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Intestinal Parasitic Infection in Roman Britain: Integrating New Evidence from Roman London

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ABSTRACT

The aim of this study is to estimate the minimum prevalence of intestinal parasites in the population of Roman London through analysis of pelvic sediment from 29 third- to fourth-century burials from the 1989 excavations of the western cemetery at 24–30 West Smithfield, 18–20 Cock Lane and 1–4 Giltspur Street (WES89). Microscopy was used to identify roundworm eggs in 10.3 per cent of burials. We integrate these results with past palaeoparasitological work in the province of Britannia *to explore disease, hygiene and diet. The most commonly found parasites (whipworm and roundworm) were spread by poor sanitation, but other species caught from animals were also present (fish tapeworm, beef/pork tapeworm and liver flukes). Parasite diversity was highest in urban sites. The health impacts of these infections range from asymptomatic to severe.*

Keywords: Palaeoparasitology; helminths; Roman Empire; Roman London; sanitation; diet

INTRODUCTION

Palaeoparasitology, or archaeoparasitology, is the study of parasite infections in past populations. Analysis of ancient sediments has revealed parasite infections dating from early prehistory through the medieval period in many regions across the world.[1] Parasite remains from archaeological sites are a useful tool for understanding diet, human–animal interactions, migration and sanitation in the past, and for tracking infectious diseases throughout history. The diverse life cycles and transmission routes of various parasites are used to gain an understanding of these lifestyle factors.[2] Such parasites can be present on the surface of the body (ectoparasites, such as fleas and lice) or inside the body (endoparasites, such as intestinal worms).[3] Endoparasites will be our focus in this study and include both helminths (worms) and

1 Mitchell 2015.
2 Mitchell 2013; 2015; Ferreira *et al.* 2014.
3 Gunn and Pitt 2012; Ash and Orihel 2015; Garcia 2016.

protozoa (single-celled organisms). Helminths can be grouped into nematodes (roundworms), trematodes (flukes) and cestodes (tapeworms). There are numerous parasites in each of these groups with varying geographic distributions, intermediate and definitive hosts, and sites of infection in the human body. In the regions conquered by the Romans, the majority of helminths for which we have evidence reside in the intestines or liver and bile ducts.[4]

When intestinal parasites establish an infection in their human host, they mate and release eggs into the faeces. These can then be recovered from archaeological sediment samples that contain faeces, such as cesspits, or in actual preserved pieces of faeces, such as coprolites. In some cases these eggs need a period of time to mature in the environment, as in the case of roundworm and whipworm,[5] while in others the larvae develop in an animal intermediate host before being transmitted to their human host, where they mature into adult worms.[6] These animal hosts can be very specific, which limits the geographical distribution of parasites and requires close proximity between the animal host and humans.[7]

As studies undertaken on Roman sediment samples have increased, it is becoming possible to look for trends in parasite infections across the Empire.[8] The majority of previously published palaeoparasitological work for this period is from British sites and has mainly been published in excavation volumes and site reports.[9] We are now in a position to pool and analyse the British data, allowing us to determine patterns in infection by site type. While different kinds of samples and different methodological approaches will affect the number of eggs from each taxonomic group recovered, the identification of these taxonomic groups of parasites at each site still provide a comprehensive data set. This level of analysis has not been possible for most other regions in the Empire, as relatively fewer palaeoparasitological studies have been undertaken outside of Britain.

The aim of this study is to contribute new evidence for parasite infection in Roman Britain through microscopic analysis of sediment from the pelvic area of skeletons excavated from the western cemetery of Roman London (*Londinium*) to understand parasite transmission better at the individual level in this community. These new data are then compared to previously published studies from Roman Britain.

ROMAN LONDON

The Roman settlement of *Londinium* was established in A.D. 48 and was firmly embedded in trade with the Rhineland, Gaul and the Mediterranean, with the military being a strong presence throughout.[10] As many parasites are transmitted by the faecal–oral route, it is valuable to understand key aspects of city structure that contribute to (or help limit) disease spread. Remains of wooden pipes indicate that the early town may have had some piped water to its centre, which could then provide clean drinking water to inhabitants.[11] There is also archaeological evidence for a series of large wells which could have provided water to the population without the need for piped water supply.[12] Such wells can be easily contaminated

4 Mitchell 2017a.
5 Garcia 2016, 299.
6 Bogitsh *et al*. 2019, 163 and 225.
7 Ledger and Mitchell 2022.
8 Anastasiou 2015; Ledger *et al*. 2020; 2021; Mitchell 2023.
9 For example Jones 1987; Jones and Hutchinson 1991; Carrott *et al.* 1995; Boyer 1999.
10 Wallace 2014; Hingley 2018; Perring 2022.
11 Perring 1991, 10–11.
12 Blair *et al*. 2006.

with waste in densely populated cities.[13] Residential areas in *Londinium* were crowded, which would contribute to spread of infectious diseases including parasites. For example, the Watling Court site (WAT78) provided evidence for multiple residential buildings separated by very narrow alleys and little green space. One of the residential buildings at the site also provided evidence for a second storey, a feature of houses that suggests increased population density.[14] Estimates of the population of *Londinium* have suggested that prior to the Boudican revolt (A.D. 60/61) there were around 10,000 people living there, and it grew to about 25,000–30,000 in the second century.[15]

In the first decades of its existence, buildings in the town were mainly constructed of timber, with wattle-and-daub walls and earth floors,[16] the latter a feature of early Roman buildings in Britain.[17] Excavations have also produced remains of concrete floors, plaster and marble in debris from the Boudican revolt, indicating that these materials were also being used in buildings.[18] Mortar and mosaic floors are found in higher-status buildings and some houses in *Londinium*.[19] Building materials and urban landscapes can have a strong impact on infectious disease transmission and are thus important considerations in our understanding of parasite transmission across different settlements.[20]

Londinium was surrounded by burial grounds, which show a mixture of inhumations and cremations, and were used by a variety of different status and social groups, including the military.[21] From the outset, *Londinium* was inhabited by people from the region and elsewhere in Britain, as well as those from Continental Europe and the Mediterranean, including migrants from North Africa.[22] Stable isotope and bioarchaeological data show the presence of first- and second-generation immigrants, some of Black African heritage, and two individuals possibly from Scandinavia were found during recent Crossrail excavations (XSM10).[23] The epigraphic and funerary datasets also provide evidence for the presence of the military community and enslaved people.[24] Therefore, it should be expected that many of the individuals in our study would have been part of this diverse population.

Environmental and stable isotope evidence for food-ways in Roman London all emphasise how different the settlement was to the rest of Britain, with evidence for the import of numerous exotic foodstuffs and the zooarchaeological data showing the influence of the military and urban dietary trends, with the dominance of cattle and pig remains, and fresh and marine seafoods being consumed. The stable isotope data echo these findings, but also show us that the diets of women and children contained less meat.[25] This diverse diet would impact the risk of zoonotic parasite infection.

13 Magnusson 2013.
14 Perring 1991, 69–70.
15 For a discussion of various population estimates, see Swain and Williams 2008.
16 Perring 2002, 31–2.
17 Perring 2002, 126.
18 Perring 1991, 11.
19 Perring 2002, 32.
20 Krause *et al.* 2015; Worrell *et al.* 2016; Cociancic *et al.* 2020.
21 Hall 1996; Barber and Bowsher 2000; Mackinder 2000; Watson 2003; Harward *et al*. 2015; McKenzie *et al.* 2020. Also see Pearce (2015, 158–9) for a review of burials excavated in London between 1990 and 2013.
22 Redfern *et al*. 2016; Shaw *et al*. 2016; Perring 2022, 219–27.
23 Redfern *et al*. 2016; Ranieri and Telfer 2017.
24 Tomlin 2016; Hingley 2018; Perring 2022.
25 King 1999; Locker 2007; van der Veen 2008; van der Veen *et al*. 2008; Ranierei and Telfer 2017; Redfern *et al.* 2018.

