Part I - Parasites, Human Hosts, and the Environment

8. Parasites as Markers of Prehistoric Migrations

Adauto Araújo
Karl Jan Reinhard
Scott L. Gardner
Luiz Fernando Ferreira

SciELO Books / SciELO Livros / SciELO Libros

ARAÚJO, A., *et al.* Parasites as Markers of Prehistoric Migrations. In: FERREIRA, L.F., REINHARD, K.J., and ARAÚJO, A., ed. *Foundations of Paleoparasitology* [online]. Rio de Janeiro: Editora FIOCRUZ, 2014, pp. 141-150. ISBN: 978-85-7541-598-6. Available from: doi: [10.7476/9788575415986.0010](https://doi.org/10.7476/9788575415986.0010). Also available in ePUB from: <http://books.scielo.org/id/zngnn/epub/ferreira-9788575415986.epub>.

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

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

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

8

Parasites as Markers of Prehistoric Migrations

Adauto Araújo • Karl Jan Reinhard • Scott L. Gardner • Luiz Fernando Ferreira

New theories on the peopling of the Americas have been supported by clinical research, field experiments, and laboratory tests. Olympio da Fonseca Filho (1972) made a particularly important contribution to the study of parasitism and prehistoric migrations, and his pioneering study happened to be published in Portuguese.

Curiously, Fonseca Filho did not refer to parasite findings in archaeological material, because at the time of his work there were already some articles published on mummies of South America (Pizzi & Schenone, 1954). His work was published in the 1970s (the first edition was in 1970, with a second edition two years later, following an abstract published in 1968 in a Portuguese-language scientific journal),

Fonseca Filho even quoted Thomas W M. Cameron's inaugural address as president of the American Society of Parasitology, in which he stated, "Parasites leave no skeletons, and attempts to trace their antiquity must rest partly on their modern anatomy and partly on the paleontology of their hosts." (1950: 20). However, the work of Fonseca Filho is fundamental for any study on the origin and evolution of parasitic infections in antiquity, unparalleled in the world literature. The publication raised questions on the presence of certain parasitic infections among pre-Columbian indigenous groups, in contrast to then-prevailing positions. Some scientists at the time attributed the origin of nearly all parasitic diseases in the Americas to the arrival of the Africans (Freitas, 1935). One cannot fail to mention the letters by Américo Vespúcio and Pero Vaz de Caminha, who encountered indigenous people living in what the Europeans considered Paradise. The same happened with the Jesuits, who only later discovered how different reality was.

The first articles referring to parasites and human migrations included the work of Ewing (1924), comparing nits and adult lice found in the hair of mummies and on scalps of Native Americans deposited in museums. Ewing (1926) proposed new species corresponding to geographic regions and human "races" (according to the prevailing concept of his time), attributing morphological adaptations to the lice species based on the characteristics of hair shafts in different individuals and populations. Human migrations purportedly spread the human louse species to other continents, where it subsequently underwent changes until diversifying into new species or subspecies.

Olympio da Fonseca referred to geographic and comparative parasitology as a new method for studying human prehistory. He began this line of research in 1924, as he recalled in the preface to his book, an anthology of his work (Fonseca Filho, 1972). He refocused on the question of the human louse species and discussed the relations between hosts and their origin on the American continent, however with this species having spread across the other continents from a single focus. He discussed *Tinea imbricata*, a very peculiar dermatosis of the native islanders of Oceania, but also of the Asian continent. He then commented on the travel diaries of Marshall Cândido Mariano da Silva Rondon and Edgar Roquette-Pinto, who described typical lesions of this mycosis among the Nambikwara in Brazil. Fonseca Filho (1924, 1925) visited indigenous groups in Rondônia, describing the skin lesions and isolating the etiological agent, which was described at the time as a new species with the name *Endodermophyton roquettei*. He went on to discuss the dispersal of this parasitic infection from Oceania and Southwest Asia to the American continent in pre-Columbian times (Fonseca, Filho, 1930). His line of argument included other parasitic infections such as epidemic exanthematic typhus and murine typhus, as well as black piedra, a superficial mycosis of the hair shaft.

