Part III - Parasite Findings in Archeological Remains: a paleogeographic view

25. The Findings in Africa

Adauto Araújo
Luiz Fernando Ferreira

SciELO Books / SciELO Livros / SciELO Libros

ARAÚJO, A., and FERREIRA, L.F. The Findings in Africa. In: FERREIRA, L.F., REINHARD, K.J., and ARAÚJO, A., ed. *Foundations of Paleoparasitology* [online]. Rio de Janeiro: Editora FIOCRUZ, 2014, pp. 403-416. ISBN: 978-85-7541-598-6. Available from: doi: [10.7476/9788575415986.0027](https://doi.org/10.7476/9788575415986.0027). Also available in ePUB from: <http://books.scielo.org/id/zngnn/epub/ferreira-9788575415986.epub>.

All the contents of this work, except where otherwise noted, is licensed under a [Creative Commons Attribution 4.0 International license](https://creativecommons.org/licenses/by/4.0/).

Todo o conteúdo deste trabalho, exceto quando houver ressalva, é publicado sob a licença [Creative Commons Atribuição 4.0](https://creativecommons.org/licenses/by/4.0/).

Todo el contenido de esta obra, excepto donde se indique lo contrario, está bajo licencia de la licencia [Creative Commons Reconocimiento 4.0](https://creativecommons.org/licenses/by/4.0/).

The Findings in Africa

Adauto Araújo • Luiz Fernando Ferreira

In Africa, there are no established research groups in paleoparasitology with researchers from the continent itself. However, the immense treasures from Africa's ancient civilizations have always attracted researchers from around the world. There is a longstanding tradition of international research groups dedicated to the study and preservation of mummies and other ancient relics from Egypt and elsewhere in Africa (Ikram & Dodson, 1998). With its Egyptian mummies, Africa has attracted scientists to investigate evidence of health and disease revealed in preserved bodies, both in the tombs of nobles and pharaohs and in the cemeteries where poor commoners were buried. In the latter corpses (buried without any artificial mummification), climate was the main determinant of preservation.

The first published paleoparasitology study usually cited is that of Ruffer (1910a), who found *Schistosoma haematobium* eggs in histological sections of kidneys from two mummies dated 1250-1000 BC, out of a total of six examined. The article refers to the medical record known as the Ebers Papyrus, which mentions hematuria, the most characteristic symptom of *S. haematobium* infection.

Although the eggs were calcified, they were perfectly identifiable due to the spicule on the extremity. The diagnosis was confirmed by Patrick Manson and Arthur Looss, famed early 20th-century experts. Ruffer (1910b) further describes the histological techniques for recovering the mummified tissue's consistency, in order to allow the use of paraffin sections and specific staining. The following year, Ruffer & Ferguson (1911) published a study on a possible case of smallpox in a mummy from the 20th Egyptian dynasty, the diagnosis of which was later challenged by Unna (Lowenstein, 2004).

Egyptian papyri mention pathological conditions that can be attributed to various parasitic diseases. Sánchez-Martín et al (2005) discuss aspects of the Ebers Papyrus, which mentions hematuria and other clinical manifestations interpreted as resulting from *Schistosoma haematobium* infection, already mentioned by Armand Ruffer. They quote a phrase from the Book of the Dead in which the followers of Ra drink the blood of his phallus, presumably a form of religious adoration. The pharaoh, considered a god, suffered from hematuria, which was not recognized as a disease at the time, and drinking such blood would be a way of worshipping him (Hoepli, 1972).

Before Ruffer (1910a), Hope (1834) had described arthropods found during the examination of Egyptian mummies. Later, Mitchell (1900) described a case of poliomyelitis in an Egyptian mummy, with the description of typical lesions.

More than eight thousand mummified bodies were found during construction of the Aswan Dam in Egypt in the early 20th century. Many were studied, but only superficially, as commented by Moodie (1923). The dam construction and numerous mummies fueled even greater interest in mummy studies, since most were commoners whose families could not afford to embalm their relatives' corpses as the nobles and priests did.

Moodie (1923), editor of the anthology of articles by Armand Ruffer published shortly after his death (Ruffer, 1921), published his own studies of Egyptian mummies, describing lesions and interpreting the findings. The book is recommended reading for all those interested in paleopathology. Another recommended book is that of paleopathologist Theodore A. Sandison, also on diseases in Ancient Egypt (Sandison, 1959).

Aidan Cockburn (1963, 1967) published two editions of his book on the origin and evolution of parasitic diseases, highlighting a section on Egypt and Nubia (now Sudan). Concerning the origin of human parasites, we should always recall that the ancestral humans came from Africa, and with them their parasites, many of which were inherited from ancestral primates. Others were acquired over the course of their evolution (Araújo et al., 2003). As emphasized by Cockburn (1963), this makes the study of parasites in archaeological remains one of the scientific fields most capable of providing data on the origin and evolution of parasitic infections and their dispersal with human hosts (as discussed in Chapter 1, since 1979 this field has been known as paleoparasitology, according to the term first used by Ferreira et al, 1979).

Morse, Brothwell & Ucko (1964) studied tuberculosis in Ancient Egypt, referring to evidence from the Old and New Worlds. At the time their studies were published, reference was made to the low reliability of American cases, while the Egyptian mummies deposited in museums since the early 20th century display typical lesions of tuberculosis, showing irrefutably that the disease existed in Ancient Egypt. The authors used human remains (bones and mummified bodies) and texts and artistic works (frescos and sculptures) to prove their findings.

Møller-Christensen & Hughes (1966) and Møller-Christensen (1967) described cases of leprosy in Egyptian mummies, in pioneering studies in archaeological remains (mummified bodies and bone lesions) on infection and disease caused by *Mycobacterium leprae*.

Giacometti & Chiarelli (1968) published studies on lesions and other dermatological characteristics of Egyptian mummies. The mummies belonged to the pre-Dynastic Period, dated to 4000 BC (or 6,000 years before present). Although they do not refer to parasites, they include a review of Egyptian embalming techniques and the conclusion that the dry climate was decisive for preserving histological structures. The authors recall that studies on diseases in archaeological remains data as far back as medieval times, but that it was Johan Czermack in 1852 who first obtained satisfactory histological preparations of tissues from Egyptian mummies (although they consider Armand Ruffer the pioneer). The article comments on the resistance of skin tissue to the elements and time, highlighting the preservation observed in histological sections. One of the most interesting finds was well-preserved red blood cells, providing a source for other authors to search for vestiges of parasitism by *Plasmodium* sp., as discussed in greater detail below.

