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Parasite Pathoecology of Salmon Pueblo and Other Chacoan Great Houses
The Healthiest and Wormiest Ancestral Puebloans

KARL J. REINHARD

ARCHAEOPARASITOLOGY AND PATHOECONOMY IN THE SOUTHWEST

Two fields of paleopathological investigation originated in the Southwest. Archaeoparasitology is the study of ancient parasite infection (Reinhard 1990, 1992b). It includes comparisons between time periods of single societies as well as comparisons of parasitism between different, contemporaneous cultures. For example, Fry (1980) compared Fremont and Anasazi parasitism, and also Archaic hunter-gatherer and ancestral Pueblo parasitism. All of these studies fall into the definition of archaeoparasitology.

By contrast, pathoecology is the reconstruction of relationships among behavior, environment, and disease organisms in the development of illness (Martinson et al. 2003; Reinhard and Buikstra 2003; Reinhard et al. 2003; Santoro et al. 2003). This field developed from the need for fine-grained analysis of prehistoric ecological and behavioral conditions to assess factors that affected disease. Pathoecological interpretation depends on archaeological information regarding parasitism, community size, trade patterns, water sources, subsistence practices, environment, medicinal use, and many other topics. Although the term is new, pathoecology developed over several decades. I view El-Naijar et al.'s (1976) study of ancestral Pueblo anemia as the first pathoecology study. Perhaps the most advanced example of pathoecology is Stodder and Martin's (1992) multifactorial perspective on ancestral Pueblo disease. My study (Reinhard 1996) of the factors that affected parasitism at Antelope House and Salmon Ruin is another application of pathoecology.

Ancestral Pueblo communities have long been the focus of archaeoparasitology. Samuels (1965) developed the methods for helminth (parasitic worm) egg recovery with coprolites from Mesa Verde. Subsequently, Stiger (1977) provided the first intersite comparison analysis for sites on Mesa Verde. Fry and his colleagues conducted the first regional comparisons of parasitism, focusing on Canyon de Chelly and Glen Canyon (Fry 1977; Fry and Hall 1975, 1986). Fry (1977) also presented the first cross-cultural analysis of Archaic, ancestral Pueblo, and Fremont sites, and pioneered the comparison of parasitism among populations practicing different subsistence strategies. Building on this previous work, I have analyzed the diversity of helminths that parasitized ancestral Pueblo peoples (Reinhard 1985a, 1985b, 1985c, 1990; Reinhard et al. 1987). By 1985, archaeoparasitologists had identified eight species of helminths that infected ancestral Puebloans (Figure 5.1).

Aidan Cockburn’s insight into the origins of disease influenced the development of pathoecology in the archaeoparasitology of ancestral Pueblo sites. Cockburn (1967, 1971) argued that the evolution of infectious diseases followed human evolution and the development of human cultures. Inspired by Cockburn, Reinhard (1985a) compared the parasitic state of Colorado Plateau Archaic peoples to ancestral Puebloan sites. He verified Cockburn’s hypothesis that occasional infections
in hunter-gatherers became major health hazards in agricultural populations. Reinhard (1988) presented a number of pathoecological findings regarding the development of parasitic disease in ancestral Puebloans relative to earlier hunter-gatherers. Parasitism was limited in hunter-gatherers due to small band size, band mobility, diffuse regional populations, and the presence of natural anti-helminthics (worm poisons) in hunter-gatherer diets. Hunter-gatherer parasitism was promoted by the consumption of uncooked meat and insects. Parasitism was promoted in ancestral Puebloan communities by contaminated water sources, concentrated populations, a more sedentary lifestyle, crowded (apartment-style) living conditions, establishment of large latrines, activities centered on water (agriculture), and activities that expanded wetlands (including irrigation of all types).

