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# Archaeoparasitology

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**Glossary**

**acanthocephalan** Any of various worms in the phylum Acanthocephala, also called thorny-headed worms, living in intestines of vertebrates having a retractile proboscis covered with many hooked spines.
**anthelminthic** A compound that affects and causes the expulsion of parasitic intestinal worms.
**archeoparasitology** The study of parasite evidence from archeological sites.
**cestode** Any of the parasitic flatworms of the class Cestoidea, including the tapeworms, having a long, segmented, flat body equipped with a specialized organ of attachment at one end.
**ectoparasite** Parasites such as lice and flies that live on the body's outer surface.

**endoparasite** Parasites such as blood flukes and pinworms that infect the internal parts of the body.
**helminth** Worm that is parasitic on vertebrates, especially roundworms and tapeworms, thorny-headed worms, and flukes.
**host** An organism that provides food and shelter to a parasite. microparasites
A microscopic organism of medical importance including bacteria, viruses, fungi, and protozoa.
**infestation** Parasites that are present on the outside of the hosts, such as ectoparasites, or the contamination of a habitat with arthropods such as mosquitoes, bed bugs, and ticks.
**infection** Parasites that are present inside the host organism, Including helminths and microparasites.
**nematode** Any of phylum Nematoda of elongated cylindrical worms some of which are parasitic in animals and plants, and others of which are free-living in soil or water.
**parasite** An organism that lives at the expense of its host by taking energy from the host and sometimes causing pathology in the host.
**prevalence** Number of hosts in a population infected with a parasite at any one time.
**protozoa (parasitic)** Single-cell organisms, some of which are parasitic and can only reproduce within a host organism. Malaria is caused by a protozoa, *Plasmodium*. Other protozoan parasites are *Giardia* and *Toxoplasma*.
**trematode** Referring to flukes, phylum Trematoda, which are parasitic flatworms having external suckers for attaching to a host.
**vector** An animal, usually a biting insect, that is responsible for the transmission of a parasitic organism.

## Introduction

Parasites are the major cause of ill health and early death in the world today. Malaria, sleeping sickness, amoebic dysentery, and hookworm infection are examples of commonplace parasitic diseases that are endemic in most parts of the world (see Health, Healing, and Disease). They were significant threats in prehistory, especially in cultures whose social complexity outstripped the development of effective sanitation, hygiene, and germ theory awareness.

Parasites are organisms that live in or on other organisms called hosts. Parasites derive sustenance and shelter from their hosts and carry out reproduction in host tissues and structures. There is a wide amount of taxonomic diversity among parasites. They range from single-celled protozoa, such as amoeba, to multicelled arthropods such as fleas. Strictly defined, parasites do not include bacteria and viruses. However, some epidemiologists refer to bacteria and viruses as microparasites. There are two general types of parasites: ectoparasites such as lice and endoparasites such as intestinal worms.

All types of parasites can be found in archeological sites. Protozoa can be identified by traces of antigens and also by certain gross pathology they left in their mummified hosts. Helminths are parasitic worms including nematode roundworms, cestode tapeworms, trematode flukes, and acanthocephalan thorny-headed worms. Helminth eggs from some species are laid in thousands within their hosts. Helminth eggs from humans and domestic animals contaminated ancient villages. The eggs are very durable and are easily retrieved from archaeological sediments, coprolites, and mummies. Fleas and lice can be found

on mummies and also in archaeological sediments. Lice are especially important in mummy studies because the eggs are cemented on hair shafts. Therefore, examination of scalps from mummies provides a method of quantifying infestations between individuals and sites.

The discipline that focuses on the relationships between behavior, environment, and parasite infection is archaeoparasitology. This field developed from the need for a fine-tuned analysis of prehistoric ecological and behavioral conditions to assess the factors that affected disease. Archaeoparasitology depends on archaeological information regarding community size, trade patterns, water sources, subsistence practices, social stratification, environment, medicine use, and many other lines of modern archaeological investigation. It also depends on biological understanding of complex parasite life cycles and other dimensions of parasite ecology. When broadly applied, archaeoparasitology defines the rise in parasitic disease associated with the development of complex societies and changes in subsistence strategies. In a more restricted application, archeoparasitology sheds light on the health impact of urbanization and empire expansion. When tightly applied to a single burial or mummy, archeoparasitology shows how habits promote disease on an individual basis.

