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Famine, the Black Death, and health in fourteenth-century London

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In the first half of the fourteenth century two catastrophes struck the population of Europe: the Great Famine and the Black Death. The latter has been extensively studied, but much less is known about the biological effects of the Great Famine. A large assemblage of skeletal remains from one of the Black Death burial grounds, the Royal Mint cemetery in London, provides a unique opportunity to investigate these effects by analyzing the teeth of individuals who survived the famine but died during the Black Death.

In 1986, archaeologists at the Museum of London began excavating a large cemetery on the site of the Royal Mint, near the Tower of London in East Smithfield. It contained many individual graves, and the excavators also found two mass-burial trenches and a mass-burial pit, densely filled with several hundred well preserved articulated skeletons (Fig. 1). The site was identified as the Black Death cemetery, which had been opened in 1348–49 by Ralph Stratford, the Bishop of London, as an emergency burial ground.[1] It is the largest and most comprehensively excavated Black Death cemetery in England and it provides a unique assemblage of people who died in 1348–49, at the peak of the Black Death epidemic in London. Over three decades earlier, the Great Famine of 1315–17 had ravaged northern Europe. Like the Black Death, this protracted period of famine is recorded as one of the greatest calamities of the medieval period; but, although it is believed to have caused great suffering and high mortality, little is known about its direct effects on the people who survived it. We are currently investigating this topic by studying the skeletal remains of people who died from the Black Death and were buried in the Royal Mint cemetery.[2]

The Black Death

The Black Death arrived in Europe from the Crimea during October 1347. Nine months later, in June–July 1348, it reached Weymouth on the south coast of England and by November it had reached London.[1] The death rate in London rose rapidly from December 1348 and reached a peak in April 1349. By June 1349 it had fallen substantially. A contemporary observer stated that, when the epidemic was at its height, 200 bodies a day were buried at one of the new cemeteries that had been established.[3] Documentary evidence shows that the Royal Mint cemetery at East Smithfield was one of two emergency burial grounds established in late 1348, or early 1349, to cope with the Black Death epidemic (the other being West Smithfield).[1] Most of an estimated 2400 people buried at the Royal Mint site are believed to have died from the Black Death, and over 600 inhumations were recovered by the Museum of London archaeologists. However, the established view that the epidemic was caused by plague has recently been challenged, and plague can no longer regarded as the only suspect.

Plague, rats and fleas

Plague is an acute epidemic disease caused by the bacterium *Yersinia pestis* and it is usually transmitted to humans by rat fleas. Patients with bubonic plague, the most common clinical form of the disease, tend to suffer from high fever, delirium, aching limbs and painful swelling of the lymph nodes called buboes. In some cases, the buboes burst after a few days, releasing pus and then healing. In others, bleeding under the skin occurs, producing black patches that can lead to fatal ulcers. If bubonic plague was the cause of the 1347–49 epidemic, such lesions may explain the origin of the term "Black Death". However, some researchers have recently highlighted several discrepancies between modern epidemics of bubonic plague and the Black Death.[4] In particular, the rapidity with which the disease spread across Europe and the unusually high overall mortality appear to contrast with the epidemiology of recent outbreaks of plague. The devastating impact of the disease on Europeans in the fourteenth-century may partly be explained by the absence of any previous