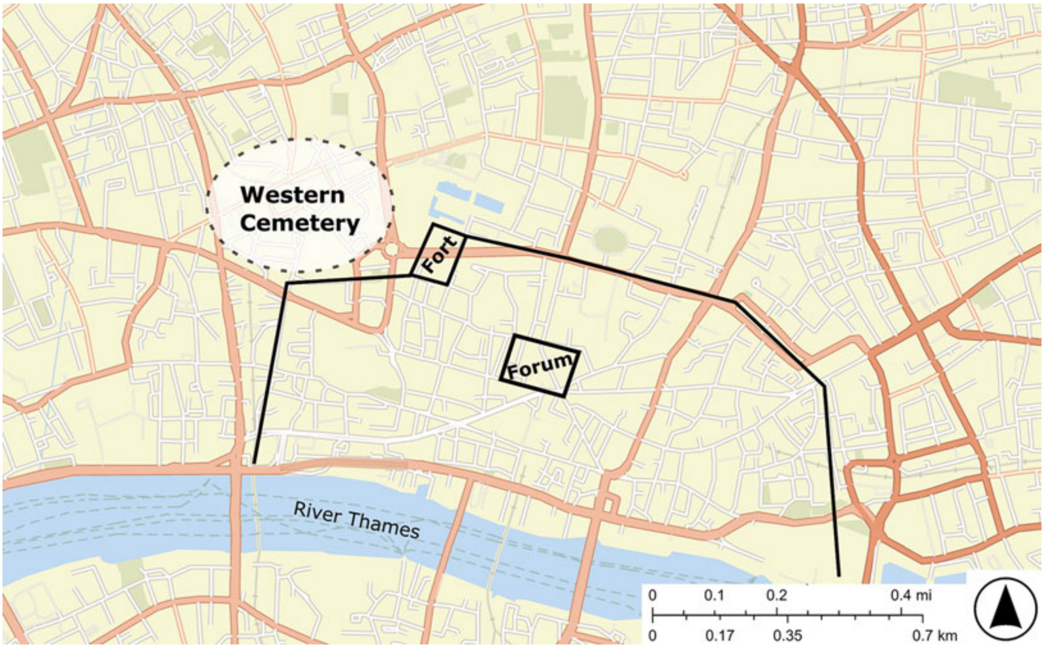

FIG. 1. Map showing the location of the Roman western cemetery within which is the WES89 site which contained the burials analysed here. The walls of the Roman *Londinium* are indicated by black lines. The size of the cemetery is not to scale. (© *Marissa Ledger*)

MATERIALS AND METHODS

Here we present evidence for parasite infections from a third- and fourth-century cemetery located on the western outskirts of *Londinium*, probably lining the road which connected London to Silchester. Excavations in 1989 at 24–30 West Smithfield, 18–20 Cock Lane and 1-4 Giltspur Street (WES89) uncovered 127 burials (see FIG. 1). Fourteen of these burials can be defined as 'chalk burials' in which the individuals were laid on, or interred within, layers of chalk placed within the grave cuts and individuals generally were orientated north–south or west–east, with adults and children represented, and the deceased often accompanied by jewellery, decorated combs or pottery.[26] The human remains are curated by London Museum and were recorded using the Wellcome Osteological Research Database (WORD). Age at death in those less than 18 years old was determined using dental development and eruption, long-bone length and epiphyseal fusion. If it was not possible to determine an age-range, individuals were recorded as 'nonadult'. In adults (>18 years old), degenerative changes to the sternal rib end, auricular surface and pubic symphysis, as well as tooth wear were used to determine age. Individuals were assigned to age-groups or 'adult' if it was not possible to determine an age-range due to skeletal completeness or preservation. Sex estimation was only undertaken for adults, and based on morphological differences in the skull and pelvis, with individuals being estimated as male, female, intermediate or undetermined.[27]

26 London Archaeologist 1992; the site remains unpublished.
27 Powers 2012; intermediate (a mixture of female and male scores) and undetermined (bones or features used to estimate sex not present).

TABLE 1. DETAILS OF SKELETAL REMAINS FROM WHICH SAMPLES FOR PARASITE ANALYSIS WERE COLLECTED (WES89); ADULT (>18 YEARS OLD); NONADULT (<18 YEARS OLD).

Context number	Age in years	Sex	Samples collected: body area
228	12–17	–	Pelvis and control from above skeleton
467	36–45	Male	Pelvis and control from above skeleton
485	Adult	Male	Pelvis and control from above skeleton
493	Adult	–	Pelvis and control from above skeleton
504	26–35	Female	Pelvis and control from above skeleton
512	36–45	Male	Pelvis
527	6–11	–	Pelvis and control from above skeleton
558	Adult	Undetermined	Pelvis
570	Adult	Undetermined	Pelvis and control from above skeleton
579	Adult	Undetermined	Pelvis (sample 36) and control from above skeleton
579	Adult	Undetermined	Pelvis (sample 43) and control from above skeleton
599	36–45	Female	Pelvis and control from above skeleton
611	Adult	Intermediate	Pelvis
656	Adult	Female	Pelvis
660	12–17	–	Pelvis and control from above skeleton
686	36–45	Male	Pelvis and control from above skeleton
691	18–25	Female	Pelvis and control from below skeleton
761	Adult	Male	Pelvis and control from above skeleton
781	6–11	–	Pelvis
785	Nonadult	–	Pelvis and control from below skeleton
837	Adult	Male	Pelvis and controls from head and above skeleton
841	Adult	Intermediate	Pelvis and control from above skeleton
848	12–17	–	Pelvis and control from above skeleton
870	Adult	Female	Pelvis and control from above skeleton
877	Adult	Intermediate	Pelvis and control from above skeleton
885	Adult	Male	Pelvis and control from above skeleton
915	18–25	Intermediate	Pelvis and control from below skeleton
935	Adult	Female	Pelvis and control from above skeleton
1004	6–11	–	Pelvis
1052	Adult	Female	Pelvis and control from above skeleton

Sediment samples were taken during the excavation of WES89, with extant samples from 29 individuals being available for analysis at London Museum Stores. Sampling took place directly anterior to the sacrum, and in most cases, control samples came from above or below the skeleton (TABLE 1).

This sampling information is crucial, because helminths which reproduce in the gastro-intestinal tract deposit eggs within the faeces of the infected individual. Thus, in order to find evidence of these parasites, samples that are likely to contain human faeces must be collected. In the case of skeletal remains, that means collecting sediment from the pelvic area of the skeleton, directly anterior to the sacrum (if the individual was buried in the supine position) where the intestines and any faeces contained within in them would have been located and later decomposed.[28] In order to ensure that any eggs found within the pelvis represent true infection rather than contamination of the wider burial environment, control samples need to be collected from areas away from the abdomen where we would not expect to find eggs from infection of the individual.

From each sample of pelvic sediment, a subsample of 0.2 g of sediment was processed for analysis. This subsample was disaggregated with 5–6 mL of 0.5 per cent trisodium phosphate

[28] Mitchell 2017b.

