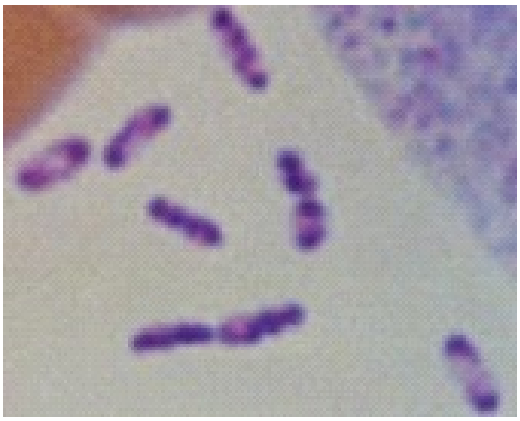
Name _____

Period _____

WHAT CAUSES THE BUBONIC PLAGUE?

Plague is caused by bacteria called *Yersinia pestis*. Bacteria are simple, single-celled organisms. Plague bacteria are about 0.00005 to 0.00008 centimeters wide (about 0.00002 to 0.00003 inches wide). Until strong microscopes were invented there was no way that people could see these microbes that were causing the plague. There were no effective treatments for plague victims until the discovery of antibiotics in the last century. Today antibiotic treatments can cure people infected with the plague. Without treatment with modern antibiotics more than half the people who got the plague are likely to die. **Plague bacteria killed millions of people before antibiotics** were discovered.



Highly magnified image of microscopic plague bacteria.
Image courtesy of the US CDC. (Detail of original)

1.) Circle the correct answer.

Plague bacteria are shaped like

a.) short rods.

b.) balls.

c.) spirals.

A person who is infected with *Yersinia pestis* will generally start showing symptoms within two to six days. The first symptoms are likely to be weakness, a headache, and a fever so it may not be obvious at first that the person has the plague. As the infection gets worse characteristic plague symptoms start to appear. There is a high risk of death unless the person is given antibiotics promptly after the plague symptoms appear.

2.) Was there any way that people could see plague bacteria before microscopes were invented?

3.) Was there any effective way to treat bubonic plague before antibiotics were discovered?

4.) Why do you think people were so confused and frightened by the plague before the invention of microscopes and the discovery of bacteria?

There are three main ways that plague bacteria, *Yersinia pestis*, can make people ill. Plague bacteria can cause large, painful swellings of lymph nodes. These are called buboes. Buboes can be several centimeters across (more than an inch across). They characteristically appear in the neck, armpits or groin. This bubonic form of illness caused by the plague bacteria is the most easy to recognize as the disease caused by *Yersinia pestis*. This is why epidemics caused by *Yersinia pestis* are often called the **bubonic plague**.

In some cases the plague bacteria spreads throughout the bloodstream of the infected person and can cause skin and other tissues to turn black and die. This **septicemic plague** is why the plague was once called the Black Death. The septicemic and bubonic forms of plague infection can be treated effectively with antibiotics, but if infected people do not take antibiotics about half of them are likely to die.

Plague is the most dangerous when it causes infection in the lungs. This is called **pneumonic plague**. People who get peumonic plague must be treated with antibiotics the day they show symptoms of the illness or the disease is likely to be fatal. When a person with pneumonic plague coughs droplets can spread in the air from the infected person and these droplets can infect other people. This sort of infection can often be prevented by wearing masks.

5.) What are the three main types of plague?

1.

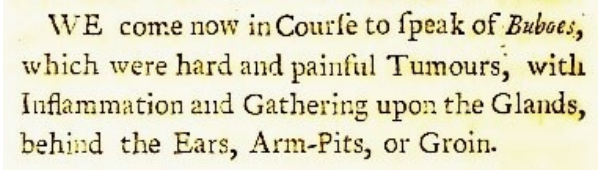
2.

3.

6.) What is the modern treatment for infections of the plague bacteria?

7.) Which kind of plague is most likely to cause a person with plague to infect another person?

