

What is plague?

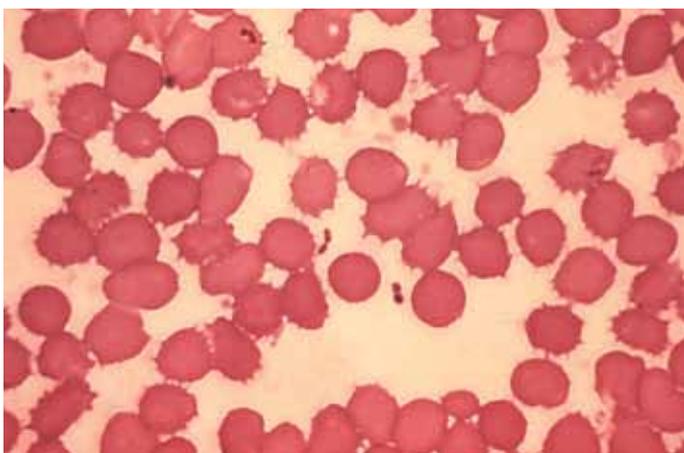
Plague – also known as ‘Black Death’, ‘the pest’, and ‘oriental plague’ – is one of the most deadly diseases to have affected humans over the centuries. Caused by infection with the organism *Yersinia pestis* (*Y. pestis*), plague infects rats and is transmitted to humans by fleas.

To scientists, it is an infection caused by bacterium; to historians its three pandemics are the greatest natural disasters of all time; to artists and writers it symbolises the fragility of human life.

Plague first appeared in Europe in the sixth century during the reign of the Emperor Justinian. This first pandemic lasted for two hundred years. Three centuries later it reappeared in Europe as the ‘Black Death’ – the second pandemic which killed thousands and devastated populations across the continent until the end of the 17th century. In the mid-19th century the third pandemic caused millions of deaths in Asia and spread along Pacific trade routes to America and Australia. This third pandemic challenged the new science of bacteriology, which at last provided the understanding needed to control plague.

1. The bacterium

Although plague has decimated populations for centuries it was not understood scientifically until the French government sent a Swiss doctor to study the 1894 Hong Kong outbreak of ‘oriental plague’. Alexandre Yersin, who had worked for almost a decade at the Pasteur Institute in Paris, isolated the bacillus from human cases and affected rats, providing direct evidence of the link between rats and plague. He published his findings quickly and comprehensively (Yersin, 1894), beating his rival Shibasaburo Kitasato, who had been sent to Hong Kong by the Japanese government.



Y. pestis is similar to common relatively harmless organisms that cause gastroenteritis. It is not difficult to grow in culture, providing the medium is enriched, but these growth requirements mean that the organism does not grow in the environment. It survives for less than an hour in airborne aerosols.

However, *Y. pestis* has developed genes that allow it to infect fleas, then change characteristic to cause fatal disease in mammals. These ‘virulence’ genes include a protease which causes blood clots to dissolve, facilitating spread from the site of the bite to the nearest lymph node. The organism then produces a very toxic capsule which allows the bacterium to survive in macrophages. When these eventually rupture the organism is released into the blood and spreads throughout the body.

2. The flea

The rat flea (*Xenopsylla cheopis*) is the first victim of *Y. pestis*. In 1898 Pasteur Institute bacteriologist Paul-Louis Simond showed that fleas could transmit plague between infected and uninfected rats housed in separate cages. Shortly afterwards, in 1901, John Ashburton Thompson, the chief medical officer of the New South Wales Board of Health, isolated *Y. pestis* from fleas captured from dead rats in Sydney.

When a rat flea ingests infected blood, *Y. pestis* grows and eventually blocks the gut, slowly starving the flea to death. The flea does not become infectious for several weeks, but by then it is ravenously hungry and bites at every opportunity. Fleas normally reside on a single animal for life, but starving infected fleas will seek new hosts and can survive for many months, continually spreading infection.

More than 30 species of flea spread plague, but the rat flea (*Xenopsylla cheopis*) is generally believed to be the most important carrier, or vector .

Living in the modern western world, it is easy to forget that most of our ancestors accepted fleas as normal flora, as in John Donne’s famous poem of 1633:

Marke but this flea, and marke in this
How little that which thou deny’st me is:
Me it suck’d first and now sucks thee,
And in this flea our two bloods mingled bee:



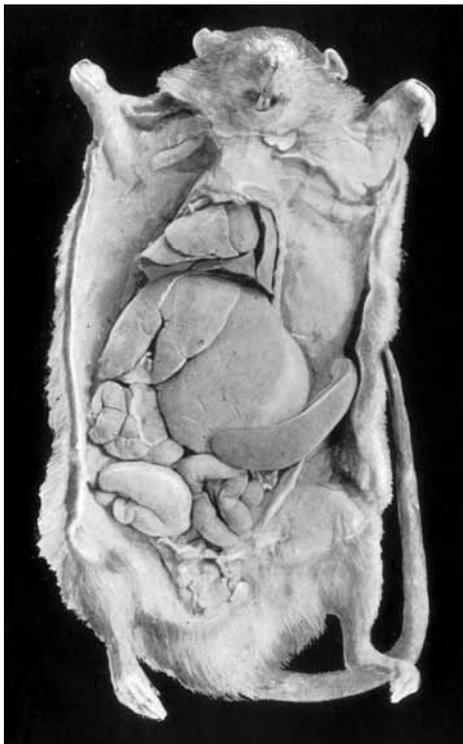
Male *Xenopsylla cheopis* (Oriental Rat Flea) engorged with blood. This flea is the primary vector of plague in most large plague epidemics in Asia, Africa, and South America.

3. The rat

The rat is *Y. pestis*'s second victim. Historically the non-aggressive black rat (*Rattus rattus*) has been the most important source of pandemic plague. These classic 'town rats' live close to human habitation, often equalling or exceeding human populations, and feed on grain and other stored produce.

Black rats do not range far by themselves – typically less than 300 metres. However, they travel long distances in cargo, which has made port cities particularly vulnerable to plague and other diseases. In Europe they were displaced by the brown rat (*Rattus norvegicus*) during the 17th century.

After a flea bite injects the plague organism into a rat, it spreads to the nearest lymph glands. The organism multiplies very quickly at body temperature and produces a capsule that protects it from the body's defences. It then multiplies and releases toxins into the bloodstream that cause swelling nodes, leading to septicaemia and death. The high bacterial content of the tissues at death means that humans who handle dead rodents may be infected through broken skin, by accidental inoculation, fleabites or even inhaling contaminated airborne particles.



'Pathological appearances in a naturally infected rat'.
Department of Public Health NSW, 1900 report by
Ashburton Thompson.



4. Humans

Bubonic Plague is an epizootic infection that mainly affects wild and domestic rats. It is transmitted to humans by the bite of an infected flea, which is most likely to occur on the legs and ankles.

The historian Procopius, writing about plague in Constantinople in 542 AD (the first recorded pandemic) tells of "bubonic swelling ... not only in the groin, but also inside the armpits, and in some cases also beside the ears and at different points on the thighs".

What Procopius witnessed has not changed during the ages. One of the first modern medical descriptions of plague was by Nathaniel Hodges, a physician in London during the Great Plague outbreak of 1665, while modern texts describe the same essential features of plague as "an infectious disease characterised classically by lymphadenitis, septicaemia and petechial hemorrhages, often with toxemia, high fever, shock, restlessness, staggering gait, mental confusion, prostration, delirium and coma" (Benenson, A. (1975) *Control of Communicable Diseases in Man*, American Public Health Association, Washington).