Hoeppli (1969) wrote on the origins of infectious diseases in Africa and their subsequent spread to other continents with the slave trade. The book, describing each parasite in detail, is essential reading for studies on the origin and evolution of parasitic infections.

The 1970s witnessed growing interest in diseases identified during autopsies of Egyptian mummies, coinciding with the creation of the Paleopathology Association in 1973, led by Aidan Cockburn, Eve Cockburn, Robin A. Barraco,

William, H. Peck, and Theodore A. Reyman. Mummified bodies in museums were studied by multidisciplinary teams, and various articles were published.

The society grew and prospered, and since the first year it began publishing a scientific journal, the *Paleopathology Newsletter*, convening members from all over the world and holding biannual congresses in the United States, Europe, and South America.

Harrison (1973) published a letter with comments on some articles, referring to possible lesions in one of the most famous mummies from Egypt, then on exhibit at the British Museum. It was the body of Tutankhamun, which the author had the opportunity to study, ruling out any possibility of suprarenal tumor, Klinefelter syndrome, Wilson disease, or flat feet, as suggested by other authors. Gray (1973) also commented on the purported gynecomastia depicted in statues and paintings of Akhenaten and Tutankhamun (father and son, respectively). Although neither author referred to parasitic infections, this debate sparked several letters and articles due to the exhibit in the British Museum.

Lewin et al. (1974) described a multidisciplinary autopsy performed on an Egyptian mummy in the Royal Ontario Museum, dated 3200 BP. They focused attention on the hepatic lesions, which they attributed to what they called cirrhosis resulting from schistosomiasis.

Cockburn et al. (1975) described in detail the third multidisciplinary study in an Egyptian mummy dated to circa 170 BC and the finding of *Ascaris lumbricoides* eggs. The study is a complete guide to the stages needed for optimum yield from archaeological material. The mummified body was called PUM II, then on deposit in the Philadelphia Art Museum. The same mummy was the object of various scientific articles, described further below.

Reyman (1976) described as schistosomal cirrhosis (currently hepatic fibrosis) the lesions he found in an Egyptian mummy dated 3200 BP, in addition to *Taenia* eggs found in the intestine. He and colleagues conducted histopathological analyses in this same Egyptian mummy, called PUM-2 (or PUM II), donated for autopsy by the Pennsylvania University Museum (hence its denomination) to the Philadelphia Art Museum (Reyman, Barraco & Cockburn, 1976). This autopsy was performed at the Wayne State University School of Medicine by a multidisciplinary team as part of a symposium entitled Death and Disease in Ancient Egypt. Although of unknown origin, it was identified as a man approximately 35 to 40 years of age who had lived in the Ptolemaic period around 170 BC. A series of lesions had been identified previously by radiological examination, including Harris lines, associated with periods of food restriction in the individual. In addition to histopathological details like atheromatous plaques and a diagnosis of silicosis, the authors found embryonated eggs of *Ascaris lumbricoides*, thus demonstrating the antiquity of infection with this parasite in the human host. The eggs were located in the intestinal mucosa, and the larvae in their interior were clearly visible.

The authors call attention to the improvement and development of new histopathological techniques for mummified tissues, also useful in forensic medicine.

In 1977, the *Canadian Medical Association Journal* published a series of short articles on studies performed by a multidisciplinary team on the Egyptian mummy dated to 3200 BP and called Nakht – ROM I (Royal Ontario Museum). The study included participation by numerous researchers from various specialties, possibly the largest team until then and coordinated by Gerald Hart and Aidan Cockburn, among others (Hart et al., 1977). Rideout (1977) headed the radiological examination. Scott, Horne & Hart (1977) described the macroscopic anatomy, while Lynn & Benitez (1977) provided details on the examination of the outer and inner ears. The parasites were described in short articles. Reyman, Zimmerman & Lewin (1977) reported finding eggs from *Schistosoma hematobium* and possibly *Schistosoma*

mansoni, totally calcified but still showing the remains of the lateral spicule. The researchers found numerous *Taenia* eggs and discussed whether the infection (according to the species) was from ingesting pork or beef. De Boni, Lenczner & Scott (1977) recorded finding *Trichinella spiralis* in histological sections. Horne & Lewin (1977) used electron microscopy to study histological sections from the mummy, describing *Taenia* eggs in the intestinal mucosa in great detail. Interestingly, the body was that of a young Egyptian some 14 to 18 years of age whose sarcophagus shows characteristics of inscriptions and a style indicating that he belonged to the working class. He thus represented the majority of the Egyptian people (Millet, 1977).

In another well-known article from the late 1970s, Peter Lewin describes “the mummies that I have known” (Lewin, 1977), a review of the autopsies performed by the group from the Paleopathology Association.

Tapp (1979) recorded the presence of *Dracunculus medinensis* and *Strongyloides* in mummies dated from 1000 to 2160 BC, and later described hydatid cyst in a mummy dated 1000 BC (Tapp, 1984).

Dzierzykray-Rogalski (1978) reported a case of leprosy in an Egyptian mummy. He then published a summary of his studies in mummies from the Egyptian Ptolemaic period, dated to the second century before Christ. The author used paleopathology data to support demographic conclusions (Dzierzykray-Rogalski, 1980).

Zimmerman (1979) described a fatal case of tuberculosis in Ancient Egypt in a child approximately 5 years of age, from the Dynastic Period. He adopted the technique recommended by Armand Ruffer for rehydrating and staining mummified tissues and used Ziehl-Neelsen staining to investigate acid-fast bacilli, with positive results both in vertebrae and in blood found in the trachea and lungs. He commented on the lack of evidence of tuberculosis in previous periods and suggested that the infection emerged in the early Dynastic Period some 5,000 years ago, coinciding with the domestication of cattle.

Cockburn et al. (1980) described the autopsy of an Egyptian mummy, with details on the preparation and preservation of the body. This was the mummified body called PUM II, in which the authors found a single parasite egg, seen by various helminthologists. According to the article, helminthologists confirmed that it was an *Ascaris* egg. Some claimed a definitive diagnosis of an *Ascaris lumbricoides* egg. The mummy was attributed to the Ptolemaic period, circa 170 BC.

Millet et al. (1980) described the mummification of individuals belonging to the non-noble population of Ancient Egypt, showing that the main factor for preservation was always the climate, as opposed to the techniques employed in nobles.

Sandison (1980) commented on parasite findings in Ancient Egypt, referring to the autopsies conducted by the group of paleopathologists from the Paleopathology Association in mummies from museum collections in Canada. He concluded that infections with *Ascaris* sp., *Schistosoma haematobium*, and *Taenia* sp. already occurred in ancient Egyptians.