By the 1990s, Reinhard (1992a) had identified wide variation in parasitism among ancestral Pueblo villages (Figure 5.2). At some settlements, parasitism was controlled, but others were overwhelmed by their pathogens. This topic was explored with a comparison of pinworm (Enterobius vermicularis) prevalence in coprolites (Reinhard 1988). The pinworm was chosen as an indicator of general infectious disease because it is transferred by person-to-person and by environmental contamination (Figure 5.3).

Over millions of years of mutual evolution with hominids and modern humans, pinworms have evolved multiple routes of infection, including anal-oral, hand-to-hand, and airborne routes. Pinworms are exceptionally remarkable among human parasites because the female worm wriggles out of the anus of her host at night to scatter her eggs. Once outside of the intestine, she disperses eggs by two different mechanisms. Two types of eggs are produced in two parts of the pinworm uterus: light and heavy. Heavy eggs are laid on the perianal folds with an irritant excretion. The resulting itching (pruritis) and nocturnal host scratching transfers the infective eggs to the host fingers. Other eggs are distributed by aerosol when the female's desiccated body bursts, which releases thousands of light eggs into the air. Ultimately, these light eggs contaminate the environment, settling on food, in water, and throughout the

Figure 5.1. Diagram showing the wide spectrum of parasites that infected ancestral Puebloans.
FIGURE 5.2. Map showing variation in percentages of pinworm parasitism among ancestral Pueblo villages.

FIGURE 5.3. Diagram showing modes of pinworm transmission to human hosts.

habitation. How long these eggs remain infective depends on warmth and humidity. In general, even in arid environments, human habitations have an elevated humidity. Thus, several infection routes result from the pinworms' nocturnal excursions. Retroinfection occurs when the eggs hatch on the perianal region, and the larvae wriggle back into the host. Hand-to-hand transfer of the eggs occurs when humans interact upon waking. Autoinfection occurs when humans eat food contaminated with the eggs from their own hands. Airborne infection occurs when humans inhale the eggs, or
when the air dissemination of eggs results in the contamination of food and water. Of course, other pathogens follow the same hand-to-hand, hand-to-mouth, and aerosol routes as pinworm infection. Therefore, high rates of pinworm prevalence suggest high rates of infection by other pathogens that are passed through the same modes of infection (see Figure 5.1).

Some ancestral Pueblo communities were extremely parasitized. In fact, some sites have the highest levels of pinworm infection recorded for ancient or modern peoples. In a modern clinical setting, only 5 percent of feces from pinworm-infected people are positive for pinworm eggs. The percentages of coprolites positive for pinworm from several sites far exceed this level. For example, 29 percent of the coprolites from Antelope House, 19 percent of those from Inscription House, and 21 percent of those from Chaco Canyon sites were positive for pinworm eggs. This indicates that pinworm parasitism was unavoidable, and that in all probability people had heavy infections. In such populations, pinworm infection is not just a nuisance, but reflects a serious health risk, particularly when one considers that other pathogens are spread by the same means.

Reinhard (1992a) showed that the prevalence of pinworm parasitism covaried with porotic hyperostosis prevalence at ancestral Pueblo sites where both coprolites and skeletons were studied (Figure 5.4). Porotic hyperostosis is an indicator of general skeletal pathology that has been used to assess maternal-infant health. The fact that these indicators of disease had a positive, statistically significant correlation underscores the use of pinworms as a general gauge of ancestral Pueblo disease state (Reinhard 1992a).

Pinworms are not very pathogenic but are a good proxy for the infectious disease environment (Reinhard 1996). Rates of pinworm infection at ancestral Pueblo and Fremont culture sites were explored by Hugot and his colleagues (1999). They found that sites in rockshelters without walled villages (some Glen Canyon sites) had the lowest levels of parasitism. Such sites had pinworm prevalence comparable to hunter-gatherers. Next, village

