		Semester V
16BCU502-A	**BASIC MICROBIOLOGY**	**4H-4C**

SCOPE

Microbiology is a specialized area of biology that concerns with the study of microbes ordinarily too small to be seen without magnification. Microorganisms are present everywhere on earth, which includes humans, animals, plants and other living creatures, soil, water and atmosphere. Many products of microbes contribute to public health as aids to nutrition, other products are used to interrupt the spread of disease, still others hold promise for improving the quality of life in the year ahead.

OBJECTIVES

The aim of this course is to train the students in the field of Microbiology, Knowledge and practical skills shall be acquired by the candidates in the sub-specialities of Bacteriology including Mycobacteriology, Virology, Parasitology, Immunology & Mycology so as to be able to deal with diagnosis and prevention of infectious diseases in the community.

Unit 1

History of Development of Microbiology

Development of microbiology as a discipline, Spontaneous generation vs. biogenesis. Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming. Role of microorganisms in fermentation, Germ theory of disease, Development of various microbiological techniques and golden era of microbiology, Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich, Elie Metchnikoff, Edward Jenner

Unit 2

Diversity of Microbial world

Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. Difference between prokaryotic and eukaryotic microorganisms. General characteristics of different groups: acellular microorganisms (Viruses, Viroids, Prions) and Cellular microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance.

Unit 3

Viruses, viroids and prions

An introduction to viruses with special reference to the structure and replication of the following: Poxvirus, Poliovirus, HIV, T4 and λ phage, lytic and lysogenic cycles.

Unit 4

Bacteria

An account of typical eubacteria, chlamydiae & rickettsiae (obligate intracellular parasites), mycoplasma, and archaebacteria (extremophiles). Applications of bacteria in industry, environment and food.

Unit 5

Algae, Fungi and Protozoa

History of phycology; General characteristics of algae including occurrence, thallus organization, algae cell ultra structure, pigments, flagella, eyespot food reserves and vegetative, asexual and sexual reproduction. Applications of Algae in agriculture, industry, environment and food. Historical developments in the field of Mycology, significant contributions of eminent mycologists. General characteristics of fungi including habitat, distribution, nutritional requirements, fungal cell ultra- structure, thallus organization and aggregation, fungal wall structure and synthesis, asexual reproduction, sexual reproduction, heterokaryosis, heterothallism and parasexual mechanism. Economic Importance of Fungi in Agriculture, environment, Industry, medicine, food, biodeterioration, mycotoxins. General characteristics with special reference to Amoeba.

TEXTBOOK

Powar, C.B., and Dahinwala, H.F., (2007). General Microbiology, Himalaya Publishing house, Mumbai.

REFERENCES

Prescott, L.J., and Klein, D., (2007). Microbiology, 7th edition McGraw Hill Publishers, London.

Pelzar, A., (2004). Microbiology, McGraw Hill Publishers, London

Atlas, R.M., (1997). Principles of Microbiology. 2nd edition. W M.T.Brown Publishers

LECTURE PLAN

DEPARTMENT OF MICROBIOLOGY

S.No	Lecture Duration Hour	Topics to be Covered	Support Material/Page Nos
		UNIT-I	
1	1	Development of microbiology as a discipline	R1: Pg: 5
2	1	Spontaneous generation vs. biogenesis	R1: Pg:4
3	1	Contributions of Anton von Leeuwenhoek, Louis Pasteur, Robert Koch, Joseph Lister, Alexander Fleming.	R1: Pg:7
4	1	Role of microorganisms in fermentation, Germ theory of disease	R1: Pg: 37-39
5	1	Development of various microbiological techniques	R1: Pg: 40 -42
6	1	Golden era of microbiology	R1: Pg: 43-45
7	1	Establishment of fields of medical microbiology and immunology through the work of Paul Ehrlich	R1: pg: 46-47
8	1	Elie Metchnikoff, Edward Jenner	R1: pg: 48
	Total No Of Hours Planned For Unit 1=8		
		UNIT-II	
1	1	Binomial Nomenclature	R1: Pg: 264
2	1	Whittaker's five kingdom	R1: Pg:265-280
3	1	Carl Woese's three kingdom classification systems and their utility	R1: Pg:281-295
4	1	Difference between prokaryotic and eukaryotic microorganisms	R2: Pg: 554-563
5	1	General characteristics of different groups: acellular microorganisms (Viruses, Viroids, Prions)	R2: Pg: 538-551

R1: Pg: 4

6	1	Cellular microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution	R2: Pg: 568-574
7	1	Occurrence, morphology	R2: pg: 575-590
8	1	Mode of reproduction and economic importance	R2: Pg: 388-395
	Total No Of Hours Planned For Unit II=08		
		UNIT-III	
1	1	An introduction to viruses with special reference to the structure	R3: Pg: 145-148
2	1	Replication of the following: Poxvirus	R1: Pg: 99-103
3	1	Poliovirus, HIV	R1: Pg: 104-106
4	1	T4 and λ phage	R3: Pg: 168
5	1	Lytic and lysogenic cycles	R3: Pg: 190-205
	Total No Of Hours Planned For Unit III=5		
		UNIT-IV	
1	1	An account of typical eubacteria	R1: Pg: 119-150
2	1	Chlamydiae & rickettsiae (obligate intracellular parasites)	R2: Pg: 107-113
3	1	Mycoplasma	R3: Pg: 160-163
4	1	Archaebacteria (extremophiles)	R1: Pg: 119-123
5	1	Applications of bacteria in industry	R3: Pg: 94-105
6	1	Environment and food	T1:Pg: 108
	Total No Of Hours Planned For Unit IV=06		
		UNIT-V	
1	1	History of phycology; General characteristics of algae including occurrence	R1: Pg: 882-884
2	1	Thallus organization, algae cell ultra structure	R1: Pg: 888-890

3	1	Pigments, flagella	R2: Pg: 907-908
4	1	Eyespot food reserves and vegetative	R3: Pg: 133-157
5	1	Asexual and sexual reproduction	R3: Pg: 159
6	1	Applications of Algae in agriculture	22: Pg: 160-183
7	1	Industry, environment and food	R3: Pg: 184-200
8	1	Historical developments in the field of Mycology	R3: Pg: 200-210
9	1	Significant contributions of eminent mycologists	R3: Pg: 210-235
10	1	General characteristics of fungi including habitat, distribution	R3: Pg: 236-247
11	1	Nutritional requirements	R1: Pg: 882-884
12	1	Fungal cell ultra- structure,	R1: Pg: 885-890
13	1	Thallus organization and aggregation,	R2: Pg: 907-908
14	1	Fungal wall structure and synthesis	R3: Pg: 134-157
15	1	Asexual reproduction, sexual reproduction	R3: Pg: 159
16	1	Heterokaryosis	R3: Pg: 160-183
17	1	Heterothallism	R3: Pg: 184-200
18	1	Parasexual mechanism	R3: Pg: 200-210
19	1	Economic Importance of Fungi in Agriculture, environment, Industry, medicine	R3: Pg: 210-235
20	1	Food, biodeterioration, mycotoxins	R3: Pg: 236-247
21	1	General characteristics with special reference to Amoeba	R1: Pg: 882-884
	Total no of Hours Planned for unit V=21		
Total Planned Hours		**48**	

TEXTBOOK

T1. Powar, C.B., and Dahinwala, H.F., (2007). General Microbiology, Himalaya Publishing house, Mumbai.

REFERENCES

R1. Pelzar, A., (2004). Microbiology, McGraw Hill Publishers, London

R2. Prescott, L.J., and Klein, D., (2007). Microbiology, 7th edition McGraw Hill Publishers, London.

R3. Atlas, R.M., (1997). Principles of Microbiology. 2nd edition. W M.T.Brown Publishers

UNIT-I
SYLLABUS

Diversity of Microbial world

Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. Difference between prokaryotic and eukaryotic microorganisms. General characteristics of different groups: acellular microorganisms (Viruses, Viroids, Prions) and Cellular microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance.

MICROBIOLOGY

MICROBIOLOGY is a specialized area of biology (Gr. *bios*-life+ *logos*-to study) that concerns with the study of microbes ordinarily too small to be seen without magnification. Microorganisms are microscopic (Gr. *mikros*-small+ *scopein*-to see) and independently living cells that, like humans, live in communities.

Microorganisms include a large and diverse group of microscopic organisms that exist as single cell or cell clusters (e.g., bacteria, archaea, fungi, algae, protozoa and helminths) and the viruses, which are microscopic but not cellular. While bacteria and archaea are classed as prokaryotes (Gr. *pro*-before+ *karyon*-nucleus) the fungi, algae, protozoa and helminths are eukaryotes (Gr. *eu*-true or good+ *karyon*-nucleus).

Microorganisms are present everywhere on earth, which includes humans, animals, plants and other living creatures, soil, water and atmosphere. Microorganisms are relevant to all of our lives in a multitude of ways. Sometimes, the influence of microorganisms on human life is beneficial, whereas at other times, it is detrimental. For example, microorganisms are required for the production of bread, cheese, yogurt, alcohol, wine, beer, antibiotics (e.g., penicillin, streptomycin, and chloramphenicol), vaccines, vitamins, enzymes and many more important products. Many products of microbes contribute to public health as aids to nutrition, other products are used to interrupt the spread of disease, still others hold promise for improving the quality of life in the year's ahead.

CONCEPTS

- Microbiology is the study of organisms that areusually too small to be seen by the unaided eye;it employs techniques—such as sterilization and the use of culture media—that are required to isolate and grow these microorganisms.
- Microorganisms are not spontaneously generated from inanimate matter but arise from other microorganisms.

- Many diseases result from viral, bacterial, fungal,or protozoan infections. Koch's postulates maybe used to establish a causal link between the suspected microorganism and a disease.
- The development of microbiology as a scientific discipline has depended on the a vailability of the microscope and the ability to isolate and grow pure cultures of microorganisms.
- Microorganisms are responsible for many of thechanges observed in organic and inorganic matter(e.g., fermentation and the carbon, nitrogen, andsulfur cycles that occur in nature).
- Microorganisms have two fundamentally different types of cells—procaryotic and eucaryotic—and are distributed among several kingdoms or domains.
- Microbiology is a large discipline, which has a great impact on other areas of biology and general human welfare.

The Discovery of Microorganisms

Even before microorganisms were seen, some investigators suspected their existence and responsibility for disease. Among others, the Roman philosopher Lucretius (about 98–55 B.C.) and the physician Girolamo Fracastoro (1478–1553) suggested that disease was caused by invisible living creatures. The earliest microscopic observations appear to have been made between1625 and 1630 on bees and weevils by the Italian Francesco Stelluti, using a microscope probably supplied by Galileo. However, the first person to observe and describe microorganisms accurately was the amateur microscopist Antony van Leeuwenhoek (1632–1723) of Delft, Holland. Leeuwenhoek earned his living as a draper and haberdasher (a dealer in men's clothing and accessories), but spent much of his spare time constructing simple microscopes composed of double convex glass lenses held between two silver plates (figure1.1*b*). His microscopes could magnify around 50 to 300 times,and he may have illuminated his liquid specimens by placing them between two pieces of glass and shining light on them at a45° angle to the specimen plane. This would have provided aform of dark-field illumination and made bacteria.

clearly visible (figure 1.1*c*). Beginning in 1673 Leeuwenhoek sent detailed letters describing his discoveries to the RoyalSociety of London. It is clear from his descriptions that he saw both bacteria and protozoa.

1.2 Early history and developments of microbiology.

Historians are unsure who made the first observations of microorganisms, but the microscope was available during the mid-1600s, and an English scientist named **Robert Hooke** made key observations. He is reputed to have observed strands of fungi among the specimens of cells he viewed. In the 1670s and the decades thereafter, a Dutch merchant named **Anton van Leeuwenhoek** made careful observations of microscopic organisms, which he called **animalcules.** Until his death in 1723, van Leeuwenhoek revealed the microscopic world to scientists of the day and is regarded as one of the first to provide accurate descriptions of protozoa, fungi, and bacteria.

After van Leeuwenhoek died, the study of microbiology did not develop rapidly because microscopes were rare and the interest in microorganisms was not high. In those years, scientists debated the theory of **spontaneous generation**, which stated that microorganisms arise from lifeless matter such as beef broth. This theory was disputed by **Francesco Redi**, who showed that fly maggots do not arise from decaying meat (as others believed) if the meat is covered to prevent the entry of flies. An English cleric named **John Needham** advanced spontaneous generation, but **Lazzaro Spallanzani** disputed the theory by showing that boiled broth would not give rise to microscopic forms of life.

The Conflict over Spontaneous Generation

From earliest times, people had believed in **spontaneous generation**—that living organisms could develop from nonliving matter. Even the great Aristotle (384–322 B.C.) thought some of the simpler invertebrates could arise by spontaneous generation. This view finally was challenged by the Italian physician Francesco Redi (1626–1697), who carried out a series of experiments on decaying meat and its ability to produce maggots spontaneously. Redi placed meat in three containers. One was uncovered, a second was covered with paper, and the third was covered with a fine gauze that would exclude flies. Flies laid their eggs on the uncovered meat and maggots developed. The other two pieces of meat did not produce maggots spontaneously. However, flies were attracted to the gauze-covered container and laid their eggs on the gauze; these eggs produced maggots.Thus the generation of maggots by decaying meat resulted from the presence of fly eggs, and meat did not spontaneously generate maggots as previously believed. Similar experiments by others helped discredit the theory for larger organisms .Leeuwenhoek's discovery of microorganisms renewed the controversy. Some proposed that microorganisms arose by spontaneous generation even though larger organisms did not. They pointed out that boiled extracts of hay or meat would give rise to microorganisms after sitting for a while. In 1748 the English priest John Needham (1713–1781) reported the results of his experiments on spontaneous generation. Needham boiled mutton broth and then tightly stoppered the flasks. Eventually many of the flasks became cloudy and contained microorganisms. He thought organic matter contained a vital force that could confer the properties of life on nonliving matter. A few years later the Italian priest and naturalist Lazzaro Spallanzani (1729–1799) improved on Needham's experimental design by first sealing glass flasks that contained water and seeds. If the sealed flasks were placed in boilingwater for 3/4 of an hour, no growth took place as long as theflasks remained sealed. He proposed that air carried germs to theculture medium, but also commented that the external air might berequired for growth of animals already in the medium. The supportersof spontaneous generation maintained that heating the airin sealed flasks destroyed its ability to support life.Several investigators attempted to counter such arguments.Theodore Schwann (1810–1882) allowed air to enter a flask containing a sterile nutrient solution after the air had passed through ared-hot tube. The flask remained sterile. Subsequently GeorgFriedrich Schroder and Theodor von Dusch allowed air to enter aflask of heat-sterilized medium after it had passed through sterile cottonwool. No growth occurred in the medium even though the air had not been heated. Despite these

experiments the French naturalist FelixPouchet claimed in 1859 to have carried out experiments conclusively proving that microbial growth could occur without air contamination.