Armitage & Clutton-Brock (1981) published a curious article on mummies of domesticated animals, such as cats from Ancient Egypt, belonging to the British Museum. Due to their rarity, we should mention that the Brazilian National Museum (Federal University of Rio de Janeiro) houses several such mummies in its collection. Our team examined samples collected from a mummified cat, with negative results for parasites under light microscopy. However tests for other parasites remain to be performed, such as *Toxoplasma gondii*, using molecular biology techniques.

Aidan Cockburn (1981) sent a letter to the editor of *The Lancet* in response to criticism for the book he published with other researchers, *Mummies, Diseases, and Ancient Cultures*. He commented on the parasite finds described in the book and the care with which the diagnoses had been performed.

Cockburn's letter especially focuses on parasitic infections in the ancient Nile River Valley, commenting on possible positive malaria results in the autopsy performed on the ROM I mummy, mentioned previously. He provided experts with samples that contained red blood cells, along with other tissues, to investigate the parasite directly or using serological techniques. One such group was that of Guy, Krotosky & Cockburn (1981). Fluorescent antibody tests were performed at the London School of Hygiene and Tropical Medicine, but proved inconclusive.

Lewin (1982) described a possible case of smallpox in an Egyptian mummy in a paper delivered to the Paleopathology Association during its regular meeting.

Deelder et al. (1990) used serological techniques to diagnose schistosomiasis in Egyptian mummies but did not define the species, whether *Schistosoma mansoni* or *Schistosoma haematobium*. The mummy was dated 1198-1150 BC.

Miller et al. (1992, 1993) then published interesting arguments on the paleoepidemiology of schistosomiasis in Africa, based on results with serological techniques and the parasite's eggs found in Egyptian mummies. They examined the two possibilities of infection, by species *S. haematobium* and *S. mansoni*, but with positive results only for the former. The authors used tissue from Chilean mummies as the control for serological reactions.

Palma (1991) described nits found on combs from mummies dated to the 5th and 6th centuries AD in Egypt.

Strouhal (1991) published two cases of vertebral tuberculosis, one of which in an adult individual 45 to 55 years of age, found in Egypt and dated to the 21st dynasty. The lesion involved fusion of T9-L1 and deformity of the T8 vertebral body, but with complete healing and adaptation of the spinal column to the resulting position. The other case, described in a young individual (22 to 24 years) dated to the 6th to 10th century AD in Nubia, showed a progressive process involving the entire thoracic and lumbar column.

The author conducted a review of tuberculosis in Egypt and nearby regions, gathering six TB cases depicted in iconographies, 30 in skeletons, and two in mummies, in addition to the two cases described in his article, in both Ancient Egypt and Nubia. The review was presented during the symposium of the Paleopathology Association in Zagreb, Yugoslavia, in 1988, entitled Human Paleopathology, current syntheses and future options, coordinated by Donald Ortner and Arthur Aufderheide.

Buikstra, Baker & Cook (1993) discussed infectious diseases in Ancient Egypt, possible origins, and dissemination to other regions. They also analyzed the impact of these diseases on the population.

Spigelman & Lemma (1993) used molecular biology techniques to diagnose TB in Egyptian mummies. Their proposal was innovative, testing bones on the assumption that they could retain residual DNA from the bacillus. The results were promising and opened new paths for molecular paleoparasitology.

Miller et al. (1994) described malaria in Egyptian mummies dated 3200 BC, diagnosing infection with *Plasmodium falciparum* using immunological diagnostic kits. This highly interesting study opened new doors for research.

Fulcheri et al. (1994) conducted an inventory of Egyptian mummies in Italian museums, with a total of 29 recorded collections. The remains were assessed for their status, and treatments were proposed for their preservation. Analyses were performed in histological sections, with the identification of contaminant fungi and bacteria.

Rafi et al. (1994) described the presence of the leprosy bacillus in mummified bodies, using molecular biology. The material with positive results for leprosy, dated 600 AD, was collected at the site of a massacre of Christians perpetrated by Persians in the year 614.

Horne & Redford (1995) found evidence of *Dracunculus medinensis* and infection with *Aspergillus fumigatus* in mummies of Egyptian nobles dated circa 1450 BC. They also mentioned helminths found in the bladder, with

morphological characteristics that could not guarantee a specific diagnosis, but whose localization suggested adult *Schistosoma haematobium*.

Evans et al. (1996) conducted the first studies in coprolites outside of the Egyptian region and opened a new line of studies in paleoparasitology in South Africa. They examined coprolites dated from 12,000 to 9,000 BP, found in the Kruger Cave site, probably inhabited by ancestors of the modern San. The results showed *Ascaris* sp. and *Trichuris* sp. eggs and free-living larvae. These finds were very interesting, demonstrating the presence of these parasites in human groups in the sub-Saharan region and the antiquity of the *Ascaris-Trichuris* association.

Baron, Hummel & Herrmann (1996) succeeded in extracting sequences of the tuberculosis bacillus from the bones of Egyptian mummies. This team of researchers is known for its pioneering and elegant studies, especially in the field of molecular paleoparasitology. Their study focused on the bones of three individuals with TB lesions using polymerase chain reaction (PCR), with positive results in bones both with and without macroscopic lesions. The authors used controls and showed that the technique can be applied to any blood-borne parasite.

Contis & David (1996) reported on a collaborative project for historical and epidemiological studies on schistosomiasis in Africa, involving the Medical Service Corporation International of Arlington, Virginia, USA, and the Manchester Egyptian Mummy Project from the University of Manchester, UK.

The project's principal researchers reviewed the 5,000 years of *Schistosoma* infection in humans and described the proposed methodology, including discovery of evidence in Egyptian mummies, description of the disease in papyri, and the current status of schistosomiasis. The project aimed to retrace the history of infection by *Schistosoma* species by studying collections of Egyptian material from various institutions around the world.

David (1997) updated the data on the use of new diagnostic technologies in archeological remains, exemplified by the identification of diseases in Egyptian mummies dated as far back as 5000 years before present. The mummies were part of the research project cited in the preceding paragraph. As for the presence of parasites, David referred to evidence of infection with *Schistosoma haematobium* and *Dracunculus medinensis*. He also found evidence of hydatid cyst (*Echinococcus granulosus*) and fragments of adult *Fasciola hepatica*, besides eggs of *Ascaris lumbricoides*, *Taenia* sp., and *Schistosoma* sp. and possible larvae of *Strongyloides* sp. The article emphasized that one of the least studied aspects of Egyptian mummies is paleodontology (with the description of dental and periodontal lesions).

