

THE POWER OF PLAGUES

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Chapter 4

An Ancient Plague, the Black Death

During the last 2,000 years, three great bubonic plague pandemics have resulted in social and economic upheavals that are unmatched by those caused by any armed conflict or any other infectious disease. In Constantinople, the capital of the Roman Empire in the East, it was the first bubonic plague pandemic (542 to 543) that surely contributed to Justinian's failure to restore imperial unity. In 1346, the second pandemic began. By the time it dissipated in 1352, the population of Europe and the Middle East had been reduced from 100 million to 80 million people (Fig. 4.1). This devastating pandemic, known as the Black Death, the Great Dying, or the Great Pestilence, put an end to the rise in human population that had begun in 5000 BC; it took more than 150 years for the population to return to its former size. Some believe this catastrophic crash in population to be Malthus's prophecy come true, but others, such as the historian David Herlihy, consider the Black Death not to be a catastrophe promoted by "positive checks" (i.e., disease, war, and famine) but an exogenous factor that served to break a Malthusian stalemate. That is, despite fluctuations in population size, relatively stable population levels were maintained over prolonged periods of time owing to "preventive checks" (changes in inheritance practices, delay in the age of marriage, and birth control). The Black Death did more than break the Malthusian stalemate: it allowed Europeans to restructure their society along very different paths.

Although those living in the medieval period recognized that plague was a contagious disease spread from person to person, its cause was not identified. Indeed, most believed it to be "a vicious property of the air" itself. Today, more than 600 years later, we know that the source of the second pandemic was microbes left over from the first pandemic (the Justinian plague), which had moved eastward and remained endemic for seven centuries in voles, marmots, and the highly susceptible black rats (*Rattus rattus*) of the arid plateau of

central Asia (roughly corresponding to Turkestan today). Plague-infected rats moved westward along the caravan routes between Asia and the Mediterranean known collectively as the Silk Road; plague traveled from central Asia, around the Caspian Sea, to the Crimea. There, the rats boarded ships and moved from port to port and country to country, spreading plague to the human populations living in filthy, rat-infested cities. Indeed, the story of the Pied Piper of Hamelin (or Hameln) may have had its roots in the plague-ridden cities of Germany (Fig. 4.2). Legend has it that on 26 June 1284, the city became infested with rats. A pied piper came to Hamelin and agreed to rid the city of rats for payment of a large sum of money. He was able to enchant the rats by playing his flute, and he led them to the river, where they drowned. The English poet Robert Browning set the story to rhyme:

Rats! They fought the dogs and killed the cats
And bit the babies in their cradles,
And ate the cheeses out of the vats,
And licked the soup from the cook's own ladles.
But then the Pied Piper was hired:
To blow the pipe his lips he wrinkled
And green and blue his sharp eyes twinkled.
And ere three shrill notes the pipe uttered
Out of the houses the rats came tumbling



Figure 4.2 The rat killer (from a 17th century drawing by Jan Georg van Vliet) through the course of time becomes the children's storybook character the Pied Piper. (Courtesy of the National Library of Medicine.)

Great rats, small rats, lean rats, brawny rats
Brown rats, black rats, gray rats, tawny rats
And step for step they followed dancing
Until they came to the river Weiser.

His work done the Pied Piper said:

"First, if you please my thousand guilders!"
A thousand guilders! The Mayor looked blue
So did the Corporation too.
"Beside" quoth the Mayor with a knowing wink
"Our business was done at the river's brink;
"We saw with our own eyes the vermin sink,
"And what's dead can't come to life, I think.
But as for guilders, what we spoke
Of them, as you very well know, was in joke
Beside our losses have made us thrifty
A thousand guilders! Come take fifty!"

The piper's face fell.
Once more he stept into the street,
And to his lips again laid his long pipe of smooth straight cane;
Soft notes as yet musicians cunning. . .
Out came the children running
All the little boys and girls,
With rosy cheeks and flaxen curls,
And sparkling teeth like pearls,
Tripping and skipping, ran merrily after
The wonderful music with shouting laughter. . .
When lo they reached the mountainside,
A wondrous portal opened wide,
As if a cavern was suddenly hollowed,
And the Piper advanced and the children followed
And when all were in to the very last
The door in the mountain-side shut fast. . .

