New World Paleoparasitology

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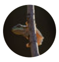

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Chapter 9

New World Paleoparasitology

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Introduction

The study of parasites found in archaeological material began with Sir Marc Ruffer in Egypt, when he described *Schistosoma haematobium* (bilharzia) eggs in mummies dated to 5,200 BP (before present).[1] Years later, in Europe, Lothar Szidat reported finding *Trichuris trichiura* (whipworm) and *Ascaris lumbricoides* (roundworm) eggs in the mummified bodies of a man and a girl found in a swamp in Prussia, dated to 600BC and 500AD.[2] However, it was up to researchers in the Americas to make important strides in the field of parasitic infections in archaeological remains. The initial work of Thomas Cameron and Eric Callen in coprolites from the Huaca Prieta archaeological site in Peru, introducing trisodium phosphate 0.5 per cent aqueous solution for rehydration of coprolites, based on the technique of van Cleave and Ross for recovering desiccated invertebrate specimens conserved in museums, allowed more advanced studies on parasites preserved in archaeological material.[3]

Initially, parasite findings in archaeological material reflected the sporadic collaboration between archaeologists and parasitologists, in which they described the parasites found and gave an interpretation of the findings. Pizzi and Schenone commented on finding *Trichuris trichiura* eggs and *Entamoeba coli* cysts in intestinal material from the mummified body of a child from the Inca period, preserved in ice in the Andes.[4] They raised the erroneous hypothesis that *Trichuris trichiura* infection had originated in the Americas. However, as highlighted by Szidat, trichuriasis

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[1] Ruffer, M.A., ‘Note on the presence of *Bilharzia haematobia* in Egyptian mummies of the twentieth dynasty’, *British Medical Journal* 1 (1910): 16.

[2] Szidat, L., ‘Uber die erhaltungsfahigkeit von helmintheneiern in vorand friihgeschichtlichen moorleichen’, *Zeitschrift für Parasitenkunde* 13 (1944): 265–74.

[3] Callen, E.O., Cameron, T.W.M., ‘The diet and parasites of pre-historic Huaca Prieta Indians as determined by dried coprolites’, *Proceedings of the Royal Society of Canada* 7 (1955): 51–2; Callen, E.O., Cameron, T.W.M., ‘A prehistoric diet revealed in coprolites’ *New Scientist* 8 (1960): 35–40; Van Cleave, H.J. Ross, J.A., ‘A method for reclaiming dried zoological specimens’, *Science* 105 (1947): 318.

[4] Pizzi, T., Schenone, H., ‘Hallazgo de huevos de *Trichuris trichiura* en contenido intestinal de un cuerpo arqueológico incaico’ *Boletin Chileno de Parasitologia* 9 (1954): 73–5.

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had already been recorded in the Old World at an earlier archaeological date than this mummy.[5]

The term paleoparasitology originated in Brazil with Luiz Fernando Ferreira, who was studying parasites in archaeological material at the Oswaldo Cruz Foundation.[6] This branch of parasitology and paleopathology, which also ended up as part of bioarchaeology, was created with the aim of establishing methods and techniques to study parasites found in archaeological material and paleontological material of both human and animal origin. The central objective is to study the origin and evolution of parasitic infections, with the definition of parasites including viruses, bacteria, protozoa, helminths, arthropods, fungi, and other forms of life that find their ecological niche in a given host.[7]

The study of infectious diseases has changed the previously accepted concepts on the origin of various organisms in the Americas. For example, it had been thought that tuberculosis was introduced by the arrival of the Europeans, and particularly in South America by the first Jesuit priests that came in the early colonial period in search of a healthy climate, not only to catechise, but to treat their own illness, whereby they ended up infecting the indigenous peoples. However, *Mycobacterium tuberculosis* infection, with its clinical manifestations, already existed in pre-Columbian America, as shown by findings in mummified bodies in Chile and Peru, as well as in other populations on the continent.[8]

Early 20th-century publications implicated the African slave trade in the introduction of a series of parasitic diseases, including intestinal parasites, but without any concrete evidence.[9] These concepts began to be challenged by methods from ethnographic and comparative parasitology, as reported by Olympio da Fonseca in studying fungal and hookworm infections and lice infestation among indigenous groups isolated from contact in South America, as previously shown by

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[5] Szidat 1944.

[6] Ferreira, L.F., Araújo, A., Confalonieri, U., 'Subsídios para a paleoparasitologia do Brasil 1. Parasitos encontrados em coprólitos no município de Unaí, Minas Gerais', Abstracts, IV Congresso Brasileiro de Parasitologia, Campinas, (São Paulo, 1979), p. 56; Ferreira, L.F., Araújo, A., Confalonieri, U., 'Finding of helminth eggs in human coprolites from Unai, Minas Gerais, Brazil', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 76 (1980): 798–800.

[7] Ferreira, L.F., 'O fenômeno parasitismo', *Revista da Sociedade Brasileira de Medicina Tropical* 4 (1973): 261–77; Araújo, A., Jansen, A.M., Bouchet, F., Reinhard, K., Ferreira, L.F., 'Parasitism, the diversity of life, and paleoparasitology', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 5–11.

[8] Prati, J.G., Souza, S.M.M., 'Prehistoric tuberculosis in America: adding comments in a literature review', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 151–9; Wilbur, A.K., Buikstra, J.E., 'Patterns of tuberculosis in the Americas: how can modern biomedicine inform the ancient past?', *Memórias do Instituto Oswaldo Cruz* 101 (Suppl. 2) (2006): 59–66.

[9] Freitas, O., '*Doenças Africanas no Brasil*', Bibliotheca Pedagogica Brasileira, Brasiliana volume 51, série V, (São Paulo: Cia Editora Nacional, 1935), p. 21–30.

Samuel Darling and Fred Soper.[10] They were searching for data to use the presence of parasites in isolated groups as an indication of prehistoric migrations. Harold Manter reviewed the studies on hookworm infection, concluding that it would be very difficult to reach a definitive conclusion on pre-Columbian migrations, due to the lack of fossil parasites.[11] The only other research possibilities available at that time were based upon the written evidence of chroniclers from the colonial period, and artistic representations left by pre-Columbian peoples.[12]

However, the parasites found in present-day isolated human groups, the artistic representations, and other archaeological vestiges may not accurately reflect situations from the remote past. Contacts would have been possible between groups with different origins, and traces of such contacts could have survived until the present. For example, one should consider the territorial disputes between indigenous groups on the Brazilian coast at the time of the discovery and the retreat of the defeated groups into the interior, with the possible dispersal of parasites.[13]

Parasites preserved in archaeological material help answer questions as to the existence (or absence) of given parasitic infections in pre-Columbian populations.[14] However, other questions emerge, like those raised by Leles et al. on the under-diagnosis of *Ascaris lumbricoides* eggs in coprolites from South American archaeological sites.[15] As shown by paleoparasitological data (Tables 9.1 and 9.2, at the end of this chapter), most helminth infections were already widespread among pre-Columbian groups in both South America and North America.[16]

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[10] Fonseca Filho, O., 'Parasitological and clinical relationship between Asiatic and Oceanian tokelau and Brazilian chimbere of some Mato Grosso Indians' *Boletim do Museu Nacional* 6 (1930): 201–21; Fonseca Filho, O., *Parasitismo e Migrações Pré-Históricas* (Rio de Janeiro: Mauro Familiar Editora, 1972); Darling, S.T., 'Observations on the geographical and ethnological distribution of hookworms', *Parasitology* 12 (1921): 217–233; Soper, F., 'The report of a nearly pure *Ancylostoma duodenale* infestation in native South American Indians and a discussion of its ethnological significance', *American Journal of Hygiene* 7 (1927): 174–84.

[11] Manter, H.W., 'Some aspects of the geographical distribution of parasites', *Journal of Parasitology* 53 (1967): 2–9.

[12] Jarcho, S., 'Some observations on diseases in prehistoric North America', *Bulletin of the History of Medicine* 38 (1964): 1–19.

[13] Medeiros, R.P., 'Povos indígenas do sertão nordestino no período colonial: descobrimento, alianças, resistência e encobrimento', *FUMDHAmentos* 2 (2002): 7–52.

[14] Araújo, A., Ferreira, L.F., Confalonieri, U., 'A contribution to the study of helminth findings in archaeological material in Brazil', *Revista Brasileira de Biologia* 41 (1981): 873–81.

[15] Leles, D., Araújo, A., Ferreira, L.F., Vicente, A.C.P., Iñiguez, A.M., 'Molecular paleoparasitological diagnosis of *Ascaris* sp. from coprolites: new scenery of ascariasis in pre-Colombian South America times', *Memórias do Instituto Oswaldo Cruz* 103 (2008): 106–8.

[16] Ferreira et al. 1980; Ferreira, L.F., Araújo, A., Confalonieri, U., 'The finding of helminth eggs in a Brazilian mummy', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 77 (1983): 65–7; Gonçalves, M.L.C., Araújo, A., Ferreira,

When the human species emerged in Africa and migrated outside the continent to colonise other parts of the world, it included individuals infected by parasite species inherited from their ancestors. However, new species of parasites were acquired over the course of their evolution, when human groups established themselves in new territories other than those from which they originated. Plants and animals were domesticated, and further parasite species started to infect humans when new habitats were settled and contacts with parasites from animal hosts were established. Parasite transfers occurred, and new species adapted to their human hosts as they occupied each new environment and territory.[17] *Homo sapiens* is indisputably one of the most successful species on Earth, having explored and dominated nearly everywhere on the planet. The history of the human species' long journey out of Africa to conquer new territories is extraordinary, but the history of the parasites that were transferred with us, and of others acquired over the course of our highly peculiar species' biological and social history, still remains to be studied in detail.

The parasite discoveries in archaeological material given here is intended to provide information on the conquest of the Americas in prehistoric times and on the way of life of the different human groups that lived there. Parasites can be used as tracers, or probes, of human migrations in the past and can indicate health and disease conditions in human groups during the human evolutionary process.[18] New approaches such as molecular biology techniques applied to diagnosis in paleoparasitology and imaging diagnosis in paleopathology, combined with traditional microscopic diagnostic techniques, have demonstrated parasite findings as biological markers of prehistoric migrations and health conditions in ancient

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L.F., 'Human intestinal parasites in the past: new findings and a review', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 103–18; Fry, G.F., Moore, J.G., '*Enterobius vermicularis*: 10,000-year-old human infection', *Science* 166 (1969): 1620; Horne, P.D., 'A review of the evidence of human endoparasitism in the pre-Columbian New World through the study of coprolites', *Journal of Archaeological Science* 12 (1985): 299–10; Reinhard, K., 'Parasitology as an interpretative tool in archaeology', *American Antiquity* 57 (1992): 231–45; Reinhard, K.J., Anderson, G.A.A., Hevly, R.H., 'Helminth remains from prehistoric coprolites on the Colorado Plateau', *Journal of Parasitology* 73 (1987): 630–39.

[17] Kliks, M.M., 'Paleoparasitology: on the origins and impact of human-helminth relationships', in N.A. Croll and J.H. Cross (eds), *Human Ecology and Infectious Disease* (New York: Academic Press, 1983), pp. 291–313; Araújo, A., Reinhard, K., Ferreira, L.F., Gardner, S., 'Parasites as probes for prehistoric human migrations?', *Trends in Parasitology* 24 (2008a): 112–15; Araújo, A., Reinhard, K., Ferreira, L.F., 'Parasite findings in archaeological remains: diagnosis and interpretation', *Quaternary International* 180 (2008b): 1–4.

[18] Araújo et al. 1981; Araújo et al. 1988; Araújo et al. 2008a; Reinhard, K., Araújo, A., Ferreira, L.F., Coimbra, C.E., 'American hookworm antiquity', *Medical Anthropology* 20 (2001): 96–101.

populations.[19] They provide quite solid information and contribute to more precise knowledge of the past.

This article only considers infections and diseases caused by helminths and protozoa in the human host or with the potential to infect it, emphasising intestinal parasites that infected pre-Columbian populations and those introduced after the arrival of Europeans and Africans. Araújo et al. and Horne have previously reviewed intestinal helminthiases in pre-Columbian America, while Reinhard, Gonçalves et al., and Fugassa have also written subsequent evaluations.[20] However, new data continue to emerge, and in consequence our knowledge and understanding of the field is improving all the time.

