Discipline Courses-I

Semester-I

Paper: Phycology and Microbiology

Unit-III

Lesson: Introduction to microbial

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Introduction

Microbiology is the field of science which deals with study of organisms majority of which are too small to be observed with naked eye. These organisms, referred to as microorganisms, include bacteria, fungi, algae, protozoa and viruses. However, a few members of some microbial groups like algae and fungi are clearly visible without the aid of microscope. Besides, bacteria like *Epulopiscium* and *Thiomargarita* are also macroscopic. Thus, it is better to define microbiology in accordance with the techniques used for isolation and culture of microorganisms rather than their size.

Microbes have been a subject of interest since time immemorial primarily because they causes a number of deadly diseases like Anthrax, Plague, Diphtheria, Rabies, Measles, Small pox and Cholera etc. However, systematic study of microorganisms has allowed us to appreciate their innumerable beneficial activities too. Microorganisms are extremely important in biogeochemical cycling of chemical elements like Carbon, Hydrogen and Nitrogen. They are also involved in biodegradation of organic waste material, thus significantly reducing the menace of pollution. In the present day scenario microorganisms have emerged as the major biological factories. They are used to synthesize a number of complex compounds of immense commercial applications like antibiotics, organic chemicals, enzymes, amino acids, biocontrol agents, beverages, vitamins, etc.. Last but not the least, microbes are the backbone of recombinant DNA technology procedures used to manipulate living organisms for generation of useful products.

A Brief History

Figure: Anton Von Leeuwenhoek (1632-1723)

Source:http://upload.wikimedia.org/wikipedia/commons/5/5e/Anton_van_Leeuwenhoek.png

Development of early microscope

The role of microorganisms in disease causation was suspected as early as 15th century [Girolamo Fracastoro, Francesco Stelluti). However, it was a Dutch draper Antony Van Leeuwenhoek (1632-1723), who first observed and described microorganisms. He was fascinated by magnifying glasses frequently used by drapers to check the quality of the cloth. He modified these lenses to create lenses with enhanced curvature and visibility. He finally developed a microscope with a magnification of approximately (50-300X), using which, he observed bacteria and protozoa.

Origin of Microbes: Spontaneous Generation or Biogenesis

Origin of microbes had been debated since a long time. Initially, it was believed that living organisms could develop from non-living matter, i.e., Spontaneous Generation.

A number of scientists believed in the theory of spontaneous generation. Even the great thinker and naturalist Aristotle (384 to 322 BC) believed that animals originated from soil, plants, etc. John Needham (1731-1781) after a series of experiments proposed that bacteria originated spontaneously from meat. Further, Néedham also postulated that air was essential for spontaneous production of microbes.

Figure: Franscesco Redi (1626-1697

Source:http://upload.wikimedia.org/wikipedia/commons/thumb/2/21/Francesco_Redi.jpg/220px-Francesco_Redi.jpg

The theory of spontaneous generation was widely prevalent in the 17th Century until it was questioned by Francesco Redi (1626-1697) an Italian physicist. He performed a set of experiments to disapprove the view that decaying meat could produce maggots of flies spontaneously. Redi placed meat in three jars, of which the first one was left uncovered, second covered with fine gauze and third covered with paper. After a brief period of incubation, maggots were detected in the uncovered jar where flies had laid their eggs. However, the meat in the other two jars did not produce the maggots spontaneously. This clearly indicated that it was the flies that produced maggots, not the meat. Lazzaro Spallanzani (1729-1799) another scientist of that era boiled beef broth in a flask, sealed it followed by incubation. There was no development of microbes in the flask, again disapproving the theory of spontaneous generation.

Other investigators like, Franz Schulze (1815-1873) and Theodore Schwann (1810-1882) passed acid and heat treated air into boiled infusions which showed no microbial growth negating the theory that air is required for spontaneous generation. Similar experiments were also performed by H. Schroeder and T. Von Dusch (1850), who filtered the air entering the heated broth through cotton. Even they reported absence of spontaneous generation of microbes.

Additional Information
Francesco Redi challenged the idea that maggots arose spontaneously from rotting meat. In the first major experiment to challenge spontaneous generation, he placed meat in a variety of sealed, open, and partially covered containers. In 1837, Charles Cagniard de la Tour, a physicist, and Theodor Schwann, one of the founders of cell theory, published their independent discovery of yeast in alcoholic fermentation. The ideas of spontaneous generation were displaced by advances in germ theory and cell theory.

Louis Pasteur, a French scientist started working on the concept of Biogenesis and it was Pasteur's experiments (1822-1895) which were a final blow to this controversy. He proved that microbes are present in air, but not generated by it. Pasteur designed a flask with a long, narrow, S shaped neck (swan necked flask). The broth in these goose-necked flasks was heated and air was allowed to pass in. There was no microbial growth in the nutrient solutions even after days. This was attributed to the fact that S shaped neck of the flask allowed air to pass through but trapped the microbes. Louis Pasteur's results proved that micro organisms do not originate from non living matter and arise as a result of "Biogenesis".

Figure: John Tyndall

Source: http://upload.wikimedia.org/wikipedia/commons/9/97/YoungJohnTyndall.jpg

John Tyndall (1820-1893), an English Physicist reinstated theory of Biogenesis by conducting a number of studies. He proved that dust contained germs which were responsible for generation of progeny of microbes. Finally, there was no doubt regarding the origin of microbes and it was proved that no mystical forces were involved in their generation.

Additional Information
Tyndall explained the heat in the Earth's atmosphere in terms of the capacities of the various gases in the air to absorb radiant heat, also known as infrared radiation. Tyndall found a way to eradicate the bacterial spores that came to be known as "Tyndallization". Conant, James Bryant (1957). "Pasteur's and Tyndall's Study of Spontaneous Generation".

Fermentation And Industrial Microbiology

Louis Pasteur was a pioneer in investigating industrial fermentations. It was Pasteur who found that alcoholic fermentation of grains and fruits was caused by microbes. Besides, he also reported that spoilage of alcoholic beverages was caused by certain "undesirable bacteria". Further, Pasteur devised a method called pasteurization to destroy the undesirable microbes. He found that heating to a temperature of 62.8^{o}C for 30 minutes was effective in killing majority of unwanted microbes. Even nowadays, Pasteurization is a very commonly used practice in fermentation and dairy industries. Pasteur, while working on fermentation also discovered anaerobic microbes which could survive only in the absence of oxygen.

Environmental & Agriculture Microbiology

Figure: Sergei Winogradsky

Source:http://upload.wikimedia.org/wikipedia/commons/thumb/b/b5/Sergei_Winogradsky.jpg/220px-Sergei_Winogradsky.jpg

The role of microbes in mineral cycling was speculated even in the earlier centuries. The primary role of bacteria in assimilating atmospheric nitrogen was investigated by the Russian Scientist Sergei Winogradsky (1856-1953). Winogradsky found that bacteria in soil could oxidize ammonia, iron and sulfur. He also demonstrated the presence of anaerobic nitrogen fixing bacteria in soil. Further, Winogradsky discovered cellulose degrading bacteria and worked on cellulose decomposition. H. Hellriegel & H. Wilfrath (1888) studied the symbiotic association between leguminous plants and bacteria. Martinus W. Beijerinck (1851-1931) a Dutch microbiologist contributed significantly in the field of soil microbiology. He isolated *Azotobacter*, a free living nitrogen fixing bacterium and another sulfate reducing bacterium.

Beijerinck and Winogradsky propagated the use of selective media for isolation of specific groups of microorganisms. They also developed the enrichment culture technique which has important bearing in various fields of microbiology.

A number of plant diseases were studied and their causative agents investigated. T.J. Burrill reported that fire blight of pears is caused by a bacteria. This study was followed by reports on the transmissible nature of plant diseases (A.E. Mayer, 1886; Erwin F. Smith). Finally, it was Dmitri Iwanowski who suggested that Tobacco mosaic disease was caused by a virus. F.W. Twort (1877-1950) & Felix D'Herelle (1873-1949) independently discovered bacteriophages. Stanley and North Rup (1935) isolated the Tobacco mosaic virus in crystalline form. These and many more such studies laid the foundations of plant pathology as an important field of microbiology.