This claim provoked Louis Pasteur (1822–1895) to settle the matter once and for all. Pasteur (**figure 1.2**) first filtered airthrough cotton and found that objects resembling plant sporeshad been trapped. If a piece of the cotton was placed in sterile medium after air had been filtered through it, microbial growth appeared. Next he placed nutrient solutions in flasks, heated their necks in a flame, and drew them out into a variety of curves, while

keeping the ends of the necks open to the atmosphere (**figure 1.3**).Pasteur then boiled the solutions for a few minutes and allowed them to cool. No growth took place even though the contents of the flasks were exposed to the air. Pasteur pointed out that no growth occurred because dust and germs had been trapped on the walls of the curved necks. If the necks were broken, growth commenced immediately. Pasteur had not only resolved the controversy by 1861 but also had shown how to keep solutions sterile. The English physicist John Tyndall (1820–1893) dealt a final blow to spontaneous generation in 1877 by demonstrating thatdust did indeed carry germs and that if dust was absent, broth remainedsterile even if directly exposed to air. During the course of his studies, Tyndall provided evidence for the existence of exceptionally heat-resistant forms of bacteria. Working independently ,the German botanist Ferdinand Cohn (1828–1898) discovered the existence of heat-resistant bacterial endospores.

1.2.1 Louis Pasteur and the germ theory. Louis Pasteur worked in the middle and late 1800s. He performed numerous experiments to discover why wine and dairy products became sour, and he found that bacteria were to blame. Pasteur called attention to the importance of microorganisms in everyday life and stirred scientists to think that if bacteria could make the wine “sick,” then perhaps they could cause human illness.

Pasteur had to disprove spontaneous generation to sustain his theory, and he therefore devised a series of **swan-necked flasks** filled with broth. He left the flasks of broth open to the air, but the flasks had a curve in the neck so that microorganisms would fall into the neck, not the broth. The flasks did not become contaminated (as he predicted they would not), and Pasteur's experiments put to rest the notion of spontaneous generation. His work also encouraged the belief that microorganisms were in the air and could cause disease. Pasteur postulated the **germ theory of disease**, which states that microorganisms are the causes of infectious disease.

Pasteur's attempts to prove the germ theory were unsuccessful. However, the German scientist **Robert Koch** provided the proof by cultivating anthrax bacteria apart from any other type of organism. He then injected pure cultures of the bacilli into mice and showed that the bacilli invariably caused anthrax. The procedures used by Koch came to be known as **Koch's postulates**. They provided a set of principles whereby other microorganisms could be related to other diseases.

The Role of Microorganisms in Disease

The importance of microorganisms in disease was not immediately obvious to people, and it took many years for scientists toestablish the connection between microorganisms and illness.Recognition of the role of microorganisms depended greatlyupon the development of new techniques for their study. Once itbecame clear that disease could be caused by microbial infections,microbiologists began to examine the way in which hostsdefended themselves against microorganisms and to ask how diseasemight be prevented. The field of immunology was born.

Recognition of the Relationshipbetween Microorganisms and Disease

Although Fracastoro and a few others had suggested that invisibleorganisms produced disease, most believed that disease wasdue to causes such as supernatural forces, poisonous vaporscalled miasmas, and imbalances between the four humorsthought to be present in the body. The idea that an imbalance betweenthe four humors (blood, phlegm, yellow bile [choler], andblack bile [melancholy]) led to disease had been widely acceptedsince the time of the Greek physician Galen (129–199). Supportfor the germ theory of disease began to accumulate in the earlynineteenth century. Agostino Bassi (1773–1856) first showed amicroorganism could cause disease when he demonstrated in1835 that a silkworm disease was due to a fungal infection. Healso suggested that many diseases were due to microbial infections.In 1845 M. J. Berkeley proved that the great Potato Blightof Ireland was caused by a fungus. Following his successes with the study of fermentation, Pasteur was asked by the French governmentto investigate the pébrine disease of silkworms that wasdisrupting the silk industry. After several years of work, he showed that the disease was due to a protozoan parasite. The disease was controlled by raising caterpillars from eggs produced byhealthy moths.Indirect evidence that microorganisms were agents of humandisease came from the work of the English surgeon Joseph Lister(1827–1912) on the prevention of wound infections. Lister impressed with Pasteur's studies on the involvement of microorganismsin fermentation and putrefaction, developed a system of antisepticsurgery designed to prevent microorganisms from entering wounds. Instruments were heat sterilized, and phenol was used onsurgical dressings and at times sprayed over the surgical area. The approach was remarkably successful and transformed surgery afterLister published his findings in 1867. It also provided strong indirectevidence for the role of microorganisms in disease because phenol, which killed bacteria, also prevented wound infections.The first direct demonstration of the role of bacteria in causingdisease came from the study of anthrax by theGerman physician Robert Koch (1843–1910). Koch (**figure 1.4**)used the criteria proposed by his former teacher, Jacob Henle (1809–1885), to establish the relationship between *Bacillus anthracis*and anthrax, and published his findings in 1876 (**Box 1.1**briefly discusses the scientific method). Koch injected healthymice with material from diseased animals, and the mice becameill. After transferring anthrax by inoculation through a series of 20 mice, he incubated a piece of spleen containing the anthrax bacillusin beef serum. The bacilli grew, reproduced, and producedspores. When the isolated bacilli or

spores were injected into mice, anthrax developed. His criteria for proving the causal relationshipbetween a microorganism and a specific disease are known as

Koch's postulates and can be summarized as follows:

1. The microorganism must be present in every case of thedisease but absent from healthy organisms.
2. The suspected microorganism must be isolated and grownin a pure culture.
3. The same disease must result when the isolatedmicroorganism is inoculated into a healthy host.
4. The same microorganism must be isolated again from the diseased host.

Although Koch used the general approach described in the postulates during his anthrax studies, he did not outline them fully until his 1884 publication on the cause of tuberculosis . Koch's proof that *Bacillus anthracis* caused anthrax was independently confirmed by Pasteur and his coworkers. They discovered that after burial of dead animals, anthrax spores survived and were brought to the surface by earthworms. Healthy animals then ingested the spores and became ill.

Although the criteria that Koch developed for proving a causal relationship between and a microorganism and a specific disease have been of immense importance in medical microbiology, it is not always possible to apply them in studying human diseases. For example, some pathogens cannot be grown in pure culture outside the host; because other pathogens grow only in humans, their study would require experimentation on people. The identification, isolation, and cloning of genes responsible for pathogen virulence have made possible a new molecular form of Koch's postulates that resolves some of these difficulties. The emphasis is on the virulence genes present in the infectious agent rather than on the agent itself. The molecular postulates can be briefly summarized as follows:

1. The virulence trait under study should be associated much more with pathogenic strains of the species than with nonpathogenic strains.c
2. Inactivation of the gene or genes associated with the suspected virulence trait should substantially decrease pathogenicity.
3. Replacement of the mutated gene with the normal wild-type gene should fully restore pathogenicity.
4. The gene should be expressed at some point during the infectionand disease process.
5. Antibodies or immune system cells directed against the geneproducts should protect the host.

The molecular approach cannot always be applied because of problemssuch as the lack of an appropriate animal system. It also is difficultto employ the molecular postulates when the pathogen is notwell characterized genetically.

1.3 The development and scope of microbiology.

In the late 1800s and for the first decade of the 1900s, scientists seized the opportunity to further develop the germ theory of disease as enunciated by Pasteur and proved by Koch. There emerged a **Golden Age of Microbiology** during which many agents of different infectious diseases were identified. Many of the etiologic agents of microbial disease were discovered during that period, leading to the ability to halt epidemics by interrupting the spread of microorganisms.

Despite the advances in microbiology, it was rarely possible to render life-saving therapy to an infected patient. Then, after World War II, the **antibiotics** were introduced to medicine. The incidence of pneumonia, tuberculosis, meningitis, syphilis, and many other diseases declined with the use of antibiotics.

Work with viruses could not be effectively performed until instruments were developed to help scientists see these disease agents. In the 1940s, the **electron microscope** was developed and perfected. In that decade, cultivation methods for viruses were also introduced, and the knowledge of viruses developed rapidly. With the development of vaccines in the 1950s and 1960s, such viral diseases as polio, measles, mumps, and rubella came under control.

Modern microbiology. Modern microbiology reaches into many fields of human endeavor, including the development of pharmaceutical products, the use of quality-control methods in food and dairy product production, the control of disease-causing microorganisms in consumable waters, and the industrial applications of microorganisms. Microorganisms are used to produce vitamins, amino acids, enzymes, and growth supplements. They manufacture many foods, including fermented dairy products (sour cream, yogurt, and buttermilk), as well as other fermented foods such as pickles, sauerkraut, breads, and alcoholic beverages.

One of the major areas of applied microbiology is **biotechnology.** In this discipline, microorganisms are used as living factories to produce pharmaceuticals that otherwise could not be manufactured. These substances include the human hormone insulin, the antiviral substance interferon, numerous blood-clotting factors and clot dissolving enzymes, and a number of vaccines. Bacteria can be reengineered to increase plant resistance to insects and frost, and biotechnology will represent a major application of microorganisms in the next century.

Two Australians, **Barry J. Marshall** and **Robin Warren** won the 2005 Nobel Prize for showing that bacterial infections of *Helicobacter pylori* (= *Campylobacter pylori*) and not the stress, is responsible for painful ulcers in the stomach and intestine. The 1982 discovery transformed **peptic ulcer disease** from a chronic, frequently disabling condition to one that can be cured by a short regimen of antibiotics and medicines. At the same time, nucleic acid sequencing methods were developed which left its impact in all the areas of biology. Sequencing technology helped microbiologists to reveal phylogenetic evolutionary)

relationships among prokaryotes, which led to evolutionary new concepts in the field biological classification. The field of **Genomics** is also a contribution of sequencing technology, in which the **comparative analysis of the genes of different organisms** is carried out. The huge amounts genomic information now in hand are leading to major advances in medicine, microbial ecology, industrial microbiology, and many other areas of biology. The genomics era has given birth to a new subdiscipline, **Proteomics.** The proteomics is defined as **the study of protein expression in cells.** The significance of such developments in molecular biology to all of biology is understood by the fact that numerous Nobel Prizes have been awarded to researchers for their work in this field

Concepts

1. Light microscopes use glass lenses to bend and focus light rays and produce enlarged images of small objects. The resolution of a light microscope is determined by the numerical aperture of its lens system and by the wavelength of the light it employs; maximum resolution is about 0.2 _m.
2. The most common types of light microscopes are the bright-field, darkfield, phase-contrast, and fluorescence microscopes. Each yields a distinctive image and may be used to observe different aspects of microbial morphology.

3. Because most microorganisms are colorless and therefore not easily seen in the bright-field microscope, they are usually fixed and stained before observation. Either simple or differential staining can be used to enhance contrast. Specific bacterial structures such as capsules, endospores, and flagella also can be selectively stained.

4. The transmission electron microscope achieves great resolution (about0.5 nm) by using electron beams of very short wavelength rather than visible light. Although one can prepare microorganisms for observation in other ways, one normally views thin sections of plastic-embedded specimens treated with heavy metals to improve contrast.

5. External features can be observed in great detail with the scanning electron microscope, which generates an image by scanning a fine electron beam over the surface of specimens rather than projecting electrons through them.

6. New forms of microscopy are improving our ability to observe microorganisms and molecules. Two examples are the confocal scanning laser microscope and the scanning probe microscope.

Microbiology usually is concerned with organisms so small they cannot be seen distinctly with the unaided eye. Because of the nature of this discipline, the microscopeis of crucial importance. Thus it is important to understand how the microscope works and the way in which specimens are prepared for examination. The chapter begins with a detailed treatment of the standard bright-field microscope and then describes other common typesof light microscopes. Next preparation and staining of specimens for examination with the light microscope are discussed. This is followed by a description of transmission and scanning electron microscopes, both of which are used extensively in current microbiological research. The chapter closes with a brief introduction to two newer forms of microscopy: scanning probe microscopy and confocal microscopy.

POSSIBLE QUESTIONS

UNIT-I

PART-A (20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B (2 MARKS)

1. Write a short note about pasteurization
2. Give a list of Anton von Leeuwenhoek contributions
3. What is binomial nomenclature?
4. Describe the spontaneous generation vs. biogenesis

PART-C (8 MARKS)

1. Give a detail about development of various microbiological techniques
2. Describe the role of microorganisms in fermentation
3. Write about the goldern era of microbiology
4. Distinguish between prokaryotic and eukaryotic microorganisms
5. Give a detail about Whittaker's and Carl Woese's classification

