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Fungal Tunneling of Hair from a Buried Body

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ABSTRACT: Tunnels produced in human head hair by fungal hyphae were examined with a light microscope and with a scanning electron microscope. The tunnels had small diameters and exhibited minimal branching. The use of a backscattered electron detector facilitated the locating of the openings of the tunnels in the surfaces of the hairs. In the backscattered electron image, tunnel openings appeared as dark spots. The tunneling hyphae did not show a preference for a particular location for entering the shaft of the hair. Some hyphae penetrated under the free edges of the cuticular scales, while others burrowed through the surfaces of the scales.

KEYWORDS: pathology and biology, fungus, hair, tunnels

The tunneling of hair by fungal hyphae[3] is a phenomenon that has long been of interest to researchers [*1–18*]. Davidson and Gregory [*1*] were the first to report on microscopic examinations of hairs that had been attacked by fungi. More detailed studies [*2–5,7*] subsequently revealed three stages in the fungal attack on hairs—lifting of the cuticle scales (possibly due to the growth of the fungal mycelium along the surface of the hair); erosion of the cortex; and tunneling of the hair by "penetrating organs" (specialized fungal hyphae). Although the term "tunneling" is frequently used in the research literature, in the case of fungi capable of digesting keratin the penetration of fungal hyphae into the hair is probably the result of the secretion of keratinase enzymes by the penetrating organs of the fungi, rather than that of mechanical boring [*12*]. Fungi that apparently lack keratinase enzymes may destroy hair by digesting the non-keratin proteins that cement together the keratinized cells of the hair; the burrowing hyphae then mechanically split apart the keratinized hair cells [*6*].

Although many forensic scientists have undoubtedly examined hairs that have been tunneled by fungi, there have apparently been no descriptions of such fungal tunneling of hair in the forensic-science literature. A search of three comprehensive reviews of forensic hair examination [*19–21*] does not reveal any mention of this phenomenon. Because this tunneling phenomenon has not been called to the attention of the forensic science community, we thought it would be worthwhile to describe our examinations of casework samples that exhibited fungal tunnels.

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[3]Hyphae are the multi-cellular filaments comprising the most common vegetative growth form of fungi that are classified as molds. A mass of hyphae is called a mycelium [*22*].

Materials and Methods

One of the authors (W.F.R.) was asked to examine hairs recovered from an automobile and to compare them microscopically with known samples of head and pubic hair taken from a murder victim and several suspects. The victim had been buried for 3 weeks before her body was exhumed and the hair exemplars obtained. When received, the hair samples from the victim appeared to the unaided eye to be clean and free of any mold. Specimen hairs were selected at random and then mounted on microscope slides using Permount (Fisher Scientific). The mounted hairs were then examined using an Ernst Leitz Dialux transmitted light microscope equipped with a Leica CL 35 mm camera attachment.

An additional specimen head hair was selected for examination with a scanning electron microscope. This hair was carbon coated with a Hitachi HS5 Carbon Evaporator and examined with a CamScan Series II scanning electron microscope equipped with a Robinson backscattered electron (BSE) detector. X-ray spectra of the hair and adherent particles were obtained using a EDAX 9800 Plus energy dispersive X-ray analyzer with a ECON IV light element detector.

Results and Discussion

The victim's pubic hairs showed no tunneling, possibly because the victim's clothing prevented fungal spores in the air or in soil from settling on the pubic region. When examined with a transmitted light microscope the victim's head hairs exhibited numerous fungal tunnels. No fungal hyphae or fungal spores were visible. Careful examination of the hairs revealed a number of interesting points about the fungal attack on the hairs. First of all, some of the hairs were extensively tunneled like that shown in Fig. 1, with several tunnels in each microscopic field of view from the root to the tip. Other hairs, such as that shown in Fig. 2, showed localized damage: tunneled regions were separated by lengths of hair shafts without any tunnels. In general, the tunnels appeared to be of a uniform diameter and small compared to the diameter of the shafts of the hairs. No large, conical tunnels such as reported by Page [*2*], Vanbreuseghem [*3*], Daniels [*4*],