Prehistoric Populations in the Americas, Paleoparasitology, and Paleoepidemiology

The New World is known as such because it was one of the last territories on Earth to be discovered and colonised by Europeans. However, America had been discovered long before the Europeans arrived. Peoples from Asia and possibly other parts of the world reached the continent many thousands of years ago.[21]

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[19] Iñiguez, A.M., Reinhard, K.J., Araújo, A., Ferreira, L.F., Vicente, A.C.P., '*Enterobius vermicularis*: ancient DNA from North and South American human coprolites', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 67–9; de Souza, S.M.M., 'Millenary Egyptian mummies – non invasive excursions', in H. Werner Jr. and J. Lopes (eds), *3D Technologies – Palaeontology, Archaeology, Fetology* (Rio de Janeiro: Livraria & Editora Revinter LTDA, 2009), pp. 77–104; Reinhard et al. 1987; Araújo, A., Reinhard, K., Bastos, O.M., Costa, L.C., Pirmez, C., Iñiguez, A.M., Vicente, A.C., Morel, C.M., Ferreira, L.F., 'Paleoparasitology: perspectives with new techniques', *Revista do Instituto de Medicina Tropical de São Paulo* 40 (1998): 371–76; Bouchet, F., Harter, S., Le Bailly, M., 'The state of the art of paleoparasitological research in the Old World', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 95–101.

[20] Araújo et al. 1981; Horne 2005; Reinhard, K.J., 'Archaeoparasitology in North America', *American Journal of Physical Anthropology* 82 (1990): 145–63; Gonçalves et al. 2003; Fugassa, M.H., *Enteroparasitosis en Poblaciones Cazadoras-Recolectoras de Patagonia Austral* (PhDThesis, Universidad Nacional de Mar del Plata, Argentina, 2006).

[21] Meltzer, D.J., 'Peopling of North America', *Development in Quaternary Science* 1 (2003): 539–63; Neves, W.A., Hubbe, M., Pilo, L.B., 'Early Holocene human skeletal remains from Sumidouro Cave, Lagoa Santa, Brazil: history of discoveries, geological and chronological context, and comparative cranial morphology', *Journal of Human Evolution* 52 (2007): 16–30; Guidon, N., Pessis, A.M., 'Serra da Capivara National Park, Brazil: cultural heritage and society', *World Archaeology* 39 (2007): 406–16; Hubbe, M., Neves, W.A., Amaral, H.L., Guidon, N., '"Zuzu" strikes again: morphological affinities of the early Holocene human skeleton from Toca dos Coqueiros, Piaui, Brazil', *American Journal of Physical Anthropology* 134 (2007): 285–91; Pucciarelli, H.M., González-José, R., Neves, W.A., Sardi, M.L., Rozzi, F.R., 'East-West cranial differentiation in pre-Columbian populations from Central and North America', *Journal of Human Evolution* 54

The human groups that lived in South America before the European discovery were quite diversified, considering those living on the Pacific coast, like the Chichorro, and those on the Atlantic, builders of shell mounds (*sambaquis*). Between the two coasts there was a wide variety of cultures, as exemplified especially by various prehistoric populations in the Andean altiplanos with their constructions and social organisations, in contrast with the groups of hunter-gatherers and Neolithic agriculturalists living on the lowlands on the other side of the Andean cordillera, on the plains, in the scrub forest (*caatinga*), in the Chaco region on the coast, and in the cold southernmost regions or the hot rainforest.[22]

It is difficult to obtain consistent data for epidemiological studies of infectious diseases in ancient populations. It is more difficult, and in most cases impossible, to assess the impact of parasitic infections in hunter-gatherer populations, since representative samples of these populations in archaeological remains are extremely rare due to the absence of specific locations such as funeral sites, and latrines were not built in the region at that early date. In consequence, samples that are representative of prehistoric infectious disease events are rare. More common are series of human remains such as skeletons or scattered bones of different individuals, in which one can attempt to study diseases from pathological lesions on the skeletal remains.[23]

In order to advance this field, new approaches have been developed in paleoepidemiology, through the study of diseases in the past using a population focus.[24] Even so, paleoepidemiology provides a paleoreconstruction of what may have occurred in extinct populations. However, paleoparasitological methods have begun to contribute concrete evidence retrieved from archaeological or paleontological remains, adding data on the presence of parasitic infections in ancient populations to the biological knowledge of each parasite found. For example, recent contributions from the use of molecular biology techniques for

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(2008): 296–30; Gaspar, M.D., Deblasis, P., Fish, S.K., Fish, P.R., ‘Sambaqui (shell mound) societies of coastal Brazil’, in H. Silverman and W.H. Isbell (eds), *Handbook of South American Archaeology* (New York: Springer, 2008), pp. 319–35; Dillehay, T., ‘Probing deeper into first American studies’, *Proceedings of the National Academy of Science of the United States of America* 106 (2009): 971–78.

[22] Silverman, H., Isbell, W.H. (eds), *Handbook of South American Archaeology* (New York: Springer, 2008).

[23] De Souza, S.M., de Carvalho, D.M., Lessa, A., ‘Paleoepidemiology: is there a case to answer?’, *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 21–7.

[24] El-Najjar, M.Y., Lozof, B., Ryan, D.J. ‘The paleoepidemiology of porotic hyperostosis in the American Southwest: radiographical and ecological considerations’, *American Journal of Roentgenology Radium Therapy Nuclear Medicine* 125 (1975): 918–25; Buikstra, J., Cook, D., ‘Paleopathology: an American account’, *Annual Review of Anthropology* 9 (1980): 433–70; de Souza et al. 2003; D’Anastasio, R., Staniscia, T., Milia, M.L., Manzoli, L., Capasso, L., ‘Origin, evolution and paleoepidemiology of brucellosis’, *Epidemiology and Infection* 7 (2010): 1–8.

parasite diagnosis in archaeological material, such as *Trypanosoma cruzi* infection, have shown that the latter may be as old as human presence in the Americas.[25]

The number of individuals in each prehistoric group varied in the different regions, and thus the conditions for the circulation of parasites and their population prevalence rates also varied. However, even with few individuals in each group, there was contact between them, and the conditions were created for given parasitic diseases to circulate, considering the population as a whole in a given region, as exemplified by the shell mounds (*sambaquis*) on the Brazilian coast. Gaspar et al. showed that on the southeast Brazilian coast, the shell mound inhabitants maintained contact between groups, which would have facilitated parasite circulation.[26]

Many of the human groups that inhabited the Andean region, both on the coast and the altiplano, culturally preserved their dead. Some artificially mummified them, such as the Chinchorro, while others offered their children and youth as sacrifices, preserving them magnificently by mummifying them in extremely cold and dry conditions.[27] Other groups living on the eastern side of the continent had a diversity of burial rituals. Some practised cremation, others transferred the bodies for secondary burial, and a few practised anthropophagic rituals.[28] Therefore, the remains vary greatly, but do not prevent tracing the impact of infectious diseases in these populations, as long as the cultural context is clearly known.[29]

In North America, an example is provided by the human groups that comprised the Ancestral Pueblo or Anasazi in the Southwest United States, including southern

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[25] Guhl, F., Jaramillo, C., Vallejo, G.A., Yockteng, R., Cardenas-Arroyo, F., Fornaciari, G., Arriaza, B., Aufderheide, A.C., 'Isolation of *Trypanosoma cruzi* DNA in 4,000-year-old mummified human tissue from northern Chile', *American Journal of Physical Anthropology* 108 (1999): 401–07; Ferreira, L.F., Britto, C., Cardoso, M.A., Fernandes, O., Reinhard, K., Araújo, A., 'Paleoparasitology of Chagas disease revealed by infected tissues from Chilean mummies', *Acta Tropica* 75 (2000): 79–84; Aufderheide, A.C., Salo, W., Madden, M., Streitz, J., Buikstra, J., Guhl, F., Arriaza, B., Renier, C., Wittmers Jr, L.E., Fornaciari, G., Allison, M., 'A 9,000-year record of Chagas' disease', *Proceedings of the National Academy of Sciences of the United States of America* 101 (2004): 2034–9; Lima, V.S., Iñiguez, A.M., Otsuki, K., Ferreira, L.F., Araújo, A., Vicente, A.C.P., Jansen, A.M., 'Chagas disease by *Trypanosoma cruzi* lineage I in a hunter-gatherer ancient population in Brazil', *Emerging Infectious Diseases* 14 (2008): 1001–2; Araújo, A., Jansen, A.M., Reinhard, K., Ferreira, L.F., 'Paleoparasitology of Chagas disease: a review', *Memórias do Instituto Oswaldo Cruz* 104 (2009): 9–16.

[26] Gaspar et al. 2008.

[27] Arriaza, B., *Beyond Death: the Chinchorro Mummies of Ancient Chile* (Washington, DC: 1995); Arriaza, B., Standen, V.G., Cassman, V., Santoro, C.M., 'Chinchorro culture: pioneers of the coast of the Atacama Desert' in H. Silverman and W.H. Isbell (eds), *Handbook of South American Archaeology* (New York: Springer, 2008), pp. 45–58.

[28] Vilaça, A.M.N., 'Relations between funerary cannibalism and warfare cannibalism: the question of predation', *Ethnos* (Stockholm) 65 (2000): 83–106.

[29] De Souza et al. 2003.

Utah and Colorado and northern Arizona and New Mexico. Exploring a semi-arid region, these groups adapted to the environment, leaving evidence of their use of natural resources and cultivated plants. In addition, by building elaborate housing on the rocky cliffs and plains, they also left latrine structures that they used to deposit faeces, leaving material that has only recently been appreciated as a source of priceless information on diet, environment, and parasitic infections, obtained by analysing the archaeological remains.[30]

The faeces found in archaeological or paleontological sites are called coprolites, and they can be preserved in mineralised or desiccated form, in this case whether in very dry, hot, or cold environments or in acid pH conditions, as in the European peat bogs. However, coprolites are not the only source for studying parasites. The soil sediments contained in the pelvic region of skeletons, on the surface of bones preserved in museums, as well as in sediments with organic content and discarded utensils, have shown the potential of studying parasites in various types of material found in archaeological sites.[31] Mummified bodies have been examined with imaging diagnostic techniques, facilitating the localisation of coprolite remains and avoiding unnecessary damage to the material.[32]

Paleoparasitological data show that many of the intestinal helminth infections found most commonly around the world at present already existed among prehistoric human groups in the Americas and were distributed relatively homogeneously among them.[33] However, whether transmitted through the consumption of wild game or domestic animals, other parasites were found to infect populations in the Americas and can be used as indicators of epidemiological transitions from the pre- to post-contact periods. Fugassa showed that among the groups that lived in the far South of Patagonia, the predominant parasite eggs were from animals eaten by these groups, while in coprolites and sediments from skeletons of Europeans, the predominant infection was with the roundworm *Ascaris lumbricoides*.[34]

Sianto et al. showed the potential for human infection with intestinal helminths from animals, such as *Echinostoma* sp., found in coprolites retained in

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[30] Reinhard 1990.

[31] Reinhard, K.J., Geib, P.R., Callahan, M.M., Hevly, R.H., 'Discovery of colon contents in a skeletonized burial: soil sampling for dietary remains', *Journal of Archaeological Science* 19 (1992): 697–705; Shafer, H.J., Marek, M., Reinhard, K.J., 'Mimbres burial with associated colon remains from the NAN Ranch Ruin, New Mexico', *Journal of Field Archaeology* 16 (1989): 17–30; Fugassa, M.H., Sardella, N.H., Guichón, R.A., Denegri, G.M., Araújo, A., 'Paleoparasitological analysis applied to skeletal sediments of meridional Patagonian collections', *Journal of Archaeological Science* 35 (2008a): 1408–11; Harter, S., Le Bailly, M., Janot, F., Bouchet, F., 'First paleoparasitological study of an embalming rejects jar found in Saqqara, Egypt', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 119–21.