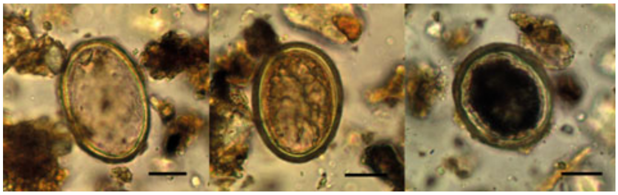

FIG. 2. Decorticated roundworm (*Ascaris* sp.) eggs from pelvic sediment of individuals buried at WES89. Scale bars are 20 µm. (© *Marissa Ledger*)

solution for at least 2 hours. Once the sediment was fully suspended in the liquid, it was passed through a stack of microsieves of mesh size 300 µm, 160 µm and 20 µm. As the eggs of intestinal parasites that infect humans in northern Europe are generally between 25 and 150 µm in size, this should concentrate the eggs on the 20 µm mesh.[29] This material was washed from the 20 µm mesh, centrifuged (3184 g for 5 minutes), supernatant removed, and mixed with glycerol. Five slides from each sample were viewed under a digital light microscope at ×400 magnification (Olympus BX40F microscope with GXCAM-9 digital camera). If any eggs were found in the first five slides then the entire sample was viewed to calculate the concentration of eggs in the sample. Eggs were identified by their shape, dimensions, colour and special characteristics in comparison to standard reference texts.[30] For samples that contained parasite eggs, 0.2 g of sediment from the control sample were also analysed to detect any generalised contamination of the burial soil by human faeces (and so parasites). The minimum prevalence of parasitic infection in the population was calculated from the number of positive individuals as a percentage of the total number of burials studied.

RESULTS

Helminth eggs were found in the pelvic sediment of three of the twenty-nine individuals (10.3 per cent) from WES89. *Ascaris* sp. (roundworm) was the only species of parasite present (FIG. 2). The positive individuals were 761 (adult male), 841 (adult, undetermined), and 935 (adult female). The eggs were decorticated, meaning that they had lost the mamillated surface coat generally found in modern roundworm eggs. This is often the case in pelvic sediment from ancient burials, as the mamillated coat can be stripped away by the action of insects and soil micro-organisms over time. The egg concentrations were low in the pelvic sediment samples. Five eggs were found in the 0.2 g sub-sample from male 761, three in individual 841 and two in female 935. The egg concentrations and mean dimensions of these eggs are listed in TABLE 2. No helminth eggs were found in the control samples from the three individuals; the entire 0.2 g sub-sample was analysed for the control samples. This suggests that the eggs we did find in the pelvic sediment likely originated from the decomposed intestines of that individual, and does not indicate generalised contamination of the burial soil by faeces and parasite eggs. The eggs were identified as *Ascaris* sp. without a species level identification as it is not possible to differentiate between the species usually found in humans (*Ascaris lumbricoides*) and that usually found in pigs (*Ascaris suum*) using the morphology of the eggs themselves.[31] Their presence in pelvic sediment from human burials would suggest that they

29 Anastasiou and Mitchell 2013.
30 Ash and Orihel 2015; Garcia 2016.
31 Betson *et al*. 2014.

TABLE 2. CONCENTRATION AND DIMENSIONS OF ROUNDWORM (*ASCARIS* SP.) EGGS RECOVERED FROM PELVIC SOIL SAMPLES FROM WES89.

Context number	**Age**	**Sex**	**Species**	**Egg concentration (eggs per gram)**	**Mean length (μm)±SD**	**Mean width (μm)±SD**
761	Adult	Male	*Ascaris* sp.	25	58.0 ± 3.2	46.1 ± 2.6
841	Adult	Intermediate	*Ascaris* sp.	15	52.3 ± 8.6	44.6 ± 6.3
935	Adult	Female	*Ascaris* sp.	10	59.5 and 68.8	45.2 and 45.7

are more likely the human-infecting species, but both species are able to infect humans.[32] Therefore, it is safest to just refer to them as roundworm.

With three of twenty-nine individuals positive for parasite eggs, this gives a minimum prevalence of 10.3 per cent in the population. We write minimum prevalence, as it is possible that more individuals were infected with parasites at the time of their death, but those eggs might have been lost over the centuries by the action of fungi and insects in the soil.

DISCUSSION

How does the intestinal parasite infection found in the London population compare with that from Britain and elsewhere? Previous palaeoparasitological work on British sites reported over a period from 1968 to 2022 is summarised in TABLE 3. Samples derived from sediment from pits, sewer drains, occupation layers, cesspits and latrines, ditches, wells, and pelvic sediment from burials. Each site was assigned to a type: military, urban, or rural, following the definitions of the Rural Settlement of Roman Britain Project.[33] Parasite diversity was then broadly compared between different site types to look for patterns in parasite transmission. The transmission routes, geographical distribution and anatomical sites of infection for these parasites are listed in TABLE 4.

The studies summarised in TABLE 3 identified six different taxa of intestinal helminths found in Britain. The most common parasites identified in Britain are roundworm (*Ascaris* sp.), which was found at 86 per cent of sites (13/15), and whipworm (*Trichuris* sp.), which was found at 67 per cent of sites (10/15). Following that, but much less common, are zoonotic parasites, including beef/pork tapeworm (*Taenia* sp.) found at 20 per cent of sites (3/15) and fish tapeworm (*Dibothriocephalus* sp.) found at 13 per cent of sites (2/15). Finally, the liver flukes, including Lancet liver fluke (*Dicrocoelium* sp.) and common liver fluke (*Fasciola* sp.) were found at 13 per cent of sites (2/15), though they were never found together. Analysis of these results by site type shows that roundworm and whipworm are the most commonly identified eggs in military sites, and roundworm was the most common parasite identified in urban and rural sites (FIG. 3). Urban sites have the highest taxonomic diversity overall with all parasite species found in Roman Britain identified in urban sites. The diversity in military sites was the lowest with only roundworm, whipworm, and *Fasciola* liver fluke being identified.

As noted above, three (10.3 per cent) of the 29 individuals from London showed evidence for roundworm (*Ascaris*) eggs in sediment from their pelvis. Pelvic sediment samples studied from Canterbury, York, Bletchingley, Bleadon and Churchill contained a higher prevalence of 38 per cent for roundworm (*Ascaris* sp.), as well as 4 per cent of individuals positive for beef/pork tapeworm (*Taenia* sp.), and 1 per cent for fish tapeworm (*Dibothriocephalus* sp.).[34] The results from *Londinium* are similar to Roman Italy, with a combined minimum prevalence of 9 per

32 Nejsum *et al.* 2012.
33 Smith *et al.* 2016, 38; Allen *et al.* 2018.
34 Ryan *et al.* 2022.

TABLE 3. PARASITE REMAINS RECOVERED FROM PREVIOUSLY STUDIED SITES IN ROMAN BRITAIN.