## History and Major Themes

Aidan Cockburn explored the origins of disease and generated interest in archeoparasitology. Cockburn theorized that there was a relation between human cultural development and the evolution of infectious diseases. In the first archeoparasitological study, Reinhard compared Colorado Plateau Archaic parasitism to agricultural Puebloan sites. Reinhard verified Cockburn's hypothesis that occasional hunter-gatherer infections became major agricultural health hazards (Figure 1). The reasons for the emergence of parasitic disease were many. Parasitism was limited in hunter-gatherer societies, called bands. Hunter-gatherer parasitism was limited by small band size, diffuse regional populations, high band mobility, and

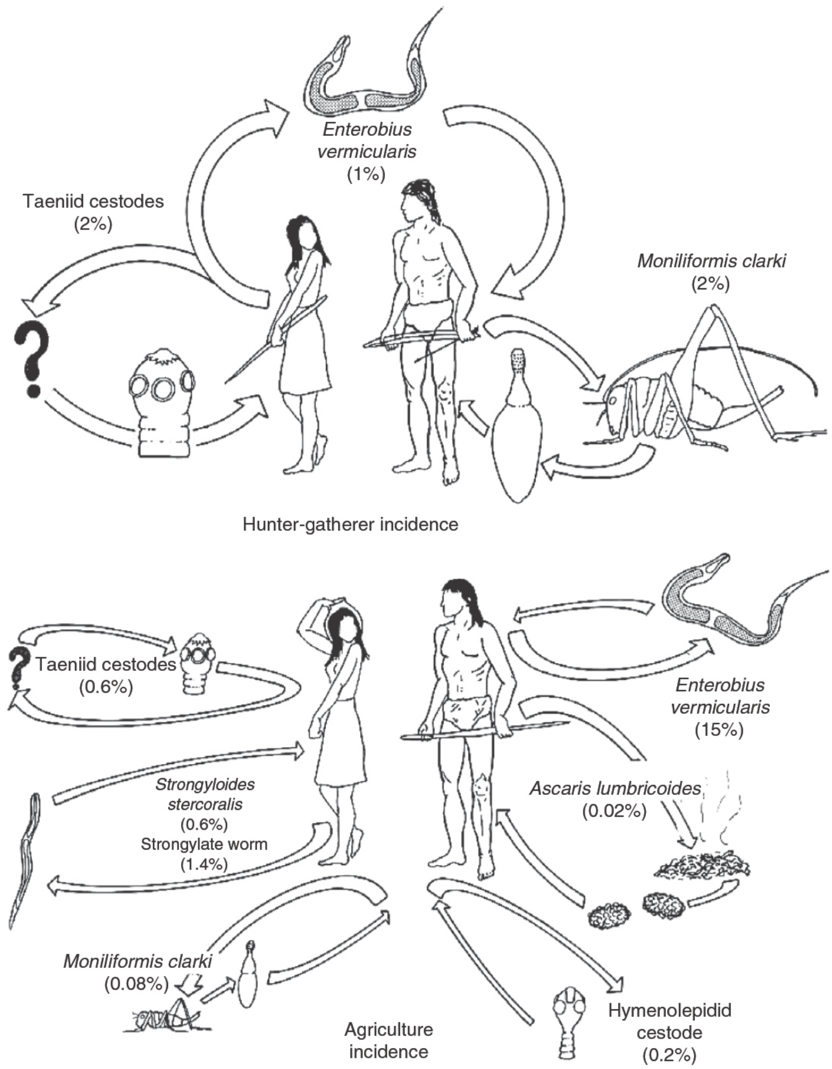


**Figure 1** The relative prevalence and diversity of parasite infections between archaic hunter-gatherers and more recent agricultural ancestral Puebloans on the Colorado Plateau. The archaic people were rare host to just a few parasites. Ancestral Puebloans hosted many more parasites species at higher prevalences (from Reinhard 1996).

presence of natural anthelminthics in hunter-gatherer diets.The one factor that could have promoted hunter-gatherer parasitism was the consumption of uncooked vertebrate meat and insects. Parasitism was promoted in descendent agricultural Puebloan communities by contaminated water sources, concentrated populations, more sedentary life, apartment-style living, absence of effective sanitation, activities centered on water (agriculture), and activities that expanded wetlands including irrigation of all types.