Why is *Y. pestis* so deadly?

What makes the disease so virulent for rats and humans is its ability to spread quickly from the site of infection to the nearest lymph nodes where it grows rapidly.

The cell walls of the bacteria are composed of a material called endotoxin which produces very acute inflammation and swelling in these glands (these painful swollen glands are called buboes). When the lymph node breaks down, the organisms and toxins spread throughout the body causing shock and haemorrhages in internal organs (which may lead to coughing up or vomiting blood) and the skin – hence the 'Black Death'.

Terminally ill plague victims exhale highly virulent encapsulated bacteria, infecting the respiratory system of close contacts. The organism can then spread rapidly in its new victim without forming local buboes to produce fatal septicaemic shock and rapid death. This is called 'pneumonic plague'.

Plague can also be transmitted by ulcerated buboes, which release organisms into the environment. However pus does not form aerosols and *Y. pestis* cannot be transmitted via unbroken skin.



From Merian's *Le Danse Des Morts*.

How does *Y. pestis* survive?

Y. pestis kills the great majority of infected rats and almost all of its vector fleas, yet has managed to survive and cause periodic pandemics for at least 1500 years. What is its secret?

Although plague causes many deaths when first introduced into a rodent colony, surviving animals are immune and non-infectious. Fleas infected with *Y. pestis* can live long enough to infect the survivors' progeny, but mother rats pass enough immunity to their offspring to modify infection so that many young rats survive to rebuild the colony. If a balance is reached both *Y. pestis* and the rat colony persist. However, if the balance is later disturbed, there may be an outbreak of rat plague.

Such imbalances occur when human activities, such as grain storage, lead to an increase in rat numbers. This is why controlling the numbers of rats in cities and towns has proved so effective in preventing plague epidemics.



The Pied Piper of Hamelin is a story based on folk tradition dating from the 13th century. As well as recognising the role of the rat, its symbolic loss of children expressed the tragedy of returning plague.

Rose Impey's
The Pied Piper of Hamelin.

Can plague be prevented?

There are two kinds of vaccines available: one made from live avirulent smooth *Y. pestis* and the other made from inactive cultures of *Y. pestis*, which can reduce mortality during epidemics.

The vaccines are moderately effective against bubonic plague, but not against pneumonic disease. The risk of spread by aerosols is reduced if exposure is recognised and contacts are immediately treated with prophylactic antibiotics.

Fumigation remains effective in destroying rodents from ships, and traps and poisons (in particular Warfarin) can control urban outbreaks. Gassing and poison baits are necessary to destroy wild rodent reservoirs of plague. Fleas in rat burrows can be eradicated using DDT dusting powder.

Can plague be treated?

Currently, antibiotics such as streptomycin are effective against the progression of the plague, provided they are given before septicaemia and shock have developed. Also, the antibiotic tetracycline is effective for humans exposed to plague.

It is not yet known whether strains of *Y. pestis* that have established long-term equilibrium with rodent colonies have lost some of these virulence genes, but maintain the potential to regain them – and other potentially dangerous genes such as antibiotic resistance – by gene transfer.



Plague today

Where is it?

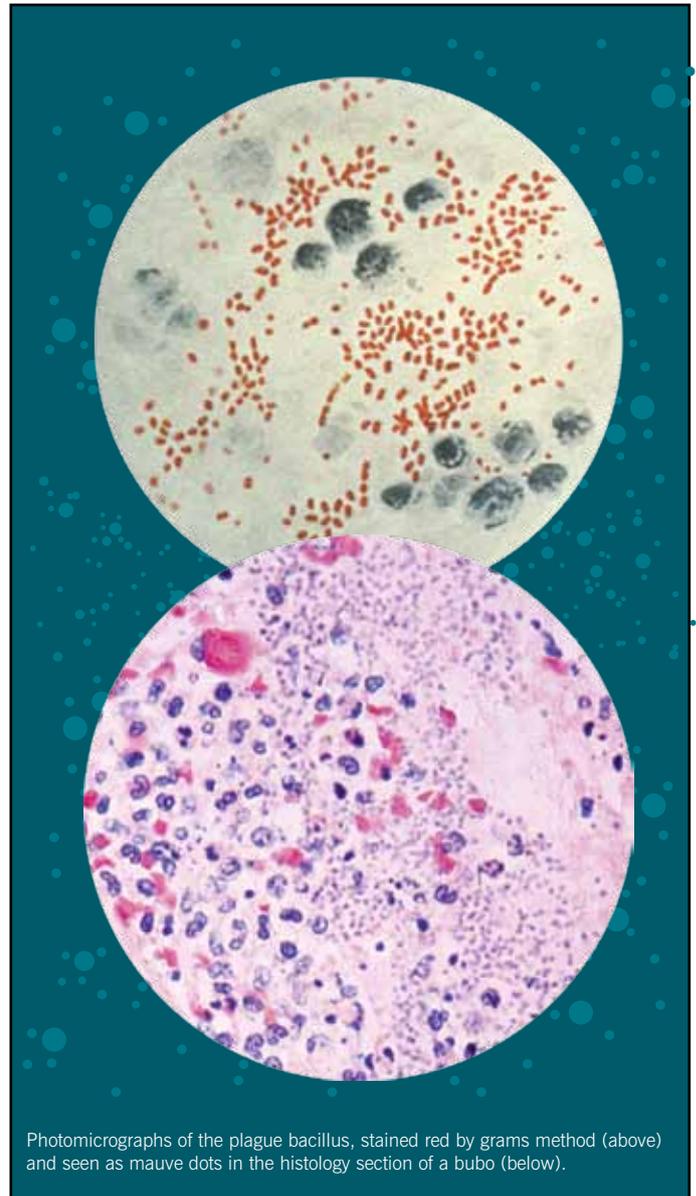
Laboratory tests identify three groups of modern *Y. pestis* strains. ‘Antiqua’ strains are found mainly in Africa, from where they are thought to have spread to cause the first recorded pandemic, the sixth-century Plague of Justinian. ‘Mediaevalis’ strains from Central Asia are grouped with isolates from Black Death victims, while ‘Orientalis’ strains from Asia and the United States are related to the third pandemic. Comparison of *Y. pseudotuberculosis* with *Y. pestis* suggests that the different strains of plague diverged from a common ancestor about the beginning of the Ice Age.

The most significant legacy of the third pandemic is the establishment of plague among the native rodent population of North America. About 30 cases of plague occur in the United States annually from contact with prairie dogs and other native rodents.

Human cases of the disease now occur when hunters and farmers invade natural habitats where plague reservoirs persist. Infection is usually acquired by inhalation of infected aerosols when dismembering infected rodent carcasses. Because the symptoms of pneumonic plague resemble those of other severe infections, the diagnosis may be made too late for effective treatment, so the mortality is high.

In India, Vietnam, sub-Saharan Africa and Madagascar small bubonic plague outbreaks still occur, and the report of a fatal case due to antibiotic-resistant *Y. pestis* is a cause for some alarm. The level of antibiotics in the natural environment of the rodent hosts is probably still too low to drive emergence of widespread antibiotic resistance of plague.

Europe, Australia and Antarctica are now the only plague-free continents. The ability of Australian native rodents to act as a reservoir of *Y. pestis* is not known, but our large cities support large populations of black rats, which certainly can. The exclusion of plague from our environment may have had an element of luck due to low density of rodents outside the immediate port areas, but in general it reflects the clear-sighted efficiency of Ashburton Thompson and the support given to him by local politicians.