Additional Information
Bacteriophages (phages) are viruses that infect bacteria. Typical phages have hollow heads (where the phage DNA or RNA is stored) and tunnel tails, the tips of which have the ability to bind to specific molecules on the surface of their target bacteria. The viral DNA is then injected through the tail into the host cell, where it directs the production of progeny phages often over a hundred in half an hour. These "young" phages burst from the host cell (killing it) and infect more bacteria.

Microbes are now increasingly being used for insect pest control, sewage treatment and for removing toxic wastes and pollutants (Bioremediation) from the environment.

Medical Microbiology And Development Of Techniques For Isolation Of Pure Cultures

In the primitive times the casual relationship between diseases and microbes was not known. It was believed that infections were caused either by supernatural powers or due to imbalances in human body. Agostino Bassi (1773-1856) was the pioneer in proposing the germ theory of disease. He showed that the silkworm disease was caused by a fungus. M.J. Berkeley (1845) showed that the Potato Blight in Ireland was also a fungal infection. In France, Louis Pasteur reported that Pebrine, a silkworm disease was caused by a protozoan.

Work in the field of human diseases was initiated by Lord Joseph Lister (1890). Lister gave the concept of antiseptic surgery to prevent contamination of wounds. He advocated the use of phenol, a bactericidal agent to prevent wound infections. The first conclusive evidence on the role of bacteria in human diseases was given by Robert Koch (1843-1910), a German Physician, again reconfirming the germ theory of disease.

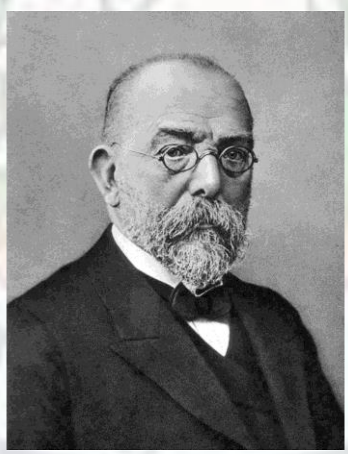


Figure: Robert Koch

Source: http://upload.wikimedia.org/wikipedia/commons/9/99/Robert_Koch_BeW.jpg

Koch was working on the disease anthrax affecting cattle (1876) and he gave four postulates to establish a causal relationship between a specific microbial pathogen and the disease. Robert Koch also discovered the causative agent of tuberculosis (1884). Meanwhile, Louis Pasteur working independently on anthrax also demonstrated that the bacterial pathogen causing this disease was *Bacillus anthracis* (1881). Robert Koch (as mentioned earlier) identified an isolated the causative agent of tuberculosis i.e *Mycobacterium tuberculosis,* for which he received a Nobel Prize.

Additional Information

KOCH'S POSTULATES

1. The causative pathogen must be present in all the diseased hosts.
2. The causative pathogen must be absent from other diseased states.
3. The causative pathogen should be isolated from the diseased hosts.
4. After the causative pathogen is grown in pure culture it should produce the same disease as before.

While working on pathogens, scientists realized that isolation of microbes in the form of pure cultures was of utmost importance. Lister isolated pure cultures of bacteria by serial dilutions in a liquid media. Robert Koch started working on development of culture media for isolation of bacteria. Initially, he tried to culture bacteria on surfaces of sterile, boiled potatoes, but this was not very successful. Koch also propagated the use of gelatin as a solidifying agent in liquid nutrient media. Again even this did not work completely, because gelatin melted at a temperature of 28°C and could be degraded by number of gelatinase producing bacteria. Gelatin was soon replaced by Agar as a solidifying agent. The use of agar in media was suggested by Fannie Eilshemius Hesse, wife of one of Koch's assistants. She was using agar to make jellies at home. Agar produced by an algae, is inert, stable and melts only at high temperature around 100° C and is thus an ideal solidifying agent.

Richard Petri, another of Koch's assistant designed Petri dish, a container for holding solid nutrient media. The petri-dish culture could help in producing isolated microbial colonies and thus pure culture. This was a very significant development in the field of microbiology. Robert Koch developed nutrient media containing meat and Beef extracts. This laid the foundation for formulation of the commonly used nutrient media viz nutrient Broth and nutrient agar. Louis Pasteur, while working on *Bacillus anthracis* and bacterium causing fowl cholera discovered the process of attenuation, i.e., if the cultures were incubated for long time periods or subjected to chemical treatment, they ceased to be infectious. Pasteur named the attenuated cultures as vaccine to honour Edward Jenner (1798) who had initiated vaccination to counter small pox infections. Pasteur also made rabies vaccine by growing the pathogen in an alternate host, i.e., Rabbit. These studies of Louis Pasteur again laid the foundation for germ theory of disease. Another significant contribution of Louis Pasteur was development of pasteurization as a method to control undesirable microbes.

After the giant body of work on vaccination, there was increasing interest in diseases and pathogens. The diphtheria bacillus was discovered by Edwin Klebs (1883) and Frederick Loeffler (1884). They showed that the diphtheria bacillus produced toxin under laboratory conditions. Emil Von Behring (1854-1917) and Shibasaburo Kitasato (1852-1931) laid the foundation of antitoxin therapy which could be used for treatment of both diphtheria and tetanus. Paul Ehrlich (1910) introduced chemotherapy (chemical treatment of disease). He used an arsenic containing compound (Salvarsan) for treatment of syphilis.

> Virulent vegetative cells of *Bacillus anthracis* after entering the hosts secrete capsules composed of poly-D-glutamic acid. These capsules inhibits their phagocytosis by macrophages because of their negative charge thus allowing the pathogenic anthrax bacterium to invade the host aggressively. **"The capsule of *Bacillus anthracis*, a review." Ezzell, J.W., Jr.; Welkos, S.L.; J. *Appl. Microbiol.* , vol. 87, no. 2, p. 250, Aug 1999.**

Elie Metchnikoff, A Russian scientist working in Pasteur’s laboratory discovered that blood cells like leucocytes could ingest pathogenic bacteria. He named this process as phagocytosis.

The causative agents of number of diseases like Botulism, Dysentery, Syphilis, etc. were now being identified and diagnostic tests were also being developed.

The Microbial World

Microbes have been rightly called ***omnipresent*** and ***omnipotent*** i.e. They are present everywhere and are capable of performing almost every activity. Let us now get acquainted with the fascinating world of microbes. Nature has offered a strangely enormous diversity to the microbial kingdom. They exist in innumerable shapes and sizes and with varied metabolic capabilities.

The prokaryotic {bacteria and archaebacteria } and eukaryotic microbes { fungi, algae and protozoa} along with the viruses will be introduced in the subsequent section.

Bacteria

Bacteria are unicellular prokaryotic microbes. The bacterial cell has varied shapes like spherical (cocci) rod (Bacilli), spiral & helical, etc. They may be present singly, in pairs, tetrads, clusters, chains, or even in filaments. The shape of the bacterium is determined by its rigid cell wall which is basically composed of peptidoglycan (Protein and Carbohydrate).

Some bacteria also possess a polysaccharide capsule which enhances the pathogenicity of bacteria. Few bacteria possess appendages known as flagella, which are used for motility. Most of the bacteria are saprophytic or parasitic, however, a few could also be photosynthetic.

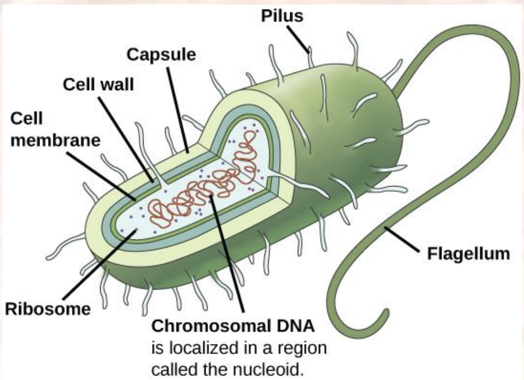


Figure: Structure of a typical bacterial cell
Source: http://cnx.org/content/m44605/latest/Figure_22_02_02.jpg

Bacteria have been classified in varied ways by different taxonomists. The various characteristics considered for classification include phenotypic or morphological features – such as shape , size , metabolic activities, cultural characteristics and chemical characteristics etc.

