
HSC Biology

The Search for Better Health

Week 2

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WEEK 2 – THEORY

DURING THE SECOND HALF OF THE 19TH CENTURY, THE WORK OF PASTEUR AND KOCH AND OTHER SCIENTISTS STIMULATED THE SEARCH FOR MICROBES AND CAUSES OF DISEASE

- Describe the contribution of Pasteur and Koch to our understanding of infectious diseases

LOUIS PASTEUR

PASTEUR AND FERMENTATION

Pasteur's earlier experiments involved examining samples of fermenting wines under a microscope.

He noticed two things:

1. **Yeasts** were converting sugars into alcohol
2. **Bacteria** were converting sugars into lactic acid

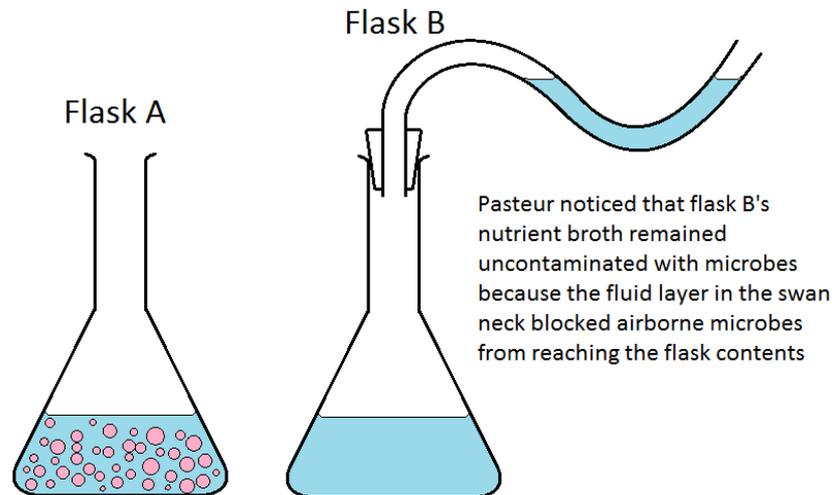
Pasteur showed that by heating the wine to 50-60 degrees Celsius for a few minutes, the spoiling microbes were killed, and no more lactic acid was produced. This method is now known as pasteurization.

This was the beginning of the "Germ Theory of Disease", which states that infectious diseases are caused by microorganisms. In this particular case, the disease was the wine spoilage and the microorganism was the spoiling bacteria.



PASTEUR'S CLASSIC EXPERIMENT

Pasteur sought to disprove the “Theory of Spontaneous Generation”, which hypothesised that disease causing organisms grew out of thin air, just as maggots would grow out of rotting rubbish. His method was simple and genius:



Pasteur's method was as follows:

1. Nutrient broth was poured into 2 flasks: an open necked flask and a swan necked flask
2. Both broths were boiled to kill existing microbes
3. The broths were then left open and allowed to cool

The microbes in the air reached the broth in flask A, however they were caught in the layer of moisture in the neck of flask B. Pasteur's swan necked design allowed air to pass into the flask, but the curved neck trapped any airborne microbes that might contaminate the broth. After time, broth A developed cloudy bacterial growths, whereas B stayed clear.

This experiment illustrated that microorganisms are present in air and can contaminate sterile solutions, however these microorganisms do not 'grow out of thin air,' **disproving the “Theory of Spontaneous Generation”**.

PASTEUR'S' WORK WITH ANTHRAX AND VACCINATION

Anthrax is a deadly bacterial disease of sheep, horses and cattle.

Pasteur developed a weakened strain of the bacterium, thereby producing the first vaccine. 25 sheep were vaccinated and 25 sheep were used as controls. All 50 sheep were then given lethal doses of the anthrax disease. The results were that the vaccinated sheep survived and the controls all died.

Although such an experiment would be considered inhumane today, it assisted in confirming the “Germ Theory of Disease” that Pasteur was working towards.



ROBERT KOCH

Koch also studied anthrax and his work was just as vital to our current understanding of disease as Pasteur's. Koch:

- Isolated the anthrax bacilli (the microbe that causes anthrax)
- Injected this microbe into healthy mice - these mice developed anthrax
- He then proved that it was the bacteria, not any other blood component, that caused the anthrax

Koch developed rules for establishing whether or not a certain microbe causes a particular disease. These rules are known as **Koch's postulates**.

