Disease Paper - *Yersinia pestis*

Description of the Microbe

The bacteria *Yersinia pestis* has been a part of human history for thousands of years. Discovered by bacteriologist Alexandre Yersin in 1894, *Y. pestis* is gram-negative, bacillus-shaped, and can't move independently. It is an aerobic bacterium, meaning it prefers to grow in the presence of oxygen (Barbieri, et al. 2020). *Y. pestis* has been found to cause about five types of plague, including pneumonic, pharyngeal, meningeal, bubonic, and septicemic plague. *Y. pestis* has also led to three detrimental plague events throughout history. The first happened around 541 CE in Europe, lasted until at least 750 CE and is known as the Justinian Plague. The second plague is more well known, the Black Death. About a third of Europe fell victim to the illness and it lasted for about four hundred years from 1346 to the 1700s. The final major plague happened in the late 1700s in China and lasted for about one hundred and fifty years (Barbieri, et al. 2020).

Y. pestis is able to grow at temperatures from 4 degrees celsius to 40 degrees, however, its optimum growth range is 28 to 30 degrees celsius. Its optimum pH level is 7.4 (Barbieri, et al. 2020). It can form colonies on MacConkey and Blood agar, however, it is considered to be a tier 1 biological agent. It is able to ferment many chemicals including glycerol, melibiose, and melecytose. It is able to go through denitrification, meaning it can reduce nitrate into different nitrogen based gasses. It can also cause blood clots (Barbieri, et al. 2020). Research into the genetics of *Y.pestis* has shown that there have been insertions within the bacteria's DNA and that it has been a part of horizontal gene transfer. The life cycle of *Y. pestis* takes place within a host, typically in fleas or the intestine of mammals (Barbieri, et al. 2020).

Discussion of the Infection Mechanisms

The plagues that *Y. pestis* causes are zoonotic, meaning they are transmitted through animals (Barbieri, et al 2020). In order to get to the human host, the bacterium must make a few stops. First, *Y. pestis* has to infect a flea and actually go through an entire stage of development and numerous processes while in the flea. Once in the flea, *Y. pestis* immediately begin to replicate and form colonies. Once enough colonies have formed, transmission can actually start to occur. Transmission at this stage of the process is called “early-phase transmission” (Hinnebusch, et al 2021). How it works is due to the buildup of bacteria, when the flea bites something and takes in blood, some blood doesn’t go to the gut and is regurgitated by the flea. *Y. pestis* can travel with this blood and can then enter the next host. However, this early transmission is not very effective and can take multiple bites for the next host to actually be infected (Hinnebusch, et al 2021).

There is a second phase that’s much more efficient in terms of infecting hosts. During this phase, enough bacteria has built up within the flea to where no blood actually makes it to the gut. The blood is forced back out of the flea, carrying enough bacteria to properly infect the host. Due to no blood, and therefore no nutrients, making it to the gut of the flea, the flea continues to bite the host trying to feed until it dies of starvation (Hinnebusch, et al 2021).

Once inside the mammalian host, the bacteria replicate. *Y. pestis* is able to transfer from a flea into over 280 species of mammals. These mammals, as well as the fleas that infect them, are reservoirs of infection (Glatter and Finkelman 2020). While rats are thought of as the main infection vector for plague, anything from cats to even humans can be directly infected by fleas carrying *Y. pestis*. From here, transmitting the disease from one host to another is more simple. Anything from a bite to a scratch can transmit *Y. pestis* to another host. Even just being near a dead animal that was infected can lead to bacteria transmission. Coming into contact with respiratory droplets from other infected people can also transmit the disease (Glatter and

Finkelman 2020). One last interesting addition to the deadliness of *Y. pestis* is that the bacteria is very good at evading host immunity. Only certain types of phagocytes are able to destroy plague once it is in the human body. Research has shown that neutrophils are successful at phagocytizing *Y. pestis* for the most part, however, macrophages seem to have no effect (Demeure, et al. 2019). All of this together is why plague can be so dangerous and spread so easily.

