# A New Report of Unique Features in the Peristome of *Funaria hygrometrica*

## A Van Andel Creation Research Center SEM Study

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### Abstract

Sporophyte capsule structures of the moss genus *Funaria* from California were studied under Scanning Electron Microscopy. The peristome of the sporangium was observed to have a unique "pad" and "web" bellows that appears to be little reported in the literature. This pad and web structure functions, along with the peristome teeth, as a tiny bellows assembly that sucks minute numbers of spores out from the capsule for dispersion during optimum conditions for spore distribution. This bellows system appears to have been skillfully designed. I conclude that such design is a result of divine intelligence.


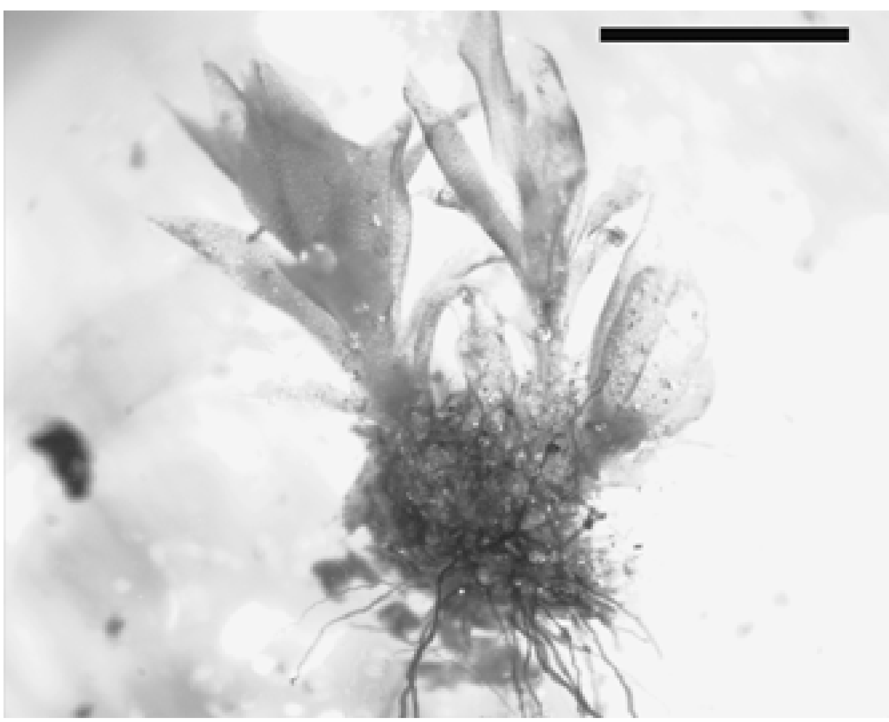

Figure 1. Light micrograph, individual fresh moss specimen complete with root ball. Scale bar = 0.5mm. The leaflike structures here are phyllids, part of the gametophyte generation from which the sporophyte emerges.

### Introduction

Moss plants (Figures 1 and 2) and their spore producing bodies (sporangia, [singular, sporangium], see Figures 3 and 4), have been of great interest for many decades. Mosses that have economic value include *Sphagnum*, which is used in the floral industry to line floral arrangement baskets for water retention, as a low-grade fuel, as packing material for shipping bare-rooted plants, and as an amendment to soil for water retention. They are, however, at the focus of

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**Figure 2** ***(left)*****. SEM micrograph, dehydrated moss. Note extensive root system. This is the gametophyte. Scale bar = 0.5mm.**