And the Piper and dancers were gone forever.

Versions of the tale were gathered by the Grimm Brothers (1812). This plague-inspired occurrence has over time come to have a moral interpretation: evil will befall those who do not carry out their promises.

The Black Death is most associated with Florence, one of the great cities of Europe at the time, and because it felt the full impact of the epidemic, it is sometimes called the Plague of Florence. Giovanni Boccaccio (1313–1375), who lived in Florence during the plague, described what he witnessed:

towards the beginning of spring . . . the doleful effects of the pestilence began to be horribly apparent by symptoms . . . an issue of blood from the nose was

a manifest sign of inevitable death; but in men and women alike it first betrayed itself by the emergence of certain tumors in the groin or armpits, some of which grew as large as a common apple, others as an egg . . . from the two said parts of the body it soon began to propagate and spread itself in all directions; after which the form changed, black spots . . . making their appearance in many cases on the arm or thigh or elsewhere, now few and large, then minute and numerous . . . almost all within three days from the appearance of said symptoms, sooner or later, died . . . such as were left alive inclining almost all of them to shun and abhor all contact with the sick and all that belonged to them, thinking thereby to make their own health secure . . . they banded together and formed communities in houses where there were no sick, and lived a separate and secluded life, which they regulated with the utmost care . . . eating and drinking moderately of the finest wines, holding converse with none but one another . . . diverting their minds with music and, other delights as they could devise.

The contagious nature of plague led to the belief that the only way security could be achieved was total isolation of the sick. Despite the fact that it was clearly recognized that the enemy was the sick, it was the lack of appreciation that microbes were the cause of infectious diseases that led to the institution of crude and generally ineffectual public health measures. In 1374 the Venetian Republic required that all ships, their crew, passengers, and cargo had to remain on board for 40 days while tied up at the dock; this gave rise to the term "quarantine" (from the Italian word *quaranta* meaning "forty"). Soon all European ports restricted entry by quarantine, but the disease continued unabated because the rats left the ships by using the docking lines. Cordon sanitaires (literally a ring of armed soldiers ordered to guard against the fugitives of disease) restricted the movement of people and may have reduced the spread of plague, but oftentimes the infected individuals were shut up in their homes with the uninfected members of the family and the flea-infested rats, leading to higher mortality. More effective measures included the burning of clothing and bedding and the burying of the dead in shallow unmarked graves sprinkled with lye. The public, unable to identify the real source of the plague, used "outsiders" as scapegoats. The Black Death also led to societal and religious changes: feudal structure began to break down; the laboring class became more mobile; merchants and craftsmen became more powerful; and guild structures were strengthened. There was also a decline in papal authority, and people lost faith in a Christian church that was powerless to stem the tide of death. The horrors of the plague during this time are depicted in Pieter Brughel's 1562 painting *Triumph of Death* (Fig. 4.3) and are graphically described in the introduction to Boccaccio's classic collection of short stories, *The Decameron*, and in Albert Camus' book *La Peste*. It is even depicted in popular movies such as *The Seventh Seal* by Ingmar Bergmann,



Figure 4.3 Detail from *Triumph of Death* by Pieter Brughel (1562), The Prado, Madrid, Spain. (Courtesy of the Wellcome Library of Medicine.)

Monty Python and the Holy Grail, and the movie based on the book *Arrow-smith* by Sinclair Lewis.

Though the Black Death was undoubtedly the most dramatic outbreak of bubonic plague ever visited upon Europe, it did not disappear altogether. Between 1347 and 1722, plague epidemics occurred in Europe at infrequent intervals, without the introduction from caravans coming from Asia. In England, the epidemics occurred at 2- to 5-year intervals between 1361 and 1480. Half of the population of Milan died in 1630, 60% of the population of Genoa died in 1656 to 1657, and 30% of the population of Marseilles died in 1720. In the Great Plague of 1665, which was described in the diary of Samuel Pepys (and fictionalized in Daniel Defoe's *Journal of the Plague Year*), at least 70,000 Londoners died, out of a population of 450,000.