[32] De Souza 2009.

[33] Gonçalves et al. 2003.

[34] Fugassa 2006.

megacolon lesions in a partially mummified body dated to 600 BP.[35] *Trypanosoma cruzi* infection was diagnosed in this same individual using molecular biology techniques, confirming a case of Chagas disease, an anthropozoonosis in groups of potter-farmers in central Brazil.[36]

Helminthiases and Intestinal Protozooses in Prehistoric America

Enterobius Vermicularis (Pinworm)

One of the most widely distributed parasites in all regions of the world occupied by humans is the pinworm nematode *Enterobius vermicularis*, with variable prevalence rates in different population groups.[37] *Enterobius vermicularis* infection can be transmitted directly from human host to host through the ingestion of eggs, without necessarily contaminating the soil. The female worms, when gravid and full of eggs, migrate to the perianal region where they release their eggs, which can contaminate the environment or the host's own hands, since the infection is characterised by perianal itching. The larvae also penetrate the anus, returning to the large intestine. External climate conditions have little or no influence on host-to-host transmission.

Enterobius vermicularis infection is believed to have originated in Africa and spread to other regions, accompanying the migratory process of human populations.[38] There are records of this parasitosis in North American

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[35] Sianto, L., Reinhard, K.J., Chame, M., Mendonça, S., Gonçalves, M.L.C., Fernandes, A., Ferreira, L.F., Araújo, A., 'The finding of *Echinostoma* (Trematoda: Digenea) and hookworm eggs in coprolites collected from a Brazilian mummified body dated 600–1,200 years before present', *Journal of Parasitology* 91 (2005): 972–5; Sianto, L., Chame, M., Silva, C.S.P., Gonçalves, M.L.C., Reinhard, K., Fugassa, M.H., Araújo, A., 'Animal helminths in human archaeological remains: a review of zoonoses in the past', *Revista do Instituto de Medicina Tropical de São Paulo* 51 (2009): 119–30.

[36] Fernandes, A., Iñiguez, A.M., Lima, V.S., Souza, S.M., Ferreira, L.F., Vicente, A.C., Jansen, A.M., 'Pre-Columbian Chagas disease in Brazil: *Trypanosoma cruzi* I in the archaeological remains of a human in Peruaçu Valley, Minas Gerais, Brazil', *Memórias do Instituto Oswaldo Cruz* 103 (2008): 514–16.

[37] Gale, E.A.M., 'A missing link in the hygiene hypothesis?', *Diabetologia* 45 (2002): 588–94.

[38] Hoeppli, R., *Parasites and Parasitic Infection in Early Medicine and Science* (Singapore: University of Malaya Press, 1959), pp. 27–28, and 157; Hugot, J.P., Reinhard, K., Gardner, S.L., 'Human enterobiasis in evolution: origin, specificity and transmission', *Parasite* 6 (1999): 201–08; Reinhard, K.J., 'Cultural ecology of prehistoric parasitism on the Colorado Plateau as evidenced by coprology', *American Journal of Physical Anthropology* 77 (1988a): 355–66; Reinhard 1990; Araújo et al. 2008a; Glen, D.R., Brooks, D.R., 'Parasitological evidence pertaining to the phylogeny of the hominoid primates', *Biological Journal of the Linnean Society* 27 (2008): 331–54.

archaeological sites dated to as far back as 10,000 BP.[39] The record shows that pinworms intermittently infected ancient hunter-gatherers. After agriculture was established, pinworm became a constant and common parasite of Ancestral Pueblo people who inhabited the apartment-like villages. The crowding of people in these ancient villages promoted infection.[40] Indeed, pinworm prevalence in coprolites may serve as the best proxy indicator of levels of infectious disease.[41]

The same contrast was found in the number of *Enterobius vermicularis* eggs (Figure 9.1) per gram of faeces in coprolites of nomad and farmer-herder populations in sites in the Atacama Desert in northern Chile, dated to 6,000 BP.[42] Santoro et al. found an increase in pinworm prevalence after the Inca moved dispersed farmers into large villages in the Lluta River Valley near Arica, Chile.[43] However, it is surprising that the results are negative thus far for *Enterobius vermicularis* eggs in archaeological sites in Brazil.[44]

Refinement of the diagnosis has been possible with the use of molecular biology techniques. In some of the samples that tested negative on microscopic examination, it was possible to retrieve genetic material from this parasite, thus expanding its distribution in archaeological sites.[45] These analyses yielded haplotypes that showed different geographic origins for this parasite in the human groups that inhabited archaeological sites on the Pacific coast of Chile compared with desert sites in Arizona, United States.[46] However, even with molecular biology techniques, the evidence for *Enterobius vermicularis* infection in Brazilian sites is still negative thus far.

Due to its mechanism of transmission, *Enterobius vermicularis* or pinworm infection was able to accompany the prehistoric migrations from Africa during the peopling of the American continent, crossing the land and ice bridge at the

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[39] Fry and Moore 1969.

[40] Reinhard, K.J., Bryant, V.M., 'Pathoecology and the future of coprolite studies', in A.W.M. Stodder (ed.), *Reanalysis and Reinterpretation in Southwestern Bioarchaeology* (Tempe: Arizona State University, 2008), pp. 199–216.

[41] Reinhard 1992.

[42] Ferreira, L.F., Araújo, A., Confallonieri, U., Nuñez, L., 'Infecção por *Enterobius vermicularis* em populações agro-pastoris pré-colombianas de San Pedro de Atacama, Chile', *Memórias do Instituto Oswaldo Cruz* 84 (suppl. 4) (1989a): 197–99.

[43] Santoro, C., Vinton, S.D., Reinhard, K.J., 'Inca expansion and parasitism in the Lluta Valley: preliminary data', *Memórias do Instituto Oswaldo Cruz* 98 (suppl. 1) (2003): 161–3.

[44] Araújo, A., Ferreira, L.F., Confalonieri, U., Nunez, L., Ribeiro Filho, B.M., 'The finding of *Enterobius vermicularis* eggs in pre-Columbian human coprolites', *Memórias do Instituto Oswaldo Cruz* 80 (1985): 141–43.

[45] Iñiguez et al. 2003.

[46] Iñiguez, A.M., Reinhard, K., Gonçalves, M.L.C., Ferreira, L.F., Araújo, A., Paulo Vicente, A.C., 'SL1 RNA gene recovery from *Enterobius vermicularis* ancient DNA in pre-Columbian human coprolites', *International Journal for Parasitology* 36 (2006): 1419–25.

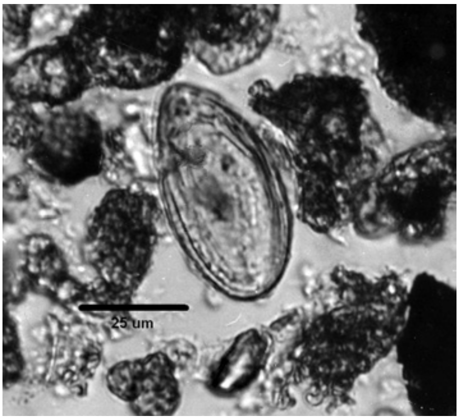

Figure 9.1.
Pinworm egg found in a human coprolite dated to the beginning of agriculture, Tulán 54, San Pedro de Atacama, Chile.

Bering Strait.[47] However, the evidence of two distinct prehistoric haplotypes in the ancient Americas could mean that pinworm arrived with two distinct prehistoric migrations.

The Introduction of Other Geohelminthiases

Other helminth species that also originated in our African ancestors could not have been introduced by this same route. This was due to the cold climatic conditions in the Bering Strait region that would have been hostile for the life cycle of the intermediate forms of the parasite while they matured in the soil.[48] Hookworms or Ancylostomidae (*Necator americanus*, *Ancylostoma duodenale*), threadworms (*Strongyloides stercoralis*), whipworms (*Trichuris trichiura*) and roundworms (*Ascaris lumbricoides)* are parasites known as geohelminths, whose life cycle necessarily includes a passage through soil and for which the temperature and humidity conditions are relatively restricted for their transmission.[49] Since they are helminth parasites that seem to have originated in the Old World, finding them in archaeological sites in America marks events involving a non-frozen environment and occupations that facilitate faecal contamination of hands or food.

Araújo et al. reviewed the geohelminth infections in prehistoric American populations and concluded that they can be used as markers of migrations by their human hosts.[50] They showed that hookworms (Figure 9.2), whose oldest

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[47] Araújo et al. 2008b.

[48] Araújo et al. 1981; Araújo et al. 2008a; Araújo et al. 2008b.

[49] Camillo-Coura, L., 'Control of soil-transmitted helminthiasis: co-ordinated control projects' in D.W.T. Compton, M.C. Nesheim and Z.S. Pawlowski (eds), *Ascariasis and its Public Health Significance* (London: Taylor and Francis, 1985), pp. 253–63.

[50] Araújo et al. 2008a.

archaeological examples in the Americas go back 7,000 years,[51] must have been introduced by other migratory routes, not the Bering Strait Crossing.[52] Montenegro et al. simulated the paleoclimatic conditions for the Bering Strait Crossing where the migrants crossed during the peopling of the continent and concluded that the conditions were unfit for maintaining the hookworm life cycle.[53] The proposed alternatives are seafaring contacts or sailing across the Aleutian Islands, which would have allowed access to regions with appropriate conditions for the hookworm life cycle some 7,000 years ago.[54]

As for *Ascaris lumbricoides*, there is interesting speculation as to whether the infection originated from a swine parasite species or, on the contrary, whether the parasite began to infect swine after their domestication by humans.[55] Findings of *Ascaris* sp. eggs in France dated to 30,000 BP led to the hypothesis that *Ascaris* sp. of swine origin emerged later than that of human origin.[56] *Ascaris* sp. is a parasite commonly found in Old World archaeological sites, especially from Medieval Europe.[57] *Ascaris* sp. egg findings have also been reported in Asian countries, like China, Japan, and Korea, in samples mainly from mummified bodies and sediment from latrines and cesspits.[58] In Japan, this parasite's origin is associated with

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[51] Ferreira, L.F., Araújo, A., Confalonieri, U., Chame, M., Ribeiro, B.M., 'Encontro de ovos de ancilostomideos em coprólitos humanos datados de 7.230 +/- 80 anos, Piauí, Brasil' *Anais da Academia Brasileira de Ciencias* 59 (1987): 280–81.

[52] Araújo et al. 1981; Araújo et al. 2008a; Reinhard et al. 2001.

[53] Montenegro, A., Araújo, A., Eby, M., Ferreira, L.F., Heatherington, R., Weaver, A., 'Parasites, paleoclimate and the peopling of the Americas: Using the hookworm to time the Clovis migration', *Current Anthropology* 47 (2006): 193–200.

[54] Araújo et al. 2008a.

[55] Loreille, O., Bouchet, F., 'Evolution of ascariasis in humans and pigs: a multi-disciplinary approach', *Memórias do Instituto Oswaldo Cruz* 98 (Suppl. 1) (2003): 39–46.

[56] Bouchet, F., Baffier, D., Girard, M., Morel, P., Paicheler, J.C., David, F., 'Paléoparasitologie en contexte pléistocène: premières observations à la Grande Grotte d'Arcy-sur-Cure (Yonne), France', *Comptes Rendus de l'Académie des sciences* 319 (1996): 147–51.

[57] Gonçalves et al. 2003; Bouchet et al. 2003.