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**FIGURE 5.4.** Graph comparing pinworm parasitism with porotic hyperostosis prevalence for several southwestern locales. The chart shows that the prevalence of pinworm parasitism covaried with porotic hyperostosis prevalence at ancestral Pueblo sites where both coprolites and skeletons were studied (Reinhard 1992a).
sites outside of rockshelters had intermediate levels of parasitism. Finally, walled villages built within rockshelters had the highest prevalence of pinworm (see Figure 5.4). If we look at data from the Chacoan realm, we find that Chacoan great houses are anomalous: they include both the wormiest and healthiest sites. Salmon Pueblo has among the lowest prevalence values (7 percent). In contrast, Pueblo Bonito and Pueblo Alto in Chaco Canyon are among the highest (21 percent). Clearly, the pathoeconomy of great houses was defined by factors other than size. Puebloans living in great houses adapted their use of the structures in ways that either promoted or limited parasitism. The remainder of this chapter explores the factors that could have limited parasitism at Salmon relative to other great house communities.

**Chacoan Great Houses as Nidi for Infection**

Realizing that for parasitic disease to occur, all factors related to the survival and reproduction of the parasite must be present, Pavlovsky (1966) combined ecological factors into a predictive tool for infection. These can include vectors, reservoir hosts, humans, and favorable external environments. He defined a *nidus* as that portion of a natural geographic landscape that contains a community consisting of a pathogen, vectors, reservoir hosts, and recipient hosts, and that possesses an environment in which the pathogen can circulate. He further found that pathogens possessed nidality: the tendency of an infectious agent to occur in distinct nidi, such as being associated with particular geographic, climatic, or ecological conditions. Thus, a nidus is a focus of infection. For humans, a nidus can be as confined as a single room accessed by rodents carrying plague-infected fleas, or as large as an entire community and its agricultural use-area, as is the case for the transmission of hookworms.

Various types of parasites circulate in nidi. Temporary parasites, which live in the external environment and come to the host only to feed, include mosquitoes, chiggers, ticks, and leeches. In these species, every individual must have good dispersal capability and the ability to find hosts when needed. Also, they must possess attributes enabling them to survive in the external environment. Features of the host have less effect on survival and reproduction of these parasites.

Nidicolous parasites live in the host's immediate environment: in beds, walls, granaries, caves, rockshelters, and under floors. Fleas, mites, bedbugs, triatomid bugs, and the diseases transmitted by these bugs are examples of nidicolous parasites. They depend upon the host not only for food but for creation of their habitat.

Permanent parasites live on or in the host except when dispersing between hosts. These include most protozoa, roundworms, flukes, and tapeworms. They are completely dependent upon their host for food and all other environmental requirements.

**Factors Outside Great House Environments**

*Water Source, Giardiasis, and Amoebic Dysentery*  
Water sources in desert environments are foci for human activity and can therefore become nidi. As long as they are plentiful and flowing, and populations are not too concentrated around them, water sources are not necessarily a pathoeological factor in the spread of parasitism. However, when water sources are few in number and stagnant, and when populations aggregate around them, these sources often becomes contaminated, providing a nidus and becoming significant pathoeological problems.

*Giardia lamblia* has been found in ancestral Pueblo coprolites (Gonçalves et al. 2002). This parasite is not highly pathogenic in most adults. In fact, most infected people show no symptoms. However, when *G. lamblia* becomes established in stagnant water sources, it becomes a problem. It is most perilous to pregnant women and their babies. Disease in mothers and children is due to poor maternal nutrition caused by malabsorption, resulting in intrauterine growth retardation. *G. lamblia* causes malabsorption when the intestinal villi become blunted and the function of intestinal mucous di-
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minishes (Carden and MacLeod 1988). Clinical symptoms include cramps, watery diarrhea, nausea, vomiting, and sometimes fever. Among pregnant women who exhibit symptoms, \textit{G. lamblia} causes malabsorption and dehydration at a period when there is a need for accentuated nutritional requirements. Such women fall into a negative nutritional balance, as demonstrated by Carden and MacLeod (1988), who summarized the effects of \textit{G. lamblia} on the fetus and newborn. With protracted maternal infections, normal fetal development is impeded. With asymptomatic maternal infections, low birth weight and infant anemia are common (De Morais and Suzuki 1997). Generally, infants become infected after three months of age. Islam et al. (1988) found that some immunity is conveyed from mother to infant, but this immunity is not effective in infected infants. Immunity to \textit{G. lamblia} increases with age (Shetty et al. 1992). Thus, the pathology caused by \textit{G. lamblia} is most significant in infants and toddlers (Hjelt et al. 1992).

