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F**.Y. B.Sc. (Sem.** I**) (CBCS)**

MICROBIOLOGY

MB-101- FUNDAMENTALS OF MICROBIOLOGY

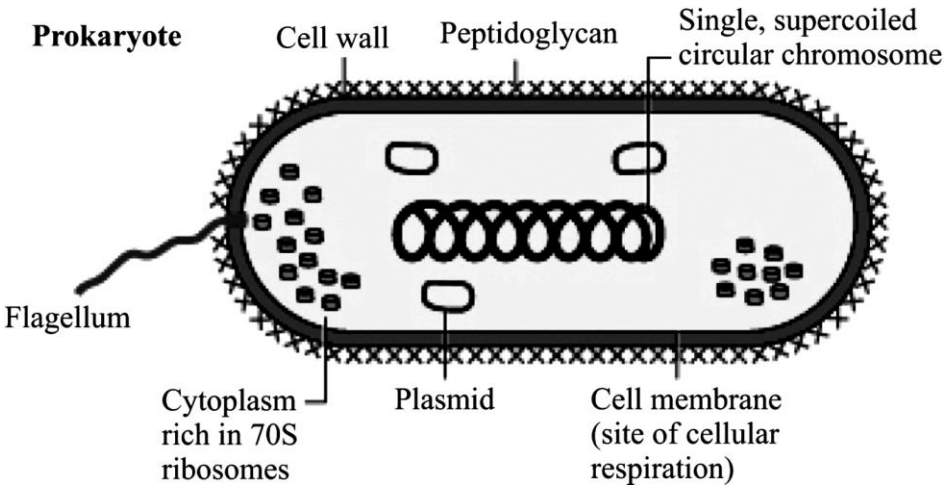
UNIT 1: SCOPE AND HISTORY OF MICROBIOLOGY