Reinhard recognized that the parasite variation between agricultural Puebloan villages nearly equaled the variation between agriculturalists and hunter-gatherers. This means that some settlements managed to control their parasite burden very effectively while others were simply overwhelmed by their pathogens. This topic was explored by a comparison of pinworm (*Enterobius vermicularis*) prevalence in coprolites by a group of specialists in pinworm disease. Pinworm was chosen as an indicator of general infectious disease because it is transferred from person to person and by contamination of living quarters and food (Figure 2). Some ancestral Pueblo communities were extremely parasitized. In a clinical setting, only 5% of feces from pinworm-infected people are positive for pinworm eggs. The percentages of coprolites positive for pinworm from several sites exceed this and range up to 29% (Figure 3). The lowest prevalence was found

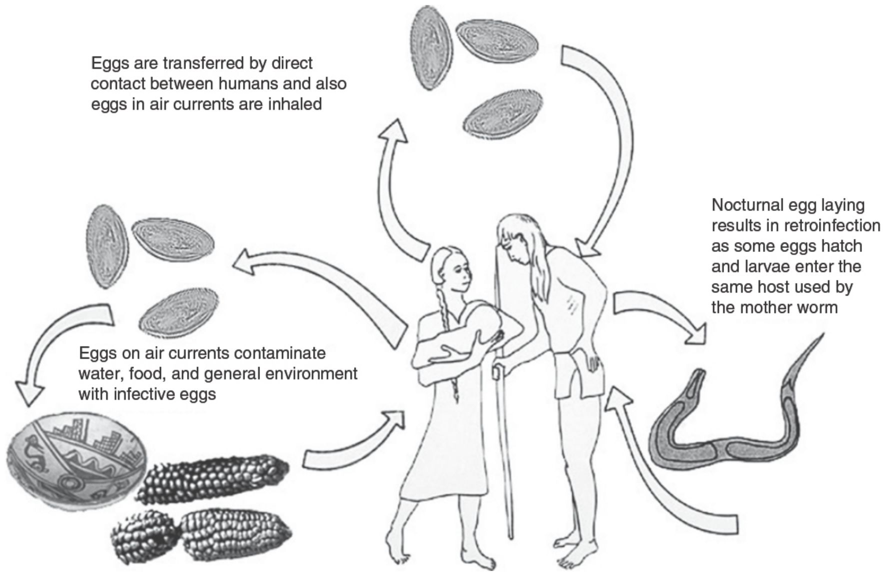


**Figure 2** Pinworm infection in ancestral Pueblo villages involved several basic modes of transmission: air contamination and inhalation of infective eggs, air contamination of the living area with infective eggs, person-to-person transmission of eggs, and retroinfection by larvas that hatch on or in the host and re-enter the same person that hosts the maternal worm.

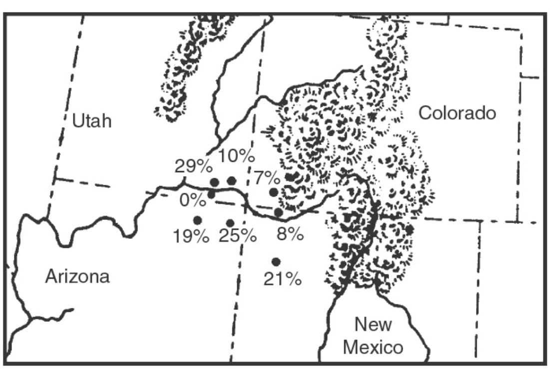


**Figure 3** The prevalence of pinworm infection varied greatly between ancestral Pueblo villages showing that lifestyle variation and population crowding influenced pinworm prevalence.

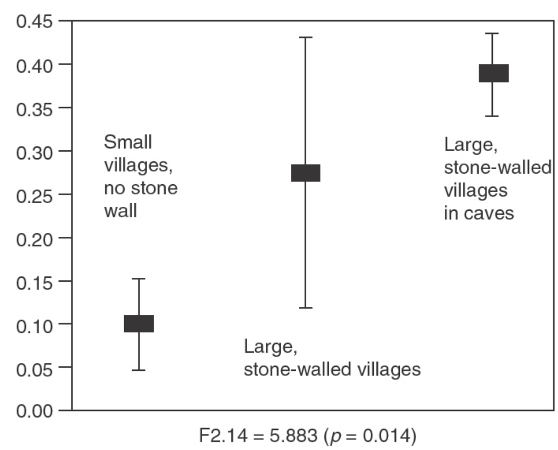


**Figure 4** This graph shows that village size, construction, and location inside or outside the caves influenced pinworm prevalence (modified from Hugo *et al.* 1999).

in small cave sites not containing walled villages. The highest prevalence came from large, walled villages built in rock shelters (Figure 4). Hugot *et al.* concluded that poor air circulation in large populations living in complex apartment-style communities resulted in truly impressive levels of pinworm parasitism. In fact, some sites have the highest levels of pinworm infection recorded for ancient or modern peoples.

