

MUSEUM OF LONDON ARCHAEOLOGY BRIEFING NOTE

DNA of bacteria responsible for London Great Plague of 1665 identified for first time

What do the ancient DNA results from the mass burial pit show?

20 samples were taken from individuals excavated from the mass burial pit from Museum of London Archaeology (MOLA) excavations of the New Churchyard (Bedlam burial ground).

Five of these have a positive result for the plague pathogen, *Yersinia pestis*. This result shows that these five individuals were exposed to plague shortly before their deaths and owing to the disease's virulence, it is likely that they died of this exposure. This is the first identification of plague DNA from 17th Century Britain.

The fact that not all of the skeletons tested from the pit came back with a positive result does not mean they were not also exposed to/died of the plague. When a body lies buried in the ground for hundreds of years the rate of survival of ancient DNA reduces considerably.

How many skeletons were sampled altogether and how is sampling done?

In total 40 individuals from the New Churchyard were sampled for ancient DNA and other scientific testing. This comprised 20 samples from individuals buried in the mass burial pit and a further 20 from elsewhere in the burial ground, as a control sample. No evidence of plague was found in the control sample.

Samples were taken from the teeth of the individuals. The enamel shell of teeth helps to protect and preserve DNA and reduces the chances of contamination. In essence, the teeth can act as little time capsules, protecting the precious genetic information that provides an indication of the bacteria that were circulating in an individual's bloodstream at the time of death. The samples were taken in controlled conditions by a team of osteologists from MOLA and then sent to the Max Planck Institute for the Science of Human History in Jena, Germany.

The team of Molecular Palaeopathologists at the Max Planck Institute in Germany comprises group leader Kirsten Bos and PhD candidate Maria Spyrou.

What does ancient DNA testing involve?

The first stage of analysis at the Max Planck Institute was to quickly screen the samples for signs of the plague pathogen, *Yersinia pestis*. A polymerase chain reaction (PCR) specific for the *pla* gene (that codes for the virulence-associated plasminogen activator) was used to rapidly scan samples and identify any plague DNA.

Samples that were found to be pathogen positive were then put forward for shotgun sequencing, a technique which allows scientists to look at pathogen DNA without the need to specifically target any single microbe. A large number of ancient molecules matching *Yersinia pestis* were found, thus authenticating the previous PCR-based results.

Is there further ancient DNA work being carried out on these samples?

Yes, at this stage the team from the Max Planck Institute has identified the plague pathogen as present but work is ongoing to sequence the full genome.

Once this is done, the genetic information can be mapped onto what we know of the evolutionary, or phylogenetic, tree of plague to see how it relates to the Black Death and other outbreaks during the second pandemic.

There are two main questions to answer:

1. What is the relationship between the outbreaks that caused the Black Death of 1348 and the Great Plague of London of 1665 (in essence, the first and final large outbreaks of the disease in Britain)?
2. During the second pandemic (the time period after the Black Death until the mid-18th Century), were waves of plague following trading routes from Asia into Europe, or was there a single introductory wave from Asia which set up a reservoir of infection within a rodent population in Europe that continued to re-infect the human population from time to time?

What other scientific tests were carried out and what do they show?

In addition to ancient DNA, the samples have undergone a number of other scientific tests including:

Isotopic analysis: (carried out on ten individuals from the mass pit)

Isotopic analysis of strontium and oxygen can provide information on local geology and rainfall, helping to identify where an individual was raised and whether they moved in their lifetime (migration).

Carbon and nitrogen stable isotopes help to distinguish diets, this includes the types of plants consumed, the general type of diet (e.g. meat-based, vegetarian or mixed) and the level of marine component consumed (e.g. fish). Variations in isotope ratios can help to reconstruct a dietary timeline for an individual and may also distinguish periods of heightened stress in early life, perhaps reflecting age of weaning.

Carbon 14 dating:

Radiocarbon dating (C14) was carried out using the dental collagen of five individuals from the mass pit. This method uses the known rate of decay of a radioactive carbon isotope (¹⁴C) to measure the age of organic material.