However, the main contribution by Fonseca Filho (1972) to the emergence of paleoparasitology was his extensive discussion of his reasoning for the antiquity of hookworm infection in the Americas, in an attempt to prove pre-Columbian maritime contacts. He started with the findings by Darling (1921) and Soper (1927), who found a proportion of 13:1 between *Ancylostoma duodenale* and *Necator americanus* among the Lengua Indians of the Chaco Region in Paraguay. The proportion was the opposite of that found in settlers of European origin. Darling and Soper argued that such a proportion was strongly indicative of the presence of *Ancylostoma duodenale* infection on the American continent prior to the arrival of Europeans and Africans, suggesting its introduction into the Americas by pre-Columbian transpacific migrations.

Olympio da Fonseca Filho died while still an active researcher at the Oswaldo Cruz Foundation, a year before the creation of the institution's Paleoparasitology Department (Ferreira, Araújo & Confalonieri, 1979).

THE DISCOVERY AND PEOPLING OF THE NEW WORLD

A longstanding and intense debate has focused on the arrival of human populations in the New World (Neves, Bernardo & Okumura, 2007), with studies comparing ancient skeletons found in South American archaeological sites, seeking data on their antiquity and the determination of their sex (Hubbe et al., 2007). Ever since the discovery of the New World, Europeans sought explanations on the origin of the native peoples, with strong religious connotations: Where could these people have come from? From which branch of Noah did they descend after the Great Flood? (Laming-Emperaire, 1980). During exploration of the new territory, the natives soon came to be seen by the colonizers no longer as inhabitants of the Garden of Eden, but as soulless creatures, subject to being enslaved and hunted like any other animal. It was not until Pope Paul III issued his Papal Bull in 1537 that the natives were restored to the category of humans, which however failed to avoid their extermination on the continent. Yet questions and investigations always remained as to their origin and antiquity.

Aleš Hrdlicka (1915) conducted the first scientifically based attempts in this direction. Hrdlicka was a Czech scientist whose family had settled in the United States in 1881, when he was 13. He graduated in medicine in the United States and anthropology in France. He founded the *American Journal of Physical Anthropology*. Since then, various disciplines have contributed to knowledge on the peopling of the Americas. Some challenged the accepted theory that the only way prehistoric Asian peoples reached the Americas was by crossing the Bering Region more than 15,000 years ago, when climatic conditions created the "Bering Land Bridge" between Siberia and Alaska.

Alternative hypotheses were proposed by other researchers, such as French physician and anthropologist Paul Rivet, founder of various museums in France (especially the Musée de l'Homme in Paris) and elsewhere in world. Rivet visited Brazil and met with Paulo Duarte and Olympio da Fonseca Filho at the University of São Paulo. He raised the hypothesis of transpacific migrations to the Americas, based on similarities in artifacts found on the American and Asian continents (Rivet, 1925).

Another researcher that proposed an alternative theory to the Bering Crossing was Portuguese physician and anthropologist António Augusto Esteves Mendes-Correia, who defended the hypothesis of the passage of human groups from Africa to the Americas, crossing land on Antarctica (Mendes-Correia, 1926).

Thor Heyerdahl's famous voyages in the 1940s crossed the Pacific Ocean from Peru to Polynesia and to the Galapagos Islands and Easter Island using replicas of rafts built by ancient South Americans. Heyerdahl was born in Norway in 1914 and became a great navigator and archaeologist, interested in the peopling of Polynesia (Heyerdahl, 1958).

In fact, human groups did use alternative paths, thereby avoiding the extreme cold in the Arctic. From a parasitological perspective, this was demonstrated by findings of intestinal parasites in archaeological sites in South America and North America. The life cycle of some intestinal parasites that are exclusive to the human species could not have been maintained in the populations that crossed from Siberia to Alaska by the Bering Route.