Cockburn, Cockburn & Reyman (1998) published a revised edition of the book *Mummies, Diseases, and Ancient Cultures* and included a special chapter to update previous studies in Egyptian mummies. The book contains the state-of-the-art from the 1990s and serves as a reference for any study on diseases in the past.

Panagiotakopulu & Buckland (1999) described ectoparasites associated with Egyptian mummified bodies. These ectoparasites were specimens of *Cimex lectularius*, known as the common bedbug, which has fed on human blood for 3,500 years and has adapted to human dwellings. This may be the only report of this parasite in archaeological material, which makes it quite interesting, since bedbugs have been found all over the world wherever humans have wandered. In a review of Cimicidae, Forattini (1990) reports that *Cimex lectularius* currently shows a wide geographic distribution and that it must have parasitized prehistoric cave-dwelling humans, considering that the species originated in the Middle East.

Cerutti et al. (1999) described infection with *Plasmodium falciparum* in an Egyptian mummy dated 3200 BC. The mummies are from the Museum of Turin, studied by the team headed by Eva Rabino Massa of the University of Turin and president of the World Congress on Mummy Studies in 2003. Applying ELISA (enzyme-linked immunosorbent

assay), Cerutti et al. compared the positive results in 42% of the mummies with macroscopic and radiological evidence of bone lesions consistent with severe anemia.

Strouhal & Horácková (1999) examined a series of bodies with the aim of conducting a demographic survey requested by the team of archaeologists excavating tombs in Saqqara, dated to the New Empire (19th and 20th dynasties). The article does not refer to parasites, but only to inflammatory processes in some skeletons, but it is interesting because of its demographic survey, relevant to the epidemiological analysis of infectious diseases.

Rutherford (1999) conducted a retrospective study of schistosomiasis, drawing on descriptions of signs and symptoms in Egyptian papyri. Hieroglyphs, artistic depictions, and various texts on the daily life of young Egyptians demonstrate their constant contact with water, the source of *Schistosoma* transmission. The author used immunochemistry techniques (indirect fluorescence staining) to test the hypothesis of schistosomiasis in Ancient Egypt, thereby describing cases of infection with *Schistosoma mansoni* and *Schistosoma haematobium* in Egyptian mummies and confirming the antiquity of these parasitic infections in African populations.

Zink et al. (2000) described a case of bacteremia in the mummified body of an Egyptian child, found during excavations by the Deutsche Archaeologische Institut, Cairo, Egypt. The mummy dates to the reign of Pharaoh Amenophis II (1424-1398 BC). The authors extracted genetic material from the marrow of bones previously treated to prevent modern contamination. PCR amplification identified the species of intestinal bacteria *Escherichia coli*, *Frauteria auranta*, and *Halobacillus* spp. The researchers also found genetic material from the bacteria *Halobacillus* spp., *Sporosarcina* spp., and *Bacillus panthothenicus* in the gingival tissue. Few studies have focused on intestinal bacteria in archaeological remains, and this one is particularly outstanding because of the technique's detailed description.

Numm & Tapp (2000) reviewed the parasitic infections attributed to the tropical climate prevailing in Ancient Egypt, commenting on infections with *Strongyloides stercoralis*, filariae, and *Schistosoma* sp. This was a comprehensive review of parasitic infections in Egypt, described in the ancient documents listed in a table, which calls attention to the potential difficulty in translating and interpreting the description of symptoms in words and phrases. The authors traced the history of studies in mummies and skeletons from Egypt, especially those from museum collections in England, highlighting the first study, conducted in Manchester in 1907.

The authors discussed some indications of infections and lesions caused by parasites. The interpretations of texts that may refer to the presence of *Dracunculus medinensis* were accompanied by two pieces of evidence from autopsies in mummified bodies. The authors further discussed the presence of filariae in histological sections of lower limbs. Next, they commented on schistosomiasis haematobium, the *Strongyloides* infection described in an Egyptian mummy from the Manchester collection in which the larvae were found in the intestinal mucosa, and other helminth parasites, such as *Ascaris lumbricoides*, *Taenia* sp., and *Trichinella* sp. They reviewed the evidence of malaria, plague, leprosy, tetanus, and other infectious diseases in the papyri, thereby highlighting the importance of multidisciplinary research.

Rabino-Massa et al. (2000) described cases of malaria in Ancient Egypt. They associated the immunoenzymatic assay for malaria with the description of thalassemia and sickle cell disease in the mummies, identifying target cells and sickle cells by microscopy. Of the 80 bodies examined, 42% of the mummies were positive for malaria, and 61% presented lesions consistent with severe anemia. Following on these studies, Bianucci et al. (2008) used immunochromatographic and immunohistochemical assays in the skin and muscles to confirm cases of *Plasmodium falciparum* malaria in Ancient Egypt.

Patrick Horne (2002) described eggs from *Enterobius vermicularis* and one species of Acanthocephala for the first time in an Egyptian mummy. Horne called attention to the fact that *E. vermicularis* (pinworm) is probably the

most ancient helminth parasite in humans, in addition to being very common at present, and that it has rarely been found in Old World archaeological remains. The same is not true in the Americas, where *E. vermicularis* eggs have been recorded in various archaeological sites. In Egypt, there were no previous reports of the parasite in mummified bodies or coprolites. However, paleoparasitological examination by the author showed very well-preserved eggs of *E. vermicularis* associated with eggs of Acanthocephala, raising an interesting discussion on the presence of this parasite in the human host (Horne, 2002). The species described in human coprolites resulted from the ingestion of arthropods, the remains of which were seen under microscopy.

Zink et al. (2003) studied tuberculosis in Egyptian mummies based on the characterization of genetic material extracted from bones and soft tissues. This research group had previously described *Corynebacterium* infection in Ancient Egypt (Zink et al., 2001) and cases of tuberculosis in Ancient Egypt, comparing the results from molecular biology techniques with modern material (Zink, Grabner & Nerlich, 2002).

Harter (2003) described various parasites found in mummified bodies from Ancient Egypt and Nubia, showing (for the first time with extremely clear microphotographs) eggs of *Schistosoma mansoni* dated as far back as 6000 BP, with excellent preservation, showing details of the miracidium in the egg's interior. Harter's PhD research included mummified bodies from Nubia, Egypt, Cyprus, and Israel.