The most widely accepted classification system of bacteria is given in the manual – Bergey's Manual of Determinative Bacteriology. This classification system for Bacterial identification was given by David Bergey and his associates in 1923.

This manual has two editions, In the first edition of this manual, the system of prokaryotic classification is phenotypic however, the second edition is primarily phylogenitic based on molecular sequencing of rRNA, DNA and proteins , primarily rRNA.

According to the IInd edition of Bergey's manual the domain bacteria is broadly divided into a number of phyla (approx 23). The phyla are further divided into a number of classes and orders. We will now discuss in brief , some of the important bacterial phyla listed in the five volumes of Bergey's Manual.

Volume 1:

This volume basically consists of phototrophic and deeply branching bacteria. The various phyla included in this volume are as under

Phylum *Aquificae* – one of the most primitive bacterial phylum known. This includes bacterial genera like *Hydrogenobacter* and *Aquifex*, which have an autotrophic mode of nutrition. They use hydrogen for production of energy. This phylum also includes thermophiles

Phylum *Thermotagae*

The most common members of this phylum include *Thermotoga* and *Geotoga*. These bacterial genera are gram negative, having multilayered cell wall with ether linked lipids and unusual fatty acids. Most of the bacterial genera are anaerobic and have a fermentative metabolism.

Phylum : *Deinococcus - Thermus*

Important bacterial genera of this phylum are *Thermus* and *Deincoccus*. *Deinococcus* is a genus of gram-positive bacteria with marked resistance to radiation. The presence of rare lipids and specially carotenoids imparts radiation resistance to these bacteria

Phylum : *Chloroflexi*

Quite a few of the bacteria in this phylum are gram-negative green non-sulphur bacteria. Two of the genera worth mentioning are the bacteria with gliding motility viz *Herpetosiphon* and *Chloroflexus*. These bacteria have peptidoglycan structure different from commonly occurring ones. Besides, inspite of being gram negative they do not contain lipopolysaccharides in their outer membranes. *Chloroflexus* is a photosynthetic bacterium, which characteristically has anoxygenic photosynthesis

Phylum Cyanobacteria

This phylum is contributed by bacteria showing oxygenic photosynthesis like plants. These bacteria usually have chlorophyll a and phycobilins. The cyanobacteria are present either as single cells or as multicellular filaments which could be branched or unbranched.

Phylum Chlorobi

This is another group of anoxygenic photosynthetic bacteria but in contrast to phylum *Chloroflexi*, they oxidize sulfide to sulfur during photosynthesis. The most significant member of this phylum is *Chlorobium*.

Volume 2 of Bergeys manual [2nd edition] are constituted by gram negative proteobacteria. This is the most important group [phylum] as far as applications of bacteria in industry research and medicine are concerned. This phylum is further divided into five classes as under:-

Class 1- *Alphaproteobacteria*

This class includes bacterial genera with variable morphology and metabolic activities like nitrogen fixation [*Rhizobium*] chemolithotrophy [*Nitrobacter*] etc. Most of the alphaproteobacteria can grow under low nutrient conditions [Oligotrophs]. This class also contains pathogenic bacteria like *Rickettsia* and *Brucella*.

Class 2- *Betaproteobacteria*

This class also has bacteria with varied metabolic types. However, most of these use nutrients released after decomposition of organic compound in anaerobic habitats. A few examples include *Alcaligenes*, (uses hydrogen), and *Nitrosomonas* [use ammonia].

Class 3- *Gammaproteobacteria*

A large class which also shows high level of diversity in terms of metabolism. Most of the bacterial genera of this class are facultative anaerobes and carry out fermentation but use different metabolic pathways for energy generation

For eg: The families Enterobacteriaceae and Vibrionaceae utilize the Embden Meyerof and pentose phosphate pathway while Pseudomonadaceae and Azotobacteriaceae use Entner-Doudoroff and pentose phosphate pathway.

The distinct members of this class include the free living nitrogen fixing bacterium-Azotobacter and the common pathogens like Escherchia ,Salmonella, Klebsiella ,Shigella , Haemophilus etc. Of these bacterial genera its important to mention Escherchia coli which is used as a model organism for research in almost all fields of biology and recombinant DNA technology.

Class IV: Deltaproteobacteria

This class includes bacterial genera with specific adaptations for example the genera *Myxococcus* are predators of other bacteria and also show formation of fruiting bodies. Another genera *Bdellovibrio* also preys on bacteria.This class also contains some anaerobic bacteria like *Desulphovibrio*

Class V: Epsilonproteobacteria

This is a small class with merely one order and three families. However, it includes important pathogens like *Helicobacter* and *Campylobacter*

Volume 3 of Bergey's manual include gram positive bacteria with low G+C [i.e. less than or equal to 50 percent G+C] content in their DNA

Phylum:- Firmicutes : This phylum contains 3 classes as discussed below

Class I- Clostridia

The members of this class are usually anaerobic but vary significantly in their phenotypic characteristics. Endospores are produced by some bacterial genera like *Desulfomaculum* and *Clostridium*. *Clostridium,* a large bacterial genus is an important human pathogen

Class II- Mollicutes

The bacterial genera included under this class lack a true cell wall and are also referred to as mycoplasmas. Because of the lack of cell wall, the mycoplasmas do not change their shape [*Pleomorphic*]. Their other characteristic feature is the obsolute requirement of sterols for growth. This class includes several important animal and plant pathogens like *Mycoplasma, Ureaplasma* and *Spiroplasma* etc.

Class iii- Bacilli

This, again is a large bacterial class which include gram positive rods and cocci with industrial applications. Some members of this class also form endospores [viz: *Bacillus* and *Sporosarcina* etc]. This class also contains important bacterial pathogens like *Streptococcus, Staphylococcus, Listeria* and *Bacillus.* The species *Bacillus anthracis* causes anthrax and its spores are used as biowarfare agents.

Volume 4 – Includes the high G+C [G+C content above 50%] gram positive bacteria. The bacteria in this volume are grouped under one phylum i.e. Actinobacteria.

Phylum – Actinobacteria: This includes one class called Actinobacteria

The bacterial genera under this class include a diversity of phenotypic forms → i.e. from cocci to rods and some even forming branching hyphae [eg. Actinomycetes]. Quite a few of the bacteria also form different types of asexual spores. This class includes bacteria with industrial and medical significance eg Actinomyces, *Streptomyces*, *Nocardia* which produce a number of antibacterial and antifungal antibiotics. Bacterial genera like *Corynebacterium* and *Cycobacterium* are important human pathogens

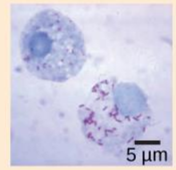
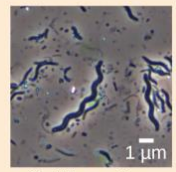
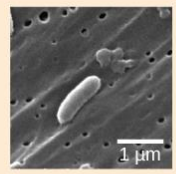
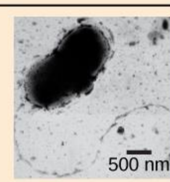
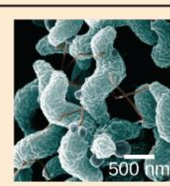
Volume 5- Includes nine phyla of gram negative bacteria which are only distantly related. They are placed together only for convenience of these nine phyla. The important phyla are discussed below

1. Phylum : *Chlamydiae*

This includes bacteria which lack a true cell wall because of absence of peptidoglycan. They are obligate intracellular parasites. They have limited amount of genetic information and enzymatic machinery, thus they depend on a living host for propagation. However they are significant human pathogens.

2. Phylum: *Spirochaetes*

These are motile spiral bacteria which are helically coiled. The important bacterial genera included under this phylum are *Treponema* and *Borrelia*. Both these are important pathogens. *Treponema palladrium* is the causative agent of sexually transmitted disease syphilis.