DISEASES IN PREHISTORIC AMERICA

Which diseases existed in Pre-Columbian America, and which were introduced by the European conquerors, either themselves or through the African slave trade somewhat later (Williams, 1909; Hoeppli, 1959; Cockburn, 1963, 1967)? The answers to these questions were traditionally based on speculative data. Authors like Freitas (1935) referred to the absence of the majority of parasitic diseases among South American Indians, attributing to the African slave trade the introduction of practically all the parasitic infections known at his time, based on circumstantial inferences. All this purportedly occurred as if human groups had not crossed and conquered new territories before the great navigations, as if the land had not been peopled before.

Other questions demanded answers: once the infections that were considered to exist in Pre-Columbian America had been introduced, which route(s) did infected individuals take and how were the infections spread across the continent?

Hookworm infection became the most widely used example for the possibility of transoceanic migrations or contacts between populations of the Old and New Worlds. According to this theory, the hookworm's life cycle would have been interrupted by the passage of human hosts through the "Arctic filter" in the path across Beringia (Stewart, 1960). But other parasites from the group of geo-helminths also show evidence of alternative routes, as discussed later in this chapter.

Arguments for the pre-Columbian presence of hookworm infection began (as mentioned above) on the basis of the different proportions between the two most common etiological agents, *Ancylostoma duodenale* and *Necator americanus*, among an indigenous people of Paraguay (Darling, 1921; Soper, 1927; Manter, 1967; Fonseca Filho, 1972).

Determination of the hookworm species is fundamental for studies on the origin of populations. Even in human groups that are now isolated, contacts may have occurred with other groups in the past, which would have been sufficient for contamination by a given parasite, in this case a hookworm species (Araújo et al., 1988). The assumption was that an indigenous group lived in proximity with Europeans during a short period at the time of contact, and

that the group was contaminated by hookworms. If the indigenous group was forced to move inland, isolating itself from contact due to wars or cultural differences, it could have carried the infection and potentially contaminated other groups inhabiting the hinterlands.

Paleoparasitology made a decisive contribution to answering this question. The finding of adult worms in the intestine of a Peruvian mummy from 900 BC (Allison et al., 1974) and hookworm larvae and eggs found in human coprolites in an archaeological site in Brazil dated to $4,390 \pm 120$ to 430 ± 70 BP (Ferreira, Araújo & Confalonieri, 1980, 1983) proved that hookworm infection was present in indigenous peoples in pre-Columbian America, which allowed the resumption of discussion on its origin (Araújo, 1980).

Based on these findings, Araújo, Ferreira & Confalonieri (1981) concluded that only seafaring migrations would have been capable of introducing hookworms into America, as proposed by Meggers & Evans (1966), dating the introduction to 3,200 BC.

Hookworm eggs and larvae have been found in archaeological sites worldwide (Gonçalves, Araújo & Ferreira, 2003). The oldest dates are in South America. Human coprolites positive for hookworm eggs, dated $7,230 \pm 80$ BP, were found in the Pedra Furada archaeological site in Piauí State, Northeast Brazil (Ferreira et al., 1987). Hookworm eggs were also found in human coprolites dated to c. 5,000 BP in Minas Gerais State, Brazil (Ferreira, Araújo & Confalonieri, 1982), and in Tiliviche, Chile, dated to 6,000 BP (Gonçalves, Araújo & Ferreira, 2003), thus confirming the antiquity of this parasitic infection in South America.

North America has yielded one finding with a pre-Columbian date, c. $2,177 \pm 145$ BP (Faulkner & Patton, 2001).

In Europe, hookworm eggs in human coprolites and latrine sediments have been dated from 5,600 to 4,400 BP, in France (Dommelier-Espejo, 2001), and in the Czech Republic, dated to 3,600 BP (Sebela, Vojtková & Vojtek, 1990 apud Aspöck, Auer & Pischer, 1999).

Hookworm larvae only evolve to the infective stage in environments with very specific temperatures (Rey, 2008; Roberts & Janovy Jr., 2009). Current data and paleoclimatic models both show that the routes from North Asia to the far North of North America never provided an environment with such climatic conditions (Montenegro et al., 2006).

We use the paleoparasitological record from a complex of intestinal parasites to challenge the hypothesis that overland migration through Beringia some 13,000 years ago was the only human migratory flow prior to the arrival of Europeans.