The limitations of plague vaccine are also a concern. Although a vaccine containing killed organisms was administered to many thousands of troops in several different campaigns, such as Vietnam, it now seems that protection is only provided against the bubonic form of infection. One positive aspect of the strategic interest in plague in biological warfare is resumption of work on an improved vaccine.

The retreat of plague from Asian cities and towns followed massive investment in public health infrastructure, especially rodent control, but the pattern is so similar to the disappearance of the disease from Europe after the first two pandemics that it seems likely that biological pressures were equally, or even more important. The prospect of a fourth pandemic is certainly a real one, and the rapid movements of people and goods around the world offer *Y. pestis* unprecedented opportunities.

Plague as a biological weapon

The idea that plague could be used to decimate the enemy has been seriously entertained ever since the siege of Kaffa in 1341. The threat was greater than reality because the complex biological requirements to establish rodent reservoirs, and the long timeframe before human cases are likely, casts doubt on plague as a short-term offensive weapon.

The fear caused by a threat of plague had undoubted propaganda value, just as anthrax attacks have caused panic in more recent times. In 1641, leading English puritan MP John Pym received a letter containing a plaster from a plague sore. He opened this with a dramatic flourish in the House of Commons as evidence of a papist conspiracy against him.

During World War II, the infamous Japanese army Unit 731 is reported to have dropped plague-infected fleas over populated areas in China and Manchuria. The resulting death toll is hard to assess, with estimates ranging from hundreds to many thousands. Anecdotes also report the flight of terrified people into the countryside. Attempts by individuals to obtain war reparations have foundered because the data is still protected by military secrecy.

After the war the major powers continued research on plague as a biological weapon, even though, with the advent of antibiotics, it has become a treatable disease. The limited value of plague vaccine against pneumonic transmission encouraged concentration on manufacture and release of aerosolised organisms rather than infected fleas. A report commissioned by the World Health Organization in 1970 predicted that the deliberate release of 50 kilograms of *Y. pestis* in aerosolised form over a city of five million people could cause pneumonic plague in as many as 150,000 persons, with 36,000 deaths.



The swollen lymph nodes in the axilla and groin of plague patients. These buboes are the most characteristic clinical feature of the disease.

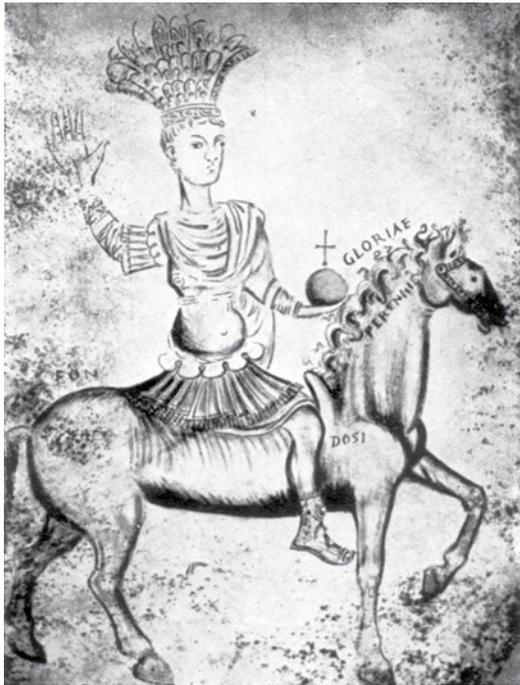


Staff of the New South Wales Emerging Infections and Biohazard Response Unit are still trained to diagnose plague today.

The occurrence of naturally antibiotic-resistant strains of *Y. pestis*, together with better understanding of the importance of acquisition of virulence factors via transmissible genetic elements has revived interest in plague as a weapon. This is of special concern as the laboratory resources needed to manipulate the organism are relatively modest. This raises the prospect of small terrorist groups arming themselves in this way. Indeed, a microbiologist with doubtful motives was arrested in Ohio in 1995 after deceitfully acquiring *Y. pestis* by mail.

The Plague of Justinian

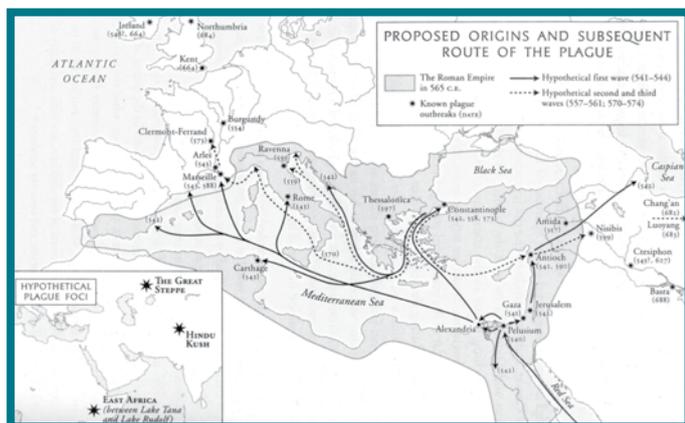
During the summer of 542 AD at least 100,000 of the half million inhabitants of Constantinople, the largest city in Europe, died of a ‘new’ disease. Even the Emperor Justinian was infected, although he survived to rule for a further 20 years.



Fifteenth-century drawing of the statue of Justinian in the Augustaeum at Constantinople. From *Procopius, VII*.

The disease soon spread throughout the Mediterranean and into Europe along Roman trade routes, and eastward along the Silk Road. It caused high mortality everywhere, mystifying doctors who found nothing similar when they consulted the works of Galen or Hippocrates.

No medical account survives from this pandemic, but the descriptions of the contemporary historian Procopius are so graphic that they might come from a modern clinical textbook.



On the other hand, John of Ephesus describes his personal experience of desolation after the loss of so many of his family.

With hindsight it seems that plague must have been well established in the rodent population of Ethiopia and the Sudan (still a reservoir today), but its northwards spread was restricted because high temperatures along the Nile shipping route inhibited flea activity. (Low temperatures also inhibit fleas so epidemics often die down as winter approaches.) In the 530s European summers were unprecedentedly cool, a climatic change variously attributed to meteor dust (perhaps from the comet that appeared when King Arthur died), or the eruption of Krakatoa. Whichever, it is thought to have led to a great expansion of the rat and flea population on Nile grain barges, bringing plague to the port of Pelusium in 541, then to Egypt’s Mediterranean port of Alexandria whence grain-laden ships and their flea-bearing rats carried the disease onwards to Constantinople.

In Constantinople, Justinian had established huge stores of grain and subterranean water cisterns in anticipation of revolts or barbarian attacks. The rat population of the city was correspondingly large, and bore the first brunt of the introduction of *Y. pestis*. Human cases soon followed and their number quickly overwhelmed the medical services, particularly when pneumonic transmission supplemented flea-borne infection.

As there were no precedents, doctors relied on Galenic first principles, employing ‘contraries’ or if that failed ‘similars’ to treat symptoms. During that terrible summer, when around 3000 people died each day, the main preoccupation of the authorities was burial given it was unthinkable to cremate Christians. After the cemeteries were full one of Justinian’s officials,



Astronomers looking at the heavens.

Theodosius, decided to use the towers of the new city walls as mass graves. The ensuing stench added to the misery of the inhabitants, and such was the apprehension of sudden death that, in the words of John of Ephesus “nobody would go out of doors without a tag upon which his name was written and which hung on his neck or his arm”.