The epidemiology of giardiasis is well known (Taus et al. 1998; Hjelt et al. 1992; Harter et al. 1982). Sullivan et al. (1991) showed that giardiasis is highly prevalent in children with chronic diarrhea and malnutrition, and that giardiasis does not respond to standard therapeutic measures. Children who have low iron or vitamin B12 levels have more severe giardiasis symptoms (Awasthi and Pande 1997; Olivares et al. 2002). Subadults in the age range of 9 months to 11 years are most susceptible to infection, though infections can occur at 3 months of age. In developing nations, 91 percent of infants of infected mothers become infected by 6 months of age. Of infected infants, 86 percent have diarrhea. Infected people tend to live in dwellings with dirt floors, simple latrines, groundwater drinking sources, and close contact with dogs. These aspects of life were common at ancestral Pueblo villages (Reinhard 1996). In addition, person-to-person transmission of \textit{G. lamblia} is common (Birkhead and Vogt 1989; Black et al. 1977; Keystone et al. 1978). The parasite \textit{Entamoeba histolytica} also afflicted ancient Pueblo groups (Gonçalves et al. 2002). Relative to \textit{G. lamblia}, \textit{E. histolytica} causes more dramatic pathology, creating ulcerations in the large bowel or ileum. Amoebas can cause nodular granuloma formation, colitis, and diarrhea. The disease can become systemic and eventually an ulcerative disease of the large intestine, liver, lung, brain, or other organs. Amoebiasis can be symptomatic or even fatal during pregnancy (Abiyoue 1973; Lee 1929; Lewis and Antia 1969; Rivera 1972). Deaths that occur are due to a rapid onset of profuse diarrhea with dehydration and severe anemia. Premature delivery results from colitis, diarrhea, dehydration, ketosis, or shock (MacLeod and Carden 1988). Weigel et al. (1996) found that high \textit{E. histolytica} load in asymptomatic infections was associated with decreased maternal serum hemoglobin and hematocrit levels, and iron-deficiency anemia. Among women who had severe problems (spontaneous abortion, stillbirth, low-birthweight babies), there was a fourfold increase in the prevalence of amoebiasis relative to normal births (Czeizel et al. 1966). In infected but asymptomatic mothers, Weigel et al. (1996) found increased indicators of diminished intrauterine growth. Despite immunity conveyed by antibodies passed through the placenta and in milk, infants can become infected. When this happens, infants exhibit fever with severe watery, sometimes bloody, diarrhea. Colitis, appendicitis, intestinal rupture, and peritonitis result in a high mortality among infected infants (MacLeod and Carden 1988).

The Pueblo III occupation of Antelope House, at Canyon de Chelly in Arizona, is the best-documented case of an ancestral Pueblo village that suffered declining health due to water source nidi. Morris (1986) describes the pathoeological conditions that led to water contamination. Towards the end of the occupation, drought affected the region. As more distant water sources dried up, the population of Antelope House and Canyon de Chelly burgeoned. The increased population and decreased water resulted in contamination. Gonçalves et al. (2003) found both \textit{E. histolytica} and \textit{G. lamblia} in Antelope House coprolites. El-Naijar (1986; El-Naijar et al. 1976) found increased skeletal evidence of systemic disease during the Pueblo III occupation of Canyon de Chelly relative to other time periods. Thus, there is a relationship
between environmental stress, increased parasitism, and skeletal indicators of morbidity in mother and infants.