The finds date as far back as 6000 BP, including *Ascaris* sp., *Trichuris* sp., *Enterobius vermicularis*, *Syphacia obvelata*, *Toxocara cati*, *Toxocara canis*, hookworm eggs, *Taenia* sp., *Diphyllobothrium* sp., *Hymenolepis* sp., *Schistosoma haematobium*, *Schistosoma mansoni*, *Fasciola hepatica*, *Fasciola gigantica*, *Dicrocoelium* sp. eggs, and *Pediculus capitis* eggs. The eggs found in the mummified bodies, preserved for thousands of years and by various processes, were mostly in excellent state, both externally and internally, as observed in the figures in Harter's PhD dissertation (2003). Many display the embryo perfectly preserved inside the eggs, which can further facilitate relevant studies with molecular biology techniques.

Harter's findings (2003) are very important and merit on-going revisions and confirmations, since they attest to the antiquity of the majority of intestinal helminth infections believed to have originated in Africa. Some of the infections originated in pre-hominids, while others must have been acquired over the course of human evolution. Even so, although not having originated by the phylogenetic route, they may have had an African origin and spread from this continent to other parts of the world.

Harter et al. (2003) described parasites in objects found alongside Egyptian mummies. One case was an embalming rejects jar dated to the 25th dynasty, circa 715 to 656 BC, found in 2001 during excavations in the mastaba, or funeral complex, at Akhthetep in Saqqara, studied by Ziegler et al. (1997). Priests used the jars to place the inner organs of individuals being prepared for embalming and later sealed them with packed earth. The jars contained everything from fragments of linen to the fetid liquid resulting from the body's putrefaction. The authors identified some of the contents, examining them separately by rehydrating each one in trisodium phosphate aqueous solution, as with any other sample for paleoparasitological examination. The studies yielded eggs from *Ascaris* sp. and *Taenia* sp., probably *Taenia saginata* due to the Egyptian habit of avoiding pork, according to the article. Both the tapeworm and roundworm eggs contained perfectly preserved embryos; the larva inside the *Ascaris* egg showed the anatomical structures on the cephalic portion, allowing study in great detail. The same is true for the hexacanth embryo in the *Taenia saginata* egg, with the aculei visible in the figure published in the article. One of this study's most interesting aspects is the analysis of the embalming rejects jar from the mummification process, yielding such well-preserved parasites. Harter-Lailheugue & Bouchet (2004) referred again to parasites found in

funeral settings left by civilizations along the Nile River, from Ancient Egypt to Nubia. The parasites eggs found were: *Schistosoma mansoni*, *Schistosoma haematobium*, *Taenia* sp., *Enterobius vermicularis*, *Ascaris lumbricoides*, and *Trichuris trichiura*. Dates varied from 3500 BP to 1500 AD.

Dittmar & Steyn (2004) described findings from paleoparasitological assays in seven coprolites of human origin, yielding eggs from *Trichuris* sp. and *Dicrocoelium* sp. They discussed the significance of these finds in relation to environmental conditions and interaction between humans and animals in the region. The morphometry of the trichurid egg defines the species as *Trichuris trichiura*, while the *Dicrocoelium* species could not be determined. However, its presence in human coprolites from 1900 BP shows the infection's antiquity in the region, probably maintained in a wild cycle and occasionally infecting humans.

Brier (2004) discussed the parasitic infections in Ancient Egypt, reinforcing the motto of the Paleopathology Association: "Mortui Viventes Docent", or "The Dead Teach the Living".

Zink et al. (2004) used molecular biology to distinguish between different *Mycobacterium* species in mummified soft tissues and bones from Ancient Egypt, dating as far as back 4000 BP. They found *Mycobacterium africanum*, leading them to challenge the origin of *M. tuberculosis* in the domestication of cattle (according to which the human tuberculosis bacillus had originated from the bovine bacillus, *M. bovis*).

Lowenstein (2004) provided the following definition: "Mummies, the preserved remains of living beings from former times, bear witness across millennia to the maladies plaguing humankind." His own research focuses on skin diseases detected in mummified bodies from different cultures, involving both the Old and New Worlds, but reviews the entire range of studies focusing on mummified bodies from all over the world, along with an extensive bibliography.

Harter-Lailheugue & Bouchet (2006) called attention to parasite findings in what they referred to as "atypical elements" from the Lower and Upper Nile, corresponding to Ancient Egypt and Nubia (now Sudan), respectively. The elements were an embalming rejects jars, a shroud, and a canopic package. They found numerous eggs of *Schistosoma mansoni*, *Schistosoma haematobium*, *Taenia* sp., *Enterobius vermicularis*, *Ascaris lumbricoides*, and *Trichuris trichiura*. Dates varied from 2700 BP in Nubia and from 3700 BP to 1500 AD in Egypt.

Zink et al. (2006) described the first case of leishmaniasis found in mummies in Egypt and Nubia. They used molecular biology techniques for amplification of genetic material and successfully identified *Leishmania donovani* in Ancient Egypt and Christian Nubia. The infection was prevalent in Ancient Egypt, dating as far back as 4000 BP, and was presumably transmitted by trade contact with the Nubians, due to the absence of vectors for the disease in Egypt.

Bruschi et al. (2006) described a case of cysticercosis in an Egyptian mummy, a young woman who died around age 20 during the Ptolemaic Period, between the first and second centuries AD. The lesion was identified by autopsy, confirmed by histological sections. This diagnosis implies pork consumption in Egypt during the Hellenistic period, leading to transmission of *Taenia solium*, according to artistic representations of the time, which contradicts the hypothesis by Harter et al. (2003) concerning the interdiction on pork consumption among Egyptians during this period.

Tuon, Amato Neto & Amato (2008) discussed the origin and evolution of leishmaniasis, concluding that they were associated with the origins of the human species itself in Africa and emphasizing the importance of paleoparasitology studies to better elucidate the evolution of *Leishmania* species in the human host.

Finally, and of course without pretending to exhaust the topic, we should mention the non-invasive techniques for analyzing archaeological remains, especially recommended for mummified bodies. Examples include the 3D images used to study the collection of Egyptian mummies at the Brazilian National Museum of the Federal University of Rio de Janeiro (Mendonça de Souza, 2008), enabling various precise diagnoses without destroying the material.

Most of the articles on paleoparasitology in Africa describe parasites in archaeological remains from Egypt, with detailed descriptions of eggs and even larvae and adults in histological sections. Many studies associate descriptions of symptoms in papyri with suggestive lesions identified during autopsy and parasite finds. Many articles are based on research performed in mummified bodies belonging to museums outside of Egypt. There is an on-going effort to encourage multidisciplinary studies, and the authors have presented the findings in various scientific journals. The effort at multidisciplinary studies is interesting, since it provides different contributions on parasitic infections, viewed from diverse angles, according to the respective researchers' expertise.