Bacteria of Phylum Proteobacteria		
Class	**Representative organisms**	**Representative micrograph**
Alpha Proteobacteria Most species are photoautotrophic but some are symbionts of plants and animals and others are pathogens. Eukaryotic mitochondria are thought be derived from bacteria in this group.	*Rhizobium* Nitrogen-fixing endosymbiont associated with the roots of legumes *Rickettsia* Obligate intracellular parasite that causes typhus and Rocky Mountain Spotted Fever (but not rickets, which is caused by Vitamin C deficiency)	 *Rickettsia rickettsia,* stained red, grow inside a host cell.
Beta Proteobacteria This group of bacteria is diverse. Some species play an important role in the nitrogen cycle.	*Nitrosomas* Species from this group oxidize ammonia into nitrate. *Spirillum minus* Causes rat-bite fever	 *Spirillum minus*
Gamma Proteobacteria Many are beneficial symbionts that populate the human gut, but others are familiar human pathogens. Some species from this subgroup oxidize sulfur compounds.	*Escherichia coli* Normally beneficial microbe of the human gut, but some strains cause disease *Salmonella* Certain strains cause food poisoning or typhoid fever *Yersinia pestis* Causative agent of Bubonic plague *Psuedomonas aeruganosa* Causes lung infections *Vibrio cholera* Causative agent of cholera *Chromatium* Sulfur-producing bacteria that oxidize sulfur, producing H_2S	 *Vibrio cholera*
Delta Proteobacteria Some species generate a spore-forming fruiting body in adverse conditions. Others reduce sulfate and sulfur.	*Myxobacteria* Generate spore-forming fruiting bodies in adverse conditions *Desulfovibrio vulgaris* Aneorobic, sulfur-reducing bacterium	 *Desulfovibrio vulgaris*
Epsilon Proteobacteria Many species inhabit the digestive tract of animals as symbionts or pathogens. Bacteria from this group have been found in deep-sea hydrothermal vents and cold seep habitats.	*Camphylobacter* Causes blood poisoning and intestinal inflammation *Heliobacter pylori* Causes stomach ulcers	 *Camphylobacter*

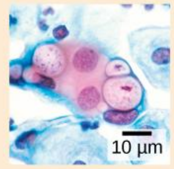
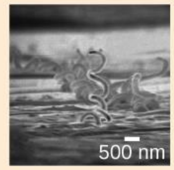
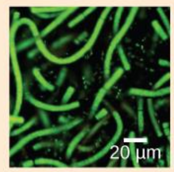
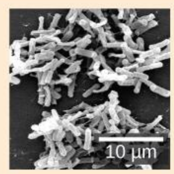
Bacteria: Chlamydia, Spirochaetae, Cyanobacteria, and Gram-positive		
Phylum	**Representative organisms**	**Representative micrograph**
Chlamydias All members of this group are obligate intracellular parasites of animal cells. Cells walls lack peptidoglycan.	*Chlamydia trachomatis* Common sexually transmitted disease that can lead to blindness	 In this pap smear, *Chlamydia trachomatis* appear as pink inclusions inside cells.
Spirochetes Most members of this species, which has spiral-shaped cells, are free-living aneaerobes, but some are pathogenic. Flagella run lengthwise in the periplasmic space between the inner and outer membrane.	*Trepanema pallidum* Causative agent of syphilis *Borrelia burgdorferi* Causative agent of Lyme disease	 *Trepanema pallidum*
Cyanobacteria Also known as blue-green algae, these bacteria obtain their energy through photosynthesis. They are ubiquitous, found in terrestrial, marine, and freshwater environments. Eukaryotic chloroplasts are thought be derived from bacteria in this group.	*Prochlorococcus* Believed to be the most abundant photosynthetic organism on earth; responsible for generating half the world's oxygen	 *Phormidium*
Gram-positive Bacteria Soil-dwelling members of this subgroup decompose organic matter. Some species cause disease. They have a thick cell wall and lack an outer membrane.	*Bacillus anthracis* Causes anthrax *Clostridium botulinum* Causes Botulism *Clostridium difficile* Causes diarrhea during antibiotic therapy *Streptomyces* Many antibiotics, including streptomyocin, are derived from these bacteria. *Mycoplasmas* These tiny bacteria, the smallest known, lack a cell wall. Some are free-living, and some are pathogenic.	 *Clostridium difficile*

Figure: The bacterial diversity

Source: http://cnx.org/content/m44605/latest/Figure_22_02_04f.jpg

http://cnx.org/content/m44605/latest/Figure_22_02_05f.jpg

Archaebacteria

They are also called the primitive bacteria. They are different from bacteria because they lack a peptidoglycan cell wall. The archaebacteria do not strictly have a peptidoglycan cell wall, but contain related sugars in their cell walls [pseudomurien]. They usually have proteins and carbohydrate etc. in their cell walls. The membrane lipids of archaebacteria have ether linked branched fatty acid chains which impart high stability required in the extreme environments in which they are usually present.

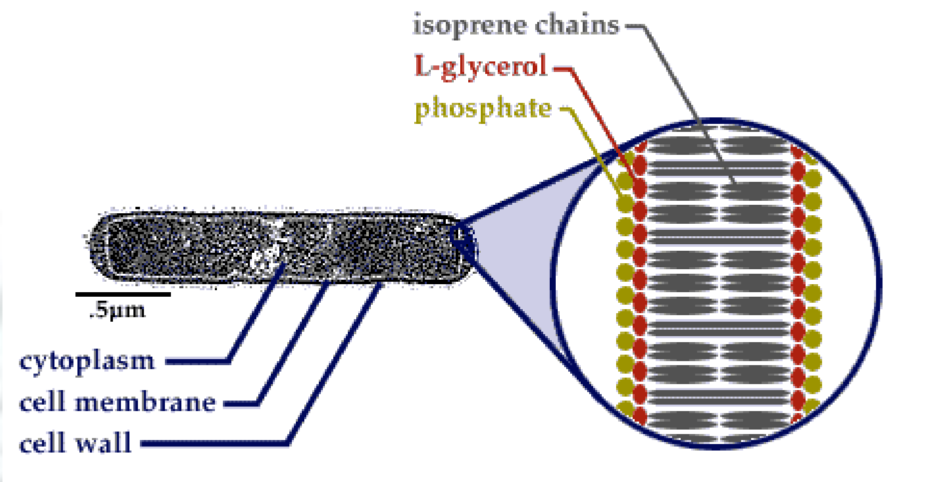


Figure:

Source: http://www.ucmp.berkeley.edu/archaea/archaeamembrane.gif

The cell of archaebacterium is primarily composed of three regions i.e. cytoplasm, cell membrane, and cell wall [as labeled above]. On the right side in the above figure is shown an enlarged view of the cell membrane with its components.

The archaebacteria are primarily classified into two phyla i.e *Crenarchaeota* and *Euryarchaeota* . However, a few scientific communities also include the phylum Nanoarchaeota and Koracheota in Archaebacteria

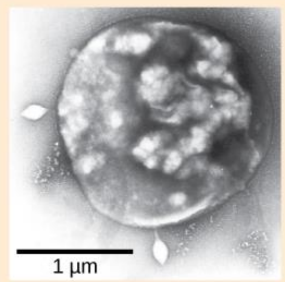
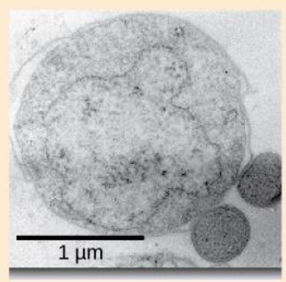
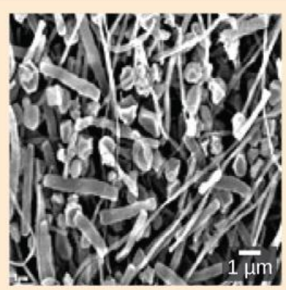
Phylum: Crenarchaeota

This phylum includes thermophiles [microbes growing under high temperature], hyper thermohiles, sulfermetabolising and psychrophilie [microbes growing under low temperature conditions].

