Chapter 1

Introduction to Microbiology

Chapter Outline

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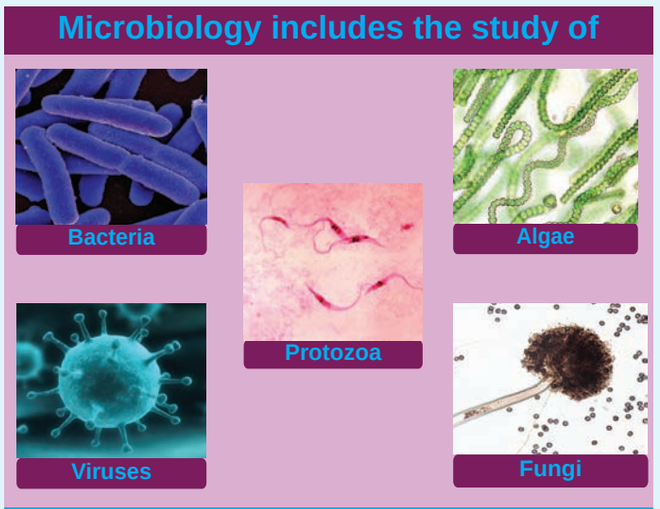


Microorganisms - Bacteria, Fungi, Algae, Protozoa and Viruses - have been around for at least 3,500 million years. Microbes affect every aspect of life on earth. They have an amazing variety of shapes and sizes. They can exist in a wide range of habitats.

Science knows no country, because knowledge belongs to humanity, and is the torch which illuminates the world.

Louis Pasteur

Learning Objectives

After studying this chapter the student will be able,

- *To know the features of microorganisms.*
- *To know the contributions of different scientists.*
- *To know the branches of Microbiology.*

Microbiology is one of the fascinating fields of science. Microorganisms and their activities are the major concerns of society both nationally and internationally. The developments in biotechnology, genetic engineering and nanotechnology have placed Microbiology in the limelight. Microorganisms provide the model for interdisciplinary research and for studying fundamental life processes. There is growing recognition of microorganisms and their potential in many applied areas like Environmental science, Agriculture, Food and Pharmaceutical industries. The uses of microorganisms are becoming increasingly attractive. Some microorganisms are beneficial to human and cannot live without them.

However microorganisms can be harmful in many ways and bring about undesirable changes. These microorganisms can cause diseases that can make us sick or even kill us. Although much more is known today about microbial life than ever before, the vast majority of this invisible world remains unexplored. Microbiologists continue to identify new ways that microbes benefit and threaten humans.

Microbiology is the study of living organisms of microscopic size, which include bacteria, fungi, algae, protozoa, and viruses. Microbiology is concerned with form, structure, reproduction, physiology, metabolism, and classification of microorganisms. It includes the study of

- their distribution in nature,
- their relationship to each other and to other living organisms,
- their effects on human beings, animals and plants,
- their abilities to make physical and chemical changes in our environment,
- their reaction to physical and chemical agents.

1.1 Groups of Microorganisms

There are many kinds of microorganisms present in the universe. They are broadly classified into the following groups.

Bacteria: They are unicellular prokaryotic organisms or simple association of similar cells. Cell multiplication usually happen by binary fission.

Example: *Escherichia coli, Bacillus subtilis*

Fungi: They are eukaryotic organisms which is devoid of chlorophyll. They are usually multicellular. They range in size and shape from single celled microscopic yeasts to giant multicellular mushrooms and puffballs.

Example: *Aspergillus niger, Agaricus bisporus*

Protozoa: They are unicellular eukaryotic organisms. Their role in nature are varied. The best known protozoa cause disease in human beings and animals.

Example: *Giardia lamblia, Plasmodium vivax*

Algae: They range from unicellular, colonial to multicellular forms. All algal cell contain chlorophyll and are capable of photosynthesis. They are found most commonly in aquatic environments and damp soil.

Example: *Spirogyra, Chlamydomonas*

Viruses: In the study of Microbiology, we encounter "organisms" which may represent the borderline of life. Viruses are simpler in structure and composition than other living cells. A virus is made up of nucleic acids and proteins. Viruses are obligate parasites. They grow only within an appropriate host cell (plant, animal, humans or microbe). They cannot multiply outside a host cell.

Example: HIV, Rabies virus

Prions are infectious agents composed entirely of protein material. Creutzfeldt–Jacob Disease (CJD) is one of the human prion diseases.