8.) Which form of the plague was most likely to kill people before antibiotics were discovered?

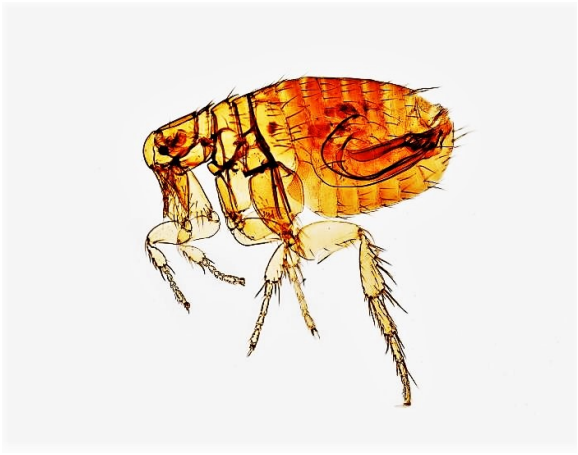

WE come now in Courſe to ſpeak of *Buboes*, which were hard and painful Tumours, with Inflammation and Gathering upon the Glands, behind the Ears, Arm-Pits, or Groin.

Nath. Hodges. *Loimologia or an Historical Account of the Plague in London in 1665* (translated in 1721)

9.) How large were the painful swellings caused by the bubonic form of the plague?

INFECTED ANIMALS CAN SPREAD THE PLAGUE

Rodents such as rats, mice and gerbils can catch the plague. When a flea bites an infected rodent the flea can take in some of the plague bacteria and the flea itself can become infected with plague bacteria. If the rodent host dies the flea will look for another host to bite. This could be another rat, or it could be a cat or the flea could bite a nearby person. Rat fleas are especially likely to spread the plague bacteria, *Yersinia pestis*.

	
Male rat flea Image courtesy of James Gathany / US CDC	Human body lice. Male louse and female louse Image courtesy of National Museum of Health and Medicine

Infected rats and rat fleas are quite likelyto spread plague bacteria, but there are many other organisms that can also become infected with *Yersinia pestis*. Most mammals from cats to camels can also catch the plague. Many types of fleas can carry the bacteria that causes plague and then spread it to people and animals. Recent research shows that human fleas and human body lice can also carry plague bacteria. Human lice bite people to suck blood and the females lay their eggs on clothing.

1.) Name three types of animals that can catch and spread the plague.

1.

2.

3.

2.) Pesticides that kills fleas can be used to slow the spread of plague. Why can this slow the spread of the plague bacteria?

Image courtesy of The Trustees of the British Museum
Accession number 1848,0911.483

Mother Louise was an innkeeper near Oxford, England. The sign at her inn was three lice under a beer mug. The three lice were arranged as if they were on a noble coat of arms as a joke over her famous pub. This portrait of Mother Louise was made around 1670 by an artist named Loggan.

Lice were common human pests during the middle ages and the early modern period. People did use herbs to try to repel these blood-sucking parasites, but lice were difficult to get rid of.

People who were living in crowded conditions could have spread human fleas and body lice to each other. Recent research has shown that body lice can carry plague bacteria. Infected lice could have spread the plague from one person to another.

During the middle ages many people slept crowded together. As cities grew the crowding became worse. Laws were passed to stop overcrowding and homelessness, but often these laws were not effective. In 1580 the English government of Queen Elizabeth I described the problem in London in one of their efforts to stop overcrowding in the city.

> yet there are such great multitudes of people brought to inhabit in small rooms, whereof a great part are seen very poor; yea, such must live of begging, or of worse means ; and they heaped up together, and in a sort smothered with many families of children and servants in one house or small tenement ; it must needs follow, if any plague or popular sickness should by God's permission enter among those multitudes, that the same should not only spread itself and invade the whole city and confines, as great mortality should ensue the same, transcribed by Creighton (1891)

When the plague was causing terrible epidemics in England people did not know anything about bacteria. People had ideas about causes of plague that included “bad air”, bad smells, comets, astrology or their own sins. Practical people were less interested in speculations than their own observations of facts.

