Brief history of microbiology

1- How Can Microbes Be Classified?

Fungi, Protozoa, Algae, Prokaryotes and other organisms of importance to microbiologists

B- The Golden Age of Microbiology

1- Is Spontaneous Generation Of Microbial Life Possible?

Redi's Experiment, Needham's Experiment, Spallanzani's Experiment, Pasteur's Experiment.

CHAPTER (1): A BRIEF HISTORY OF MICROBIOLOGY

Microbiology is the study of organisms and agents too small to be seen clearly by the naked eye. It is the study of microorganisms, or germs or microbes. However, some of these microorganisms are large and visible by our naked eye such as mushrooms, brown algae, and lichens.

Viruses, bacteria, algae, fungi, and protozoa belong to microorganisms.

Life would not exist without microorganisms. Plants depend on microorganisms to help them obtain their nitrogen they need from air. Animals such as cows and sheep need microorganisms in order to digest the cellulose in their diets.

Our ecosystem rely on microorganisms to enrich soil, degrade wastes and supports life. Without microbial recyclers, the world would be buried under dead organisms.

We use beneficial microorganisms to make our food such as cheese, yoghurt, bread, to develop our vaccines, hormones, vitamins and antibiotics. The human body is home to billions of microorganisms, many of which help keep us healthy.

Microorganisms are not only an essential part of our lives; they are quite literally a part of us. Microorganisms can be both beneficial and harmful (infectious disease agents) to humans, animals and plants.

Some harmful microorganisms also do cause diseases, from the common cold to AIDS. The threats of bioterrorism and new or re-merging infectious diseases are real problem.

We will explore all the roles (both harmful and beneficial) that microorganism's play in our lives in this fascinating course.

- Importance of bacteria

Bacteria can be categorized into harmful and useful bacteria, while some bacteria are non harmful-non useful.

- Harmful bacteria

1. Bacteria cause some major diseases to humans, animals and plants. Among these diseases: cholera, typhoid, tetanus, pneumonia, tuberculosis and meningitis.
2. Some pathogenic bacteria produce poisonous chemicals called toxins which affect certain parts of the host body.
3. In food industry, bacteria cause spoilage of food and food poising.

- Useful bacteria

1. Bacteria produce antibiotics which for the treatment of diseases.
2. Bacteria provide enzymes for biological washing powders.
3. Bacteria are used as microbial insecticides protecting crops from insect pests.
4. Bacteria are used to leach out metals from some low grade ores such as copper and gold.
5. Bacteria contribute greatly to food industry (butter, cheese, and yogurt).
6. Certain bacteria are used to convert lactose (milk sugar) into lactic acid.
7. Certain bacteria are used to convert alcohol into vinegar.
8. Bacteria have an essential role in the natural cycles of matter. In the soil, bacteria affect fertility, structure and productivity of corps.

One of the most important roles of bacteria is the breakdown of dead organisms and organic wastes into its basic inorganic parts. Carbon dioxide, water, nitrogen, and sulfur are some of the most important materials returned to the soil and atmosphere. Such cycling of materials could not occur in the absence of certain bacteria.

9. As a source of food (single cell protein (SCP). Bacteria are a good source of (SCP) with plenty of food and space. (SCP can be produced using bacteria growing in waste paper, pollutants or any food waste product).

- The Early Years Of Microorganisms

The early years of microbiology brought the first observations of microbial life, and the initial efforts to organize them into logical classification.

Early investigators suspected the existence of microorganisms and their role in disease development even before microorganisms were detected.

The first person observed and described microorganisms was Antony van Leeunwenhoek (The Father of Bacteriology and Protozoology) (Dutch) in 1674. He was a tailor and a lens grinder. He used to manufacture lenses to examine the quality of the clothes.

He invented simple microscope in 1674 and he observed, drew, and measured large numbers of minute living organisms including bacteria and protozoa in pond water. He also described the motion, morphology and diversity of bacteria and protozoa.

- How Can Microbes Be Classified?

Shortly after Leeunwenhoek made his discoveries, the Swedish botanist Linnaeus developed a taxonomic system-that is a system for naming plants and animals and grouping similar organisms together. Linnaeus and other scientists of that period grouped all organisms into either animal kingdom or the plant kingdom. Today biologists use the five kingdoms classification system and the three kingdoms classification system.

The microorganisms that Leeunwenhoek described can be grouped into five basic categories: fungi, protozoa, algae, prokaryotes and small animals. The only microbes not described by Leeunwenhoek are viruses which are too small to be seen without an electron microscope.

