



Using paleopathology to provide a deep-time perspective that improves our understanding of one health challenges: Exploring urbanization

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Analysis

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Abstract

The question posed is how deep-time perspectives contribute to tackling contemporary One Health challenges, improving understanding and disease mitigation. Using evidence from the field of paleopathology, it is possible to explore this question and highlight key learning points from the past to focus the minds of those making healthcare policy decisions today. In previous centuries urbanization led to poorer health for a wide range of indicators, including life expectancy, sanitation and intestinal parasites, airway disorders such as maxillary sinusitis, metabolic diseases such as rickets, and even conditions resulting from clothing fashions such as bunions. Modern concerns regarding the quality of urban air and rivers show we have still to incorporate these lessons. When we consider major infectious diseases affecting past societies such as bubonic plague, tuberculosis and leprosy, interaction between humans and wild mammal reservoirs was key. Wild red squirrels in Britain today remain infected by the medieval strain of leprosy that affected people 1,500 years ago. It is clear that the One Health focus on the interaction between humans, animals and their environment is important. Eradicating zoonotic infectious diseases from humans but not these reservoirs leaves the door open to their spread back to people in the future.

Introduction

The research idea I have been asked to consider is ‘how can deep time perspectives contribute to tackling contemporary One Health challenges, improving understanding and disease mitigation?’ (Bendrey and Fourmié, 2023). One Health has been defined by the World Health Organisation as an integrated, unifying approach to balance and optimize the health of people, animals and ecosystems (WHO, 2022). Past research into deep-time perspectives on One Health has sometimes focused on specific infectious diseases, such as brucellosis or leprosy (Bendrey et al., 2020; Urban et al., 2021), while others have attempted a broad theoretical overview of how zoonoses and environment might have interacted from a One Health perspective in past era (Kim and Agarwal, 2023; Rayfield et al., 2023). The study of health and disease in past populations is termed paleopathology (Gauer, 2022). One particular challenge is that the significant majority of paleopathological research has investigated humans, with much less work targeted towards the health of animals in the past. This greatly limits the evidence that might be brought to bear from the perspective of animal health, which is clearly a key component of the One Health approach.

One way to investigate this question from a different angle is to explore the archaeological evidence for some of the ways in which human and animal health has changed during the process of urbanization, and to do this here we will mainly focus on Europe. Applying a range of examples from paleopathology can provide that deep-time perspective and show the ways in which interaction between people, animals and their environment has led to dramatic changes in health over the last two thousand years. The majority of those living in rural areas of Europe since the Neolithic period made their living through agriculture (Shennan, 2018). In contrast, the majority of people in urban centers were involved with trade, manufacturing, administration, education and religious institutions (Haslam, 2010; Fernández-Götz, 2018). With the Industrial Revolution in Britain in the mid 1700s, and rest of Europe over the subsequent century, the use of coal-fired machinery resulted in a great expansion of manufacturing and faster long-distance sea travel (Glenn, 2019; Stearns, 2020). However, the cramped working conditions in factories, risk of injury from machinery, pollution of air and rivers, poor housing, ineffective sanitation, limited town planning, having to import food from the countryside, and high population density might all have led to major health consequences, as we can see below.

Paleopathology and urbanization

Life expectancy can be used as a crude indication of how healthy living conditions were in different past environments. Both archaeological evidence from cemeteries and historical

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Research
Directions



evidence from census records show that in medieval Britain the life expectancy of people living in the countryside was higher than those living in towns (Lewis, 2003; Kowaleski, 2014). Similarly, government records from 19th to early 20th century Poland showed lowest life expectancy in the city of Poznan, intermediate life expectancy in small towns, and best life expectancy in rural villages (Budnik and Liczinska, 2006). At a very simple level, these are examples of how urbanization was often bad for health in past societies.