Assuming for a moment that this was the only migratory flow, the pre-Columbian presence of hookworms on the American continent could be explained by the following scenarios: a) migrations across extremely cold regions, where the parasite's life cycle could not have been maintained, occurred so rapidly that the adult worms persisted in the human hosts. All this necessarily occurred in the limited period of eight years, corresponding to the mean life span of adult worms in the intestine of the human host (Cheng, 1986); b) migrants made stops and were re-infected at specific sites where the prevailing temperature was sufficiently high for the larvae to develop; and/or c) the hookworm population brought by migrants was different from the present, with larvae capable of developing at lower temperatures.

We can rule out scenario 'c', because no hookworm varieties could exist that would be capable of surviving such cold temperatures, either in Asia or the Americas. Scenario 'b' implies that the migrants routinely used shelters where the temperatures were significantly higher than in the outdoor environment, specifically at the higher latitudes. Such conditions would have been highly unlikely in the caves on route from Siberia to Alaska. Even at present, temperatures inside such caves are significantly lower than 17-20°C, the lowest survival threshold for hookworms.

As for scenario 'a', no precedent exists for the speed at which prehistoric migrants would have had to walk from Siberia to Alaska. Nomadic bands of hunter-gatherers would have left regions of Asia where the hookworm life cycle would have been maintained and walked directly to North America, to regions with a sufficiently warm climate (Montenegro et al., 2006).

STRONGYLOIDES STERCORALIS

The presence of another parasite, *Strongyloides stercoralis* (threadworm), in prehistoric America has demanded explanations for years (Reinhard, 1985; Dorris, Viney & Blaxter, 2002). The threadworm's dual life cycle makes it highly peculiar among human parasites. The cycle involves alternating generations, free-living and parasitic. Females are parthenogenetic, and in the environment outside the host they produce larvae that develop into free-living males or females. After copulation, new larval forms emerge, undergoing two rhabditiform larval stages until developing into new free-living adults. We now know that *Strongyloides stercoralis* has only one free-living generation. For unknown reasons, some first-stage rhabditiform larvae develop into another type, known as filariform larvae. The latter are highly active, capable of remaining in the soil for many days, but they only complete their evolution when they find a new host (Lok, 2007; Rey, 2008).

Only parthenogenetic females are found in the human intestine, particularly in the duodenal mucosa and initial portions of the jejunum. The eggs are deposited in the mucosa and soon release larvae, excreted in the stool. These larvae can develop through a direct or indirect life cycle.

In the direct cycle, rhabditiform larvae excreted in the stool become infective filariform larvae. This can occur in the soil, on the skin of the perineum, or in the host's own intestine. In the indirect cycle, after successive transformations in the soil, rhabditiform larvae become free-living males and females. The females deposit eggs that produce rhabditiform larvae, which finally develop into infective filariform larvae. Both cases can be a factor for maintaining infection in the host (Lok, 2007; Rey, 2008).

Threadworm infection is currently endemic in the tropics and subtropics. The archaeological record shows threadworms in three prehistoric American sites, all in the Southwest United States (Hall, 1972; Reinhard, Ambler & McGuffie, 1985; Reinhard, 1990). As with *Trichuris trichiura* and hookworm, the introduction of *Strongyloides stercoralis* infection into the Americas would not have been consistent with human migrations via Beringia.

EVIDENCE OF MIGRATIONS BASED ON A COMPLEX OF PARASITES

As discussed previously, parasites are defined as biological species or gene sequences capable of reproducing and that find their ecological niche in other species. They are thus subject to the same biological pressures of natural selection (Araújo et al., 2003). Like all biological species, parasites could not emerge simultaneously in different geographic regions. The parasite species currently existing in humans consist of parasites inherited from ancestors, as well as parasites acquired over the process of human biological and social evolution.

Criticism has been raised against the paleoparasitological evidence for only one of the parasites mentioned above (Fuller, 1997). Analysis of the three species of nematodes, namely human hookworms, *Trichuris trichiura*, and *Strongyloides stercoralis* (all geo-helminths), helps support the hypothesis of transpacific prehistoric human migrations (Reinhard et al., 2001).