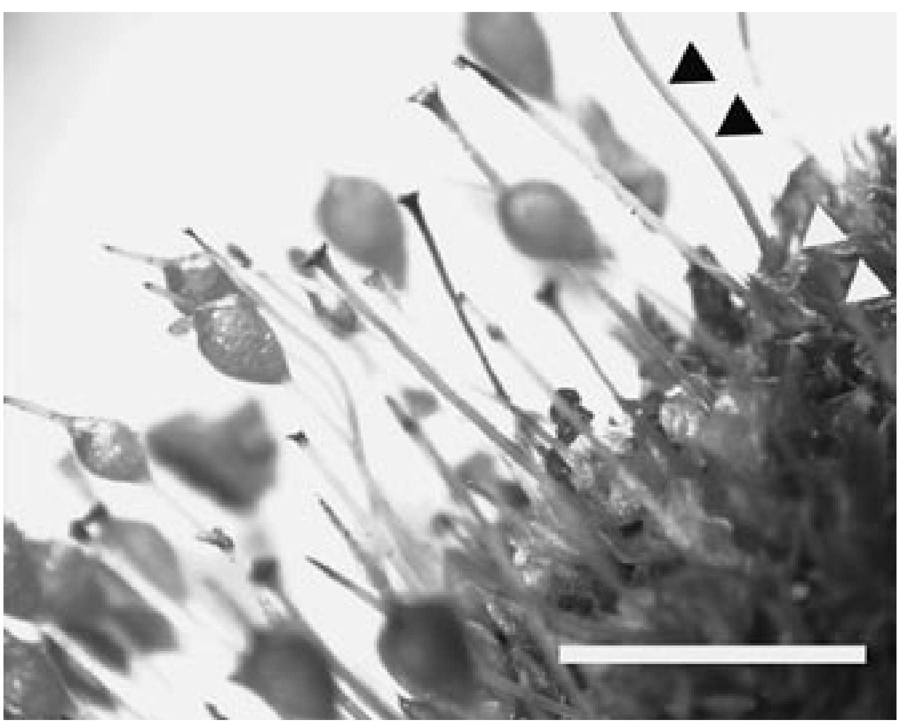


**Figure 3** ***(below left)*****. Light micrograph, moss gametophyte generation (white arrow heads) supporting vertical sporophyte generation (black arrow heads). Scale bar = 2.0 cm.**

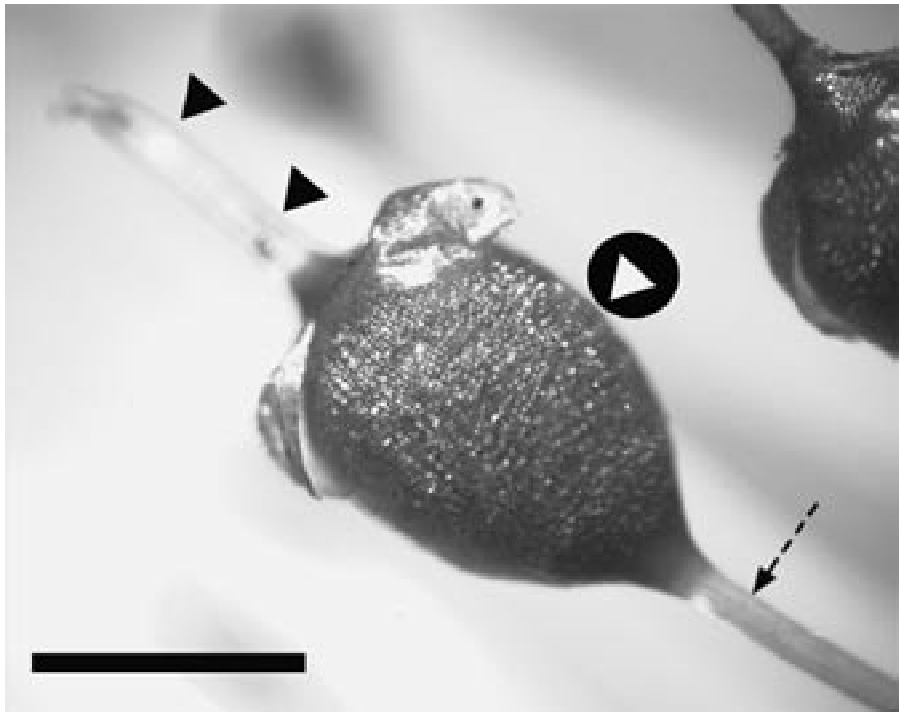
the ongoing intense debate among evolutionists as to which were "the earliest divergent land plants" (Wellman et al., 2003, p. 284), and in that sense, mosses are very important.