1.2 Contributors to Microbiology

Many scientists contributed to the science of Microbiology from the 17th century to the present day. Some prominent microbiologists who have made significant contribution to the study of microorganisms are given below:

1.2.1 Antony Van Leeuwenhoek

Antony Van Leeuwenhoek (1632-1723) of Holland (Figure 1.1) developed microscopes. He was a Dutch merchant and a skilled lens maker. He made a variety of lenses with magnifying power 50-300X.

He was the first person to invent simple microscope. It has a single biconvex lens with a magnification of about 200X (Figure 1.2). His microscopes resolved bodies with diameters measuring below 1micron. He examined water, mud, saliva and found living organisms. He called these microorganisms as **Animalcules** (little animals). Bacteria like cocci, bacilli and spirochetes were recognized. He proposed that the size of bacteria is one sixth the diameter of Red Blood Cells.

He observed the growth of bacteria in infusions. The existence of spermatozoa and RBC was revealed by him. Animal histology was established by him. He described capillary circulation and added a new dimension to Biology. All kinds of unicellular microorganisms were accurately described by him including human oral microbial flora. He is commonly known as the '**Father of Microbiology**'.

1.2.2 Louis Pasteur (1822-1895)

Louis Pasteur was a French chemist and a crystallographer (Figure 1.3). His greatest contribution to microbiology made him to be the '**Father of Modern Microbiology**'.

Figure 1.1:
Antony Van Leeuwenhoek

Antony Van Leeuwenhoek wrote many letters. He wrote them in Dutch, the only language that he knew. These letters, described his complete scientific output. Antony Van Leeuwenhoek in a letter dated 12th June 1716, wrote "... *my work, which I've done for a long time, was not pursued in order to gain the praise I now enjoy, but chiefly from a craving after knowledge, which I notice resides in me more than in most other men. And therewithal, whenever I found out anything remarkable, I have thought it my duty to put down my discovery on paper, so that all ingenious people might be informed thereof*".

Contribution to science as a chemist

Louis Pasteur was working with tartaric acid crystals. He could pick up the dextro and levo rotatory crystals by seeing the morphology of the crystals. Later he was called to solve some of the problems in fermentation industry and turned his attention to biological process of fermentation.

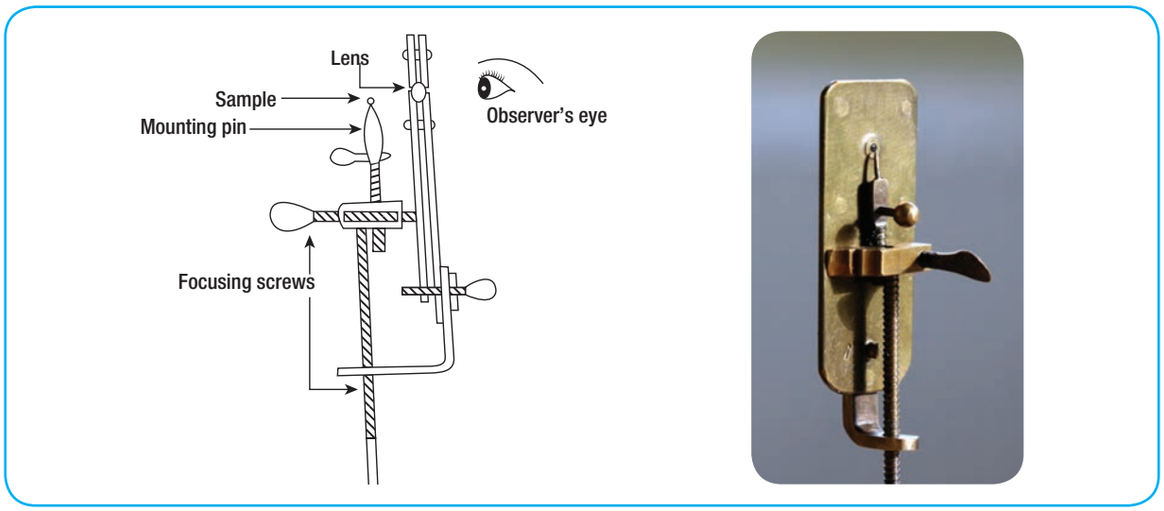


Figure 1.2: Leeuwenhoek's Microscope

Figure 1.3: Louis Pasteur (1822-1895)

Contribution to Microbiology

To wine industry

Louis Pasteur discovered alcohol production from grape juice was due to yeast. The presence or contamination of rod shaped bacteria resulted in large amounts of lactic acid production in wine. He also found that microorganisms in fermented fruits and grains, resulting in alcohol production. He coined the term "**fermentation**".

