Isolation and Eradication of Fungi Contaminating the Mummified Corpses from Qilakitsoq

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During the period when they were kept at the National Museum, Copenhagen, the mummies demonstrated increasing contamination with fungi, followed by decomposition of the material. The fungi were isolated and identificated as the species *Penicillium*, *Aspergillus* and *Botrytis*. After decontamination with gamma radiation (2–2.5 megarad) the mummies were transported in tight plastic bags to the museum in Nuuk, Greenland. To avoid recontamination they are now displayed in airtight showcases at a suitably low temperature and humidity.

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The mummified corpses from Qilakitsoq were discovered in 1972, but it was not until 1978 that the first, viz. two baby mummies were transferred to the National Museum in Copenhagen for preservation and scientific investigations (Møller 1978). On arrival whitish, dusty patches in the face and on the clothes of the smallest mummy were observed. From these patches *Sporothrix fungorum* was isolated. They were treated and responded well to nystatin (Bodenhoff *et al.* 1979).

Later on, when the remaining adult mummies were transferred to the National Museum, new problems emerged. On the skin of the mummies and in the seal and bird skins from which their clothes were prepared, areas of destruction caused by fungal invasion gradually extended. These areas were characterized by dusty, whitish grey, brown, black and green coatings and pronounced mouldering of the material, which disintegrated when touched (Fig. 1), indicating fungal contamination.

This exuberant fungal growth raised four questions. Were the fungi pathogenic and therefore dangerous to the individuals doing the preservation work? How destructive for the mummies would the fungal growth be in the long term? Which methods would be most appropriate in the decontamination of the mummies? And finally how were the mummies to be kept in future in order to avoid new contamination?

To answer these questions, it was necessary to culture and identify the fungi. It was easy to see the areas of the mummies from which it was most appropriate to take the cultures, the fungal contamination being macroscopically visible in many locations, as mentioned above. Samples were taken under sterile conditions with swabs and scalpels from the eyesockets and sealskins of mummies 1 and 4; from the sealskins of mummies 2 and 6; from the kamiks and bird skins of mummies 1 and 3; and from the eyesocket, back and front of the sealskin of the baby mummy.

The material was inoculated on Petri dishes with Sabouraud dextrose agar 2% with chloramphenicol 0.5 mg/l and incubated at 26°C.

Numerous different fungal colonies appeared on all Petri dishes (Fig. 2). Pure cultures for identification were obtained from the various morphological forms. The following species were isolated: *Penicillium verrucosum* var. *cyclopium* (Westhing); *P. chrysogenum*

Fig. 1. Sealskin contaminated with fungi.

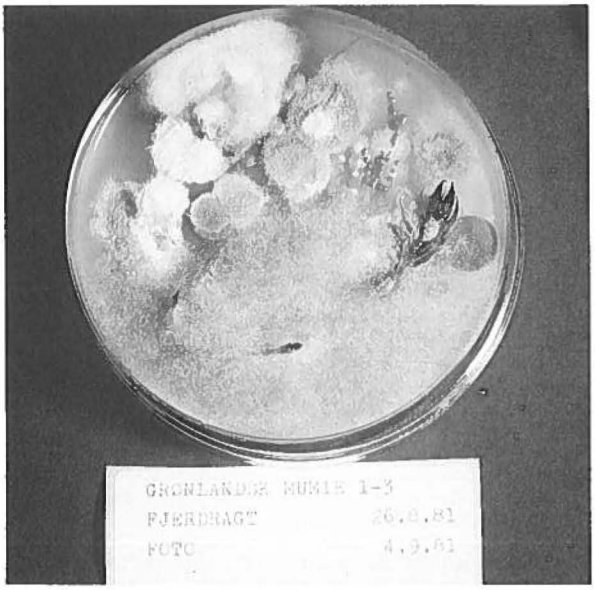

Fig. 2. Primary culture from bird skin.

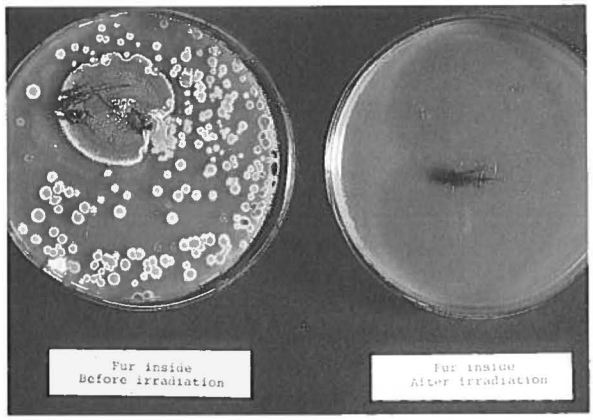

Fig. 3. Irradiation experiment. Positive and negative culture from contaminated fur before and after irradiation.

Thom, *Botrytis cinerarea* Pers. ex Fr. and *Aspergillus versicolor* (Vuill) Tiraboschi. *Sporothrix fungorum* was not rediscovered.

Spores from *Penicillium* and *Aspergillus* may cause allergy and may be pathogenic, especially in immunocompromised individuals, and production of toxins may occur during growth. However, in the present case there was no reason to assume that they would constitute a risk to the staff that was to carry out the preservation. The immediate impression was that the fungi were harmful to clothing and that continuous growth would be destructive, especially in the event of high temperature and humidity. *Botrytis* species have a known destructive effect on plant material at high humidities (Alexopoulos & Mims 1971), while *Penicillium* and *Aspergillus* may under special circumstances attack human skin, and it is well known that they grow well on, and are able to destroy, textiles (Gray 1959).

Decontamination of the mummies was thus necessary. At first, chemicals had to be rejected as in the long view the material might be injured or there might be changes in colour. Antimycotics were not expected to be effective for more than a short period, because their effectiveness is most often restricted to growing fungi. Ethylene oxide is fungicidal and treatment with this medicament is not considered to be injurious to mummies or skins. However, treatment with this was not practically possible, among other things because of the long airing phase after the treatment.

The successfull sterilization of the mummy of Ramses II in 1977 using gamma radiation (Brouqui *et al.* 1978) prompted us to experiment with the efficacy of electron irradiation with 3 megarads of contaminated skin samples. This was done in collaboration with dr. Bährenstein, Risø Research Centre, Roskilde. The material was cultured before and after irradiation and the dosage used proved fungicidal (Fig. 3). Given this, all the mummies were then sterilized with gamma radiation at 2–2.5 megarads at Nunc A/S, Roskilde, which had the necessary capacity. The sterilization was carried out with the mummies sealed in tight-fitting plastic bags which were then transported unopened to Greenland. The last problem was to decide the conditions under which the mummies had to be kept in Greenland with minimal risk of new fungal attacks. To reduce the chance of invasion by contaminating microorganisms, it was suggested that the mummies shoul be displayed in aseptic conditions in air-tight glass cases in which air humidity could be registered by hygrometers. Application of silicagel in the socket was considered sufficient to ensure that the relative air humidity would remain around 50. Finally, a suitably low temperature, preferably not more than 20°C, was recommended. In this way it is hoped that these so well-preserved 500-year-old human remains will be kept in a lasting resting place as safe as the one they had in the crevice.

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