Unit - I	Option 1	Option 2	Option 3	Option 4
1. Which event came first?	a. Koch demonstrates that a bacterium, Anthrax, can cause disease	**b. Leewen hocks organism discription**	c. Koch 's colony purification	d. None of the above
2. Which event came first?	a. Avery demonstrates that DNA carries genetic information.	**b. World War II begins**	c. Aids vaccine development	d. None of the above
3. Who first described microorganisms such as bacteria?	a. Louis Pasteur	b. Robert Koch	c. Fannie Hesse	**d. Anton von Leeuwenhoek**
4. Who first developed the process of colony purification on solid media?	a. Louis Pasteur	**b. Robert Koch**	c. Fannie Hesse	d. Anton von Leeuwenhoek
5. What was the first successful solid medium for colony purification of bacteria?	a. Agar	**b. Potato**	c. Gelatin	d. Meat
6. Who first suggested using the thickening agent most commonly used for colony purification today?	a. Louis Pasteur	b. Robert Koch	**c. Fannie Hesse**	d. Richard Petri
7. The most important innovation (new idea) in Pasteur's 'swan neck flask' experiments was	a. a glass barrier prevented contamination	b. heating media prevented microbial growth.	**c. fresh air could directly contact the medium**	d. the experimenter could look for contamination without disturbing the

				experiment
8. Credit for the first vaccine for the prevention of human disease is generally given to	**a. Edward Jenner for the prevention of small pox**	b. Louis Pasteur for the prevention of rabies	c. Louis Pasteur for the prevention of anthrax	d. Robert Koch for the prevention of tuberculosis
9. To make a vaccine against chicken cholera that would not kill the chicken, Pasteur	a. treated the sample with heat to kill the microorganisms	**b. attenuated the strain by repeatedly passaging it in culture**	c. used a related but different microorganism from animals	d. used very small, non-lethal amounts of material
10. When Louis Pasteur first tried his vaccine on a young boy, there was a possibility that the vaccine itself could kill the child. This was permissible under the standards of the day because	a. the importance of the Science was worth the risk	b. less value was placed on human life than today	c. the child was from a poor family	**d. the child had rabies, which was always fatal**
11. What was the first bacterium shown to cause human disease?	**a. Anthrax**	b. Mycobacterium	c. Diphtheria	d. Streptococcus
12. What was the first virus shown to cause disease?	a. Polio	b. Hepatitis	**c. Tobacco mosaic virus**	d. Potato blight
13. The primary use of Koch's postulates is to	a. clearly identify and characterize a particular microorganism	b. isolate microorganisms from diseased animals	**c. demonstrate that a disease is caused by a microorganism**	d. develop vaccines for specific diseases
14. Which of the following is NOT part	a. the microorganism is never found in healthy	b. the microorganisms is always found in diseased	c. the microorganism	**d. the microorganism**

of Koch's postulates	animals	animals	must cause disease in healthy animals	**must secrete a toxin in culture**
15. The role of antibodies in fighting disease was first demonstrated by	a. vaccination of humans with rabies	**b. injection of rabbit "antitoxin" to protect against diphtheria**	c. attenuation of rabies by passage in atypical host	d. observation of phagocytosis of bacteria
16. The role of blood cells in fighting disease was first demonstrated by	a. Pasteur with his swan necked flasks	b. Koch with acid fast staining of mycobacteria	**c. Metchnikoff with his observation of phagocytosis**	d. Chamberland with his filtration of virus through porcelain
17. The first observation that bacteria-like organisms could be found in normal air was by	**a. Louis Pasteur**	b. Robert Koch	c. Fannie Hesse	d. Anton von Leeuwenhoek
18. The first physician to make practical application of the germ theory of disease to surgery was	a. Louis Pasteur	b. **Joseph Lister**	c. Fannie Hesse	d. Anton von Leeuwenhoek
19. Louis Pasteur's studies on the unwanted production of acid from beet sugar was the first demonstration that	a. sugars are unstable and can breakdown into either ethanol or acid	**b. bacteria can cause specific chemical reactions**	c. ethanol is unstable and can convert to acid	d. microorganisms can be found in air
20. Which of the following discoveries is NOT attributed to Sergei Winogradsky	**a. Colony isolation on solid phase medium**	b. Colony enrichment on selective medium	c. Bacteria oxidation of iron and sulfur	d. CO2 fixation by non-photosynthetic

			to obtain energy	microorganisms
21. A 40X objective and an 10X ocular produce a total magnification of	a. 50	b. 100	**c. 400**	d. 500
22. Living, unstained cells and organisms can be observed best using	a. fluorescent microscopy	b. TEM	c. phase contrast microscopy	d. light microscopy
23. Scanning electron microscopy (SEM) is best used to study	a. small internal cell structures	b. surface morphology	c. Vissible structures	d. all of the above
24. A microscope in which an image is formed by passing an electron beam through a specimen and focusing the scattered electrons with magnetic lenses is called a	a. transmission electron microscope	b. scanning electron microscope	c. phase-contrast microscope	d. none
25. Resolution is the ability of a lens to distinguish between small objects close together. What approximate resolution can be obtained with a lower power (10X, N.A. 0.25) objective lens?	a. 0.2 microns	b. 0.3 microns	c. 0.9 microns	d. 0.25
26. Fixation is the process by which the structures of the cells are preserved and fixed in position. An advantage of chemical fixation over heat fixation is that it	a. magnifies the specimen	**b. does not destroy internal structures**		
27. Monochromatic (one color) light is sometimes used to increase the	a. Red	b. Oranbge	c. Greeen	**d. Blue**

resolution of light microscopes. Light of which color below would give you the best resolution?				
28. Which of the following objectives would give you the best resolution of small objects?	a. 10x air, N.A. 0.25	b. 20x oil, N.A. 0.4	**c. 64x oil, N.A. 1.4**	d. 40x oil, N.A. 5.4
29. Transmission electron microscopy is best for high magnification viewing of	**a. internal structure of fixed cells**	b. external structure of live cells	c. internal structure of motile cells only	d. external structure of all cells
30. Which of the following statements is most correct about the differential Gram stain?	a. Crystal violet differentially stains Gram positive cells	b. Gram's iodine differentially stains Gram positive cells	**c. Acetone differentially destains Gram negative cells**	d. Saffron red differentially stains Gram negative cells
31. Which of the following statements about Transmission Electron Microscopy is not true	**a. The specimen must be stained with osmium or other heavy metal**	b. The specimens are placed in a high vacuum for viewing	c. The specimens must be sliced very thin, 20-100 nm in thickness	d. The beam is focused by electromagnetic lenses
32. Phase Contrast microscopy	a. Continuously changes the phase of the incident light from the condenser to improve contrast in the specimen	**b. Uses circular filters in the condenser and objective to give contrast to parts of the cell with different refractive indices**	c. Uses special lenses to distinguish between solid and liquid phases of the cell	d. Uses special lenses to change the color of light passing through them

33. Which of the following is NOT equivalent to 10 micrometers	**a. 0.0001 cm**	b. 0.01 mm	c. 10,000 nm	d. 100,000 Angstroms
34. Parfocal" refers to microscopes with multiple objectives where	a. objectives are used in pairs for stereoscopic effects	b. each objective has the same working distance above the specimen	**c. each objective is positioned to be in focus at the same stage height**	d. sequential objectives increase power by a factor of two
35. Ability of a lens to separate or distinguish between small objects that are closed together is called	a. Revolution	b. Resonance	**c. Resolution**	d. Repression
36.Who provided the proof for Germ theory of Marrenation?	a. Carl Linnaeus	b. Robert Koch	c. Lotus Pasture	d. Invanovski
37. With ---------- microscopy, it is possible to observe structures within cells which are not stained.	a. Fluorescence microscopy	b. Dark-field microscopy	c. Phase contrast microscopy	d. Bright field microscopy
38. In electron microscopy , the contrast may be increased by combining the cell components with metals of high atomic weight. The process is called	a. Shadow casting	b. Positive staining	c. Negative staining	d. Immunofluorescence
39.Fluorescence microscopy uses	a. White light	b. Blue light	c. Ultraviolet light	d. Orange light
40. The minimum time for sterilization	a. 5 minutes	b. 15 minutes	c. 45 minutes	d. 1 hour.

by autoclaving is				
41. Criteria needed to prove a specific microbe causes a particular disease is proposed by	a. T.J .Burril	b. Robert koch	c. Ogston	d. Bruce.
42. Edward jenner discovered	a. World of microorganisms	**b. Vaccination**	c. Viruses	d. bacteriophages
43. Medium containing vitamins can be sterilized by using	a. Autoclave	b. Hot air oven	c. Membrane filter	d. HEPA filter
44. Which of the following is the source of agar agar	a. Red algae	b. Brown algae	c. Green algae	d. None of the above
45.Anthrax is caused by a spore forming bacterium was first shown by	**a. Robert Koch**	b. Debary	c. Louis Pastuer	d. Adolf Meyer
46.Which one of the following can be employed to sterilize heat labile laboratory media?	a. Autoclaving	b. Hot air oven	c. Disinfection	d. Ultrapreparation
47.Pasteurization is a method of	a. Heat Sterilization	b. Sterilization by filtration	c. Chemical Disinfections	d. Heat sterilization under pressure
48.Robert koch name is associated with	a. Gelatin as a solidifying agent	b. Pour plate method	c. Enrichment culture	d. None of the above
49.Tyndalization is the process of	a. Continuous heating	b. Discontinuous heating	c. Seridry heating	d. High temperature

				heating
50. The term organized bodies was coined by	a. Spallan Zani	b. Francois Appert	c. Louis Pasteur	d. Robert Koch
51. What was one of the first and most useful microscopic tests for classifying bacteria that is still important today	a. silver stain	b. flagellar stain	**c. gram stain**	d. negative stain
52. The ultimate limit of what we are able to see with a microscope is defined by __.	a. magnification	**b. resolution**	c. light intensity	d. visual acuity
53. When the oil-immersion lens is used __.	a. light rays are scattered so unnecessary background material is not seen.	**b. light rays are concentrated by minimizing refraction to increase clarify**	c. objects are held in place on the microscope slide	d. magnification of objects is increased about ten-fold
54. Which of the following types of optics would provide the greatest contrast and best reveal the sub-cellular structural detail for observing the bacterial cell?	a. bright field	b. dark field	**c. phase contrast**	d. none of the above
55. Which of the following areas of microbiology was not a major research interest of Louis Pasteur?	a. fermentation	b. vaccine production	**c. nitrogen fixation**	d. sterilization
56. Stains useful for identifying fungus	a. haematoxylin and	b. Gomori methanamine	c. PAS (periodic	**d. All the above**

include:	eosin	silver	acid-Schiff)	
57. When the oil-immersion lens is used __.	a. light rays are scattered so unnecessary background material is not seen.	**b. light rays are concentrated by minimizing refraction to increase clarify**	c. objects are held in place on the microscope slide	d. magnification of objects is increased about ten-fold
58. Which of the following types of optics would provide the greatest contrast and best reveal the sub-cellular structural detail for observing the bacterial cell?	a. bright field	b. dark field	**c. phase contrast**	d. none of the above
59. Criteria needed to prove a specific microbe causes a particular disease is proposed by	a. T.J .Burril	b. Robert koch	c. Ogston	d. Bruce.
60. Edward jenner discovered	a. World of microorganisms	**b. Vaccination**	c. Viruses	d. bacteriophages

UNIT-II
SYLLABUS

Diversity of Microbial world

Binomial Nomenclature, Whittaker's five kingdom and Carl Woese's three kingdom classification systems and their utility. Difference between prokaryotic and eukaryotic microorganisms. General characteristics of different groups: acellular microorganisms (Viruses, Viroids, Prions) and Cellular microorganisms (Bacteria, Algae, Fungi and Protozoa) with emphasis on distribution and occurrence, morphology, mode of reproduction and economic importance.

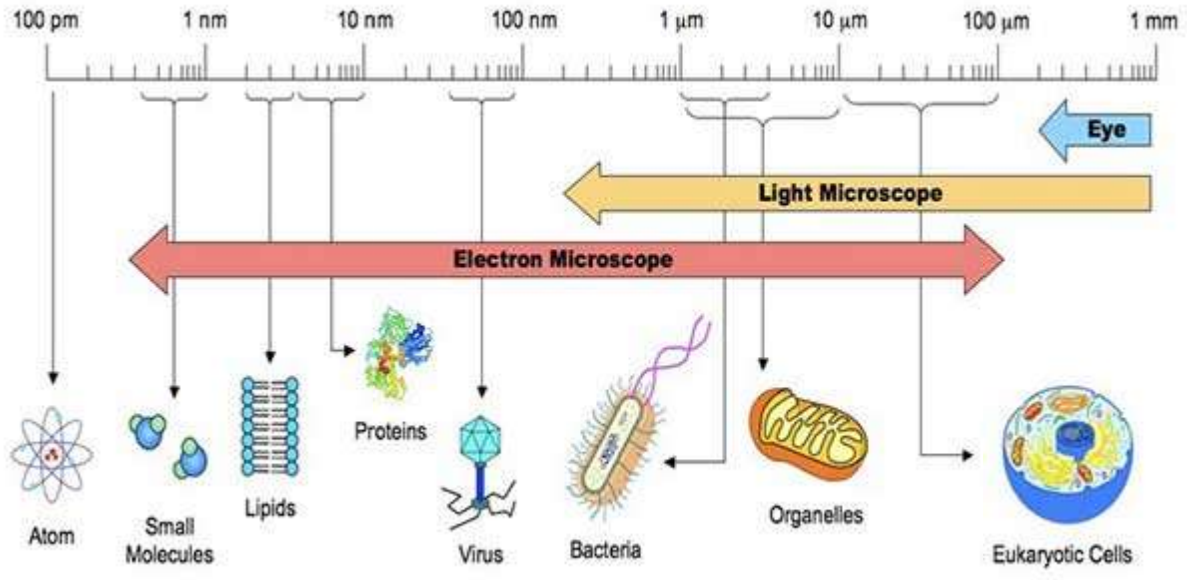
BACTERIA

Bacteria are prokaryotic, unicellular microorganisms, which lack chlorophyll pigments. The cell structure is simpler than that of other organisms as there is no nucleus or membrane bound organelles.

Due to the presence of a rigid cell wall, bacteria maintain a definite shape, though they vary as shape, size and structure.

Size of bacterial cell

Most bacteria are 0.2 um in diameter and 2-8 um in length.

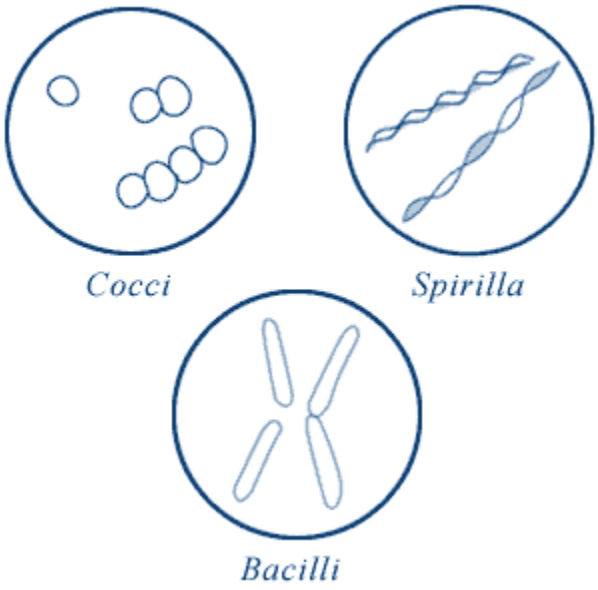


The average diameter of spherical bacteria is 0.5-2.0 µm. For rod-shaped or filamentous bacteria, length is 1-10 µm and diameter is 0.25-1 .0 µm.

- E. coli, a bacillus of about average size is 1.1 to 1.5 µm wide by 2.0 to 6.0 µm long.
- Spirochaetes occasionally reach 500 µm in length and the cyanobacterium
- Oscillatoria is about 7 µm in diameter.
- The bacterium, Epulosisciumfishelsoni , can be seen with the naked eye (600 mm long by 80 mm in diameter).
- One group of bacteria, called the Mycoplasmas, have individuals with size much smaller than these dimensions. They measure about 0.25 µ and are the smallest cells known so far. They were formerly known as pleuropneumonia-like organisms (PPLO).
- Mycoplasma gallicepticum, with a size of approximately 200 to 300 nm are thought to be the world smallest bacteria.
- Thiomargaritanamibiensis is world's largest bacteria, a gram-negative Proteobacterium found in the ocean sediments off the coast of Namibia. Usually it is 0.1—0.3 mm (100—300 µm) across, but bigger cells have been observed up to 0.75 mm (750 µm).