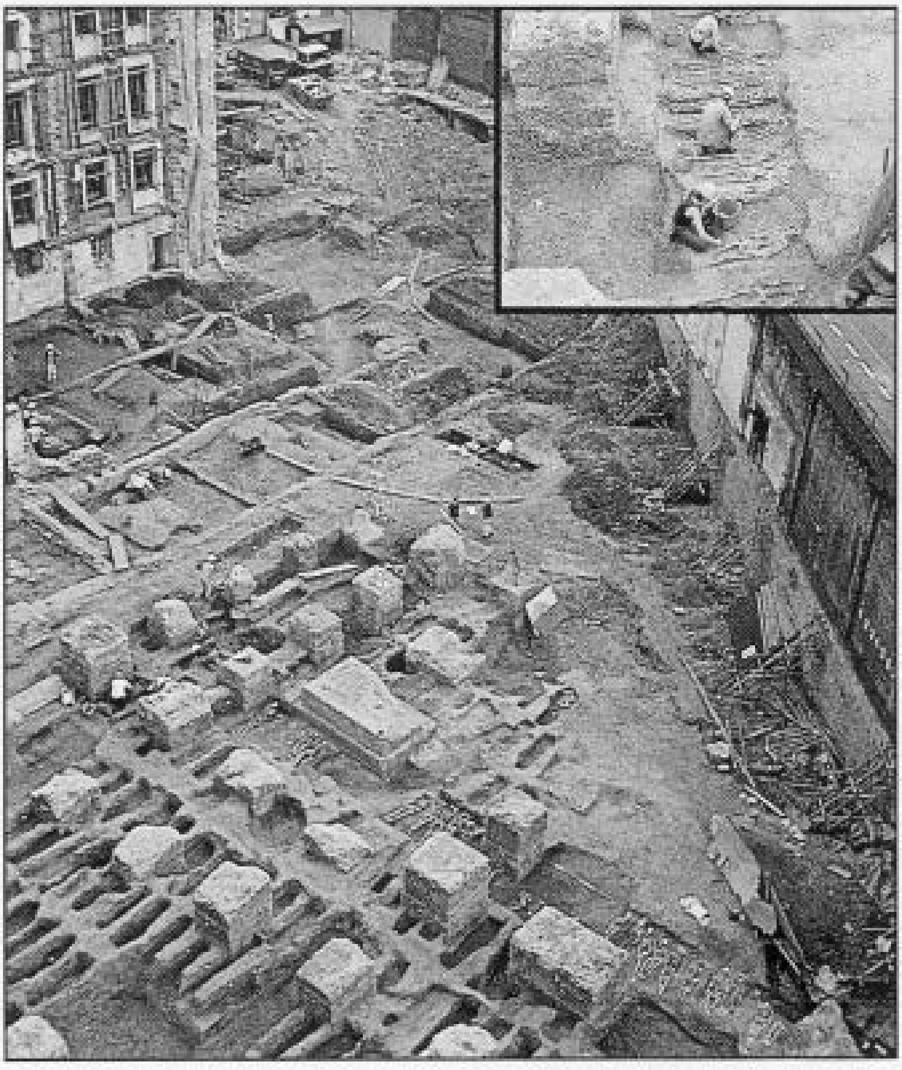

Figure 1 *Mass-burial trench and graves from the Black Death cemetery of East Smithfield in London, excavated by archaeologists from the Museum of London; the inset shows part of the mass-burial trench under excavation.*

exposure to it, but the role played by rats, and their fleas, in the biology of plague is now being questioned. It has been argued, for example, that fleas would have had great difficulty reproducing in the cool climatic conditions of northern Europe. Rats are themselves susceptible to dying from the plague, and outbreaks tend to be preceded by the presence of many dead rats. Contemporary accounts appear to lack any mention of rat mortality and, unlike Asia, Europe does not have plague-resistant wild rodents that would act as a natural reservoir for the disease. Without such a reservoir, it is hard to explain how plague continued to affect Europe for another three centuries, as it did. Furthermore, despite two well authenticated epidemics of plague in Iceland in the fifteenth century, the island is believed to have been free of rats until much later.[5]

Discrepancies such as these warrant further research. One suggestion is that a virus, similar to the filoviruses responsible for highly contagious and often lethal haemorrhagic fevers such as Ebola, caused the Black Death epidemic rather than the bacterium that causes plague.[6] However, regardless of these new uncertainties over the cause of the Black Death, the Royal Mint cemetery provides a unique opportunity to analyze a large assemblage of the remains of people who died within a few months of each other in 1348–49, three decades after the Great Famine.