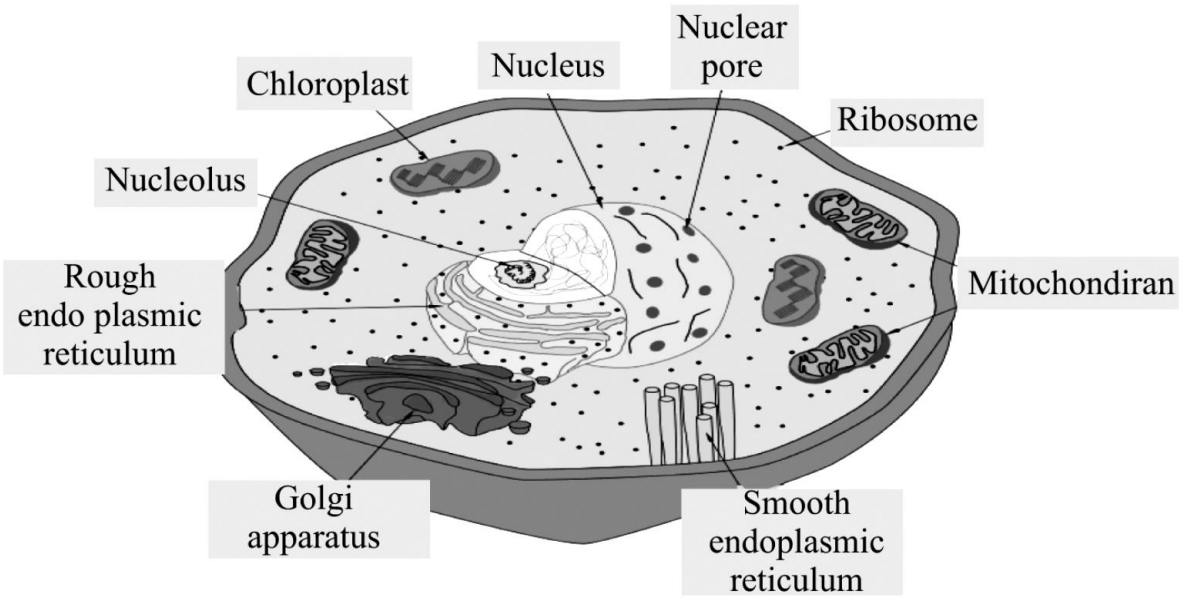
1.1 Microbiology as a field of Biology

Microbiology is the study of the biology of microscopic organisms - viruses, bacteria, algae, fungi, slime molds, and protozoa. The methods used to study and manipulate these minute and mostly unicellular organisms differ from those used in most other biological investigations. Recombinant DNA technology uses microorganisms, particularly bacteria and viruses, to amplify DNA sequences and generate the encoded products. Moving genes from one microorganism to another, or amplifying them within microorganisms, permits application of microbial skills to solve medical and environmental problems. Many microorganisms are unique among living things in their ability to use gaseous nitrogen from the air for their nutritional requirements, or to degrade complex macromolecules in such materials as wood. By rearranging the genes that control these and other processes, scientists seek to engineer microorganisms that will process wastes, fertilize agricultural land, produce desirable biomolecules, and solve other problems inexpensively and safely.

The prokaryotic cells have the following characteristics such as

- No organelles, all the action takes place in the cytosol or cytoplasmic membrane
- Most bacteria possess peptidoglycan, a unique polymer that makes its synthesis a good target for antibiotics
- Protein synthesis takes place in the cytosol with structurally different ribosome's





The major characteristics of Bacteria are based on their size, shape and arrangements

1.2 DEFINITION OF MICROBIOLOGY

Microbiology is defined as the study of organisms and agents that are too small to be seen clearly by the unaided eye. To be simpler, microbiology is the **study of microorganisms** which are the living organisms of microscopic size. **Microorganisms** are the living organisms that are less than 1 millimeter in diameter which cannot be seen by our naked eye. Microorganisms can be viewed through microscopes and they can exist as single cells or clusters. Microorganisms include the cellular organisms like **bacteria, fungi, algae and protozoa**. **Viruses** are also included as one of the microorganisms but they are acellular.

DIFFERENCE BETWEEN MICROBIAL CELL AND PLANT/ANIMAL CELL

S. No	Microbial cell	Plant/Animal cell
(a)	A microbial cell can **live alone**	Plant or animal cell exist only as part of organisms
(b)	Growth, energy generation and reproduction by a microbial cell are **independent**	Plant or animal cell depend on other cells for all processes

1.3 DIFFERENCE BETWEEN PROKARYOTES AND EUKARYOTES

Characteristics	Prokaryotes	Eukaryotes
Cell size	Generally, 1 to 10 µm in linear	Generally, 5 to 100 µm in linear
Cell division	Binary fission	Mitosis
Cellular organism	Unicellular	Mostly multicellular with
Cell wall	Complex structure with peptidoglycan	Absent or composed of cellulose or chitin
Plasma membrane	Present, no sterols except in	Present, contain sterols
Metabolism	Anaerobic or	Aerobic
DNA	Circular DNA in cytoplasm	Very long, linear DNA molecule bounded by nuclear
Membrane bound	Absent	Present
Extra chromosomal DNA (Plasmid)	Present	Absent
Histones	Absent	Present
RNA and protein	RNA and protein synthesized in same compartment	RNA synthesized and processed in nucleus; proteins synthesized in
Membrane bound organelles	Absent	Present (Nucleus, mitochondria, chloroplast,
Ribosomes	70S type	80S type
Lysosomes	Absent	Present
Locomotion	Rotating flagella and gliding	Undulating flagella and cilia and
Flagella	Consists of two protein building	Consists of multiple
Pili	Present	Absent
Glyocalyx	Present as a slime layer or capsule	Present in some cells that lacks cell
Site for cellular respiration	Cell membrane	Mitochondria
Sexual reproduction	Conjugation	Meiosis
Examples	Bacteria and	Fungi, Algae and

1.4 MICROBIAL GROUPS

Based on the morphological, phylogenetic and physiological characteristics, microorganisms are divided into six distinct groups, they are as follows

1) Bacteria

2) Archaea

3) Fungi

4) Protozoa

5) Algae

6) Viruses

1) BACTERIA are **prokaryotes** that are usually single celled organisms. They multiply by binary fission and reproduces asexually. They are the most **dominant** group of microorganisms in soil, water and air. Some bacteria even live in environment that has extreme temperatures, pH or salinity. Many of them play more **beneficial roles** in nutrient cycling, decomposition of organic matter, production of commercial industrial products like vitamins, antibiotics, etc. Wherein, some of them cause diseases and food spoilage. Ex: Bacillus, Pseudomonas.