[58] Wei, O., 'Internal organs of a 2100-year-old female corpse', *The Lancet* 7839 (1973): 1198; Liangbiao, C., Tao, H., 'Scanning electron microscopic view of parasites worm ova in an ancient corpse', Acta Academica Sinicae 3 (1981): 64–5; Yang, W.Y., Wei, D.X., Song, G.F., Wu, Z.B., Teng, R.S., 'Parasitologic investigations on the ancient corpse of Chu dynasty the warring states unearthed from the Ma-zhuan tomb No. 1, Jiangling County', Acta Academiae Medicinae Wuhan 14 (1984): 43–45; Cheng, T.O., 'Glimpses of the past from the recently unearthed ancient corpses in China', Annals of Internal Medicine 101 (1984): 714–5; Su, T.C., 'A scanning electron microscopic study on the parasite eggs in an ancient corpse from a tomb of Chu Dynasty, the Warring State, in Jiangling County, Hubei Province', Journal of Tongji Medical University 7 (1987): 63–4; Han, E.T., Guk, S.M., Kim, J.L., Jeong, H.J., Kim, S.N., Chai, J.Y., 'Detection of parasite eggs from archaeological excavations in the Republic of Korea', Memórias do Instituto Oswaldo Cruz 98 (Suppl. 1) (2003): 123–26; Matsui, A., Kanehara, M., Kanehara, M., 'Paleoparasitology

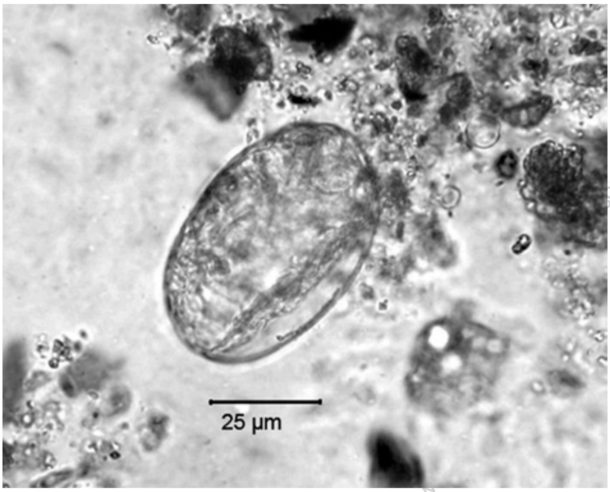

Figure 9.2. Hookworm egg found in a partially mummified body dated 560 ± 40 BP from Peruaçu Valley, Minas Gerais, Brazil.

the introduction of rice farming by the Chinese.[59] In the last decade, molecular diagnosis has contributed to the study of this parasitosis in Europe, South America and Asia.[60] Recently, the use of molecular biology techniques and the possibility of comparing paleoepidemiology and modern epidemiology of the infection enabled us to improve our understanding of the origin of *Ascaris* sp. infection, and helped to conclude that *Ascaris lumbricoides* and *Ascaris suum* are a single species (named *Ascaris lumbricoides* as a priority name), infecting both humans and pigs.[61]

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in Japan - discovery of toilet features', Memórias do Instituto Oswaldo Cruz 98 (Suppl. 1) (2003): 127–36.

[59] Matsui et al. 2003.

[60] Loreille, O., Roumat, E., Verneau, O., Bouchet, F., Hänni, C., 'Ancient DNA from *Ascaris*: extraction amplification and sequences from eggs collected in coprolites', *International Journal for Parasitology* 31 (2001): 1101–6; Leles et al. 2008; Seo, M., Guk, S.M., Kim, J., Chai, J.Y., Bok, G.D., Park, S.S., Oh, C.S., Kim, M.J., Yi, Y.S., Shin, M.H., Kang, I.U., Shin, D.H., 'Paleoparasitological report on the stool from a medieval child mummy in Yangju, Korea', *Journal of Parasitology* 93 (2007): 589–92; Shin, D.H., Chai, J.Y., Park, E.A., Lee, W., Lee, H., Lee, J.S., Choi, Y.M., Koh, B.J., Park, J.B., Oh, C.S., Bok, G.D., Kim, W.L., Lee, E., Lee, E.J., Seo, M., 'Finding ancient parasite larvae in a sample from a male living in late 17th century Korea', *Journal of Parasitology* 95 (2009): 768–71; Oh, C.S., Seo, M., Lim, N.J., Lee, S.J., Lee, E.J., Lee, S.D., Shin, D.H., 'Paleoparasitological report on *Ascaris* aDNA from an ancient East Asian sample', *Memórias do Instituto Oswaldo Cruz* 105 (2010b): 225–8.

[61] Leles, D., Reinhard, K., Fugassa, M., Ferreira, L.F., Iñiguez, A.M., Araújo, A., 'A parasitological paradox: why is ascarid infection so rare in the prehistoric Americas?', *Journal of Archaeological Sciences* 37 (2010): 1510–20; Leles, D., Gardner, S.L.,

Intestinal Protozoa

Finding the cysts or other forms of intestinal parasitic protozoa in coprolites in the Americas is very rare.[62] Using serological techniques such as ELISA (enzyme-linked immunosorbent assays), some diagnoses have been made.[63] These show the presence of *Entamoeba histolytica* and *Giardia intestinalis* infection in human coprolites recovered from sites in Arizona.

Reviewing Diagnoses in the Paleoparasitological Record

The record of parasite species recovered from archaeological sites is large. Studies have been undertaken by a diverse range of specialists ranging from archaeologists to archaeobotanists to parasitologists. The research has appeared in a variety of formats ranging from unpublished theses, to site reports, to book chapters and peer-reviewed journal articles. Over the years, hypothesis and biases have changed. For example, early researchers were reluctant to report hookworm evidence in the Americas as such because there was a prevailing belief in the parasitological community that hookworm could not be present. This was eliminated in the classic debate between Ferreira et al. and Kliks.[64] However, earlier discoveries were either modified by the discoverer or greeted with trepidation by peer reviewers. For this reason, some parasitologists preferred to publish the detailed descriptions of their finds at a higher taxonomic level of 'strongylate nematode' rather than risk misidentification. Other finds are mentioned in archaeological texts with reference to an opinion of a parasitologist, but where no other detailed publication of that parasitologist exists. Therefore, some published records are simply anecdotal.

Reinhard, K., Iñiguez, A.M., Araújo, A., 'Are Ascaris lumbricoides and Ascaris suum a single species?' *Parasites & Vectors* 5 (2012): 42.

[62] Gonçalves et al. 2003; Fugassa, M.H., Sardella, N.H., Taglioretti, V., Reinhard, K., Araújo, A., 'Morphometric variability in oocysts of *Eimeria macusaniensis* (Guerrero et al. 1967) in archaeological samples from the Holocene of Patagonia, Argentina', *Journal of Parasitology* 94 (2008b): 1418–20.

[63] Gonçalves, M.L.C., Araújo, A., Duarte, R., Pereira da Silva, J., Reinhard, K., Bouchet, F., Ferreira, L.F., 'Detection of *Giardia duodenalis* antigen in coprolites using a commercially available enzyme-linked immonosorbent assay', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 96 (2002): 640–43; Gonçalves, M.L.C., da Silva, V.L., de Andrade, C.M., Reinhard, K., da Rocha, G.C., Le Bailly, M., Bouchet, F., Ferreira, L.F., Araujo, A., 'Amoebiasis distribution in the past: first steps using an immunoassay technique', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 98 (2004): 88–91; Allison, M.J., Bergman, T., Gerszten, E., 'Further studies on fecal parasites in antiquity', *American Journal of Clinical Pathology* 112 (1999): 605–09; Ortega, Y.R., Bonavia, D., '*Cryptosporidium*, *Giardia*, and *Cyclospora* in ancient Peruvians', *Journal of Parasitology* 89 (2003): 635–36.

[64] Ferreira et al. 1980; Ferreira et al. 2003; Klicks 1983.

Discoveries of parasites in unusual circumstances, for example tropical parasites in arctic sites or northern hemisphere species in South American sites, should be presented as provisional.

We are taking the opportunity here to present potential biases in the parasitological record from the Americas. Because of these considerations noted above, it is important to approach the record with a degree of healthy scepticism. We feel that the most secure identifications are those that have been accomplished by a trained parasitologist who has sought independent evaluation of his/her diagnoses. The secure identifications should be presented in a peer-reviewed outlet to ensure that errors are caught. Identifications should be accompanied by full analyses with illustrations.

A case in point is Reinhard and Clary's report of *Strongyloides* in the Chaco Canyon burials.[65] This report has several areas that could have been improved, and we can be honest about these as Reinhard (a co-author of this article) was a co-author of this Chaco Canyon paper. Firstly, it was completed at a time when the conventional wisdom stated that hookworm could not have been a prehistoric parasite in the Americas. As a master's student in 1984, Reinhard considered the importance of conventional wisdom compelling. Therefore, Reinhard did not include hookworm species in the differential diagnosis of the third stage larvae that he identified. Secondly, the identification was not independently evaluated by another parasitologist. Thirdly, the results were published in an unreviewed book. Recognising these deficiencies, Reinhard is currently having the same samples from the 1986 study re-examined independently by trained parasitologists as part of a re-evaluation of his past work aimed at eliminating the bias of changing conventional wisdom in his record of discoveries. The list of finds in Table 9.2 is annotated for some identifications that may be mistaken due to analyst bias.

There are anecdotal accounts in the older literature that have never been properly published in detail. A first example is the note of an acanthocephalan egg found in a coprolite excavated from Black Mesa, Arizona.[66] The note is not accompanied by any details of the analysis of the coprolite. Indeed, there is no substantiation that the coprolite is human. No independent paper was published on the egg. Therefore, this case is anecdotal and should be viewed as highly provisional. Another example is the Daws Island hookworm recovered from a coprolite.[67] There is some description of the find, but the specimen was sent

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[65] Reinhard, K.J., Clary, K.H., 'Parasite analysis of prehistoric coprolites from Chaco Canyon', in N.J. Akins (ed.), *A Biocultural Approach to Human Burials from Chaco Canyon, New Mexico* (Santa Fe: National Park Service, 1986), pp. 177–86.

[66] Gummerman, G.J., Westfall, D.A., Weed, C.S., '*Archaeological Investigations on Black Mesa: The 1969–1970 Seasons* (Arizona: Prescott College Pr., 1972).

[67] Rathbun, T.A., Sexton, J., Michie, J., 'Disease patterns in a formative period South Carolina coastal population', in P. Willey and F.H. Smith (eds), *The Skeletal Biology of Aboriginal Populations in the Southeastern United States* (Knoxville: Tennessee Anthropological Association, 1980), pp. 53–74.

to a parasitology lab and no publication appeared. Therefore, this too should be regarded as a provisional diagnosis.

We also present as provisional those case studies that report a parasite species at locations extensively studied by other parasitologists who did not report the same species, especially of common parasites. For example, Goncalves et al. reported an *Ascaris lumbricoides* egg from the Ancestral Puebloan site of Antelope House, Canyon de Chelly, Arizona.[68] Previously, four studies by various authors had all failed to note *Ascaris* at this site.[69] The discovery by Goncalves in the same coprolites analysed by other parasitologists suggest that either *Ascaris* sp. was extremely rare, or that one or more of them were in error. For this reason, the *Ascaris lumbricoides* egg found by Goncalves must be considered as provisional until verified by independent examination.

Discoveries of parasites in unexpected locations are always sensational. The cases of Allison et al.'s long-ignored discovery of hookworm in a pre-Inca Peruvian mummy and Ferreira et al.'s hotly debated hookworm discovery are cases in point.[70] Indeed, 20 years after their publication, these discoveries were still the focus of debate.[71] The lesson learned from this is that discoveries in unusual locales must be thoroughly described and verified by independent analyses. An example of a fully documented discovery in an unusual location is the Buldir Island hookworm.[72] Although peer-reviewed, the surprising nature of the discovery of parasites in an Arctic midden needs to be verified, especially as no images of this parasite were included in the paper.

It is important for readers to be aware that some work is being undertaken by untrained parasitologists on a contractual level. The work can be erroneous. For example, one such contractor reported the find of *Diphyllobothrium latum* eggs in prehistoric Chile.[73] The researchers seem to be unaware of the probability

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[68] Gonçalves et al. 2003.

[69] Reinhard 1992; Fry, G., Hall, H.J., 'Human coprolites from Antelope House: preliminary analysis', *Kiva* 41 (1975): 87–96; Fry, G.F., Hall, H.J., 'Human coprolites', in D.P. Morris (ed.), *Archaeological Investigations at Antelope House* (Washington, DC: National Park Service, 1986), pp. 165–88; Reinhard et al. 1987.