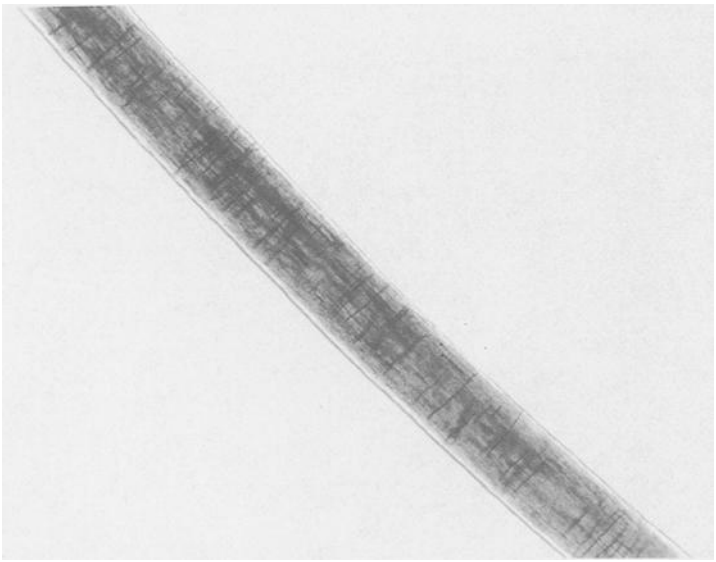

FIG. 1—*Transmitted light photomicrograph of extensively tunneled human head hair.*

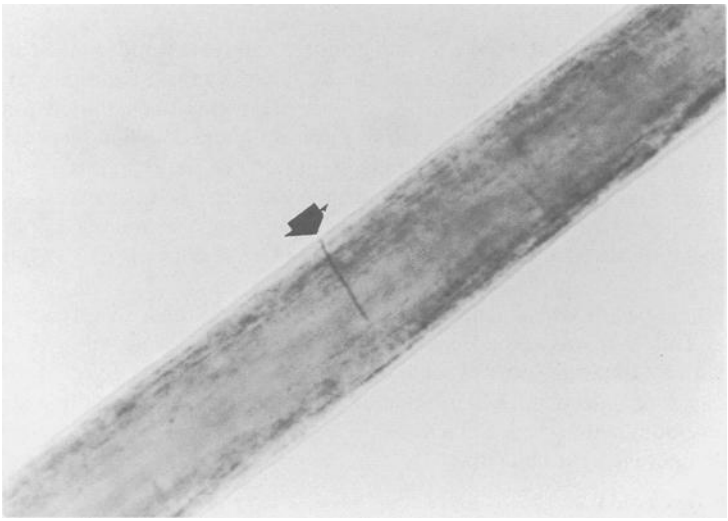

FIG. 2—*Transmitted light photomicrograph of nearly undamaged region of hair shaft. Note passage of tunnel (arrow) from surface through the hair's cuticle into the cortex.*

Barlow and Chattaway [*5*], English [*7,8,10*] and Hawks and Rowe [*17*] were observed. Such large tunnels appear to be characteristic of the tunneling of hair by dermatophytes (fungi that parasitically infest skin, nails and hair and therefore have keratinolytic properties). Virtually all of the hairs had unbranched, transverse tunnels. A few of the tunnels had developed branches (Fig. 3). Overall, the tunneling of the head hairs most closely resembled the tunnels produced in vitro by *Curvularia ramosa* [*7*] and *Alternaria* species [*8*]. Similar tunnels have been reported by Serowik and Rowe [*16*] and Kundrat and Rowe [*18*] in human head hairs that had been buried in well-watered soil. Numerous studies [*4,7,8,11*] have reported that in later stages of fungal attack the hyphae that have tunneled downward into the shaft of the hair begin to spread through the cortex parallel