Hawdon & Johnston (1996) argue that hookworms have hypobiotic potential capable of allowing their migration across the Arctic route. Hypobiosis is the capacity of hookworm larvae to remain viable in tissues until favorable conditions stimulate the resumption of their biological cycle. This argument fails to hold up if one considers the passage from Siberia to Alaska, when human groups dispersed slowly across the region, taking hundreds of years.

Hypobiosis does not exist in trichurids, yet evidence remains for trichurids in prehistoric New World populations. Even considering the durability of *Trichuris* eggs, the cold Arctic conditions could not have allowed their survival and evolution in the soil.

The possibility of autoinfection with *Strongyloides stercoralis* favors the persistence of this parasitic infection for several years in the human host after the initial infection, but this occurs mainly in the severe forms and with host immunodeficiency. Thus, the parasite's natural cycle would not explain its persistence throughout the migratory process in the peopling of the Americas.

Combined, the three intestinal parasites require a given type of soil and favorable temperature, which would have been impossible in Beringia during the long trek by their human hosts from the tropics to the tropics, i.e., from Asia to the Americas.

The parasitological evidence points to an alternative human migratory route during prehistoric times. People infected with geo-helminths could have reached the Pacific Coast of the Americas by crossing the ocean in boats or rafts. They may not have created new colonies, but they infected persons that already lived in the Americas. Since these individuals probably had the same Asian origin, no outstanding genetic trace remained, but only their parasites. These ocean crossings date to more than 7,000 BP (Ferreira et al., 1987).

PINWORM INFECTION IN PREHISTORIC AMERICA

Pinworm eggs are common in archaeological sites in various parts of the Americas. *Enterobius vermicularis* is the species found among the oldest prehistoric populations of the Americas (Hall, 1972). More than any other parasite, pinworm phylogeny is consistent when associated with primate phylogeny (Hugot et al., 1999; Sorci et al., 2003). This shows that pinworms and their primate hosts evolved in parallel. Genetic drift occurred in pinworm species as human populations dispersed geographically. Divergence and drift resulted in the emergence of at least one new species, *Enterobius gregori*, in human populations in Asia and Africa (Hugot, 1999).

Alena Iñíguez et al (2002, 2003) investigated the possibility that genetic drift occurred in pinworms in different parts of the Americas. They raised the hypothesis that human migration across Beringia brought a different strain of *Enterobius vermicularis* than migrations by other routes. They demonstrated differences in the parasite's genome sequences recovered from archaeological sites in North America and Chile, and thus pointed to different origins of *Enterobius vermicularis* strains.

CONCLUSIONS

How did parasites reach the New World? Montenegro et al (2006) tested the hypothesis that migrations occurred over a brief period, allowing these parasites (adapted to the tropical and subtropical climate) to be brought from the Old World to the Americas. The distribution of hookworms, *Trichuris trichiura*, and *Strongyloides stercoralis* in prehistoric America was also tested with a coastal migration model, along the North of the continent.

Montenegro et al (2006) used hookworm findings in archaeological material, climatic data, and paleoclimatic modeling to test the hypothesis that human groups from areas in Asia consistent with the hookworm life cycle crossed Beringia quickly enough to maintain the infection and introduce it into the Americas.

The authors used their model to test the hypothesis that before European contact, all inhabitants of the Americas (except the Arctic and Subarctic) descended from migrants to the continent using inland terrestrial routes, across the land and ice bridge of Beringia some 13,000 years ago.

Various authors have gradually used paleoparasitological data for proposals on the peopling of the Americas. Thus, Sorenson & Johannessen (2006) used paleoparasitological data as the basis for their arguments, combined with genetics, botany, and the knowledge of agriculture among ancient peoples as new evidence of prehistoric seafaring migrations. Their results showed that the ancient migrant peoples that used the route across Beringia to North America did not cross this environment (hostile to hookworm survival) quickly enough to introduce the infection into prehistoric America. Montenegro et al (2006) contended that introduction of hookworms into the Americas by overland migrations some 13,000 years ago could only have occurred under extraordinary conditions, and even then at a speed of migration inconsistent with what we know from the continent's archaeology. They concluded that although migration of the Clovis culture (North American prehistoric culture) may have been the first, it was not the only migratory wave to the Americas. Based on the paleoclimatic and paleoparasitological evidence, they concluded that other migratory routes may have been used, such as costal or transoceanic navigation.