The data indicate that pinworm parasitism was unavoidable and that in some villages people had heavy infections. In such populations, pinworm infection prevalence reflects serious health risks, when one considers that other pathogens are spread by the same means. Reinhard showed that the prevalence of parasitism co-varied with porotic hyperostosis prevalence at ancestral Pueblo sites where both coprolite and skeletons were studied (Figure 5). Porotic hyperostosis is a general skeletal pathology indicator long used to assess maternal-infant health.

In Brazil, the cultural transfer of parasites has been

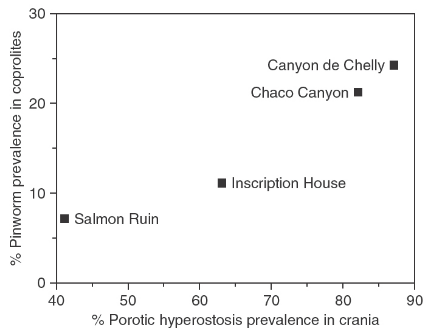


**Figure 5** Although pinworm does not cause significant disease, pinworm prevalence is a good gauge of the general level of infection with other parasites and microparasites. Therefore, it can be compared with skeletal evidence of infectious disease. In this graph, the pinworm prevalence in coprolites has a positive correlation with the skeletal frequency of anemia in ancestral Pueblo sites.

a focus for many years. The discovery of hookworm and whipworm in prehistoric South American mummies and coprolites was sensational. These are human-specific nematodes that cannot parasitize humans in the Arctic and subarctic because they require warm, moist soils for maturation once the eggs are defecated. Therefore, the discovery of these parasites in prehistoric South America mummies and coprolites was sensational. These are human-specific nematodes that cannot parasitize humans in the Arctic and subarctic because they require warm, moist soils for maturation once the eggs are defecated. Therefore, the discovery of these parasites in prehistoric South America indicated that there was a nonarctic migration of humans from the Old World to the Americas.

The most long-standing debate in archeoparasitology revolved around the discovery of hookworms in prehistoric sites. One species of hookworm, *Ancyclostoma duodenale*, was diagnosed from examination of adult worms in prehistoric Peruvian mummies, and later larvas were discovered in coprolites and mummies from Brazil, and the United States. Hookworms are host specific, which means that one species of worm only infects one species of host. *Ancyslostoma duodenale* only infects humans. Hookworms require tropical or subtropical environments for their eggs to hatch and larvas to mature to infective stage. Finally, hookworms have their evolutionary origins in the Old World. Therefore, to reach the New World, they had to migrate with human populations from a tropical or subtropical environment (Figure 6). The conventional wisdom of the twentieth century was that hookworms arrived in the New World in historic times with European colonists and African slaves. This conventional wisdom has been so strong that over a dozen papers have appeared in anthropological and parasitological journals debating the validity and meaning of the hookworm finds.

**Figure 6** The presence of hookworm and whipworm in the prehistoric Americas indicates a non-Beringean migration to the New World at some point in time. This could have been a coastal migration or an oceanic migration.

In historic archeology, archeoparasitology focuses on sociological and urbanization concerns. Historic archeologists can define the ethnicity, economic level, and social status of people associated with archeological features. Therefore, archeoparasitologists have the opportunity to examine the effect of social differentiation on parasitism. The role of urbanization on the emergence of parasitic disease is a common theme in historic context along with the development of sanitation in controlling parasitism. Ascarid roundworms (*Ascaris lumbricoides*) and whipworms (*Trichuris trichiura*) are the main indicators for assessing the parasitic state of historic sites. These two species are most associated with fecal contamination, crowding, and poor sanitation. These parasites are used for comparative evaluation of the threat of parasitism between neighborhoods, villages, and cities. Other parasites, especially tapeworms and flukes associated with different types of meat, are useful indicators of ethnicity.