Thus a few bacteria are much larger than the average eukaryotic cell (typical plant and animal cells are around 10 to 50 µm in diameter).

The three basic bacterial shapes are coccus (spherical), bacillus (rod-shaped), and spiral (twisted), however pleomorphic bacteria can assume several shapes.

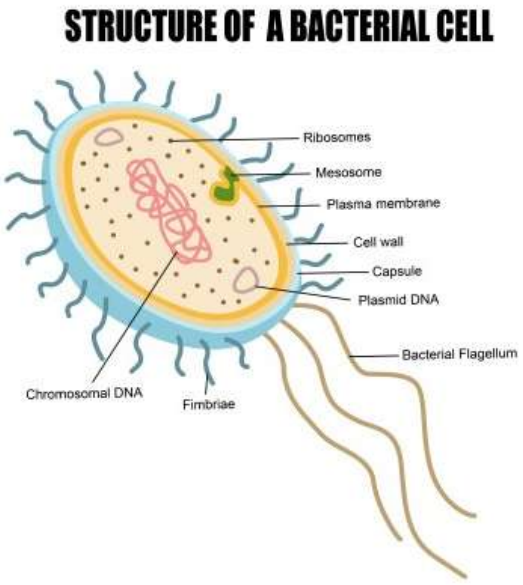


Shape of Bacterial Cell

- **Cocci** (or coccus for a single cell) are round cells, sometimes slightly flattened when they are adjacent to one another.
- **Bacilli** (or bacillus for a single cell) are rod-shaped bacteria.
- **Spirilla** (or spirillum for a single cell) are curved bacteria which can range from a gently curved shape to a corkscrew-like spiral. Many spirilla are rigid and capable of movement. A special group of spirilla known as spirochetes are long, slender, and flexible.

Bacterial Cell Wall Structure and Chemical Composition

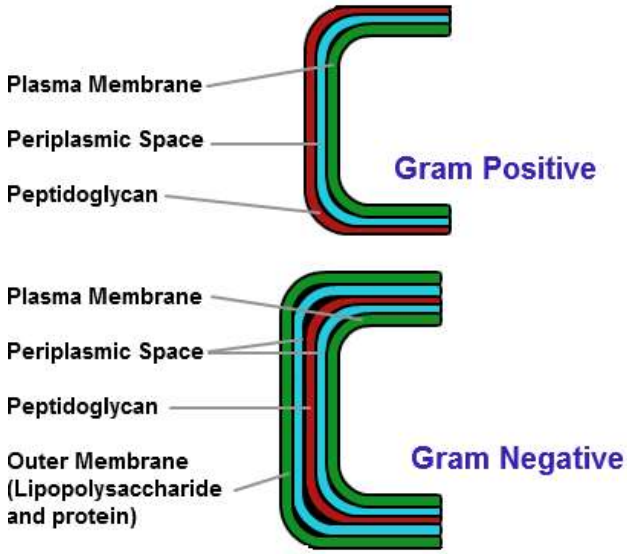
Bacterial cell wall is made up of peptidoglycans also known as murein. The cell wall of bacteria is essential for the survival of bacteria.



Cell wall of bacteria is broadly classified into two types: gram positive and gram negative. The names are given to the reaction of the cells to gram staining. This experiment is employed for the classification of bacterial species.

The gram positive bacteria have a thick cell wall and is made up of many layers of peptidoglycan and teichoic acids.

The gram negative bacteria have thinner cell walls, and is made up of few layers of peptidoglycans and is surrounded by a lipid membrane containing lipopolysacccharides and lipoproteins.

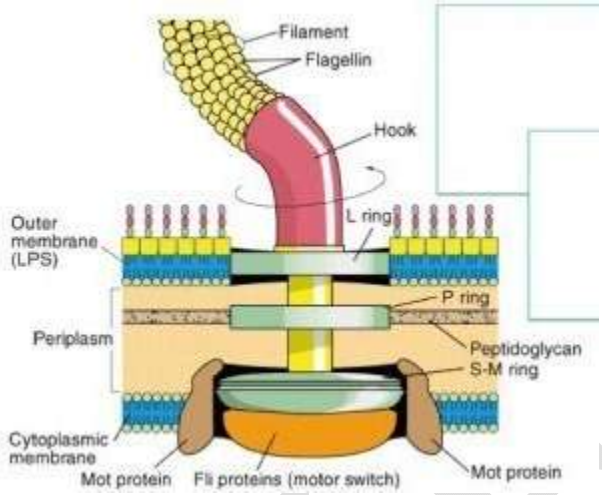


1.1.3 Flagella and motility, pili (fimbrane), capsules and spores

Flagella and motility

Bacterial flagella are long, thin (about 20 nm), whip like appendages that move the bacteria towards nutrients and other attractants. Flagella are free at one end and attached to the cell at the other end. Flagellum can never be seen directly with the light microscope but only afterstaining with special flagella stains that increase their diameter. The long filament of flagella is composed of many subunits of a single protein, flagellin, arranged in several intertwined chains. The energy for movement, the proton motive force, is provided by ATP.

Flagella are helical shaped structure which is composed of subunits of a protein called flagellin.The wider region at the base of the flagellum is called hook. It is different in structure than that of the filament. Hook connects filament to the motor portion of the flagellum called basal body.



The basal body is anchored in the cytoplasmic membrane and cell wall. There are presence of rings which are surrounded by a pair of proteins called Mot. These proteins actually drive the flagellar motor causing rotation of the filament. Another set of proteins called Fliproteinsfunction as the motor switch, reversing rotation of the flagella in response to intra-cellular signals.

1.1.4 Pili (fimbrae)

Pili are hair-like structures in bacterial walls that allow bacterial cells to adhere to other surfaces throughout their environment. Pili are also known as fimbriae.Medically, pili are virulence factors for pathogenic bacteria. A virulence factor is any property of a bacterial cell that allows the bacterium to infect another organism. Pili are considered virulence factors because they allow bacterial cells to adhere to tissues and can help the bacterial cells resist attack from immune cells in the human body. In turn, the bacterial cells can colonize the tissue and spread throughout the body, causing the organism to become sick.

1.1.5 Capsules

The cell capsule is a very large structure of some prokaryotic cells, such as bacterial cells. It is a polysaccharide layer that lies outside the cell envelope of bacteria, and is thus deemed part of the outer envelope of a bacterial cell. It is a well-organized layer, not easily washed off, and it can be the cause of various diseases.

The capsule—which can be found in both Gram-negative bacteria and Gram-positive bacteria—should not be confused with the second lipid membrane (or bacterial outer membrane), which contains lipopolysaccharides and lipoproteins and is found only in Gram-negative bacteria. When the amorphous viscid secretion (that makes up the capsule) diffuses into the surrounding medium and remains as a loose undemarcated secretion, it is known as slime layer.

1.1.6 Spores

A bacterial spore is a structure produced by bacteria that is resistant to many environmental or induced factors that the bacteria may be subjected to. Spores help bacteria to survive by being resistant to extreme changes in the bacteria's habitat including extreme temperatures, lack of moisture/drought, or being exposed to chemicals and radiation. Bacterial spores can also survive at low nutrient levels and antibiotics and disinfectants are usually ineffective against spores. These factors make it nearly impossible to eliminate bacterial spores, as they are found in many places, especially in food products.

Most bacterial spores are not toxic and do not cause any harm, but some bacteria that produce spores can be pathogenic. Most spore-forming bacteria are contained in the bacillus and clostridium species but can be found in other species of bacteria as well. There are different types of spores including endospores, exospores, and spore-like structures called microbial cysts. Each of these aid the bacteria in survival and serve as protection for the cell.

Mode of reproduction

Asexual Reproduction

Asexual reproduction in bacteria is very simple. The cell increases in size. A double wall develops across the midline of the enlarged cell. The cell separates into two cells at the midline wall. Each cell is then able to function as a separate entity. The process of multiplication can be quite rapid. The bacterium *E. coli* may double in number every 20 minutes in ideal conditions. If you plot the graph of population over time, you get an exponential increase.

Sexual reproduction

Sex in bacteria differs somewhat from what we consider sex in eukaryotes. It involves the plasmid, which has several important characteristics:

1. A plasmid is a loop of DNA. Plasmids can multiply autonomously within the cell. Thus we may find from zero to many of one or more plasmids in each cell.
2. Many plasmids can insert into the DNA of the nucleus, and detach from it. In doing so, the plasmid may leave part of the plasmid DNA behind, and take some of the nuclear DNA with it.
3. plasmids can transfer from cell to cell. The cells need not be of the same bacterial 'species'.

ALGAE

General characters

Algae (/ˈældʒi, ˈælgi/; singular alga /ˈælgə/) is an informal term for a large, diverse group of photosynthetic organisms which are not necessarily closely related, and is thus polyphyletic. Included organisms range from unicellular genera, such as Chlorella and the diatoms, to multicellular forms, such as the giant kelp, a large brown alga which may grow up to 50 m in length. Most are aquatic and autotrophic and lack many of the distinct cell and tissue types, such as stomata, xylem, and phloem, which are found in land plants. The largest and most complex marine algae are called seaweeds, while the most complex freshwater forms are the Charophyta, a division of green algae which includes, for example, Spirogyra and the stoneworts.

No definition of algae is generally accepted. One definition is that algae "have chlorophyll as their primary photosynthetic pigment and lack a sterile covering of cells around their reproductive cells". Some authors exclude all prokaryotes thus do not consider cyanobacteria (blue-green algae) as algae

Algae are eukaryotic organisms that have no roots, stems, or leaves but do have chlorophyll and other pigments for carrying out photosynthesis. Algae can be multicellular or unicellular.

Unicellular algae occur most frequently in water, especially in plankton. Phytoplankton is the population of free-floating microorganisms composed primarily of unicellular algae. In addition, algae may occur in moist soil or on the surface of moist rocks and wood. Algae live with fungi in lichens.

According to the Whittaker scheme, algae are classified in seven divisions, of which five are considered to be in the Protista kingdom and two in the Plantae kingdom. The cell of an alga has eukaryotic properties, and some species have flagella with the “9-plus-2” pattern of microtubules. A nucleus is present, and multiple chromosomes are observed in mitosis. The chlorophyll and other pigments occur inchloroplasts, which contain membranes known as thylakoids.

Most algae are photoautotrophic and carry on photosynthesis. Some forms, however, are chemoheterotrophic and obtain energy from chemical reactions and nutrients from preformed organic matter. Most species are saprobes, and some are parasites.

Classification of Algae

F E Fritsch proposed 11 classes of algae which are as follows:

1. Chlorophyceae (Green algae)
2. Cryptophyceae
3. Phaeophyceae (Brown algae)
4. Rhodophyceae (Red algae)
5. Xanthophyceae (Yellow-green algae)
6. Dinophyceae
7. Bacillariophyceae (Diatoms)
8. Chloromonadineae
9. Eugleniae
10. Chrysophyceae
11. Myxophyceae.

Distribution and Occurrence

Most algae grow permanently submerged, and are either attached (benthos) or free-floating (plankton). In fresh waters the algae of the benthos grow on stones, twigs, and larger aquatics, while the benthic seaweeds are nearly all lithophytes (i.e., fixed to rocks) . Few algae (Chara, Caulerpa) can obtain a foothold in loose sand or mud, and a rock on a sandy beach often stands covered with vegetation like an oasis in a desert. Members of the benthos may become detached from their substratum and float freely, like the tangles of filamentous algae found in ponds, or the seaweed Sargassum, innumerable plants of which drift into the North Atlantic from the Gulf of Mexico and the Caribbean sea and thus give rise to the Sargasso sea. Unattached species of Fucus are not uncommon in salt marshes, but most seaweeds are doomed when torn away from their substratum. In rivers too all algal growth, other than the plankton, is attached, either encrusting rocks and pebbles (Myxophyceae, the red Hildenbrandtia) or forming long tresses trailing out with the current (Cladophora, Ulothrix, various red algae). All benthic forms bear numerous epiphytes and their dense tangles usually harbour a wealth of smaller algae and animal life.

Reproduction

Reproduction in algae occurs in both asexual and sexual forms. Asexual reproduction occurs through the fragmentation of colonial and filamentous algae or by spore formation (as in fungi). Spore formation takes place by mitosis. Binary fission also takes place (as in bacteria).

During sexual reproduction, algae form differentiated sex cells that fuse to produce a diploid zygote with two sets of chromosomes. The zygote develops into a sexual spore, which germinates when conditions are favorable to reproduce and reform the haploid organism having a single set of chromosomes. This pattern of reproduction is called alternation of generations.

Economic Importance of Algae

1. Food:

Algae have been in use as human food for centuries in various parts of the world, including Scotland, Ireland, Norway, Sweden, France, Germany, North and South America, China, and Japan. Algae are taken in several ways according to the choice and taste of the people. They may be taken as a salad, cooked with meat or eaten as vegetable, sprinkled with oatmeal or fried with meat.

2. Fodder:

The sea weeds as fodder have been widely used in Norway, Sweden, Denmark, Scotland, America, China and New-Zealand. In Norway, Rhodymenia palmate has come to be known as 'Sheep's weed' since sheep are very fond of this particular alga. Laminaria saccharine, Ascophyllum sp., Sargassum sp. and Fucus sp., are equally liked by the catties.

3. Fertilizers:

The large Brown and Red algae are used as organic fertilizers, especially on land close to the sea. The weed is used either directly or as a seaweed meal. A concentrated extract of seaweed is also sold as a liquid fertilizer. Coralline algae Lithothamnioncalcareum and Lithophyllum sp. are used profusely for liming the soil. Similar is the use of Chara which becomes encrusted with calcium carbonate.

4. Binding of Soil Particles:

Algae act as an important binding agent on the surface of the soil. Disturbed or burnt soils are soon covered with a growth of green and blue-green algae thus reducing the danger of erosion. The role of Cyanophycean members as a pioneer in colony formation and thus in soil formation is well known.

5. Commercial Products:

Many forms of marine algae, Phaeophyceae and Rhodophyceae, are highly valuable for certain commercial products, chiefly agar-agar, algin or alginic acid and carrageenin

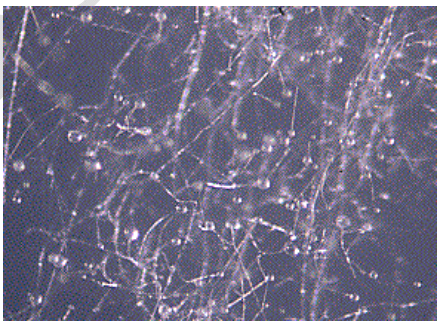
FUNGI

General Characters, distribution and occurrence

The Kingdom Fungi includes some of the most important organisms, both in terms of their ecological and economic roles. By breaking down dead organic material, they continue the cycle of nutrients through ecosystems. In addition, most vascular plants could not grow without the symbiotic fungi, or mycorrhizae, that inhabit their roots and supply essential nutrients. Other fungi provide numerous drugs (such as penicillin and other antibiotics), foods like mushrooms, truffles and morels, and the bubbles in bread, champagne, and beer.