Site name	Parasite species	Site type	Sample type	Date (A.D.)	Reference
Ambleside	*Ascaris* sp. *Trichuris* sp.	Military	Pit	First to fourth century	Jones 1985
Bearsden, Scotland	*Ascaris* sp. *Trichuris* sp.	Military	Sewer/drain	142-158	Knights *et al*. 1983
Bleadon, Wentwood Drive	*Ascaris* sp.	Rural	Burials	Roman	Ryan *et al.* 2022
Canterbury, Peugeot Garage	*Ascaris* sp. *Dibothriocephalus* sp. *Taenia* sp.	Urban	Burials	Second to fourth century	Ryan *et al.* 2022
Carlisle, Castle Street	*Ascaris* sp. *Fasciola* sp. *Trichuris* sp.	Military	Occupation layer	First to third century	Jones and Hutchinson 1991
Churchill, South Strategic Support Mains	*Ascaris* sp. *Taenia* sp.	Rural	Burials	Roman	Ryan *et al.* 2022
Dorset, Poundbury Camp	*Ascaris* sp. *Trichuris* sp.	Rural	Burial	Roman	Jones 1987
Leicester, Causeway Lane	*Ascaris* sp. *Fasciola* sp. *Trichuris* sp.	Urban	Cesspit/latrine	First to second century	Boyer 1999
Lincoln, Waterside NW	*Trichuris* sp.	Urban	Occupation layer	Third century	Carrott *et al*. 1995
London, 15-35 Copthall Avenue (KEY83)	*Dicrocoelium* sp. *Trichuris* sp.	Urban	Ditch	Second to fourth century	de Moulins 1990
London, Hibernia Wharf (HIB73)	*Ascaris* sp. *Dibothriocephalus* sp. *Taenia* sp. *Trichuris* sp.	Urban	Well	First to second century	Rouffignac 1985
London, (WES89)	*Ascaris* sp.	Urban	Burials	Roman	This study
Winchester, Owslebury	*Ascaris* sp. *Dicrocoelium* sp. *Trichuris* sp.	Rural	Pit	Roman	Pike 1968
York, All Saints in the Marsh	*Ascaris* sp.	Urban	Burials	45–49 BC	Ryan *et al.* 2022
York, Church Street Sewer	*Ascaris* sp. *Trichuris* sp.	Urban	Sewer/drain	First to fifth century	Wilson and Rackham 1976

cent at the sites of Lucus Feroniae, Oplontis, Vacone and Vagnari (first century B.C. to fourth century A.D.),[35] and of 28 per cent in fourth- to fifth-century A.D. Florence.[36] A further study of individuals from Neolithic to Roman era Greece found a minimum prevalence of 16 per cent.[37] We describe this as a minimum prevalence, as eggs that were originally present in other individuals may have washed away or been destroyed by soil fungi and insects, so we regard these individuals as negative, when they may have been infected during life. Furthermore, it is important to keep in mind that these proportions indicate how many individuals were infected at their time of death, and are not a perfect reflection of the living population. School-aged

[35] Ledger *et al*. 2021.
[36] Roche *et al.* 2019.
[37] Anastasiou *et al.* 2018.

TABLE 4. DETAILS OF HELMINTHS FOUND IN SAMPLES FROM ROMANO-BRITISH SITES.

Scientific name	**Common name**	**Transmission**	**Common signs and symptoms**
Ascaris sp.	Roundworm	Faecal–oral	Asymptomatic, altered bowel habits, abdominal pain, intestinal obstruction
Dibothriocephalus sp.	Fish tapeworm	Ingestion of raw or undercooked fish*	Asymptomatic, anaemia, altered bowel habits, abdominal pain
Dicrocoelium dendriticum	Lancet liver fluke	Ingestion of ants (true infection)	Altered bowel habits, flatulence, jaundice, hepatomegaly, vomiting
Fasciola sp.	*Fasciola* liver fluke	Ingestion of aquatic plants (true infection)	Abdominal pain, hepatosplenomegaly, inflammation of liver/gallbladder/ pancreas, biliary obstruction
Taenia sp.	Beef/pork tapeworm	Ingestion of raw or undercooked beef/pork	Asymptomatic, altered bowel habits, weight loss, cysticercosis (*T. solium*)
Trichuris sp.	Whipworm	Faecal–oral	Asymptomatic, altered bowel habits, abdominal pain, anaemia

Note: *in Europe the species present are typically acquired from freshwater fish only.

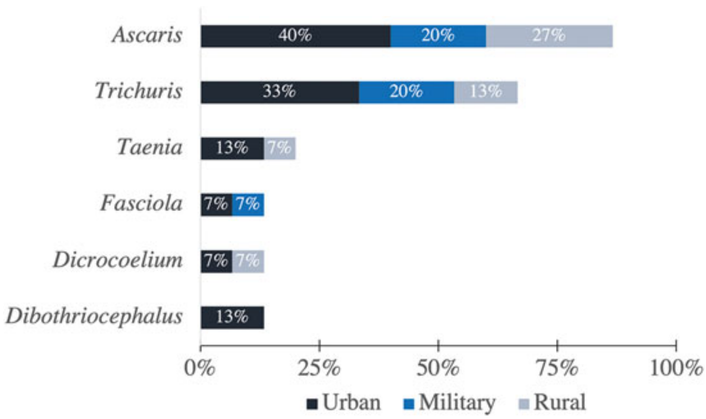

FIG. 3. Proportion of sites in which each taxa of parasite was found, further broken down by site type.

children (5–15 years old) are the most commonly infected age group in modern populations,[38] and in ancient populations where infant mortality was quite high, those infants who survived past the age of five would have a higher life expectancy and may be found in the cemetery as adults. Thus, we may be missing a number of childhood infections, if those at high risk for infection survived these years and were buried in adulthood without an active infection. However, when considered together, such data start to give perspective on how common intestinal parasite infection may have been in the Roman world.

PARASITE DIVERSITY IN ROMAN BRITAIN

Roundworm (the only parasite found in the individuals studied from *Londinium*) is a soil-transmitted helminth, often grouped with whipworm (*Trichuris trichiura*), and hookworm

[38] Bundy *et al*. 1987; Crompton and Nesheim 2002; Hotez and Kamath 2009.

(*Ancylostoma duodenale/ceylanicum* and *Necator americanus*). They are all similarly transmitted by ingestion or contact with infective eggs or larvae in soil that has been contaminated with human faeces.[39] In modern populations, soil-transmitted helminths are estimated to infect about 1.5 billion people worldwide, though their distribution is heavily concentrated in sub-tropical regions and low- and middle-income countries.[40] Roundworm is the most common parasite found in British sites overall, and the most common parasite recovered from urban sites (FIG. 3). Roundworm is transmitted by the faecal–oral route. Infection is acquired when eggs are accidentally ingested from the environment, typically through unwashed fruits and vegetables, unwashed hands, or contaminated water.

Sanitation conditions are strongly linked to the transmission of soil-transmitted helminths including roundworm; thus the recovery of this parasite in 10.3 per cent of individuals studied from *Londinium* gives an indication of ineffective sanitation infrastructure and the presence of practices that would have allowed for the spread of faecal–oral pathogens. Removal of waste from living areas becomes more challenging with increasing population density, and adequate removal is important for preventing the spread of gastro-intestinal infections. Removing the faecal waste of the 25,000 to 30,000 people estimated to be living in *Londinium* in the second century required planning and systematic implementation by a regulatory authority within the settlement.[41] Without regular emptying of cesspits and organised areas for chamber pots to be dumped, faecal waste could easily contaminate water sources such as the wells.