The third pandemic began in the 1860s in the war-torn Yunnan region of China. Troop movements from the war in that area allowed it to spread to the southern coast of China. Plague-infected rodents, now assisted by modern steamships and railways, quickly spread the disease to the rest of the world. In the three pandemics, it is estimated that rat-borne bubonic plague killed more than 200 million people.

A Look Back

At the beginning of the 12th century, the European population grew quickly after achieving relatively stable numbers during the Dark Ages. One of the reasons for the unchanging numbers of people was poor harvests and famine, but with the introduction of new crops, windmills, waterwheels, horse collars, and the mould board plow, agricultural production increased. Money instead of barter began to be used in trade, and with this prosperity new towns grew and so did the population. But by the 13th century, there was ushered in a sustained period of cold winters and rainy summers. Agriculture could not keep up with the population rise, and over the next century famines occurred every few years. The result was poverty and misery, especially in the crowded and filthy cities.

The tens of thousands of people now living in the dirty, garbage-laden cities had contact with a resident black rat population that lived in the thatch of the roofs. Rats and humans lived in close quarters not only in the cities, but also in the ships that traveled between them. As the human population soared, so did the rat population: it was the humans who provided food and shelter for these rodents. Black rats, highly susceptible to plague, became infected, and with a dying-off of rodents, humans became victims. By 1347 there were outbreaks in the port cities of Kaffa (present-day Feodosia), Constantinople (present-day Istanbul), and Genoa, and, continuing to move by ship, plague spread via North Africa to Spain by 1348. By this time, it had already reached central Europe, including France, Germany, Switzerland, and Austria, and even got as far as Great Britain. From there it traveled to Scandinavia aboard a ship from London that docked in Bergen in 1349 carrying crew, wool cargo, and plague. By 1351, it was in Poland, and when in 1352 it reached Russia, plague had completed its circuit, and a deadly noose had been secured around Europe.

In 1358, Agnolo di Tura, a citizen of Siena, described the situation:

Father abandoned child; wife, husband; one brother, another; for this illness seemed to strike through the breath and sight. And so they died. And no one could be found to bury the dead for money or for friendship . . . and in many places in Siena great pits were dug and piled deep with huge heaps of dead. . . . And I, Agnolo di Tura, called the Fat, buried my five children with my own hands and so did many others likewise. And there were also so many dead throughout the city who were so sparsely covered with earth that the dogs dragged them forth and devoured their bodies.

The short-term effects of plague were shock and fear. Panic and fright broke the continuity of the existing economic structure and disrupted the routines of work and service. People were terrified, and they deserted the cities and towns. In consequence, communities were thrown into chaos. But the Black Death also had its positive aspects: it contributed to technological

advances through the invention of labor-saving devices, as well as a reevaluation of Galenic medicine, and it also led to a more diversified economy with a redistribution of wealth.

Public health

Deaths from plague radically reduced the average life expectancy from 35 or 40 years to 20. The contagious nature of plague led to the belief that security could be found only by total isolation of the sick. To protect the populace, boards of health were established and given sweeping powers that abrogated civil liberties. Since the sick were regarded as the enemy, they had to be segregated from the healthy. Infected individuals were removed from their homes and families and isolated in special hospitals called pest houses. Often, people were sealed up in their houses with the infected rats and left to starve to death or to die from plague. Few were ever cured or survived their time in the pest house; yet their isolation may have helped curb the spread of disease. The dead were removed and quickly buried. The burning of the clothing and bedding of the infected may also have helped. Other public health measures of a crude sort, such as quarantine, were put into play. However, even with quarantine, and with 90% of the sailors dying aboard ship, 50% of the population of Venice died.