[70] Allison, M.J., Pezzia, A., Hasegawa, I., Gerszten, E., 'A case of hookworm infestation in a pre-Columbian American', *American Journal of Physical Anthropology* 41 (1974): 103–6; Ferreira et al. 1980; Ferreira et al. 1983.

[71] Fuller, K., **'**Hookworm: not a pre-Columbian pathogen', *Medical Anthropology* 17 (1997): 297–308.

[72] Bouchet, F., Lefèvre, C., West, D., Corbett, D., 'First paleoparasitological analysis of a midden in the Aleutian Island (Alaska): results and limits', *Journal of Parasitology* 85 (1999): 369–72.

[73] Cummings, L.S., Nepstad-Thornberry, C., Puseman, K., *Paleofeces from the Ramaditas Site in Northern Chile: Addressing Middle to Late Formative Period Diet and Health* (1999). Unpublished manuscript on file with Paleo Research Institute and Beloit College, Beloit, Wisconsin Stable. URL: http://core.tdar.org/document/378500, DOI: doi:10.6067/XCV8TQ60WS

that this species, which infects freshwater fish, did not exist in prehistoric Chile. Alternatively, *D. pacificum* is very common in the area from eating saltwater fish. Simple morphological examination of the eggs is used to separate the two species. The report mistakenly proposed that the prehistoric inhabitants were infected by eating lake fish. It specifies that the prehistoric people habitually fish in high Andean lakes. Of course, trained parasitologists realise that in South America diphyllobothriids did not infect lake fish in prehistoric times. Unfortunately, the archaeologist who paid for the work does not have this training and their interpretation of prehistory is being distorted by error. Contract workers do not publish their work, and therefore such errors cannot be caught in the peer-review system. Therefore, researchers must be aware that erroneous finds can be generated from the contract archaeology world.

Health Consequences of Parasitic Disease

A major potential contribution by paleoparasitology to studies of the occupation of archaeological sites relate to the standards of health of the human groups that lived there. In the past there have been few papers attempting to determine the effect of intestinal parasites upon the health of prehistoric populations.[74] This is a challenging area, as it can be difficult to determine whether one population was healthier than another from the study of just their skeletal remains.[75] When it comes to specific lesions on the skeleton, there is debate as to whether the bony lesions of porotic hyperostosis on the skull vault and cribra orbitalia in the skull orbits may be caused by different types of anaemia, and whether they may be a result of anaemia secondary to intestinal helminths.[76]

While it can be very difficult to establish paleoepidemiological parameters that can answer these questions, it is not always impossible. When favourable conditions for preservation are found, as in the archaeological sites in the southwestern United States, it is possible to gather data capable of shedding some light on the health and disease of individuals in a population.[77] In this case, the archaeoparasitological reconstruction produced data on the way of life of these

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[74] Reinhard 1992.

[75] Wood, J.W., Milner, G.R., Harpending, H.C., Weiss, K.M., 'The osteological paradox: problems of inferring prehistoric health from skeletal samples', *Current Anthropology* 33 (1992): 343–58.

[76] Martinson, E., *Assessing the Etiology of Cribra Orbitalia and Porotic Hyperostosis: A Case Study of the Chiribaya of the Osmore Drainage, Peru* (University of New Mexico: PhD Thesis, 2002); Walker, P.L., Bathurst, R.R., Richman, R., Gjerdrum, T., Andrushko, V.A., 'The causes of porotic hyperostosis and cribra orbitalia: a reappraisal of the iron-deficiency-anemia hypothesis', *American Journal of Physical Anthropology* 139 (2009): 109–125.

[77] Reinhard and Bryant 2008; Reinhard, K.J., Araújo, A., Sianto, L., Costello, J.G., Swope, K., 'Chinese liver flukes in latrine sediments from Wong Nim's property, San

populations by exploiting evidence for parasitic infections. There seem to have been differences in the exposure to hookworm and pinworm infections in order to explain variation in the number of eggs found in coprolites studied by Reinhard.[78] One possible hypothesis is that children and women stayed longer inside the dwelling places, but the men wandered in search of game, leaving them less exposed to geohelminth infections.[79]

In South American archaeological sites, several hypotheses have been tested on the health and disease conditions of pre-Columbian populations. In the prehistoric groups that lived in the Atacama Desert, their exceptionally good preservation means that some inferences are possible on the relationship between the environment and the parasitic infections that affected them. Based on the El Niño climate phenomenon and its intermittent occurrence, as well as the parasite cycle in fish and mammals, it was possible to speculate on the prevalence of *Diphyllobothrium pacificum* infection at different moments in the past.[80] This tapeworm (cestode) has its life cycle in crustaceans, fish, and marine mammals in the Pacific Ocean, and it has the potential to infect humans when they eat contaminated fish. The larvae contained in the fish flesh develop into adult worms in the human intestine, reaching some 1 to 10 meters in length. They attach themselves to the intestinal mucosa and can cause discomfort, leading to complaints of abdominal pain. *Diphyllobothrium pacificum* infection was first noted in prehistoric populations that lived in Peru and Chile, and it proved to have been common in other prehistoric groups on the Pacific coast.[81] A combined study of climate factors generated by the El Niño phenomenon in the past and the presence of marine fish species led to the hypothesis of fluctuation in this infection's prevalence among prehistoric groups at different points in time, based upon the presence of different intermediate host fish species and the human host.[82]

Research began in Patagonia, attempting to determine moments of change, or epidemiological transitions, in the disease process before and after contact with

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Bernardino, California: archaeoparasitology of the Caltrans District Headquarters', *Journal of Parasitology* 94 (2008): 300–3.

[78] Reinhard, K.J., 'Effects of parasitism on Ancestral Pueblo maternal and infant health', *American Journal of Physical Anthropology* Suppl. 40 (2004): 179.

[79] Reinhard 1988a.

[80] Arriaza, B., Reinhard, K., Araújo, A., Orellana, N.C., Standen, V.G., 'Possible influence of the ENSO phenomenon on the pathoecology of diphyllobothriasis and anisakiasis in ancient Chinchorro populations', *Memórias do Instituto Oswaldo Cruz* 105 (2010): 66–72.

[81] Patrucco, R., Tello, R., Bonavia, D., 'Parasitological studies of coprolites of pre-Hispanic Peruvian populations', *Current Anthropology* 24 (1983): 393–94; Ferreira, L.F., Araújo, A., Confalonieri, U., Nuñez, L., 'The finding of *Diphyllobothrium pacificum* in human coprolites (4100–1950 BC) from Northern Chile', *Memórias do Instituto Oswaldo Cruz* 79 (1984): 175–80; Santoro et al. 2003.

[82] Arriaza et al. 2010.

the European colonists.[83] The prehistoric groups from the southernmost region of the American continent were exceptionally well adapted to the environment, but differed from each other in relation to the interactions that allowed them to subsist by exploring diverse ecosystems, such as the seacoast and the fields of Patagonia.[84] The paleoparasitological evidence shows changes beginning at the time of contact with the Europeans.[85] Human coprolites from sites in Patagonia yielded parasites resulting from the ingestion of animals infected with parasites, both capable of causing infection or disease in humans, called zoonoses, or simply parasites indicating the ingestion of animals, but incapable of establishing themselves in the human host.[86] The model used for prehistoric groups in Patagonia is very interesting and provides consistent information on the way of life of these populations and the changes brought by contact with the Europeans.

Considering the available information for Patagonia, it is possible to formulate paleoepidemiological scenarios, and, based on them, to consider the risks associated with various biocultural situations in diverse ecosystems and periods in the Holocene. It should be possible to interpret the evidence as it gradually accumulates, and to then improve our models. Based on ecological strategies of parasite dispersal,[87] criteria were defined to assess which aspects of biocultural information on human groups that existed in Patagonia during the Holocene could be relevant for the occurrence of various parasites. This required a broad approach to anthropological, archaeological, historical and ethnographic knowledge of the region.

According to conditions of agglomeration and mobility, tropism, the ecosystem occupied, and cultural behaviour (for example, hygiene, habitat and preparation of foods), a general table can be constructed that indicates probability of infection

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[83] Fugassa, M., Guichón, R.A., 'Modelos paleoepidemiológicos para el Holoceno patagónico', *7th Jornadas de Arqueología de la Patagonia*. 21–25 April 2008, Conference Proceedings Abstracts (Ushuaia, 2008), p. 30.

[84] Borrero, L.A., 'Human dispersal and climatic conditions during Late Pleistocene times in Fuego-Patagonia', *Quaternary International* 53–53 (1999): 93–99; Guichón, R.A., Suby, J.A., Casali, R., Fugassa, M.H., 'Health at the time of Native-European contact in Southern Patagonia: first steps, results, and prospects', *Memórias do Instituto Oswaldo Cruz* 101 (Suppl. 2) (2006): 97–05.

[85] Fugassa, M.H., Araújo, A., Guichón, R.A., 'Quantitative paleoparasitology applied to archaeological sediments', *Memórias do Instituto Oswaldo Cruz* 101 (suppl. 2) (2006): 29–33.

[86] Fugassa et al. 2008b; Fugassa, M.H., Beltrame, M.O., Sardella, N.H., Civalero, M.T., Aschero, C., 'Paleoparasitological results from coprolites dated at the Pleistocene-Holocene transition as source of paleoecological evidences in Patagonia', *Journal of Archaeological Science* 37 (2010a): 880–4; Fugassa, M.H., Reinhard, K.J., Johnson, K.L., Gardner, S.L., Vieira, M., Araújo, A., 'Parasitism of prehistoric humans and companion animals from Antelope Cave, Mojave County, Northwest Arizona', *Journal of Parasitology* 97 (2011): 862–867.

[87] Fugassa et al. 2006; Fugassa and Guichón 2008.

by groups of parasites. The dichotomous ordering of the factors identified and described thus far has provided various combinations that are interpreted as possible scenarios for parasite paleoepidemiology in Patagonia.[88] In general, the epidemiology of human groups in Patagonia is quite different from that of groups in other regions, as a result of the climate and biocultural conditions. Widely diverse and unusual parasite forms were able to infect human groups in Patagonia, including species that were able to proliferate due to favourable biocultural habits. The diversity of parasite forms found in hunter-gatherers in Patagonia offers a complex panorama that can be underestimated by conventional paleopathological studies, which emphasise just a few parasitoses that cause bone lesions from anaemia. Morbidity models, based upon more exhaustive models of occurrence, are needed to improve these theoretical proposals. Thus far, the empirical evidence brought by paleoparasitology is consistent with these models.

Parasites of Animals in Humans

Despite the difficulties involved in a paleoepidemiological approach to prehistoric groups in Brazil, a study was attempted in archaeological sites in the Serra da Capivara National Park in the semi-arid region of Northeast Brazil. With the retrieval of a considerable number of human and animal coprolites, it was possible to evaluate different parasitic infections in periods ranging from 30,000 BP to historical times and to estimate potential zoonotic infections in the region. The results showed that in addition to infections with intestinal helminths more common to humans, there was the potential for infections with specific animal helminths with the capacity to infect the human host.[89]

These studies on animal parasites found in humans demonstrate the use of food resources, often with the ingestion of the animal host whole and raw (without any cooking). Cases of ingestion of potential parasite vectors have also been recorded, like fragments of arthropods found in coprolites, showing their ingestion, intentional or not, by the human host.[90] Both Fugassa and Sianto et al. reviewed cases of animal parasites found in archaeological sites in the Americas.[91] In the case of animal parasites in human coprolites, it is necessary to distinguish between true infections, in which the parasite installs itself and lays eggs and

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[88] Fugassa and Guichón 2008.

[89] Sianto, L., '*Parasitismo em Populações Pré-Colombianas: Helmintos de Animais em Coprólitos de Origem Humana do Parque Nacional Serra da Capivara, PI, Brasil*', (Escola Nacional de Saúde Pública, Fundação Oswaldo Cruz, Rio de Janeiro: PhD Thesis, 2008).

[90] Johnson, K.L., Reinhard, K., Sianto, L., Araújo, A., Gardner, S.L., Janovy Jr, J., 'A tick from a prehistoric Arizona coprolite', *Journal of Parasitology* 94 (2008): 296–98.