Important bacterial genera includes *Thermoproteus*, *Pyrodictium* and *Sulfolobus.*

Phylum – Euryarchaeota

This is very diverse phylum which includes thermophiles, methanogens [methane producing microorganisms] halophiles [sulfur reducing] archaebacteria. It is divided into seven classes etc. The important genera included are *Methanobacterium*, *Methanococcus*, *Halobacterium*, *Thermoplasma* , *Themococcus* and *Pyrococcus* etc.

Archaea		
Phylum	**Representative organisms**	**Representative micrograph**
Euryarchaeotes This phylum includes methanogens, which produce methane as a metabolic waste product, and halobacteria, which live in an extreme saline environment.	*Methanogens* Methane production causes flatulence in humans and other animals. *Halobacteria* Large blooms of this salt-loving bacteria appear reddish due to the presence of bacterirhodopsin in the membrane. Bacteriorhodopsin is related to the retinal pigment rhodopsin.	 *Halobacterium* strain NRC-1
Crenarchaeotes Members of the ubiquitous phylum play an important role in the fixation of carbon. Many members of this group are sulfur-dependent extremophiles. Some are thermophilic or hyperthermophilic.	*Sulfolobus* Members of this genus grow in volcanic springs at temperatures between 75° and 80°C and at a pH between 2 and 3.	 *Sulfolobus* being infected by bacteriophage
Nanoarchaeotes This group currently contains only one species, *Nanoarchaeum equitans*.	*Nanoarchaeotes equitans* This species was isolated from the bottom of the Atlantic Ocean and from a hydrothermal vent at Yellowstone National Park. It is an obligate symbiont with *Ignococcus*, another species of *archaebacteria*.	 *Nanoarchaeotes equitans* (small dark spheres) are in contact with their larger host, *Ignococcus*.
Korarchaeotes Members of this phylum, considered to be one of the most primitive forms of life, have only been found in the Obsidian Pool, a hot spring at Yellowstone National Park.	No members of this species have been cultivated.	 This image shows a variety of korarchaeotes species from the Obsidian Pool at Yellowstone National Park.

Source: http://cnx.org/content/m44605/latest/Figure_22_02_06f.jpg

Fungi

Fungi are a diverse group of eukaryotic micro-organisms lacking chlorophyll. They include both unicellular (Yeasts) and multicellular (Molds) forms and can reproduce both asexually and sexually. The thallus (the main body of fungus) is a single cell in yeast which could be elongated, spherical or ovoid. In molds the thallus is mycelial, composed of filaments (hyphae) and spores. Certain fungi which exist in both these two forms, that is, yeast and mold are known as Dimorphic fungi. The fungi are usually classified on the basis of type of sexual spores and fruiting bodies. Fungi are hetrotrophs, i.e., they require pre-formed organic matter as a nutrient source. They can also be saprobic in nature, when feeding on dead organic matter.

The study of fungi is known as “mycology”. Fungi are present everywhere i.e. on land and in fresh or marine water. Fungi form useful associations with either plants (**Mycorrhiza**) or algae and cyanobacteria (**Lichens**).

Fungi are economically very important because they affect mankind in both harmful and beneficial manner. They are significant plant pathogens affecting a wide variety of crops causing huge economic losses. Fungi also cause diseases in animals and humans [Mycoses]. However, they carry out a number of important and beneficial activities like biodegradation i.e. decomposition of complex organic waste and release of simple nutrients, which could be used by animals and plants. Besides, fungi have significant industrial importance, fungi have significant industrial importance. They [yeasts] are used in majority of industrial fermentations like production of wine, beer, organic acids, bread , cheese etc. In addition fungi are also used for synthesis of a number of antibiotics like penicillin, Griseofulvin etc. Fungi are also used as research models in various biological sciences.

Fungi have been classically classified into four basic divisions [or phylum] based on their sexual reproduction. However recently, based on the 18S RNA analysis , few changes have been made in the classification i.e. the fungi initially placed under Deuteromycota [fungi imperfecti --> no sexual stage detected] now relocated to either of the other 3 divisions[i.e. *Zygomycota*, *Ascomycota*, *Basidiomycota*] and another division has been added [*Chytridiomycota*]. Now there are four major division of *Eumycota* [true fungi] i.e.

1-*Zygomycota*

2-*Ascomycota*

3-*Basidiomycota*

4- *Chytridiomycota*

In addition, 3 other divisions are also studied by mycologists because they resemble the above mentioned true fungi, in morphology, reproduction and life cycle however their molecular characters [18Srna] are different. These includes

1. *Myxomycota*
2. *Acrasiomycota*
3. *Oomycota*

Now will discuss in brief, the important characteristics of various divisions

Zygomycota

These fungi are also called zygomycetes, and are usually found on dead decaying plant and animal organic matter. The hyphae are aseptate and carry globose asexual sporangia [filled with spores] on the tip [present on aerial hyphae]. Sexual reproduction involves union of opposite mating types. This is followed by formation of a thick walled zygote or zygospore under favourable condition .The zygospore undergoes meiosis to produce the progeny hyphae. The most common examples include *Rhizopus* and *Mucor*.

Ascomycota

These fungi are referred to as Ascomycetes or sac fungi. They are named so because they produce a specific reproductive structure which is sac like in shape called ascus. Their mycelium is septate and asexual reproduction is mediated by conidiospores.

Sexual reproduction is by fusion of specialized male and female ascogeneous hyphae. The resultant zygote undergoes two meiotic divisions to form eight nuclei in an ascus (ascospores). A number of asci are carried in an ascocarp which is either cup or flask shaped. During favourable conditions the ascospores germinate to start the cycle again

The common member of this division are the yeasts which have a number of industrial application in fermentation. Another mold, *Neurospora crassa* which is a frequently used research tool also belongs to ascomycota. Quite a few of the ascomycetes are plant pathogens eg *Claviceps purpurea*-which causes ergot of rye

When the infected grains are consumed by humans, it leads to ergotism [A disease characterized by convulsion, nervous spasms abortion etc due to production of lysergic acid by *Claviceps*]

Basidiomycota

This includes Basidiomycetes or the club fungi. They are characterized by production of a basidium which is a club shaped structure produced on a hyphae during sexual reproduction.

The basidium produces basidiospores which germinates to produce hyphae.The common fungal genera belonging to the division includes mushrooms commonly used as food, rust and smuts- the plants pathogenic fungi causing huge economic losses, human pathogens like *Cryptococcus neoformans*, besides a number of saprophytic fungi involves in biodegradation.

Chytridiomycota

This division includes the primitive chytridomycetes fungi also known as chytrids. They are microscopic and extremely simple in structure. They exist either as single cells in a mass or as mycelia forms. They are either saprophytes or parasites on algae, fungi and plants. They show both asexual and sexual reproduction. The sexual reproduction involves production of a zygote which forms a resting spore and germinates during favorable conditions. The important genera includes *Rhizophydium* and *Allomyces.*

Myxomycota

They are the acellular slime molds which are present commonly as flowing mass of protoplasm without a cell wall, on decaying organic matter like logs and leaves etc. They are usually coloured and referred to as plasmodium. They obtain their nutrition by phagocytosis. During unfavourable conditions, the plasmodium develops fruiting bodies, which in turn form spores to tide over the adverse conditions .On return of favourable conditions spores germinates to form myxamoebae which can later fuse to form a zygote. The zygote can divide mitotically to produce the acellular plasmodial form. Common example includes *Hemitrichia, Stemonitis ,Physarum* etc.

Acrasiomycota

They are also called cellular slime molds and are composed of amoeboid cells referred to as myxamoebae which can produce progeny mitotically. However during adverse environmental condition myxamoebae begin to start aggregating via the production of chemical messenger CAMP (cyclic adenosine monophosphate). This leads to production of a coherent unit called pseudoplasmodium-> which at a later stage can differentiate into a stalk and a spore cell. On the arrival of favourable conditions the spores germinate producing amoebae.