2) ARCHAEA are phylogenetically related prokaryotes that are distinguished from bacteria by many features, most notably their unique ribosomal RNA sequences. Many archaea are found in extreme environments. Some have unusual metabolic characteristics, such as the methanogens, which generate methane gas. Ex: Methanobacterium.

3) ALGAE are eukaryotes that contain chlorophyll and are capable of performing photosynthesis. Algae are found most commonly in aquatic environments. They reproduce either sexually or asexually. Mostly they are used as food supplements. They are mainly used in the preparation of agar. Ex: Spirulina, Gelidium.

4) FUNGI are eukaryotes. Next to bacteria, they are the most dominant organism in the soil. In general, fungi range in size and shape from single-celled microscopic yeasts to gaint multicellular mushrooms. They possess filamentous mycelium composed of individual hyphae and reproduce either sexually or asexually by fission, budding or by means of spores borne on fruiting structures. Unicellular fungi like yeast are involved in the production of alcoholic beverages like wine and beer. Multicellular fungi like molds are useful for industrial production of antibiotics like penicillin. Ex: Mucor, Rhizopus.

5) PROTOZOA are unicellular eukaryotes that are usually motile and lack cell wall. Many free living protozoa function as the primary hunters and grazers of the microbial world. They can be found in

many different environments and some are normal inhabitants of the intestinal tracts of animals, where they aid in digestion of complex materials such as cellulose. Some of them are parasitic and can cause diseases. Ex: Amoeba, Paramecium.

6) VIRUSES are acellular (non cellular) organisms that are too small and can be visualized only using electron microscopes. All are obligate parasites that require a living cell for reproduction. They are pathogenic to plants, animals and humans. At most of the cases they cause human diseases. Ex: Cauliflower mosaic virus, Cucumber mosaic virus.

1.5 SCOPE OF MICROBIOLOGY

Currently, we are in the era of Microbiology. Microorganisms are recognized as the **basic research tools** as they help to understand the chemical and physical basis of life as they are the dominant group of living organisms in the biosphere and are actively involved in our day to day activities. Microbiology primarily paves way to analyze the biochemical and genetic **background of living things**. Moreover as microbes are the excellent **models** for understanding the cell functions and as they play important role in the field of medicine, agriculture and industry that assures human welfare, microbiology is considered as one of the vital branch of science with utmost promising scopes. Microbiology is not just one small subject to be explored. It has nearly six major branches. They are as follows,

Agricultural Microbiology deals with soil nutrient cycling by microbes, microbial decomposition of organic wastes, plant associated microbes that enhance soil fertility, etc.

2. **Food Microbiology** covers information about the microbes involved in food spoilage, food borne diseases, commercial food products prepared using microbes, etc.

3. **Industrial Microbiology** explores the utility of microbes in the production of antibiotics, enzymes, alcoholic beverages, fermented food products, etc.

4. **Medical Microbiology** deals with the studies related to the microbes that causes diseases, their diagnostic and preventive measures, drug designing, etc.

5. **Aquatic Microbiology** deals with water purification and biological degradation of wastes in aquatic ecosystems by microbes.

6. **Aero Microbiology** talks about the microorganisms prevalent in air, their abundance and beneficial or harmful issues.

7. **Exomicrobiology** is all about the exploration of life in outer space.

8. **Geochemical Microbiology** analyses the microbial life and their contribution in coal, oil and gas formation areas.