For Chacoan great houses, coprolites from Salmon Ruin were tested for *G. lamblia* with negative results (Wilson et al. 2006). The absence of giardiasis at Salmon is logical given the presence of a flowing water source (the San Juan River) within 200 m of the community. Given these conditions, there was little chance for contamination. No coprolites from Chacoan great houses have been tested for *E. histolytica.*

*Irrigation, Hygiene, and Hookworm*

Hookworm has been found in coprolites from Antelope House and Pueblo Bonito, but at no other ancestral Pueblo. Hookworm is the greatest parasitic threat to the mother, fetus, and infant. Iron-deficiency anemia resulting from intestinal blood loss is the major consequence of hookworm infection (Variyam and Banwell 1982; Ali et al. 1990). Treatment for this type of anemia is administration of iron supplements. According to Gilman (1982), development of hookworm-induced iron-deficiency anemia is dependent on the intensity of infection, the species of hookworm, and the ability of the host to resist infection and to maintain adequate stores of iron. Loss of blood is caused by direct ingestion of red blood cells and by tissue trauma produced by worm attachment and feeding.

The species that causes the more serious pathology and that has been identified in ancient New World remains is *Ancylostoma duodenale* (Allison et al. 1974). This is a fascinating, human-specific parasite that has evolved several infection modes and adaptations. Perhaps the most remarkable aspect of *A. duodenale* is its hypobiotic ability. Hypobiosis occurs when a parasite suspends its development in host tissues in a way that prevents a strong immunologic response. *A. duodenale* can go into hypobiosis in winter and come out of hypobiosis in summer. This is a significant adaptation because the females can lay their eggs in the season that is optimal for larval survival. The larvae hatch within a few days, exit the feces, and develop through three larval stages as free-living soil nematodes. Subsequently, as third-stage larvae, they locate human hosts and burrow through the skin. Also, *A. duodenale* can achieve transmammary and transplacental infection. Thus, fetuses and infants can be infected without ever coming in contact with contaminated soil.

Hookworm causes specific problems in pregnancy. One of the most common causes of death in labor in the developing world is cardiac failure from severe anemia attributed to hookworm infection (Cintron Villaronga 1967). As many as 90 percent of pregnant women are infected in endemic areas (Ananthakrishnan et al. 1997; Navitsky et al. 1998). Crompton and Whitehead (1993) present calculations comparing effects of hookworms on a nonpregnant woman versus a pregnant woman. The model predicts that hookworms more rapidly deplete stored iron, with a rapid effect on red cell density per milliliter of blood in pregnant women. MacLeod (1988) verified this model from the clinical perspective. Each worm consumes 0.27 ml of blood per day, and only 20 weeks after initial infection, hypochromic, macrocytic anemia can develop. The minor symptoms of infection are indistinguishable from complaints of pregnancy (epigastric pain, heartburn, and so on). However, with moderate infections there is low-grade fever, fatigue, dyspnea, heart palpitations, flow murmurs, and anemia. In heavy infections, constipation or diarrhea, jaundice, emaciation, cardiac failure, or pre-eclampsia occur. If a woman survives labor, she cannot recover as easily from post-partum hemorrhage, which can contribute to maternal death.

Hookworms also have a negative impact on fetuses and infants (MacLeod 1988). Abortion, stillbirth, and premature labor are associated with severe hookworm infection. Women infected with hookworm give birth to low-birth-weight infants (a 2 percent hematocrit drop in the mother correlates to a 100 gram decline in birth weight). Because of transplacental migration, infants are infected at birth. Severe and sometimes fatal hemorrhage occurs in infants less than four months of age. Chaudhary and Jayaswal (1984) first described an anemic infant resulting from transplacental migration. In a survey of hundreds of transplacental-infected infants in China, Yu et al. (1995) defined the symptoms of transplacental infection, which include
bloody stools, melena, anorexia, listlessness, and edema. *A. duodenale* was the species implicated in these types of infection. Transplacental migration is not rare. Nwosu (1981) documented that 10 percent of 316 Nigerian newborns (four to five weeks old) were infected with *A. duodenale*. Transmammary infections from mother to infant also occur, with similar health results (MacLeod 1988). Studies of many groups from around the world link hookworm disease, especially from *A. duodenale*, to severe iron deficiency and anemia in children (Albonico 1998; Stoltzfus et al. 1998).