Common fungal genera belonging to this division is *Dictyostelium.*

Oomycota

The Oomycetes or water molds have hyphae like true fungi. They have a characteristic sexual reproduction in which a large sized egg cell or Oogonium is fertilized by small sized anthredium (sperm cell) producing a zygote. Zygote germinates to produce flagellated zoospores.
Common example includes plant pathogen, *Perenospora* and *Phytothora* etc.

Protozoa

Protozoans are unicellular eukaryotic microbes which require moisture to grow. They have either one or more nucleus and vacuoles. Protozoa usually lack a cell wall. They are usually heterotrophs obtaining nutrition by holozoic or saprozoic nutrition. Protozoans occur either as single celled or in colonial forms. They are common in aquatic habitats, both in fresh water and sea. Protozoans exist in varied shapes and sizes. Most of the protozoans are mobile and move by either cilia, flagella or pseudopodia. Protozoans can be free living or parasitic in nature and reproduce by fission, budding, regeneration and sexual fusion of gametes.
Lately protozoans have been divided into various phyla and classes on the basis of 18S RNA sequencing. However in this section the standard classification based on mode of nutrition, reproduction and locomotion and number and types of nuclei present.

Phylum: Sarcomastigophora

These Protozoans have either flagella or pseudopodia as locomotary appendages. They reproduce both asexually by binary fission and sexually by syngamy. The members of this phylum have only one kind of nucleus. This phylum is divided into two subphyla – Mastigophora and Sarcodina.

The representative genera include *Giardia, Leishmania* and *Amoeba*. These are all human pathogens with *Giardia* and *Amoeba* causing acute diarrhea. *Leishmania* causes Kala azar.

Phylum: Labyrinthomorpha

The members of this phylum are usually marine and spindle shaped cells, some produce mucous tracks. These Protozoans are usually saprozoic but can also parasitize algal cells and even sea grass.

The most common example of this phylum is *Labyrinthula*.

Phylum: Apicomplexa

The members of this phylum are also known as Sporozoans, because they always have a spore producing phase in their life cycle. Their vegetative cells lack a specific locomotory appendage. The Sporozoans are usually parasitic on animals and have a complex life cycle which is completed on two different hosts e.g. *Plasmodium*, which causes malaria carries out a part of its life cycle on humans and the other part in mosquito. The other common examples include the pathogens *Toxoplasma* and *Cryptosporidium.*

Phylum: Microspora

This phylum includes spore forming obligately parasitic (intracellular) protozoans. They usually parasitize insects especially the beneficial ones e.g. the species *Nosema bombycis* is parasitic on silkworms and causes the disease Pebrine. These microsporans have recently been used as biocontrol agents for insects pests. They are also involved in causing opportunistic infections in immunocompromised patients especially in AIDS. The important genera include *Nosema, Microsporium, Pleistophora* etc.

Phylum: Ascetospora

This is a small phylum of spore forming protozoans which are commonly parasitic on invertebrates. The representative genera of this phylum are *Haplosporidium* which parasitizes molluscs.

Phylum: Myxozoa

These aquatic protozoans are also parasitic usually on fish. They also form spores with coiled polar filaments. The most significant member of this phylum is *Myxosoma* which parasitizes the fishes trout and salmon affecting their nervous system.

Phylum: Ciliophora

The members of this phylum use cilia as a locomotory appendage. A member of cilia arranged either longitudinally or in spirals help these organisms to move. The cilia also help these protozoans to capture their food. The shape of the cell is variable with some of them even being stalked.

The Cilliphorans contain two nucleus- a macro and a micronucleus. Some of them have contractile vacuoles for osmoregulation. They commonly reproduce by fission or conjugation. Common examples include *Paramecium, Vorticella, Didinium and Balantidium*

Various Systems of protozoans

Musculo-Skeletal: No specific muscular–skeletal system present different protozoans move by varied method for eg- Amoeba moves with a false foot , euglena moves with a whip like tail.

Digestive: Protozoan's feed on algae and bacteria, they take in both solid and liquid food and store it in vacuoles

Nervous: Protozoans have marginally developed nervous system however they respond to changes in light and temperature.

Circulatory: Circulatory system is rudimentary water flows in the cell through pores.

Respiratory: Oxygen intake and expulsion of carbon dioxide occurs through the cell membrane.

Reproductive: Reproduction in protozoans is by fission

Excretory: Excretion in protozoan is also through vacuoles

Algae

Algae are photosynthetic eukaryotic microbes which are prevalent in aquatic habitats. They have a very significant role in carbon dioxide fixation. Algae can occur in both unicellular and multicellular forms. The single cells may usually be spherical or rod shaped while the multicellular ones can be organized in the form of either colonies or filaments. Asexual reproduction may be by fragmentation or sporulation while sexual reproduction involves fusion of gametes. Algae are usually classified on the type of pigments they contain, such as, Blue green algae(BGA), Euglenoids, Dianoflagellets, Diatoms etc.

Algae occur in varied habitats but are usually present in water as planktonic (freely suspended) or benthic (present at the bottom) forms. They are usually autotrophic, but few could also be heterotrophic. Algae reproduce both asexually (Fragmentation, fission, sporulation) and sexually by production of oogonia and antheridium.

Algae have been divided into seven divisions according to the classical classification system, primarily based on the type of pigments they contain, their cell wall composition, number and types of flagella and their habitat. Recently, based on molecular phylogenetics and type of mitochondrial cristae algae have been placed under different divisions. However, in the present text, we will discuss the classical classification system of algae only.

According to this, algae have been divided into seven divisions as under:

Division: Chlorophyta

It is one of the largest divisions of algae containing approx 7,500 species. They are also known as green algae and are usually aquatic (both fresh water and marine) and at times terrestrial . They contain chlorophyll a and b and other carotenoids. Their storage products include starch and sugar .The cell wall is composed of cellulose, mannan proteins etc. They could be either unicellular or colonial or even filamentous.

The common algal genera includes in this division include *Chlamydomonas* (unicellular), *Volvox* (colonial), *Chlorella* etc.

Division: Charophyta

Their common name is stone worts or brittle worts because some of them tend to precipitate out calcium and magnesium carbonate from water giving rise to a lime stone like appearance on the bottom of their aquatic habitats . They contain chlorophyll a and b with carotenoid pigments. Their cell wall is primarily cellulosic, but could be of calcium carbonate. Their main storage product is starch.

The important genera of this division includes *Chara*

Division: Euglenophyta

The members of this division are commonly present in aquatic habitats. They contain chlorophyll a and b besides the carotenoids. They store food in the form of sugar oil and paramylon . They characteristically lack a cell wall and the cells are bounded by a plasma membrane.

The important algal genera included in this division is *Euglena*.

Division: Chrysophyta

They include golden – brown and yellow- green algae besides diatoms present either in water or land. They contain an array of pigments like chlorophyll a, c1, c2,d and a variety of carotenoids . The major food resource is in the form of oils and chrysolaminarin. Cell wall if present could be composed of cellulose, silica, $CaCO_3$ and chitin. They could be unicellular or colonial.

The important algal genera includes *Mallomonas , Ochromonas* and diatom *Cyclotella*

The diatoms have significant economic importance. They constitute the major component of phyto plankton and act as a food material for aquatic animals. They are also involved in carbon fixation and in cycling of silica. They are source of diatomaceous earth – a material which is used in filteration , insulation and as additive in detergents , paints , fertilizers etc . Diatoms are now being used as indices of water quality and as bio insecticides.

Division: Phaeophyta

They are also known as brown algae and are commonly present in marine water. These algae contain chlorophyll a and c besides the carotenoids especially flucoxanthin – which imparts a brown color to them. They have a cell wall composed of either cellulose, fucoidan and alginic acid. They store reserve food material in the form of Oils, Laminarin and Mannitol. Most of them are multicellular with some genera of keeps being differentiated. The common algal genera includes *Nereocystis* and *Sargassum.*

Division: Rhodophyta

They are also known as red algae and usually present in water. These algae are also referred to as seaweeds. The red color of these algae is because of presence of Phycoerythrin , a red colored pigment . They usually have chlorophyll a and a number of phycobiliproteins and carotenoids. The red algae store food in the form of floridean starch. Their cell wall is composed cellulose and galactans (in the form of agar). The agar extracted from red alga like *Geledium* is used as a solidifying agent in various microbiological nutrient media.