Plague undermined confidence in local church leaders, and many people left on pilgrimages to seek salvation elsewhere. Pilgrimages increased the number of travelers on the highways, and these strangers provoked hostility; at the same time, they were the "seeds" for spreading the infection. To restrict the movements of such strangers, cordon sanitaires were established. Towns closed their gates to travelers. These measures circumscribed plague to certain towns while protecting others. Restricting the long-distance movement of people and baggage from infected cities may also have helped to reduce the spread of the black rat.

Discrimination

Restrictions such as cordon sanitaires and quarantine frequently were expanded to limit personal freedom and to identify the culprits. The medieval public wanted to know who was to blame. They found in their community likely sources—strangers, lepers, beggars, the poor, prostitutes, and the Jews. Plague aided in the spread of anti-Semitism, a practice already begun when Jews were slaughtered beginning with the First Crusade in 1096. In some Muslim countries it was the Christians who were blamed; however, in both Christian and Muslim countries the Jews were blamed. Although Jews as the largest cultural minority had been free to practice their religion by both Roman and canon law, once plague claimed the lives of the

political leaders of a town, such freedom was soon abrogated. Early in 1348 the rumor arose that Jews were spreading the disease by poisoning the Christian wells. Though this appeared absurd to the kings and popes, and Pope Clement VI of Avignon (France) tried to discredit the charge by issuing a bull calling the accusations "unthinkable," Jews continued to be blamed and persecuted. By the fall of 1348, formal accusations were brought against Jews, and when court officials extracted confessions, the rumors began to be believed. Accounts of "well poisoning" by Jews spread from Avignon to Strasbourg and then to all of Germany and Poland. Riots occurred in Strasbourg, and when the members of the local government tried to protect the Jews, they were thrown out of office. With a new government in place, more than 900 Jews, about half the entire community, were rounded up, and on 14 February 1349 they were burned on the grounds of the Jewish cemetery. At Freiburg, all Jews were placed in a large wooden building and burned to death. In northern Italy, legislation was enacted to identify the suspect groups—they chose the color yellow—and Jews were required to wear a yellow Star of David on their clothing; prostitutes were also forced to wear yellow labels. (It is noteworthy that yellow was traditionally used to identify lepers and criminals.) And because Jews were prohibited from owning land, they had become merchants, bankers, financiers, moneylenders, and pawnbrokers. Although they had the knowledge for mercantile trade, they were still discriminated against, especially in Germany and France. Killing of the Jewish moneylenders and bankers had another benefit—no loans to repay. The king of Poland, Casimir, had a Jewish mistress and needed the expertise of the Jews, so they were invited to settle in Poland; as a consequence, in western Russia and Poland, Jews became a significant part of the population after the Black Death. (Their numbers would once again be reduced three centuries later by pogroms and gas chambers—latter day instruments of anti-Semitism.)

Church

In cities of 50,000 people, more than 500 died each day. Priests who gave last rites had a very high mortality, and there was a loss of faith in the clergy because they seemed so powerless to prevent death or the spread of death from disease. There was also a decline in papal authority. The Roman Catholic Church passed the responsibility for plague on to God, suggesting that this was Judgment Day, that people had sinned and so nothing could be done to reduce the suffering. However, even God's servants were not spared: all of the friars of a monastery near Avignon, and another near Marseilles, succumbed to plague.

Fear of plague also led to a greater consciousness of religion, especially the "magical religion" embodied in the cults of healer saints. These patron saints, who not only knew suffering but also had the power to heal the sick

and provide comfort, usurped the veneration of God alone and set the stage for long and divisive debates over the nature of religion. One of these healer saints was St. Sebastian, and another was St. Roch (Fig. 4.4). Although it is not known whether the life of St. Roch is truth or fiction, his story comes to us in written form in 1414 from the Venetian humanist and scholar Francisco Diedo. Roch was born in Montpellier, France, in 1295, and he is said to have had a birthmark in the form of a red cross on his breast. As a young man he gave to the poor and embarked on pilgrimages to Rome. Wherever he traveled there was plague, and he was able to cure the afflicted by placing his hands on the buboes. He eventually contracted the disease, was expelled from Montpellier, and died in 1327. St. Roch is often depicted as a pilgrim carrying a purse and a staff and pointing to a bubo on his inner thigh.