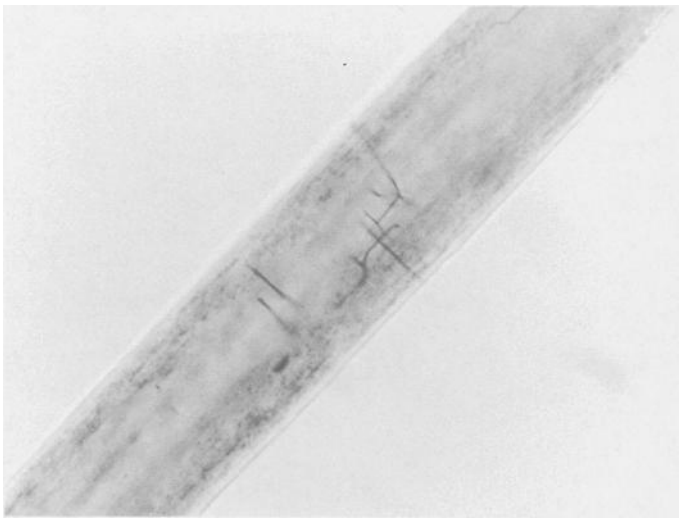

FIG. 3—*Transmitted light photomicrograph showing branching of fungal tunnels.*

to the axis of the hair. The tunneling in this case, therefore, represents an early stage of fungal attack.

Examination of the hair surface with the scanning electron microscope revealed a number of interesting features. No fungal hyphae were observed on the surface of the hair examined. The cuticular scales in many areas were peeling from the surface of the hair, to such a degree that no scales could be found on some segments of the hair shaft. As noted earlier, lifting of the cuticular scales is the earliest stage observed in the fungal attack on hair. The openings of many tunnels were readily apparent. The backscattered electron (BSE) image proved to be particularly useful in searching for tunnels. Tunnels always appeared as black spots in the backscattered electron image, due to there being relatively few backscattered electrons returned to the detector when the electron beam encounters a tunnel. In the secondary electron (SE) image tunnels sometimes appeared as bright spots which at low magnification resembled adherent particles. Other tunnels appeared as craterlike features.

Previously published scanning electron microscope studies of hairs subjected to fungal attack [*11,15*] concentrated on the internal morphology of the tunnels, usually in the late stage of fungal deterioration of the hair. Examination of the hairs in the present case permit examination of the openings of tunnels in an early stage of fungal attack. The fungi appeared to show no preference for the points of attack on the hair surface. In some instances the hyphae had penetrated under the free edge of a scale (Fig. 4), while in others the hyphae had clearly penetrated through the surfaces of the scales (Figs. 5 and 6). Such variation in the points of attack has been previously noted by English [*8,10*]. The entrances to the tunnels shown in Figs. 5 and 6 closely resemble English's *camera lucida* drawings of the entrances to tunnels produced by *Chrysosporium keratinophilum* (although the tunnels made by *C. keratinophilum* do not otherwise resemble the tunnels