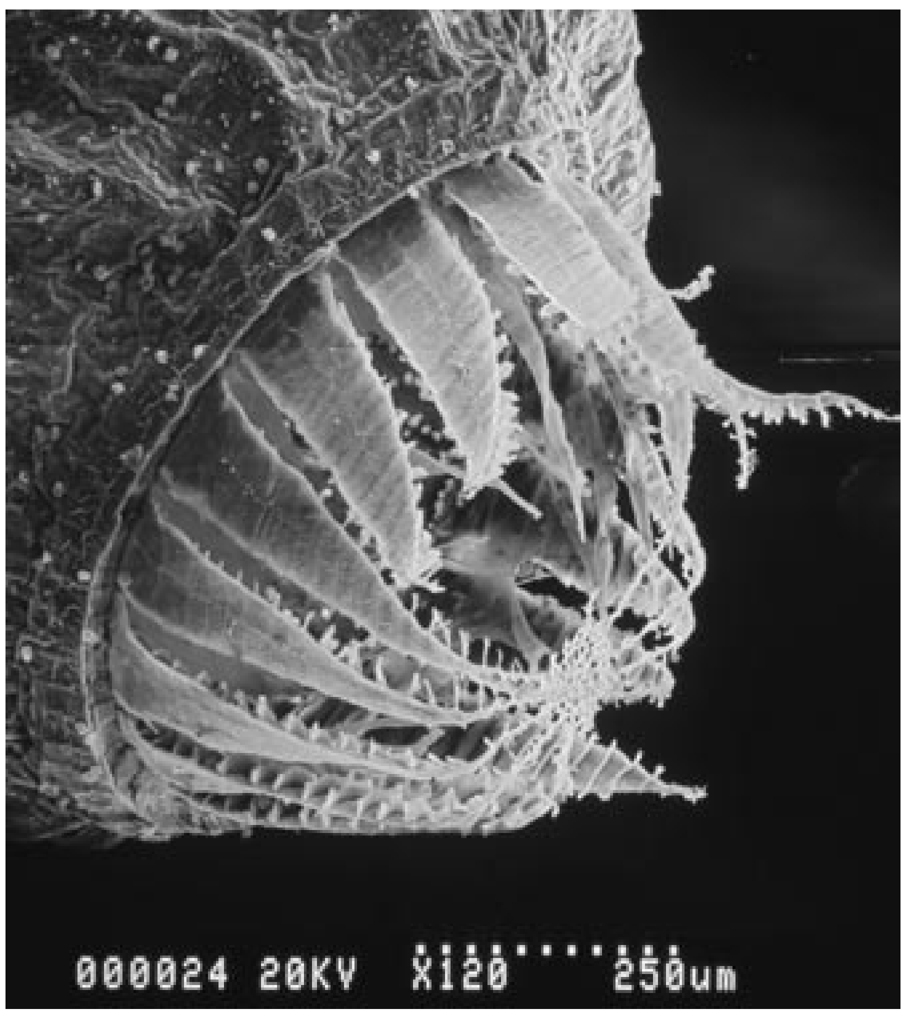
Most, but not all, mosses possess a specialized, tooth-like structure within the sporangium called a peristome (see Figure 5), which circumscribes the inner opening of the sporangium and is integral for the timely dispersal of spores into the surrounding environment. Peristome teeth are usually hygroscopic, thus, in response to changes in humidity, they will flex back and forth within the sporangium. This has the effect of catapulting tiny spores from the spore capsule to be carried away by the wind.

Several early workers, most notably in France and Germany, carefully described these sporangial capsules and their peristome teeth as early as the mid to late 1800's (Berkshire, 1863, Bescherelle, 1885; Hutton 1874; and Philibert, 1888). One early worker even showed how stages of the life cycle differ remarkably from each other in water absorption mechanisms (Vaizey, 1887). Vaizey did not describe the peristome from the

**Figure 4** ***(right)*****. Light micrograph, of the upper portion of *****Funaria***** sporophyte. This is a close up of the seta or stalk (black dotted arrow), sporangium (white arrowhead), and calyptra covering (black arrowheads). Scale bar = 1.5 mm.**

**Figure 5** ***(below right)*****. SEM micrograph, moss sporangium with uncovered peristome teeth. Note several teeth ripped away from the place where they were attached to the central pad. Dotted scale bar = 250 micrometers.**






mosses he studied. Hutton provided drawings of the various types of sporangia found in New Zealand and stated that for the one group he studied, the peristome teeth were touching at their pointed tips. Thus, they were touching or interlaced, so as to form a cage-like structure over the mouth, allowing the spores to be gradually blown away in small numbers (and strictly by high winds) (e.g. Hutton, 1874, p. 345). Thus, in this instance, the peristome functions as little more than a passive cage. With respect to another variety of moss, Hutton (1874) stated, "of the genus *Funaria*…[in] this moss, the peristome is double, the points of the teeth of the outer one, being connected by a disc, which in time falls away," (p. 346), although this "disc" structure was not featured in any of his figures. However, Hutton (1874) did not discuss the structure of this disc, nor the functions it performed.

Some workers have conducted scanning electron microscope (SEM) studies of the peristome teeth (Anderson and Palmer, 1982; Gallego et al., 2004; Huttunen, 2004; and Konopka et al., 1998). This lack of research is puzzling since the peristome teeth may be essential for the classification of mosses. Electron micrographs could assist in the taxonomic diagnosis of these minute plants. Anderson and Palmer (1982), Gallego et al. (2004), Huttunen (2004), and Konopka et al. (1998) all displayed high magnification images of peristome teeth but did not discuss or illustrate a "disc" or web connecting the teeth one to each other. Nor did Troughton and Sampson (1973) mention this structure in their plant kingdom SEM survey, even though they supplied two photos of the peristome (pp. 48 & 49). A fascinating set of SEM micrographs of moss sporophyte images (including peristome teeth) is found online at: http://www.botany.ubc.ca/bryophyte/index.html (accessed on 12/26/07).