Pasteur disproved spontaneous generation

Spontaneous generation states that life could arise spontaneously from inanimate (non-living) materials (Abiogenesis). Pasteur disproved the theory of spontaneous generation. He strongly supported theory of Biogenesis (life orginates from pre-existing life forms). To prove this he carried out several experiments. Pasteur poured meat infusions into flasks and then drew the top of each flask into a long curved neck that would admit air but not dust (Figure 1.4). He found that if the infusions were heated, they remained sterile (free from any growth) until they were exposed to dust. After opening them on a dusty road and resealing them, he demonstrated the growth of microorganisms in all the flasks. The unopened flasks were sterile. Thus he disproved the theory of spontaneous generation.

Pasteurization

Louis Pasteur used heat to destroy undesirable microbes in fruit juices. He employed 62.8°C (145°F) for 30 mins to kill microbes. This process is called Pasteurization which is commonly used in distillaries and dairy industry.

Discovery of diseases

Louis Pasteur found that Pebrine disease in silk worm was caused by a protozoan parasite. He suggested that Pebrine disease could be eliminated by using only healthy,

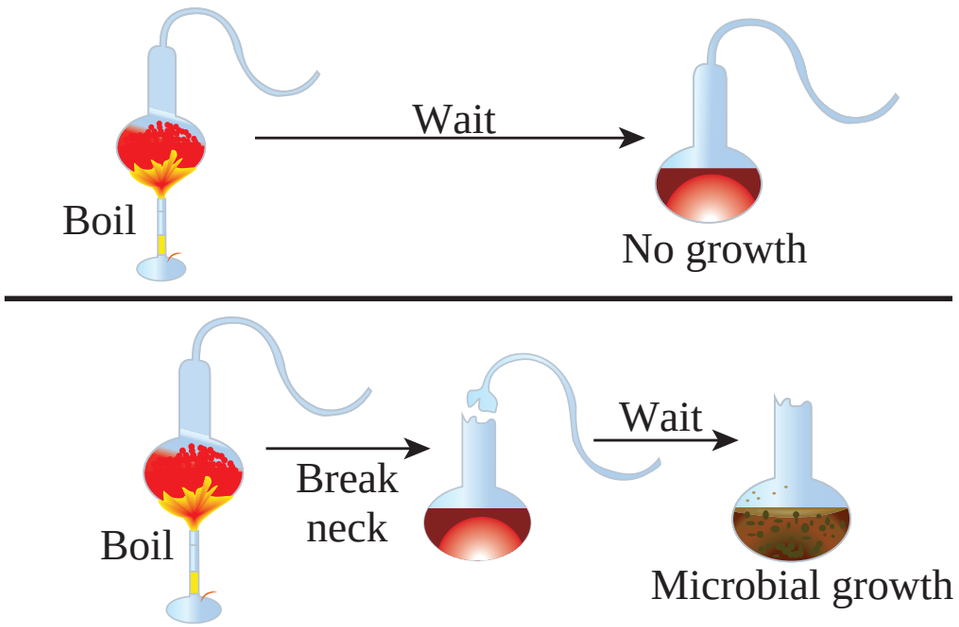


Figure 1.4: Pasteur's swan neck flask experiment

disease free silk worms. Wool Sorter's disease was named as "Anthrax" by him. He isolated *Bacillus anthracis* from the blood of infected animals. Chicken cholera bacterium was also isolated by Louis Pasteur using pure culture.

He proved that many diseases were caused by the presence of foreign microorganisms (**Germ theory of disease**). He discovered various infection causing microorganisms such as *Staphylococcus, Streptococcus* and *Pneumococcus.*

Vaccination

Pasteur found out that bacteria could be attenuated by growing them in unnatural conditions. He coined the term "**attenuation**". It is a process wherein bacteria lose their virulence due to repeated subculturing under laboratory conditions. He used attenuated cultures as vaccines for immunizing and protecting an individual against the disease. He developed vaccines for anthrax and rabies.

1.2.3 Edward Jenner (1749-1823)

In ancient observation, persons who had suffered from a specific disease such as small pox (causative agent of small pox is varicella virus) or mumps, resisted the infection on subsequent exposures. They rarely contracted these infections for second time. Edward Jenner, a country doctor in England noted a pustular disease on the hooves of horses called the grease. This was carried by farm workers to the nipples of cows (cow pox). This was again carried by milk maids. They got inflamed spots on the hands and wrists. The people who got this cow pox were protected from small pox. He reported that 16 farm workers who had recovered from cow pox (causative agent of cow pox is vaccinia virus) were resistant to small pox infection.

