Part I - Parasites, Human Hosts, and the Environment

2. The Preservation of Organic Material over Time

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The Preservation of Organic Material over Time

Luiz Fernando Ferreira

This chapter is not intended to provide a complete review of the theme of mummification over time, or even of the processes that led to the preservation of organic remains in which parasites have been found. The objectives are to discuss how parasite findings can occur, alerting parasitologists to the possibilities of studying parasites and their remains, and to remind our archaeologist colleagues of the importance of preserving any materials they find. These include any discarded dust, adhesions, or concretions in the bones, especially those of the pelvis and adjoining areas, pottery and other utensils, and other materials that may contain parasite remains (Fugassa, 2006).

The pioneering mummy studies began with Grafton Elliot Smith (anatomy), Armand Ruffer (parasitology and histology), Alfred Lucas (chemistry), Thomas Pettigrew (history of mummy studies), and Warren Royal Dawson (surgery) in Egypt in the late 19th and early 20th centuries (Peck, 1998). Today, studies on mummies have been resumed successfully, led by Aidan Cockburn, who published two editions of his book *Mummies, Disease, and Ancient Cultures*, organized with his wife Eve Cockburn and their colleague Theodore A. Reyman (Cockburn & Cockburn, 1980; Cockburn, Cockburn & Reyman, 1998), and later by Arthur Aufderheide (Aufderheide & Rodrigues-Martín, 1998). Both books provide the essentials for studying mummies, their parasites, and their diseases, and are indispensable reading for whoever intends to begin research on the subject (Figures 1 and 2).

The theme sparked such great interest among scientists that the first international congress on mummy studies was organized, coordinated by Conrado Rodríguez-Martín in Tenerife, Canary Islands (Spain), in February 1992. The group has met regularly since then, with growing participation by researchers from a wide range of fields (Atoche Peña, Rodríguez-Martín & Ramírez Rodríguez, 2008).

Aidan Cockburn defines “mummy” as follows:

Today, the term mummy has been extended to cover all well-preserved dead bodies. The majority of these are found in dry places such as the sands of deserts or dry caves, where desiccation has taken place rapidly, doing naturally what Egyptians did by artifice. The basic procedure in either process is the same: water is extracted rapidly from the tissues (Cockburn, Cockburn & Reyman, 1998:1).

Intentional or natural preservation occurred in various parts of the world, where different cultures established themselves and developed. Notwithstanding the different mummification techniques, whether of the Chinchorro in South America (Arriaza, 1995), or in Africa (Egypt and Sudan) (Aufderheide, 2003), specific climatic conditions allowed finding organic remains (including completely preserved bodies) in diverse situations. For example, preservation can occur naturally due to the cold in the Andean *altiplanos* or in the Arctic. In the bogs of Northeast Europe, the pH and moisture (contrary to conditions in the desert) preserve human and animal bodies, or so-called “bog bodies”, without any elaborate artifice or technique (Brothwell & Sandison, 1967).

One can thus analyze both the processes resulting from techniques developed by cultural groups, mostly as a function of religious values, and natural mummification resulting from favorable climatic conditions. References to mummification processes are found in ancient documents, as in the Old Testament of the *Bible*, Genesis, Chapter 50:

2 And Joseph commanded his servants the physicians to embalm his father, so the physicians embalmed Israel. 3 forty days were required for it, for so many are required for embalming. (...) 26 So Joseph died, being a hundred and ten years old; and they embalmed him, and he was put in a coffin in Egypt.

Among the ancient classics, Herodotus and Diodorus Siculus refer to mummies. Herodotus was born in Halicarnassus in 480 BC, of Dorian ancestry and an illustrious family. His book describes embalming techniques, the organization of medical services, the importance of specialization, and various other considerations on health and disease. Diodorus Siculus was born in Agyrium, Sicily, and spent many years in Egypt. His book is a world history. Ferreira, Reinhard & Araújo (2008) quote the part that describes embalming techniques, showing the different types used in ancient Egypt, in keeping with each individual's financial status. They show how the techniques varied over time, using the trial-and-error method.

As described by Herodotus, embalming in its most refined form was expensive and had to be simplified to extend the practice beyond the nobility to the non-noble well-to-do: the well-known process of cutting costs to expand the market.