Paleoparasitological data can be a highly useful source for specialists and researchers on the peopling of the Americas (Santos, Leite & Santos, 2010). The parasites discussed in this chapter are excellent markers for tracing human migrations in the past (Araújo, Reinhard & Ferreira, 2008; Araújo et al., 2008).

REFERENCES

- ALLISON, M. J. et al. A case of hookworm infestation in a pre-Columbian American. *American Journal of Physical Anthropology*, 41: 103-106, 1974.
- ARAÚJO, A. *Contribuição ao Estudo de Parasitos Encontrados em Material Arqueológico no Brasil*, 1980. Master's thesis, Rio de Janeiro: Instituto Oswaldo Cruz, Fundação Oswaldo Cruz.
- 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: 873-881, 1981.
- ARAÚJO, A.; REINHARD, K. & FERREIRA, L. F. Parasite findings in archaeological remains: diagnosis and interpretation. *Quaternary International*, 174: 1-4, 2008.
- ARAÚJO, A. et al. Hookworm and the peopling of the Americas. *Cadernos de Saúde Pública*, 2: 226-233, 1988.
- ARAÚJO, A. et al. Parasitism, the diversity of life, and paleoparasitology. *Memórias do Instituto Oswaldo Cruz*, 98, supl. 1: 5-11, 2003.
- ARAÚJO, A. et al. Parasites as probes for prehistoric migrations? *Trends in Parasitology*, 24: 112-115, 2008.
- ASPOCK, H.; AUER, H. & PICHER, O. Parasites and parasitic diseases in prehistoric human populations in Central Europe. *Helminthologia*, 36: 139-145, 1999.
- CAMERON, T. W. M. Parasitology and evolution. Presidential Address. *Transactions of the Royal Society of Canada*, S. 3(44), section 5, 1: 20, 1950.
- CHENG, T. C. *General Parasitology*. Orlando: Academic Press, 1986.