[91] Fugassa 2006; Sianto et al. 2009.

leaves larvae, from cases of pseudo-parasitism, in which eggs are found in the faeces, but infection does not occur and the eggs disappear within a few days.

As an example of pseudo-parasitism, *Calodium* sp. (*Capillaria* sp.) eggs have been found in coprolites in Argentina and in modern-day indigenous communities in Brazil.[92] Humans can be infected by two routes: by ingesting the poorly cooked flesh of wild animals, in which pseudo-parasitism occurs, or by ingesting embryonated eggs present in the soil, leading to capillariasis, which is usually fatal. Carvalho-Costa et al. recently identified a case of pseudo-parasitism in an 85-year-old woman in a community of indigenous descent in the Upper Rio Negro in the Brazilian Amazon.[93] Since the woman had eaten tapir (*Tapirus terrestris*) meat just a few days before the stool test and this animal had been identified as a host for the parasite, the authors concluded that tapir was the source of the infection.

Conclusion

In prehistoric America, evidence has been shown for the presence of helminths that originated in the Old World and that accompanied their human hosts along migrations across the continents, as well as for the presence of other types of parasite that they encountered while exploring their new environment. Paleoparasitology has the ability to retrace the various events in which these disease transfers occurred, in addition to identifying moments of change in parasitic infections due to contacts between different human ethnic groups, especially when Europeans conquered the American continent. Together with paleogeography, paleoparasitology is capable of situating parasitic infections in human groups in time and space and tracing their paths in prehistory. In combination with paleoepidemiology, paleoparasitology helps us to reconstruct possible scenarios that explain the impact of parasitic diseases on the ancient inhabitants of the Americas.

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[92] Fugassa, M.H., Araújo, A., Sardella, N., Denegri, G.M., 'New paleoparasitological finding in caves from Patagonia, Argentina', *Paleopathology Newsletter* 137 (2007): 17–21; Fugassa, M., Taglioretti, V., Gonçalves, M.L.C., Araújo, A., Sardella, N.H., Denegri, G.M., '*Capillaria* spp. findings in Patagonian archaeological sites: statistical analysis of morphometric data', *Memórias do Instituto Oswaldo Cruz* 103 (2008c): 104–5; Lawrence, D.N., Neel, J.V., Abadie, S.H., Moore, L.L., Adams, L.J., Healy, G.R., Kagan, I.G., 'Epidemiologic studies among Amerindian populations of Amazonia III. Intestinal parasitoses in newly contacted and acculturating villages', *American Journal of Tropical Medicine and Hygiene* 29 (1908): 530–7; Coimbra Jr, C.E.A., Mello, D.A., 'Enteroparasites and *Capillaria* sp. found in Indians of the Suruí group, Parque Indígena Aripuanã, Rondônia', *Memórias do Instituto Oswaldo Cruz* 76 (1981): 299–302.

[93] Carvalho-Costa, F.A., Silva, A.G., Souza, A.H., Moreira, C.J.C., Souza, D.L., Valverde, J.G., Jaeger, L.H., Martins, P.P., Meneses, V.F., Araújo, A., Bóia, M.N., 'Pseudoparasitism by *Calodium hepaticum* (syn. *Capillaria hepatica*; *Hepaticola hepatica*) in the Negro River, Brazilian Amazon', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 103 (2009): 1071–3.

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Table 9.1 Intestinal parasites found in coprolites and other human archaeological remains in North America

Parasite Species	Date	Location	Reference
Cestoda			
Diphyllobothrium	1400–1700AD	Aleutian Islands, USA	Bouchet et al. 1999, ref.72
Diphyllobothrium latum	300BC–200AD	Saginaw Valley, Michigan, USA	McClary 1972, ref.94
Diphyllobothrium pacificum	1070–1150AD	Adak Island, Alaska USA	Bouchet et al. 2001, ref.94
	3700–3490BC	Village of Namu, Fitz Hugh Sound, British Columbia, Canada	Bathurst 2005*, ref.94
Hymenolepidid cestode	?	Antelope House, Arizona, USA	Reinhard 1988a, ref.38
	?	Elden Pueblo, Arizona, USA	Hevly et al. 1979, ref.94
	1175–1250AD	Antelope House, Arizona, USA	Reinhard et al. 1987, ref.16
	1070–1250AD	Elden Pueblo, Arizona, USA	Reinhard et al. 1987, ref.16
Other Cestode	5330–250BC	Hogup Cave, Utah, USA	Fry 1977, ref.94
	20AD	Danger Cave, Utah, USA	Fry 1977, ref.94
	1070–1250AD	Elden Pueblo, Arizona, USA	Reinhard et al. 1987, ref.16
	1250–1300AD	Glen Canyon, Utah, USA	Fry 1977, ref.94
	1700–1800AD	Newport, Rhode Island, USA	Reinhard et al. 1986, ref.65
Taeniid cestode	1600–1700AD	Ferryland site Newfoundland, Canada	Horne & Tuck 1996, ref.94
		Elden Pueblo, Arizona, USA	Hevly et al. 1979, ref.94
		Schultz site, Michigan, USA	McClary 1972, ref.94
		Danger Cave, USA	Fry 1977, ref.94
		Río Zape, Durango, Mexico	New finding
	Middle Holocene	Village of Namu, Fitz Hugh Sound, British Columbia, Canada	Bathurst 2005, ref.94
Trematoda			
Clonorchis sp.	Historical period	Chinese community, Sacramento, California, USA	Hall 1982, ref.94, Reinhard et al. 2008, ref.40

Parasite Species	Date	Location	Reference
Clonorchis sinensis	Historical period	Wong Nim's Property, San Bernardino, California, USA	Reinhard et al. 2008, ref.40
Cryptocotyle lingua	335–475AD	St Lawrence Island, Bering Sea	Zimmerman & Smith 1975, ref.94
Dicrocoelium dendriticum	1600–1700AD	Ferryland Newfoundland, Canada	Horne & Tuck 1996, ref.94
Fasciola spp.	500BC–1150AD	Lovelock Cave, Nevada, USA	Dunn & Watkins 1970, ref.94
Nanophyetus salmincola	Not available	Village of Namu, Fitz Hugh Sound, British Columbia, Canada	Bathurst 2005, ref.94
Opisthorchiformis	1250 AD	Glenn Canyon, Utah, USA	Moore et al. 1974, ref.94
Trematode	500BC–1150AD	Lovelock Cave, Nevada, USA	Dunn & Watkins 1970, ref.94
		Río Zape, Durango, Mexico	New finding
Nematoda			
Ascaridid		Río Zape, Durango, Mexico	New finding
Ascaris lumbricoides	900–1250AD	Antelope House, Arizona, USA	Goncalves et al. 2003, ref.16
	1125–290BC	Upper Salts Cave, Kentucky, USA	Fry 1974, ref.94
	1070–1250AD	Elden Pueblo, Arizona, USA	Hevly et al. 1979, ref.94, Reinhard et al. 1987, ref.16
	372–82BC	Big Bone Cave, Tennessee, USA	Faulkner et al. 1989, ref.94
	405–135BC	Big Bone Cave, Tennessee, USA	Faulkner 1991, ref.94
	1070–1150AD	Adak Island, Alaska, USA	Bouchet et al. 2001, ref.94
	1755–1783AD	Queen Anne Square, Newport, Rhode Island, USA	Reinhard et al. 1986, ref.65
	1720AD	Williamsburg, Virginia, USA	Reinhard 1990, ref.20
	1620AD	Ferryland site, Newfoundland, Canada	Horne & Tuck 1996 **, ref.94
	3050–2050BC	Village of Namu, Fitz Hugh Sound, British Columbia, Canada	Bathurst 2005 *, ref.94

Parasite Species	Date	Location	Reference
	Colonial Period	Wong Nim's Property, San Bernardino, California, USA	Reinhard et al. 2008, ref.40
Enterobius vermicularis	8467–7207BC	Danger Cave, Utah, USA	Fry & Hall 1969, ref.94, Wilke & Hall 1975, ref.94, Fry & Moore 1969, ref.16
	4000BC	Dirty Shame Rockshelter, Oregon, USA	Hall 1976, ref.94
	4010BC–100AD	Hogup Cave, Utah, USA	Fry & Hall 1969, ref.94, Fry & Moore 1969, ref.16
	2100–600BC	Hinds Cave, Texas, USA	Reinhard 1988b, ref.94
	350 BC	Clyde's Cavern, Utah, USA	Hall 1972, ref.94
	372–82BC	Big Bone Cave, Tennessee, USA	Faulkner et al. 1989, ref.94
	405–135BC	Big Bone Cave, Tennessee, USA	Faulkner 1991, ref.94
	350 AD	Turkey Pen Cave, Utah, USA	Reinhard et al. 1987, ref.16
	460–1500AD	Clyde's Cavern, Utah, USA	Hall 1972, ref.94
	505–695AD	Canyon del Muerto, Arizona, USA	El-Najjar et al. 1980, ref.94
	600AD	Rio Zape, Durango, Mexico	Reinhard 1990, ref. 20
	?	Río Zape, Durango, Mexico	New finding
	900–1250AD	Hoy House, Mesa Verde, Arizona, USA	Stiger 1977, ref.94
	920–1200AD	Chaco Canyon, New Mexico, USA	Reinhard & Clary 1986, ref.94, Reinhard et al. 1987, ref.16
	950AD	Step House, Mesa Verde, Colorado, USA	Samuels 1965, ref.94
	1070–1250AD	Elden Pueblo, Arizona, USA	Hevly et al. 1979, ref.94, Reinhard et al. 1987, ref.16
	1075–1100AD	Antelope House, Arizona, USA	Fry & Hall 1975, ref.69
	1100–1140AD	Antelope House, Arizona, USA	Fry & Hall 1975, ref.69
	1075–1250AD	Antelope House, Arizona, USA	Reinhard et al. 1987, ref.16

Parasite Species	Date	Location	Reference
	1200–1275AD	Salmon Ruin, New Mexico, USA	Reinhard et al. 1987, ref.16
	1250–1300AD	Inscription House, Arizona, USA	Fry & Hall 1973, ref. 94, Horne 1985, ref.16
	?	Antelope Cave, USA	Fugassa et al. 2011, ref.86
	?	Antelope House, USA	Reinhard 1988a, ref.38
	?	Salmon Ruin,	Reinhard et al. 1985, ref. 94
	?	Antelope House, USA	Fry & Hall 1986, ref.69
	?	Hogup Cave, USA	Fry 1977, ref.94
	?	Danger Cave	Fry 1977, ref.94
	900AD	Antelope House, Arizona, USA	Reinhard 1990, ref.20, Iniguez et al. 2003, ref.19
	1700–1300BC	Daws Island, South Carolina, USA	Rathbun et al. 1980 *, ref.67
Hookworm	372–82BC	Big Bone Cave, Tennessee, USA	Faulkner 1991, ref.94, Faulkner et al. 1989, ref.94
	1125–290BC	Upper Salts Cave, Kentucky, USA	Dusseau & Porter 1974 * in Wilke & Hall 1975, ref.94
	1400–1700AD	Buldir Island, Alaska, USA	Bouchet et al. 1999 **, ref.72
	1700–1800AD	Newport, Rhode Island, USA	Reinhard et al. 1986, ref.65
	??	Río Zape, Mexico	New Finding
	?	Antelope House, USA	Fry & Hall 1986, ref.69
Rhabditiform larvae		Inscription House, Arizona, USA	Fry & Hall 1973, ref.94
	405–135BC	Big Bone Cave, Tennessee, USA	Faulkner 1991, ref.94
	400–1200AD	Clyde's Cavern, Utah, USA	Hall 1972, ref.94
Strongyloides stercoralis	920–1130AD	Chaco Canyon, New Mexico, USA	Reinhard & Clary 1986, ref.94
	1175–1250AD	Antelope House, Arizona, USA	Reinhard et al. 1987*, ref.16
	?	Antelope House, USA	Fry 1980, ref.94, Reinhard 1988a, ref.38
Strongyloides sp.	6800–4800BC	Dust Devil Cave, Utah, USA	Reinhard et al. 1985, ref.94