The evidence for latrines in Britain varies based on the type of site. In military camps and forts, latrines were often set up, even on a semi-permanent basis. In temporary camps, latrines would have been trenches dug into the ground that could then be filled over, as opposed to more permanent latrines built as part of bath complexes or as independent buildings in permanent forts.[42] The pit that was studied from Ambleside (Cumbria) may have been one of these temporary latrines at the fort. Less work has been done looking at the location of private latrines in Britain, but we may expect that many non-elite houses did not have private latrines, and in these cases chamber pots were likely used. There is evidence for the use of chamber pots across the Empire.[43] Cesspits were also common throughout the Empire, and in homes that did have private latrines, these were likely small cesspits located inside the house or in gardens outside the house, as has been found in the north-western provinces.[44] These cesspits and chamber pots would have needed to be emptied, and the process for collecting and removing human excrement from the city could have created opportunities for individuals to come into contact with faecal material of others and for wider contamination of settlements.[45]

Flooring and building techniques can influence pathogen transmission, and in particular soil-transmitted helminths like roundworm. As discussed above, there is evidence that early Roman period buildings in Britain were constructed with earth-beaten floors.[46] Worrell and colleagues found that having finished household floors was a protective factor against soil-transmitted helminths in modern populations in Kenya.[47] Earth-beaten floors may have been harder to wash compared to those finished with materials such as stone or concrete, and could easily be contaminated with faecal material on shoes or spills from chamber pots. Furthermore, the numerous flies known to be present in Roman settlements could have resulted

39 Vaz Nery *et al*. 2019.
40 Pullan *et al*. 2014.
41 Swain and Williams 2008; Taylor 2015; Furlan 2017.
42 Revell 2007; Hobson 2009, 33–5; Rushworth 2009, 222; Breeze 2018.
43 Rabinow *et al*. 2022.
44 Andrikopoulou *et al.* 2018; Heirbaut 2018.
45 Scobie 1986; Jones 2012.
46 Perring 2002, 31–2.
47 Worrell *et al*. 2016.

in helminth eggs being moved around the home and contaminating other areas such as food-processing areas.[48]

Interestingly, no zoonotic parasites (those transmitted from non-human animals to humans) were found in the pelvic sediment from individuals from the western cemetery despite the parasite diversity at urban sites in Britain being higher than any other site type (FIG. 3). Zoonotic parasites that have been found in other urban sites in Britain include beef or pork tapeworm (*Taenia saginata* or *Taenia solium*, respectively), fish tapeworm (*Dibothriocephalus* sp.) and liver flukes (*Fasciola* sp. and *Dicrocoelium dendriticum*).

In fact, the majority of evidence for tapeworms, both fish and beef/pork tapeworms, comes from urban centres, in particular *Londinium*. This may be a result of access to a larger variety of foods in major centres. Fish tapeworm infection is acquired in northern Europe through the consumption of freshwater fish that carry larvae.[49] Analysis of sulphur isotope values in Roman human remains suggests that freshwater and marine fish were consumed,[50] and faunal remains reveal that the most common species of fish recovered from British sites are eel, herring, plaice, cyprinid and salmonid.[51] *Dibothriocephalus* sp. can be found in salmon and cyprinids; thus consumption of these fish could have resulted in infection if they were eaten raw, smoked or undercooked. Marine fish were generally preferred over freshwater fish in the Roman period.[52] If fish sauce (*garum*), a popular condiment, was produced from freshwater fish in this area of Britain, it is possible that it could transmit fish tapeworm if salting conditions were not adequate to kill larvae.[53] Recovery of fish bones and amphora in Britain has provided evidence for importation of fish sauce and pickled fish from Iberia starting in the Iron Age and increasing into the Roman period.[54] These amphorae become less common in the second century, and it has been suggested that this may be a reflection of fish-sauce production locally within Britain.[55] The only evidence for fish tapeworm in Britain comes from *Londinium* and Canterbury. There was possible evidence for *garum* or *liquamen* production at Peninsular House, a Roman waterfront site in *Londinium*.[56] However, the fish remains found suggest that *garum* was made from herring and sprat, which are not common intermediate hosts of *Dibothriocephalus* sp. Thus, it may be more likely that fish tapeworm infection was acquired from ingestion of freshwater fish rather than fish sauce imported into *Londinium*.

Beef or pork tapeworm have also mainly been found in major urban centres including *Londinium* and Canterbury (TABLE 3). These eggs can represent infection with beef tapeworm (*Taenia saginata*) or pork tapeworm (*Taenia solium*). It is not possible to differentiate the two species based on the morphology of the eggs. Both have very similar life cycles.[57] Eggs are ingested by grazing cattle or pigs and the larvae develop in the tissues of the animal and can cause infection when the animal is eaten. In order to prevent infection, the meat needs to be cooked to at least 56–65 degrees Celsius.[58] Pig remains make up a higher proportion of faunal

48 See Knights *et al.* 1983 and Rowan 2014, 145 for evidence of flies in cesspits and Ledger *et al.* 2021 for a discussion of how these flies can be a vector for moving helminth eggs from cesspits to other locations through the adherence of these eggs to the legs of flies.

49 Scholz *et al.* 2009.

50 Nehlich *et al.* 2011

51 Locker 2007.

52 Locker 2007.

53 Mitchell 2017a.

54 Cool 2006, 59.

55 Cool 2006, 61.

56 Bateman and Locker 1982.

57 Gunn and Pitt 2012; Ash and Orihel 2015; Garcia 2016.

58 Wittner *et al.* 2011. Larvae can in some cases be killed by extensive salting or smoking; the requirements for salt concentration and time exposed to salting or smoking in order to kill larvae are less clear. See Rodriguez-Canul *et al.* 2002 and Rivera-Guerrero *et al.* 2004 for an analysis of traditional smoking and salting methods needed to kill larvae.

assemblages in *Londinium*, similar to other urban sites, compared to other sites in Roman Britain.[59] Numerous cattle scapulae have been found in Britain with a hole through the centre which suggests that shoulders were hung to be dried or smoked.[60] Smoking and drying are not very effective at killing parasite larvae, and this could be another practice leading to beef tapeworm infection.[61] Higher levels of pig remains coupled with the practices of preserving cattle meat mean it is possible that the *Taenia* sp. eggs found in *Londinium* could have come from infective beef or pork.

Liver flukes found in Britain include *Dicrocoelium dendriticum* and *Fasciola* sp. Only *Dicrocoelium* has been previously found in *Londinium*. The evidence for *Fasciola* and *Dicrocoelium* in Britain was found in occupation layer soil, pits and ditches, none of which can be confidently linked to human ingestion of eggs or human infection (see TABLE 1).[62] While both *Fasciola* and *Dicrocoelium* can infect humans, they can also result in pseudoparasitism, when a person eats the liver or intestines of an infected animal, so that the parasite eggs are mixed in with the human faeces, but without that human actually being infected.

HEALTH AND DISEASE IN ROMAN BRITAIN

The impact on health from roundworm infection in these individuals can be quite varied depending on worm burden (the number of worms one individual carries) and various host factors such as health status, immune function and co-existing infections.[63] A higher number of worms carried within one's intestines causes more severe symptoms, although it is important to note that in many cases an individual may be asymptomatic with these infections. The health impact of intestinal helminths can be considered in a stepwise fashion. First, health impacts can be reversible. For example, in children infected with roundworm, these infections can negatively impact growth. However, if the infection is cleared, their growth may catch up, so the impacts on health are potentially reversible.[64] With chronic infections or continual reinfections, however, children can experience stunting of growth from which they do not recover. Infections also cause malnutrition which can be reversible or chronic, and this occurs through multiple mechanisms. The worms themselves result in decreased nutrient absorption and intake as a result of decreased appetite and abdominal symptoms.[65] Malnutrition has widespread effects from growth loss, decreased physical fitness, impaired cognitive development in children, and increased susceptibility to infection.[66] Helminth infections including roundworm can also cause acute and life-threatening illness in some cases. Roundworm can cause bowel obstruction, for which children are at higher risk, given their smaller intestinal lumens. Through blocking of lumens within the gastro-intestinal system, roundworm can also cause appendicitis, cholecystitis, and pancreatitis which can be life-threatening if untreated, as would have been the case in the Roman period.[67]