Figure 1 – Elaborately decorated coffin of Sha-Amun-em-su containing the mummy of the priestess/songstress from the temple of Amon in Thebes. This object has been studied with computerized tomography and other techniques

Collection of the National Museum in Rio de Janeiro. Photo by A. Brancaglion and S. M. Souza.

Figure 2 – 3D computerized tomography reconstruction of a child's head recovered from a tomb in Titicaca, Bolivia, probably of Aymara origin, showing a fatal fracture and intentional reshaping of the skull

Collection of the National Museum in Rio de Janeiro. Photo by S. M. Souza.

In the Americas, although less known, there are mummies that were preserved with special techniques. The oldest known examples are the Chinchorro mummies, from a culture in the Atacama Desert. The desert in which the Chinchorro lived, ranging from Northern Chile to Southern Peru, was and still is extremely dry.

There are hundreds of archaeological sites in the Andes, and it is common to find archaeological remains while walking across the desert sand (Figure 3). The ancient pre-ceramic inhabitants lived by fishing, hunting, and gathering, obtaining most of their food from the ocean. According to Bernardo Arriaza, an expert on this culture (Arriaza, 1995), the Chinchorro prepared the bodies in different ways, suggesting social differences between individuals, as in Egypt. Alongside natural mummifications one finds bodies in which the viscera and muscles were removed, replaced with straw and wooden artifacts, painted with various colors, and covered with clay masks.

Figure 3 – Atacama Desert, Northern Chile. Mummified remains preserved in the desert

Photograph from the Laboratory of Paleoparasitology (Ensp/Fiocruz).

Figure 4 – Chinchorro mummified body

Collection of the Archaeological Museum of San Miguel de Azapa, Arica, Chile. www.uta.cl/masma/, page organized by Bernardo Arriaza.

Europe has famous peat bogs, swampy areas where the low (acid) pH and anaerobic environment are spectacular for preserving organic remains. Many examples have been described in detail by Cockburn, Cockburn & Reyman (1998), Aufderheide & Rodrigues-Martín (1998), and Aufderheide (2003). Some of these bodies still have the individuals' look and facial expression, even though they were not preserved intentionally. On the contrary, many were sacrificed and the bodies were thrown into the bogs. In other regions of Europe, bodies have been found preserved by the intense cold, like the famous Ice Man Ötzi, who provided material for studies by various fields (Rollo et al., 2002).

In South America, on the other side of the Andes, no embalming was used for the dead. Funeral practices varied greatly, but they mainly aimed to release the spirit from the body. Various practices were used, such as cremation and secondary burials, in which the corpses were buried and the remains (mainly the bones) were later transferred either to urns or directly into the ground.

However, once again the climate, especially the aridness in certain areas, led to the rapid desiccation of bodies, thus preventing rotting by microorganisms. Ferreira, Reinhard & Araújo (2008) quote a passage from the book *Os Sertões (Rebellion in the Backlands)*, by Euclides da Cunha (1902), in which the author describes the finding of the mummified bodies of a soldier and his horse, killed during the War of Canudos in the late 19th century in the hinterlands of Bahia, Northeast Brazil.

The collection of the National Museum of the Federal University of Rio de Janeiro houses several examples of naturally mummified bodies. Some have been studied by experts (Beltrão & Lima, 1986) (Figure 5). Although they have some well-preserved parts, the abdominal cavity had been partially destroyed by bacterial putrefaction. However, morphologically identifiable mites were still found (Araújo et al., 1986).

Figure 5 – Necropsy of a mummified body at the National Museum, Federal University of Rio de Janeiro, organized by Maria Beltrão and Tânia Andrade Lima

Photograph from the Laboratory of Paleoparasitology (Ensp/Fiocruz).

Other bodies have been found in specific situations, like those in the church in the town of Itacambira, northern Minas Gerais State, Brazil, another region sufficiently dry to preserve organic matter in good conditions (Figure 6). The corpses were removed from the churchyard when the church was renovated some 300 years after it was built, in the 17th century. During renovation in the early 20th century, when the bodies were found, the priest decided to store them in the church basement, where they were destroyed by time. However, some were removed and preserved by local citizens or individuals from neighboring towns, which allowed studies involving paleopathology and paleoparasitology (Ferreira et al., 1984).

Figure 6 – Naturally mummified child's body. Itacambira, Minas Gerais, Brazilian colonial period

Photograph from the Laboratory of Paleoparasitology (Ensp/Fiocruz).