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Symptoms

Infected individuals experience a myriad of symptoms. The form and extent of the symptoms depend on the type of plague. Bubonic plague, which is the most common, can include symptoms such as a fever, aches, chills, and overall feeling unwell (Yang 2017). Other symptoms include swelling of the lymph nodes, irritated skin, and immense pain at the site of the flea bite if there is one. If left untreated *Y. pestis* moves through the blood and can lead to Bubonic plague advancing into other forms of plague. The end result plague is typically pneumonic plague. Pneumonic plague is much worse than bubonic plague and the symptoms are far more severe, as it is a lung based plague. It has the additional symptoms of serious coughing and signs of plague that can be viewed through an x-ray. Shock has also been reported. Once pneumonic plague has set in, it is most likely fatal. These symptoms arise at an alarming rate due to *Y. pestis* replicating so rapidly within the body and its ability to avoid immune cell actions. The short manifestation period of these symptoms as well as how truly serious they are has led to great fear of *Y. pestis* being used as a biological weapon. Some symptoms of plague being quite similar to symptoms of other illnesses has also added to this fear (Yang 2017).

Epidemiology

Y. pestis and therefore plague has been shown to cause epidemics throughout history. Meaning that it appears in great bursts in a small amount of time within a certain area and then goes back down to low levels (Barbieri, et al. 2020). The last large event of plague was in the early 1900s and since then there has been a comparably small number of cases. Within the last thirty years, about 26,000 cases of plague caused by *Y. pestis* have been reported. The majority of these cases were of bubonic plague. About 1,800 were pneumonic plague (Barbieri, et al. 2020). The cases are spread across the globe, in Africa, Asia, Europe, and the Americas. Africa had the greatest number of cases at about 25,000. Madagascar has been a hot spot of plague. It's gone so far to where rats there have been found to be resistant to the plague carrying fleas. About 300 cases were reported in America and the rest of the cases were split up between Asia and Europe. Many cases where marmots were a vector were seen in Mongolia and Russia (Barbieri, et al. 2020).

Treatment

As stated above, if plague is not caught and diagnosed early, Bubonic plague can transform into deadlier forms of plague and treatment becomes substantially harder. Typically, treatment needs to be given within a day for the disease to not become fatal (Sebbane and Lemaitre 2021). Antibiotics are what are given to patients infected by *Y. pestis*. Through numerous tests, it has been determined that *Y. pestis* is susceptible to the antibiotics sulfonamide, aminoglycoside, tetracycline, and fluoroquinolones. Other antibiotics, such as gentamicin, ampicillin, ciprofloxacin, and meropenem have also been found to be effective (Sebbane and Lemaitre 2021). There are a number of variables however, that can impact the success of antibiotics. Depending on the area, certain antibiotics may not be readily available or

they may not be able to be given to certain age groups. Different strains may not be as susceptible to certain antibiotics. Antibiotic resistance has also been an issue. Finally, as with most drug studies, tests are done on animals, which don't always present results that would be the same for humans (Sebbane and Lemaitre 2021). Different therapies have also been used to treat plague, including phage therapy and immunotherapy, however, these have not all been utilized in some circles (Yang 2017).

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Prevention of Infection

Prevention of *Y. pestis* infections has been a bumpy road. While there have been attempts at prevention through medical techniques, there has been nothing concrete and nothing widespread. There are of course the obvious precautions you can take in your day to day life. Don't touch animals in areas where plague has been reported. Don't go near dead animals in general, but especially if they may have plague. General hygiene habits are also always good. In terms of medical prevention, multiple vaccines have been produced, however, none have been successful (Demeure, et al. 2019). One had been used in the U.S. and Australia, however, it is no longer in use as it was not long-lasting. There is one that is still being used in Madagascar and parts of Europe and Asia, however, it is not licensed (Demeure, et al. 2019). Many forms of a vaccine are currently being studied. One vaccine that's currently under development hasn't been able to stop primates from getting sick and therefore developers are unsure if it would work in humans. All other vaccines are still in the early stages of the production process. It's surprising that after thousands of years there is still no prevention method for *Y. pestis* and plague in general (Demeure, et al. 2019).

Works Cited

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