Morphology

Like plants and animals, fungi are eukaryotic multicellular organisms. Unlike these other groups, however, fungi are composed of filaments called hyphae; their cells are long and thread-like and connected end-to-end, as you can see in the picture below. Because of this diffuse association of their cells, the body of the organism is given the special name mycelium, a term which is applied to the whole body of any fungus. When reproductive hyphae are produced, they form a large organized structure called a sporocarp, or mushroom. This is produced solely for the release of spores, and is not the living, growing portion of the fungus.



In addition to being filamentous, fungal cells often have multiple nuclei. In the chytrids and zygomycetes, the cells are coenocytic, with no distinction between individual cells. Rather, the filaments are long and tubular, with a cytoplasm lining and large vacuole in the center. By contrast, the

ascomycetes and basidiomycetes are septate; their filaments are partitioned by cellular cross-walls called septa. The structure of these septa varies, and is taxonomically useful.

Another feature of fungi is the presence of chitin in their cell walls. This is a long carbohydrate polymer that also occurs in the exoskeletons of insects, spiders, and other arthropods. The chitin adds rigidity and structural support to the thin cells of the fungus, and makes fresh mushrooms crisp.

Most members of the kingdom Fungi lack flagella; the structures are completely absent in all stages of their life cycle. The only exception are the chytrids, which produce flagellated gametes. The absence of flagella then, is a synapomorphy which unites all the remaining groups of fungi. This has had a tremendous impact on fungal biology, because it means that no fungus can produce motile gametes, and two organisms must therefore come into direct physical contact to effect sexual reproduction. For more on reproduction in fungi, click on "Life History and Ecology".

Economic Importance of fungi

Food

Fungi, especially the brewer's yeast *Saccharomyces cerevisiae*, provide us with numerous foods and beverages, including staples like bread and beer.

The brewer's yeast is not only important for the production of delicious consumables but is nutritious, being especially rich in vitamin B12. Some moulds are important in the maturation of cheeses like blue cheeses (the colour comes from the mould's spores) and for providing a meat-like flavor in the production of many rice, wheat, and soybean products (for example tempeh, miso, soy sauce) used extensively in Asian cuisine. Similarly, fungi are even used as a meat substitute in products mimicking meat, like Quorn®.

Medicine

Fungi provide extraordinarily powerful medicines that have revolutionised human health and have massive economic worth (eg antibiotics, immunosuppressants, cholesterol medicine). The penicillins and cephalosporins, cyclosporine, and statin drugs are all based on natural chemicals produced by fungi.

Mushrooms are also important ingredients in Traditional Chinese Medicine (TCM) and myriad therapeutic activities have been attributed to them, including anti-inflammatory, anti-viral and even anti-tumour effects.

Industry

Fungi have industrial applications as well and several of the 'model organisms' which enable our understanding of fundamental biology like genetics and development, are fungi. Entrepreneurs are applying fungi to provide sustainable and biodegradable structural products such as building materials, packing materials, and even vehicle bumpers.

Many enzymes produced by fungi are valuable in the paper pulp industry, for bioremediation, and even for fashion: fungal enzymes are used to soften and fade denim jeans. Scientifically, the mould *Neurosporacrassa* and the yeast *Saccharomyces cerevisiae* (brewer's yeast) are model organisms used all over the world in basic and applied science laboratories. And, in 1996, *Saccharomyces cerevisiae* became the first eukaryote to have its genome sequenced.

Agriculture

Fungi are also the humble accomplices in the domination of the planet's soils by plants: most plants rely on fungi in or on their roots to facilitate water and nutrient uptake – in fact, it is thought that root-associated fungi enabled the initial colonisation of land by plants nearly 600 million years ago. They are also the main decomposers of organic material, providing an essential service to life on the planet by recycling nutrients.

Mode of reproduction

Asexual and sexual reproduction is occurred in fungi. The most common method of vegetative reproduction is fragmentation. The hypha breaks up into small fragments accidentally or otherwise. Each fragment develops into a new individual. In the laboratory the 'hyphal tip method' is commonly used for inoculation of saprophytic fungus. The asexual reproduction takes place by means of spores. Each spore may develop into a new individual. The spores may be produced asexually or sexually and thus named (a) asexual spores and (b) sexual spores. Under asexual reproduction, only asexual spores will be considered.

VIRUSES

Viruses occupy the twilight zone that separates the 'living' from the 'non-living'. They do not have a cellular organization and contain only one type of nucleic acid, either DNA or RNA but never

both. The medical importance of viruses lies in their ability to cause a very large number of human diseases. Viral diseases range from minor ailments like common cold to terrifying diseases like rabies and AIDS.

Concept of Viruses in relation to other Organisms

Viruses occupy the twilight zone that separates the 'living' from the 'non-living'. They do not have a cellular organization and contain only one type of nucleic acid, either DNA or RNA but never both. Viruses are obligate intracellular parasites. They lack the enzymes necessary for protein and nucleic acid synthesis. They are dependent for replication on the synthetic machinery of host cells. They multiply by a complex process and not by binary fission. They are unaffected by antibacterial antibiotics. The differences between viruses and bacteria are shown in Table below

Properties	**Bacteria**	**Viruses**
Cellular organization	Present	Absent
Growth on inanimate media	Yes	No
Binary fission	Yes	No
DNA and RNA	Both are present	Either DNA or RNA
Ribosomes	Present	Absent
Sensitivity to antibacterial antibiotics	Yes	No

3.1.1 Morphology and structure of Viruses

Size:

- The extracellular infectious virus particle is called virion.
- Viruses are much smaller than bacteria.
- They are too small to be seen under the light microscope.
- Some large viruses like the poxviruses can be seen under the light microscope when suitably stained.

- The viruses range in size from 20 nm to 300 nm.
- Poxviruses are one of the largest viruses and parvoviruses are one of the smallest viruses.
- The earliest method of estimating the size of virus particles was by passing them through collodion membrane filters of graded porosity.
- The average pore diameter of the finest filter that permitted passage of the virion gave an estimate of its size.
- With the development of the ultracentrifuge, a second method became available. From the rate of sedimentation of the virus in the ultracentrifuge, the particle size could be calculated using Stoke's law.
- The third and the most direct method of measuring virus size is electron microscopy. By this method, both the shape and size of virions can be studied.

Structure, shape and symmetry:

- The virion consists essentially of a nucleic acid surrounded by a protein coat, the capsid.
- The capsid with the enclosed nucleic acid is called the nucleocapsid.
- The capsid protects the nucleic acid from harmful agents in the environment.
- It is composed of a large number of capsomers which form its morphological units.
- The chemical units of the capsid are polypeptide molecules which are arranged symmetrically. They form a shell around the nucleic acid.
- The capsid shows two kinds of symmetry – icosahedral (cubical) and helical.

An icosahedron is a polygon with 12 vertices and 20 facets or sides. Each facet is in the shape of an equilateral triangle. Two types of capsomers are present in the icosahedral capsid. They are the pentagonal capsomers at the vertices (pentons) and the hexagonal capsomers making up the facets (hexons). There are always 12 pentons but the number of hexons varies with the virus group. Examples of viruses with icosahedral symmetry of the capsid are Adenovirus and Herpes Simplex Virus.

In the nucleocapsids with helical symmetry, the capsomers and nucleic acid are wound together to form a helical or spiral tube, for example tobacco mosaic virus. All viruses do not show the typical icosahedral or helical symmetry. Some, like the poxviruses, show a complex symmetry. Virions may be enveloped or nonenveloped. The envelope of viruses is derived from the host cell membrane. This occurs when the virus is released from the host cell by budding. Protein subunits may be present as projecting spikes on the surface of the envelope. They are called peplomers. The influenza virus carries two kinds of peplomers: haemagglutinin and neuraminidase. Haemagglutinin is a triangular spike and neuraminidase is mushroom-shaped. Envelope is sensitive to the action of lipid solvents. Envelopes confer chemical, antigenic and biological properties on viruses. The overall shape of the virus particle varies in different groups of viruses. Most animal viruses are roughly spherical. The rabies virus is bullet shaped. Poxviruses are brick-shaped.

Chemical properties:

Viruses contain only one type of nucleic acid, either DNA or RNA. Viruses are unique because they carry genetic information on RNA. This property is not seen in any other organism in nature. Viruses also contain protein which makes up the capsid. Enveloped viruses contain lipids derived from the host cell membrane. Most viruses do not have enzymes for the synthesis of viral components or for energy production. Some viruses have enzymes, for example the influenza virus has neuraminidase. Resistance: Viruses are destroyed by heat except a few. They are stable at low temperatures. For long term storage, they are kept at -70°C. A better method for prolonged storage is lyophilisation or freeze-drying. Viruses are inactivated by sunlight, UV rays and ionising radiation. They are, in general, more resistant than bacteria to chemical disinfectants. Phenolic disinfectants have a weak action on viruses.

Classification and naming of viruses

Till about 1950 little was known of the basic properties of viruses. They were named haphazardly, based on the diseases they caused or on the place of their isolation. They were grouped according to affinity to different systems or organs of the body (tropism). So, human viruses were classified as dermotropic, that is those producing skin lesions (smallpox, chickenpox, measles), neurotropic, that is those affecting the nervous system (poliomyelitis, rabies), pneumotropic, that is those affecting the respiratory tract (influenza, common cold) and viscerotropic, that is those affecting visceral organs (hepatitis). Bawden (1941) made the pioneering suggestion that viral nomenclature and classification should be based on the properties of viruses and not upon host responses. From the early 1950s, viruses began to be classified into groups based on their physiochemical and structural features. Nomenclature and classification are now the official responsibility of the International Committee on Taxonomy of Viruses (ICTV). Viruses are classified into two main divisions based on the type of nucleic acid they possess: riboviruses contain RNA and deoxyriboviruses contain DNA. Further classification is based on other properties like strandedness of nucleic acid, symmetry of nucleic acid, presence of envelope, size and shape of virion and number of capsomeres. DNA viruses: A few medically important families of DNA viruses are - Herpesviridae, Adenoviridae, Hepadnaviridae, Parvoviridae and Papillomaviridae. The Herpesviridae family consists of enveloped double-stranded DNA viruses having an icosahedral capsid. Examples of this family are herpes simplex virus and varicella zoster virus. Herpes simplex virus causes skin lesions like herpes labialis. It can also cause viral encephalitis. Parvoviridae consists of nonenveloped single-stranded DNA viruses, for example Parvovirus B19. The Hepadnaviridae family includes Hepatitis B virus which is a partially doublestranded DNA virus. Papillomaviridae family includes human papilloma virus which is responsible for causing skin warts. RNA viruses: Some medically important families of RNA viruses are – Picornaviridae, Orthomyxoviridae and Paramyxoviridae, Flaviviridae, Rhabdoviridae and Retroviridae. Members of the family Picornaviridae are small (20-30 nm), non-enveloped,

icosahedral viruses with single-stranded RNA genome. Examples include poliovirus and coxsackievirus. The viruses included in Orthomyxoviridae are enveloped viruses carrying haemagglutinin and neuraminidase peplomers on the envelope. The genome consists of singlestranded RNA in several (eight) pieces. Thus, they have a segmented genome. An example of this family is influenza virus. Flaviviridae consists of enveloped single-stranded RNA viruses. Examples include yellow fever virus, Japanese encephalitis virus and dengue virus. The members of Retroviridae family are enveloped RNA viruses which have a special enzyme called 'reverse transcriptase'. This enzyme is an RNA dependent DNA polymerase. It is required in the synthesis of DNA from RNA. An example of the Retroviridae family is Human Immunodeficiency Virus (HIV) which causes AIDS (acquired immunodeficiency syndrome). Based on the mechanism of replication, Baltimore (1970) categorised viruses into seven categories. This is called the Baltimore classification.

Virion:

A complete viral particle, consisting of RNA or DNA surrounded by a protein shell capsid and constituting the infective form of a virus. It is also known as virus is ready for infection. The capsid protects the interior core that includes the genome and other proteins. All virions have genomic nucleic acid: this maybe either RNA or DNA, ss (single stranded) or ds(double stranded). After the virion binds to the surface of a specific host cell, its DNA or RNA is injected into the host cell and viral replication occurs with eventual spread of the infection to other host cells.

Virusoids:

Virusoids are circular single-stranded RNAs dependent on plant viruses for replication and encapsidation. The genome of virusoids consists of several hundred nucleotides and only encodes structural proteins. Virusoids are similar to viroids in size, structure and means of replication .Virusoids while being studied in virology, are not considered as viruses but as subviral particles.

Prion:

It is an infectious protein particle similar to a virus but lacking nucleic acid; thought to be the agent responsible for scrapie and other degenerative diseases of the nervous system. The term Prion was coined in 1982 by Neurologist Stanley Prusiner. Prions are infectious proteinaceous particles that lack nucleic acid. Prions are said to be in the border zone between nonliving and living things because they have no need to metabolize or the capacity to reproduce but they are capable of replication within the body of a human or of some mammals.

Prions can gain entry into the body mainly by ingestion, e.g. of contaminated human. Growth Hormone or of contaminated blood or blood products. Prions may also arise from a mutation in the gene that encodes the protein. They not only fold into unusual shapes but also seem to have the ability to cause other (normal) proteins to alter their shape as well.

Viroid:

Viroid an infectious agent that consists solely of a single strand of RNA and causes disease in certain plants. It was discovered by T.O .Diener in 1971 .Viroids lack the protein coat (known as capsid) of viruses and are the smallest known infectious agents containing only about 250 to 375 base pairs. They are much smaller than the smallest genomes of viruses and have no genes for encoding proteins. Viroids are believed to cause disease by interfering with the host cell's gene regulation. They are destructive to many important commercial plants, including potatoes, Lycopersicom, Cucumis, Cocos, and Chrysanthemum etc.

