The Black Death

Contents Updated: Sunday, 02 April 2006

The Great Pestilence

A disease spread rapidly through Europe from 1347 to 1351. Called at the time the Great Pestilence, Victorian scientists labeled it the Great Plague and the Black Death. It was a terrible epidemic, killing a third of the population—25 million people. Victims got a fever and boils, then swollen lymph nodes, pain and blotches on the skin, finally vomiting blood and dying, all within three days. Nor did it stop. It has ravaged Europe several times in the past two millennia, most famously at the time of the Great Fire of London. The cause has traditionally been bubonic plague or *Yersinia pestis*, a bacterial disease of rodents carried to humans by fleas. The threat of bioterrorism has put plague into the spotlight. Plague is a category A bioterrorism pathogen, listed by the US Centers for Disease Control and Prevention in Atlanta, Georgia, and many US researchers have turned to understanding its biology.

There have been three great pandemics of plague. The first, known as the Justinian plague, occurred in around 540 AD and was confined mainly to Africa and some parts of the Middle East. The second seemed to originate in central Asia and spread along trading routes into Europe. This is the pandemic that occurred in the fourteenth and fifteenth centuries as the Black Death, but hung around on and off into the sixteenth and seventeenth centuries. During the nineteenth century, after initial worldwide spread, the third pandemic of plague was confined mainly to Asia.

Was *Y pestis* responsible for any of the great pandemics of plague? Well, for the first two pandemics it is not strong enough to be certain, but the symptoms do closely match the documented symptoms known today. That *Y pestis* was the aetiological agent of the third pandemic is irrefutable—the plague bacillus was first isolated and identified by Alexander Yersin during this outbreak.

Alexandre Yersin, a French bacteriologist, in the late nineteenth century, investigated the complex biology of the contemporary bubonic plague outbreak. He saw the disease had a feature in common with the Black Death, the bubo, a dark, painful, swollen lymph gland usually in the armpit or groin. Deciding the two were the same, he named the bacterium *pestis* after the Great Pestilence. Yet buboes are not confined to bubonic plague, and the strains of *Y pestis* we know could not have been responsible for the great pandemics of plague. The symptoms and pattern of spread of the disease during the Black Death pandemic are inconsistent with our experience of plague during the twentieth century. Fleas would be inactive during the winter months when many cases of plague occurred in the fourteenth century. However, plague in England during the sixteenth and seventeenth centuries was seasonal, with most cases occurring during the summer months.

Bubonic plague spreads slowly, only at the speed the disease could spread with its agent, rats. In 1907, the British Hague Commission in India reported an

outbreak that took six months to move 300 feet. After bubonic plague arrived in South Africa in 1899, it moved inland at just 20 kilometres a year, even with steam trains to help. Yet the Black Death jumped across great tracts of open country—up to 300 kilometres between towns in France—in only a few days with no intermediate outbreaks. It swept fron Marseilles to Paris at four kilometres a day, far faster than a rat could travel. It raced across the Alps and through northern Europe at temperatures too cold for fleas to hatch. The pattern of spread of the Black Death does not fit a rat and flea borne disease. Duncan notes:

> Iceland had no rats at all, but the Black Death was reported there too.

The rats necessary to spread the disease simply were not there. The only rat in Europe in the Middle Ages was the black rat, *Rattus rattus*, which stays close to human habitation. For the disease to spread from human to human via the bite of a flea requires them to have enough Yersinia in their blood for a flea to pick it up. To happen, they are already very sick. They could only pass the infection in this way for a short time. Whoever the flea bit would sicken within a week—the incubation time of *Yersinia* is only short. It simply does not match the actual pattern.

The disease stayed in Europe for 300 years until 1666 with outbreaks somewhere almost every year, and larger outbreaks from time to time. Yet Yersinia kills rats and other rodents too, just as it kills humans, so no population of rats could have persisted carrying the disease. The Black Death could never have settled in Europe.

Some Evidence

Susan Scott and Christopher Duncan, epidemiologists of Liverpool University, UK, disagree with tradition. From fourteenth century ecclesiastical records, they estimated that outbreaks of the Black Death in a given town or diocese typically lasted 8 or 9 months, typical of diseases with a long incubation time. The pattern in seventeenth century Florence, Milan and elsewhere in Italy, as well as London, Colchester, Newcastle, Manchester and Eyam in Derbyshire was the same. In 1665, the people of Eyam selflessly confined themselves to the village. A third died but the disease did not reach other towns. Rats were not thus confined!

Bubonic plague is not unusually contagious. The Black Death was—it killed one person in three. In India in the nineteenth century, only one person in fifty died, and nor did it kill massively in south Africa, south Amertca and the southern US when it arrived there. The Black Death evidently spread directly from person to person, as Scott and Duncan have shown from sixteenth century burial records. The disease spread from one person to another with an incubation period of 20 to 30 days, killing about 37 days after infection. The first 10 to 12 days were not infectious. The next 20 to 22 days were. Illness only struck in the last five days or less, by which time people had been infected for weeks. People realized the disease was infectious, and sensibly imposed quarantine. No one could disembark from a ship for 40 days, or *quarantina* in Italian—the very origin of the word.