He took the material (pus) from the cow pox and inoculated into the cut of 8 year old boy on 14th May 1796 (Figure 1.5). Two

months later Jenner inoculated the same boy with material taken from small pox patients. This was a dangerous but accepted procedure at that time. This procedure was called variolation. The boy was protected against small pox. His exposure to the mild cow pox disease had made him immune to the small pox disease. In this manner Jenner began the Science of Immunology, the study of the body's response to foreign substances. Edward Jenner was regarded as the **'Father of Immunology'**.

Figure 1.5: Dr. Edward Jenner performing his first vaccination (1796)

1.2.4 Robert Koch (1843-1910)

Robert Koch was a German physician and microbiologist (Figure 1.6). He was the founder of Modern Bacteriology. Robert Koch discovered *Bacillus anthracis* (Anthrax bacillus), *Mycobacterium tuberculosis*, and *Vibrio cholerae*. For the first time he showed the evidence that a specific germ (Anthrax bacillus) was the cause of a specific disease (splenic fever in sheep) and introduced scientific approach in Microbiology.

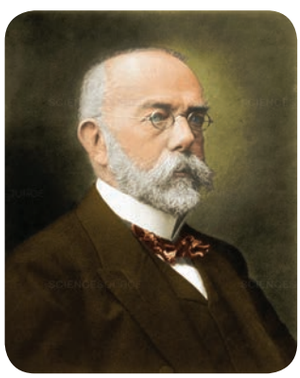


Figure 1.6: Robert Koch (1843-1910)

He modified Ziehl-Neelsen Acid Fast staining procedure which was introduced by Ehrlich. He devised solid medium to grow microorganism. He developed powerful method to isolate the microorganisms in pure culture from diseased tissue. He also perfected the techniques of identification of the isolated bacteria.

He introduced Koch's thread method to find out the efficacy of disinfectants. He established certain rules that must be followed to establish a cause and effect relationship between a microorganism and a disease. They are known as Koch's Postulates. He also described the Koch's Phenomenon. He was regarded as the **'Father of Medical Microbiology'**.

Infobits

Koch's Thread Method

Robert Koch carried out systematic experiments on disinfection, using pure cultures of bacteria. By means of his Thread Method, he investigated the effect on anthrax spores of the popular disinfectants at that time. Koch's Thread Method also called as carrier test. A carrier such as silk is contaminated by submerging in a liquid culture of the *Bacillus anthracis,* a test organism. The carrier is further dried and immersed in the disinfectant solution for a given exposure time. Thereafter the thread is cultured in a nutrient broth. No growth after incubation indicated that the product (disinfectant) is active.

Koch's Postulates

Four criteria were established by Robert Koch to identify the causative agents of an infectious disease. These include

1. A specific organisms can always be found in association with a given disease. If we take typhoid as an example it is caused by a bacterium *Salmonella typhi.*
2. The organism can be isolated and grown in pure culture in the laboratory. *Salmonella typhi* are grown in soild media under laboratory conditions.
3. The pure culture will produce the diseases when inoculated into a susceptible animal.

Almost all the pathogenic organisms produce the same disease in experimental animals. Usually rats, mice, rabbits or guinea pigs are used as experimental animals. *Pneumococci* produce pneumonia in animals. *Salmonella* species do not produce typhoid fever in rat, mice or rabbit. So chimpanzee is taken as experimental animal and it produces fever in chimpanzee.

4. It is possible to recover the organism in pure culture from the experimentally infected animals and it is observed to be the same as originally inoculated pathogen. Figure 1.7 explains the Koch's postulates.

Limitations

Some organisms have not yet been grown in artificial culture media

Example: *Mycobacterium leprae* and *Treponema pallidum*.

Modern addition to Koch's Postulates

Today we recognize additional criteria of causal relation between a microorganism and a disease. The important one is the demonstration of abnormally high concentration of specific circulating antibodies to the organism in the infected host or the presence of abnormally high degree of specific immunity or hypersensitivity to the infecting agent in