The peristome teeth and the sporophyte capsule are often illustrated by many authors, (Ignatova, et al., 2003; Munoz, 1999; Ochyra, 1999), but no such disc or connection between teeth tips is discussed or illustrated. One SEM photo of a central disk connecting the peristome teeth, resembling Figure 6 of this paper, was published by Richardson (1981, p. 74), yet his observation of the workings of the bellows system of spore dispersal was incomplete. With respect to spore dispersal, Richardson (1981) merely stated, "the stalk twists or untwists (under moist conditions) so that the capsule rotates quite rapidly" (p.74). The web structure was described as "a central plate of cells" and as "a small white central disk" (Richardson, 1981, p. 73 & 74), yet no undulation of the bellows system was described.

The present research used the SEM to study the elegantly complex design of the moss peristome mechanism and the amazing process by which spores are ejected from the capsule.

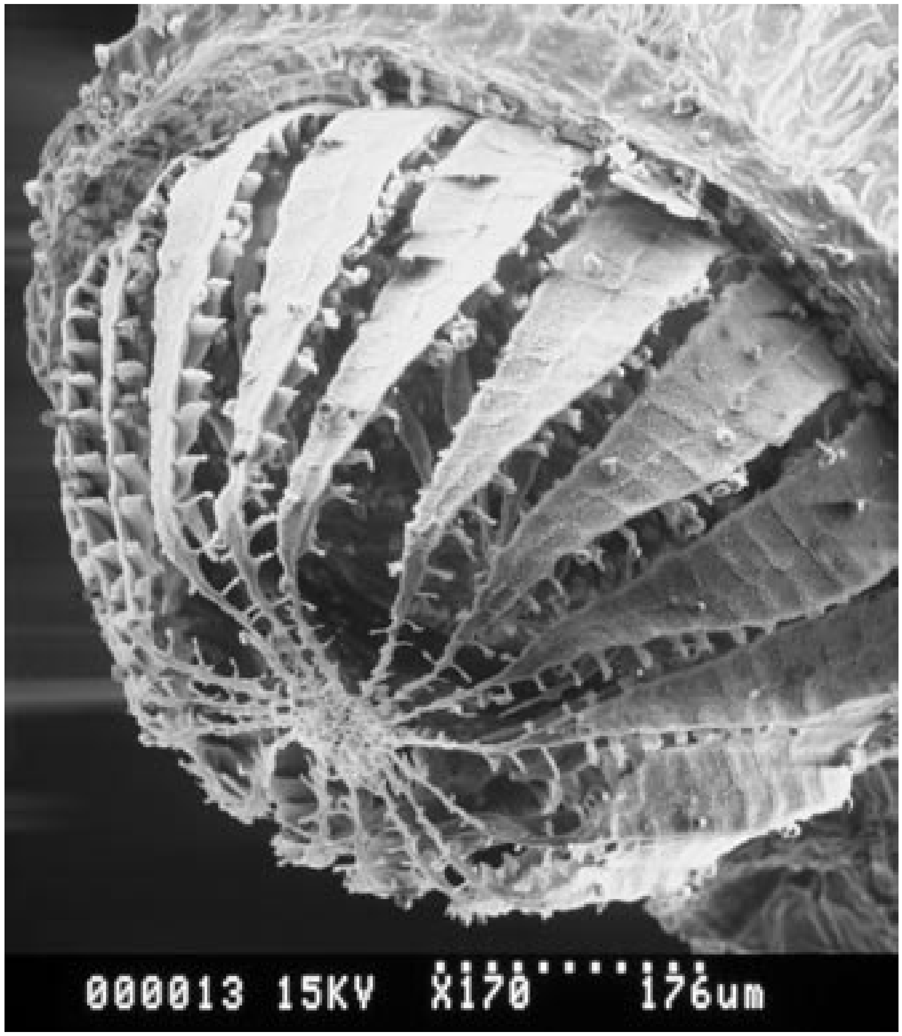



**Figure 6. SEM micrograph, moss sporangium with uncovered peristome teeth. Note that all the teeth are attached to the central pad. The peristome teeth and the pad form the web. Dotted scale bar = 176 micrometers.**