The plague disappeared from Constantinople as winter set in, only to recur several times. In its aftermath a shortage of workers weakened the army and reduced trade, undermining Justinian’s ability to defend the Empire. Although the depleted population of Constantinople was rapidly restored, the loss of confidence affected all aspects of life, paving the way for the Empire’s political disintegration under Justinian’s successor.

Many other cities and towns in the Roman Empire were soon affected by the scourge of plague. It reached Spain and Gaul in 543, Tunisia in 548, Ireland in 545, and Antioch in 594, but did not reach England until 664. *Y. pestis* established itself in local rodent populations in many areas, and for almost two centuries would re-emerge to cause periodic outbreaks among humans. In other areas the survival of plague was short lived, for instance it disappeared from England after 687.

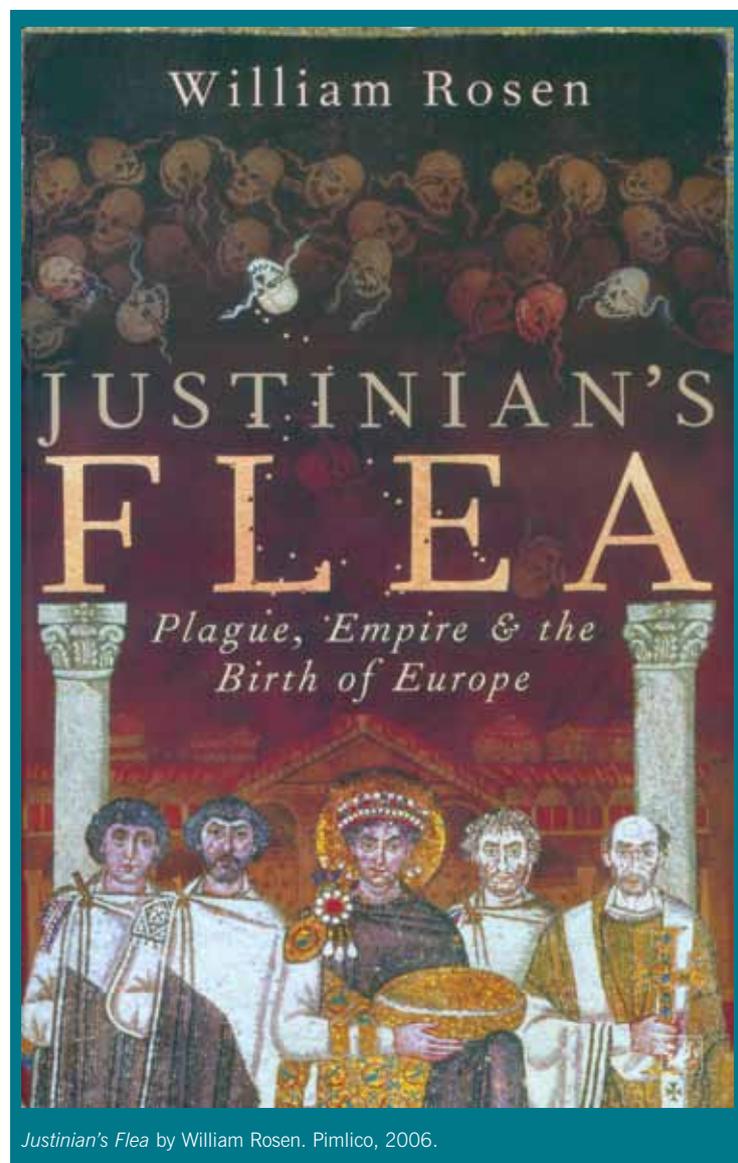
Plague outbreaks persisted in Europe and the Middle East for several centuries. They varied in intensity and mortality, possibly due to changes in the virulence of *Y. pestis* but more likely due to the fluctuating immune status of human and rat populations.

The first epidemics of plague affected all age groups equally, while later outbreaks in the same community especially targeted the young, giving support to the concept of immunity amongst survivors.

Perhaps because of their contacts with Rome, monasteries were especially vulnerable to plague. However, monks were also prolific writers in a largely illiterate age, and their accounts of the effect of plague outbreaks in monasteries and royal courts give some indication about the wider impact. The Venerable Bede lived through the two great epidemics in England. Writing many years later he recorded the deaths of four of the eight English bishops and two kings from plague during the 660s.

Familiarity with plague did little to rob it of its power to instil panic and despair. The church responded with special liturgies, the medical profession with herbal treatments and prophylactics based on a mixture of folk and Galenic medicine, and charlatans with magical charms and nostrums.

Then in around 750, plague unexpectedly vanished from Europe.



The Black Death

Plague re-entered Europe in 1346 after the siege of Kaffa, a strategic trading city at the western end of the Silk Road. According to contemporary accounts, the besieging Tartar armies were decimated by plague and forced to retreat. Before leaving, they used their catapults to hurl infected



Medieval patient, from the anonymously written *Ars moriendi*.

bodies over the walls. Plague soon affected the Genoese defenders and followed them home after they too abandoned Kaffa, while it pursued the retreating Tartars into Asia.

Modern science undermines this version of events. Person-to-person transmission of plague usually requires a living patient to generate infected aerosols. Furthermore, while a few of the Genoese in Kaffa might have been infected by handling infected corpses, a plague outbreak, even in a crowded, besieged castle, would not take hold unless resident rats and fleas were infected. It seems clear that both retreating armies carried infected fleas and rats in their baggage, and that these hungry vectors soon transmitted plague to rats at their destinations. This would explain the almost simultaneous emergence of epidemics in far-flung European cities.

The impact of the Black Death

The Black Death is considered the greatest biological disaster to have affected the human race, killing a quarter of the world's population between 1348 and 1356.

Epidemics in subsequent decades slowed population regrowth and had wide reaching social effects.

Not least among these was the end of the European feudal system. Suddenly peasants were able to demand better wages and conditions, and surviving tradesmen had new commercial and political bargaining power.

The certainty of faith that had characterised medieval Christianity was also threatened. In following centuries the Dance Macabre was often painted in churches to remind the living that death was ever present. Prelates and princes, old and young, men and women, wise men and fools are all led to the tomb by a laughing skeleton.

Meanwhile, the problem of caring for the sick and burying the dead once again overwhelmed society. The grim reality of the plague pits where bodies were dumped without ceremony, a coffin or even a shroud is reflected in contemporary depictions of purgatory.

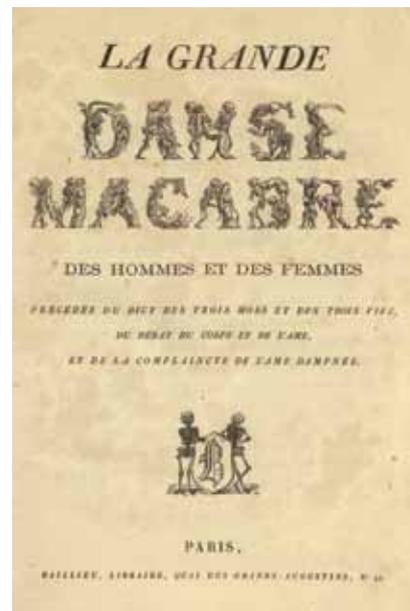


Skeletal trumpeters, from Merian's *Le Danse Des Morts*.