1.2 Historical developments in Microbiology

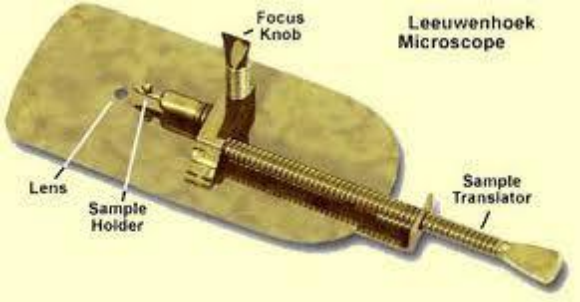
The field of microbiology developed further and gained its importance after the fascinating discoveries later than 1600's by the discovery of microscopes by pioneer scientists. The important discoveries that contributed much to the discipline of microbiology is the conflict over the 'Theory of Spontaneous Generation' followed by 'Koch's Postulates' that completely changed the view of microorganisms. This chapter gives a vivid outlook on the contributions of many pioneers like Pasteur, Koch, etc.

2.1. ROBERT HOOKE (1635 – 1700)

Hooke was the first person to discover the cell (honey comb like structures) from the cross sections of a cork. He noticed some microscopic fungi too. He also developed simple microscopes of 30x magnification and observed few microorganisms.

2.2. ANTONY VAN LEEUWENHOEK (1632 – 1723)

Leeuwenhoek is a famous person who is always praised as the Father of Microbiology. He was a Dutch merchant and his hobby was making lenses and microscopes. His microscopes were simple microscopes composed of double convex glass lenses held between two silver plates that could magnify 50 to 300 times. He was the first to describe the protozoa and bacteria. He observed some bacteria from plagues of his own teeth. He named them as animalcules.



1.3 The Place of Microorganisms in the living world: Groups of Microorganisms and their distribution in Nature

The first form of life to develop on Earth were single-celled microorganisms. These organisms are so small that they are visible only through a microscope. They exist as a single cell or a cluster of cells. Between 1665-1683, two biologists from The Royal Society, Robert Hooke, and Antonie Van Leeuwenhoek discovered the existence of microorganisms. All unicellular organisms like protozoans, bacteria and some algae are included under the category of microorganisms and are largely diverse.

Microorganisms are omnipresent, they are found everywhere. They live in every nook and corner you could possibly imagine. On your seat, under the table, over the roof, even on your body parts, your palms, literally everywhere. They also dwell in extreme weather conditions like the equator, poles, deserts, ice-cold water bodies, hot boilers etc and adapt accordingly.

- **Microorganisms And Us – Role of Microorganisms**

  Microorganisms play a very integral part of our lives. Some are harmful while some are very beneficial to man. Let us look at some of the microorganisms that are beneficial:

  Friendly Microorganisms

  Microorganisms are being used for a multitude of purposes. Since ages, it has been used in the production of alcohol. They are also used in the preparation of cakes, bread, and curd. Apart from this, some microbes help clean up the environment, such as bacteria. They are also used for the following applications:

  - Helps break down organic wastes into reusable substances which are harmless.

- Used in the preparation of medicine
- To increase the fertility of the soil by nitrogen fixation

- **Making Of Curd and Bread**

The curd is obtained by the action of bacteria on milk. A bacterium named Lactobacillus is present in the milk, which promotes the formation of curd by multiplying itself continuously in milk. Bacteria are involved in the making of:

- Cheese
- Pickles
- Yeast and bacteria are important in the fermentation of dosa and idli batter

Yeast is used extensively in the baking industry to make pastries, cakes etc. They do so by continuously reproducing and as they respire they produce carbon dioxide as a result of which dough increases in size due to bubble formation.

- **Commercial Use of Microorganisms**

Microorganisms such as yeast are grown on natural sugars to produce alcohol, wine, and vinegar on a large scale. Fermentation is the process of converting sugar into alcohol. Yeasts take part in fermentation.

- **Medicinal Use of Microorganism**

Microorganisms are the primary source of making antibiotics. Antibiotics are medicines that stop or inhibit the growth of disease-causing microorganisms. Antibiotics are produced by growing many fungi and bacteria and are used to treat numerable diseases. Few antibiotics are:

- Erythromycin
- Amoxicillin
- Streptomycin

In animals, antibiotics are used to check microbial infections. They are used in plants to control diseases as well.