Sanitation and the management of human waste became a challenge with the transition from a rural agricultural lifestyle to urban living. While toilets had been developed in ancient Greece during the Bronze Age (Angelakis et al., 2005; Antoniou, 2007), in much of Europe it was only when latrines and sewers were introduced by the Romans that people had an alternative to depositing their feces on open middens and rubbish areas. Over time we see changes in intestinal parasite infection with the onset of urbanization. In the neolithic period and those living in lakeside villages in the Bronze Age and Iron Age, we see a mixture of zoonotic parasites contracted from eating wild animals and fish, along with roundworm and whipworm that are spread by the contamination of food and drink by human feces (Mitchell, 2023, 42–52). However, by the Roman period and continuing into the medieval period, we see a dominance in urban areas of roundworm, whipworm and the protozoa that cause diarrhea and dysentery (Mitchell, 2015, 2017). This shows how high population density coupled with the fecal contamination of rivers that run through towns led to the dominant parasites being those spread by ineffective sanitation. Pollution of rivers today remains a major concern for both health and the environment (Fuller et al., 2022).

Maxillary sinusitis is a condition where the air sinuses in the face become inflamed and the secretions that accumulated in the sinus may become infected by bacteria (Chang et al., 2018). Comparison of maxillary sinusitis in a rural and urban population in medieval Britain found a significantly higher prevalence of sinusitis in those living in the city (York). It was proposed that the difference may have been due to air pollution from the higher population density in the city, the use of coal in urban household cooking fires, and industries such as lime kilns to make cement for building in the city (Lewis et al., 1995). Air pollution in modern towns and cities is an ongoing challenge that has a significant detrimental impact upon health (Fuller et al., 2022).

Rickets is a condition where deficiency in vitamin D during childhood leads to impaired bone development (Gentile and Chiarelli, 2021). Humans can make vitamin D in their skin from sunlight, and so conditions where children are exposed to little sunlight can lead to rickets. During the Industrial Revolution in the late 1700s and 1800s, air pollution from coal-fired industry, coupled with child labor in factories during daylight hours, led to rickets becoming more common. It can be detected in human skeletal remains from the altered shape of the long bones in the limbs, pelvis, ribs and increased porosity of bones across the skeleton (Mays et al., 2006). A large study comparing the skeletons of 1154 individuals who lived in 11th–17th century Britain with 4157 individuals living at the time of the industrial revolution (18th–19th century) found prevalence of rickets severe enough to cause permanent change to the shape of the bones increased by a factor of $\times 10$ over this period, from 0.5% to 6% (Buckberry and Crane-Kramer, 2022).

In the past, people living in towns often had a higher income than those in the countryside, as a result of the higher wages for skilled tradesmen and business owners compared with less skilled

farm laborers. One consequence of this wealth discrepancy that can be detected in the archaeological record is the health consequences of changing fashions in shoe design. In 10th–13th century England shoes generally had a rounded toe-box, but in the 14th century the fashion for shoes with a pointed toe-box was introduced from France (Fizzard, 2007). Research on modern patients has shown that pointed shoes tilt the big toe to the side and trigger hallux valgus (bunions) (Menz et al., 2016). Not only does this deformity cause pain at the base of the big toe, it also makes falls more likely in older people, with a corresponding increased rate of fractures (Mickle et al., 2009). A study of different groups of people living in and around Cambridge during this period showed that 10%–45% of those living in the town had hallux valgus, compared with just 3% of those who lived in a rural farming community outside Cambridge. It was also found that fractures were significantly more common in those with hallux valgus than those without, which matches what we know about the increased risk of falls (Dittmar et al., 2021). This highlights how human behavior associated with urbanization, mediated by variation in income between rural and urban areas and coupled with access to the latest fashions, can lead to adverse health consequences in the past.

However, certain aspects of human health do not seem to have followed the pattern of worse health in urban areas in the past. Comparison between prevalence of tuberculosis in urban and rural sites in medieval Denmark showed no notable difference, suggesting that TB was equally successful at infecting people living in towns and villages (Kelmelis and Pedersen, 2019). Assessment of disease in children from urban and rural sites in northern England during the industrial period showed similar levels of anemia and dental disease, while those with a rural lifestyle showed more evidence for short stature and respiratory disease (Gowland et al., 2018).

Paleopathology and zoonotic infectious diseases

Many infectious diseases that caused morbidity through deep time were zoonoses, meaning that they infected both humans and other animals (Romich, 2008). Some micro-organisms required specific groups of animals to complete different parts of their life cycles, but others were generalists that were equally happy to infect humans or other mammals with similar physiology as the opportunity arose.