Explaining plague

Seven spectacular comets were observed in Europe between 1328 and 1335, with many believing they were portents of plague. Comets and other celestial events were supposed

to generate the poisonous miasma which penetrated the skin and caused the disease. Astrology became a major part of the curriculum in university medical schools, and horoscopes were used to predict the course of illness in individual patients and warn of epidemics.



Title page from Baillieu's *La Grande Danse Macabre*.

This rarified approach had little practical application. Although the circumstantial

evidence of human transmission overshadowed all other theories of plague transmission, scapegoats were sought and found with Jews bearing the brunt of the blame (not only were they involved in trade with the Levant, but they were spurned by the church).

Having observed the unpredictable occurrence of outbreaks, as well as cases in people who had had no contact with a plague victim, the modern medical investigator might ask questions about possible non-human reservoirs of infection, but at that time supernatural explanations were invoked. The plague maiden, dressed in flowing red garments, was supposed to flit from house to house, spreading disease as she went.

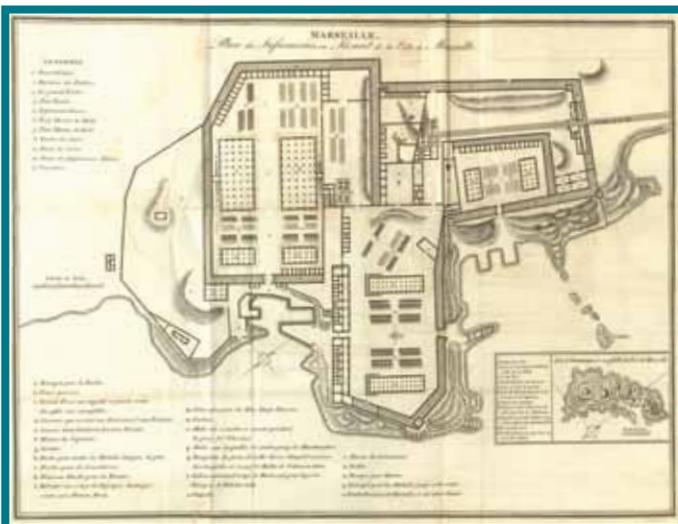


From Holbein's *La Triomphe De La Mort*.

A new approach

After the first wave of the Black Death subsided, profound changes in political and intellectual life began to emerge – the first stirrings of the renaissance that started to supersede less scientific beliefs. The need for a collective response to plague strengthened civil administration, which became increasingly separate from the church.

Civic authorities began to build more formal defences against the return of plague, with the Mediterranean ports in particular introducing quarantine arrangements. The risk posed by shipping from the Levant was clear, and soon goods as well as people came under scrutiny. In 1374 Venice designated one of the islands in its lagoon as a quarantine station for ships arriving from affected ports. A period of 40 days isolation was prescribed, and Genoa, Marseilles and Ragusa soon introduced similar measures. The first permanent quarantine station was built near the church of San Lazzaro near Pisa in 1464 (an appropriate saint in view of his sores), leading to the name “lazaretto”.



Major buildings were constructed in some cities for reception of plague patients, and whenever an outbreak appeared imminent bonfires were lit to disperse the miasma, and apothecaries did a great trade in preventive pills, draughts and pomanders.

But plague did not go away. Outbreaks continued, albeit less frequently and with lower mortality rates due to better levels of immunity among human and rat survivors.

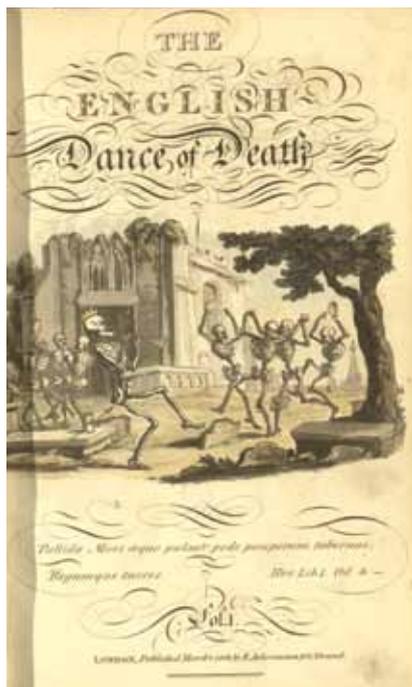
However, neither the general public or the medical profession made the connection between poverty, contact with vermin and their fleas, and risk of plague. Two hundred years after the siege of Kaffa, an outbreak of plague in Venice and Padua caused Venetian physician and scholar Fracastorius to flee to his country villa, where he studied the illness and theorised that invisible seeds (“seminaria contagiosum”) caused infection. This theory was developed one-and-a-half centuries later by Kirchner, an early microscopist who in 1685 thought he saw worm-like organisms in the blood of plague patients and theorised that they were actually alive (“Contagium animate”).



From *Theatri Mortis Humanae*.

The Great Plague of London

Despite great advances in other areas of medical science in the 17th century there was little progress in understanding plague or how to treat it. Fumigation of houses, streets and even whole cities was advocated, in line with the ancient theory of miasma, while herbs were burned to purify the air of private houses. Travellers and cargoes from infected ports were quarantined, and plague victims were isolated in their own households, or special ‘pest houses’.



Title page from Rowlandson's *The English Dance of Death*.

In London, authorities had introduced improved administrative measures to deal with plague outbreaks, despite the lack of advance in medical science.

Justices of the Peace had been charged with organising plague prevention measures, as detailed in government orders dating from 1601. They appointed examiners in every parish; people who refused the role could be imprisoned. Examiners had to:

“enquire and learne from time to time what houses in every parish be visited and what persons be sicke, and of what diseases ... and if they find any person sick of the Infection to give order to the Constable that the house be shut up...”

Infected houses were monitored by two watchmen, one during the day and the other at night, who restricted movements to and from the building. Once a victim died, women searchers had to “make due search and true report whether the persons whose bodies that are appointed to search doe die of the Infection”.

The searchers ran a significant risk of contracting plague, but their financial recompense – twelve pence a body – was modest.

The searchers’ reports become a public obsession. Since 1538, every burial in England had to be documented in order to be legal and to allow implementation of the will. The number of deaths were compiled on a weekly and annual basis in so-called Bills of Mortality, which after 1603 included the reports of the searchers. These records provided the raw data for John Graunt’s book *Natural and Political Observations Made upon the Bills of Mortality* (1662), regarded as one of the first works to use vital statistics and epidemiology.

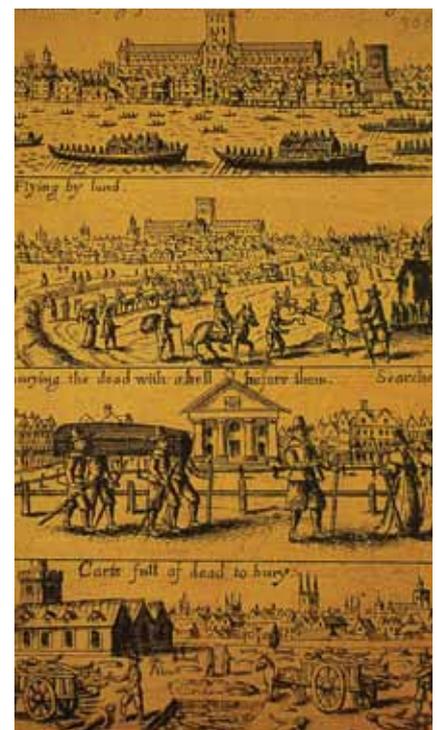
The examiner of health had to be notified within two hours of anyone displaying plague symptoms. If plague was diagnosed, the person was immediately isolated. “And in case he be so sequestered then though he die not, the house wherein hee sickened shall be shut up for a month, after the use of due preventatives ...”