Cells are of two types:

1- Prokaryotic cells (pro = before, karyon = nut or kernel). Example: Bacteria

(i) Organisms very simple in shape.

(ii) The cells lack true membrane delimited nucleus.

2- Eukaryotic cells (Eu = true, karyon = nut or kernel). Examples: Algae, fungi, protozoa, higher plants and animals.

(i) Morphologically more complex than prokaryotes and larger in size.

(ii) Organisms with true nucleus. They have a membrane enclose nucleus. .

Biologists have divided living organisms into five kingdoms:

1. Kingdom Monera or Prokaryote: includes prokaryotic organisms (Bacteria and archea) and Cyanobacteria (the blue-green bacteria, formerly called blue-green algae).
2. Kingdom Protista: Include either unicellular or colonial eukaryotic organisms that lack true tissues (Protozoa, small algae, and lower fungi).
3. Kingdom Fungi: Includes eukaryotic organisms with absorptive nutrition and often multinucleate. Fungi includes moulds (filamentous fungi) and yeasts (unicellular fungi).
4. Kingdom Animalia: Multicellular animals with ingestive nutrition (Vertebrates and invertebrates).
5. Kingdom Plantae: Multicellular plants with walled eukaryotic cells and photosynthetic ability.

Viruses do not fit into the classification of living organisms (five kingdoms classification system) because they are dependent on other cells for their reproduction (obligate parasites). Nevertheless viruses are also studied by microbiologists.

The recent classification divided organisms into 3 kingdoms based on the analysis of the 16S RNA.

1. Bacteria (True bacteria or Eubacteria).
2. Archaea (Archaeobacteria).
3. Eukarya (All eukaryotic organisms).

Fungi (Mycology)

Fungi are organisms whose cells are eukaryotic with a true nucleus surrounded by a nuclear membrane. Fungi differ from animals by having cell walls. Fungi are different from plants because they are heterotrophic (obtain their food from other organisms which is different from plants (obtain their food by themselves through photosynthesis i. e. autotrophic).

Microscopic fungi include molds (filamentous fungi) and yeasts (unicellular fungi). Molds are multicellular organisms that are grow as long filaments called hyphae that intertwine to make up the body of the mold. Molds reproduce by sexual and asexual spores which produce new individuals.

Yeasts are unicellular and they reproduce by budding. Many types of fungi are beneficial and some are also very harmful to humans causing many diseases.

Mushroom is a typical example of macroscopic fungi. Some mushrooms are also poisonous and can cause death.

Protozoa (Protozoology or Parasitology)

Protozoa are single celled eukaryotic microorganisms with true nucleus that are similar to animals in their nutritional needs and cellular structure. The suffix protozoa in Greek mean (the first animals). Most protozoa are capable of locomotion through pseudopodia, cilia or flagella.

Protozoa typically live freely in water, but some live inside animal hosts, where they can cause diseases. Most protozoa reproduce asexually, however some can reproduce sexually.

Algae (Phycology)

Algae are unicellular or multicellular photosynthetic autotrophic organisms. Algae are categorized on the basis of their pigmentation, storage products and their cell walls.

Large algae commonly called seaweeds and kelps are common in the oceans. Unicellular algae are common in freshwater ponds, streams and lakes and in the oceans as well. They are the major food source of small aquatic and marine animals and provide most of the world's oxygen as a by-product of photosynthesis.

Prokaryotes (Bacteriology)

Prokaryotic microorganisms are unicellular microbes that lack nuclei. There are two kinds of prokaryotes: true bacteria (Eu-bacteria) and archaea (Archaeobacteria). Bacterial cell walls are composed of a polysaccharide called peptidoglycan, although some bacteria lack cell walls. Bacteria without cell walls are called mycoplasma. The cell walls of archaea lack peptidoglycan and instead are composed of other polymers.

Most bacteria and archaea are much smaller than the eukaryotic microorganisms. True bacteria are found in all environments, however, archaea are only found in extreme environments (Difficult or harsh environments) (e. g. High or low temperature, high or low pH, high salinity, high pressure).

Other Organisms Of Importance To Microbiologists

Microbiologists also study parasitic worms which range in size from microscopic forms to adult tapeworms over 7 meters in length.

The only type of microbes that remained hidden from Leeunwenhoek and other early microbiologists are viruses, viroids and prions which are much smaller than the smallest prokaryotic microorganisms and are not visible by light microscopy. Viruses could not seen until the electron microscope was invented in 1932.