Hookworm infection is dependent on moisture, shade, and warmth. The Colorado Plateau is normally too dry to promote infection, and in historic times hookworm was unknown. Thus, the discovery in Anasazi sites of hookworm eggs and another parasite with a similar infection mode, *Strongyloides stercoralis*, was surprising (Reinhard 1985; Reinhard et al. 1987). Clearly, ancestral Puebloans created microenvironment nidi where parasite larvae could hatch and mature in moist, warm, and shaded soil. Puebloans also spent time in these nidi, where they spread eggs and became infected by larvae. It is very likely that irrigated fields were hookworm and *S. stercoralis* nidi.

Studies of hand and foot washing in Bengal show that the larvae can be washed off easily within a few minutes of coming into contact with the skin. The infection occurred in defecation grounds, and washing was prescribed by religious rules (Nawalinski et al. 1978). We do not know if ancestral Puebloans had similar rules, but it is very likely that hookworms could penetrate the skin of Puebloan farmers as they worked in irrigated fields. If the division of labor resulted in men working more in irrigated fields, it may be that they were more often infected than women.

**Internal Great House Factors**

*Apartment, Plazas, Kivas, and Second-Floor Living*

Pat Horne (1985) attributed the remarkable pinworm prevalence among ancestral Pueblos to crowded, apartment-style living conditions. As noted above, Hugot et al. (1999) elaborated this theme by detailing the aspects of architecture and village location that aggravated pinworm infection. Although pinworm prevalence was highest in walled villages built within rockshelters, it is important to note that no thoroughly studied ancestral Pueblo site has been found to be pinworm free. Related cultures also were infected. The earliest Basketmaker II coprolites from Bighorn Cave (Grand Gulch, Utah) have a prevalence of 25 percent. Later, the diffuse populations of ancestral Pueblo and Fremont in the Glen Canyon area were infected. Even the Sinagua inhabitants of Elden Pueblo were infected (Hevly et al. 1979). The infections resulted from air humidified by human activity and contaminated with floating eggs within confined spaces.

Although pinworm infection tends to be asymptomatic, a high prevalence of heavy infections can result in severe pathology, including secondary bacterial infections in juveniles. However, to my mind the real relevance of pinworm relates to other diseases that are also airborne transferred. For the ancestral Pueblos, tuberculosis was the other airborne disease. Among the most poignant epidemiological descriptions of the tuberculosis threat to Pueblos, is applicable to pinworms as well, is provided by Fink (1985), who examined details of Anasazi life such as communal living, lack of knowledge of germ theory, and cramped living conditions that promoted infectious diseases.

The San Juan period at Salmon Pueblo is enigmatic in the context of pinworm prevalence at other sites. Only 7 percent of 112 coprolites studied contained pinworm eggs—approximately one-fifth the prevalence recorded for other Pueblo III sites, including Pueblo Alto and Pueblo Bonito. A probable explanation for this relates to Paul Reed’s (2006c) finding that the San Juan residents of Salmon used primarily the second-floor rooms for human activities. Air conditions in the lowest rooms, and those closest to the windowless rear wall, would have been more likely to increase pinworm infection. Such rooms would have had the most stagnant and humid air, promoting airborne infection with pathogens. Use of hearths in second-floor rooms would have produced a much less humid environment, and any rooms opening towards the large Salmon plaza would have been healthier.
with ventilation from the dry, relatively breezy air outside the pueblo.

