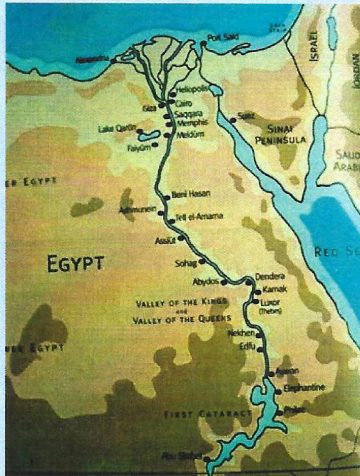
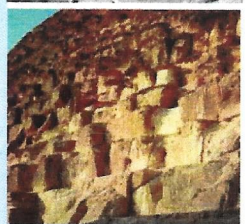
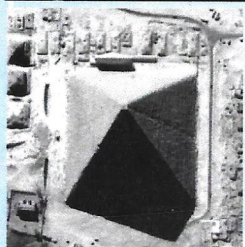
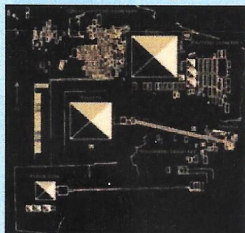


# New Molds in Old Tombs: The Burial Chambers of Tutankhamun and Khufu

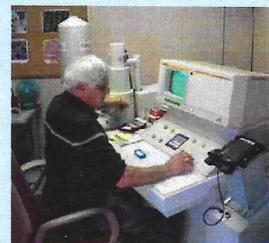


Khufu Pyramid, Giza Plateau, Egypt, burial complex layout

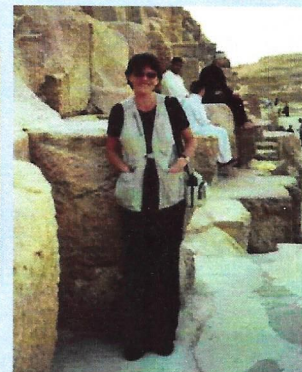


## Project Background and Objectives

Khufu (Cheops) pyramid is one of the Wonders of the World; it is the oldest and largest pyramid on the Giza plateau in Lower Egypt dated to 3100 BC. Its chambers and passages contain neither inscriptions nor decorations and its sarcophagus was found empty. The present study examined fungal deposits from the limestone walls of the Ascending Passage collected on December 5, 2000. The purpose of the examination was to determine the species of fungi present and to compare those growing on the barren limestone of the Khufu Pyramid with those on the mural painting in the Tutankhamen Tomb in the Valley of the Kings near Luxor, Egypt. (Szczepanowska & Cavaliere, 2004).<sup>\*</sup> Also of interest in this study was the impact of extensive tourist visitations on the closed environments of both tombs.



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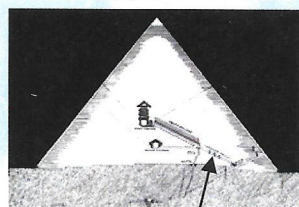
Hanna Szczepanowska, Conservator  
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## Methodology

Fungal aerial mycelium was collected from the walls of both tombs, placed in sterile vials and returned to our microbiology laboratory at Gettysburg College, Gettysburg, PA, where they were cultured and studied.

### Assessment of fungi viability:

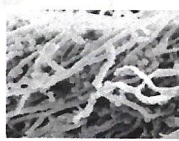
- Isolation of pure cultures;
  - samples were inoculated on culture dishes containing a number of media (corn meal agar, Sabouraud's dextrose agar, Czapek Dox agar, potato dextrose agar)
  - samples were incubated at room temperature
  - samples isolated into individual cultures with the first appearance of hyphal strands to prevent cross contamination of species
- Microscopic examination under light microscope up to 1000x; using a Nikon Optiphot with attached camera, FX-35 WA
- SEM examination up to 5000x
  - samples prepared by fixation with Karnovsky's fixative and dehydrated using Tousimis Samdri 790 Critical Point Dryer
  - samples mounted on aluminum stubs, coated with 10nm of gold in a Denton Desk II Sputter Coater
  - examination with a JOEL 5200 Scanning Electron Microscope
  - photographs taken with a Polaroid 545 camera using Polaroid 55posihg film. Images were further digitized using an EDAX Imaging System.



Mold samples were collected from the walls of the Ascending Passage, (arrow) and cultured (top right).



*Aspergillus* (350x)



*Sporulating colony* (350x)



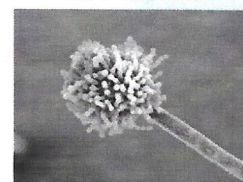
*Penicillium* (350x)



*Cladosporium herbarum* (1000x)



*C. herbarum* spores (3500x)



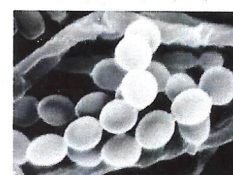
*Aspergillus flavus* (750x)



*A. flavus* phialides & spores (2000x)

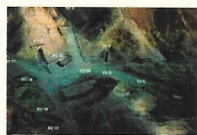


*Penicillium chrysogenum* (3500x)

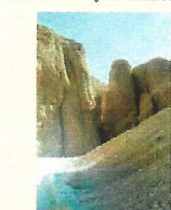


*P. chrysogenum* spores (5000x)

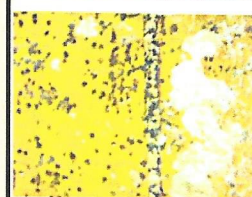
## Comparative analysis of fungal infestation of the mural painting at the Tutankhamun Tomb, Valley of the Kings



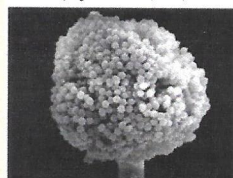
The Valley of the Kings across the Nile from Luxor is one of the richest archaeological sites in the world. It is a necropolis of 18-20 dynasty pharaohs who reigned in the new Kingdom from about 1539 to 1078 BC. Among 62 tombs, the last one, No. 62, was discovered untouched since the king's death in 1323 BC.



The rock strata forming the cliffs of the valley consists of two types of rock-marine limestone (the Theban Limestone Formation) and shale (The Esna Shale Formation). The limestone is easy to excavate but when saturated by floodwater retains moisture supporting fungal growth.



*Aspergillus nidulans* (1200x)



*Aspergillus nidulans* spores (5000x)



Mural painting in the Tutankhamun chamber. (Top Left) Detail of the mural painting showing black, fungal colonies. (Bottom Left and above) <sup>\*</sup>Szczepanowska and Cavaliere, 2004: Tutankhamun Tomb: A Closer Look at Biodeterioration-Preliminary Report, In: Schimmel, Gefahr für Mensch und Kulturgut durch Mikroorganismen. THEISS, Verband der Restauratoren; Bonn.

## Conclusions

We found many similarities between the species growing on the Tutankhamun painted mural and those on the Khufu unpainted tomb surfaces. The fungus colonies on the bare limestone walls, however, were more luxuriant and conidial production appeared to be prolific. Based on our findings, we need to modify our initial supposition that the pigments of the mural painting in the Tutankhamun tomb was the primary cause supporting growth of particular mold species. It appears, however, that the role of a biofilm produced by various ubiquitous microorganisms and human visitors is of equal significance in supporting fungal growth than the pigments in the mural.

## Acknowledgments

Rafal Szczepanowski (late) ALP JHU, for procurement of sample material. From Gettysburg College: Matt Cirigliano, for color enhancement of SEM images, and Kim Breighner for final poster formatting.