The African countries lack teams dedicated to systematic studies of parasites in archaeological remains, especially those harboring remains of ancestral humans and the first species of genus *Homo*. As listed in this chapter, the findings are concentrated in the Nile River Valley and are repeated in various publications, either by the same authors or others. The list of intestinal parasites, although extensive, may not represent all of the infections that affected ancient African populations, especially if one considers the contacts between peoples of distinct cultures occupying nearby territories but with different potential for infection. An example is the situation studied by Zink et al. (2006) in relation to leishmaniasis, showing contacts between diverse cultures in which the infection circulated. The research possibilities are immense, but thus far no African groups have been formed with a focus on paleoparasitology (which however is expected to happen soon). One of the most important potential topics for exploration is that the majority of the helminth species now found all over the world originated in ancestral humans in Africa (e.g., *Trichuris trichiura* as well as *Ancylostoma duodenale* and *Necator americanus*, possibly the two most common hookworm species in humans). Some, like *Enterobius vermicularis* (Horne, 2002), have already been recorded in African material, but much further research is needed. Phylogenetic studies based on the recovery of ancient DNA (Dittmar, 2009) will unveil interesting approaches for understanding parasite-host evolutionary relations since the dawn of humankind.

According to Buzon (2006), studies that aimed to reconstruct life in the ancient Nile Valley failed to take the organic remains into account, focusing (with few exceptions) on historical texts and the artifacts left by the ancient inhabitants. The author showed the importance of studying paleopathological evidence on the lives of ancient peoples. He concentrated particularly on the epidemiological transition during the Egyptians' colonization of the Upper Nile (Nubia), by studying skeletons and single bones from common people.

He commented briefly on infectious diseases, but they were not the main focus of his study. However, not only the marks of bone lesions caused by injuries or even chronic diseases, but also those from parasitic infections (whether detected by parasite finds or the recovery of their genetic material in archaeological remains) are extremely helpful for recovering data to reconstruct the past.

Many of the most common human helminth infections were already present in peoples of the ancient Nile Valley at least 6,000 years ago (Harter, 2003). These include *Ascaris* sp., *Trichuris* sp., *Enterobius vermicularis*, hookworms, *Taenia* sp., *Diphyllobothrium* sp., *Hymenolepis* sp., *Schistosoma haematobium*, and *Schistosoma mansoni*, besides others that are now rarer, such as *Fasciola hepatica*, *Fasciola gigantica*, and *Dicrocoelium* sp. However, it is not possible to suggest changes in the profile of these parasitic infections with the limited data currently available. It is possible to raise questions concerning eating habits that may have facilitated the transmission of infection by the ingestion of specific foods or certain ways of preparing them.

Paleoparasitology thus makes important contributions to these studies, especially considering the life cycles of parasites together each species' environmental needs (Lafferty et al., 2008; Byers, 2009).

REFERENCES

- ARAÚJO, A. et al. Parasitism, the diversity of life, and paleoparasitology. *Memórias do Instituto Oswaldo Cruz*, 98, supl. 1: 5-11, 2003.
- ARMITAGE, P. L. & CLUTTON-BROCK, J. A radiological and histological investigation into the mummification of cats from ancient Egypt. *Journal of Archaeological Science*, 8: 185-196, 1981.
- BARON, H.; HUMMEL, S. & HERRMANN, B. *Mycobacterium tuberculosis* complex DNA in ancient bones. *Journal of Archaeological Science*, 23: 667-671, 1996.
- BIANUCCI, R. et al. Immunological evidence of *Plasmodium falciparum* infection in an Egyptian child mummy from the Early Dynastic period. *Journal of Archaeological Science*, 35: 1.880-1.885, 2008.
- BRIER, B. Infectious diseases in ancient Egypt. *Infectious Disease Clinics of North America*, 18: 17-27, 2004.
- BRUSCHI, F. et al. Short report: cysticercosis in an Egyptian mummy of the late Ptolemaic period. *American Journal of Tropical Medicine and Hygiene*, 74: 598-599, 2006.
- BUIKSTRA, J. E.; BAKER, B. J. & COOK, D. C. What diseases plagued the ancient Egyptians? A century of controversy considered. In: WALBER, R. (Ed.). *Biological Anthropology and the Study of Ancient Egypt*. London: British Museum Press, 1993.
- BUZON, M. R. Health of the non-elites at Tombos: nutritional and disease stress in New Kingdom Nubia. *American Journal of Physical Anthropology*, 130: 26-37, 2006.
- BYERS, J.E. Including parasites in food webs. *Trends in Parasitology*, 25: 55-57, 2009.
- CERUTTI, N. et al. Immunological investigation of malaria and new perspectives in paleopathological studies. *Journal of Biological Research*, 75: 17-20, 1999.
- COCKBURN, A. *The Evolution and Eradication of Infectious Diseases*. Baltimore: The Johns Hopkins Press, 1963.
- COCKBURN, A. (Ed.). *Infectious Diseases: their evolution and eradication*. Springfield: Charles C. Thomas, 1967.
- COCKBURN, A. Ancient parasites on the west bank of the Nile. *The Lancet*, 2: 938, 1981.
- COCKBURN, A.; COCKBURN, E. & REYMAN, T. *Mummies, Disease, and Ancient Cultures*. 2nd Ed. Cambridge: Cambridge University Press, 1998.
- COCKBURN, A. et al. Autopsy of an Egyptian mummy. *Science*, 187: 1.155-1.160, 1975.
- COCKBURN, A. et al. A classic mummy: PUM II. In: COCKBURN, A. & COCKBURN, E. (Ed.). *Mummies, Disease and Ancient Cultures*. Cambridge: Cambridge University Press, 1980.
- CONTIS, G. & DAVID, A. R. The epidemiology of bilharzia in Ancient Egypt: 5,000 years of schistosomiasis. *Parasitology Today*, 12:253-255, 1996.
- DAVID, A. R. Disease in Egyptian mummies: the contribution of new technologies. *The Lancet*, 349: 1.760-1.763, 1997.
- DE BONI, U.; LENCZNER, M. M. & SCOTT, J. W. Autopsy of an Egyptian mummy (Nakhat – ROM I). 6. *Trichinella spiralis* cysts. *Canadian Medical Association Journal*, 117: 461-476, 1977.
- DEELDER, A. M. et al. Detection of schistosome antigen in mummies. *The Lancet*, 335: 724-725, 1990.
- DITTMAR, K. Old parasites for a new world: the future of palaeoparasitological research. *The Journal of Parasitology*, 95(2): 365-371, 2009.
- DITTMAR, K. & STEYN, M. Paleoparasitological analysis of coprolites from K2, an Iron Age archaeological site in South Africa: the first finding of *Dicrocoelium* sp. eggs. *The Journal of Parasitology*, 90: 171-173, 2004.
- DZIERZYKRAY-ROGALSKI, T. Un cas de la lèpre à un stade avancé découvert dans le nécropole musulmane de Kôn El-Dikka, à Alexandrie. *Africana Bulletin*, 28: 140-146, 1978.