Scientific analysis – test results still to come:

Microbiome DNA: (samples were taken from eight individuals from the mass pit)

This is the analysis of small samples of dental calculus formed of hardened plaque accumulated on the teeth during life (particularly evident in those with poor dental hygiene).

Metagenomic analysis of the calculus looks at the oral microbiome, the mix of bacteria living in the mouth which can work in tandem (symbiotic) with the body but can also cause disease, in particular in individuals with compromised immune systems. It also looks at the

DNA of food remnants and of the individual tested. Microscopy of the calculus samples identifies food consumed (dietary starches, plant and animal fibres) and air borne particles (pollen, dust and pollutant particles such as charcoal).

What more can we say about the individuals buried in the pit from studying their remains?

Alongside scientific testing, a team of osteologists from MOLA have been studying the skeletons from the mass burial pit macroscopically, as part of their detailed analysis of the 3,300 individuals excavated from the New Churchyard.

A greater proportion of sub-adults (0 to 17 years) were found in the mass burial pit when compared to the remainder of the burial ground. This is consistent with 'catastrophic assemblages' in which you are more likely to see a truer representation of the living population.

What have we learnt about the mass burial pit from studying the archaeological evidence?

Of the 42 individuals buried in the mass burial pit approximately two-thirds were coffined, with the remainder probably buried in shrouds. The burials were stacked, up to eight deep in places, and were alternated head-to-toe to make best use of the available space. The last burials were placed around the edges of the pit to fill any remaining gaps.

In most instances the coffins had almost entirely decayed, however one coffin was recognisable as a flat-lidded 'single break' form, which became ubiquitous during the second half of the 17th Century. The absence of any soil between the burials in the pit could suggest that it was filled in a single event and not kept open for more than a short period.

How big was the mass burial pit and how many people were buried in it?

The surviving section of the mass burial pit measured 2.3m by 2.3m and contained 42 burials. However, this section represents only the south end of the pit and no more than half of its original size. The remaining part of the pit had been disturbed by 19th and 20th Century development of the site. It can be estimated that the pit may well have originally contained at least 90 to 100 individuals.

The stacks of coffins within the pit would have been at least 1.5m deep before they collapsed and compressed because of decay over time.

Are you able to accurately date the mass burial pit?

A number of indicators point to a mid-17th Century date, including the sequence of archaeology (stratigraphy), dates of finds within the pit, as well as datable coffins and coffin furniture.

The Great Plague of 1665, in which 100,000 people are thought to have died, was the only significant outbreak of plague in London during the mid-17th Century. The last known cases of plague were recorded in London in the 1670s. The only documented use of pit burials at the New Churchyard for plague victims was during the summer of 1665.

Were there any artefacts found in the mass burial pit?

There was very little artefactual material found within the pit. Finds were limited to a few fragments of pottery and glass as well as the handles on one of the coffins.

What do historical records tell us about the use of the New Churchyard (aka the Bedlam burial ground) during the Great Plague?

Burial registers indicate that the New Churchyard only took a few plague victims each year outside of major epidemics. However, the registers show dramatic increases in 1625 and 1665 (the 'Great Plague') with burials peaking during the summer months.

Daniel Defoe's *A Journal of the Plague Year*, published in 1722, includes the New Churchyard among a list of burial grounds used during the 1665 epidemic:

"a piece of ground in Moorfields, by the going into the street which is now called Old Bethlem"

An entry from the Court of Aldermen records, dated 6 September 1665, paints a vivid picture of the burial ground's struggle to cope with a crisis of capacity in August–September 1665:

"This Court being now informed of the noisome stench arising from the great multitude of dead bodies buried in the new Churchyard in Bethlem during this mortality...doth order that Mr Clitherowe Keeper of the said Churchyard shall not henceforth make any Pitts for burials during this said visitation and only in single graves of sufficient depth and in such convenient places from whence noe annoyance may arise; And that (at his owne charge) hee cause such quantity of fresh mould to bee forthwith laid on the places complained of as may effectually smother and suppress the stench or annoyances likewise cause all the bones lying above the ground to bee buried and pieces of coffin boards to bee burnt this evening in the midst of the said Churchyard."