The Great Famine

The famine of 1315–17 appears to have resulted from a series of abnormally cold winters and wet summers, which caused a catastrophic succession of failed harvests across northern Europe. In London, the impact of the famine can be monitored through records of wheat prices,[7] which reached unprecedented heights in July 1315, fell again after the harvest, and then rose to their highest level between April and July 1316. After the harvest of 1317 they appear to have fallen, but they rose once more during May in what may have been a less serious episode of shortage. During the famine, even the modestly wealthy could not afford enough food,[8] the hungry flocked to London to find relief, and many died in the streets. The mortality rate varied locally, but the population of Essex villages fell by approximately 15 per cent as a result the famine, including those who left for London. Starvation must have left its mark on many who survived. The famine is also likely to have had a profound effect on the health of children growing up at the time. Previously there was no way in which the direct biological effects of the famine could be determined, but now an opportunity to investigate them has arisen from recent advances in the study of dental tissues and access to the skeletal assemblage excavated at the Royal Mint cemetery.

The current research project

Bones and teeth form during childhood, and their formation can be affected by the child's overall health. As the Black Death occurred some 30 years after the Great Famine, individuals who died in their thirties and forties would have lived through it as children. For example, a person born in 1314, one year before the Great Famine began, would (depending on their date of birth) have been 33 or 34 years old in 1348. By studying the development of one such individual's bones and teeth, it is possible to investigate the effect of the famine on their overall health. The Museum of London's initial study of the skeletal assemblage identified 224 individuals aged from 15 to 44 years at death. We re-examined this group in order to identify specimens suitable for our project. A group of 30 individuals, showing good preservation and most likely to be aged between 30 and 40 years at death, were selected for analysis. Their age was established using standard archaeological and forensic methods[9] by three trained observers acting independently (ourselves and Tony Waldron). A control group of seven individuals, who would have been born after the Great Famine, and were aged between 20 and 30 years at death, were also selected.

The methods we use to investigate growth of the selected individuals involve detailed microscopic examination of their teeth. Four to six teeth per individual are extracted.[10] Microscopic structures inside teeth, similar to the growth rings of trees, mark out dental development, and recent research has proved that the finest marks, visible in thin sections and known as enamel prism cross-striations, represent daily growth structures.[11] It is possible to use these structures to build a detailed chronology of tooth formation and to map out any disruptions that may have occurred during formation.[12] Indeed, systemic disturbances (those that affect the entire body) experienced by a child during the period of dental development, such as episodes of nutritional stress, can disrupt tooth formation. Any such event can result in the formation of furrows or pit-like depressions known as hypoplastic defects, which can be observed on the surface of tooth crowns and are expressed internally as lines of disturbed growth (Figs 2, 3). Because dental tissues, unlike bones, do not renew themselves once they are formed, teeth offer a detailed permanent record of any disturbances that occurred during childhood when they were growing. In our project we are using growth lines to build a very detailed record of health in the early years of life of the individuals being studied, including any periods of growth disruption. By counting and matching these structures, it is possible to determine the ages at which the disruptions to development occurred and this provides us with an extended record of growth from birth to the late teens, when

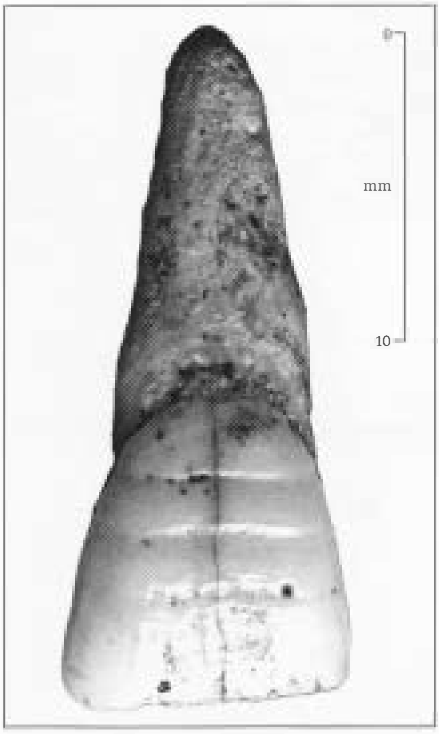

Figure 2 *Hypoplastic defects on the surface of an anterior tooth (upper left incisor) from one of the specimens selected for analysis. The hypoplastic defects represent disruptions to regular crown growth and are visible as furrows running horizontally across the tooth.*

dental formation ends.[13] We have now sectioned most of the teeth from all 37 individuals in the main group and the control group, and are currently analyzing them.