The palaeoparasitological analyses undertaken on British sites so far give us some evidence for the distribution of parasite infections in these communities. One recent British study found that for roundworm alone, Roman females and individuals over 13 years of age showed slightly higher rates of infection; however, neither result was statistically significant.[68] The pelvic sediment samples studied from *Londinium* in the current study only identified roundworm infections in

59 Maltby 2016.
60 Cool 2006, 89.
61 Rodriguez-Canul *et al.* 2002; Rivera-Guerrero *et al.* 2004.
62 Boyer 1999; Jones and Hutchinson 1991.
63 Gunn and Pitt 2012; Ash and Orihel 2015; Garcia 2016.
64 Stephenson *et al.* 2000a.
65 Stephenson *et al.* 2000a; 2000b.
66 Bethony *et al.* 2006.
67 Bethony *et al.* 2006.
68 Ryan *et al.* 2022. This may be due to a sample size of only 36 individuals.

adult individuals (one male, female and undetermined sex). While this seems to suggest that adults were commonly infected in this community, only four of the twenty-nine individuals studied were non-adults between 6 and 11 years old. With these types of analyses it is important to remember that these pelvic soil samples are from the non-survivors and they do not necessarily reflect the living population.[69] Despite these limitations, we would expect similar individual-level distributions of infections to those seen in most endemic communities today, as infection rates are very consistent between communities around the world. In modern communities, often a small proportion of a population carries the largest burden of worms. In particular, school-aged children are at highest risk for infection, which usually decreases in adulthood.[70] Factors that may contribute to higher rates of infection in this age group include playing outdoors in areas where soil is contaminated, defecation in open areas and decreased hand washing.[71] Further analysis of larger series of pelvic soil samples will be needed to understand the distribution of parasite infections better at the individual level in *Londinium*.

CONCLUSION

The excavations of the western cemetery produced new evidence for roundworm (*Ascaris* sp.) infection in individuals from *Londinium*. As elsewhere in the Empire, soil-transmitted helminths, roundworm and whipworm, were the dominant parasites in Britain and are the only type of parasite found in the individuals studied in the sample of individuals from the cemetery. Transmission of roundworm in *Londinium* was probably due to poor sanitation, as well as the management and reuse of faecal material in agriculture.[72] In Britain, there is also evidence for zoonotic parasites including tapeworms and liver flukes, although these were not found in this study. Our results, coupled with other studies of populations in Europe, suggest that perhaps a minimum of 10–30 per cent of people living in Britain in this period may have been infected by intestinal parasites. The evidence for parasites across Roman Britain suggests that the health impacts of parasites should be taken into consideration in discussions of infectious diseases in individuals living in this time period. Infections with these parasites were likely to cause nutrient deficiencies, stunting of growth and impaired cognitive development, as well as acute mortality from abdominal complications of infection.[73]

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69 Wood *et al*. 1992.
70 Bundy *et al*. 1987; Crompton and Nesheim 2002; Hotez and Kamath 2009.
71 Wang *et al*. 2012; Krause *et al*. 2015.
72 Jones 2012; Mitchell 2017a.
73 Jourdan *et al.* 2018.

BIBLIOGRAPHY

Allen, M., Blick, N., Brindle, T., Evans, T., Fulford, M., Holbrook, N., Lodwick, L., Richards, J.D., and Smith, A. 2018: *The Rural Settlement of Roman Britain: An Online resource*, York. https://doi.org/10.5284/1030449

Anastasiou, E. 2015: 'Parasites in European populations from prehistory to the Industrial Revolution', in Mitchell 2015, 203–17.

Anastasiou, E., and Mitchell, P.D. 2013: 'Simplifying the process of extracting intestinal parasite eggs from archaeological sediment samples: a comparative study of the efficacy of widely-used disaggregation techniques', *International Journal of Paleopathology* 3, 204–7.

Anastasiou, E., Papathanasiou, A., Schepartz, L.A., and Mitchell, P.D. 2018: 'Infectious diseases in the ancient Aegean: intestinal parasitic worms in the Neolithic to Roman period inhabitants of Kea, Greece', *Journal of Archaeological Science: Reports* 17, 860–4.

Andrikopoulou, J.-N., Fiedler, M., and Höpken, C. 2018: 'An outhouse in the garden? – Looking at a backyard in the vicus of Bonn', in Hoss 2018, 35–42.

Ash, L.R., and Orihel, T.C. 2015: *Atlas of Human Parasitology* (5th edn), Chicago.

Barber, B., and Bowsher, D. (eds) 2000: *The Eastern Cemetery of Roman London: Excavations 1983–1990*, MoLAS Monograph Series 4, London.

Bateman, N., and Locker, A. 1982: 'The sauce of the Thames', *London Archaeologist* 4, 204–7.

Bethony, J., Brooker, S., Albonico, M., Geiger, S.M., Loukas, A., Diemert, D., and Hotez, P.J. 2006: 'Soil-transmitted helminth infections: ascariasis, trichuriasis, and hookworm', *Lancet* 367, 1521–32.

Betson, M., Nejsum, P., Bendall, R.P., Deb, R.M., and Stothard, J.R. 2014: 'Molecular epidemiology of ascariasis: a global perspective on the transmission dynamics of *Ascaris* in people and pigs', *Journal of Infectious Diseases* 210.6, 932–41.

Blair, I., Spain, R., Swift, D., Taylor, T., and Goodburn, D. 2006: 'Wells and bucket-chains: unforeseen elements of water supply in early Roman London', *Britannia* 37, 1–52.

Bogitsh, B.J., Carter, C.E., and Oeltmann, T.N. 2019: *Human Parasitology*, London.

Boyer, P. 1999: 'The parasites', in A. Connor and R. Buckley (eds), *Roman and Medieval Occupation of Causeway Lane, Leicester Excavations 1980 and 1991*, Leicester Archaeology Monographs, Leicester, 344–46.

Breeze, D.J. 2018: 'The latrine at the Roman fort on the Antonine Wall at Bearsden', in Hoss 2018, 19–22.

Bundy, D.A., Cooper, E.S., Thompson, D.E., Didier, J.M., and Simmons, I. 1987: 'Epidemiology and population dynamics of *Ascaris lumbricoides* and *Trichuris trichiura* infection in the same community', *Transactions of the Royal Society of Tropical Medicine and Hygiene* 81, 987–93.

Carrott, J., Issitt, M., Kenward, H., Large, F., McKenna, B., and Skidmore, P. 1995: *Insect and Other Invertebrate Remains from Excavations at Four Sites in Lincoln (site codes: WN87, WNW88, WF89 and WO89): Technical Report*, Reports from the Environmental Archaeology Unit, York 95/10.

Cociancic, P., Torrusio, S.E., Zonta, M.L., and Navone, G.T. 2020: 'Risk factors for intestinal parasitoses among children and youth of Buenos Aires, Argentina', *One Health* 9, 100116.

Cool, H.E.M. 2006: *Eating and Drinking in Roman Britain*, Cambridge.

Crompton, D.W.T., and Nesheim, M.C. 2002: 'Nutritional impact of intestinal helminthiasis during the human life cycle', *Annual Review of Nutrition* 22, 35–59.

de Moulins, D. 1990: 'Environmental analysis', in C. Maloney and D. de Moulins (eds.), *The Archaeology of Roman London Volume I: The Upper Walbrook in the Roman Period*, CBA Research Report, York, 85–115.

Ferreira, L.F., Reinhard, K.J., and Araújo, A. (eds) 2014: *Foundations of Paleoparasitology*, Rio de Janeiro.