- DZIERZYKRAY-ROGALSKI, T. Paleopathology of the Ptolomaic inhabitants of Dakhlah Oasis (Egypt). *Journal of Human Evolution*, 9: 71-74, 1980.
- EVANS, A. C. et al. Late stone-age coprolite reveals evidence of prehistoric parasitism. *South African Medical Journal*, 86: 274-275, 1996.
- FERREIRA, L. F.; ARAÚJO, A. & CONFALONIERI, U. Subsídios para a paleoparasitologia do Brasil I. Parasitos encontrados em coprólitos no município de Unaí, MG. *In: CONGRESSOS BRASILEIROS DE PARASITOLOGIA, IV*, Campinas, 1979. Resumos... Campinas, 1979.
- FORATTINI, O. P. Os cimicídeos e sua importância em saúde pública (Hemiptera-Heteroptera; Cimicidae). *Revista de Saúde Pública*, supl.: 1-37, 1990.
- FULCHERI, E. et al. De mummie dell'antico Egitto custodite nei musei italiani. *Museological Science*, 11(1-2): 1-11, 1994.
- GIACOMETTI, L. & CHIARELLI, B. The skin of Egyptian mummies. *Archives of Dermatology*, 97: 712-716, 1968.
- GRAY, J. E. Tutankhamun postmortem. *The Lancet*, 1: 259, 1973.
- GUY, M. W.; KROTOSKY, W. A. & COCKBURN, A. Malaria and an Egyptian mummy. *London School of Hygiene and Tropical Medicine*, 75: 601, 1981.
- HARRISON, R.G. Tutankhamun postmortem. *The Lancet*, 1: 259, 1973.
- HART, G. D. et al. Autopsy of an Egyptian mummy (Nakht - ROM I). *Canadian Medical Association Journal*, 117: 461, 1977.
- HARTER, S. *Implication de la Paléoparasitologie dans l'Étude des Populations Anciennes de la Vallée du Nil et du Proche-Orient: études de cas*, 2003. Thèse, Reims: UFR de Pharmacie, Université de Reims Champagne-Ardenne.
- HARTER, S. et al. First paleoparasitological study of an embalming rejects jar found in Saggara, Egypt. *Memórias do Instituto Oswaldo Cruz*, 98, supl. 1: 119-121, 2003.
- HARTER-LAILHEUGE, S. & BOUCHET, F. Paleoparasitological investigation in funerary contexts along the Nile. *Paleopathology Newsletter*, 128: 5-9, 2004.
- HARTER-LAILHEUGE, S. & BOUCHET, F. Paleoparasitological study of atypical elements of the low and high Nile Valley. *Bulletin de la Société de Pathologie Exotique*, 99: 53-57, 2006.
- HOEPPLI, R. Parasitic Diseases in Africa and the Western Hemisphere: early documentation and translation by the slave trade. Basel: für Recht und Wissenschaft, 1969.
- HOEPPLI, R. Haematuria parasitaria and urinary calculi: early indications from Africa. *Acta Tropica*, 29: 205-217, 1972.
- HOPE, F. W. Several species of insects found in the heads of Egyptian mummies. *Journal of the Proceedings of the Royal Entomological Society of London*, 1: 11-13, 1834.
- HORNE, P. D. First evidence of enterobiasis in ancient Egypt. *The Journal of Parasitology*, 88: 1019-1021, 2002.
- HORNE, P. D. & LEWIN, P. K. Electron microscopy of mummified tissue: autopsy of an Egyptian mummy. *Canadian Medical Association Journal*, 117: 472-473, 1977.
- HORNE, P. D. & REDFORD, S. Aspergillosis and dracunculiasis from the tomb of Parennefer. *Paleopathology Newsletter*, 92: 10-12, 1995.
- IKRAM, S. & DODSON, A. *The Mummy in Ancient Egypt: equipping the dead for eternity*. London: Thames and Hudson, 1998.
- LAFFERTY, K. D. et al. Parasites in food webs: the ultimate missing links. *Ecology Letters*, 11: 533-546, 2008.
- LEWIN, P. K. Mummies that I have known. *American Journal of Diseases of Children*, 131: 349-350, 1977.
- LEWIN, P. K. Ramses V: smallpox victim? Paper presented at the 9th annual meeting of the Paleopathology Association, Toledo, OH, USA. *Abstracts in Paleopathology Newsletter*, 36: 10, 1982.