Mode of Reproduction

Multiplication of Viruses

Multiplication of viruses is called viral replication. Viruses contain the genetic information for their replication but they lack the enzymes. They depend on host cell machinery for replication. The viral replication cycle can be divided into six phases – adsorption, penetration, uncoating, biosynthesis, maturation and release. Adsorption: In this phase, the virus gets attached to the host cell. The host cell should have specific receptors on its surface. These receptors recognize viral surface components. This cell-virus interaction helps the virus to attach to the host cell surface. Penetration: In this phase, the virus enters into the host cell. Bacteria have rigid cell wall. So, viruses which infect bacteria cannot penetrate into the bacterial cell. Only the nucleic acid of the virus enters the bacterial cell. Animal and human cells do not have cell walls. Therefore, whole virus enters the cell. Virus particle may be engulfed by a process called viropexis. In case of enveloped viruses, the viral envelope may fuse with the cell membrane of the host cell. Then the nucleocapsid is released into the cytoplasm. Uncoating: This is the process in which the outer layers and capsid of the virus are removed. This mostly occurs by the action of lysosomal enzymes of the host cell. This can also occur by a viral uncoating enzyme. Finally, the viral nucleic acid is released into the cell. Biosynthesis: In this phase, the viral nucleic acid and capsid are synthesised. The enzymes necessary in the various stages of viral synthesis, assembly and release are also synthesised. Certain 'regulator proteins' are synthesised. They shut down the normal metabolism of the host cell. They direct the production of viral components. In general, most DNA viruses synthesise their nucleic acid in the host cell nucleus. Exceptions are the poxviruses. They are DNA viruses, but they synthesise all their components in the host cell cytoplasm. Most RNA viruses synthesise all their components in the cytoplasm. Orthomyxoviruses and some paramyxoviruses are exceptions. They synthesise some components in the host cell nucleus. Biosynthesis consists essentially of the following steps: 1.

Transcription of messenger RNA (mRNA) from the viral nucleic acid 2. Translation of mRNA into "early proteins" or "non-structural proteins". They are enzymes responsible for the synthesis of viral components. 3. Replication of viral nucleic acid 4. Synthesis of "late proteins" or "structural proteins". They are the components of daughter virion capsids. Maturation: This is the assembly of daughter virions following the synthesis of viral nucleic acid and proteins. It can take place in the host cell nucleus or cytoplasm. Herpesviruses and adenoviruses are assembled in the nucleus. Picornaviruses and poxviruses are assembled in the nucleus. Release: Viruses which infect bacteria (bacteriophages) are released by lysis of the infected bacterium. Animal viruses are usually released without cell lysis. Myxoviruses are released by budding from the cell membrane. The host cell is unaffected. Daughter virions are released into the surrounding medium and may infect other cells. In some viruses (for eg. varicella), transmission occurs directly from cell to cell. In this case, there is very little free virus in the medium. The poliovirus causes cell damage and may be released by cell lysis. From the stage of penetration till the appearance of mature daughter virions, the virus cannot be demonstrated inside the host cell. During this period, the virus seems to disappear. This is called the "eclipse phase". The time taken for a single cycle of replication is about 15-30 minutes for bacteriophages. It is about 15- 30 hours for animal viruses. A single infected cell may release a large number of progeny virions

POSSIBLE QUESTIONS

UNIT-I

PART-A (20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B (2 MARKS)

1. Write a short note about pasteurization
2. Give a list of Anton von Leeuwenhoek contributions
3. What is binomial nomenclature?
4. Describe the spontaneous generation vs. biogenesis

PART-C (8 MARKS)

1. Give a detail about development of various microbiological techniques
2. Describe the role of microorganisms in fermentation
3. Write about the goldern era of microbiology
4. Distinguish between prokaryotic and eukaryotic microorganisms
5. Give a detail about Whittaker's and Carl Woese's classification

S.No	Unit - II	Option 1	Option 2	Option 3	Option 4	Answer
1	Filament synthesis is an excellent example of	self assembly	Mutualism	Parasitism	Commensalism	**self assembly**
2	The inclusion bodies of procaryotic cells are present in the .	plasma membrane	cytoplasmic matrix	nucleus	ribosomes	**cytoplasmic matrix**
3	is needed for peptidoglycan synthesis.	lactose	mannitol	glucose	sucrose	**glucose**
4	are present in many cyanobacteria, nitrifying bacteria and thiobacilli	carboxyzomes	nitrates	pigment	pili	**carboxyzomes**
5	is the typical example of bacterium with rod shape.	Bacillus megaterium	Streptococcus	Corynebacterium	Proteus	**Bacillus megaterium**
6	Some bacteria are variable and lack a single characteristic form are called .	atrichous	pleomorphic	irregular	diploid	**pleomorphic**
7	The length of Oscillatoria is about in diameter.	7micrometer	2micrometer	5micrometer	1micrometer	**7micrometer**
8	The most widely accepted current model for membrane structure is the .	Direct model	Varied model	Fluid mosaic model	Common model	**Fluid mosaic model**
9	contains beta hydroxybutyrate molecules joined by ester bonds between the carboxyl and hydroxyl groups.	Poly beta hydroxybutyrate	magnetosomes	Esters	phosphate granules	**Poly beta hydroxybutyrate**
10	Many bacteria store phosphate as .	iron	phosphate	polyphosphate granules	butyrate	**polyphosphate granules**
11	The inorganic inclusion bodies magnetosome contain iron in the form of .	iron	magnetite	Phosphate	esters	**magnetite**
12	The S in 70S ribosome and similar values stands for	Svedberg unit	Simple unit	Sample unit	Sigma unit	**Svedberg unit**

13	. The chromosome in the procaryotic cell is located in an irregularly shaped region called .	ribosome	cytoplasm	nucleoid	cell wall	**nucleoid**
14	The peptidoglycan layer lying outside the plasma membrane is otherwise called as .	Murine layer	Glycan layer	outer layer	cell wall	**Murine layer**
15	The gram positive cell wall usually contains large amounts of .	Calcium ions	Iron	teichoic acid	Lipopolysaccharide	**teichoic acid**
16	A is a zone of diffuse, unorganised material that is removed easily.	Murine layer	Slime layer	outer layer	Flagellin	**Slime layer**
17	bacteria have a single flagellum at each pole.	Pertrichous	Atrichous	Amphitrichous	Polar flagella	**Amphitrichous**
18	The filament of flagella consist of a single protein called .	insulin	Flagellin	Thymine	Pectin	**Flagellin**
19	Cyanobacteria undergo a different type of motility called .	Gliding motility	Twisting motility	Dwelling	Moving	**Gliding motility**
20	The special resistant dormant structure produced by gram positive bacteria is called an .	Exospore	Outer coat	Spore coat	Endospore	**Endospore**
21	As much as 15% of the endospores dry weight consist of .	Magnesium ions	Lipopolysaccharide	Dipicolinic acid	Peptidoglycan	**Dipicolinic acid**
22	The endospores spore coat is made up of .	Lipopolysaccharide	Peptidoglycan	teichoic acid	Dipicolonic acid	**Peptidoglycan**
23	Movement toward chemical attractants and away from repellents is known as .	Chemoreceptors	Chemotaxis	Chemical repellents	Repellents	**Chemotaxis**
24	Attractants and repellents are	Chemoreceptors	Chemotaxis	Chemical	Repellents	**Chemoreceptors**

	detected by a special proteins called .			repellents		
25	links the filament to its basal body and act as a flexible coupling.	Neck	Hook	Filament	Hair	**Hook**
26	The meaning of trichous is .	Head	Thin	Long	Hair	**Hair**
27	aid in the attachment of bacteria to objects .	pili	Fimbriae	Flagella	cell wall	**Fimbriae**
28	aids in the motility of gliding bacteria.	Slime	Fimbriae	Flagella	Pili	**Slime**
29	Sporulation takes place for 10hrs in .	Streptococcus	Bacillus megaterium	Bacillus anthraces	Corynebacterium	**Bacillus megaterium**
30	The synthesis of flagella involves genes	20-30	40-50	15-30	30-40	**20-30**
31	The information required for flagella construction is present in the structure of .	Flagellin	hook	filament	basal body	**Flagellin**
32	The peptidoglycan material found in archaeobacterial cel wal is called _____	Glycopeptide	Mucopeptine	Pseudomurein	Muramic acid	**Pseudomurein**
33	Bacterial flagella anchor in to the cell wall and membrane by means of the ----------	Pilin	. Stalk	Periplasm	Basal body	**Basal body**
34	Flagella of Spirocheates are called ---------- flagella	Triplasmic	Periplasmic	Metaplasmic	Megaplasmic	**Metaplasmic**
35	---------- are membrane bound organelles in eukaryotic cells that contain very powerful digestive enzymes.	Mesosomes	Lysosomes	Metasomes	Trisomes	**Lysosomes**
36	The peptidoglycon layer of Gram negative bacteria is located in the ---------- space	Triplasmic	Metaplasmic	Periplasmic	Megaplasmic	**Periplasmic**
37	Mycoplasma is an example of	Gram negative	Cellwall high	Neutral	Cellwall less	**Cellwall less**

	---------- bacteria					
38	In archaeobacterial cell wall instead of NAM _____ is present	N-acetyl talosaminuronic acid	N-butyl talosaminuronic acid	D-alanine	L-Lysine	**N-acetyl talosaminuronic acid**
39	Pili contains the protein _____	Pilin	Valine	Glutamin	Primidine	**Pilin**
40	Carboxysomes are involved in _____ fixation	N_2	O_2	CO_2	H_2	**CO2**
41	Cell membrane of archaeobacteria contains long chain branched alcohol called _____	Phytanol	Butanol	Acetanol	Methanol	**Phytanol**
42	Lipid content is more in the cell wall of Gram _____ bacteria	Negative	Positve	parasite	virus	**Negative**
43	Volutin granules are also called as _____	Gas vacuoles	. Mitochondria	Endoplasmic reticulum	Metachromatic granules	**Metachromatic granules**
44	Membrane invaginations in to the bacterial cytoplasm are known as _____	Mesosomes	Cytosomes	Hydroxysomes	Carboxysomes	**Mesosomes**
45	The outer L ring is assosiated with layer in the Gram negative bacteria	Lipid	Lipopolysaccharide	Lactose	Lactone	**Lipopolysaccharide**
46	In prokaryotic cells the region where DNA is located is referred to as_____	Nucleoid	Nuclear region	Nuclear body	Nucleosome	**Nuclear region**
47	Which of the following structure is not present in bacterial cells?	Ribosome	RNA	Cell membrane	Mitochondria	**Ribosome**
48	The nuclear material in a bacterial cell is known as _____	Nucleus	Nucleoid	Nucleous	Nucleosome	**Nucleous**
49	Which of the following	Contains	Contains cell	Contains	Contains outer	**Contains**

	statement is correct with reference to Gram positive bacteria?	periplasmic space	membrane	lipopolysaccharide	membrane	**lipopolysaccharide**
50	Semi rigid extension of bacterial cell wall and cell membrane is called_____	Capsule	Stalk	Slime	Prosthecae	**Prostheca**
51	Gas vesicles are mostly present in _____	Gram positive bacteria	Gram negative bacteria	Photosynthetic bacteria	Aquatic bacteria	**Aquatic bacteria**
52	Bacterial ribosomes are composed of	Protein and DNA	Protein and rRNA	Protein and mRNA	Protein and RNA	**Protein and rRNA**
53	Which of the following is found in both Gram positive and Gram negative bacteria?	Peptidoglycon	Teichoic acid	O antigen	Outer membrane	**Peptidoglycon**
54	Sub units of bacterial ribosome are _____	60S and 40S	70S and 80S	60S and 30S	50S and 30S	**50S and 30S**
55	Periplasmic space is found in _____	Between cell wall and cell membrane	Below cell membrane	Within outer membrane	In between outer membrane and peptidoglycon	**Between cell wall and cell membrane**
56	Which of the following is a motile bacterium?	*E. coli*	*Shigella*	*Klebsiella*	Giardia	**E. coli**
57	Which of the following is not a motile bacterium?	*Pseudomonas*	*Vibrio*	*Bacillus*	*Klebsiella*	**Klebsiella**
58	Fungi with known sexual stages are called _____	Pathogenic fungi	Rreproductive fungi	Perfect fungi	Saprophytic fungi	**Perfect fungi**
59	A temporary projection of part of cytoplasm that helps in the motility of protozoa is called	Flagellum	Pseudopodium	Pili	Cilia	**Pseudopodium**
60	The bacterium which bears many flagellum at one end is	Peritrichous	Lophotrichous	Monotrichous	Amphitrichous	**Lophotrichous**

known as

UNIT- III

SYLLABUS

Viruses, viroids and prions

An introduction to viruses with special reference to the structure and replication of the following: Poxvirus, Poliovirus, HIV, T4 and λ phage, lytic and lysogenic cycles.

3.1 Viruses

Viruses occupy the twilight zone that separates the 'living' from the 'non-living'. They do not have a cellular organization and contain only one type of nucleic acid, either DNA or RNA but never both. The medical importance of viruses lies in their ability to cause a very large number of human diseases. Viral diseases range from minor ailments like common cold to terrifying diseases like rabies and AIDS.

3.2 phages

3.2.1 Types of phages

Bacteriophage (also known as phages) are viruses that target and infect only bacterial cells. The first observation of what since turned out to be bacteriophage was made in 1896. Almost twenty years later, the British bacteriologist Frederick Twort demonstrated that an unknown microorganism that could pass through a filter that excluded bacteria was capable of destroying bacteria. He did not explore this finding in detail, however. In 1915, the French Canadian microbiologist Felix d'Herelle observed the same result, and named the microorganism bacteriophage (bacteria eater, from the Greek *phago,* meaning to eat).

Many types of bacteriophage have been identified since their discovery in 1915, and they are named according to the type of bacteria they infect. For example, staphylophages are specific viruses of the staphylococcal bacteria, and coliphages specifically infect coliform bacteria.

Bacteriophage are the most thoroughly studied and well-understood viruses. They occur frequently in nature, carry out similar biological functions as other viruses, yet do not target human cells for infection. Phages have proven to be a valuable scientific research tool for a variety of applications: as models for the study of viral infectious mechanisms, as tools of biotechnology that introduce new genes into bacterial cells, and as potential treatments for human bacterial infection. For example, the experiments that lead to the discovery of messenger

Ribonucleic acid, one of the keys to the manufacture of protein in bacteria, viruses, and even cells found in humans, were accomplished using a bacteriophage. Another example is the bacteriophage designated T4, which specifically infects the bacterium *Escherichia coli*. T4 has been a cornerstone of molecular biology; studies of the way T4 makes new copies of itself has revealed a great deal of information about

bacteriophage genetics and the regulation of the expression the gene viral genetic material. Additionally, another bacteriophage, called lambda, has been fundamentally important to molecular biology as a model system for gene regulation and as a means of moving genetic material from one bacterium to another.

3.2.2 Phage Structure

The virion of T-even phage is binal or tadpole like structure with a polyhedral head connected to a helical tail through a short collar. The head composed of about 2000 capsomeres arid encloses a tightly packed dsDNA (50 nm long). The tail has an inner hollow tube called core, surrounded by a contractile sheath which consists of 24 annular rings. The distal end of the tube is connected to a hexagonal basal plate with spike or tail spin at each corner. Six long, flexible tail fibers also arise from the basal plate which helps in adsorption to bacteria.

