a monocot or dicot plant, at least one nucleic acid sequence encoding a polypeptide having .DELTA.6-desaturase activity…" This patent application was submitted 16 September 2014 and has just been approved (September 2017), added on to a patenting history starting in 1987.

Food Preservation

Modern methods of packing food have actually increased the incidence of botulism more than 12-fold among Alaskan natives since 1966 (Segal 1992). Traditionally, the natives processed fish and sea mammals on the ground where the animals easily made contact with bacteria from the soil or animal viscera. The food was then placed in a shallow pit lined with wood, animal skins, or leaves. These buried animals were then covered with moss or leaves and left to ferment for one or two months. However, the natives switched to modern technology and used plastic bags to line the pits and enclose the food, eliminating the use of moss and other plant matter. The anaerobic conditions created by this method promoted the growth of *Clostridium botulinum* (Figure 100-Figure 101), permitting the production of the botulism toxin. The natives do not trust the advice of outsiders, so the Health Department feels the best plan to reduce the spread of the disease is to encourage them to return to their traditional use of mosses. The mosses permit aeration and may even have antibiotic effects.

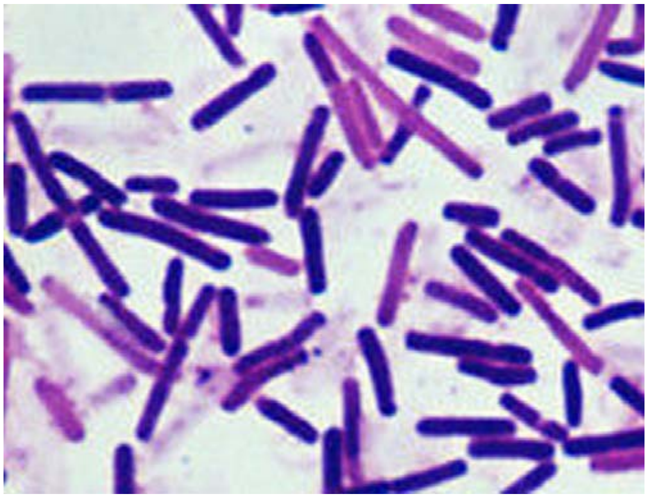

Figure 100. ***Clostridium botulinum***, a source of food poisoning that can be prevented by storing food with mosses. Photo by Science Photo Library, through Creative Commons.

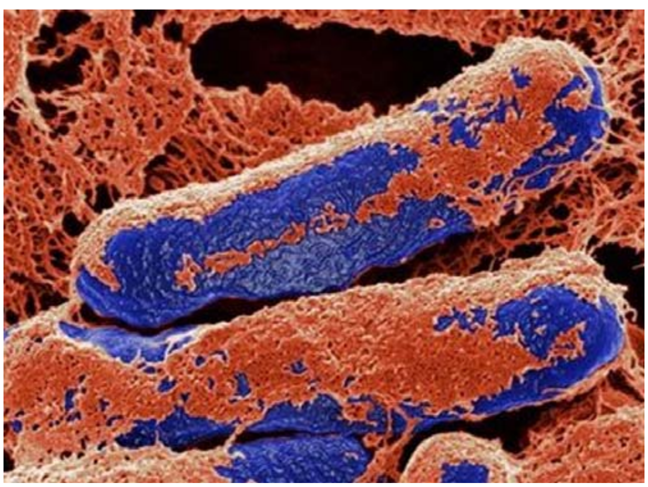

Figure 101. ***Clostridium botulinum*** SEM. Photo by Christine Schramm, through Creative Commons.

Mark Smits (Bryonet 20 February 2015) reports that ***Sphagnum*** bogs (Figure 102) were used to preserve food, including butter (Figure 103). Reade (2013) noted the use of "bog butter," especially in Scotland and Ireland. This is butter that has been buried in a peat bog. The earliest known use of this method is from the Middle Iron Age (400-350 BC). Reade reports on the experiment of Daniel C. Fisher that found bacterial counts in meat after one year in a peat bog was comparable to that which had been in a freezer for the same length of time.

Figure 102. Raised bog with ***Sphagnum fimbriatum*** surrounded by ***Sphagnum magellanicum***, a suitable site for making bog butter. Photo from Tuberas de Chile, through Creative Commons.

Figure 103. Bog butter found near Enniskillen, County Fermanagh, Ireland. Photo by Bazonka, through Creative Commons.