## Materials and Methods

Colonies of fresh moss *Funaria hygrometrica* Hedw. were collected from under a perennial shade-casting bush in a well-kept lawn in Covina, CA during the spring of 2007. Specimens were placed in an open plastic dish and were kept in the shade within a greenhouse where they were watered daily. When individual plants were selected for microscopy, the dish was placed on the base of a Carl Zeiss GSZ dissecting microscope (Jena, Germany) outfitted with a fluorescent ring-light illuminator. Individual plants were removed with fine forceps under 10X magnification and immersed in cold, 2% buffered glutaraldehyde for fixation. Plants were processed for SEM according to the protocol outlined by Armitage and Howe (2004). Optical photographs were captured with a DVC digital camera and EPIX/PIXCI image capture board. SEM images were captured with a Hitachi S-2400 SEM employing standard and backscattered electron imaging (housed at the Van Andel Creation Research Center, Chino Valley, AZ). Figure 7 was obtained using a new Hitachi S-3600 "wet-SEM" (environmental microscope) to photograph living, unprocessed moss sporangia.

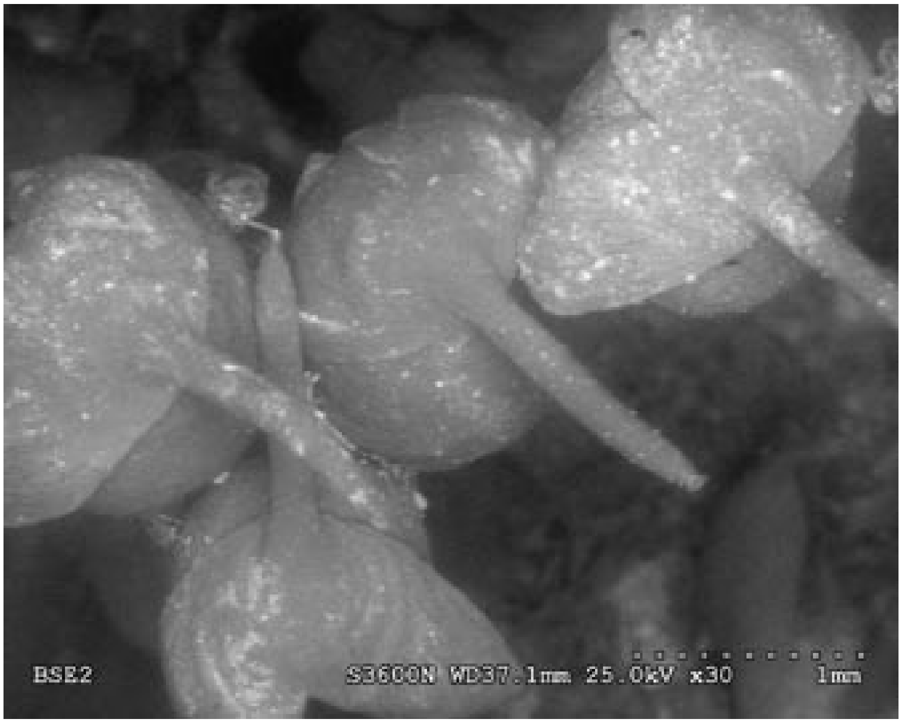
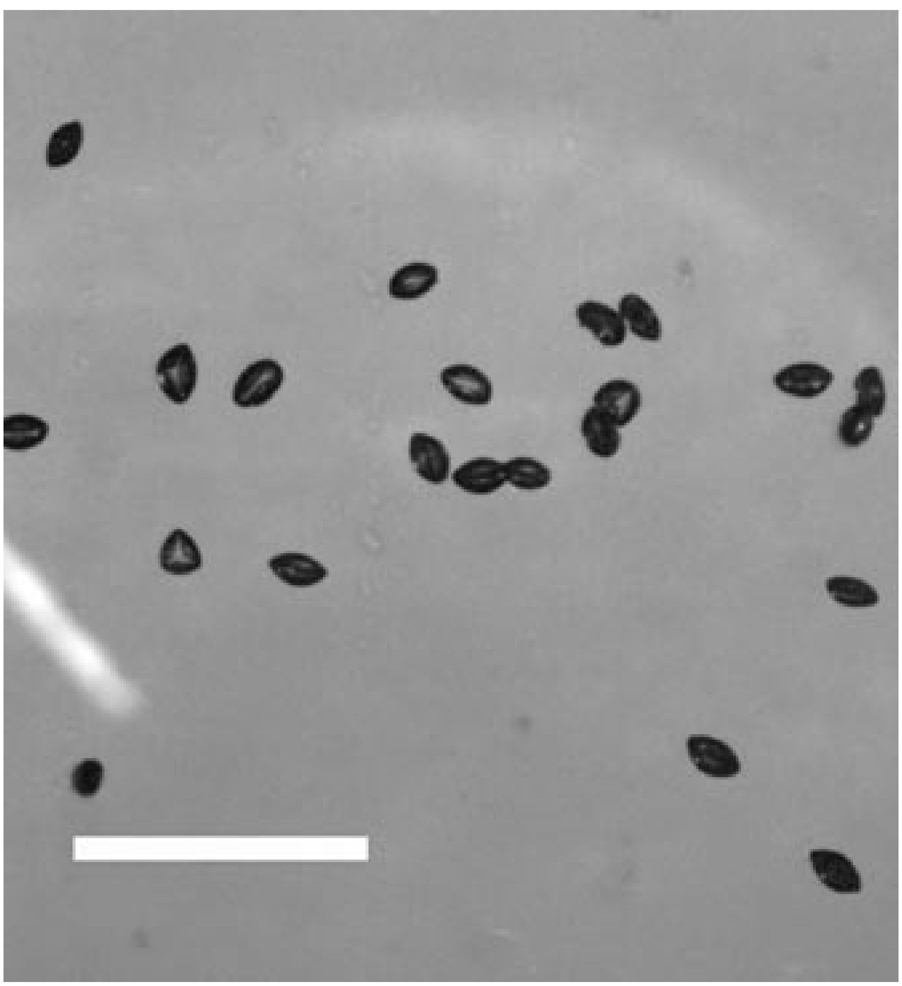