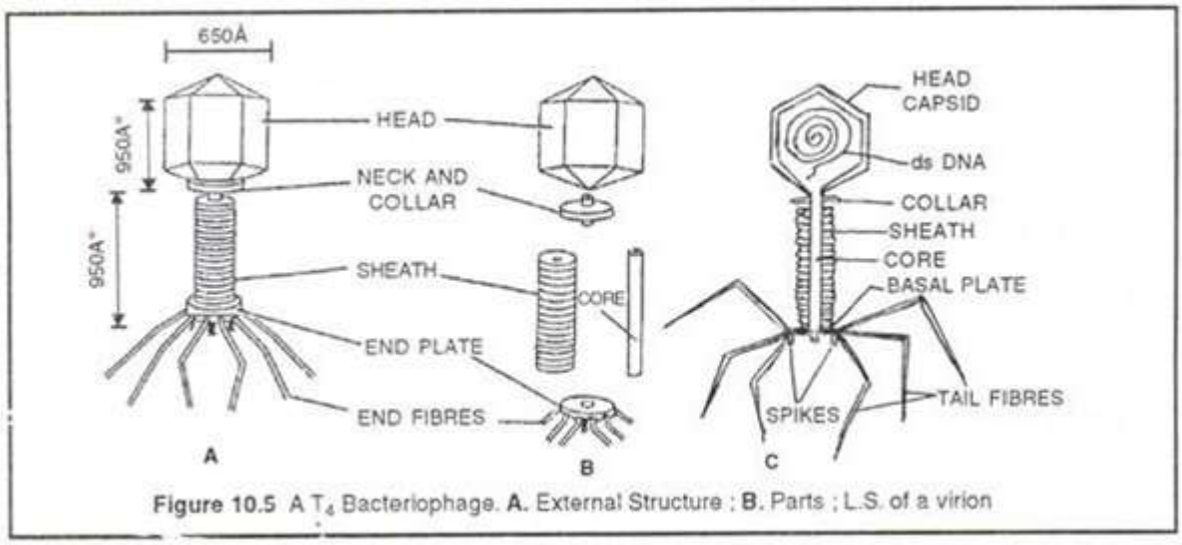


Figure 10.5 A T_4 Bacteriophage. **A.** External Structure ; **B.** Parts ; L.S. of a virion

Reproduction (Replication cycle):

Bacteriophages exhibit two types of replication cycle – virulent or lytic cycle and temperate or lysogenic cycle.

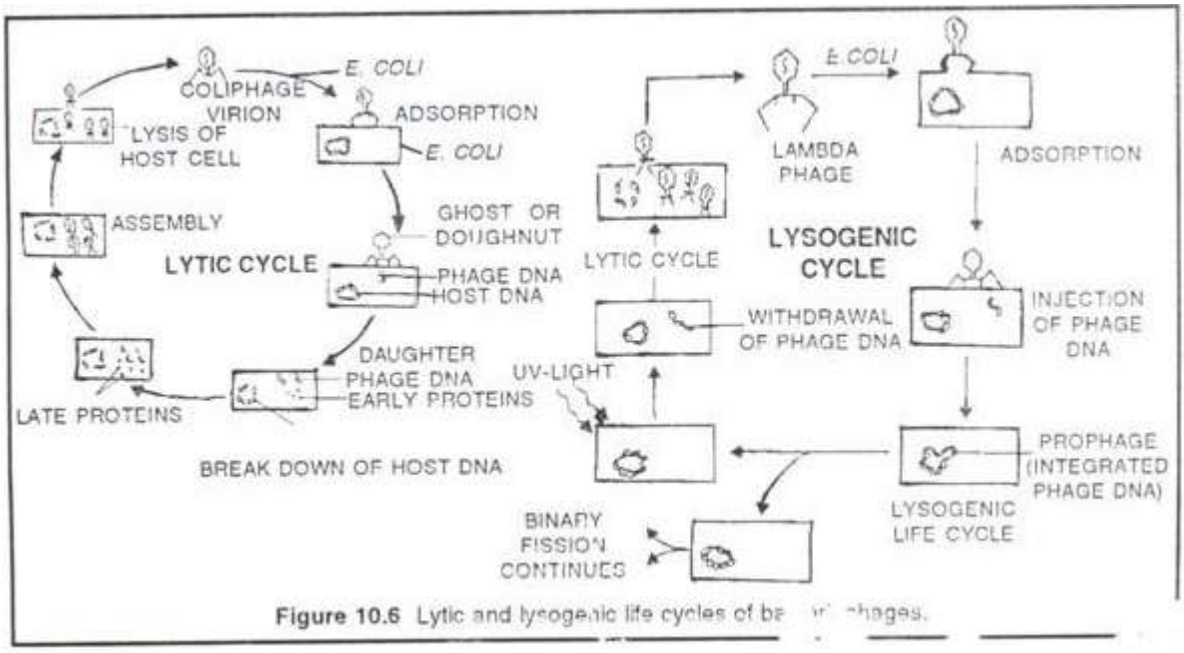


Figure 10.6 Lytic and lysogenic life cycles of bacteriophages.

3.2.3 Virulent or lytic cycle:

The phages undergoing lytic cycle are called lytic phages or virulent phages, e.g., T-series bacteriophages. In lytic cycle, a lytic phage infects and kills the host cell to release progeny virions.

The whole process involves following steps:

(a) Adsorption or infection

(b) Penetration or injection

(c) Synthesis of phage components

(d) Virion assembly

(e) Lysis or release

Step-1. Adsorption or infection:

The lytic cycle begins with a collision between T-phage virion and a susceptible host cell i.e. Escherichia coli. The process of attachment of a virion on the host cell surface is called adsorption. The tips of tail fibers bind or adsorb to specific receptors on the surface of E. coli.

The viral receptors may be F-pili, lipoproteins, iron transport proteins etc. The T-phage virion adsorb to specific receptors by the tip of tail fibers. For example, T4 and T7 coliphages bind to lipopolysaccharides.

Step-2. Penetration or Injection:

The tail fibers of virion bend to bring the spikes and basal plate in contact with the surface of bacterial wall. The tail sheath contracts so that the hollow tail core (inner tube) penetrates the bacterial wall and injects the viral genome into the cytoplasm. After penetration, the empty capsid that remains outside the bacterium is called the ghost or doughnut.

Step-3. Synthesis of phage components:

Immediately after penetration, the phage DNA (genome) synthesizes early proteins. Some early proteins break down the bacterial (host) DNA and take the control of the bacterial cell machinery. The other early proteins used as enzymes for replication of phage DNA. The newly synthesized phage DNAs produces late proteins, which are the protein subunits of the phage capsid (head and tail).

Step-4. Virion assembly:

The capsid proteins assemble to form empty head and a condenced viral DNA is packed inside it. Finally the separately assembled tail joins to head to form a daughter or progeny virion.

Step-5. Lysis or release:

During assembly of progeny virions, the bacterial cell becomes spherical. The phage enzymes weaken the cell wall which ultimately burst or lyse to release about 100-200 progeny virions.

3.2.4 Temperate or lysogenic cycle:

The phages that exhibit lysogenic cycle are called temperate phages or non-virulent phages. For example, λ, (Lambda)- phages attacking, E. coli. During lysogenic cycle, the phage DNA integrates into the bacterial DNA and is now called as prophage. The host bacterium containing prophage is called a lysogenic bacterium or lysogen. The prophage passively replicates along with the host DNA for many generations. When a lysogenic bacterium exposed to UV-light or a chemical, the prophage withdraw from the host DNA to undergo lytic cycle. This conversion of a prophage into a lytic phage is called induction.

3.3 Retro viruses

A retrovirus is a single-stranded positive-sense RNA virus with a DNA intermediate and, as an obligate parasite, targets a host cell. Once inside the host cell cytoplasm, the virus uses its own reverse transcriptase enzyme to produce DNA from its RNA genome, the reverse of the usual pattern, thus retro (backwards). The new

DNA is then incorporated into the host cell genome by an integrase enzyme, at which point the retroviral DNA is referred to as a provirus. The host cell then treats the viral DNA as part of its own genome, translating and transcribing the viral genes along with the cell's own genes, producing the proteins required to assemble new copies of the virus. It is difficult to detect the virus until it has infected the host. At that point, the infection will persist indefinitely.

In most viruses, DNA is transcribed into RNA, and then RNA is translated into protein. However, retroviruses function differently, as their RNA is reverse-transcribed into DNA, which is integrated into the host cell's genome (when it becomes a provirus), and then undergoes the usual transcription and translational processes to express the genes carried by the virus. The information contained in a retroviral gene is thus used to generate the corresponding protein via the sequence: RNA → DNA → RNA → polypeptide. This extends the fundamental process identified by Francis Crick (one gene-one peptide) in which the sequence is DNA → RNA → peptide (proteins are made of one or more polypeptide chains; for example, haemoglobin is a four-chain peptide).

Retroviruses are valuable research tools in molecular biology, and they have been used successfully in gene delivery systems.

3.3.1 HIV-AIDS virus working of immune system in the presence of HIV- Replication in target cell

Introduction

Human immunodeficiency virus (HIV) is a virus that causes the condition acquired immunodeficiency syndrome (AIDS). The virus attacks a specific type of immune system cell in the body, known as CD4 helper lymphocyte cells. HIV destroys these cells, making it harder for your body to fight off other infections. When you have HIV, even a minor infection (like a cold) can be much more severe because your body has difficulty healing.

HIV is transmitted through contact with the following bodily fluids:

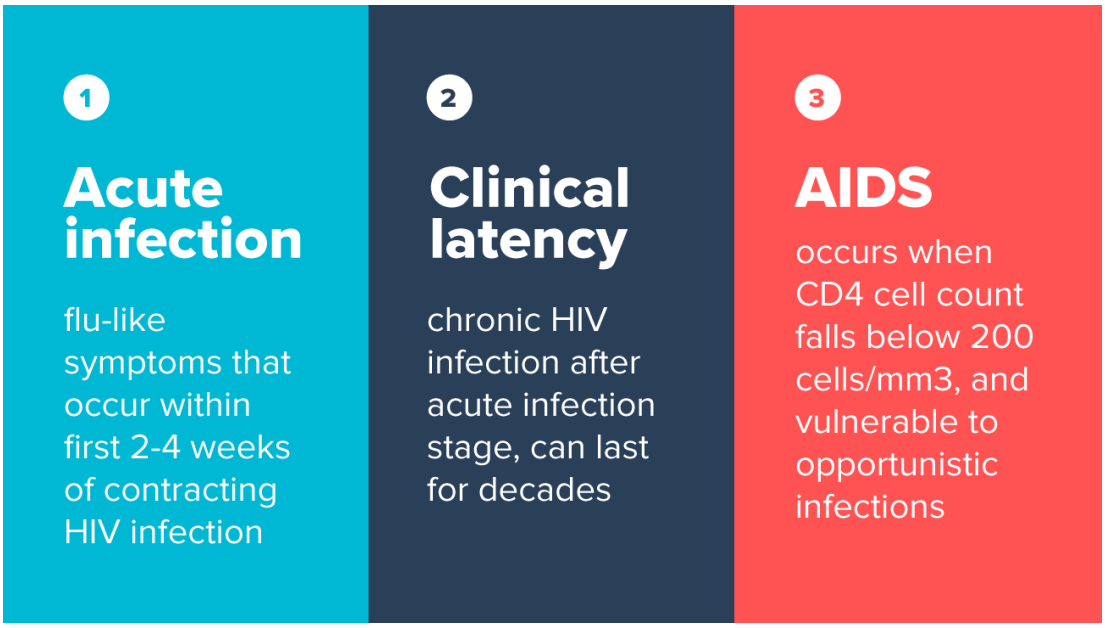
- blood
- breast milk
- semen
- vaginal fluid

Sexual contact and sharing contaminated needles — even tattoo or piercing needles — can result in the transmission of HIV.

Not only does HIV attack CD4 cells, it also uses the cells to make more of the virus. When the virus has destroyed a certain number of CD4 cells, doctors will call this stage AIDS. A person with AIDS is very vulnerable to infections, such as pneumonia. People with lowered immune systems can also get cancers, such as lymphoma.

HIV doesn't always multiply rapidly. It can take years for a person's immune system to be affected enough to have symptoms. A person with HIV will often progress through several phases before their condition is considered AIDS. Taking medications carefully can help to slow the disease's progression.

Stages of HIV



Doctors have classified three HIV stages: acute HIV infection, chronic HIV infection, and AIDS.

Acute HIV infection

Once a person becomes infected with HIV, an acute infection will take place two to four weeks later. At this time, the virus is multiplying in the body, attacking CD4 cells. This initial infection can result in flu-like symptoms. Examples of these symptoms include:

- fever
- headache
- rash

However, not all people with HIV experience initial flu-like symptoms. The flu symptoms are due to the increase of HIV viruses in the body. During this time, the amount of CD4 cells starts to fall very quickly. The immune system then kicks in, which causes CD4 levels to once again rise. However, the CD4 levels may not return to their preinfection height.

In addition to causing symptoms, the acute stage is when HIV is at its greatest risk for transmission to other people. This is because HIV levels are very high at this time. The acute stage typically lasts between several weeks and months.

Clinical latency

The chronic HIV infection stage is known as the latent or asymptomatic stage. During this stage, you usually won't have as many symptoms as you did during the acute phase. The virus multiplies less quickly during the chronic stage. However, you can still transmit the HIV infection.

Without any treatment, the chronic HIV infection stage lasts anywhere from 10 to 12 years before advancing to AIDS. If a person is taking treatments for HIV, the chronic HIV infection stage may last several decades. According to AIDS.gov, if you take treatments for HIV and your HIV levels are low, you can live a normal to nearly normal life span. It's also possible that the infection will never progress to the AIDS phase.

AIDS

A doctor diagnoses a person with AIDS when they have a CD4 count of less than 200 cells/^{3} (a measurement of the cells in the blood) and they've had an opportunistic infection, such as tuberculosis, cancer, or pneumonia. A normal CD4 count ranges from 500–1,600 cells/mm^3 in healthy adults.

Unfortunately, when a person's HIV progresses to AIDS, the survival rate is usually about three years.

What factors affect disease progression?

While HIV does progress in phases, some people go through the phases more quickly than others. Taking medicatijons, known as antiretroviral therapy (ART), can slow this progression for more people. Factors that affect HIV progression can include:

- Your age when your symptoms started: Being older can result in faster progression of HIV.
- Your health before treatment: If you had other diseases, such as tuberculosis, hepatitis C, or other sexually transmitted diseases, it can affect your overall health.
- How soon you were diagnosed after you were infected: The longer between your diagnosis and treatment, the faster the disease can progress.
- Your lifestyle: Maintaining an unhealthy lifestyle, such as having a poor diet and experiencing severe stress, can aid HIV progression.
- Whether you take your medications as prescribed
- Your genetic history: Some people just seem to progress more quickly through their disease.