Furlan, G. 2017: 'When absence means things are going well: waste disposal in Roman towns and its impact on the record as observed in Aquileia', *European Journal of Archaeology* 20.2, 317–45.

Garcia, L.S. 2016: *Diagnostic Medical Parasitology*, Washington, DC.

Gunn, A., and Pitt, S.J. 2012: *Parasitology: An Integrated Approach*, Chichester.

Hall, J. 1996: 'The cemeteries of Roman London,' in J. Bird, M. Hassall, and H. Sheldon (eds), *Interpreting Roman London: Papers in Memory of Hugh Chapman*. Oxbow Monograph 58, Oxford, 57–84.

Harward, C., Powers, N., and Watson, S. 2015: *The Upper Walbrook Valley Cemetery of Roman London: Excavations at Finsbury Circus, City of London, 1987–2007*, MOLA Monograph Series 69, London.

Heirbaut, E.N.A. 2018: 'Roman toilets in Nijmegen, Oppidum Batavorum and Ulpia Noviomagus, the Netherlands', in Hoss 2018, 77–88.

Hingley, R. 2018: *Londinium a Biography. Roman London from its Origins to the Fifth Century*, London.

Hobson, B. 2009: *Latrinae et Foricae: Toilets in the Roman World*, London.

Hoss, S. (ed.), *Latrinae: Roman Toilets in the Northwestern Provinces of the Roman Empire*, Oxford.

Hotez, P.J., and Kamath, A. 2009: 'Neglected tropical diseases in sub-saharan Africa: review of their prevalence, distribution, and disease burden', *PLoS Neglected Tropical Diseases* 3, e412.

Jones, A.K.G. 1985: *Parasitological Investigations on the Ambleside Roman Pit*, Historic England Report 4600.

Jones, A.K.G. 1987: *Parasitological Investigations on Samples of Organic Material Associated with Human Burials at the Roman Inhumation Cemetery at Poundbury, Dorset (site code PC72-76)*, Ancient Monuments Laboratory Report 40/87.

Jones, A.K.G., and Hutchinson, A.R. 1991: 'The parasitological evidence', in M.R. McCarthy (ed.), *The Structural Sequence and Environmental Remains from Castle Street, Carlisle: Excavations 1981–2*, Kendal, 68–72.

Jones, R. (ed.) 2012: *Manure Matters: Historical, Archaeological and Ethnographic Perspectives*, Farnham.

Jourdan, P.M., Lamberton, P.H.L., Fenwick, A., and Addiss, D.G. 2018: 'Soil-transmitted helminth infections', *Lancet* 391, 252–65.

King, A. 1999: 'Diet in the Roman world: a regional inter-site comparison of the mammal bones', *Journal of Roman Archaeology* 12, 168–202.

Knights, B.A., Dickson, C.A., Dickson, J.H., and Breeze, D.J. 1983: 'Evidence concerning the roman military diet at Bearsden, Scotland, in the 2nd Century AD', *Journal of Archaeological Science* 10, 139–52.

Krause, R.J., Koski, K.G., Pons, E., Sandoval, N., Sinisterra, O., and Scott, M.E. 2015: '*Ascaris* and hookworm transmission in preschool children from rural Panama: role of yard environment, soil eggs/larvae and hygiene and play behaviours', *Parasitology* 142, 1543–54.

Ledger, M.L., Micarelli, I., Ward, D., Prowse, T.L., Carroll, M., Killgrove, K., Rice, C., Franconi, T., Tafuri, M.A., Manzi, G., and Mitchell, P.D. 2021: 'Gastrointestinal infection in Italy during the Roman Imperial and Longobard periods: a paleoparasitological analysis of sediment from skeletal remains and sewer drains', *International Journal of Paleopathology* 33, 61–71.

Ledger, M.L., and Mitchell, P.D. 2022: 'Tracing zoonotic parasite infections throughout human evolution', *International Journal of Osteoarchaeology* 32.3, 553–64.

Ledger, M.L., Rowan, E., Gallart Marques, F., Sigmier, J.H., Šarkić, N., Redžić, S., Cahill, N.D., and Mitchell, P.D. 2020: 'Intestinal parasitic infection in the eastern Roman Empire during the Imperial Period and Late Antiquity', *American Journal of Archaeology* 124, 631–57.

Locker, A. 2007: 'In *piscibus diversis*; the bone evidence for fish consumption in Roman Britain', *Britannia* 38, 141–80.

London Archaeologist 1992. 6. https://archaeologydataservice.ac.uk/library/browse/issue.xhtml?recordId=1147478 (Accessed July 2023).

Mackinder, A. 2000: *A Romano-British Cemetery on Watling Street: Excavations at 165 Great Dover Street, Southwark, London*, MoLAS Monograph Series 4, London.

Magnusson, R.J. 2013: 'Medieval urban environmental history', *History Compass* 11.3, 189–200.

Maltby, M. 2016: 'The exploitation of animals in Roman Britain', in M. Millett, L. Revell, and A.J. Moore (eds), *The Oxford Handbook of Roman Britain*, Oxford, 791–806.

McKenzie, M., Thomas, C., Powers, N., and Wardle, A. 2020: *In the Northern Cemetery of Roman London: Excavations at Spitalfields Market, London E1, 1991–2007*, MOLA Monograph Series 58, London.

Mitchell, P.D. 2013: 'The origins of human parasites: exploring the evidence for endoparasitism throughout human evolution', *International Journal of Paleopathology* 3, 191–8.

Mitchell, P.D. (ed.) 2015: *Sanitation, Latrines and Intestinal Parasites in Past Populations*, Farnham.

Mitchell, P.D. 2017a: 'Human parasites in the Roman world: health consequences of conquering an empire', *Parasitology* 144, 48–58.

Mitchell, P.D. 2017b: 'Sampling human remains for evidence of intestinal parasites', in P.D. Mitchell and M. Brickley (eds), *Updated Guidelines to the Standards for Recording Human Remains*, Reading, 54–6.

Mitchell, P.D. 2023: *Parasites in Past Civilizations and Their Impact upon Health*, Cambridge.

Nehlich, O., Fuller, B.T., Jay, M., Mora, A., Nicholson, R.A., Smith, C.I., and Richards, M.P. 2011: 'Application of sulphur isotope ratios to examine weaning patterns and freshwater fish consumption in Roman Oxfordshire, UK', *Geochimica et Cosmochimica Acta* 75.17, 4963–77.

Nejsum, P., Betson, M., Bendall, R.P., Thamsborg, S.M., and Stothard, J.R. 2012: 'Assessing the zoonotic potential of *Ascaris suum* and *Trichuris suis*: looking to the future from an analysis of the past', *Journal of Helminthology* 86.2, 148–55.

Pearce, J. 2015: 'Urban exits: commercial archaeology and the study of death rituals and the dead in the towns of Roman Britain,' in N. Holbrook and M. Fulford (eds), *The Towns of Roman Britain: The Contribution of Commercial Archaeology since 1990*, London, 138–66.

Perring, D. 1991: *Roman London*, London.

Perring, D. 2002: *The Roman House in Britain*, London.

Perring, D. 2022. *London in the Roman World*, Oxford.

Pike, A.W. 1968: 'Recovery of helminth eggs from archaeological excavations, and their possible usefulness in providing evidence for the purpose of an occupation', *Nature* 219, 303–4.

Pullan, R.L., Smith, J.L., Jasrasaria, R., and Brooker, S.J. 2014: 'Global numbers of infection and disease burden of soil transmitted helminth infections in 2010', *Parasites & Vectors* 7, 37.