Shut-up houses were marked with a red cross to warn people away, much as plague workers also had to carry visible warnings of their profession:

“Searchers, Chirurgeons, Keepers and Buriers are not to passé the streets without holding a red Rod or Wand of three foot in length in their hands, open and evident to be seen, and are no to goe into any other house than into their owne or into that whereunto they are directed or sent to...but to forebeare and abstaine from company.”

Despite these elaborate administrative arrangements, medical defences remained entirely based on medieval and ancient concepts, although supposedly reflecting the most advanced medical theory of the time.

Even the defences drawn up for Charles I by the College of Physicians in 1636 (opposite) rely on remedies such as herbal nosegays or pomanders to defend against catching plague. Bloodletting and purging were key treatments for plague victims, while a hot loaf of bread was applied to buboes.



‘Plague of London’ 1665 woodcut.

The plague returns

It should not surprise that such treatments failed to prevent the plague's return to London in 1665. The first victim, Margaret Porteous, was buried on 12 April 1665 in Covent Garden. By the end of that year at least 110,000 people had died in London out of a population of around 500,000.



Samuel Pepys

Samuel Pepys's famous diary tracks the progress of the epidemic in a detailed account that records how the regulations worked in practice, and shows how London life went on throughout the calamitous years of the plague and the Great Fire.

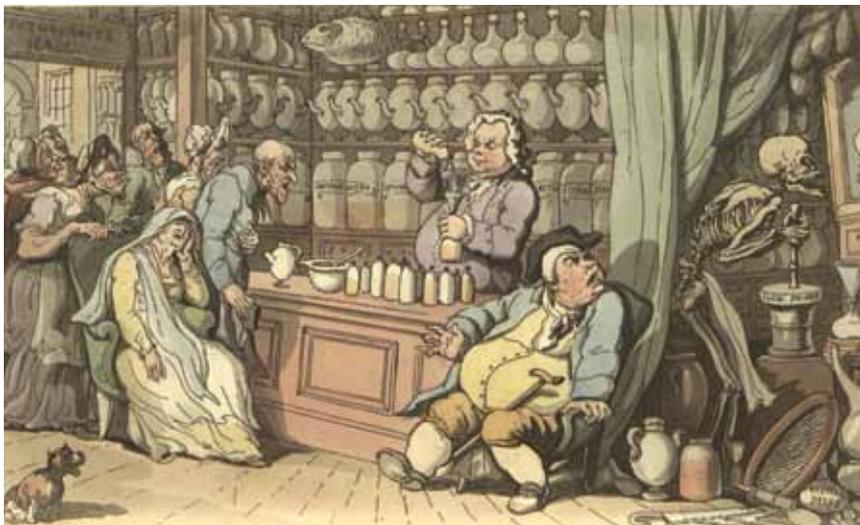
7 June 1665

The hottest day that I ever felt in my life. This day, much against my will, I did in Drury Lane see two or three houses marked with a red cross upon the doors, and "Lord have mercy upon us", writ there; which was a sad sight to me, being the first of that kind that to my remembrance I ever saw.

10 August 1665

By and by to the office, where we sat all morning; in great trouble to see the Bill this week rise so high, to above 4000 in all, and of them above 3000 of the plague. Home to draw over anew my will...the town grown so unhealthy that a man cannot depend on living two days.

The Great Plague of London left some interesting medical references. Nicholas Culpeper, a former soldier in Cromwell's army who carried his radical puritan beliefs into the Restoration, defied the College of Physicians by selling his English translation of the *London Pharmacopeia*. Although not a physician, he had studied astrology, botany and pharmacy. His books explaining Galenic medicine for non-university trained apothecaries and doctors and for the 'educated' public are most revealing about the way doctors thought about plague and the medicines they prescribed.



Rowlandson gleefully depicts death awaiting 'the quack' as he profits from the plague.

One distinguished doctor who remained in London throughout 1665 was Nathaniel Hodges (1629–88) His book *Loimologica* gives a professional viewpoint of plague.

He was a first-hand witness to the inadequacy of conventional Galenic remedies and theories, but uses very deferential language to avoid overtly expressing such controversial thoughts. He also goes out of his way to avoid any hint of criticism of his fellow physicians who followed their aristocratic patients into the relative safety of the countryside.

Other responses harked back to previous epidemics. The clergy preached messages of divine retribution, provided prayers of consolation for the dying, and conducted services on the days officially proclaimed for fasting and prayer for divine intervention.

The Great Plague was finally terminated by the fire of 1666, which consumed the old St Paul's Cathedral and its famous Dance of Death fresco as well as most of the medieval houses and their resident rats. London erected The Monument (completed in 1677) as a memorial to the fire but, strangely, the dedication makes no mention of plague.



The Great Fire of London cleansed the city of bubonic plague.

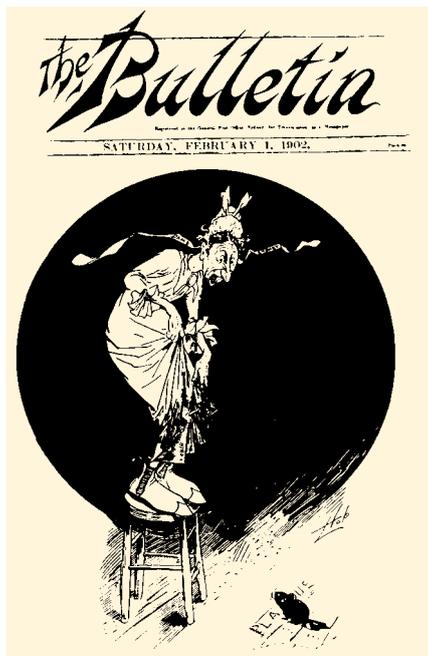
Sydney in 1900 and the third pandemic

It's hard to imagine, but Australia suffered greatly from the effects of bubonic plague in the first two decades of the 20th century.

Australia's proximity to Asia meant it soon became exposed to the threat of plague spreading along the shipping trade routes that drove the country's expansion.

In the middle of the 19th century plague broke out in Yunan province in north-west China, leading to further outbreaks throughout the Chinese interior over subsequent decades as people dispersed to escape the long running civil war which engulfed the western Muslim states.

By the 1890s, this third pandemic of plague reached China's coastal ports, causing large outbreaks of bubonic disease. In the city of Canton alone 60,000 people died in the summer of 1894. The same year, plague deaths in the nearby trading port of Hong Kong hit 100,000 in just two months, alarming the world as it rapidly spread to numerous Asian ports, causing particular devastation in India, Manchuria and then spreading to Russia.



'A Gentle Reminder'.
The Bulletin, 1 February 1902.

In Manchuria, the disease was mainly pneumonic, which may have been because the local *Y. pestis* strain had acquired an extra virulence gene. The fresh outbreaks challenged both the emerging science of bacteriology and the international public health bureaucracy.

Sydney prepares

The Australian colonial government had been wary of plague arriving in Australia since the Hong Kong outbreak. When plague spread to India in 1896, New South Wales health authorities, led by Chief Medical Officer John Ashburton Thompson, discussed the threat to Sydney. Ashburton Thompson had already accepted the rat–flea–human theory of French epidemiologist PL Simond and knew that gaining first-hand knowledge of the bacillus would be key to curtailing a potential outbreak.