Division: Pyrrhophyta

The Pyrrophyta are aquatic algae (usually marine) also known as Dinoflagellates. They are single celled, photosynthetic algae, which produce light. These dinoflagellates cause luminescence during night in seawaters. Their reserve food material is usually starch and oils. Dinoflagellates have chlorophyll a and c, besides the carotenoids. If the cell wall is present,its cellulosic in nature and usually in form of stiff cellulosic plates with depositions of silica. Their another characteristic feature is presence of specific flagella with spinning motion.

The representative genera of Pyrrhophyta include *Noctiluca, Gonyaulax, Pyrodinium* .

Viruses

Viruses are ultra microscopic, ultrafilterable, obligate intracellular parasites. They vary in sizes from 20 -300nm and can thus easily pass through the bacterial filters. Viruses can only be observed using an electron microscope. They cannot grow and reproduce on their own, because they lack the requisite cellular components like proteins, enzymes, etc. Viruses are inert and depend on their living host cells (animal, plant or microbial) for replication. However, they have their own genetic information in the form of either DNA or RNA. This nucleic acid core is usually surrounded by a protein coat known as capsid. In a few viruses an envelope composed of lipids might be additionally present. Viruses are one of the most important causative agents of human diseases. Viruses are important to the study of molecular and cell biology as they provide simple systems that can be used to manipulate and investigate the functions of cells.

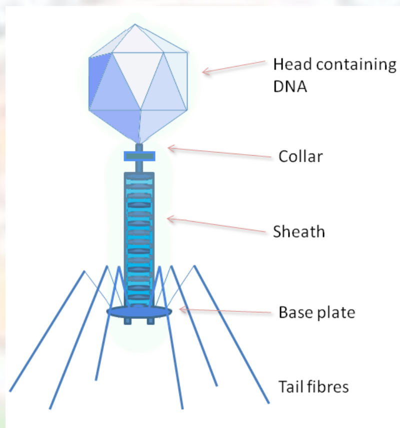


Figure: Bacteriophage

Source: http://upload.wikimedia.org/wikipedia/commons/b/b0/Phage.png

The taxonomic status of various groups of viruses is not clearly stated because little is known about their origin, evolution and molecular characteristics. Viruses have been classified in varied ways, but the most commonly accepted classification system is the one proposed by International Committee for Taxonomy of Viruses [1971, ICTV]. This taxonomic system divides viruses into various groups based on the following characteristics:-

a) Type of nucleic acid [DNA or RNA]
b) Strands of DNA/RNA [single or double]
c) Whether the ssRNA is positive sense or negative sense.
d) Type of host [animal, plant etc]
e) Symmetry of the capsid

Only the important taxonomic groups of viruses will be discussed in the forthcoming text:

Animal Viruses

a) Animal viruses with Double stranded DNA

The important families included in this group are

1. Family : Adenoviridae

These viruses lack an envelope and have linear double stranded DNA. They have icosahedral symmetry. Common Genera are *Mastadenovirus* infecting humans and other mammals *Aviadenoviruses* infecting birds.

2. Family : Baculoviridae

These viruses are characterized by presence of an envelope and circular double stranded DNA. They specifically have a protein inclusion body. These viruses infect insects and are used as *biopesticides* to control *Lepidoptera* and *Coleoptera*. Common genera include *Granulovirus* and *Nucleopolyhedrovirus.*

3. Family : Herpesviridae

They are enveloped DNA [linear, double stranded] viruses carrying spikes on the envelope. These viruses become latent after infection. This family contains number of human pathogens which causes sexually transmitted disease and even cancer. Important genera include *Simplexviruses* [e.g. Herpes simplex virus type 1], *Varicellovirus* [chickenpox viruse], *Gammaherpesvirinae* [oncogenic virus]

4. Family : Papillomaviridae

They lack an envelope and contain circular double stranded DNA. These viruses have an iscoschedral symmetry and are oncogenic e.g. Human papilloma virus (HPV)

5. Family : Polyomaviridae

They lack an envelope and show icosahedral symmetry. Are oncogenic e.g. simian virus type 40 (SV 40)

6. Family : Poxviridae

These are large sized viruses (220-450nm) with a complex structure. Their double stranded DNA is linear. They infect humans and other vertebrates besides insects common examples of genera are *Orthopoxvirus* (e.g. vaccinia virus), Vatapoxvirus (e.g. virus of monkeys and insects)

7. Family : Hepadnaviridae

Their genome is a partial double stranded DNA molecule, which specifically replicates through an RNA intermediate. These viruses contain enzyme reverse transcriptase and DNA polymerase e.g. the genera orthohepadnavirus[hepatitis B virus]

b) Animal viruses with single stranded DNA

One of the important families of this group is:-

1. Family : Parvoviridae

These viruses are non-enveloped and have icosahedral symmetry. They are small sized (18-25nm) and lack the enzymatic machinery. The important genera include *Parvovirus* (virus of cat and mice)

c) Animal viruses with dsRNA

The important family in this group is as follows-

1.Family: Reoviridae

They are non-enveloped viruses with icosahedral symmetry and linear double stranded DNA. The important genera include *Rotavirus* (cause diarrhea in infants) *Cypovirus* (include the cytoplasmic polyhedrosis viruses which affect Lepidoptera, Diptera etc)

d) Animal viruses with ssRNA

8. Family : Coronaviridae

They are enveloped viruses with a helical symmetry. The envelope bears spikes on the surface. These spikes are composed of protein. Their genetic material is positive sense single stranded RNA. Important genera are *Coronavirus* and *Torovirus*

9. Family : Picornaviridae

They lack an envelope and contain positive sense ssRNA genome. The symmetry is icosahedral. Important genera include *Enterovirus* (e.g. Poliovirus etc) and *Rhinovirus* (Virus affecting upper respiratory tract)

10. Family : Orthomyxoviridae

They are enveloped viruses carrying protein spikes on the envelope. The symmetry is helical and genome is negative sense ssRNA. Important genera include *Influenza virus.*

11. Family : Paramyxoviridae

They also have an envelope with protein spikes on it. The genome is negative sense ss RNA and symmetry helical. They are usually respiratory viruses e.g. the genera *Respirovirus* and *Pneumovirus*

12. Family : Rhabdoviridae

They include viruses which have a characteristic bullet shaped with a helical symmetry and negative sense ssRNA. They are enveloped and carry spikes e.g.genera *Lyssavirus* (e.g. rabies virus)

13. Family : Retroviridae

These viruses have positive sense ssRNA as their genome. They have an envelope bearing spikes. Retroviruses have a characteristic feature- replication of their genome is through formation of DNA intermediate. This is mediated by enzyme reverse transcriptase carried by these viruses. Some of the important genera are *Retrovirus* (Alpha, Beta, Gamma, Delta and Epsilon all oncogenic) and *Lentivirus* (include HIV-1 and HIV-2)

Plant viruses

Only some of the important families of plant viruses will be discussed

1. Family : Geminiviridae

These have single stranded DNA as their genome and lack an envelope. They do not multiply in the vector e.g. *Curtovirus*(infects beet)

2. Family : Caulimoviridae

They contain a partial double stranded DNA molecule as a genetic material and replicate via an RNA intermediate. They carry the enzyme reverse transcriptase e.g. genera *Caulimovirus* [e.g. cauliflower mosaic virus]

Plant viruses with RNA

1. Family : Reoviridae

These viruses have dsRNA and lack an envelope. The symmetry is icosahedral. They contain the enzyme RNA dependent RNA polymerase e.g. genera *Oryzavirus*(rice stunt virus).

2. Family : Bromoviridae

They have a positive sense ssRNA as genetic material and lack an envelope e.g. genera *Alfamovirus* (alfalfa mosaic virus)

Viruses of Algae, fungi and protozoa

1. Family : Phycodnaviridae

Viruses that infect algae. They contain double stranded DNA as genetic material. They have been found to infect *Chlorella* and *Paramecium*.