KOCH'S POSTULATES

1. The organism must be present in every organism with the disease
2. The organism must be able to be isolated from the host and grown in pure culture
3. Organisms from the pure culture, when inoculated into healthy, suitable hosts must produce the same disease
4. The organism must be reisolated from the second host and be identified as the same species as the original culture

This technique is still used today to identify the pathogen of an infectious disease.

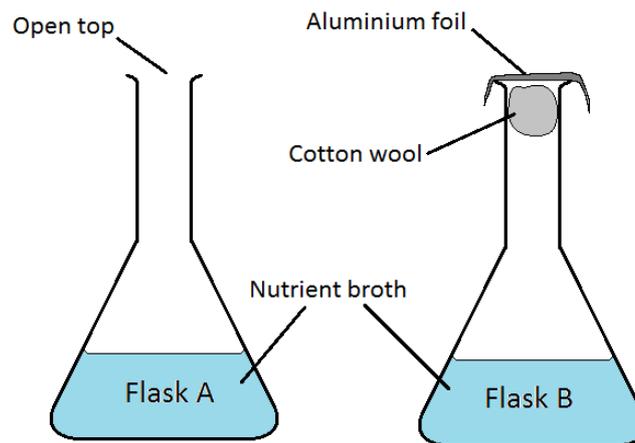


- Perform an investigation to model Pasteur's experiment to identify the role of microbes in decay

Although there are various methods to perform this experiment, this is a simple and effective way to model Pasteur's experiment (that does not require swan necked flasks!).

METHOD

A nutrient broth consisting of vegemite and water was placed in 2 equally sized flasks, and set up as follows:



One flask had an open neck; the other flask's neck was closed with a cotton wool ball and some aluminium foil.

Both flasks were heated with a Bunsen burner for two minutes to kill any pre-existing microbes in the broths. Following this, the flasks were left in the open air for 48 hours and the broths were compared.

RESULTS

The flask with the open neck developed **cloudy bacterial growths**, whereas the flask with the closed off neck remained sterile.

DISCUSSION

Like in Pasteur's experiment, the broths were boiled prior to leaving them in the open, to kill any pre-existing microbes, making the experiment valid. Although a swan necked flask was not used, the al foil and cotton wool plug served as an effective substitute for the swan neck and thus, achieved the same result.

As always, repeating the experiment and getting the same results multiple times would ensure the reliability of the experiment.

Some **safety considerations** for this experiment:

- Wear safety goggles throughout the entire experiment
- Do not taste the broth
- Handle the flasks carefully, as they are easy to break

CONCLUSION

Our experiment served as a suitable model for Pasteur's, illustrating that microorganisms are present in the air and can contaminate food (i.e. – broth). It is therefore important to maintain cleanliness and to properly store food to reduce the risk of contamination.

- **Identify the role of antibiotics in the management of infectious disease**
- **Process information from secondary sources to discuss problems relating to antibiotic resistance**

ANTIBIOTICS

Antibiotics are chemicals which **destroy or inhibit the growth of bacteria** which cause disease. They act selectively, in that they attack the bacteria but not the host. Note that antibiotics are only used against bacteria and not against other pathogens (viruses, prions etc.).

Antibiotics can be either:

- **bactericidal** (i.e. – kills the bacteria) or
- **bacteriostatic** (i.e. – prevents the growth of the bacteria)

Antibiotics can work in a number of ways. They can disrupt the cell wall of the bacteria (e.g. Penicillin), destroy the cell membranes of the bacteria (e.g. Nystatin), or disrupt protein synthesis (e.g. Streptomycin).

Some antibiotics are broad spectrum, which affect a wide range of bacteria and can be used to treat a range of diseases. Others are narrow spectrum, which are specific to particular pathogens.

Fleming, Florey and Chain were credited for their work with the first antibiotic Penicillin, which they discovered in 1928. The discovery was made while the scientists were working with Penicillium (a type of mould) which produces a natural substance that kills nearby bacteria.

ANTIBIOTIC RESISTANCE

Although antibiotics are crucial in our fight against disease causing pathogens, some bacteria can develop antibiotic resistant strains that **become immune to our drugs**. This is generally due to the **high mutation rates of bacteria**, in addition to the bacteria's ability to pass on plasmids (through transposons) which can carry the resistance from bacteria to bacteria.

In order to reduce the resistivity of bacteria to our antibiotics, individuals must be sure to complete their medications rather than stopping half way through, or else weakened strains of the bacteria can survive and develop resistance. In addition, antibiotics must not be overprescribed unnecessarily, as this can contribute to the build-up of resistance within bacteria strains.