Officials gathered *Y. pestis* cultures towards the end of 1897 to study its characteristics during the following 12 months. By October 1899, plague had hit more ports internationally and it was clear Sydney was highly at risk. NSW authorities were asked to abide by the process for international notification of plague, as defined by the 1897 Venice International Convention, and their first supply of prophylactics arrived at the end of 1899. When Noumea was declared a plague-infected port in December 1899, the NSW Board of Health resolved that plague should be added to the list of diseases notifiable under the Public Health Act.

When plague did reach Australia in 1900, many medical practitioners and scientists still believed the disease was essentially a human infection and spread through human contact with the infected. However, health authorities were aware of the building evidence that plague epidemics were associated with an epizootic infection in rats and had begun to incorporate preventative strategies to prevent its entry through the ports.



'A heap of rats. About 600'. Sydney, 1900.

Plague strikes

In 1900 Sydney was a city of environmental and demographic contrast. Life for some was comfortable, affluent and relatively insulated from the risk of casual infections. However, working and living conditions for most people were hazardous, overcrowded, unsanitary – and ripe for the transmission of infectious diseases.

When plague reached Australian shores the government and public response was one of panic and dread, fuelled by knowledge of the history and ravenous potential of the disease. There were 12 major plague outbreaks in Australia between 1900 and 1925 as ships imported wave after wave of infection, which sometimes spread to other major coastal towns. Government health archives record a total of 1371 cases and 535 deaths. Sydney was worst affected, but the disease also spread to North Queensland, while more sporadic cases were documented in Melbourne, Adelaide and Fremantle.



'Cleansing the wharves'. Sydney 1900.



'Cleansing the streets'. Sydney, 1900.

Despite the prevention efforts of government health workers and water authorities, bubonic plague reared its ugly head in Sydney on 19 January 1900. Australia's first victim was Arthur Paine, a 33-year-old deliveryman whose daily work brought him into contact with Central Wharf. The diagnosis was made by Dr Sinclair Gillies, an honorary assistant physician at the Royal Prince Alfred Hospital who also had rooms in Elizabeth Street in central Sydney.

The so-called Case 1 did not immediately raise undue concern amongst the medical authorities – prompting comment 10 days later in the *Sydney Morning Herald*. “Possibly this may be due to the circumstance that members of the medical profession generally are pretty well employed, but there is nothing to show that Sydney is experiencing an unusual season of sickness,” the newspaper reported on 29 January.

Indeed, there was no further news for a month, until 23 February, when sailmaker Thomas Dudley was reported as ill with the plague. The following week there were two more cases. By the end of February, 20 cases had been reported and it was clear that Sydney was hovering on the brink of a large-scale outbreak.

Six months later, 303 people had contracted plague, and 103 had died. Many others were displaced or quarantined, and vast expenditure was incurred by individuals, businesses and government.

The government response

After Arthur Paine was diagnosed with plague, authorities immediately demanded information on all deaths that had been attributed to blood-poisoning, acute abscess or septic intoxication since the beginning of the year so that further investigations could determine whether they were in fact undiagnosed cases of plague.

Paine was taken to the Quarantine Station at the North Head along with all other household occupants and people with whom he had been in recent close contact, setting the pattern for subsequent cases. When the second case was discovered on 23 February the Board of Health ordered the establishment of an ambulance service and the appointment of disinfecting staff at the Quarantine Depot in Woolloomooloo Bay.



Above: Quarantine burial ground, John Skinner Prout.
Below: Quarantine station hospital. Sydney, 1900.



Rat catchers. Sydney, 1900.

Sydney was declared a plague-infected port, and by 1 March the official response encompassed three main strategies: the removal of patients and their close contacts to the North Head; the quarantining and cleansing of large areas of the inner city and dock area; and an extensive campaign to exterminate Sydney's rat population.

According to the retrospective report of the Chief Medical Officer, John Ashburton Thompson, it was difficult to pinpoint where the Sydney outbreak had originated because ships had sailed to Sydney from several infected ports during the previous year. However, he was more definitive as to how plague arrived in Australia:

“The disease was not introduced either by some unobserved imported case in man, or by importation of infected articles, but by infected rats; and it is spread to local rats which, in turn, communicated it first to Case 1, and, as will subsequently appear, to other persons afterwards.”

Quarantine

When a suspected case of plague was reported, a medical officer from the Department of Health visited the patient. If plague was diagnosed, arrangements were made to transport the person and their immediate contacts to the Quarantine Station. They were first taken to the Woolloomooloo depot, before travelling to the North Head by steamboat. Patients were transferred at all hours, even in the dead of night and inclement weather. One observer survived to record the trip:

“In the stern there were about a dozen people sitting. Forward there was a long shapeless bundle lying on a stretcher. It was a case. The others were ‘contacts’, friends. Lodgers, and relations who had lived in the same house with the case. They had come to be isolated for ten days, so that the microbe of the Black Death might show whether or not it was in their blood. They were taken out of the boat first ... No farewells were permitted, just a look that might be the last ... Then the stretcher with the long bundle on it was lifted and carried on to the wharf.

“The next journey of that particular ‘case’ was to the cemetery four days afterwards ... There was only one passenger this time, and he travelled in a coffin.”
From G Griffiths, *In an Unknown Prison Land* (1901).

When the boats arrived at the North Head, plague patients were immediately isolated and transferred to the permanent hospital, while their contacts were accommodated in separate detached dwellings. Convalescents were discharged as soon as they had a normal temperature for 10 days, had no unhealed sores and appeared fit for discharge in general. The period of quarantine was later reduced to five days. Between January and the end of September 1900, 1759 people were quarantined, 1746 of them at North Head. Of these 1496 were contacts and 263 were actual plague cases.

The North Head medical staff consisted of two doctors and a dispenser. All nurses were volunteers from the Coast Hospital or Quarantine Service. Other medical professionals were permitted to visit the hospital to study the illness on condition that they had been inoculated against plague, wore a special suit of clothing during the visit and washed themselves before dressing again in their own clothes.



‘Exeter Place demolished’. Sydney, 1900.



‘Unsanitary conditions’. Toilet, 1900.

Cleansing

In February 1900 Sydney council established a Plague Department, which was charged with cleansing the streets and improving the hygiene of areas close to the central business district and wharves. Gangs were employed to inspect houses and businesses, flush out and disinfect drains and toilets, and catch and destroy rats. Other areas were quarantined and cleansed as new cases were reported.

The cleansing process was thorough. All ceilings and walls were washed with lime, and woodwork and floor coverings swabbed thoroughly with carbolic water. All waste, garbage, ashes, dung, and stable bedding had to be removed, and all drains, gullies, sinks, and water-closets were first flushed with hot water, then with carbolic water, and afterwards treated with lime chloride.

Much of the rubbish collected was immediately burnt in the local area. Some was dumped several kilometres out at sea until complaints were received about rubbish washing back to shore.

Extermination

On 16 March the council organised teams to fumigate coastal vessels to destroy rats, continuing work already begun by several private companies. Inbound ships were not permitted to communicate with the shore until they had been issued with a certificate stating they had been fumigated in line with Department of Health regulations.

When clinical examination of Case 1 revealed an apparent flea-puncture mark consistent with the rat–flea–human transmission chain, the Board of Health placed notices in daily newspapers



Rat incinerator. Sydney, 1900.

asking the public to notify any signs that rat deaths were rising above average. Case 2 further supported the rat link, when investigation of Thomas Dudley's Sussex Street premises revealed a defective sewer connection, allowing rats to enter the building. It also emerged that the victim had recently removed dead rats from an outside toilet.