All complete viruses are acellular (not composed of cells) obligatory parasites composed of small amounts of genetic material (genome) (RNA or DNA never both) surrounded by a protein coat. The incomplete virus (Prions) consists only of protein coat and there is no nucleic acid and only attacks human and animals. While the incomplete virus (Virioid) consists only of nucleic acid and there is no protein coat and only attacks plants.

Leeunwenhoek fist reported the existence of microorganisms in 1674, but microbiology did not develop significantly as a field of study for almost two centuries. There were a number of reasons for this delay. First, Leeunwenhoek was a suspicious and secretive man. Though he built over than 400 microscopes, he never trained an apprentice, and he never sold or gave away a microscope. When Leeunwenhoek died, the secret of creating superior microscope was lost. It took almost 100 years for scientists to make microscopes of equivalent quality.

Another reason that microbiology was slow to develop as a science is that scientists in the 1700s considered microbes to be curiosities of nature and in-significant to human affairs. But in the late 1800s, scientists began to adopt a new philosophy, one that demand experimental proof rather than mere acceptance of traditional knowledge. This fresh philosophical foundation, accompanied by improved microscopes, new laboratory techniques, and a drive to answer a series of important questions, propelled microbiology to the forefront as a scientific discipline.

The Golden Age of Microbiology

For about 50 years during what is now called “ The Golden Age of Microbiology”, scientists were driven by the search for answers o the following 4 questions:

1. Is spontaneous generation of microbial life possible?
2. What causes fermentation?
3. What causes diseases?
4. How can we prevent infection and disease?

Competition among scientists, who were striving to be the first to answer these questions, drove exploration and discovery in microbiology during the late 1800s and early 1900s. These scientist’s discoveries and the fields of study they initiated continue to shape the course of microbiological research today.

1 – Is Spontaneous Generation Of Microbial Life Possible?

In the ancient times, many peoples believed that living organisms could develop from non-living matter, and they named this phenomenon as spontaneous generation (abiogenesis). Aristotle believed that simple invertebrates could arise by spontaneous generation. He also believed that frogs and shrimps could arise from mud, insects from the morning dew and maggots from decaying meat. The validity of this theory came under challenge in the 17th century.

Redi's Experiment (1626-1697).

The spontaneous generation conflict was finally challenged by the Redi (1688), who carried out a series of experiments using decayed meat and he studies the ability of meat to produce maggots spontaneously. He concluded that maggots do not arise by spontaneous generation.

In unsealed flask: The maggots covered the meat within few days.

In the sealed flasks: The flies were kept away and no maggots appeared on the meat.

In the gauze-covered flask: The flies were kept away and no maggots appeared on the meat, although a few maggots appeared on the top of the gauze.

Needham's Experiment (1713-1781).

He boiled beef broth in a sealed flask. Some days later he demonstrated that many of these flasks became cloudy and contained microorganisms. He thought that the organic matter in the meat contained a vital force that could give the properties of life from non-living matter. Since he heated the flasks he thought that the microorganisms is coming from the non living beef broth.

Spallanzani's Experiment (1729-1799).

Spallanzani's in 1799 reported results that contradicted Needham's findings. Spallanzani boiled some infusions for one hour and sealed the vials by melting their slender necks closed. His infusion remained clear, unless he broke the seal and exposed the infusion to air, after which they became cloudy with microorganisms. He concluded three things:

1. Needham had either failed to heat his vials sufficiently.
2. Microorganisms exist in the air and can contaminate the experiments.
3. Spontaneous generation of microorganisms does not occur. All living things arise from other living things.

Criticisms of Spallanzani's work were:

1. The sealed vials did not allow enough air for organisms to survive.
2. The prolonged heating for long time (one hour) destroyed the " Life force".

The debate continued until the French chemist Louis Pasteur conducted experiments that finally solved the theory of spontaneous generation to rest.

Pasteur's Experiment (1822-1895).

In 1861, Pasteur (The Father of Microbiology) solved the spontaneous generation conflict.

The Swan Neck Experiment

Pasteur placed nutrient solutions in flasks heated their necks in a flame and drew them out in a variety of curved shapes, and he kept the ends of the neck open to the air. He then boiled the nutrient solutions for a few minutes and allowed them to cool. No microbial growth was observed; even the flask contents were exposed to the external air currents.