It appears that the potential use of ***Sphagnum*** for preservation is still alive. Børsheim *et al.* (2001) experimented with fish preservation in ***Sphagnum***, peat, and holocellulose. Salmon (*Salmo salar*) skin and whole zebra fish (*Brachydanio rerio*) were preserved for many weeks in ***Sphagnum palustre*** and compared to those in peat that came mostly from ***Sphagnum*** mosses, acetone-extracted moss, and chlorite holocellulose of the moss. Interestingly, the chlorite holocellulose performed as well or better than the other products. The watersoluble sphagnan in this holocellulose portion produced the same results as the other treatments. Similarly, mackerel (*Scomber scombrus*) skin became brown and completely bio-resistant after repeated immersion in aqueous (3% w/v) sphagnan (with intermittent drying). This process achieved the same effect as smoking the fish. However, the process does not work on filleted fish muscle because the soluble protein diffuses out too quickly and neutralizes the carbonyl groups in the sphagnan.

It appears we should give more consideration to bryophytes for our modern food storage. Not so long ago, before refrigerators were invented, people built root cellars to preserve vegetables through the winter. But today, we can still use mosses for this purpose. Dorothy Allard (12 August 2017) shared with me her use of ***Sphagnum*** to keep her carrots for several months in a root cellar at 4-16ºC. She washed the carrots, cut off their tops, and layered them in a 5-gallon (19-liter) plastic bucket so that the carrots were not touching each other. The carrots did not rot, but they did develop a few small root hairs and eventually developed a "peat mossy" taste. It was easier to clean them than carrots packed in sand.

Cookery and Pottery

The use of peat as a fuel in northern parts of Europe is common, and this includes its use for heat for cooking. The pendant ***Antitrichia curtipendula*** (Figure 104) was also used by Native Americans in earthen ovens for cooking (Compton 1993).

Figure 104. ***Antitrichia curtipendula***, a species used in ovens by Native Americans. Photo by Hermann Schachner, through Creative Commons.

Early uses of mosses in pottery can be traced as far back as the Stone-age people, who apparently used the moss ***Neckera crispa*** (Figure 105) (Grosse-Brauckmann 1979) in a region now settled by Germany. In the French Stone Age, ***Neckera crispa***, ***Tortula*** (Figure 107), and other mosses were used as we now use sand, apparently to make the pottery less "fat," improving the quality of the pottery (H. J. During pers. comm.; Figure 106). Analysis of ancient pottery demonstrates presence of animal parts, and the defatting agents help in defatting their fats. In both France and Belgium, mixtures of moss containing ***Neckera crispa***, in particular, were used to temper pottery (Constantin & Kuijper 2002). Is it possible that the mosses kept the pottery safe after it was used for cooking or serving animal foods, discouraging the multiplication of bacteria and fungi?

In France and Belgium the Epi-Rössen and Michelsberg cultures have used mosses, primarily ***Neckera crispa*** (Figure 105), as a temper (degreasant = defatter) in making pottery (Figure 108) (Constantin & Kuijper 2002; Jan & Savary 2011; Jan 2016). The mosses were used for tempering the ceramics during the Mid-Neolithic (~4700-3500 BC) (Denis Jan, pers. comm. 14 December 2015). Some of the mosses resemble ***Rhytidiadelphus squarrosus*** (Figure 17). Other studies have revealed the use of ***Neckera crispa*** and ***Fissidens dubius*** (Figure 109). When mosses are used as a temper they reinforce the clay of vases like a wattle for mud. Combustion of the ceramic causes the plant parts to disintegrate and create a high porosity. This serves two purposes – it makes the vase lighter and absorbs shock waves that would otherwise cause the vase to break.

Figure 105. ***Neckera crispa***, a large, pleurocarpous moss of tree trunks that has been used as a mordant in pottery. Photo by Michael Lüth, with permission.

Figure 106. A piece of ancient pottery with the impression of ***Neckera crispa*** that has been used as a mordant. Photo courtesy of Heinjo During of Universiteit Utrecht and Wim Kuijper from Archeological Centre of Leiden University.

Figure 107. ***Tortula calcicolens***, a moss used as a defatter in making pottery. Photo by Michael Lüth, with permission.

Figure 108. Ceramic with moss inclusions, before firing. Photo courtesy of Dennis Jan.

Figure 109. ***Fissidens dubius*** with capsules, a moss used as a defatter in making pottery. Photo by Hermann Schachner, through Creative Commons.