Parasite Species	Date	Location	Reference
Trichostrongylus spp.	1175–1250AD	Antelope House, Arizona, USA	Reinhard et al. 1987, ref.16
	600AD	Rio Zape, Durango, Mexico	Reinhard 1990, ref. 20
		Río Zape, Durango, Mexico	New finding
	1070–1250AD	Elden Pueblo, Arizona, USA	Hevly et al. 1979, ref.94, Reinhard et al. 1987, ref.16
	1070–1250AD	Elden Pueblo, Arizona, USA	
Trichuris trichiura			
	1700–1800AD	Queen Anne Square, Newport, Rhode Island, USA	Reinhard et al. 1986, ref.65
	1800–1900AD	Greenwich, New York, USA	Reinhard 1990, ref.20
	1720AD	Williamsburg, Virginia, Southwest USA	Reinhard 1990, ref.20
	1600–1700AD	Ferryland, Newfoundland, Canada,	Horne & Tuck 1996, ref.94
	1867–1891AD	Fayette, Michigan, USA	Faulkner et al. 2000, ref.94
	?	Río Zape, Durango, México	New finding
	Colonial Period	Wong Nim's Property, San Bernardino, California, USA	Reinhard et al. 2008, ref.40
		Inscription House, Arizona, USA	Fry & Hall 1973, ref.94
Unidentified Nematodes			Moore et al 1984, ref.94; Reinhard et al. 1987, ref.16
		Salts Cave, Kentucky, USA	Dusseau & Porter 1974 in Wilke & Hall 1975, ref.94
		Salts Cave, Kentucky, USA	Dusseau & Porter 1974 in Wilke & Hall 1975, ref.94
Acanthocephala			
Acanthocephala	8000–2000BC	Hogup Cave, Utah, USA	Fry & Hall 1969, ref.94, Fry 1970, ref.94

Parasite Species	Date	Location	Reference
	4850BC–1550AD	Dirty Shame Rockshelter, Oregon, USA	Hall 1977, ref.94
	9500BC, 8000BC, 2000BC, 20AD	Danger Cave, Utah, USA	Fry & Hall 1969, ref.94, Fry 1980, ref.94
	350BC and 400–1200AD	Clyde's Cavern, Utah, USA	Hall 1972, ref.94
	900–1300AD	Glen Canyon, Utah, USA	Fry & Hall 1969, ref.94, Fry 1977, ref.94
	?	Antelope Cave, USA	Fugassa et al. 2011, ref.86
Macracanthorrynchus sp.	?	Hogup Cave, Utah, USA	Fry 1977, ref.94, Moore et al. 1974, ref.94
Moniliformis clarki	?	Danger Cave, Utah, USA	Fry 1977, ref.94
	?	Glen Canyon, Arizona, USA	Fry 1977, ref.94
	1929–1809BC and 220BC–260AD	Danger Cave, Utah, USA	Moore et al. 1969, ref.[94]

Key: *uncertain diagnosis; **human origin? ***pseudo-parasitism? BC = Before Christ; AD = Anno Domini/After Christ.

Footnote [94]: McClary, W.H., 'Notes on some Late Middle Woodland coprolites', in J.E. Fitting (ed.), *The Shulz Site at Green Point: A Stratified Occupation Area in the Saginaw Valley of Michigan*, Anthropology Memoir no.4 (Ann Arbor, University of Michigan Museum, 1972), pp. 131–6; Bouchet, F., West, D., Lefèvre, C., Corbett, D., 'Identification of parasitoses in a child burial from Adak Island (Central Aleutian Islands, Alaska)', *Comptes Rendus de l'Académie des sciences* 324 (2001): 123–7; Bathurst, R.R., 'Archaeological evidence of intestinal parasites from coastal shell middens', *Journal of Archaeological Science* 32 (2005): 115–123; Hevly, R.H., Kelly, R.E., Anderson, G.A., Olsen, S.J., 'Comparative effects of climate change, cultural impact, and volcanism in the paleoecology of Flagstaff, Arizona, A.D. 900–1300', in P.D. Sheets and D.K. Grayson (eds), *Volcanic Activity and Human Ecology* (New York: Academic Press, 1979), pp. 487–523; Fry, G.F., *Analysis of Prehistoric Coprolites from Utah*, Anthropology Papers series no. 97 (Salt Lake City: University of Utah Press, 1977); Horne, P.D., Tuck, J.A., 'Archaeoparasitology at a 17th century colonial site in Newfoundland', *Journal of Parasitology* 82 (1996): 512–5; Hall, A., 'Intestinal helminths of man: the interpretation of egg counts', *Parasitology* 85 (1982): 605–613; Zimmerman, M.R., Smith, G.S., 'A probable case of accidental inhumation of 1600 years ago', *Bulletin of the New York Academy of Medicine* 51(1975): 828–837; Dunn, F.L., Watkins, R., 'Parasitological examination of prehistoric human coprolites from Lovelock

Cave, Nevada', in R.F. Heizer and L.K. Napton (eds), *Archaeology and the Prehistoric Great Basin Lacustrine Subsistence Regime as Seen from Lovelock Cave, Nevada,* Archaeological Research Facility Contributions no.10 (Berkeley: University of California, 1970), pp. 178–185; Moore, J.G., Grundmann, A.W., Hall, H.J., Fry, G.F., 'Human fluke infection in Glen Canyon at AD 1250', *American Journal of Physical Anthropology* 41 (1974): 115–7; Fry, G.F., 'Ovum and parasite examination of Salt Cave paleofeces', in P.J. Watson (ed.), *Archaeology of the Mammoth Cave Area* (New York: Academic Press, 1974), p. 61; Faulkner, C.T., Patton, S., Johnson, S.S., 'Prehistoric parasitism in Tennessee: evidence from the analysis of desiccated fecal material collected from Big Bone Cave, Van Buren County, Tennessee', *Journal of Parasitology* 75 (1989): 461–3; Faulkner, C.T., 'Prehistoric diet and parasitic infection in Tennessee: evidence from the analysis of desiccated human paleofeces', *American Antiquity* 56 (1991): 687–700; Fry, G.F., Hall, H.J., 'Parasitological examination of prehistoric human coprolites from Utah', *Proceedings of Utah Academy of Sciences, Arts and Letters* 46 (1969): 102–5; Wilke, P.J., Hall, H.J., *Analysis of Ancient Feces: a Discussion and Annotated Bibliography* (Berkeley: University of California, 1975); Reinhard, K.J., *Diet, Parasitism and Anemia in the Prehistoric Southwest* (College Station, Texas A & M University: PhD Thesis, 1988a); Hall H.J., *Diet and disease at Clyde's Cavern, Utah* (Salt Lake City, University of Utah: PhD Thesis, 1972); El-Najjar, M.Y., Benitez, J., Fry, G., Lynn, G.E., Ortner, D.J., Reyman, T.A., Small, P.A., 'Autopsies on two native American mummies', *American Journal of Physical Anthropology* 53 (1980): 197–202; Stiger, M.A., '*Anasazi Diet: The Coprolite Evidence'* (Boulder: University of Colorado: MA Thesis, 1977); Reinhard, K.J., Clary, K.H., 'Parasite analysis of prehistoric coprolites from Chaco Canyon', in N.J. Akins (ed.), *A Bioarchaeological Approach to Human Burials from Chaco Canyon, New Mexico* (Santa Fe: National Park Service, 1986), pp. 177–86; Samuels, R., 'Parasitological study of long dried fecal samples', *American Antiquity* 31 (1965): 175–9; Fry, G.F., Hall, H.J., *Analysis of Human Coprolites from Inscription House: Preliminary Report* (Tucson: Report to the National Park Service, Arizona Archaeological Center, 1973); Reinhard, K.J., Ambler, J.R., McGuffie, M., 'Diet and parasitism at Dust Devil Cave', *American Antiquity* 50 (1985): 819–824; Fry, G.F., 'Prehistoric diet and parasites in the desert west of North America', in D.L. Browman (ed.), *Early Native Americans* (The Hague: Mouton Press, 1980), pp. 325–339; Faulkner, C.T., Cowie, S.E., Martin, P.E., Martin, S.R., Mayes, C.S., Patton, S., 'Archaeological evidence of parasitic infection from the 19th Century Company Town of Fayette, Michigan', *Journal of Parasitology* 85 (2000): 846–9; Moore, J.G., Krotoskynski, B.K., O'Neill, H.J., 'Fecal odorgrams. A method for partial reconstructions of ancient and modern diets', *Digestive Disease and Sciences* 29 (1984): 907–911; Fry, G.F., 'Preliminary analysis of the Hogup Cave coprolites', *University of Utah Anthropological Papers* 93 (1970): 247–250; Hall, H.J., 'A paleoscatological study of diet and disease at Dirty Shame Rockshelter, Southeast Oregon', *Tebiwa* 8 (1977): 1–15; Moore, J.G., Fry, G.F., Englert, E., 'Thorny-headed worm infection in North American prehistoric man', *Science* 163 (1969): 1324–5.

Table 9.2 Intestinal parasites found in coprolites and other human archaeological remains in South America

Parasite Species	**Date**	**Location**	**Reference**
Cestoda			
Diphyllobothrium spp.	3000BC	Huaca Prieta, Peru	Callen & Cameron 1960*, ref.3
	3000–1200BC	Huaca Prieta, Peru	Callen & Cameron 1955, ref.3
	2050–3050BC	San Miguel de Azapa, Chile	Reinhard & Urban 2003, ref.95
	Inca Period	Lluta Valley, Chile	Santoro et al. 2003, ref.43
	600–1476AD	Chiribaya Baja, Peru	Holliday et al. 2003, ref.95
	600–1476AD	San Geronimo, Peru	Holliday et al. 2003, ref.95
D. pacificum	1025AD	Osmore, Peru	Martinson et al. 2003, ref.95
	1020–1156AD	Osmore, Peru	Martinson et al. 2003, ref.95
	Chiribaya Alta	Osmore, Peru	Martinson 2002, ref.76
	1025AD	Osmore, Peru	Martinson 2002, ref.76
	2700–2850BC	Huarmey Valley, Peru	Patrucco et al. 1983, ref.81
	50BC	Northern Chile	Reinhard & Aufderheide 1990, ref.95

Parasite Species	Date	Location	Reference
	8050–2050BC	Coastal Peru	Reinhard & Barnum 1991, ref.95
	4110–1950BC	Tiliviche, Iquique, Chile	Ferreira et al. 1984, ref.81
Hymenolepis nana	2050–50BC	Santa Elina, Mato Grosso, Brazil	Gonçalves et al. 2003, ref.16
	6080–5780BC	M22 CCP7, Santa Cruz, Argentina	Fugassa et al. 2007 *, ref.92
	7170–6770BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010*, ref.86
	Pre-Inca Period	Lluta Valley, Chile	Santoro et al. 2003, ref.43
Trematoda			
Echinostoma sp.	1350–1430AD	Peruaçu Valley, Minas Gerais, Brazil	Sianto et al. 2005, ref.35
Paragonimus sp.	2500BC–5900BC	Atacama Desert, Chile	Hall 1976, ref.94
Nematoda			
Ancylostomid	5360–5200BC	Pedra Furada, Piauí, Brazil	Ferreira et al. 1987, ref.51
	4100–1950BC	Tiliviche, Iquique, Chile	Goncalves et al. 2003, ref.16
	3040–2870BC to 565–685AD	Boqueirão Soberbo, Minas Gerais, Brazil	Ferreira et al. 1982, ref.95
	1660–1420BC to 1450–1590AD	Gentio Cave, Minas Gerais, Brazil	Ferreira et al. 1980, ref.6, 1983, ref.16
	550–150BC	Toconao, San Pedro de Atacama, Chile	Goncalves et al. 2003, ref.16