Powers, N. (ed.) 2012: *Human Osteology Method Statement, Museum of London*, London.

Rabinow, S., Wang, T., Wilson, R.J.A., and Mitchell, P.D. 2022: 'Using parasite analysis to identify ancient chamber pots: an example of the fifth century CE from Gerace, Sicily, Italy', *Journal of Archaeological Science: Reports* 42, 103349.

Ranieri, S., and Telfer, A. (eds), 2017: *Outside Roman London: Roadside Burials by the Walbrook Stream*, Crossrail Archaeology Series 9, London.

Redfern, R.C., Gröcke, D.R., Millard, A.R., Ridgeway, V., Johnson, L., and Hefner, J.T. 2016: 'Going south of the river: a multidisciplinary analysis of ancestry, mobility and diet in a population from Roman Southwark, London', *Journal of Archaeological Science* 74, 11–22.

Redfern, R., Gowland, R., Millard, A., Powell, L., and Gröcke, D. 2018: '"From the mouths of babes": a subadult dietary stable isotope perspective on Roman London (Londinium)', *Journal of Archaeological Science: Reports* 19, 1030–40.

Revell, L. 2007: 'Military bath-houses in Britain – a comment', *Britannia* 38, 230–7.

Rivera-Guerrero, M.I., Sánchez-Rueda, L., and Rodríguez-Bataz, E. 2004: 'Efecto de algunos agentes físicos y químicos sobre el metacéstodo de *Taenia solium* presente en carne adobada y chorizo', *Salud Publica de Mexico* 46, 425–9.

Roche, K., Pacciani, E., Bianucci, R., and Le Bailly, M. 2019. 'Assessing the parasitic burden in a Late Antique Florentine emergency burial site', *Korean Journal of Parasitology* 57, 587–93.

Rodriguez-Canul, R., Argaez-Rodriguez, F., De la Gala, D.P., Villegas-Perez, S., Fraser, A., Craig, P.S., Cob-Galera, L., and Dominguez-Alpizar, J.L. 2002: '*Taenia solium* metacestode viability in infected pork after preparation with salt pickling or cooking methods common in Yucatán, Mexico', *Journal of Food Protection* 65, 666–9.

Rouffignac, C. 1985: 'Parasite egg survival and identification from Hibernia Wharf, Southwark', *London Archaeologist* 5, 103–5.

Rowan, E. 2014: *Roman Diet and Nutrition in the Vesuvian Region: A Study of the Bioarchaeological Remains from the Cardo V Sewer at Herculaneum*, DPhil, University of Oxford.

Rushworth, A. (ed.) 2009: *Housesteads Roman Fort - The Grandest Station: Excavation and Survey at Housesteads, 1954–95*, London.

Ryan, H., Flammer, P.G., Nicholson, R., Loe, L., Reeves, B., Allison, E., Guy, C., Doriga, I.L., Waldron, T., Walker, D., Kirchhelle, C., Larson, G., and Smith, A.L. 2022: 'Reconstructing the history of helminth prevalence in the UK', *PLoS Neglected Tropical Diseases* 16, e0010312.

Scholz, T., Garcia, H.H., Kuchta, R., and Wicht, B. 2009: 'Update on the human broad tapeworm (genus *Diphyllobothrium*), including clinical relevance', *Clinical Microbiology Reviews* 22, 146–60.

Scobie, A. 1986: 'Slums, sanitation, and mortality', *Klio* 68, 399–433.

Shaw, H., Montgomery, J., Redfern, R., Gowland, R., and Evans, J. 2016: 'Identifying migrants in Roman London using lead and strontium stable isotopes', *Journal of Archaeological Science* 66, 57–68.

Smith, A., Allen, M., Brindle, T., and Fulford, M. 2016: *The Rural Settlement of Roman Britain*, Britannia Monograph Series 29, London.

Stephenson, L.S., Holland, C.V., and Cooper, E.S. 2000b: 'The public health significance of *Trichuris trichiura*', *Parasitology* 121, S73–95.
Stephenson, L.S., Latham, M.C., and Ottesen, E.A. 2000a: 'Malnutrition and parasitic helminth infections', *Parasitology* 121 Suppl., S23–38.
Swain, H., and Williams, T. 2008: 'The population of Roman London', in J. Clark, J. Cotton, J. Hall, R. Sherris, and H. Swain (eds), *Londinium and Beyond: Essays on Roman London and its Hinterland for Harvey Sheldon*, York, 33–40.
Taylor, C. 2015: 'A tale of two cities: the efficacy of ancient and medieval sanitation methods', in Mitchell 2015, 69–97.
Tomlin, R.S.O. 2016: *Roman London's First Voices: Writing Tablets from the Bloomberg Excavations, 2010–14*, MoLA Monograph Series 72, London.
van der Veen, M. 2008: 'Food as embodied material culture: diversity and change in plant food consumption in Roman Britain', *Journal of Roman Archaeology* 21, 83–109.
van der Veen, M., Livarda, A., and Hill, A. 2008: 'New plant foods in Roman Britain – dispersal and social access', *Environmental Archaeology* 13.1, 11–36.
Vaz Nery, S., Pickering, A.J., Abate, E., Asmare, A., Barrett, L., Benjamin-Chung, J., Bundy, D.A.P., Clasen, T., Clements, A.C.A., Colford Jr, J.M., Ercumen, A., Crowley, S., Cumming, O., Freeman, M.C., Haque, R., Mengistu, B., Oswald, W.E., Pullan, R.L., Oliveira, R.G., Einterz Owen, K., Walson, J.L., Youya, A., and Brooker, S.J. 2019: 'The role of water, sanitation and hygiene interventions in reducing soil-transmitted helminths: interpreting the evidence and identifying next steps', *Parasites & Vectors* 12, 273.
Wallace, L.M. 2014: *The Origin of Roman London*, Cambridge.
Wang, X., Zhang, L., Luo, R., Wang, G., Chen, Y., Medina, A., Eggleston, K., Rozelle, S., and Smith, D.S. 2012: 'Soil-transmitted helminth infections and correlated risk factors in preschool and school-aged children in rural Southwest China', *PLoS One* 7, e45939.
Watson, S. 2003: *An Excavation in the Western Cemetery of Roman London: Atlantic House, City of London,* MoLAS Archaeology Studies Series 7, London.
Wilson, A., and Rackham, D.J. 1976: 'Parasite eggs', in P.C. Buckland (ed.), *The Environmental Evidence from the Church Street Roman Sewer System*, York, 32–3.
Wittner, M., White, A.C., and Tanowitz, H.B. 2011: '*Taenia* and other tapeworm infections', in R.L. Guerrant, D.H. Walker, and P.F. Weller (eds), *Tropical Infectious Diseases: Principles, Pathogens and Practice* (3rd edn), Edinburgh, 839–47.
Wood, J.W., Milner, G.R., Harpending, H.C., and Weiss, K.M. 1992: 'The osteotological paradox: problems on inferring prehistoric health from skeletal samples', *Current Anthropology* 33.4, 343–58.
Worrell, C.M., Wiegand, R.E., Davis, S.M., Odero, K.O., Blackstock, A., Cuéllar, V.M., Njenga, S.M., Montgomery, J.M., Roy, S.L., and Fox, L.M. 2016: 'A cross-sectional study of water, sanitation, and hygiene-related risk factors for soil-transmitted helminth infection in urban school- and preschool-aged children in Kibera, Nairobi', *PLoS One* 11, e0150744.