One of the most noteworthy infectious diseases to affect Europe during the last two thousand years was bubonic plague. Caused by the bacterium *Yersinia pestis*, this zoonosis is sustained in wild rodent reservoir populations but can be transmitted to humans by the bite of rodent fleas such as *Xenopsylla cheopis* (Chouikha and Hinebusch, 2012). Just such a transfer in Asia resulted in the Plague of Justinian in humans from 541 to 543 CE, and subsequent outbreaks recurred until the 8th century when it appears to have died out in Europe (Little, 2006). A new strain was introduced from Asia in the mid 14th century to cause the Black Death, and repeat outbreaks recurred until the 17th century (Benedictow, 2021). It has been argued that these episodic epidemics in humans were only possible due to the infection of European wild rodent populations, which acted as reservoirs until the environmental conditions facilitated its spread back to humans by flea bites once again (Carmichael, 2015). It remains unclear why plague died out in humans in Europe in the 17th century, but persists to this day in many tropical regions such as Madagascar.

Tuberculosis was a common infectious disease in the past populations of Europe (Roberts and Buikstra, 2003). It was previously thought that tuberculosis spread to humans from cattle

following the domestication of wild animals by early farmers (Cockburn, 1963; Manchester, 1984). However, when analysis of human skeletal remains with lesions suggestive of TB at the medieval farming settlement of Wharram Percy in Britain was performed, the DNA showed that the infections were by *Mycobacterium tuberculosis* (the human form) and not *M. bovis* (the form evolved to specialize in cattle) (Mays et al., 2001). Researchers had to think again. Since then, studies exploring the DNA of ancient and modern strains of tuberculosis in humans and a wide range of animals suggest that tuberculosis probably originated as a pathogenic disease in humans (Wirth et al., 2008). Subsequent mutations allowed the development of the various forms of TB that we find in other animals today, such as *M. bovis*, *M. caprae*, *M. pinnipedii*, *M. mungi*, *M. orygis* and *M. microti*. It appears that the form of tuberculosis that affects seals and sea lions (*M. pinnipedii*) was probably transmitted to the Americas by the pinnipeds migrating across the Atlantic Ocean from Africa or Europe, resulting in the zoonotic infection of humans in South America by the seal and sea lion form of TB around 1,000 years ago (Bos et al., 2014; Vågene et al., 2022).

A further example of a widespread disease to affect humans throughout the medieval period was leprosy. Its chronic disease course, ability to cause destructive facial lesions and perceived association with religious impurity led to the foundation of numerous leprosaria, where those with more visually apparent infections could live together in groups (Rawcliffe, 2006). Caused by *Mycobacterium leprae*, it was long thought to be an infection so closely evolved to infect humans that involvement of other mammals was perhaps an incidental dead end. However, in recent years it has come to light that wild red squirrels in England, Scotland and Ireland sustain leprosy infections within their populations today (Avanzi et al., 2016). Analysis of the skeletal remains of people infected with leprosy in the Anglo-Saxon and medieval periods in Britain has found that exactly the same strain (ancestral variant of subtype 3l) infected them as still infects red squirrels now (Inskip et al., 2017). Potential explanations for the link include the medieval use of squirrels for fur and as pets, both of which would have facilitated the spread of leprosy between them. While leprosy died out as an endemic disease of humans in Britain over 200 years ago, the squirrel population struggles on with this disease.

Conclusion

Here we have explored examples from the field of paleopathology that give a deep-time perspective on many issues that are key to the One Health approach. The examples of the health impacts of urbanization, and the spread of infectious diseases between humans and wild animal reservoirs, highlight the long view of the complexity associated with One Health challenges today.

Our environment is key to our health, so it is crucial that we learn which elements of urbanization impair health, and remove those from modern towns and cities. Similarly, when we face infections by zoonoses that can be sustained in animal reservoirs for centuries, we need to approach the health of those wild animals just as seriously as the health of humans who might once again contract infectious diseases from them. On so many levels, it is a good thing that we no longer wear squirrel fur coats.

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Connections references

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