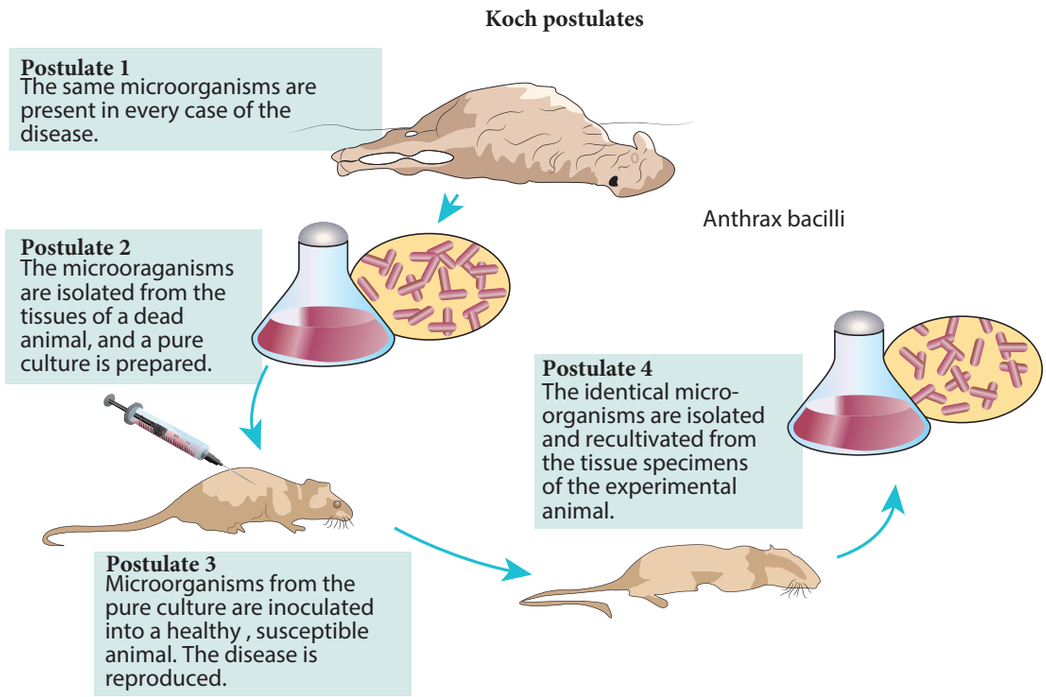


Figure 1.7: Koch's postulates for infectious diseases

a recently recovered host. In addition to culture techniques, serological techniques are also used for diagnosis of diseases.

Usefulness of Koch's Postulates

- It is useful in determining pathogenic organisms.
- To differentiate the pathogenic and nonpathogenic microorganism.
- For the classification of organisms.
- To detect the susceptibility or resistance of the laboratory animals.

1.2.5 Joseph Lister(1827-1912)

Joseph Lister was a British surgeon (Figure 1.8). He found out that microorganisms were responsible for wound infections. He developed a system of antiseptic surgery. He used bandages soaked in phenol solution to prevent wound infection. He sterilized instruments by heat and sprayed diluted phenol over surgical area and prevented contamination of wounds. He was the first person to isolate bacteria in pure culture using liquid culture. Thus, he was considered as co-founder of Medical Microbiology with Koch, who later isolated bacteria on solid media.

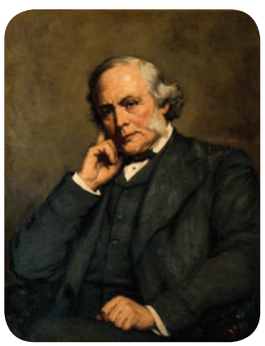


Figure 1.8: Joseph Lister (1827-1912)

1.2.6 Alexander Fleming (1881-1955)

He was a British Bacteriologist. He observed a mold (*Penicillium notatum*) growing on a plate of *Staphylococcus aureus*. The growth of *Staphylococcus aureus* around the mold colony was inhibited (Figure 1.9). He also showed that the culture filtrate of mold inhibited the growth of *Staphylococcus aureus*. He called this substance Penicillin, which acted on Gram positive bacteria. For the discovery of this antibiotic Fleming (Figure 1.10), Florey and Chain got Nobel Prize in 1945. Penicillin eventually came into use during world war II as a result of the work of a team of scientists led by Howard Florey of the University of Oxford.

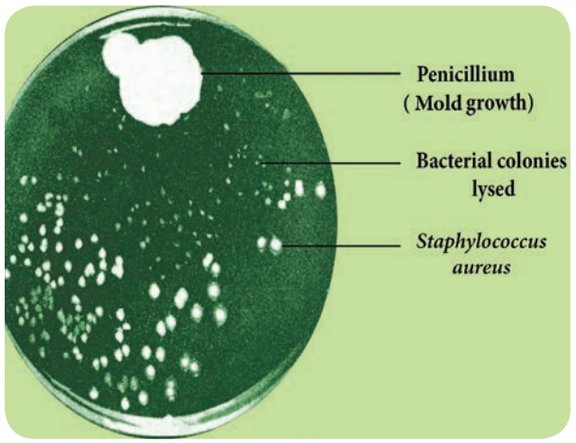


Figure 1.9: Original culture plate on which the observation of action of penicillin was made by Alexander Fleming

Figure 1.10: Alexander Fleming (1881-1955)

Alexander Fleming, the discoverer of penicillin warned about the possibility of antibiotic resistant bacteria due to antibiotics misuse, as early as in 1920s.