PROBLEMS OF ANTIBIOTIC RESISTANCE FOR SOCIETY

Antibiotics have been so overused that some bacteria strains have become resistant to them. Examples of this include the "Golden Staph" (MSRA – *Staphylococcus aureus*) and *Streptococcus pneumoniae*.

The development of antibiotic resistance can be explained by Darwin's theory of evolution by natural selection. The use of antibiotics provides an environmental pressure to the bacteria, and those resistant strains possess favourable characteristics will survive and pass on their genes, giving rise to a new strain of 'super-bacteria'.

The more resistant bacteria strains become the less effective our medicines are. This will result in more people being affected by a number of infectious diseases, in addition to a more urgent need for research into new antibiotics. This requires a great deal of money and as resistant strains keep developing, it seems as if this cycle is never-ending.

It is therefore important to complete the full course of prescribed medication as mentioned above, in addition to only using antibiotics when necessary. The greater the unnecessary use of antibiotics, the more likely it is that a mutated bacteria will survive, passing on its resistant genetic makeup, creating antibiotic resistant strains. It is also sometimes effective to use a mixture of antibiotics, so that if bacteria isolated from a patient are resistant to one antibiotic, they may still be destroyed by one of the others.

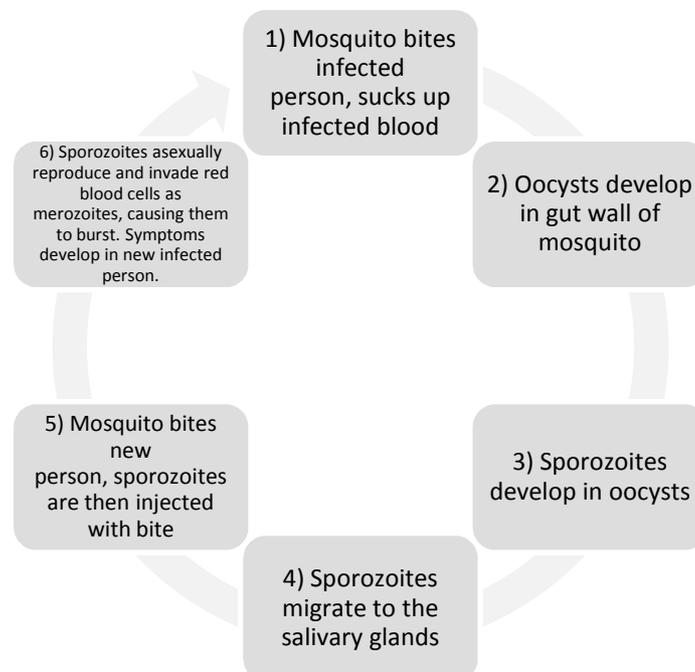
- Gather and process information to trace the historical development of our understanding of the cause and prevention of malaria

HISTORICAL DEVELOPMENT OF OUR UNDERSTANDING OF THE CAUSE OF MALARIA

The symptoms of malaria have been recorded for over the past 2000 years. As early as 4 BC, the **Greeks** thought malaria was caused by bad air in marshes and the **Chinese** linked the disease to demons found in bad water.

- It was in the 17th century that most of our understanding of malaria began to develop. In 1880, **Charles Laveran** linked the cause of the disease with microorganisms he observed in the blood of infected patients.
- In 1886, **Golgi** observed asexual reproduction of the protozoan in infected blood, further supporting Laveran's observations.
- In 1898, **Grassi** and **Bastianelli** suggested the Anopheles mosquito as the vector of the malaria causing pathogen.
- In 1899, **Ronald Ross** established the **Plasmodium protozoan** as the cause of malaria. It was he who described the complete lifecycle of the *Plasmodium* and was awarded the Nobel Prize for Medicine in 1902.

LIFECYCLE OF THE PROTOZOAN *PLASMODIUM FALCIPARUM*



HISTORICAL DEVELOPMENT OF OUR UNDERSTANDING OF THE TREATMENT OF MALARIA

In earlier times, natural drugs such as quinine were used to treat the symptoms of malaria.

In the early 1900's, the artificial drug chloroquine was developed and while it was initially highly effective, resistant strains of the protozoan evolved. Other anti-malarial drugs have since been developed, including primaquine and mefloquine; however similar problems with resistance have resulted.

By the 1950's the World Health Organisation started to use DDT to kill the vector – the *Anopheles* mosquito. While this method was initially effective, DDT – resistant strains of mosquitoes developed, also rendering this method less effective.