Pasteur pointed out that no growth was observed because dust and germs had been collected on the walls of the curved pre-heated necks. If the necks were broken, microbial growth appeared. The results obtained by Pasteur were against the spontaneous generation theory.

2- What Causes Fermentation?

Pasteur developed the pasteurization a process of heating the grape juice just enough to kill most contaminating bacteria without changing the juice backs qualities so it could then be inoculated with yeast to ensure that alcohol fermentation occurred.

Pasteur thus began the field of industrial microbiology or biotechnology in which microbes are used to manufacture beneficial products.

Today pasteurization is used routinely on milk to eliminate pathogenic bacteria that cause tuberculosis and is also used to eliminate pathogenic bacteria and fungi in juices and other beverages.

Because of Pasteur many significant accomplishments in working with microbes, Pasture is considered the Father of Microbiology.

3- What Causes Diseases?

Robert Koch (German Doctor) (the golden age of microbiology 1880-1920) was the first person to demonstrate the role of bacteria in causing anthrax disease in 1876. Koch’s proof that Bacillus anthracis caused anthrax.

Koch discovered that bacteria are responsible for causing a disease. This was called the germ theory of disease. The science of etiology (the study of causation of diseases) was dominated by Robert Koch.

Koch established criteria for proving the causal relationship between a microorganism and a specific disease. These criteria are known as Koch postulates, and it can be summarized as follows:

(i)- The organism should be constantly present in animals or plants suffering from the disease and should not be present in healthy individuals.

(ii)- The organism must be cultivated in pure culture away from the animal or plant body.

(iii)- Such a culture when inoculated into susceptible animals or plants should initiate the characteristic disease symptoms.

(iv)- The organism should be re-isolated from these experimental animals or plants and cultured again in the laboratory, after which it should still be the same as the original organism.

Koch also developed media suitable for the isolation of pure bacterial cultures from human body. He developed nutrient broth and nutrient agar media.

In 1882 Koch has used these methods to isolate the bacteria that cause tuberculosis.

During Koch’s studies on bacterial pathogens, it became necessary to isolate suspected bacterial pathogens. At first, he cultured bacteria on sterile surfaces of cut, boiled potatoes. This was unsatisfactory because bacteria would not always grow well on potatoes because of the acidity of the potato tissues.

He then tried to solidify regular liquid medium by adding gelatin. Separate bacterial colonies developed after the surface had been streaked with a bacterial sample. When the gelatin medium hardened, individual bacteria produced separate colonies. Despite its advantages, gelatin was not an ideal solidifying agent because it was digested by many bacteria and melted when the temperature rose above 28°C.

Fannie Hesse suggested a better alternative. She suggested the use of agar as a solidifying agent. Agar is derived from red algae. Agar was not attacked by most bacteria and did not melt until reaching a temperature of 100°C unlike gelatin.

Richard Petri developed the Petri dish (Plate) in 1887, a container for making solid culture media. This development made possible the isolation of pure cultures that contained only a single microorganism.

Koch and his colleagues are also responsible for many other advances in laboratory microbiology, including the following:

Simple staining techniques for bacterial cells and flagella.

The first photomicrograph of bacteria.

The first photograph of bacteria in diseased tissues.

Techniques for estimating the number of bacteria in a solution based on the number of colonies that form after inoculation onto a solid surface.

The use of steam to sterilize growth media.

The use of Petri dishes to hold solid growth media.

Aseptic laboratory techniques such as transferring bacteria between media using platinum wire that has been sterilized in a flame.

Koch hypothesized that each bacterial colony consisted if the progeny of a single cell.

Koch use laboratory animals to inject bacteria and study disease development.

For these achievements, Koch is considered as the Father of the Microbiological laboratory.

Gram's stain

Although Koch reported a simple staining technique in 1877, the Danish scientist Gram developed a more important staining method in 1884. His procedure which involves the application of series of dyes made some microbes blue and other's red. The blue cells are called the Gram positive and the red cells are called the Gram negative. We now use Gram Stain to separate bacteria into these two large groups.

The gram stain is still the most widely used staining technique. It is one of the first steps carried out in any laboratory where bacteria are being identified.

4 – How Can We Prevent Infection And Disease?

1 – Semmelweis and Hand washing

Semmelweis was a physician began requiring medical students to wash hands with chlorinated lime water.