1.2.7 Selman Abraham Waksman (1888-1973)

Waksman was from Rutger University, USA (Figure 1.11). His research was largely on soil microorganisms. He showed antimicrobial activity of streptomyces that led to the discovery of Streptomycin and several other antibiotics.

Figure 1.11: Selman Abraham Waksman (1888-1973)

Waksman and his co-workers isolated Actinomycin in 1940, Streptothrecin in 1942, Streptomycin in 1943, and Neomycin in 1949.

Streptomycin is produced by *Streptomyces griseus*. It is a secondary metabolite produced by *Streptomyces griseus* which is not required for its growth but may help it to compete with other bacteria for food and space in the environment. Streptomycin is used in the treatment of tuberculosis. Waksman got Nobel Prize in 1952. for his work on Streptomycin

Antibiotics are usually not effective for sore throats and common colds. They are commonly caused by viruses rather than bacteria. Taking antibiotics for such illnesses is considered more harmful than beneficial.

1.3 Branches of Microbiology

Microbiology can be classified into Pure and Applied Microbiology. Pure Microbiology is classified based on taxonomical and integrative characteristics. Table 1.1 shows various branches of microbiology.

Table 1.1: Branches of Microbiology

Based on Taxonomical characteristics	
Bacteriology	The study of bacteria
Mycology	The study of fungi
Protozoology	The study of protozoa
Based on Taxonomical characteristics	
Phycology (or algology)	The study of algae
Parasitology	The study of parasites
Immunology	The study of the immune system
Virology	The study of viruses
Nematology	The study of the nematodes

Based on integrative characteristics	
Microbial Cytology	The study of microscopic and sub microscopic details of microorganisms
Microbial Physiology	The study of biochemical functions of microbial cell. It also includes the study of microbial growth, microbial metabolism and microbial cell structure
Microbial Ecology	The study of relationship between microorganisms and their environment
Microbial Genetics	The study of gene are organisation and regulation in microbes in relation to their cellular functions.
Cellular Microbiology	A discipline bridging microbiology and cell biology
Evolutionary Microbiology	The study of the evolution of microbes
Microbial Taxonomy	The study of naming and classification of microorganisms
Microbial Systematics	The study of the diversity and genetic relationship of microorganisms
Systems Microbiology	A discipline bridging systems biology and microbiology
Generation Microbiology	The study of microorganisms which have the same characters as their parents
Molecular Microbiology	The study of the molecular principles of physiological processes in microorganisms
Nano Microbiology	The study of microorganisms at nano level
Exo Microbiology (or Astro Microbiology)	The study of microorganisms in outer space
Biological Warfare	The study of microorganisms used in weapon industries
Applied microbiology	
Medical Microbiology	The study of the pathogenic microbes and the role of microbes in human illness. Includes the study of microbial pathogenesis and Epidemiology and is related to the study of disease, Pathology and Immunology
Pharmaceutical Microbiology	The study of microorganisms that are related to the production of antibiotics, enzymes, vitamins, vaccines, and other pharmaceutical products

Industrial Microbiology	The study of exploitation of microbes for use in industrial processes. Examples include industrial fermentation and waste water treatment. This field also includes brewing, an important application of microbiology
Microbial Biotechnology	The study of manipulation of microorganisms at the genetic and molecular level to generate useful products
Food Microbiology and Dairy Microbiology	The study of microorganisms in food spoilage, foodborne illness and food production.