Packing

One wouldn't expect a plant that harbors a wide range of insects to be a suitable insect repellent, but the Himalayans dried mosses, made them into a coarse powder, and sprinkled them over grains and other containerized goods to repel insects (Pant & Tewari 1989). They covered the top of the container with a plug of mosses. When they were ready to use the grain, they simply blew off the light-weight mosses from the grain. Just consider the safety of this natural way of repelling the insects while protecting the human consumer. In the Pacific Northwest, mosses are collected to pack mushrooms and keep them safe (Cleavitt 1996).

Taxidermy usually requires the use of arsenic to keep hungry beetles from consuming our treasures. But at the British Museum, it was mosses that served this role. Curators stuffed the skins with mosses to ward off the dermestid beetles and at the same time keep the skins plump and natural (Harrington 1985).

Packing materials vary with what is available locally and can even be used to determine the region and habitat of origin. In the western USA, A. J. Grout (in a comment to Clarke 1902) cited the use of ***Dendroalsia abietina*** (Figure 110) and ***Antitrichia californica*** (Figure 111) to pack vegetables that were shipped from California to Seattle. These reportedly came from Boulder's Island. Epiphytic mosses such as ***Antitrichia californica***, ***Dendroalsia abietina***, and ***Metaneckera menziesii*** (Figure 112) provided suitable packing material for vegetables by helping to retain moisture (Frye 1920), whereas today similar bryophyte species are used to pack mushrooms (C. W. Smith, pers. comm.).

Figure 110. ***Dendroalsia abietina***, a moss used in the Pacific states of the USA as packing material for fresh vegetables. Photo by Paul Wilson, with permission.

Figure 111. ***Antitrichia californica***, a moss used in the Pacific states of the USA as packing material for fresh vegetables. Photo by Michael Lüth, with permission.

Figure 112. ***Metaneckera menziesii***, a moss used in the Pacific states of the USA as packing material for fresh vegetables. Photo by Michael Lüth, with permission.

The Himalayans still use both soil and epiphytic mosses such as ***Brachythecium salebrosum*** (Figure 113), ***Cryptoleptodon flexuosus***, ***Hypnum cupressiforme*** (Figure 5), ***Macrothamnium submacrocarpum*** (Figure 114), ***Taiwanobryum crenulata***, ***Trachypodopsis serrulata*** var. ***crispatula***, ***Thuidium tamariscellum***, and ***Sphagnum*** (Figure 29-Figure 34) to pack apples and plums (Pant & Tewari 1989). But in the tropics, it is the leafy liverworts that play this role because of their abundance (Bland 1971). Large and abundant mosses like ***Pseudoscleropodium purum*** (Figure 91) (Dickson 1967; Figure 115), ***Hylocomium splendens*** (Figure 16), and ***Rhytidiadelphus squarrosus*** (Figure 17) have been dispersed and grow around the world due to their widespread use as packing materials (Seaward & Williams 1976). Allen and Crosby (1987) refer to these worldwide expansions of ***Pseudoscleropodium purum*** as legendary – even today, it is used for packing young trees destined for Tristan da Cuñha, where its establishment is imminent. It seems to have arrived on the West Coast of North America by the late 1800's (Miller & Trigoboff 2001).

Figure 113. ***Brachythecium salebrosum***, a moss used in the Himalayas to pack apples and plums. Photo by Hermann Schachner, through Creative Commons.

Figure 114. ***Macrothamnium submacrocarpum***, a moss used for packing apples and plums in the Himalayas. Photo courtesy of Hiroyuki Akiyama.

Figure 115. ***Pseudoscleropodium purum***, a moss commonly used in packing. Photo by Michael Lüth, with permission.

In some Asian countries, bryophytes are used for packaging gifts and displays during the Christmas Season (Tan 2003).

Large mosses make good cushions for fragile objects. In Japan, boxes packed with large pendant mosses such as ***Aerobryopsis subdivergens*** (Figure 116), ***Barbella determesii***, and ***Meteorium helminthocladulum*** (Figure 117) guarded ancient silk clothes, providing a clean and soft packing (Noguchi 1952). Where dirty soil was of less concern, soil mosses such as ***Rhytidiadelphus triquetrus*** (Figure 118) protected fragile China (Dickson 1973), and Espie (1997) claims it is "most valuable for packing material for porcelain" in New Zealand; it was pre-shredded for packing to protect other delicate objects (Kenneth Adams, pers. comm. 1 November 2013). Other mosses are used for packing fragile items in the Philippines (B. C. Tan, pers. comm.). ***Hypnum*** (Figure 5), ***Plagiomnium undulatum*** (Figure 93), and ***Sphagnum*** (Figure 29-Figure 34) guarded the blades of daggers and scrapers (Dickson 1967). Even the Department of Defense used mosses (***Sphagnum***) to pack fragile bomb sights during World War II (K. Parejko, pers. comm.).