3.) Practical people had observed that people were more likely to die of the plague if they lived in poor, crowded parts of the city. Why was this the case?

While the Black Death had spread across Europe during the Middle Ages people had made the observation that some people got the plague from clothes or bedding that had been used by an infected person. There were even laws to prevent the plague from being spread by clothing and bedding.

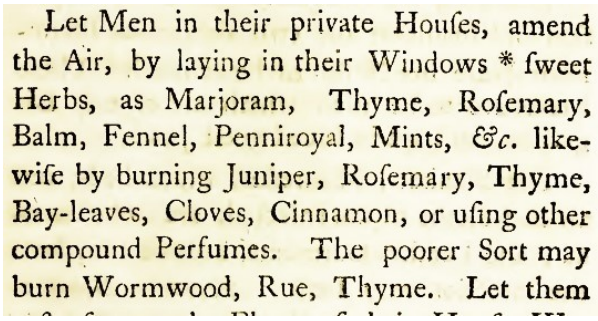
In 1543 Henry VIII was the king of England. His quarantine law required people to take all straw from the rooms of an infected house and burn it. Clothing from infected people was to be taken outside the city and "cured". During the reign of his daughter Queen Elizabeth I the City of London published the 1568 quarantine orders that included the following:

> That all bedding and cloathes and other thinges apt to take infection which were about infected persons bee burnt or such order taken that infection may not be increased by them.

Transcribed by Charles Creighton. *A History of Epidemics in Britain*. (1891)

4.) After someone in a household got the plague their clothes were supposed to be burned or to be exposed to poisonous fumes. How would this have helped slow down the spread of plague infections?

5.) Beds, clothing, mattresses and sheets were expensive during the Middle Ages and the early modern period. People listed items of clothing, bedding, and even sheets in their wills.Why would the relatively high value of clothes and bedding make it more difficult to stop the spread of the plague?



Let Men in their private Houſes, amend the Air, by laying in their Windows * ſweet Herbs, as Marjoram, Thyme, Roſemary, Balm, Fennel, Penniroyal, Mints, &c. likewiſe by burning Juniper, Roſemary, Thyme, Bay-leaves, Cloves, Cinnamon, or uſing other compound Perfumes. The poorer Sort may burn Wormwood, Rue, Thyme. Let them

Francis Herring. *Preservatives Against the Plague Published at the Request of the City of London.*

The herbs were supposed to "sweeten" the air to prevent the plague from spreading. This sort of advice had been published in booklets during the reign of Queen Elizabeth I. People may not have realized some of the herbs were helping by repelling insects, but they noticed the herbs could make a difference.

6.) During plague outbreaks people would try to spread herbs that repelled insects through their homes and shops. Herbs were often placed in the doors and windows to prevent "bad air" from bring the plague inside. How would this have helped protect these people from the plague?

PREHISTORIC PLAGUE PANDEMICS

Primative kinds of plague bacteria were infecting prehistoric people in the late neolithic and early bronze age. People died of the plague after bacteria spread through their entire bodies. Some of the plague bacteria even circulated in the blood vessels inside the teeth of people who died from the bacterial infection.

Teeth from ancient skeletons sometimes contains DNA from plague bacteria. This bacterial DNA can be found even after several thousand years. Just as each person has DNA that can identify them, bacteria also have DNA that allows them to be identified. Scientists have been looking for plague DNA in human teeth from ancient burials. Some teeth that contain plague DNA come from skeletons that are around 5,000 years old.

An early kind of *Yersinia pestis* DNA has been found in teeth of plague victims who died around 5000 years ago. They lived in a neolithic communities without written records. The kind of *Yersinia pestis* that killed them would not have survived in the guts of fleas. This early type of plague would have been transmitted by people or animals coughing on each other.