**Figure 7 *(left)*. Backscattered electron SEM image (photographed on a new Hitachi S3600 "wet SEM" microscope.) Note pointed ends of the four calyptra loosely attached to each sporangia. This is a view from the top, looking down on the calyptra. Dotted Scale bar = 1 mm.**

**Figure 8 *(below left)*. Light micrograph, individual moss spores. The spores are pulled out of the sporangium by the pumping action of the web mechanism. Scale bar = 90 micrometers.**



## Results and Discussion

The sporangia of *Funaria hygrometrica* are 1–2 mm in length. They have a sausage-shaped container at the apical end of the stalk called seta (plural, setae). The stalk and capsule are part of the sporophyte generation and are attached to the gametophyte (see Figures 3 and 4). These capsules produce spores (Figure 8) and then disperse them in a unique fashion. If conditions are suitable, the spores are released and then germinate forming a new gametophyte generation. For an excellent illustration of the entire life cycle of this plant see Bergman (1998).

As the sporangium matures, it grows upward from the gametophyte to a height of about 1–2 cm. The developing capsule can be seen covered by a tiny calyptra which resembles a "witches' hat" (see Figures 4 and 7). Once the sporangium has reached full size, the calyptra is shed making the operculum visible (Figures 9, 10, and 11). The operculum is sometimes shaped like a saucer stretching over the capsule opening. On other opercula, it resembles a

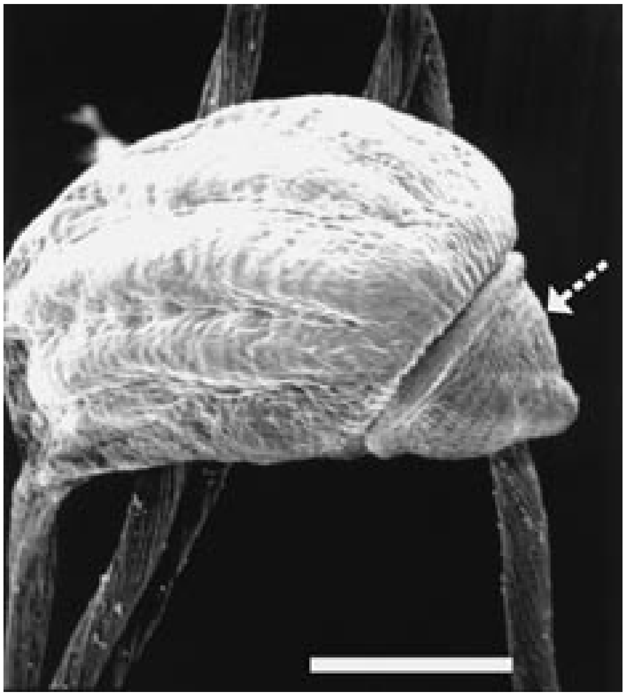


**Figure 9. SEM micrograph, moss sporangium. Note pointed operculum (white arrow). The difference in operculum shape between specimens (Figures 9 and 10), might be due to genetic differences. Scale bar = 0.75 mm.**