- LEWIN, P. K. et al. Nakht, a weaver of Thebes. *Rotunda (The Journal of the Royal Ontario Museum)*, 7: 15-19, 1974.
- LOWENSTEIN, E. Paleodermatoses: lessons learned from mummies. *Journal of the American Academy of Dermatology*, 50: 919-936, 2004.
- LYNN, G. E. & BENITEZ, J. T. Examination of ears. *Canadian Medical Association Journal*, 117: 469, 1977.
- MENDONÇA DE SOUZA, S. M. Diagnóstico não invasivo em múmias milenares. In: WERNNER JR., H. & LOPES, J. (Eds.). *Paleontologia, Arqueologia, Fetologia, Tecnologias 3D*. Rio de Janeiro: Revinter, 2008.
- MILLER, R. L. et al. Paleoepidemiology of schistosome infection in mummies. *British Medical Journal*, 304: 555-556, 1992.
- MILLER, R. I. et al. Predynastic schistosomiasis. In: DAVIS, W. V. & WALKER, R. (Eds.). *Biological Anthropology and the Study of Ancient Egypt*. London: British Museum Press, 1993.
- MILLER, R. L. et al. Diagnosis of *Plasmodium falciparum* infections in mummies using the rapid manual ParaSight TM-F test. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 88: 31-32, 1994.
- MILLET, N. B. Archaeologic background. *Canadian Medical Association Journal*, 117: 462, 1977.
- MILLET, N. B. et al. ROM I: mummification for the common people. In: COCKBURN, A. & COCKBURN, E. (Eds.). *Mummies, Disease and Ancient Cultures*. Cambridge: Cambridge University Press, 1980.
- MITCHELL, J.K. Study of a mummy affected with anterior poliomyelitis. *Transactions of the Association of American Physicians*, 15: 134-136, 1900.
- MØLLER-CHRISTENSEN, V. Evidence of leprosy in earlier peoples. In: BROTHWELL, D. & SANDISON, T. A. (Eds.). *Diseases in Antiquity*. Springfield: Charles C Thomas, 1967.
- MØLLER-CHRISTENSEN, V. & HUGHES, D. R. An early case of leprosy from Nubia. *Man (London)*, 1: 242-243, 1966.
- MOODIE, R. L. *Paleopathology: an introduction of the study of ancient evidence of disease*. Urbana: University of Illinois Press, 1923.
- MORSE, D.; BROTHWELL, D. & UCKO, P. J. Tuberculosis in ancient Egypt. *American Review of Respiratory Diseases*, 90: 524-530,
- NUMM, J. F. & TAPP, E. Tropical diseases in ancient Egypt. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 94: 147-153, 2000.
- PALMA, R. L. Old comb reveals nits on the Nile: mummified head lice found on ancient Egyptian comb. *The Journal of Egyptian Archaeology*, 77: 194, 1991.
- PANAGIOTAKOPULU, E. & BUCKLAND, P. C. *Cimex lectularius* the common bedbug from Pharaonic Egypt. *Antiquity*, 73: 908-911,
- RABINO-MASSA, E. et al. Malaria in Ancient Egypt. Paleoenvironmental investigation on predynastic mummified remains. *Chungará*, 32: 7-9, 2000.
- RAFI, A. et al. DNA of *Mycobacterium leprae* by PCR in ancient bone. *International Journal of Osteoarchaeology*, 4: 287-290, 1994.
- REYMAN, T. A. Schistosomal cirrhosis in an Egyptian mummy. *Yearbook of Physical Anthropology*, 20: 356-358, 1976.
- REYMAN, T. A.; BARRACO, R. A. & COCKBURN, A. Histopathological examination of an Egyptian mummy. *Bulletin of the New York Academy of Medicine*, 52: 506-516, 1976.
- REYMAN, T. A.; ZIMMERMAN, M. R. & LEWIN, P. K. Histopathologic investigation. *Canadian Medical Association Journal*, 117: 470-471, 1977.
- RIDEOUT, D. F. Radiologic examination. *Canadian Medical Association Journal*, 117: 463, 1977.
- RUFFER, M. A. Note on the presence of '*Bilharzia haematobia*' in Egyptian mummies of the twentieth dynasty (1250-1000 B.C.). *British Medical Journal*, 1: 16, 1910a.
- RUFFER, M. A. Remarks on the histology and pathological anatomy of Egyptian mummies. *The Cairo Scientific Journal*, 10: 3-7,

- RUFFER, M. A. Studies on paleopathology of Egypt. In: MOODIE, R. (Ed.). *Studies on Paleopathology of Egypt*. Chicago: University of Chicago Press, 1921.
- RUFFER, M. A. & FERGUSON, A. R. Note on eruption resembling that of variola in the skin of a mummy of the Twentieth Dynasty (1200–1100 B.C.). *The Journal of Pathology and Bacteriology*, 15: 1, 1911.
- RUTHERFORD, P. Immunochemistry and the diagnosis of schistosomiasis. Ancient and modern. *Parasitology Today*, 15: 390-391,
- SÁNCHEZ-MARTÍN, F. M. et al. Sangre, hemorragia, hematuria, urología. *Actas Urológicas Españolas*, 29: 815-825, 2005.
- SANDISON, T. A. Diseases in ancient Egypt. *Rivista di Antropologia*, 56: 225-227, 1959.
- SANDISON, A. T. Diseases in ancient Egypt. In: COCKBURN, C. & COCKBURN, E. *Mummies, Disease, and Ancient Cultures*. Cambridge: Cambridge University Press, 1980.
- SCOTT, J. W.; HORNE, P. D. & HART, G. Gross anatomic and miscellaneous studies. *Canadian Medical Association Journal*, 117: 464-465, 1977.
- SPIGELMAN, M. & LEMMA, E. The use of the polymerase chain reaction to detect *Mycobacterium tuberculosis* DNA in ancient skeletons. *International Journal of Osteoarchaeology*, 3: 137-143, 1993.
- STROUHAL, E. & HORÁČKOVÁ, L. Report from Egypt: anthropology and paleopathology. *Paleopathology Newsletter*, 106: 13-15, 1999.
- STROUHAL, F. Vertebral tuberculosis in Egypt and Nubia. In: ORTNER, D. J. & AUFDERHEIDE, A. C. (Eds.). *Human Paleopathology: current synthesis and future options*. Washington, London: Smithsonian Institution Press, 1991.
- TAPP, E. Disease in the Manchester mummies. In: DAVID, A. R. *The Manchester Museum Mummy Project*. Manchester: Manchester Museum Press, 1979.
- TAPP, E. Disease and the Manchester mummies: the pathologist's role. In: DAVID, A. R. (Ed.). *Evidence Embalmed*. Manchester: Manchester University Press, 1984.
- TUON, F. F.; AMATO NETO, V. & AMATO, V. S. *Leishmania*: origin, evolution and future since the Precambrian. *FEMS Immunology and Medical Microbiology*, 54: 158-166, 2008.
- ZIEGLER, C. et al. La mission archéologique du musée du Louvre à Saqqara. Résultats de quatre campagnes de fouilles de 1993 à 1996. *Bulletin de l'Institut Français d'Archéologie Orientale*, 97: 269-292, 1997.
- ZIMMERMAN, M. R. Pulmonary and osseous tuberculosis in an Egyptian mummy. *Bulletin of the New York Academy of Medicine*, 55: 604-608, 1979.
- ZINK, A. R.; GRABNER, W. & NERLICH, A. G. Molecular study of human tuberculosis in contemporary tissue samples and time delineated populations from ancient Egypt. *Journal of Paleopathology*, 14: 59-68, 2002.
- ZINK, A. et al. Molecular evidence of bacteremia by gastrointestinal pathogenic bacteria in an infant mummy from Ancient Egypt. *Archives of Pathology and Laboratory Medicine*, 124: 1.614-1.618, 2000.
- ZINK, A. et al. *Corynebacterium* in Ancient Egypt. *Medical History*, 45: 267-272, 2001.
- ZINK, A. R. et al. Characterization of *Mycobacterium tuberculosis* complex DNAs, from Egyptian mummies by spoligotyping. *Journal of Clinical Microbiology*, 41: 359-367, 2003.
- ZINK, A. R. et al. Molecular characterization of *Mycobacterium tuberculosis* complex in Egyptian mummy. *International Journal of Osteoarchaeology*, 14: 404-413, 2004.
- ZINK, A. R. et al. Leishmaniasis in Ancient Egypt and upper Nubia. *Emerging Infectious Diseases*, 12: 1.616-1.617, 2006.