1.) The primative form of *Yersinia pestis* that killed people 5000 years ago would have died inside a flea. Fleas could not have spread this early form of plague. How would an infected person spread the lung infection caused by this early plague bacteria to other people?

2.) How was the human-to-human spread of the 5000-year-old kind of plague bacteria similar to the way that people can spread the Covid-19 virus to each other?

Neolithic pot
Adapted from A.P. Madsen

Neolithic people were farmers who raised crops and animals. They built houses near their fields and made beautiful pottery. Carts allowed them to trade with other communities.

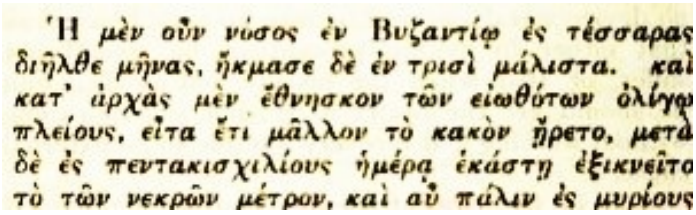
3.) Some 6000-year-old neolithic farming towns had thousands of residents. Then around 5500 years ago most of the larger settlements started disappearing. Most neolithic people started living in tiny villages or small family farms. There are a variety of theories about why people stopped living in large settlements. What is one possible reason people would have stopped living in large, crowded towns?

JUSTINIAN PLAGUE

The first plague pandemic that was clearly recorded in historical documents was the plague of Justinian. Historians and archaeologists disagree about where this plague started. It was first documented in Egypt in 541 C.E. In the next two years it spread around the Mediterranean Sea and then across Europe. Outbreaks of plague kept occurring until 750 C.E. During this time outbreaks of other serious diseases such as smallpox also caused widespread deaths so in some cases it can be difficult to know which disease was the cause of an outbreak in a particular region. Until recently some historians were not certain that the Justinian plague was caused by bubonic plague. Recently DNA from *Yersinia pestis* has been found in teeth from some of the people who died then, so it is now accepted that the Justinian plague was bubonic plague.

The writer Procopius was an eyewitness to the Justinian plague. He was in Byzantium when the plague arrived there. He felt as if the plague “embraced the entire world, and blighted the lives of all men, though differing from one another in the most marked degree, respecting neither sex nor age.”

Image modified from Roger Culos
Emperor Justinian



Ἡ μὲν οὖν νόσος ἐν Βυζαντίῳ ἐς τέσσαρας
διῆλθε μῆνας, ἤκμασε δὲ ἐν τρισὶ μάλιστα. καὶ
κατ' ἀρχὰς μὲν ἔθνησκον τῶν εἰωθότων ὀλίγῳ
πλείους, εἶτα ἔτι μᾶλλον τὸ κακὸν ἤρετο, μετὰ
δὲ ἐς πεντακισχιλίους ἡμέρᾳ ἑκάστῃ ἐξικνεῖτο
τὸ τῶν νεκρῶν μέτρον, καὶ αὖ πάλιν ἐς μυρίους

Greek text of Procopius
The English translation used here was by H.B. Dewing (1914)

4.) How did scientists show that people had the plague bacterium, *Yersinia pestis*, during the Justinian plague pandemic?

Procopius reported that the first symptom was a mild fever.

> But on the same day in some cases, in others on the following day, and in the rest not many days later, a bubonic swelling developed ; and this took place not only in the particular part of the body which is called "boubon,that is, below the abdomen, but also inside the arm-pit, and in some cases also beside the ears, and at different points on the thighs.

THE BLACK DEATH

The worst plague pandemic that devastated Europe was the Black Death. The plague reached Italy in 1347. Genoese merchant ships carried the plague to many ports around the Mediterranian. The plague quickly spread throughout Europe and probably killed 30% to 50% of the population. During the Black Death pandemic many people suffered from the bubonic form of the plague but the peumonic form also spread rapidly.

A witness to the 1347 outbreak in France, Lodewijk Heyligen, gave a vivid description of the disease. He describes both the bubonic form of plague and also the pneumonic form that attacks the lungs.