- **Vaccine**

  On a large scale, vaccines are manufactured using microorganisms to protect animals and humans from various diseases. Diseases such as smallpox, hepatitis, tuberculosis can be prevented using vaccines.

- **Harmful Microorganisms**

  While most microorganisms are beneficial, some are very harmful to living organisms. Pathogens are disease-causing microbes. These pathogens cause harm in many ways: either by producing diseases, spoiling food, bringing about degradation in commercial products like leather and clothing etc. Let us know more about their damaging activities

- **Disease-Causing Microorganisms In Humans**

  Communicable diseases are the diseases that spread through infected food, water, air or physical contact from an infected person to a healthy person. These may spread through droplets of moisture while sneezed through the air or by consuming contaminated water or food. In some cases, diseases are spread by carriers. Carriers are insects and animals that carry the disease-causing pathogens. Example: Housefly, female Anopheles mosquito carries the parasite of malaria, dengue virus is carried by Female Aedes mosquito.

1.4 Spontaneous generation versus Biogenesis

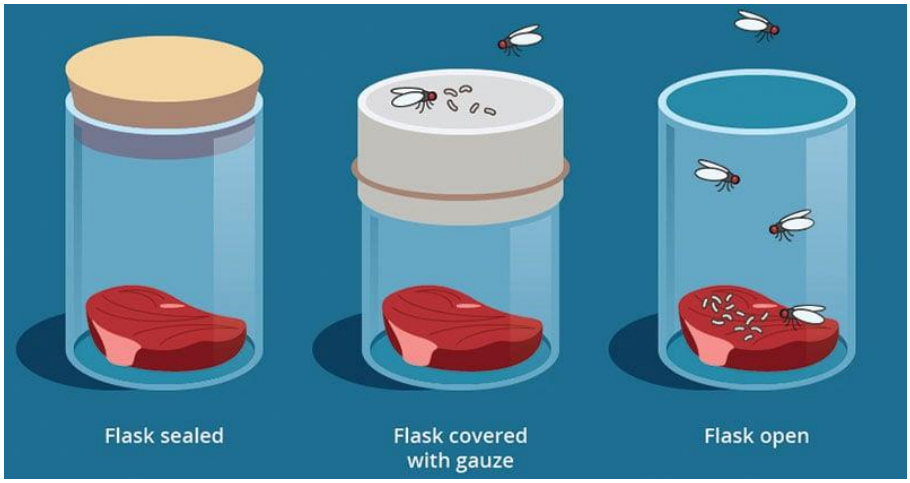
After the discovery of microorganisms by Leeuwenhoek, scientists began investigations about the origin of microbes. Since organic matter decomposes quickly outside the living body, it was assumed that microorganisms were arising by spontaneous generation. Francesco Redi (1626), supported spontaneous generation theory. He boiled the meat and covered the mouth of the flask with wire gauze. The flies attracted due to the odour of meat, laid eggs on the wire gauze, that later developed into maggots. Thus he established that origin of maggots was from meat and not from fly. Additionally, John Needham (1749), an Irish priest, observed the appearance of microorganisms in putrefying meat and interpreted this as spontaneous generation.

Spontaneous generation is an obsolete theory which states that living organisms can originate from inanimate objects.

The theory believed that dust created fleas, maggots arose from rotting meat, and bread or wheat left in a dark corner produced mice among others.

Although the idea that living things originate from the non-living may seem ridiculous today, the theory of spontaneous generation was hotly debated for hundreds of years.

During this time, many experiments were conducted to both prove and disprove the theory.



- **Experiments in Support of Spontaneous Generation**

  The doctrine of spontaneous generation was coherently synthesized by Aristotle, who compiled and expanded the work of earlier natural philosophers and the various ancient explanations for the appearance of organisms, and was taken as scientific fact for two millennia.

