

## Pharaohs and Mummies: Diseases of Ancient Egypt and Modern Approaches

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### Introduction

In 2013 scientists published, in *The Lancet*, a study of whole-body CT scans of 137 mummies, which included several analyses of ancient Egyptians [1]. The studies, along with previous research, indicate that many of the mummified corpses of the Egyptian pharaohs died as a result of microbial diseases ranging from tuberculosis [2] to caries [3]; and from malaria to pathogenic fungi. These examinations of the causes of death are not only of historical interest; they are also of some importance in helping scientists understand the origin and evolution of diseases that remain prevalent in the twenty-first century. By comparing the ancient forms of such diseases with their contemporary equivalents, researchers can attempt learn how particular diseases evolved; what makes them so harmful; and possibly how to stop them. This field of paleopathology is becoming increasingly sophisticated, aided by advances to scientific techniques.

This article presents an overview of recent research pertaining to the entwined concerns of paleopathology and Egyptology.

### Mummification

Mummies are a link between human biology and cultural practices. As a cultural practice, artificial mummification is the complex preservation of the corpse due to mortuary rituals, practices which required specialist methods the preparation and treatment of cadavers for mummification. In Egyptian society mummification was the preserve of royalty and the very wealthy [4]. Whilst the process of mummification has presented researchers with unique insights of bodies from two to five millennia ago, because mummies are both rare and delicate researchers have been limited in what techniques they can use to investigate them.

### Importance of Paleopathology

The methods of paleopathology are used to obtain data on health, disease, and death from ancient populations [5]. Paleopathological investigations often coincide with bio-anthropological inquires, which provide information pertaining to anthropometric characteristics, population of descent, age, and sex. The diagnostic methods that can be deployed to examine mummified remains include what can be categorised as non-destructive, less-destructive methods and destructive methods [6]. Non-destructive methods include radiography, computerised tomography scanning (with advanced three-dimensional visualizations), and endoscopic techniques [7]. Of these tomography is arguably the most sophisticated and rewarding. As a non-invasive method it enables accurate images of both the bone and tissue of a mummy to be obtained. Less-destructive methods include stable isotopes, trace metals, and DNA. Microscopic analysis of carefully removed fragments can also be useful. Here techniques which such as the preparation of thin-ground sections from undecalcified bone samples and non-rehydrated mummified soft tissues can be examined [8].

More destructive methods include the forensic examination of skeletal remains, supplemented by X-rays, chemical analysis, biomolecular methods (ancient DNA analysis) and other laboratory

methods. With the examination of bone, the primary signs of disease can be seen through osteomyelitis [9]. Osteomyelitis describes an infection of the bone and the bone marrow. In relation to disease causing agents, the skeletal changes consist of bone destruction along with new bone formation (involucrum) and necrotic bone (sequestrum). The affected bones are enlarged, highly deformed, and show an irregular surface covered with pits, cavities, and plaques of new bone; furthermore, formation of cloacae (drainage canals) may be present in many cases. Further analysis of fragments can be undertaken through the use of next-generation sequencing technology, using specific and sensitive polymerase chain reaction protocols [10]. Some diseases that can be detected, based on changes in bone structure, include tuberculosis, leprosy and syphilis.

With each of the different methods, successful examinations can reveal an individual's history of health and disease, as well as their age and cause of death.

### Analysing Mummies for Causes of Death

Many of the diseases which cause problems in today's society afflicted Egyptian populations. These include tuberculosis, malaria and schistosomiasis. In drawing upon examples of each beginning with the bacterial, a high proportion of mummified corpses are individuals who died from tuberculosis [11]. This has been shown through PCR-amplification of mycobacterial DNA, extracted from growth centres and spongy areas of the bone. Through specific primers recognising a 133 bp fragment of the gene of a mycobacterial surface antigen, the causative agent *Mycobacterium tuberculosis* can be selected [12]. Tuberculosis is presumed to have been transmitted from domesticated cattle to humans through ingestion of contaminated meats and the drinking of contaminated milk.

With malaria, this pertains to a famous mummy. Hitherto the cause of death of the Egyptian pharaoh Tutankhamun was a matter of speculation; however, according to a recent article in the *JAMA*, new evidence has been provided which suggests malaria as the cause of death [13]. With a different parasite - *Schistosoma haematobium* (the worm responsible for urinary schistosomiasis) - this was a major health problem along the Nile Valley. It is unsurprising, therefore, that calcified *Schistosoma* eggs have been found in Egyptian mummies. Using ELISA techniques, Ziskind, for example, has shown that bilharzia plagued ancient Egypt [14].

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Received October 10, 2013; Accepted October 10, 2013; Published October 12, 2013

Citation: Sandle T (2013) Pharaohs and Mummies: Diseases of Ancient Egypt and Modern Approaches. *J Anc Dis Prev Rem* 1: e110. doi: 10.4172/2329-8731.1000e110

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Although not directly linked to causes of death, studies of ancient Egyptian tombs that had not been exposed to modern contaminants have found pathogenic fungi like *Aspergillus niger* (a causative agent of aspergilloma) and *Aspergillus flavus* (associated with aspergillosis of the lungs). At the concentrations typically found, these pathogens are generally only dangerous to persons with weakened immune systems [15].

### The Importance of Preservation

The examination of excavated mummies also informs about the measures that need to be taken to preserve mummies for museums in a way that makes them less susceptible to damage from destructive bacteria and fungi. One preventative measure is the regular monitoring of the remains to ensure that they remain free from infection. This can be undertaken by using special staining methods on sections. Through this method researchers can identify biologically active forms and thus histological tissue analysis can act as an important guide to help with the preservation and protection of the integrity of biological remains held within museum collections [16].

### Conclusions

Studying paleopathology is of importance in order to reconstruct the impact of disease on past human populations. In doing so, however, it should be noted that samples of human remains are not necessarily representative of the living. Therefore, care needs to be taken when interpreting data and making references to living populations from past populations, as a significant difference might be evident. It may be, for instance, that skeletal lesions do not give the complete information as to how an individual lived and died.

Nonetheless, where information can be gained with a level of certainty, such information can advance our understanding about diseases and the history of infection. It may be, for example, that causes of death are linked to underlying genetic factors, or are the consequences of certain ways of living, and that these commonalities can be compared and contrasted with actions taken to combat diseases in the twenty-first century. Therefore, the study of the causes of death of Egyptian mummies is of importance for understanding the nature of disease in contemporary society.

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