An account by Thomas Vincent's in *God's Terrible Voice in the City by Plague and Fire*, first published in 1667, describes London in August of 1665:

"Now the cloud is very black, and the storm comes down upon us very sharp. Now Death rides triumphantly upon his pale Horse through our streets, and breaks into every house almost, where any inhabitants are to be found. Now people fall as thick as leaves from the Trees in Autumn, when they are shaken by a mighty wind. Now there is a dismal solitude in London-streets...Now we could hardly go forth, but we should meet with many Coffins, and see many with sores, and limping in the streets."

On 30 August 1665, the famous diarist Samuel Pepys was likely referring to the New Churchyard when he recorded that he *"walked towards Moorefields"* to see if he could see *"any dead corps going to the grave."*

Burial restrictions imposed upon the burial ground resulted in the drastic reduction in recorded burials at the New Churchyard, plague or otherwise, from early September 1665. Thereafter the parishes of London had to find room in their own churchyards or send burials to new grounds, such as Bunhill Fields.

<http://www.museumoflondonprints.com/image/134533/john-dunstall-detail-of-plague-broadsheet-comprising-nine-scenes-relating-to-the-1665-plague>

Do archaeological evidence and historical accounts of use of the New Churchyard (aka the Bedlam burial ground) during the Great Plague tally?

Forgoing normal Christian burial practice in favour of mass graves was unusual in 17th-Century London and probably only occurred during the worst epidemics. Mass graves were chiefly used for reasons of practicality and hygiene, since they could achieve the most rapid burial of large numbers of individuals. Parishes may also have dug mass pits to save money. By the height of the Great Plague many families found themselves unable to contribute to the cost of burial and the expense was increasing shouldered by the parish.

Pit burials were documented at the New Churchyard and this is borne out in the archaeological evidence. The burials in the mass grave were mostly coffined and tightly packed but they were buried in an orderly fashion. Whether this was out of respect for the dead or for reasons of practicality is not known. This does not, however, tally with Daniel Defoe's description of burial in the 'Great Pit' at Aldgate in mid-September 1665:

"The cart had in it sixteen or seventeen bodies; some were wrapt up in linen sheets, some in rags, some little other than naked, or so loose that what covering they had fell from them in the shooting out of the cart, and they fell quite naked among the rest; but the matter was not much to them, or the indecency much to any one else, seeing they were all dead, and were to be huddled together into the common grave of mankind, as we may call it, for here was no difference made, but poor and rich went together; there was no other way of burials, neither was it possible there should, for coffins were not to be had for the prodigious numbers that fell in such a calamity as this."

If Defoe's retrospective account is accurate, it may refer to a period following the closure of the New Churchyard to plague burials when there was a great degree of panic and disorder. The pit appears to have contravened the Plague Orders of 1 July 1665, which stipulated that plague burials had to be at least six foot deep (1.83 metres). Archaeological evidence indicates that the upper burials in the pit lay just half a metre below the surface. The description of 'noisome stench' coming from pits at the burial ground in 1665 appears to confirm that the burials lay much closer to the surface than was legal.

Can you identify any of the individuals buried in the pit?

Although there are parish records providing names of people who died of the plague during the 1665 outbreak, there was no biographical evidence within the mass grave to identify them.

Elsewhere on the site MOLA archaeologists uncovered a headstone, reused in a later wall, that belonged to a plague victim named Mary Godfrey. Mary's burial is recorded in the burial register of St Giles, Cripplegate, on 2 September 1665.

Is there any risk of releasing plague from the excavation and scientific analysis of the remains?

The plague bacterium does not survive in the ground so there is no risk of releasing plague.