We are also comparing the timing of growth disturbances provided by the tooth record with the detailed chronology of the Great Famine, including the record of wheat prices in London. It is hoped that enough close matches between the distribution of growth disturbances and the chronology of the famine will be found in order to identify individuals who were children during the famine.[14] In these cases, it is possible to build a detailed sequence of changes, day by day, based on the dental development (Fig. 4), and to compare it with the history of the famine. The impact of the crisis on their skeletal development is also being investigated. The data generated will provide us with an insight into the impact of the famine on the dental and skeletal development of individuals who were children during this period, and thus add greatly to our knowledge of its effect on the overall health of Londoners in the fourteenth century.

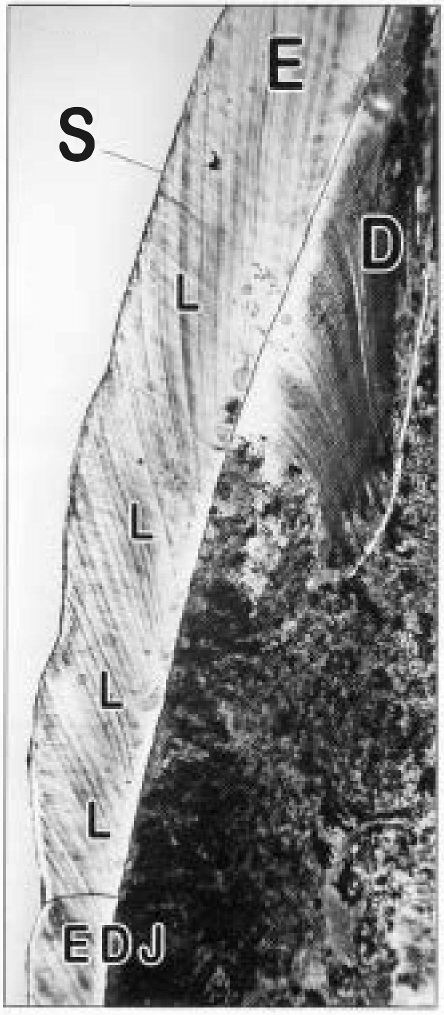

Figure 3 *Detail of a thin section,* c. *700 microns long, of the tooth shown in Figure 2 (polarized transmitted-light microscopy). The surface, enamel and dentine are labelled S, E and D. The dark vertical lines (L), seen radiating away from the enamel/dentine junction (EDJ), represent periods during which tooth formation was disrupted and are associated with the surface hypoplastic defects visible in Figure 2.*

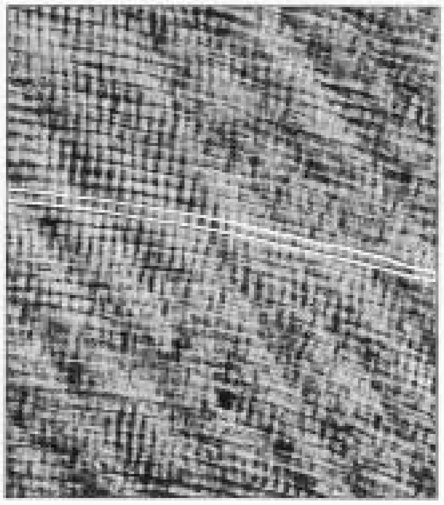

Figure 4 *High-magnification detail from the thin section (Fig. 3), showing the regular growth structures found in enamel (polarized transmitted-light microscopy). The approximately weekly growth layers, known as brown striae of Retzius, can be seen running from bottom right to top left. The enamel prisms (one outlined by two white lines) run across from right to left, and along their length the cross-striations are visible approximately 4 microns apart. The cross-striations represent circadian growth markers and they can be used to determine the precise timing of crown formation, as well as the number of days between any disruption of this formation. (Circadian rhythms occur with a periodicity very close to the 24-hour cycle.)*