**Figure 10. Backscattered electron SEM image. Note two sporangia with saucer-shaped opercula (white arrows). The sporangium at the right was squashed during processing. Dotted Scale bar = 0.75 mm.**

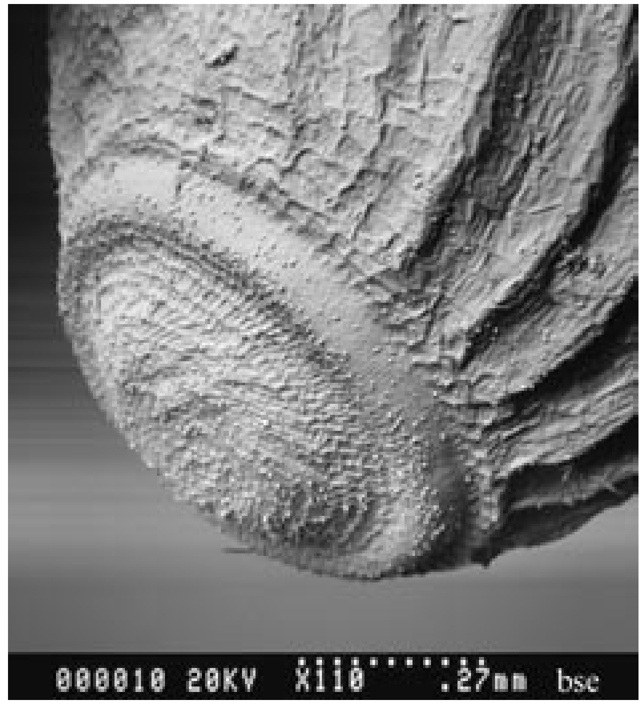



**Figure 11. Backscattered electron SEM image, sporangium operculum. Scale bar = 0.27 mm.**

**Figure 12. Light micrograph, showing the peristome teeth and the central pad which together form the web. The white arrow points to the white pad at the center of the web. Both the calyptra and the operculum are missing so one is looking directly down at the web. Scale bar = 1.25 mm.**

pointed hat (Figure 9). The difference in shape between the two calyptras seen in Figures 9 and 10 may be due to genetic variations.

The sporangium tips over and faces downward, which may prevent mist or dew from entering the capsule and jeopardizing the prompt dispersal of its spore cargo. When the relative humidity is favorable, the operculum falls off, revealing the tightly wound spiral of peristome teeth (Figure 12). These teeth then slowly unwind and open, to some extent.