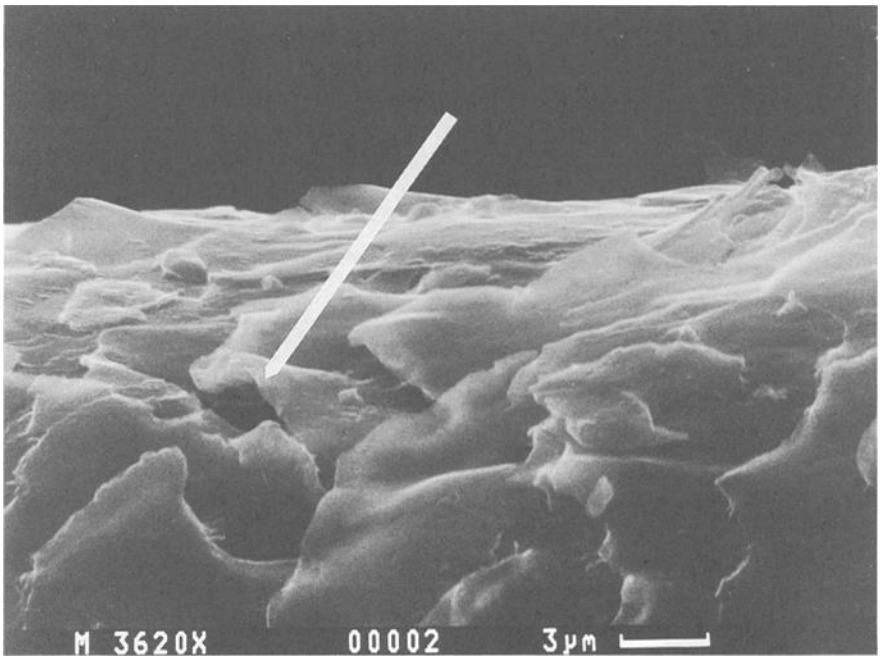

FIG. 4—*Scanning electron micrograph showing tunnel entrance (arrow) under edges of uplifted scales. Backscattered electron image.*

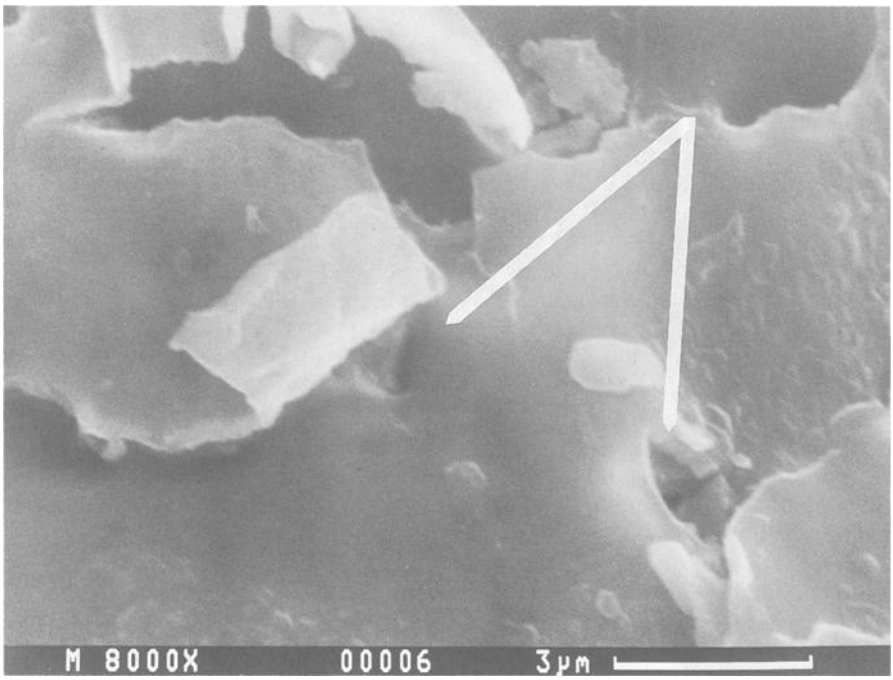

FIG. 5—*Scanning electron micrograph showing tunnel entrances (arrows). Backscattered electron image.*