Organic matter can thus be preserved in diverse situations and by different means. Archaeological sites contain the material that has been studied most extensively for the presence of parasites, namely feces that have been preserved by desiccation or some other process of preservation, called coprolites.

The word “coprolite” comes from the Greek *κοπρος*, meaning feces, and *λιθος*, or rock. The word thus refers to hardened, stony feces. As a function of their time in the environment as well as edaphic and climatic conditions, coprolites may simply be dehydrated by the rapid loss of water, or mineralized, when the organic matter has been replaced and shaped by minerals.

When coprolites are removed directly from human or animal bodies, the researcher has already identified the host, thereby facilitating identification of the parasite (Figure 7). In most cases, however, the coprolite is found loose in the middle of the excavation. Such cases require a series of tests to reach a positive identification. Other times, coprolites are found accumulated in deposits, either naturally formed or constructed for specific purposes, like medieval latrines or those used by the Ancestral Pueblo in the United States. The coprolites may be dispersed or mixed with other

organic remains, and the farther they are from an association with a possible animal that produced them, the more difficult their zoological diagnosis.

Figure 7 – Egyptian cat mummy. National Museum, Federal University of Rio de Janeiro

Photo from the Laboratory of Paleoparasitology (Ensp/Fiocruz).

Coprolites can be found in latrines and other deposits, mixed in an amorphous mass consisting of various layers formed over time. In some cases it has been possible to study changes in the profile of parasitism at successive moments in the archaeological site's occupation (Reinhard, 1988; Le Bailly et al., 2007).

Ancient European latrines were studied by Reinhard et al (1986), who reported on the diversity of findings and quantitative studies of helminth eggs found in this type of deposit. Jones (1982) also discussed the preservation of coprolites and helminth eggs, studying material from archaeological sediments in York, England. Both the coprolites and eggs were found in mineralized concretions, requiring appropriate techniques such as the use of hydrochloric acid to separate the material.

Paleontologists have also found coprolites in much more ancient material. Coprolites from an extinct species of hyenas in Italy (Figure 8), dated to 1.5 million years BP, contained a nematode, but diagnosis to the species level was not possible: it was an extinct parasite in an extinct host (Ferreira, Araújo & Duarte, 1993). Current techniques allow approximations of the group of parasite infestations involved, and more precise phylogenetic studies may be possible in the near future.

The climatic conditions for preservation of coprolites (as with mummified bodies), vary according to the diverse effects of desiccation, cold, and acid or alkaline pH, so that parasites can potentially be retrieved in totally opposite situations of extreme cold or heat.

Figure 8 – Hyena coprolites, Italy, 1.5 million years BP

Photo from the Laboratory of Paleoparasitology (Ensp/Fiocruz).

Bouchet, Harter & Le Bailly (2003) reviewed these issues, discussing how organic remains can be recognizable for years, as long as adequate techniques are used, which now allow a wide range of studies. The processes involved in the preservation of coprolites are the same as with mummified bodies, differing according to climatic conditions and cultural situations (Ferreira, Reinhard & Araújo 2008).

Coprolites vary greatly: some remain morphologically recognizable, sunk in a moist environment or even immersed in water, as in peat bogs or anaerobic environments, while others are completely desiccated, as in the Atacama Desert, or exposed to the arid and stormy climate of southern Patagonia. Paleoparasitological tests are possible from one extreme to the other, as demonstrated by Bouchet, Harter & Le Bailly (2003) and Fugassa et al (2006).

Cultures that occupied different parts of the world obviously differed from each other. Many such cultures left their remains inadvertently. Others used devices that allowed the preservation of feces, e.g., latrines or specific waste deposits. Various artifacts, especially in Europe and Colonial America, can contain parasites or interesting remains. When archaeologists collect materials, it is extremely important not to clean them before testing for parasites or genetic material. Various pieces of pottery, including those used for personal hygiene, are important sources of material (Lima, 1996), as are bones, even when stored in museums for long periods of time, as shown by Fugassa et al (2007).

Important findings of parasite forms include fungal spores, bacteria, viral capsules, protozoan cysts, helminth eggs or larvae, and other forms from parasites' life cycles. Equally important are sequences of genetic material that can be recovered using molecular techniques. Deoxyribonucleic acid (DNA) is extremely special material, and studies have already proven that DNA is maintained better in field conditions (i.e., in the original sites) than in collections in museums or other institutions (Pruvost et al., 2007).

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