2 – Lister's Antiseptic Technique

Joseph Lister (1867), an English surgeon found indirect evidence that microorganism were agents of human disease. He worked on the prevention of wound infection. He developed a system of antiseptic surgery designed to prevent microorganism from entering wounds. Instruments were heat sterilized and phenol was used on surgical dressings and sprayed over the surgical area. He provided a strong evidence for the role of microorganisms in disease development because phenol which killed bacteria also prevented wound infections.

3 – Nightingale and Nursing

Nightingale was an English nurse and she is the founder of modern nursing and she introduced cleanliness and antiseptic techniques into nursing practices.

4 – Snow and Epidemiology

John Snow an English physician plays a key role ion setting standards for good public hygiene to prevent the spread of infectious diseases.

His study was the foundation for two branches of microbiology (infection control) and epidemiology (study of the occurrence, distribution and spread of disease in humans).

5 – Jenner's Vaccine

On 1796, Edward Jenner used cowpox-infected material to successfully vaccinate people against human small pox.

He names the process vaccination after Vaccinia, the virus that causes cowpox.

Jenner invented vaccination or immunization.

In honor of Jenner's work with cowpox, Pasteur used the term vaccine to refer to all weakened protective strains of pathogens.

6 – Ehrlich's magic bullets and Chemotherapy

Ehrlich found that chemicals could be used to kill microorganisms.

He discovered chemicals active against trypanosomes the protozoan that causes sleeping sickness and against Treponema that cause syphilis. His discoveries began the branch of chemotherapy.

The Modern Age of Microbiology

1 – How Do Genes work?

Over the past 40 yeasts, advances in microbial genetics developed into several new disciplines that are among the faster growing areas of scientific research today; including:

Molecular biology

A – Molecular Biology

Molecular biology combines aspects of biochemistry, cell biology and genetics to explain cell function at the molecular level.

Molecular biologists are concerned with genome sequencing.

A full understating of the genomes of organisms will result in practical ways to limit disease, repair genetic defects and enhance agricultural yield.

B – Recombinant DNA technology

Molecular Biology is applied in recombinant DNA technology, commonly called genetic engineering which was first developed using microbial models. This includes the production of human insulin in genetically engineered bacteria.

C – Gene therapy

An exciting new area of study is the use of recombinant DNA technology for gene therapy. This is a process that involves inserting a missing gene or repairing a defective gene in human cells. This procedure uses harmless viruses to insert a desired gene into host cells where it is incorporated into a chromosome and begins to function normally.

2 – What Roles Do Microorganisms Play in the Environment?

The study of microorganisms in their natural environment is called environmental Microbiology or microbial ecology.

3 – How We Defend Against Disease?

Advancements in chemotherapy were made in the 1900s with the discovery of numerous substances such as penicillin and sulfa drugs that inhibit bacteria.

4 – The Scope And Relevance of Microbiology

Microbiology has both basic aspects and applied aspects. A scientist working in the field of microbiology is called a microbiologist. Many microbiologists are interested in the biology of microorganisms. They may focus on a specific group of microorganisms and are called: Virologist (Virology is the study of viruses), Bacteriologist (Bacteriology is the study of bacteria), Phycologist (Phycology is the study of algae), Mycologist (Mycology is the study of fungi), and Protozoologist (Protozoology is the study of protozoa).

Other microbiologist work in other fields such as microbial physiology, microbial cytology, microbial ecology, and microbial taxonomy. Other microbiologists have more practical applied fields such as medical microbiology, food and dairy microbiology, and public health microbiology.

- Medical Microbiology: Deals with human and animal diseases.
- Agricultural Microbiology: Deals with the application of microorganisms in agriculture.
- Public health Microbiology: Deals with the control of the spread of diseases.
- Food and dairy Microbiology: Deals with the application of microorganisms by man to make foods such as cheese, bread, and other important products.
- Industrial Microbiology: Deals with the industrial application of microorganisms such as the production of vaccines, antibiotics, vitamins and enzymes.
- Microbial Ecology or Environmental microbiology: Deals with the relationship between microorganisms and their environments.

- Microbial physiology and Biochemistry: Deals with the study with physiology of microorganisms and the effects of physical and chemical agents on the survival of microorganisms.

6 – What Will The Future Hold?

What will microbiologists discover next?

Among the questions for the next 50 years are the following:

1. What is the physiology of life forms that can not be grown in laboratory and only known to us now by their nucleic acid sequences?
2. Does life exist beyond planet Earth, and if so, what are its features?
3. How can we reduce the threat of infectious diseases, especially those that can be used by bioterrorists?