In the twenty-first century, the discipline of archeoparasitology became global. Researchers published parasitological finds from Japan, Korea, Germany, Peru, Chile, Brazil, and many other countries. The intellectual foci of these studies are diverse. In Japan, parasites were analyzed in context of the development of sanitation and food practices. They were also used to identify areas used by foreign ambassadors who hosted parasite species exotic to Japan but endemic to China. In Korea, archeoparasitology was used to trace the origins of indigenous species, especially trematodes. The impact of the expansion of the Inca Empire was defined in Chile. There, the Inca compelled indigenous people to move from small, scattered communities to large towns, resulting in increased infection with certain parasite species. Also, parasitism of the oldest hunter-gatherers, the Chinchorro, was characterized. Chinchorro consumption of undercooked fish resulted in heavy cestode infection. Archeoparasitology in Peru examines the diseases of humans and domestic animals, and especially the transfer of deadly protozoa from animals to humans via insect vectors.

One theme that crosscuts the global diversity of modern archeoparasitology is defining the distribution of parasites. In a Brazilian mummy, Sianto *et al.* discovered eggs of hookworm and of a trematode genus, *Echinostoma*. *Echinostoma* has never been found in people from the Americas and shows that an indigenous species has the ability to infect humans. This adds to the medical knowledge of the diversity of parasites infective to humans. On the Texas–Coahuila border, Reinhard *et al.* discovered the gross pathology of megacolon which is often associated with Chagas' disease. Infection with *Trypanosoma cruzi* causes Chagas' disease. Previously, Chagas' disease was thought to have originated in the high Andes and then spread to lowland South America in historic times. The discovery of Chagas' disease in prehistoric border of Mexico and Texas shows that the disease spread further and earlier than generally believed.

## Data Sources and Methods

Archeoparasitologists find their data in a variety of archeological contexts. Historical medical texts provide information about ancient parasitological knowledge and treatment. Artifacts provide rare glimpses of the pathology caused by certain parasites. For example, potters of the Peruvian Moche culture portrayed the facial disfigurement resulting from *Leishmania* infection (Figure 7). This protozoan parasite can cause destruction of the soft and hard tissue of the face.

**Figure 7** Moche ceramics depict facial lesions consistent with the pathology caused by one form of the protozoan *Leishmania brasiliensis* which is transmitted by a sand fly vector.

Skeletal remains can reveal hard tissue pathology caused by parasites. Calcification of soft tissue of the urinary tract often results from *Schistosoma hematobium* (blood fluke) infection. Cysts of the tapeworm *Echinococcus granulosis* calcify and are preserved in burials (Figure 8). Destructive bone lesions resulting from *Leishmania* infection are evident in skeletal remains from Peru (Figure 9). Sediments such as soil within burial pelvic girdles (see Burials: Dietary Sampling Methods) are an important source of information about parasites. For example, German researchers were able to recover liver fluke (*Fasciola hepatica*) from the sediment of human and cattle pelvic girdles. This showed that this debilitating parasite was a threat to humans and their domestic livestock.

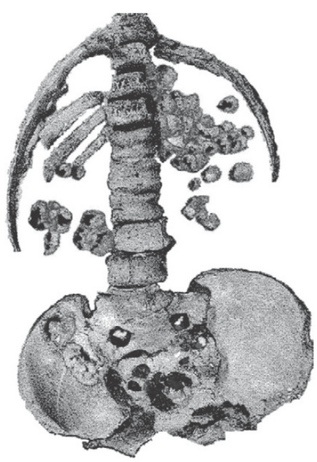

**Figure 8** This is a drawing of hydatid cyst disease excavated from Medieval Denmark. Hydatid disease is caused by a parasitic infection by a tapeworm of the genus *Echinococcus*. The brown nodules are the mineralized cysts cause by the tapeworm larvae.

Mummies preserve the hard tissue and soft tissue pathology caused by parasites as well as the parasites themselves. Ectoparasites such as fleas, head lice, body lice, and crab lice are easily recovered from mummies and the clothing buried with mummies. Parasites of the lungs, intestinal tract, liver, and urinary tract are evident. Molecular biological diagnosis can recover the DNA of ancient parasites from mummified tissue,

**Figure 9** This pathology from a skeleton in Peru could be the result of infection with *Leishmania brasiliensis*. (Reprinted with permission from Memorias do Instituto Oswaldo Cruz.)

even when the parasites themselves have decomposed. Therefore, each mummified corpse is extremely important in the analysis of parasitic diseases. Also, mummified animals are a wonderful source about parasites that may have threatened the vitality of domestic animals.