Notes

1. See P. Ziegler, *The Black Death* (Harmondsworth: Penguin, 1970) and D. Hawkins, "The Black Death and the new London cemeteries of 1348", *Antiquity* **64**, 637–42, 1990.
2. The project is funded by a Wellcome Trust Postdoctoral Research Fellowship in Bioarchaeology held by one of us (D. A.). We wish to thank the Museum of London, and in particular John Shepherd and Bill White of the Museum's Centre for Human Bioarchaeology, for allowing us access to the Royal Mint skeletal assemblage. Other participants in the project are Professor Derek Keene (Institute of Historical Research, University of London), Professor Chris Dean (Department of Anatomy and Developmental Biology, UCL), and Gustav Milne and Professor Tony Waldron (Institute of Archaeology, UCL).
3. See pp. 64–5 in R. D. Horrox, *The Black Death* (Manchester: Manchester University Press, 1994).
4. See detailed discussions in S. Scott & C. J. Duncan, *Return of the Black Death* (Wiley: Chichester, 2004) and *The biology of plagues: evidence from historical populations* (Cambridge: Cambridge University Press, 2001); and S. K. Cohn Jr, *The Black Death transformed: disease and culture in early Renaissance Europe* (London: Arnold, 2003). A review of the debate surrounding the cause of the Black Death epidemic can also be found in S. Porter, "An historical whodunit", *Biologist* **51**, 109–113, 2004.
5. See G. Karlsson, "Plague without rats: the case of fifteenth-century Iceland", *Journal of Medieval History* **22**, 263–84, 1996.
6. See Scott & Duncan 2004 (*n.* 4 above).
7. Personal communication from Derek Keene, and see B. M. S. Campbell, J. A. Galloway, D. Keene, M. Murphy, *A medieval capital and its grain supply: agrarian production and distribution in the London region c. 1300* (Historical Geography Research Series 30, Institute of British Geographers, London, 1993).
8. W. C. Jordan, *The Great Famine: northern Europe in the early fourteenth century* (Princeton: Princeton University Press, 1996).
9. The ageing of an adult skeleton is usually based on the degenerative age-related changes that occur on parts of the skeleton where two bones come into contact (joint surfaces). The most reliable areas are found on the hip bone and the changes are assigned scores. Scores are combined to provide an approximate age-at-death within a 5- or 10-year range. See J. E. Buikstra & D. H. Ubelaker, *Standards for data collection from human skeletal remains* (Arkansas Archeological Survey Research Series 44, Fayetteville, 1994).
10. The permanent teeth develop in a sequence, starting just before birth with the first molars, followed by incisors, canines, second molars and premolars, and finally the third molars (wisdom teeth). Several teeth, with overlapping periods of formation, are required to investigate growth over several years.
11. See D. Antoine, C. Dean, S. Hillson, "The periodicity of incremental structures in dental enamel based on the developing dentition of post-medieval known-age children", in *Dental morphology 1998*, J. T. Mayhall & T. Heikkinen (eds), 48–55 (Oulu: Oulu University Press, 2000) and S. Hillson & D. Antoine, "Ancient bones and teeth on the microstructural level" in *Deciphering ancient bones – the research potential of bioarchaeological collections,* G. Grupe & J Peters (eds), 141–57 (Rahden: Leidorf, Documenta Archaeobiologiae, 2003).
12. S. Hillson, D. Antoine, C. Dean, "A detailed developmental study of the defects of dental enamel in a group of post-medieval children from London" 102–111 in J T Mayhall & T Heikkinen (see *n.* 11 above).
13. In order to extend the chronology beyond six years of age (when the crown of the second molar completes its formation), it is necessary to include root formation. Unfortunately, microscopic growth structures are harder to observe in the root. Nonetheless, in many of the specimens sectioned to date, it was possible to observe these structures and to extend the growth record beyond six years.
14. The distribution of growth disturbances in the 30–40 year-old group should differ from that of the younger control group (aged between 20 and 30 years). Interestingly, individuals in their mid-twenties who would have been born before 1322 should also show signs of a less extreme famine that is believed to have occurred in 1322–23.