Another threat to the Church was a pilgrim movement of another sort. The Brethren of the Flagellants began in eastern Europe, but its strongest bases were in Germany and France. The flagellants, sometimes as many as a thousand, marched in procession through the town; they were led by a master



Figure 4.4 St. Roch, the patron saint of those suffering from plague. The original hangs in the Galleria Dell' Accademia, Venice, Italy.

carrying a banner of purple velvet and were dressed in cloth of gold. Masked and dressed in dark clothing emblazoned with a red cross, each flagellant carried a whip made of leather thongs and tipped with metal studs with which they beat their backs and chests. (This is graphically shown in Goya's painting of the flagellants as well as in Ingmar Bergmann's movie *The Seventh Seal*.) The flagellants were a counterculture to the Church, and they claimed divine authorization for their mission—to alleviate the plague. Pope Clement VI initially encouraged the flagellant movement; until 1349 the flagellants had their way in recruiting other pilgrims, but when the pope saw he could not control them, he issued a bull denouncing the movement and its practices. Eventually, the movement ceased for reasons not fully understood. However, in its time, the flagellant movement did some good: it brought about a spiritual revival, sinners confessed, robbers returned stolen property, hope was raised (albeit temporarily), and it provided a theatrical diversion. In the final analysis, however, the movement did more harm than good. Jews became the special victims of the flagellants, and their persecutions were the forerunners of the pogroms. In Frankfurt in 1349, the flagellants rushed into the Jewish quarter and incited the people to engage in wholesale slaughter. In Brussels, the mere announcement of their arrival triggered a massacre of 600 Jews. Death from the Black Death itself, coupled with that due to virulent anti-Semitism, virtually wiped out Jewish communities in many parts of Europe and also led to permanent shifts in their populations to Poland and Lithuania.

Medicine

Medicine was also affected. Medieval society had four kinds of medical practitioners: academic physicians, who knew theory but did not care for the sick; surgeons, who learned their trade as apprentices and who were the principal caregivers of the sick; barbers, who did bloodletting and minor surgery; and those who practiced folk medicine, mostly women. Academic physicians were generally older men who relied on the teachings of Galen, who believed, as did Hippocrates before him, that disease was a result of an imbalance in the four humors of the body (blood, phlegm, and black and yellow bile). However, since plague appeared to have little to do with humoral changes, confidence in the academic physicians diminished. When these holders of the chairs of medicine at the great European universities died, the newer and younger appointees moved into other clinical areas, such as anatomy. Surgeons, who wore a costume with a beak containing perfume or spices, a cloak of waxy leather, eye lenses, and a wand with incense (Fig. 4.5), died at higher rates than did the other medical practitioners. Because of this, their role in curing disease was little valued. Indeed, the stench of death was so great during the plague years that to "purify" the air, the perfume *eau de cologne* was invented in Germany and named after the city of Cologne. Today the perfume is known as "4711," the address of the household where it was first



Figure 4.5 Doctor Pestis, the plague doctor, in costume. (Courtesy of the Wellcome Library of Medicine.)

made. New prestige fell to the barbers, and bloodletting and surgery (Fig. 4.6) became an integral part of their practice rather than barbering alone. This also led to an emphasis on studies of human anatomy in health and disease, and the Galenic system, which had no clear theory of contagion, declined in importance. Slowly—very slowly—change occurred both in the ideas and in the practice of medicine, and it was the Black Death that instigated that change.

One of the first physicians to advance a theory of contagion was Girolamo Fracastoro (1478–1553) in his book *On Contagion and Contagious Diseases*. Infectious disease, Fracastoro wrote, could be transmitted by *semanaria* ("germs") in three ways—by direct contact, through carriers such as dirty linen, and through airborne transmission. His theory was put into practice when as physician to Pope Paul III he recommended the transfer of the Council of Trent from Trent to Bologna as a response to plague. Other physicians, however, did not subscribe to Fracastoro's theory, and soon the practices were displaced by misguided suggestions until they were revived in the 19th century by Louis Pasteur and Robert Koch and their associates.