> It is said that the disease takes three forms. In the first people suffer an infection of the lungs, which leads to breathing difficulties. Whoever has this corruption or contamination to any extent cannot escape, but will die within two days. . . . all those who died suddenly had infected lungs, and had been coughing up blood. And this form ... is the most contagious, for when one infected person dies everyone who saw him during his illness, visited him, had any dealings with him, or carried him to burial, immediately follows him, without any remedy.

from 'The plague in Avignon', in Rosemary Horrox (trans. and ed.), *The Black Death*, 1994 (from Walloe)

Modern analysis of bacterial DNA from the Justinian pandemic that started in 541 shows that a slightly different strain of *Yersinia pestis* caused the Black Death of 1347. When swelling in the armpit, neck or groin are described by witnesses it is clear that the infected people were suffering from the bubonic form of the plague caused by *Yersinia pestis*.

Procopius said that people who cared for the sick and buried the dead in 542 were not especially likely to catch the disease. The bubonic form of plague is commonly caught from biting insects such as fleas. The pneumonic form can spread through the air from one person to another. The strain of *Yersinia pestis* that caused the pandemic during the reign of the Byzantine emperor Justinian seems to have spread mostly by biting insects.

The *Yersinia pestis* strain that caused the Black Death sweeping across Europe in the 1340s was easily spread as the pneumonic type of plague that people can spread to each other. The Black Death could also spread as the bubonic type of plague that is spread by fleas and lice biting people to suck their blood.

5.) What are two forms of plague that spread across Europe during the 1340s?

ATTEMPTS TO ESCAPE THE PLAGUE

The plague that started spreading across Europe during the 1340s kept returning to devastate new generations for the next several hundred years. Sometimes the pneumonic form of the plague spread from one person to another causing the deadly infection of their lungs. Many people believed that the disease was caused by bad smells in the air. There was no way they could have known about bacteria before the invention of microscopes and microbiology. It was true that the plague could spread through the air so their observations were correct even if their conclusions were wrong. The pneumonic form of the plague was spread by droplets in the air from coughs, sneezes or even the breathing of plague victims.

Image from The Trustees of the British Museum
https://www.britishmuseum.org/collection/object/P_1880-0710-522

The personal protective equipment of a Roman plague doctor in 1656. The long beak was stuffed with flowers and herbs that were supposed to stop the "bad air" that many people of that time thought was the carrier of the plague. It is possible that the beaks on these costumes did act like masks.

6.) How was pneumonic plague spread?

7.) Why would a mask help prevent the spread of pneumonic plague?

Generations of plague sufferers tried many kinds of remedies. Nothing they tried really worked. Up to half of the victims of the bubonic form of plague could survive if they got good nursing care. Pneumonic plague was almost always deadly. Now that we have modern antibiotics people can be cured if they catch the plague, but it is still deadly to infected people who are not put on antibiotics promptly.

8.) The antibiotic streptomycin was discovered in the 1940s and the antibiotic gentamicin was discovered in the early 1960s. These are two of antibiotics that are used to treat *Yersinius pestis* infections. The first modern antibiotics were found in the 1930s. Why was the plague so horrifying before antibiotics were available?

The city of London provided detailed documentation of the later plague outbreaks there. The last plague epidemic in London was in 1665. People from poor neighborhoods in London were more likely to die of the plague. Wealthy people often left the city when plague epidemics started. People in small towns and villages tried to keep travelers fleeing from the city out of their smaller communities. Everyone realized that people fleeing from an outbreak in London would be carrying the plague to the rest of the country. Efforts to stop the spread of plague by keeping people in London were not generally successful.