Newspaper advertisements, posters and pamphlets told the public about the disease and the need to be vigilant to ensure its eradication.

The government employed dedicated ratcatchers, and paid two pence for each rat delivered to a dedicated furnace in Bathurst Street. The incinerator was later relocated to Darling Island, but the transportation of dead rats across the city posed further problems and prompted the government to open a network of suburban receiving depots. Rat poison was provided to municipal councils free-of-charge for distribution to their constituents. The Board of Health also oversaw the fumigation of sewers with burning sulphur. By the end of October 108,308 rats had been killed by government employees; the numbers killed by private individuals are more difficult to assess.

The government also offered inoculations throughout the outbreak, starting with the arrival of a supply of Haffkine vaccine in March, but supplies soon ran out as public panic fuelled demand. By the beginning of April 8000 people had been inoculated, but another batch did not arrive until May. By the end of August, 10,700 people had been inoculated, of whom 14 subsequently caught plague. The serum developed by Yersin (known as Yersin-Roux) only became available late in the outbreak but did not prove to be very effective.

Return of the rats

Following the Sydney outbreak of 1900, plague reappeared in Australia each year until 1910, infecting 1215 people and causing 467 deaths. There was one reported case in 1916, then a series of outbreaks from 1920 to 1923. The last reported case was in 1925.

Australia was fortunate that the number of deaths was minor compared to other outbreaks throughout world history. This was due to two principal factors: Australian authorities were able to draw on recent advances in scientific knowledge, as well as the experience of other countries.

Image credits

1. *The English Dance of Death* from the designs of Rowlandson. (From William Combe, London 1815). Original held in Rare Books and Special Collections Library, Fisher Library.
2. Micrograph of a blood smear courtesy of the Public Health Image Library, Centre for Disease Control, Atlanta. Retrieved March 2009 from www.cdc.gov/ncidod/dvbid/plague.
3. Photograph of Yersin's straw hut courtesy of Institut Pasteur Paris, University Museum and Art Gallery, the University of Hong Kong website. Retrieved March 2009 from www.hku.hk/hkumag/exhibitionpasteur.html.
4. Image of male oriental rat flea courtesy of the Public Health Image Library, Centre for Disease Control, Atlanta. Retrieved March 2009 from www.cdc.gov/ncidod/dvbid/plague.
5. Image of dissected rat from Department of Public Health NSW, *Outbreak of Plague at Sydney*, 1900. Vol. 1, Plate 5.
6. *Le Danse Des Morts* from designs of Merian, Matthieu, Paris, 1744. Original held in Rare Books and Special Collections Library, Fisher Library.
7. Pied Piper image from Impey, Rose, *The Pied Piper of Hamelin*, Loughborough, Ladybird Books, 1985, p. 27.
8. Photographs of swollen lymph nodes and photomicrographs of the plague bacillus courtesy of the Public Health Image Library, Centre for Disease Control, Atlanta. Retrieved March 2009 from www.cdc.gov/ncidod/dvbid/plague.
9. Photographs of staff of the New South Wales Emerging Infections and Biohazard Response Unit by Dianne Porter, Multimedia Services, Sydney West Area Health Services.
10. Reproduction of 15th-century drawing of statue of Justinian from Procopius, VII, *Buildings: General Index to Procopius*, London, William Heinemann Ltd; Cambridge, Harvard University Press, 1954.
11. Plague route map from Rosen, William, *Justinian's Flea: Plague, Empire and the Birth of Europe*, London, Pimlico, 2008, p. 220.
12. Astronomers looking at the heavens from Cantor, Norman F, *In the Wake of the Plague: The Black Death and the World it Made*, New York, The Free Press, 2001, p. 121.
13. Cover of Rosen, William, *Justinian's Flea: Plague, Empire and the Birth of Europe*, London, Pimlico, 2008.
14. Image of medieval patient from the anonymously written *Ars Moriendi*. Original held in Rare Books and Special Collections Library, Fisher Library.

15. Image of skeletal trumpeters announcing the arrival of more plague victims for mass internment from Merian's *Les Danse Des Morts*. Original held in Rare Books and Special Collections Library, Fisher Library.
16. Title page of Baillieu's *La Grande Danse Macabre*. Original held in Rare Books and Special Collections Library, Fisher Library.
17. Image of figure of death from Holbein's *La Triomphe De La Mort*. Original held in Rare Books and Special Collections Library, Fisher Library.
18. Map of Marseilles quarantine station from Howard, John, *An Account of the Principal Lazarettos of Europe*, London, T Cadell, 1789.
19. Original of image from *Theatri Mortis Humanae* held in Rare Books and Special Collections Library, Fisher Library.
20. Title page of *The English Dance of Death* from the designs of Rowlandson. Published by R Ackermann, London 1815. Original held in Rare Books and Special Collections Library, Fisher Library.
21. Plague of London woodcut from Kiple, Kenneth F (ed.), *Plague, Pox and Pestilence: Disease in History*, London, Phoenix Illustrated, 1999, p. 61.
22. Samuel Pepys from the portrait by Kneller in Pepys, Samuel, *The Diary of Samuel Pepys*, London and Glasgow, Collins, n.d.
23. Rowlandson's 'Quack Doctor' illustration from *The English Dance of Death*, published by R. Ackermann, London 1815.
24. Image of Great Fire of London from Kiple, Kenneth F (ed.) *Plague, Pox and Pestilence: Disease in History*, London, Phoenix Illustrated, 1999, p. 64.
25. Image from *The Bulletin* taken from Curson, Peter and McCracken, Kevin, *Plague in Sydney: the Anatomy of an Epidemic*, Kensington, UNSW Press, n.d., chapter 1, plate 10.1.
26. Image of pile of dead rats from Curson, Peter and McCracken, Kevin, *Plague in Sydney: the Anatomy of an Epidemic*, Kensington, UNSW Press, n.d., chapter 1, plate 6.20.
27. Cleansing the wharves, Sydney 1900, courtesy State Records NSW. Retrieved March 2009 from <http://investigator.records.nsw.gov.au>.
28. Cleansing the Streets, Sydney 1900, courtesy State Records NSW. Retrieved March 2009 from <http://investigator.records.nsw.gov.au>.
29. Images of the Quarantine Station from the *Town and Country Journal*, 3 February 1900 in Foley, Jean Duncan, *In Quarantine: A History of Sydney's Quarantine Station 1828–1984*, Kenthurst, NSW, Kangaroo Press, 1995, p. 48.
30. Rat catchers, Sydney 1900, courtesy State Records NSW. Retrieved March 2009 from <http://investigator.records.nsw.gov.au>.

31. Images of Exeter Place, courtesy State Records NSW. Retrieved March 2009 from <http://investigator.records.nsw.gov>.

32. The rat incinerator, Sydney 1900. McCredie File, Mitchell Library Sydney, in Curson, Peter and McCracken, Kevin, *Plague in Sydney: the Anatomy of an Epidemic*, Kensington, UNSW Press, n.d., chapter 1, plate 6.21.

Acknowledgements

This exhibition was researched and curated by Professor Yvonne Cossart, Dr Lise Mellor and Dr Vanessa Witton, Sydney Medical School.

All citations: Cossart, Y, Mellor, L and Witton, V (2009) *Plague! Rats in the Realm*, Sydney Medical School Online Museum and Archive, <http://www.medfac.usyd.edu.au>

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