Since the late 1960's, global strategies were introduced which aimed to eliminate the breeding grounds of mosquitoes, with insecticides and minnows to eat the mosquito larvae. These days, when travelling to areas where malaria is prevalent, it is advised that travellers take anti-malarial drugs, wear protective clothing, use insect repellent and mosquito nets when sleeping at night. Development of a malarial vaccine is the main direction that research is going.



- **Identify date sources, gather, process and analyse information from secondary sources to describe one named infectious disease in terms of its:**
 - **Cause**
 - **Transmission**
 - **Host response**
 - **Major symptoms**
 - **Treatment**
 - **Prevention**
 - **Control**

MALARIA

CAUSE

Malaria is caused by the infection of 4 species of the protozoan *Plasmodium*. The most severe form of malaria is caused by the species *Plasmodium falciparum*.

TRANSMISSION

The pathogen that caused malaria is transmitted via a vector, the *Anopheles* mosquito.

In summary, when the mosquito bites an infected person, it sucks up infected blood, consuming gametocytes of the *Plasmodium* protozoan. Soon after, oocysts develop in the gut wall of the mosquito, which eventually develop into sporozoites. These sporozoites migrate to the salivary glands so that when the mosquito bites a new healthy person, the sporozoites are injected with the bite. Once inside the host, the sporozoites invade the liver cells of the host, where they asexually reproduce and invade red blood cells as merozoites. This causes the red blood cells to burst, where the person will develop the usual symptoms (covered later). When another mosquito bites this person, gametocytes of the *Plasmodium* protozoan will be sucked up with the blood and this cycle will restart itself.

HOST RESPONSE

The infected person produces antibodies in response to the protozoan; however the changing surface antigen of *Plasmodium's* cell membrane allows it to pass antibodies undetected. At each stage of the parasite's life cycle, it produces a different set of antigens which stimulate the immune response. Simply, because the protozoan's antigens continually change, the antibodies we produce are unable to 'keep up', so the immune response is not effective.



MAJOR SYMPTOMS

When the *Plasmodium* merozoites burst out of the red blood cells every 48-72 hours, they release toxins which cause the symptoms of malaria.

The toxins cause:

- Fever
- Shivering fits
- Headaches
- Nausea
- Profuse sweating
- Lethargy

TREATMENT

Antimalarial drugs (e.g. chloroquine) reduce the temperature and the symptoms associated with malaria, however some resistant strains of *Plasmodium* have developed.

Modern efforts are directed towards developing a vaccine for malaria.

CONTROL

Because of the problems associated with resistant strains and treatment, control measures are often more effective in 'treating' malaria.

Measures have been introduced to destroy the vector, including the WHO campaign to kill the *Anopheles* mosquito through the use of DDT in the 1950's, and efforts to destroy the breeding grounds of the vector.

In addition, people are encouraged to wear protective clothing, use insect repellent and sleep in insect nets when travelling to areas of high malaria prevalence.



WEEK 2 – HOMEWORK

- **Describe the contribution of Pasteur and Koch to our understanding of infectious diseases**

1. Nick's dog is sick and using his microscope, Nick has observed an unfamiliar looking microorganism in a blood sample from his dog.

Outline how Koch's postulates could be used to show whether or not it is the observed microorganism that made Nick's dog sick. **[4 marks]**

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2. Outline elements of Pasteur's classic experiment that made it such a big success. **[3 marks]**

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2. Write a definition for the following: **[1 mark each]**

a. Antibiotic

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b. Bactericidal

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c. Bacteriostatic

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3. Distinguish between broad spectrum and narrow spectrum antibiotics. **[2 marks]**

4. Use the development of antibiotic resistance within bacteria as an example to support Darwin's Theory of Evolution by Natural Selection. **[3 marks]**

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- Gather and process information to trace the historical development of our understanding of the cause and prevention of malaria
- Identify date sources, gather, process and analyse information from secondary sources to describe one named infectious disease in terms of its:
 - Cause
 - Transmission
 - Host response
 - Major symptoms
 - Treatment
 - Prevention
 - Control

1. What is the vector for malaria?

- a. Mosquito
- b. *Plasmodium*
- c. Human
- d. Both the mosquito and *Plasmodium*

2. Outline the lifecycle of the *Plasmodium Falciparum* organism. [3 marks]

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3. Complete the following table, outlining the history of our understanding of both the cause and prevention of malaria.

Date	Event / Historical Development

End of homework