Figure 116. ***Aerobryopsis subdivergens***, a moss used for packing in Japan. Photo by Digital Museum, University of Hiroshima, with permission.

Figure 117. ***Meteorium helminthocladulum***, a moss used for packing material in Japan. Photo from Digital Museum, University of Hiroshima, with permission.

Figure 118. ***Rhytidiadelphus triquetrus***, a moss used for packing material in Japan. Photo by Malcolm Storey, through Creative Commons.

The Open-Air Natural History Museum states that ***Sphagnum*** (Figure 29-Figure 34) is good for winter storage of carrots to keep them fresh (Open-Air 2007).

The antibiotic properties of ***Sphagnum*** (Figure 29-Figure 34) make it ideal for shipping small amphibians such as salamanders and frogs from biological supply houses (Figure 119). It keeps the animals moist and helps prevent diseases like red leg by absorbing the urine and reducing bacterial growth.

Figure 119. ***Rana pipiens***, sitting on ***Sphagnum***, protected from red leg by the ***Sphagnum*** substrate in the terrarium. Photo by Janice Glime.

In New Zealand, where ***Sphagnum*** (Figure 29-Figure 34) has never been common, new commercial uses are surfacing (SFF Project Summary 2006). In a project titled "Economically sustainable novel Sphagnum moss products," three new commercial uses are proposed. These include packaging due to the absorbent and antibiotic properties that would reduce fruit spoilage. They likewise suggest using ***Sphagnum*** for animals, but on the larger scale of veterinarian services, reducing odors and providing absorption. Their third suggestion, already done in several large wars, is to use the moss for bandages, especially those that are particularly "weepy" and thus more prone to infection. In their early experiments, however, they failed to show that ***Sphagnum*** protects apricots or avocados from post-harvest infections. They are currently looking for a sponsor to research the effects of using ***Sphagnum*** bandages on burn victims.

In his accountig of mosses and liverworts W. H. Burrell observed that ***Thamnobryum alopecurum*** (as *Porotrichum*) is 'used by the gamekeeper as a packing for eggs' (Nicholson 1914). What a nice cushion before the modern-day egg cartons.

Burial Wreath

In Nairobi, Kenya, mosses are used to make wreaths for burial ceremonies (Itombo Malombe, pers. comm. 15 August 2017). These are mostly pendent mosses, including ***Neckera*** (Figure 11-Figure 12) and ***Pilotrichella*** (Figure 120). A sack of mosses for this purpose is sold for 10,000 ksh (~$100 US) and more than ten sacks are used.

Figure 120. ***Pilotrichella***, a moss used in burial wreaths in Nairobi. Photo from iNaturalist, through Creative Commons.

Summary

Mosses are used for carrying water, stuffing mattresses, pillows, and dolls, collecting urine from farm animals, making bandages, cushioning fruits, making soap, and packing fragile articles. They even provide vitamin supplements to animal feed. In northern areas they are used for heating, making wicks, and in Morocco they are used to wash hair.

Recently, one of the more important uses is for physiological studies and genetic studies linking genes to processes. This investigation is leading to the possibility of transplanting genes for traits like drought tolerance and antiherbivory into agricultural plants.

Despite the unpleasant taste of most bryophytes, ***Sphagnum*** has been used in Scotch whisky, ***Marchantia polymorpha*** has been added to wine, and one European chef is experimenting with new recipes using bryophytes. Capsules may be more tasty if collected at the right stage. Some mosses serve indirectly by providing the overwintering home for gall aphids. The galls made by these insects are used for food and medicine. More commonly, mosses are used for culturing a variety of food plants.

Mosses have been used for making and decorating clothing and pressed buttons. Most importantly, they have been used for diapers and other absorbent roles like lining boots.

Pottery makers in the used bryophytes to temper the pottery.

The soft and flexible texture of mosses makes them ideal for packing a variety of items, leading to the spread of some species around the world. Their antibiotic properties make them ideal for shipping amphibians.

Acknowledgments

I am grateful to Robin Stevenson who has sent me several of the stories covered by this chapter. Patxi Heras Pérez and Marta Infante Sánchez alerted me to the use of mosses to temper pottery. John Steel alerted me to the publication on bread and provided me with a copy of the chapter by John Lindley. Jim Dickson has been an invaluable resource in providing anecdotes and references. Denis Jan has provided me with helpful discussion and an unpublished copy of his manuscript. Ralf Reski was very helpful in documentation of bryophyte genes being transferred to crop plants.

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