But there are two forms of the disease. Besides developing from the bite from an infected flea and characterized by swollen lymph nodes, another form, pneumonic plague, sometimes develops in people with bubonic plague, towards its end, when the bacteria can proliferate in the lungs and be coughed up to be inhaled by people nearby. The airborne transmission of the disease to other humans is then possibile. This is the fall back position for Yersinia theorists. Pneumonic plague can spread directly from person to person, and is invariably

fatal. However, plague is pneumonic only when the victim is almost dead, and it kills within six days:

> It is simply impossible that people sick enough to have developed the pneumonic form of the disease could have travelled far.

Yet the Black Death spread from town to town in just the time a healthy human took to travel. With a short infectious period, outbreaks of pneumonic plague end within the 8 or 9 months it took plague. Rats and fleas can start a new outbreak, but with the characteristics of a fleaborne disease, spreading slowly and haphazardly. Richard W Titball of the UK Defence Science and Technology Laboratory, Porton Down, Salisbury, agrees that pneumonic plague is not sustainable for more than a few cycles of transmission, but thinks it wrong to imagine that pneumonic plague patients would be too ill to travel and spread the disease. Twentieth-century examples of the disease spreading in this way are well documented. A complex interplay between the slowly spreading bubonic form of the disease and the explosive outbreaks of pneumonic plague occurred during the great pandemics, rather than one form alone. Wendy Orent points out that this exact pattern of disease occurred during the Black Death. Animal species other than rats might have played a role in the spread of disease and fleas and flea bites were much more common between the fourteenth and seventeenth centuries than they are now. Finally, pneumonic plague lacks the one thing that links Yersinia to the Black Death—buboes.

What Was It?

If the Black Death was not bubonic plague, then what was it? A protein, CCR5 on the surface of white blood cells helps control inflammation caused by viruses. A form of CCR5 gives some protection against HIV, and seems to have arisen in north-eastern Europe some 2000 years ago. Around 700 years ago, it suddenly increased in incidence in the population for rare, about one in 40,000 to common, about one in five. A plausible explanation is that it helped its carriers survive the plague. Europeans were certasinly getting more resistant from the fourteenth to the seventeenth centuries. Any evidence that Yersinia had cauxsed the immunity itself directly was unconclusive. The association of CCR5 with viruses suggests the Black Death was a virus. Deadly viruses typically emerge suddenly, mutate suddenly into killers, then disappear suddenly.

The symptoms, including a distinctive retching or hiccupping, of the plague of Athens around 430 BC described by Thucydides are remarkably similar to Ebola, according to the work of scientists and classicists in 1996 at San Diego. And except the hiccupping, they were similar to the Black Death, and the plague of Constantinople in 540 AD. If these plagues were the same, it emerges every few centuries. Unfortunately, filoviruses like ebola are hard to catch, and have an incubation period of only a week or less, not three weeks or more. As deadly as the Black Death can be Lassa fever in Africa, another haemorrhagic virus, and Eurasian hantaviruses. Lassa fever is fairly contagious, and incubates up to three weeks, while hantaviruses can incubate up to 42 days, but are not usually directly contagious between people.

Europeans first recorded the Black Death in Sicily in 1347. The Sicilians blamed it on Genoese galleys that arrived from Crimea just as the illness seriously showed itself. The long incubation period means the infection must have arrived earlier. Africa is nearer, is full of human pathogens, and plagues of Athens and Cainstantinople were thought to have come via trade routes from the Central African interior, according to the locals.

But Yersinia cannot be so easily discounted. Some strains of *Y pestis*, and especially those found in marmots (large guineapig-like rodents) in Asia, are

especially virulent. The genome of *Y pestis* is quite labile and over past decades some researchers have suggested that hyper-virulent strains of *Y pestis* might appear periodically.

Titball explains that recent molecular studies with *Y pestis* provide additional evidence linking the bacterium with the earlier great pandemics. The molecular clock (baseline mutations in housekeeping genes) suggests that *Y pestis* evolved somewhere between 1,500 and 20,000 years ago, the former figure in remarkable agreement with the appearance of the Justinian plague. Additionally, molecular phylogeny has revealed three genetically defined groups of *Y pestis*, and these appear to correspond to the groups of strains associated with the three pandemics of plague.

A large number of corpses were buried anonymously under towns and cities during the Black Death. Viable bacteria will be long gone, but tell-tale DNA might still be present. One way to solve the puzzle could be to look for the pathogen's DNA in the plague pits of Europe. Three skeletons in a fourteenth century mass grave in Montpellier, France, matched only *Yersinia*, but attempts at Oxford University to replicate the results have failed. Similar attempts to find *Yersinia* DNA at mass graves in London, Copenhagen and another burial in southern France have also failed. Testing old DNA is difficult still. We do not yet have conclusive proof that *Y pestis* was the cause of the three great plagues.