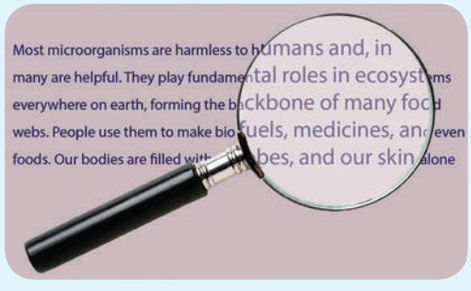
Summary

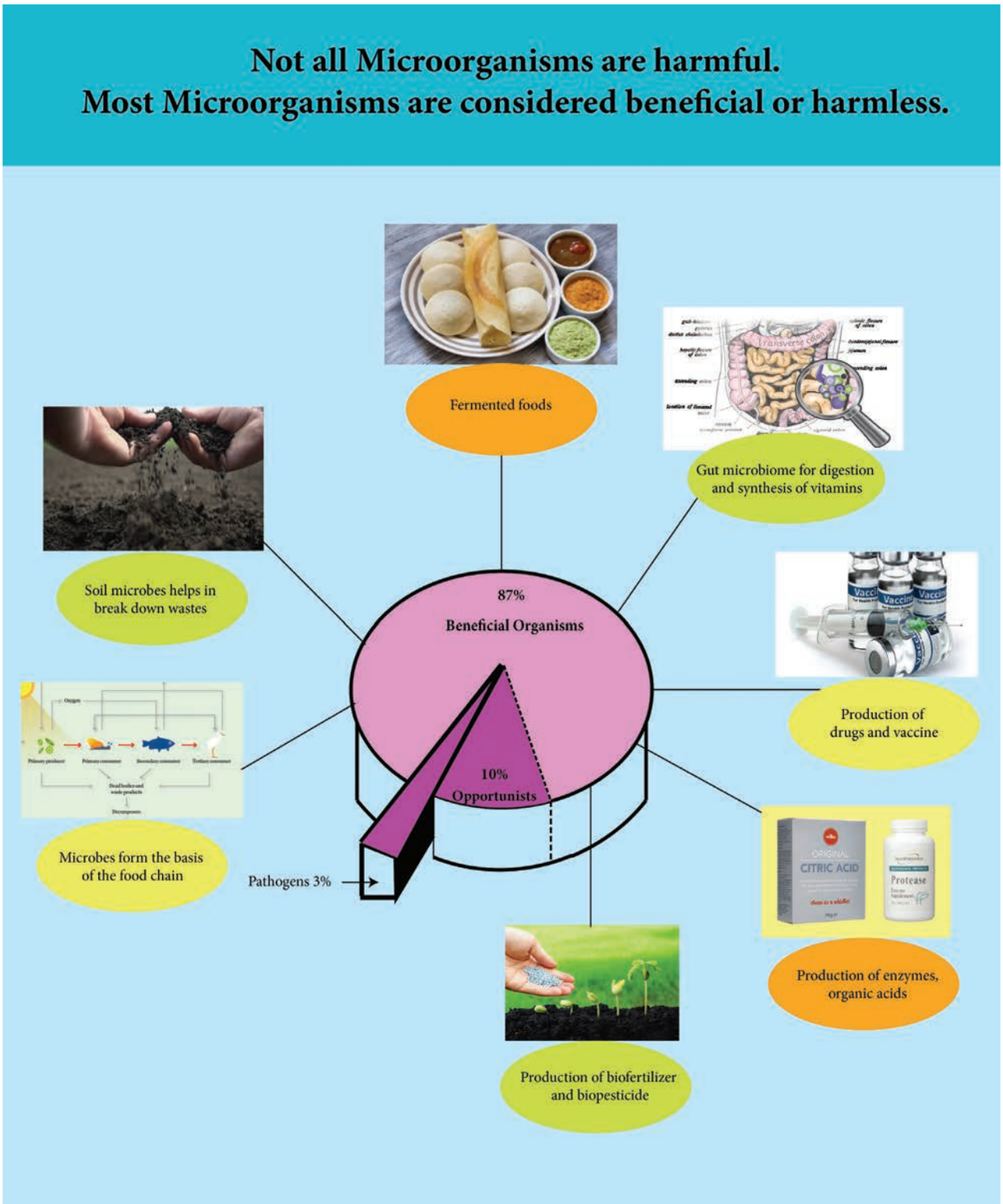
Microbiology is the study of microorganisms that includes bacteria, fungi,algae,protozoa and viruses. Many scientists contributed to the science of microbiology.

Antony Van Leuwenhoek made simple microscope. For the first time, Antony Van Leuwenhoek described the microorganisms. Louis Pasteur disproved the theory of spontaneous generation. Germ theory of disease came from the work of Pasteur and Robert Koch. Vaccines for Anthrax and rabies was developed by Pasteur. Direct relationship between the suspected pathogen and disease was established by Koch's postulates. Koch developed the technique of pure culture on solid medium. Joseph lister developed antiseptic surgery. Alexander Fleming discovered Penicillin. Waksman showed antimicrobian activity that led to the discovery of Streptomycin and other antibiotics. The branches of microbiology can be classified into pure and applied microbiology. Pure microbiology is classified based on taxonomical and integrated characteristics. Microbiology has got vast areas open for job opportunities.