- COCKBURN, T. A. *The Evolution and Eradication of Infectious Diseases*. Baltimore: Johns Hopkins Press, 1963.
- COCKBURN, T. A. *Infectious Diseases: their evolution and eradication*. Thomas Springfield, 1967.
- DARLING, S.T. Observations on the geographical and ethnological distribution of hookworms. *Parasitology*, 12: 217-233, 1921.
- DOMMELIER-ESPEJO, S. *Contribution à l'Étude Paléoparasitologique des Sites Néolithiques en Environnement Lacustre dans les Domaines Jurassien et Péri-Alpin*, 2001. Thesis, Reims: Université de Reims.
- DORRIS, M.; VINEY, M. E. & BLAXTER, M. L. Molecular phylogenetic analysis of the genus *Strongyloides* and related nematodes. *International Journal for Parasitology*, 32: 1.507-1.517, 2002.
- EWING, H. E. Lice from human mummies. *Science*, 60: 389-390, 1924.
- EWING, H. E. A revision of the American lice of the genus *Pediculus*, together with a consideration of the significance of their geographical and host distribution. *Proceedings of the United States National Museum*, 68: 1-30, 1926.
- FAULKNER, C. T. & PATTON, S. Pre-Columbian hookworm evidence from Tennessee: a response to Fuller (1997). *Medical Anthropology*, 20: 92-96, 2001.
- FERREIRA, L. F.; ARAÚJO, A. & CONFALONIERI, U. Subsídios para a Paleoparasitologia do Brasil – I. Parasitos encontrados em coprólitos no município de Unaí, Minas Gerais. In: CONGRESSO DA SOCIEDADE BRASILEIRA DE PARASITOLOGIA, 1979, Campinas. *Anais...* Campinas, 1979.
- FERREIRA, L. F.; ARAÚJO, A. & CONFALONIERI, U. Finding of helminth eggs in human coprolites from Unaí, Minas Gerais, Brazil. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, 76: 798-800, 1980.
- FERREIRA, L. F.; ARAÚJO, A. & CONFALONIERI, U. Subsídios para a paleoparasitologia do Brasil – IV. Sobre a presença de ovos de ancilostomídeos e *Trichuris* em múmia encontrada na Gruta do Gentio II – Minas Gerais, Brasil. In: CONGRESSO DA SOCIEDADE BRASILEIRA DE PARASITOLOGIA, VII, 1982, Porto Alegre. *Resumos...* Porto Alegre, 1982.
- 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: 65-67, 1983.
- FERREIRA, L. F. et al. Encontro de ovos de ancilostomídeos em coprólitos humanos datados de 7.230 ± 80 anos, Piauí, Brasil. *Anais da Academia Brasileira de Ciências*, 59: 280-281, 1987.
- FONSECA FILHO, O. Sobre a etiologia do 'chimberê', dermatose endêmica dos índios do rio S. Miguel. *Sciencia Médica*, 2: 1-3, 1924.
- FONSECA FILHO, O. Sur l'étiologie du chimbéré, nouveau type de dermatose endémique des Indiens du fleuve S. Miguel, *Endodermophyton roquettei*. *Comptes Rendus des Séances de la Société de Biologie*, 92: 305-306, 1925.
- FONSECA FILHO, O. Afinidades parasitológicas e clínicas entre o Tokelau da Polinésia e o chimberê dos indígenas de Matto Grosso. *Boletim da Academia Nacional de Medicina*, 102: 212-228, 1930.
- FONSECA FILHO, O. *Parasitismo e Migrações Humanas Pré-históricas*. Rio de Janeiro: Mauro Familiar, 1972.
- FREITAS, O. *Doenças Africanas no Brasil*. São Paulo: Companhia Editora Nacional, 1935. v. 51. (Brasiliana, 51)
- FULLER, K. Hookworm: not a pre-Columbian pathogen. *Medical Anthropology*, 17: 297-308, 1997.
- GONÇALVES, M. L.; ARAÚJO, A. & FERREIRA, L. F. Human intestinal parasites in the past: new findings and a review. *Memórias do Instituto Oswaldo Cruz*, 98, supl. 1: 103-118, 2003.
- HALL, H. J. *Diet and Disease at Clyde's Cavern*, 1972. Thesis, Salt Lake City: Department of Anthropology, University of Utah.
- HAWDON, J. M. & JOHNSTON, S. A. Hookworms in the Americas: an alternative to trans-Pacific contact. *Parasitology Today*, 12: 72-74, 1996.
- HEYERDAHL, T. *Aku-Aku: The Secret of Easter Island*. London: George Allen & Unwin, 1958.