Figure 4.6 A woodcut showing a barber-surgeon as he lances a bubo.

Education

As the death toll from the plague increased, the number of learned individuals decreased. This affected the universities where lawyers, physicians, and clerics were trained. As the number of university students declined, so too did the number of universities. Before 1348, all of Europe had 30 universities, but by the time the plague ended, 5 of these had been wiped out completely. The institution of cordon sanitaires as well as other restrictions on travel prevented students from enrolling at distant universities, and so local universities were established. Cambridge University in England acquired four new colleges, each founded by a bequest of a rich and pious patron and all benefiting poor local scholars and clerics. Similarly, new universities were established throughout Europe in cities such as Vienna, Prague, and Heidelberg, so that it no longer became necessary to travel to Bologna or Paris for an education. This not only diminished the dominance of certain centers of learning, but it also led to curriculum reform, and instruction began to be carried out in the vernacular tongue.

Economy and social order

The immediate effect of the Black Death was paralysis. Trade ceased. The economic effect of the Black Death was inflation and a sharp rise in the cost of

food. The Hundred Years War between England and France was halted by a truce in 1349 because of the lack of able-bodied men. In depopulated Europe, even soldiers received higher wages. Another innovation to compensate for depopulated armies was the development of improved firearms; fewer soldiers but with better and more destructive weapons could then successfully engage the enemy in battle.

The nature of farming was altered, too. In medieval times, farming involved the land of lords worked by their serfs. The serfs and their families occupied a small village consisting of several small white-washed two-room huts made of reeds and claylike sod with a thatched roof. In one room lived the family, and in the neighboring room lived their animals. The floor was dirt or covered with leaves or rushes, and in the center were flat stones on which the fire was placed. There was no chimney and no windows, so the smoke of the fire escaped through a hole in the roof or through the open door. Furniture, such as it was, consisted of a table, a few stools, a storage chest, and wooden pallets that served as beds. Adjacent to each hut was a half acre of land used by the serf and his family for the garden; there was a chicken coop and a pigpen, and the nearby stream had ducks and geese. Manure or "night soil" was used as fertilizer, and plow animals such as horses and oxen were shared among several villages.

Medieval villages were organized around large fields that were used for growing grains such as wheat, barley, or oats. The land was cultivated by the serf and his family but owned by the lord of the land (landlord), who usually lived in a large, fortified manor house. The serfs labored for the landlord; their duties were mostly unspecified and subject to the whims of the landlord. The landlord also had almost complete legal power over these poor and illiterate peasants. This feudal system of serfs and landlords declined coincident with the substitution of money for manual services. In effect, salary began to replace labor duties, and rents were paid to the landlord. Since so many peasants had died during the Black Death, if the lord wanted to farm his land he either had to obtain more laborers (usually at a dearer cost) or rent out his land to the survivors from neighboring villages or from the now deserted towns. The government, in league with the landlords, tried to enforce service without payment of the laborers; over time, this engendered great hostility among the peasants as their numbers continued to decline owing to disease. In England, when the crown instituted a series of poll taxes, there was an uprising, called the Peasants Revolt, in 1381. The revolt failed and repressive measures were instituted, but in the end, the landlords had to capitulate because they recognized that without a labor force they would receive no income from the land. The landlords devised another scheme: they would continue to own the land, but now estate managers or stewards were hired to manage the fields and collect the rents. The stewards now lived in a grand house, and the rent-paying peasants were

tenant farmers on the lord's land. However, as disease and death continued to deplete the available labor pool, the tenant farmers had to recruit and pay other peasants or landless city-folk. In this way, as the landlord's fields came to be worked by non-land-owning and rent-paying tenant farmers, the feudal system slowly began to change in character. To compensate for their loss in income (due to higher wages), the landlords continued to acquire more and more land, and the tenant farmers in turn began to use less labor-intensive farming practices. This they could accomplish by the invention of the mould board plow and through the conversion of farmland into pastureland. In England, in particular, pasturelands were devoted to sheep farming, which became so profitable that, in some regions, the growing of crops was completely replaced by the raising of sheep for wool.