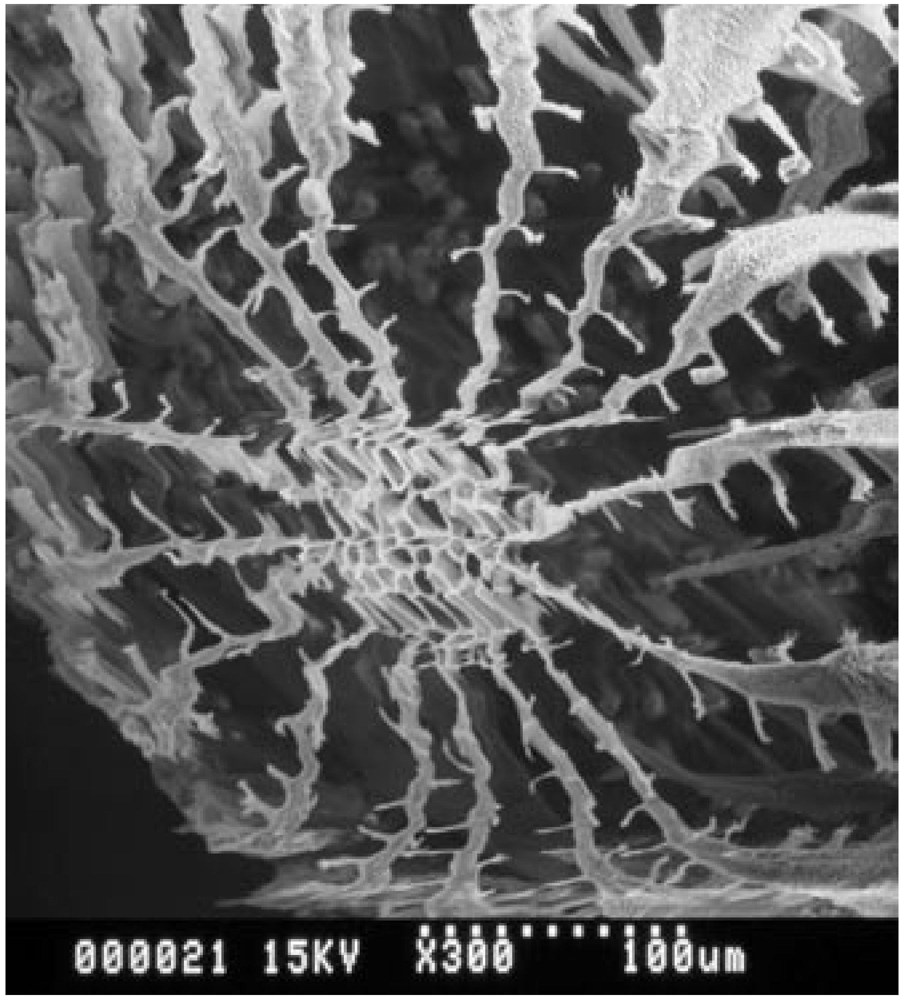



**Figure 13. SEM micrograph, moss sporangium showing the web mechanism. Note depressions and other structural detail visible in the central pad. Dotted scale bar = 100 micrometers.**

1. The tip of each peristome tooth is bound by a thin, flexible connection to a pad-like structure that is positioned at the opened center, (Figures 6, 12 and 13).
2. The peristome teeth join to the pad forming a "web."
3. Attached to the pad, the peristome teeth are held in a certain conformation. As the peristome desiccates, this pad and web system stretches, allowing further opening of the peristome teeth. When the teeth become spread apart evenly and stand perpendicular to the annular ring, which surrounds the peristome, they are bound tightly to the pad and they produce the web.
4. Figure 13 provides a view of the peristome teeth attached to the central pad.
5. Upon further desiccation, a fascinating process allows the release and spread of spores. Air currents pass over the dilated peristome and cause the web with its center pad to oscillate repeatedly in and out of the spore filled sporangium in an undulating fashion, much like the pumping of a bellows or a fluttering parachute. This was observed repeatedly with many different sporangia employing the dissecting microscope equipped with a fiber-optic illuminator. As a result of this undulation of the web, I observed wisps of spores being sucked out of the capsule and pulled into the open air for dispersal. I never observed the pad to "fall away" as Hutton (1874) noted. Perhaps the peristomes that he observed were severely desiccated, causing the falling away of the pad.
6. Although some of the peristome teeth are shown disconnected from the pad in Figures 5 and 14, this is not normally the case. The operculum was inadvertently mechanically removed in these individual sporangia, which resulted in tearing the pad from the teeth.
7. This web and pad structure serves several purposes, and appears to have been skillfully designed:
   a. Spores are kept safe and dry in an enclosed, protected, downward-facing environment and the peristome keeps them from falling out.
   b. The peristome provides a physical barrier to prevent the entrance of insects.
   c. Only when conditions are favorable for spore dispersal are spores released by the repeated pumping action of the web and center pad.


**Figure 14. SEM micrograph, moss sporangium with uncovered peristome teeth. Note several teeth ripped away from their previous position on the central pad. Dotted scale bar = 100 micrometers.**


**Figure 15. SEM micrograph, moss sporangium with uncovered peristome teeth. Note the detail visible on the edges of the peristome teeth. Dotted scale bar = 50 micrometers.**

d. Only a small portion of total spore production is released at a given time, when air currents can carry them some distance.

The arrangement, quantity, and size of the peristome teeth have been used as a diagnostic character in determining the "relatedness" or taxonomy of different mosses (Goffinet, et al., 1999). In addition other features such as the appendages on the peristome teeth (shown in Figure 15) can be used for taxonomic purposes. Of late, however, many botanists have been studying and comparing the nucleotide sequences of these plants for this purpose. This has led to some major reversals in the historical taxonomic scheme, because the DNA sequence comparisons do not result in a moss taxonomic scheme that is consistent with a morphology-based taxonomy (Goffinet et al., 2001 and Budke et al., 2007). Moreover, throughout the putative "fossil record," moss sporangia and their peristome teeth are identical to modern observed living specimens. Intact peristome teeth and capsules have even been found in moss specimens buried in volcanic tephra (ash) in layers purported to be over 25,000 years old (Zazula et al., 2006), yet they are identical with contemporary specimens. Furthermore, recent creationist work in radiometric dating (Vardiman et al., 2005) has shown these dates are suspect and probably subject to gross error.

## Conclusion

The sporangia of *Funaria hygrometrica*, with their associated peristome teeth are a remarkably well-engineered system by which an orderly and timely release of spores occurs. Future work will focus on the various stages of the moss life cycle with special attention given to features of these interesting organisms that demonstrate the design features endowed to them by the Creator. It would also be important to determine if there exists a web mechanism in other species of mosses.

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