- HOEPLI, R. *Parasites and Parasitic Infection in Early Medicine and Science*. Singapore: University of Malaya Press, 1959.
- HRDLICKA, A. The peopling of America. *Journal of Heredity*, 6: 79-91, 1915.
- HUBBE, M. et al. Brief communication: 'Zuzu' strikes again: morphological affinities of the Early Holocene human skeleton from Toca dos Coqueiros, Piauí, Brasil. *American Journal of Physical Anthropology*, 134: 285-291, 2007.
- HUGOT, J. P. Primates and their pinworm parasites: the Cameron hypothesis revisited. *Systematic Biology*, 48: 523-546, 1999.
- HUGOT, J. P. et al. Human enterobiasis in evolution: origin, specificity and transmission. *Parasite*, 6: 201-208, 1999.
- IÑIGUEZ, A. M. et al. *Enterobius vermicularis*: specific detection by amplification of an internal region of 5S ribosomal RNA intergenic spacer and trans-splicing leader RNA analysis. *Experimental Parasitology*, 102: 218-222, 2002.
- IÑIGUEZ, A. M. et al. *Enterobius vermicularis*: ancient DNA from North and South American human coprolites. *Memórias do Instituto Oswaldo Cruz*, 98, supl. 1: 67-69, 2003.
- LAMING-EMPERAIRE, A. Le problème des origines américaines: theories, hypotheses, documents. *Cahiers d'Archéologie et d'Ethnologie d'Amérique du Sud*. Éditions de la Maison des Séances de l'Homme - Presses Universitaires de Lille, 1980.
- LOK, J. B. *Strongyloides stercoralis*: a model for translational research on parasitic nematode biology. *WormBook*, 17: 1-18, 2007.
- MANTER, H.W. Some aspects of the geographical distribution of parasites. *The Journal of Parasitology*, 53: 2-9, 1967.
- MEGGERS, B. J. & EVANS, C. A transpacific contact in 3000 BC. *Scientific American*, 214: 28-35, 1966.
- MENDES-CORREIA, A. A. E. *Homo: os modernos estudos sobre a origem do homem*. 2. ed. Coimbra: Atlântida, Livraria Editora, 1926.
- MONTENEGRO, A. et al. Parasites, paleoclimate and the peopling of the Americas: using the hookworm to time the Clovis migration. *Current Anthropology*, 47: 193-198, 2006.
- NEVES, W. A.; BERNARDO, D. V. & OKUMURA, M. M. M. A origem do homem americano vista a partir da América do Sul: uma ou duas migrações? *Revista de Antropologia USP*, 50: 9-44, 2007.
- PIZZI, T. & SCHENONE, H. Hallazgo de huevos de *Trichuris trichiura* en un cuerpo arqueológico incaico. *Boletín Chileno de Parasitología*, 9: 73-75, 1954.
- REINHARD, K. J. *Strongyloides stercoralis* in the prehistoric Southwest. In: MERBS, C. F. & MILNER, R. J. (Eds.). *Health and Disease in the Prehistoric Southwest*. Tempe: Arizona State University, 1985.
- REINHARD, K. J. Archaeoparasitology in North America. *American Journal of Physical Anthropology*, 82: 145-162, 1990.
- REINHARD, K. J.; AMBLER, J. R. & MCGUFFIE, R. J. Diet and parasitism at Dust Devil Cave. *American Antiquity*, 50: 20-24, 1985.
- REINHARD, K. J. et al. American hookworm antiquity. *Medical Anthropology*, 20: 97-101, 2001.
- REY, L. *Parasitologia*. Rio de Janeiro: Guanabara Koogan, 2008.
- RIVET, P. Les origines de l'homme Américain. *L'Anthropologie*, 25: 293-319, 1925.
- ROBERTS, L. S. & JANOVY, J. *Foundations of Parasitology*. Dubuque: McGraw-Hill International Edition, 2009.
- SANTOS, A. K. C. R.; LEITE, D. S. & SANTOS, S. E. B. DNA mitocondrial em populações humanas pré-colombianas da Amazônia e as interações do passado (paleogenética). In: PEREIRA, E. (Org.). *Arqueologia da Amazônia*. 1. ed. Belém: Museu Paraense Emilio Goeldi, 2010. v. 1.
- SOPER, F. L. The report of a nearly pure *Ancylostoma duodenale* infestation in native American Indians and a discussion of its ethnological significance. *American Journal of Hygiene*, 7: 174-184, 1927.
- SORCI, G. et al. Correlated evolution between host immunity and parasite life histories in primates and oxyurid parasites. *Proceedings of the Royal Society of Biological Sciences*, 270: 2.481-2.484, 2003.

- SORENSEN, J. L. & JOHANNESSEN, C. L. Biological evidence for pre-Columbian transoceanic voyages. *In*: MAIR, V. H. *Contact and Exchange in the Ancient World*. Honolulu: University of Hawai'i Press, 2006.
- STEWART, T. D. A physical anthropologist's view of the peopling of the New World. *Southwestern Journal of Anthropology*, 16: 259-273, 1960.
- WILLIAMS, H. U. The epidemic of the Indians of New England, 1616-1620, with remarks on the native American infections. *Johns Hopkins Hospital Bulletin*, 20: 340-349, 1909.