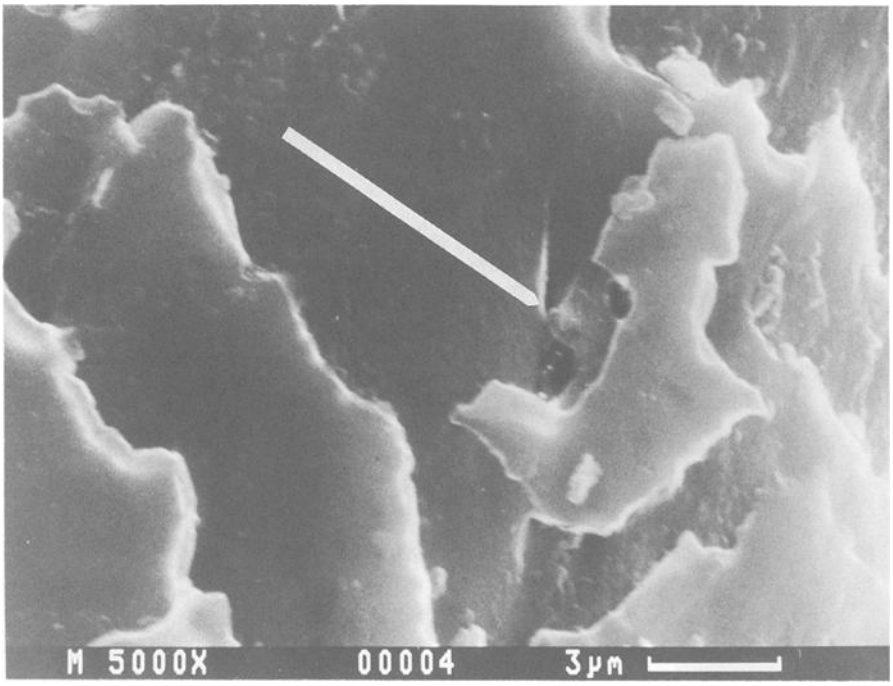

FIG. 6—*Scanning electron micrograph showing tunnel entrances (arrows). Backscattered electron image.*

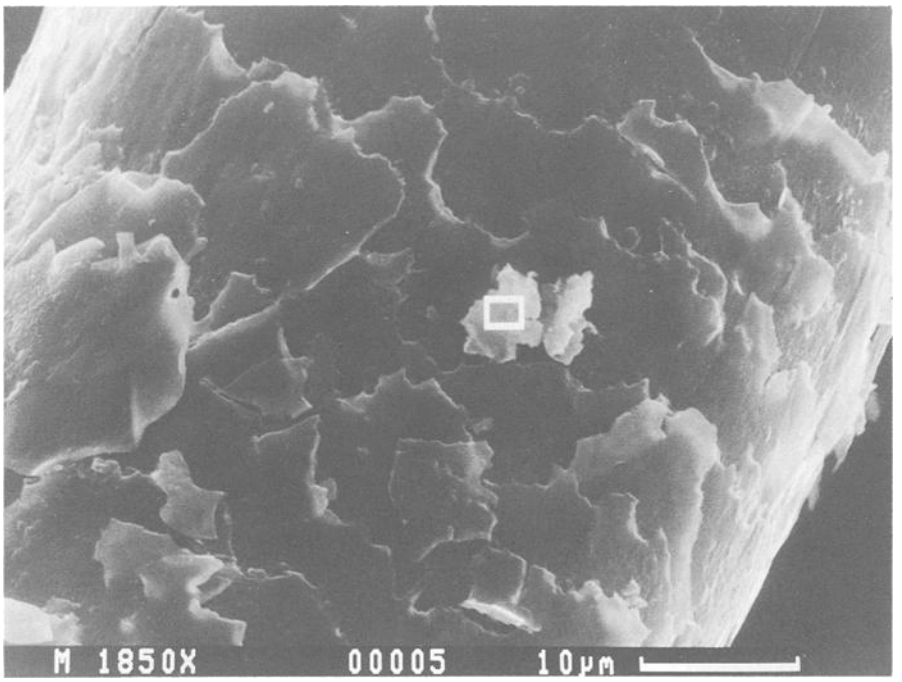

FIG. 7—*Particle adhering to shaft of hair (white rectangle). Backscattered electron image.*

in the present head hair specimens, being much larger and running predominantly parallel to the axis of the hair [*10*].

Although the hairs were, as indicated earlier, generally clean and free of debris, several small particles were noted adhering to the shafts of the head hairs (Fig. 7). The energy dispersive X-ray spectra of the particles revealed them to be particles of gold in combination with trace amounts of copper. Evidently the victim was buried with gold jewelry or gold dust in her hair.

Conclusion

Tunnels produced in human head hair by fungal hyphae were examined with a light microscope and with a scanning electron microscope. The tunnels had small diameters and exhibited minimal branching. The use of a backscattered electron (BSE) detector facilitated the locating of the openings of the tunnels in the surfaces of the hairs. In the backscattered electron image tunnel openings appeared as dark spots. The tunneling hyphae did not show a preference for a particular location for entering the shaft of the hair. Some hyphae penetrated under the free edges of the cuticular scales, while others burrowed through the surfaces of the scales.

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