Parasite Species	Date	Location	Reference
	950–1450AD	Valle Encantado, Neuquén, Argentina	Goncalves et al. 2003, ref.16
	890–950AD	Tihuanaco, Peru	Allison et al. 1974, ref.70
	Not available	Sítio do Meio, Piauí, Brazil	Goncalves et al. 2003, ref.16
	7170–6770BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010, ref.86
Ascaridid	1770–2028BC	Orejas de Burro, Santa Cruz, Argentina	Fugassa & Barberena 2006, ref.95
Ascaris lumbricoides	6910–6790BC	Sítio do Meio, PI, Brazil	Gonçalves et al. 2003, ref.16, Leles et al. 2008, ref.15
	6050–5050BC	Lapa Pequena, MG, Brazil	Gonçalves et al. 2003, ref.16
	2458–2096BC	Huarmey Valley, Peru	Patrucco et al. 1983, ref.81
	2050–50BC	Santa Elina, Mato Grosso, Brazil	Gonçalves et al. 2003, ref.16
	1660–1420BC to 1450–1590AD	Gruta do Gentio II, Minas Gerais, Brazil	Ferreira et al. 1980, ref.6, 1983, ref.16, Leles et al. 2008, ref.15
	1080–950BC	Tulán, San Pedro de Atacama, Chile	Gonçalves et al. 2003, ref.16, Leles et al. 2008, ref.15
	2458–2096BC	Huarmey Valley, Peru	Patrucco et al. 1983, ref.81

Parasite Species	Date	Location	Reference
	1540±120 BC-1520±70 AD	Gentio Cave, Minas Gerais, Brazil	Gonçalves et al. 2003, ref.16
	1500–1600AD	Nombre de Jesús, Cabo Virgenes, Argentina	Fugassa et al. 2006, ref.20, Leles et al. 2010, ref.61
Capillarids	Historic	Las Mandibulas, Tierra del Fuego, Arg	Fugassa et al. 2008c***, ref.95
	ca. 1100 AD	Caleta Falsa, Tierra del Fuego, Arg	Fugassa et al. 2008c***, ref.95
	5930 ± 150 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2007*, ref. 92
	1770–2028 cal. BC	Orejas de Burro, Santa Cruz, Argentina	Fugassa & Barberena 2006, ref.95
	6970 ±200 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010, ref.86
	7780 ± 100 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010, ref.86
	4590 ±110 BC	CCP5, PN Perito Moreno, Santa Cruz, Argentina	Fugassa 2006, ref.20
Enterobius vermicularis	4110–1950 BC	Tiliviche, Iquique, Chile	Araújo et al. 1985, ref.44, Gonçalves et al. 2003, ref.16, Iñiguez et al. 2003, ref.19, 2006, ref.46

Parasite Species	Date	Location	Reference
	1080–950 BC	Tulán, San Pedro de Atacama, Chile	Ferreira et al. 1989a, ref.42, Iñiguez et al. 2003, ref.19, 2006, ref.46
	400 BC – 800 AD	Caserones, Tarapacá Valley, Chile	Ferreira et al. 1984, ref.81, Araújo et al. 1985, ref.44, Iñiguez et al. 2003, ref.19, 2006, ref.46
	2277 ± 181 BC	Huarmey Valley, Peru	Patrucco et al. 1983, ref.81
	770–830 BC	Pv35–4, Peru	Patrucco et al 1982, ref.95, 1983, ref.81
	pre-Columbian	Pie de Palo, Argentina	Zimmerman & Morilla 1983, ref.95
	Inca Period	Lluta Valley, Chile	Santoro et al. 2003, ref.43
	4590 ±110 BC	CCP5, PN Perito Moreno, Santa Cruz, Argentina	Fugassa 2007**, ref.95
Metastrongylus sp. or *Physaloptera* sp.	5930 ± 150 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2007 *, ref. 92

Parasite Species	**Date**	**Location**	**Reference**
Nematodirus sp.?	5930 ± 150 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2007 *, ref.92
	6970 ± 200 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010*, ref.86
	7780 ± 100 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010*, ref.86
	4590 ±110 BC	CCP5, PN Perito Moreno, Santa Cruz, Argentina	Fugassa 2006, ref.20
Rhabditoid larvae	8580 ± 620 BC	CCP7, PN Perito Moreno, Santa Cruz, Argentina	Fugassa 2006, ref.20
Trichostrongylus spp.	1080–950 BC	Tulán, San Pedro de Atacama, Chile	Gonçalves et al. 2003, ref.16
	950–1450 AD	Valle Encantado, Neuquén, Argentina	Gonçalves et al. 2003, ref.16
	1450–1525 AD	Catarpe 2, San Pedro de Atacama, Chile	Gonçalves et al. 2003*, ref.16
	18th century AD	Itacambira, Minas Gerais, Brazil	Araújo et al. 1984, ref.95
Trichuris sp.	19th century AD	Cerro Norte XI, Pali Aike, Santa Cruz, Argentina	Fugassa et al. 2010b**
	4590 ±110 BC	CCP5, PN Perito Moreno, Santa Cruz, Argentina	Fugassa 2007, ref.95
Trichuris trichiura	6050–5050 BP	Lapa Pequena, Minas Gerais, Brazil	Gonçalves et al. 2003, ref.16
	2955±85BC–625±60 AD	Boqueirão Soberbo, Minas Gerais, Brazil	Ferreira et al. 1982, ref.95
	2050–50 BC	Santa Elina, Mato Grosso, Brazil	Gonçalves et al. 2003, ref.16

Parasite Species	Date	Location	Reference
	1540±120BC–1520±70 AD	Gentio Cave, Minas Gerais, Brazil	Ferreira et al. 1980, ref.6, 1983, ref.16
	1080–950 BC	Tulán, San Pedro de Atacama, Chile	Gonçalves et al. 2003, ref.16
	50 BC	Estrago Cave, Pernambuco, Brazil	Ferreira et al. 1989b*, ref.95
	1000 AD	Huarmey Valley, Peru	Patrucco et al. 1983, ref.81
	Pre-Columbian	El Plomo, Santiago, Chile	Pizzi & Schenone 1954, ref.4
	ca. 1500 AD	Inca mummy	Pike 1967 **, ref.95
	Colonial Period	Murga culture, Peru	Fouant et al 1982, ref.95
	18th century AD	Itacambira, Minas Gerais, Brazil	Confalonieri et al 1981, ref.95
	Not available	Pedra Furada, Piaui, Brazil	Gonçalves et al. 2003, ref.16
	1000 BC	Tulan, San Pedro de Atacama, Chile	Ferreira et al 1989a, ref.42
	437 ± 48 AD	Parador Nativo, Rio Negro, Argentina	Fugassa & Dubois 2009, ref.95
	1261 ± 44 AD	Centro Minero, Rio Negro, Argentina	Fugassa & Dubois 2009, ref.95
	16th century AD	Nombre de Jesús, Cabo Vírgenes, Argentina	Fugassa et al. 2006, ref.85
	5930 ± 150 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2007, ref.92

Parasite Species	Date	Location	Reference
	1770–2028 cal. BC	Orejas de Burro, Santa Cruz, Argentina	Fugassa & Barberena 2006, ref.95
	7780 ± 100 BC	CCP7, Santa Cruz, Argentina	Fugassa et al. 2010, ref.86
	Inca and Pre-Inca Period	Lluta Valley, Chile	Santoro et al. 2003, ref.43
	1020–1156 AD	Osmore, Peru	Martinson et al 2003, ref.95
	770–830 BC	Pv35–4, Peru	Patrucco et al 1982, ref.95, 1983, ref.81
	Historic?	Tierra del Fuego, Argentina	New finding
	Late Holocene	Salitroso, Santa Cruz, Argentina	New finding
Acanthocephala			
Acanthocephala	2955±85BC–625±60 AD	Boqueirão Soberbo, Minas Gerais Brazil	Gonçalves et al. 2003, ref.16
	1540±120BC–1520±70 AD	Gentio Cave, Minas Gerais, Brazil	Gonçalves et al. 2003*, ref.16
	770–830 BC	Pv35–4, Peru	Patrucco et al. 1982, ref.[95]

Key: *uncertain diagnosis; **human origin? ***pseudo-parasitism? BC = Before Christ; AD = Anno Domini/After Christ

Footnote [95]: Reinhard, K., Urban, O., ‘Diagnosing ancient Diphyllobothriasis from Chinchorro mummies’, *Memórias do Instituto Oswaldo Cruz* 98 (2003): 191–3; Holiday, D.M., Guillen, S., Richardson, D.J., ‘Diphyllobothriasis of the Chiribaya Culture (700–1476 AD) of Southern Peru’, *Comparative Parasitology* 70 (2003): 171–6; Martinson, E., Reinhard, K.J., Buikstra, J.E., Cruz, K.D., ‘Pathoecology of Chiribaya parasitism’, *Memórias do Instituto Oswaldo Cruz* 98 (2003): 195–205; Reinhard, K.J., Aufderheide, A.C., ‘Diphyllobothriasis in prehistoric Chile and Peru: adaptive radiation of a helminth species to native American populations’, *Paleopathology Newsletter* 72 (1990): 18–9; Reinhard, K.J., Barnum, S.V., ‘Parasitology as an interpretative tool in archaeology’, *American Antiquity* 57 (1991): 231–245; Ferreira, L.F., Araújo, A.J.G., Confalonieri, U.E.C., ‘News from the field’, *Paleopathology Newsletter* 38 (1982): 5; Fugassa, M., Barberena, R., ‘Cuevas y zoonosisantiguas: paleoparasitologíadel sitio Orejas de Burro 1 (Santa Cruz, Argentina)’ *Magallania (Punta Arenas)* 34 (2006): 57–62; Patrucco, R., Tello, R., Bonavia, D., ‘*Homo sapiens sapiens*’, in D. Bonavia (ed.), *Los Gavilanes. Mar, Desierto y Oasis en la Historia del Hombre* (Lima: Corporación Peruana de Desarrollo, S.A. – Instituto Arqueológico Alemán, 1982), pp. 226–232; Fugassa, M.H., Taglioretti, V., Gonçalves, M.L.C., Araújo, A., Sardella, N.H., Denegri, G.M., ‘*Capillaria* spp. findings in Patagonian archaeological sites: statistical analysis of morphometric data’, *Memórias do Instituto Oswaldo Cruz* 103 (2008c): 104–5; Zimmerman, M.R., Morilla, R.E., ‘Enterobiasis in pre-Columbian America’, *Paleopathology Newsletter* 42 (1983): 8; Fugassa, M.H., ‘Camélidos, parásitos y ocupaciones humanas: registrospaleoparasitológicos en Cerro Casa de Piedra 7 (Parque Nacional Perito Moreno, Santa Cruz, Argentina)’, *Intersecciones en Antropología* 8 (2007): 265–9; Araújo, A.J.G., Confalonieri, U.E.C., Ferreira, L.F., ‘Encontro de ovos de Trichostrongylideo e *Trichuris trichiura* em corpo mumificado do período colonial brasileiro’, *Revista do Centro de Ciencias Biológicas e da Saúde* (1984): 11–4; Ferreira, L.F., Araújo, A.J.G., Confalonieri, U.E.C., Lima, J.M.D., ‘*Trichuris trichiura* eggs in human coprolites from the archaeological site of Furna do Estrago, Brejo da Madre de Deus, Pernambuco, Brazil’, *Memórias do Instituto Oswaldo Cruz* 84 (1989): 581; Pike, A.W., ‘The recovery of parasite eggs from ancient cesspit and latrine deposits: an approach to the study of early parasite infections’, in D. Brothwell, A.T. Sandison (eds), *Diseases in Antiquity* (Springfield: CC Thomas, 1967), pp. 184–8; Fouant, M.M., Allison, M., Gerszten, E., Focacci, G., ‘Parasitos intestinales entre los indigenas precolombinos’, *Revista Chungará* 9 (1982): 285–299; Confalonieri, U.E.C., Araújo, A.J.G., Ferreira, L.F., ‘*Trichuris trichiura* infection in colonial Brazil’, *Paleopathology Newsletter* 35 (1981); Fugassa, M.H., Favier Dubois, C.M., ‘Primer registro paleoparasitológico de *Trichuris* SP (**N**ematoda, Capilariidae) en muestras asociadas a restos humanos del Holoceno tardío de Patagonia septentrional’, *Revista Argentina de Antropología Biológica* 1 (2009): 61–72.