- **Aristotle**

  The Greek philosopher Aristotle (384–322 BC) was one of the earliest recorded scholars to articulate the theory of spontaneous generation, the notion that life can arise from nonliving matter. Aristotle proposed that life arose from nonliving material if the material contained pneuma ("vital heat"). As evidence, he noted several instances of the appearance of animals from environments previously devoid of such animals, such as the seemingly sudden appearance of fish in a new puddle of water.

John Needham

- The English naturalist John Turberville Needham was in support of the theory.
- Needham found that large numbers of organisms subsequently developed in prepared infusions of many different substances that had been exposed to intense heat in sealed tubes for 30 minutes.
- Assuming that such heat treatment must have killed any previous organisms, Needham explained the presence of the new population on the grounds of spontaneous generation.
- **Germ Theory of diseases**

  The germ theory of disease states that many diseases are caused by microorganisms such as bacteria, viruses, protozoa, or fungi. These diseases are caused by the growth and replication of microorganisms.

  The germ theory of disease was devised by Louis Pasteur. He also performed various experiments to demonstrate the relationship between microorganisms and diseases.

  History of Germ Theory of Disease

  Until germ theory was accepted, the Miasma theory was prevalent which stated that the disease was caused by the decomposition of organic matter which released poisonous air carrying disease-causing agents. During the 1600s, the concept of spontaneous generation of diseases was proved wrong by the experiments performed by Francesco Redi. In his experiments, he placed a loaf of meat and an egg in three distinct jars: The first jar was left uncovered. It was observed that the maggots covered the meatloaf and the egg. The second jar was sealed tightly with a lid. No maggots were observed. The third jar was covered only with gauze. It was observed that no maggots were inside the jar but were present on the top of the gauze.

- **Thus, Redi refuted the concept of spontaneous generation.**

  Anton Van Leeuwenhoek, the first microbiologist to observe the microorganisms under a microscope, also supported the germ theory of disease. Richard Bradley later postulated that diseases were caused by microorganisms which were later supported by Marcus Antonius Von Plenzic.

Also read: Microbes and Disease

- **Experiments in support of Germ Theory of Disease**

The freshly boiled broth was exposed to air under the below-mentioned conditions: The growth medium was kept in a vessel containing a filter to prevent the entry of particulates. The growth medium was kept in a vessel without a filter and was exposed to room air. The growth medium was kept in a vessel and was exposed to room air through a long tube to prevent the entry of any dust particles.

Pasteur observed that the broth which was exposed to the room air without a filter developed microorganisms. In addition to him, Ignaz Semmelweis, John Snow and Robert Koch are also some important contributors to the germ theory of disease. However, the experiments conducted by Louis Pasteur and Robert Koch provided accurate prooves in support of the germ theory of disease.

- **Germ Theory of Fermentation**

The experiments performed by Louis Pasteur made him conclude that the microbes present in the air spoiled the fermentation broths. He performed various other fermentation processes for compounds like lactic acid, butyric acid, etc. Thus, he postulated the germ theory of fermentation which states that every fermentation process is acted upon by certain microbes. He further extended the theory to animal and human diseases. He observed that the diseases are also caused by the germs present in or around the body.

1.	Medical microbiology	Diagnostic procedures for identification of causative agents of various diseases and their preventive measures
2.	Aquatic microbiology	Water purification; microbiological examination of water; biological degradation of waste; ecology (marine and fresh water)
3.	Aeromicrobiology	Contamination and spoilage; dissemination of diseases
4.	Food microbiology	Food preservation and preparation; food borne diseases and their prevention
5.	Agricultural microbiology	Soil fertility; factors determining soil fertility; plant and animal diseases
6.	Industrial microbiology	Production of medicinal products such as antibiotics and vaccines; fermented beverages, industrial chemicals; production of proteins and hormones by genetically engineered microorganism
7.	Exomicrobiology	Exploration of life in outer space
8.	Geochemical microbiology	Formation of coal, mineral oil and natural gas; prospecting for deposits of coal, oil, and gas; recovery of minerals from low-grade ores