Student Activity

1. Want to see spontaneous generation of life?
   Take chicken soup or meat soup boil it in a bottle. Keep it over the shadow of your window/or in a open place with mouth open. Observe for a week. You will see maggots (worms) growing. Observe and record your findings.
2. For you to enjoy-like Antony Van Leeuwenhoek !!
   Get a palmist lens, see through it a paper print. You will see letter becomes big, bigger, and at one point it is no longer magnifying the letter. A simple convex lens is magnifying things. Leeuweenhoek used such lens only. (as seen above) You know useful and useless magnification.





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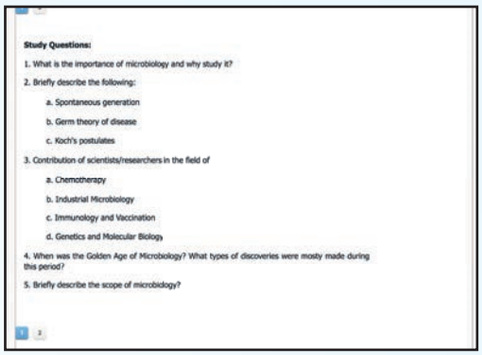
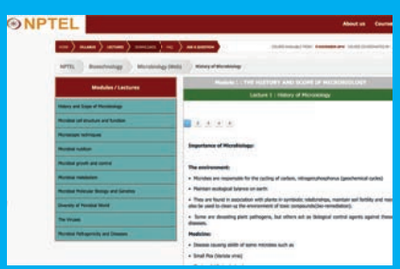
Microbiology

Lets meet our micro friends

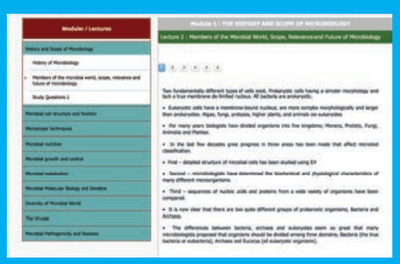


STEPS:

- Use the URL or scan the QR code to open 'NPTEL' page.
- Click 'History' and 'Scope of Microbiology' to know the history of microbiology.
- Select history of microbiology and click 'Start Course' at the bottom.
- Select 'Members of the Microbial world' to know about it.



Step1



Step2

Step3

URL:

http://nptel.ac.in/courses/102103015/41#

Evaluation

Multiple choice questions

1. Theory of spontaneous generation was disproved by whom?
   a. Robert Koch
   b. Edward Jenner
   c. Louis Pasteur
   d. All of them
2. Which of the following did Edward Jenner used to protect the boy against small pox?
   a. Cow pox material
   b. Small pox material
   c. Both the above
   d. Rabbit pox
3. Among the following scientists, who discovered solid medium?
   a. Louis Pasteur
   b. Edward Jenner
   c. Robert Koch
   d. None of them
4. Which of the following organisms does not obey Koch's postulates?
   a. Cow pox virus
   b. Small pox virus
   c. Treponema pallidum
   d. M.Tuberculosis
5. Who modified Ziehl-Neelsen staining technique?
   a. Louis Pasteur
   b. Robert Koch
   c. Ziehl-Neelsen
   d. All the above
6. Which of the following fungi grow on Alexander Fleming's plate?
   a. *Penicillium chrysogenum*
   b. *Penicillium notatum*
   c. *Streptomyces griseus*
   d. *Penicillium mornefii*
7. Which of the following antibiotics were discovered by Selman Abraham Waksman?
   a. Streptomycin
   b. Neomycin
   c. Actinomycin
   d. All the above

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Answer the following

1. Name the causative agent of cow pox and small pox.
2. Explain the method of Edward Jenner used to protect people against small pox.
3. List two organisms that do not obey Koch's postulates.
4. Give the usefulness of Koch's postulates.
5. What are the modern additions to Koch's postulates?
6. List the contribution of Alexander Fleming.
7. What is the theory of spontaneous generation?
8. How was spontaneous generation theory disproved?
9. Highlight the contribution of Waksman.
10. State the characteristics of streptomycin.
11. Give a list of contribution of Louis Pasteur to wine industry.
12. Explain Koch's postulates?
13. Describe the microscope made by Antony Van Leeuwenhoek.
14. What are the contributions of Antony Van Leeuwenhoek to microbiology?