In the twentieth century, coprolites provided most of the information about parasitic disease. The eggs and larvas of parasites that disperse their offspring are easily found in coprolites. However, Bain describes the increasing importance of analysis of domestic archeological sediments in archeoparasitology. Sediments from latrines, sewers, drains, streets, yards, and living floors contain parasite eggs. Parasites were so abundant in medieval and colonial villages that hundreds of parasite eggs per milliliter of house sediments are commonly found. In latrines, drains, and sewers, the numbers of eggs range into hundreds of thousands per milliliter of sediment. The analysis of sediments from domestic context will be increasingly important in the future.

The microscope is the main tool of the archeoparasitologist. Most diagnoses of helminths and arthropods have been made with compound or binocular microscopes. However, molecular biology and enzyme diagnostic methods have expanded the range of parasites identified from archeological sites. Enzyme-linked immunoassay is a new, proven method for the identification of parasite antigens that can be applied to coprolites,mummies, and all types of archeological sediments. So far, protozoa have been effectively diagnosed. This is very important because protozoa cysts are ephemeral in archeological remains and are only rarely found with the microscope. Molecular biological characterization of ancient parasite DNA is very useful in making definitive diagnosis of ancient parasites and identifying genetic strains of single species.

The power of modern archeoparasitology is based based on its ability to quantify infections for comparative evaluation of disease. There are a variety of methods evaluation of disease. There are a variety of methods for quantification of eggs per milliliter or gram of archeological sediments and coprolites. These include dilution methods derived from clinical techniques and concentration methods derived from palynological techniques. Quantifying eggs allows comparative evaluation of parasitism between sites and features within sites.

## The Future of Archeoparasitology

Several trends in archeoparasitology are evident by comparing the nature of studies in the last century and the current century. Many studies from 1960 to 1990 are focused on the recovery and diagnosis of ancient parasites. With the exception of Brazilian research into migration and Southwestern research into epidemiology, few researchers answered behavioral questions with archeoparasitological data. This preliminary stage is over. Now archeoparasitologists place their data in behavioral context to reveal aspects of migration, food preparation, effect of social status on disease, cross-infection between humans and animals, and many other topics of anthropological interest. There is also a new interest in the influence of parasitic disease on the vitality of cultures and site abandonment. Finally, there is now a solid nexus between biological parasitology and archeoparasitology in exploring questions of parasite biogeography and endemicity that have relevance to modern health. These areas will continue to expand as archeoparasitology becomes a standard archeological discipline.

*See also*: **Americas, North**; American Southwest, Four Corners Region; **Burials**; Dietary Sampling Methods; **Health,Healing,andDisease**;**NewWorld,Peoplingof**.

## Further Reading

Aidan CT (1971) Infectious diseases in ancient populations. *Current Anthropology* 12: 45–62.

Bain A (2001) Archaeoentomological and archaeoparasitological reconstructions at îlot Hunt (CeEt-110): New perspectives in historical archeology (1850–1900). In: *BAR International*, p. 153. Series 973, Oxford: Archaeopress.

Fisher CL, Reinhard KJ, Kirk M, DiVirgilio J, and Miller TS (in press) Archeoparasitology of Historic

Albany, New York. *Historic Archeology*.
Gonçalves MLC, da Silva VL, de Andrade CM, *et al.* (2004) Amebiasis distribution in the past: First steps using an immunoassay technique. *The Transactions of the Royal Society of Tropical Medicine and Hygiene* 98: 88–91.
Hugot JP, Reinhard KJ, Gardner SL, and Morand S (1999) Human enterobiasis in evolution: Origin, specificity, and transmission. *Parasite* 6: 201–208.
Montenegro A, Araújo A, Hetherington R, Ferreira LF, Weaver A, Eeby M (2006) Parasites, paleoclimate and the peopling of the Americas: using the hookworm to time the Clovis migration. *Current Anthropology* 47: 193–198.
Reinhard KJ (1988) The cultural ecology of prehistoric parasitism on the Colorado Plateau as evidenced by coprology. *American Journal of Physical Anthropology* 77: 355–366.