2. Family : Barnaviridae

These viruses infect fungi. They contain single stranded RNA as genetic material. They lack an envelope and have been commonly found to infect mushrooms.

3. Family : Totiviridae

These viruses infect both protozoans and fungi. They contain double stranded DNA and lack an envelope. Important genera are *Giardiavirus* and *Leishmaniavirus*.

Viruses of Archaebacteria, Bacteria, Mycoplasma and Spiroplasma

Some of the families affecting these prokaryotes are discussed

1. Family : Fuselloviridae

These viruses contain double stranded DNA as a genetic material. They lack a head-tail structure present in some bacterial viruses. They are found to infect Archaebacteria like *Desulfolobus* and *Methanococcus*.

2. Family : Podoviridae

These bacterial viruses have a head to tail structure and lack an envelope. They have double stranded DNA as genetic material. Include T3 and T7 (coliphages) and phage P22 (of enterobacteria)

3. Family : Inoviridae

These viruses contain single single stranded DNA. They lack an envelope and have rod like shape. Important genera includes *Plectovirus* (Infects *Mycoplasma* and *Spiroplasma*)

Besides these groups, satellite viruses [Incomplete viruses which need a helper virus to replicate] of animal, plant, fungi, bacteria etc are also included in the classification system.

From the above discussion it is clear that Microbiology is a broad area of enquiry and encompasses diverse biological sciences like biochemistry, genetics, ecology, molecular biology, etc. Over the past few decades, Microbiology has emerged as a major scientific discipline. However, it is still a young science and has immense potential for research and development of path breaking technologies to meet various challenges staring at mankind.

Summary

Microbiology : An Overview

1. Microbiology is the study of organisms which cannot be seen with the unaided eye.

2. Some microbes are larger in size. Large sized bacteria are called Monostrous Microbes.

3. Microbes cause a number of diseases.

4. Some microbes are very useful to environment and mankind.

Brief History Of Microbiology

1. Study of microbiology was aided by development of early microscope by Anton Van Leevwenhock.

2. Origin of microbes was debated since ancient times.

3. A number of scientists like Aristotle, John Needham, etc. believed in the spontaneous generation of microorganisms.

4. The concept of biogenesis gained momentum and was supported by Tyndall, Louis Pasteur, etc.

5. Louis Pasteur reported that fermentation was caused by Microbes. He also gave Pasteurization, a method of Preservation.

6. In the field of environment microbiology, important discoveries (presence of N_2 fixing bacteria) were made by Winogradsky and Beijerinck.

7. Research in the field of plant diseases caused by microbes laid the foundation of virology.

8. Microbes can be used in biodegradation, bioremediation sewage treatment, etc.

9. Bassi proposed the germ theory of disease, i.e., diseases are caused by microorganisms.

10. Pasteur and Robert Koch gave significant contributions in the field of medical microbiology.

11. Vaccine Research, initiated by Edward Jenner was carried forward by Pasteur and Robert Koch.

12. Paul Ehrlich laid the foundation of chemotherapy by discovering arsphenamine (Salvarsan) for treatment of syphilis.

Microbial World

1. Bacteria are unicellular prokaryotes locking a defined nuclear.
2. Bacterial have varied shapes like rods and cocci and are present in different arrangements
3. The cell wall of bacteria is composed of Peptidoglycan
4. Archaebacteria are also prokaryotic but they are characterized by the absence of peptidoglycan in their cell walls.
5. Archaea are divided into two groups, and bacteria into 23 phyla.
6. Fungi are eukaryotic, achlorophyllus microbes.
7. Fungi are usually saprophytic in nature.
8. Fungi includes both yeasts and moulds.

9. Fungi are classified into various divisions according to mode of sexual reproduction.

10. Protozoans are eukaryotic unicellular microbes.

11. Protozoans occur either as single celled forms or as a colony.

12. Protozoans have been divided into seven phyla.

13. Algae are photosynthetic microbes, which can occur in either unicellular or multicellular forms.

14. Algae have been divided into seven divisions according to type of pigment and cell wall composition

15. Viruses are acellular and obligately parasitic on host cells.

16. The genetic information in viruses is in the form of their DNA or RNA.

17. The most commonly accepted classification system of viruses is the one proposed by ICTV(1971), This system divides into different group according to their host and type of nucleic acid.

18. Microbiology has emerged as a significant biological science with ample of scope for research and developments.

Exercises

Short answer Questions

1. What is microbiology? Define.
2. Describe the early microscope developed by Anton Van Leeuwenhoeck in brief.
3. Enlist one important contribution of the following scientists?

   (i) John Tyndall

   (ii) Sergei Winogradsky

   (iii) F.W. Twort

   (iv) Emil Von Behring

(v) Elie Metchnikoff

4. What is agar?
5. Define viruses.

Long answer questions

1. Review the history and the importance of the major milestones of microbiology.
2. Discuss the major contributions of Louis Pasteur and Robert Koch in the field of microbiology.
3. What is spontaneous generation? Elaborate the major contributions of scientists in the support of this theory of microbial origin.
4. Distinguish between bacteria and archaebacteria?
5. Discuss in detail the important phyla of archaebacteria?
6. What are viruses? Elaborate their classification system?

Glossary

Agar-Agar: A solidifying agent composed of complex sulfonated polysaccharides.

Algae:Eukaryotic microorganisms with photosynthetic form of nutrition and lacking complex sex organs.

Anthrax:An infectious disease of animals caused by *Bacillus anthracis*. Can also infect humans.

Antibiotics:Compounds produced by microorganisms inhibitory for other groups of microbes.

Bacteria: Primitive organisms with a prokaryotic cell structure

Bacteriophage:A virus that uses bacteria as its host.

Botulism:Food poisoning caused by bacterium by *Clostridium botulinum*.

Cholera:An infectious disease caused by *Vibrio Cholerae*. Usually contracted by intake of contaminated water and food.

Diptheria:A bacterial infection caused by *Corynebacterium dipththeriae*. This diseas is very contagious.

Enzymes:They are biocatalyst which increase the rate of reaction they catalyze.

Fermentation: A reaction carried out using organic molecules as both electron donors and users , fermentation involves production of energy.

Fungi: Eukaryotic microorganisms which are usually multicellular and have heterotrophic mode of nutrition composed of both moulds and yeasts

Measles:Infection caused by viruses belonging to family paramyxoviridae. This disease is highly infectious

Pasteurization:The process to kill harmful pathogenic microorganisms by heating milk below boiling temperature.

Peptidoglycan:Polymer containing alternating N-acetylglucosamine and N-acetylmuramic acid residues.

Plague:Infectious disease, caused due to bacterium *Yersinia pestis*.

Protozoa or Protozoans: Protozoans are eukaryotic microorganisms which are either unicellular or acellular.

Rabies: A disease caused by rhabdo viruses . infects both humans and warm blooded animals like dogs

Selective media: Culture media containing specific compounds which prevent the growth of certain microbial groups.

Small Pox: A disease caused by a poxvirus and also characterized by the appearance of rashes on the skin.

Vaccine:A preparation of either killed , live and weakened (attenuated) microorganisms; or inactivated bacterial toxins (toxoids), administered to induce development of the immune response.

Viruses:An obligate intracellular parasite having a protein coat and nucleic acid [DNA/RNA]

References

1. Pelczar M J, Chan ECS, Krieg N R. Microbiology (5^{th} Ed.) 2008. Tata Mcgraw Hill,New Delhi.

2. Prescott LM, Harley JP, Klein DA: Microbiology (6th Edition) 2005. Mcgraw Hill Higher Education, New York.

3. Tortora GJ, Funke BR, case CL. Microbiology: An introduction (9th Ed.) 2008. Pearson Education New Delhi.

4. Panicker, Ananthanarayanan: Textbook of microbiology and immunology

Links

http://www.ucmp.berkeley.edu/archaea/archaeamm.html

http://bugs.bio.usyd.edu.au/learning/resources/CAL/Microconcepts/

http://www.microbiologytext.com/index.php?module=Book&func=displayarticlesinchapter&chap_id=35

http://www.bbc.co.uk/programmes/b007753d