Mills that once were used for grinding wheat and barley could now be diverted to spinning cloth, operating the bellows of furnaces, and sawing wood. In England, raising of sheep exceeded all other crops, and wool became the basis of prosperity. But the tenant farmers were continually being stressed by ever-increasing rents, as well as taxes imposed by the crown on the land-owning lords. This is immortalized in the nursery rhyme "Baa Baa Black Sheep": "Baa baa black sheep, have you any wool? Yes, marry, have I, three bags full: One for my master, one for my dame and one for the little boy that lives in the lane." (The hardworking peasant had to give one-third of his income to the king, "his master," and one third to the landlord, "my dame," leaving only one third for himself, "the little boy.")

The tenant farmers who had raised sheep for wool became richer and more powerful than their predecessors. By taking advantage of the anarchy caused by the land-grabbing and warring aristocracy (culminating in the War of the Roses, 1455 to 1485), the sheep raisers were able to buy up larger and larger parcels of land from the estates of the ruined lords, becoming wool barons in the process. The smaller labor force in the cities led to their having a stronger negotiating position, so there was a need to pay higher wages; as a consequence, the standard of living was improved. Many individuals, however, fled the cities and moved to the country, where the survivors were induced by landowners to harvest the crops for higher wages. The standard of living among the urban and rural populations improved, and the laboring classes became more mobile. Thus, the Black Death was a contributing factor in altering the social and economic structure in England, where, by the 16th century, landlord and serf ceased to exist. However, feudalism did linger for several more centuries in Europe.

Governments that sought to control wages sowed the seeds of discontent both in the city and on the farm. This led to what is called factor substitution—cheap land and capital were substituted for the more expensive labor. Peasants would not accept a lease unless the landlord provided additional capital in the form of oxen and seeds. In the city, tools and machines (cap-

tal) were substituted for human labor. Sometimes the higher labor costs led to technological innovation in the form of labor-saving devices. One such innovation was the invention of movable type and the printing press. As plague continued to deplete the numbers of guild members as well as the pool from which new members could be drawn, the guilds had to take on new apprentices without family connections to a particular trade. Shorter years of apprenticeship, rapid turnover in guild members, and increased recruitment of new members led to a decline in the quality of the product. Scribes who had been employed to copy sheets of manuscript and then to assemble them into a bound volume could not keep up with the demand for their services from an emerging and increasingly more literate population. A way out of this labor-intensive method of bookmaking was to find a cheaper solution. Johann Gutenberg's invention of printing using movable metal type in 1453 was one way that this was accomplished.

Another was to employ an economy of scale in sea- and ocean-going transport vessels. Bigger ships with smaller crews could remain at sea for longer periods of time and would be able to sail directly from port to port; however, this would require better ship construction, improvements in navigational instruments, and new business enterprises, such as maritime insurance to protect the investment in cargo and the ship. As a consequence, merchants such as bankers and craftsmen became more powerful. The new economy became more diversified. There was a more intensive use of capital, technological innovations became more and more important, and there was a greater redistribution of wealth. In time, the aristocracy found it had to yield power to the masses. The social and economic fabric of Europe began to be altered, and it was the Black Death that promoted the change.

Finding the Killer

As plague raged through medieval Europe, it became increasingly apparent that the disease was contagious. However, even if Fracastoro's idea of "seeds of contagion" was accepted, at this time there would still be no means to precisely identify the causative agent. Identifying the "seed" would require not only a technological innovation, but also a change in the concept of infectious (contagious) diseases. The novel concept was that disease could result from the invasion of the body by microbes or germs—the germ theory of disease—and the technological innovation, the microscope, allowed humans to actually see germs. Two schools of thought, one in France under the leadership of Louis Pasteur and the other in Germany, led by Robert Koch, were responsible for firmly grounding the germ theory, and for all of their lives these two microbe hunters remained fierce competitors.

As the plague ravaged China during the third pandemic, Pasteur dispatched Alexandre Yersin (1863–1943), a Swiss-born member of the French