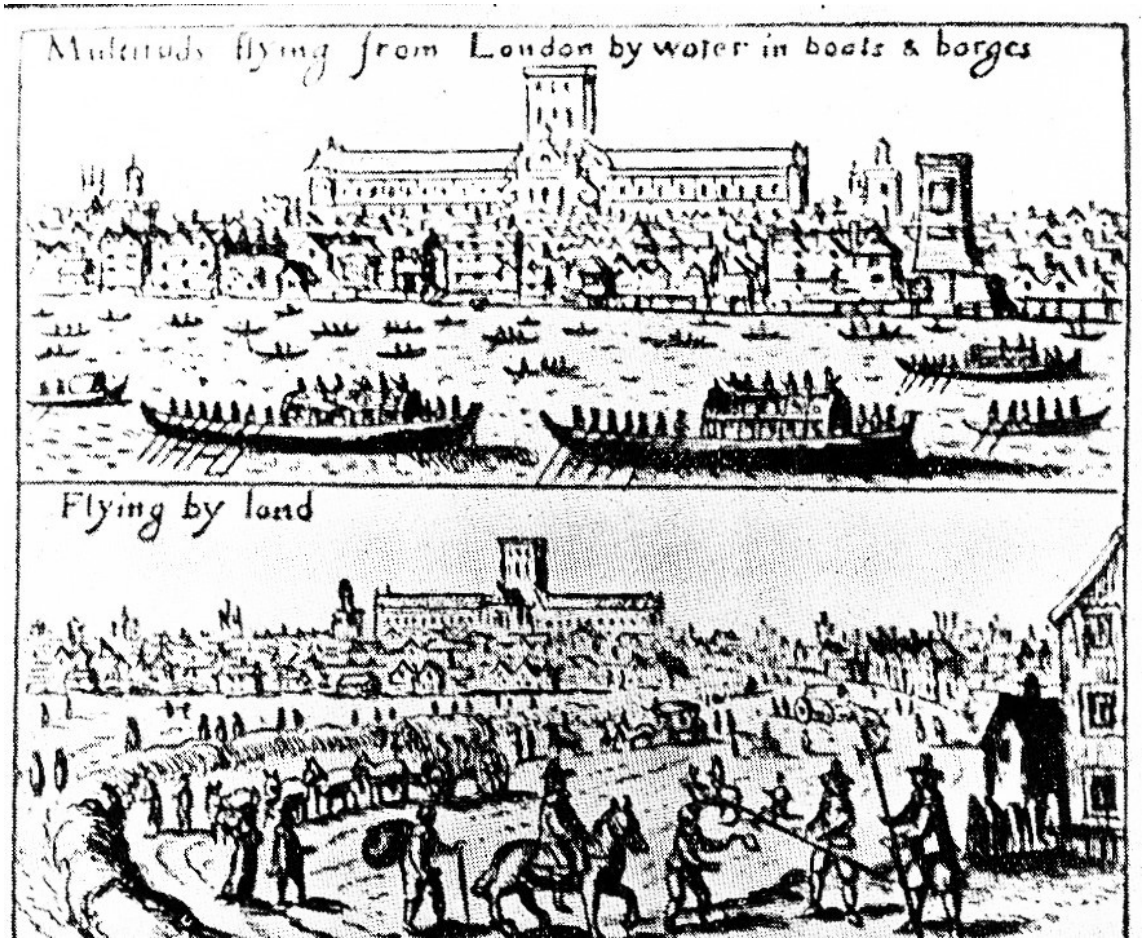


Image detail from print in Pepysian Collection, Cambridge courtesy Wellcome Images (L0011005)
http://catalogue.wellcomelibrary.org/record=b1349075

Studying historical and ancient spread of diseases helps us learn how to prevent new epidemics. Contagious diseases can be controlled, but we need to learn from the past.

Plague bacteria are still infecting wild rodents today. Vaccines were developed more than 100 years ago but are not very effective. There are modern efforts to develop an effective vaccine for people who are likely to be exposed to *Yersinia pestis*. Every year hundreds of people around the world still die of the plague, mostly because they do not get antibiotics soon enough. Eradicating plague in rodents all over the world is not practical, but hopefully research can stop *Yersinia pestis* from killing any more people.