Subterranean rooms such as kivas would have provided the primary vector for transmitting airborne disease. In kivas, the air would have been humid, and the air flow around the ventilator would have been sufficient to transmit particles around the room, but not to remove infectious particles from the structure. This would explain, in part, why Basketmaker groups, who lived in pithouses with little or no circulation, developed a high prevalence of infection. After Basketmaker times, however, kivas would have been the most likely subterranean nidi of pinworm dissemination. One way to test this hypothesis is through analysis and comparison of sediment samples from kiva, living room, and milling room floors.

By far the healthiest place to work and live at Salmon was outside, in the plaza and on rooftops. Sunlight would have desiccated and radiated pathogens, thereby reducing the number of infectious airborne contaminants, and the clean air moving across the plaza would have provided people with alternate, healthy air. Humidity also was undoubtedly much lower in these open spaces compared to confined rooms and kivas.

Sanitation and Hymenolepidid Tapeworm Infection

With regard to tapeworms, there are two main types of hosts. The definitive host is the animal in which tapeworms accomplish sexual reproduction, whereas intermediate hosts are infected with nonsexual stages. Usually, tapeworm infections in humans occur through ingestion of infected intermediate hosts.

The most common tapeworm (*Hymenolepis nana*) found in ancestral Puebloan coprolites took a different infectious pathway. This tiny tapeworm evolved the ability to use an intestinal villus as its intermediate host. The larvae emerge and become adults in the intestinal lumen, thus using humans as both their definitive and intermediate hosts.

Tapeworms have two methods of laying eggs. The tapeworm's anterior end, the scolex, attaches to the intestinal wall. Proglottids are the sexually reproducing tapeworm organs that develop from the scolex. As the they progress downward along the length of the tapeworm, their ovaries and testes mature, fertilization occurs, and eggs mature. When a proglottid is filled with mature eggs, it is said to be gravid. In some tapeworms, such as those that infect humans who eat undercooked fish, the eggs are laid through gravid proglottid genital pores. In other species, such as those that infect humans who eat undercooked beef, entire gravid proglottids break off of the tapeworm. These proglottids are partly motile and squirm their way out of the host body.

*Hymenolepis* lays eggs through genital pores, and these eggs are infective when they pass into the environment. Although they have been found in Canyon de Chelly coprolites, they have not been found in Chacoan great houses.

**Conclusion**

The Chacoan great houses provided many potential nidi for temporary, permanent, and nidiculous parasites. Great house inhabitants created or eliminated nidi through different activities and practices. Although there is was no way to completely eliminate the transmission of permanent parasites, some aspects of life at Salmon reduced the prevalence of pinworm relative to other great houses. A lower population density, among other factors, would have accomplished this.

The absence of fecal-borne parasitism indicates that nidi of fecal exposure were eliminated at Salmon Ruin through the use of specific rooms as latrines, an effective way of stopping the spread of parasites such as *Giardia lamblia*.

Nidi external to Salmon Ruin where hookworm and *S. stercoralis* transmission could have taken place did not exist. This was probably due to a different type of irrigation (perhaps using the free-flowing San Juan River) and gardening relative to that of Pueblo Alto and Pueblo Bonito, where hookworms did infect humans.

In the future, more extensive analysis of ancestral Pueblo coprolites should be conducted using a variety of research methods. Some sites, such as Antelope House, are currently the focus of molecular, immunological, and microscopic analysis. Other sites, such as those in Glen Canyon, were studied
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only through microscopy and could yield beneficial data with newer approaches. Once a range of meth-ods has been applied to a larger sample of sites, we will be able construct a more complete picture of ancestral Pueblo parasite pathoecology.

In addition, parasitological methods must be developed for analysis of remains other than coprolites. Many nidiculous pathogens such as bed bugs and kissing bugs live in walls and roofing. There-fore, archaeological excavations should include soil samples from architectural remains to search for the presence of insect exoskeletons. Also, analysis of trash sediments for all types of parasites must be developed in order to obtain parasitological data from sites that lack coprolites. Once these ap-proaches are developed, then a true archaeology of parasitic disease will emerge.
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