Some factors can delay or slow the progression of HIV. These include:

- taking your ART medications as your doctor prescribes
- seeing your doctor as recommended for HIV treatments
- eating a healthy diet
- taking care of yourself, including having protected sex, trying to minimize stress in your life, and sleeping regularly

Living a healthy lifestyle and seeing your doctor regularly can make a big difference in your overall health.

How is HIV treated?

Treatments for HIV typically involve ART. This isn't a specific regimen, but instead a combination of several drugs. There are currently 25 different FDA-approved medicines to treat HIV. ART works to prevent the virus from copying itself. This maintains your immunity levels while slowing the progression of HIV.

Your doctor will take into consideration your health history, the levels of the virus in your blood, possible side effects, costs, and any allergies you may have before prescribing medications. There are six classes of HIV drugs. Most doctors will start you on a combination of three medications from at least two different drug classes. These classes are:

- CCR5 antagonists (CCR5s)
- fusion inhibitors
- integrase stand transfer inhibitors (INSTIs)
- non-nucleoside reverse transcriptase inhibitors (NNRTIs)
- nucleoside reverse transcriptase inhibitors (NRTIs)
- protease inhibitors

Your doctor may prescribe several different medication types before you find the best regimen for you.

How is HIV prevented?

HIV is an especially dangerous virus because it doesn't cause a lot of outward or noticeable symptoms until the disease has progressed. For this reason, it's important to understand how HIV is transmitted and ways you can work to prevent transmission.

HIV can be transmitted by:

- having sex, including oral, vaginal, and anal sex
- sharing needles, including tattoo needles, needles used for body piercing, and needles used for injecting drugs
- coming in contact with body fluids, such as blood, semen, vaginal fluid, and breast milk

HIV is not transmitted by:

- breathing the same air as an infected person
- getting bitten by a mosquito or other biting insect
- hugging, holding hands with, kissing, or touching an infected person
- touching a door handle or toilet seat an infected person has used

Keeping this in mind, some of the ways you can prevent HIV include:

- refraining from oral, anal, or vaginal sex (known as the abstinence method)
- always using a latex barrier, such as a condom, when you have oral, anal, or vaginal sex
- never sharing needles with others

If you've had unprotected sex or shared needles with anyone in the past, doctors usually recommend getting an HIV test at least once a year. Symptoms can take years to appear, which is why it's so important to get tested regularly.

Conclusion

Advances in HIV treatments mean that people can live longer with the condition. Getting tested regularly and taking good care of yourself is vital to keeping your disease from progressing to the AIDS phase.

Pox Virus:

Yaba virus produces histiocytoma (benign tumour) in natural host (monkey) while shope fibroma virus induces fibroma in rabbit. Molluscumcontagiosum virus produces benign growths in humans.

POSSIBLE QUESTIONS

UNIT-I

PART-A (20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B (2 MARKS)

1. Write a short note about pasteurization
2. Give a list of Anton von Leeuwenhoek contributions
3. What is binomial nomenclature?
4. Describe the spontaneous generation vs. biogenesis

PART-C (8 MARKS)

1. Give a detail about development of various microbiological techniques
2. Describe the role of microorganisms in fermentation
3. Write about the goldern era of microbiology
4. Distinguish between prokaryotic and eukaryotic microorganisms
5. Give a detail about Whittaker's and Carl Woese's classification

S.No	Unit - III	Option 1	Option 2	Option 3	Option 4	Answer
1	Filament synthesis is an excellent example of	self assembly	Mutualism	Parasitism	Commensalism	**self assembly**
2	The inclusion bodies of procaryotic cells are present in the .	plasma membrane	cytoplasmic matrix	nucleus	ribosomes	**cytoplasmic matrix**
3	is needed for peptidoglycan synthesis.	lactose	mannitol	glucose	sucrose	**glucose**
4	are present in many cyanobacteria, nitrifying bacteria and thiobacilli	carboxyzomes	nitrates	pigment	pili	**carboxyzomes**
5	is the typical example of bacterium with rod shape.	Bacillus megaterium	Streptococcus	Corynebacterium	Proteus	**Bacillus megaterium**
6	Some bacteria are variable and lack a single characteristic form are called .	atrichous	pleomorphic	irregular	diploid	**pleomorphic**
7	The length of Oscillatoria is about in diameter.	7micrometer	2micrometer	5micrometer	1micrometer	**7micrometer**
8	The most widely accepted current model for membrane structure is the .	Direct model	Varied model	Fluid mosaic model	Common model	**Fluid mosaic model**
9	contains beta hydroxybutyrate molecules joined by ester bonds between the carboxyl and hydroxyl groups.	Poly beta hydroxybutyrate	magnetosomes	Esters	phosphate granules	**Poly beta hydroxybutyrate**
10	Many bacteria store phosphate as .	iron	phosphate	polyphosphate granules	butyrate	**polyphosphate granules**
11	The inorganic inclusion bodies magnetosome contain iron in the form of .	iron	magnetite	Phosphate	esters	**magnetite**
12	The S in 70S ribosome and similar values stands for	Svedberg unit	Simple unit	Sample unit	Sigma unit	**Svedberg unit**

13	. The chromosome in the procaryotic cell is located in an irregularly shaped region called .	ribosome	cytoplasm	nucleoid	cell wall	**nucleoid**
14	The peptidoglycan layer lying outside the plasma membrane is otherwise called as .	Murine layer	Glycan layer	outer layer	cell wall	**Murine layer**
15	The gram positive cell wall usually contains large amounts of .	Calcium ions	Iron	teichoic acid	Lipopolysaccharide	**teichoic acid**
16	A is a zone of diffuse, unorganised material that is removed easily.	Murine layer	Slime layer	outer layer	Flagellin	**Slime layer**
17	bacteria have a single flagellum at each pole.	Pertrichous	Atrichous	Amphitrichous	Polar flagella	**Amphitrichous**
18	The filament of flagella consist of a single protein called .	insulin	Flagellin	Thymine	Pectin	**Flagellin**
19	Cyanobacteria undergo a different type of motility called .	Gliding motility	Twisting motility	Dwelling	Moving	**Gliding motility**
20	The special resistant dormant structure produced by gram positive bacteria is called an .	Exospore	Outer coat	Spore coat	Endospore	**Endospore**
21	As much as 15% of the endospores dry weight consist of .	Magnesium ions	Lipopolysaccharide	Dipicolinic acid	Peptidoglycan	**Dipicolinic acid**
22	The endospores spore coat is made up of .	Lipopolysaccharide	Peptidoglycan	teichoic acid	Dipicolonic acid	**Peptidoglycan**
23	Movement toward chemical attractants and away from repellents is known as .	Chemoreceptors	Chemotaxis	Chemical repellents	Repellents	**Chemotaxis**
24	Attractants and repellents are	Chemoreceptors	Chemotaxis	Chemical	Repellents	**Chemoreceptors**

	detected by a special proteins called .			repellents		
25	links the filament to its basal body and act as a flexible coupling.	Neck	Hook	Filament	Hair	**Hook**
26	The meaning of trichous is .	Head	Thin	Long	Hair	**Hair**
27	aid in the attachment of bacteria to objects .	pili	Fimbriae	Flagella	cell wall	**Fimbriae**
28	aids in the motility of gliding bacteria.	Slime	Fimbriae	Flagella	Pili	**Slime**
29	Sporulation takes place for 10hrs in .	Streptococcus	Bacillus megaterium	Bacillus anthraces	Corynebacterium	**Bacillus megaterium**
30	The synthesis of flagella involves genes	20-30	40-50	15-30	30-40	**20-30**
31	The information required for flagella construction is present in the structure of .	Flagellin	hook	filament	basal body	**Flagellin**
32	The peptidoglycan material found in archaeobacterial cel wal is called _____	Glycopeptide	Mucopeptine	Pseudomurein	Muramic acid	**Pseudomurein**
33	Bacterial flagella anchor in to the cell wall and membrane by means of the ----------	Pilin	. Stalk	Periplasm	Basal body	**Basal body**
34	Flagella of Spirocheates are called ---------- flagella	Triplasmic	Periplasmic	Metaplasmic	Megaplasmic	**Metaplasmic**
35	---------- are membrane bound organelles in eukaryotic cells that contain very powerful digestive enzymes.	Mesosomes	Lysosomes	Metasomes	Trisomes	**Lysosomes**
36	The peptidoglycon layer of Gram negative bacteria is located in the ---------- space	Triplasmic	Metaplasmic	Periplasmic	Megaplasmic	**Periplasmic**
37	Mycoplasma is an example of	Gram negative	Cellwall high	Neutral	Cellwall less	**Cellwall less**

	---------- bacteria					
38	In archaeobacterial cell wall instead of NAM _____ is present	N-acetyl talosaminuronic acid	N-butyl talosaminuronic acid	D-alanine	L-Lysine	**N-acetyl talosaminuronic acid**
39	Pili contains the protein _____	Pilin	Valine	Glutamin	Primidine	**Pilin**
40	Carboxysomes are involved in _____ fixation	N_2	O_2	CO_2	H_2	**CO2**
41	Cell membrane of archaeobacteria contains long chain branched alcohol called _____	Phytanol	Butanol	Acetanol	Methanol	**Phytanol**
42	Lipid content is more in the cell wall of Gram _____ bacteria	Negative	Positve	parasite	virus	**Negative**
43	Volutin granules are also called as _____	Gas vacuoles	. Mitochondria	Endoplasmic reticulum	Metachromatic granules	**Metachromatic granules**
44	Membrane invaginations in to the bacterial cytoplasm are known as _____	Mesosomes	Cytosomes	Hydroxysomes	Carboxysomes	**Mesosomes**
45	The outer L ring is assosiated with layer in the Gram negative bacteria	Lipid	Lipopolysaccharide	Lactose	Lactone	**Lipopolysaccharide**
46	In prokaryotic cells the region where DNA is located is referred to as_____	Nucleoid	Nuclear region	Nuclear body	Nucleosome	**Nuclear region**
47	Which of the following structure is not present in bacterial cells?	Ribosome	RNA	Cell membrane	Mitochondria	**Ribosome**
48	The nuclear material in a bacterial cell is known as _____	Nucleus	Nucleoid	Nucleous	Nucleosome	**Nucleous**
49	Which of the following	Contains	Contains cell	Contains	Contains outer	**Contains**

	statement is correct with reference to Gram positive bacteria?	periplasmic space	membrane	lipopolysaccharide	membrane	**lipopolysaccharide**
50	Semi rigid extension of bacterial cell wall and cell membrane is called_____	Capsule	Stalk	Slime	Prosthecae	**Prostheca**
51	Gas vesicles are mostly present in _____	Gram positive bacteria	Gram negative bacteria	Photosynthetic bacteria	Aquatic bacteria	**Aquatic bacteria**
52	Bacterial ribosomes are composed of	Protein and DNA	Protein and rRNA	Protein and mRNA	Protein and RNA	**Protein and rRNA**
53	Which of the following is found in both Gram positive and Gram negative bacteria?	Peptidoglycon	Teichoic acid	O antigen	Outer membrane	**Peptidoglycon**
54	Sub units of bacterial ribosome are _____	60S and 40S	70S and 80S	60S and 30S	50S and 30S	**50S and 30S**
55	Periplasmic space is found in _____	Between cell wall and cell membrane	Below cell membrane	Within outer membrane	In between outer membrane and peptidoglycon	**Between cell wall and cell membrane**
56	Which of the following is a motile bacterium?	*E. coli*	*Shigella*	*Klebsiella*	Giardia	**E. coli**
57	Which of the following is not a motile bacterium?	*Pseudomonas*	*Vibrio*	*Bacillus*	*Klebsiella*	**Klebsiella**
58	Fungi with known sexual stages are called _____	Pathogenic fungi	Rreproductive fungi	Perfect fungi	Saprophytic fungi	**Perfect fungi**
59	A temporary projection of part of cytoplasm that helps in the motility of protozoa is called	Flagellum	Pseudopodium	Pili	Cilia	**Pseudopodium**
60	The peptidoglycon layer of Gram negative bacteria is	Triplasmic	Metaplasmic	Periplasmic	Megaplasmic	**Periplasmic**

located in the ---------- space

UNIT- IV

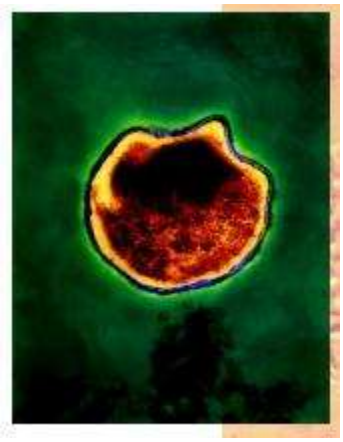
SYLLABUS

Bacteria

An account of typical eubacteria, chlamydiae & rickettsiae (obligate intracellular parasites), mycoplasma, and archaebacteria (extremophiles). Applications of bacteria in industry, environment and food.

Eubacteria

Bacteria are microscopic organisms that comprise the domain Eubacteria. A domain is the highest grouping of organisms, superseding the level of kingdom in the classical Linnaean system of biological classification. There are three domains, two of which, Eubacteria and Archaea, are composed entirely of prokaryotic organisms; the third domain, Eucarya, encompasses all other (eukaryotic) life forms, including the single-cell and multicellular protists, as well as animals, green plants, and fungi. Unlike eukaryotic cells, prokaryotic cells lack nuclei and other organelles , and tend to be less complex.



The spherical-shaped Chlamydia pneumonia bacteria.

Eubacteria are differentiated from archaea primarily based on chemical composition of cellular constituents. For example, bacterial cell walls are composed of peptidoglycan (though there are examples of bacteria that lack cell walls) while archaeal cell walls are composed of a protein -carbohydrate molecule called pseudopeptidoglycan or other molecules. Bacterial cell membranes are composed of fatty acids joined to glycerol by ester bonds (COOC), while archaeal membranes are composed of isoprenoids rather than glycerol, linked to fatty acids by ether bonds (COC). In addition, the archaea have a more complex ribonucleic acid (RNA) polymerase than bacteria.

Life Cycle

Reproduction in bacteria involves duplicating the genetic material and dividing the cell into two daughter cells, a process known as binary fission. Under very favorable conditions, certain bacterial cells can divide as often as once every twenty minutes. Some bacteria, such as *Clostridium* and*Bacillus* species, possess the ability to form a resting state, or "spore," when unfavorable conditions are encountered. These spores are very resistant to heat, drying, radiation, and toxic chemicals. Bacterial spores have reportedly been reawakened from a 250-million-year-old salt crystal that existed before the time of the dinosaurs. Sterilization techniques used in medicine must overcome these resistant properties.

Size and Shape

Prokaryotes range in size from 0.2 micrometers to more than 50 micrometers, although the average prokaryote is around 1 to 3 micrometers in size. Eukaryotic cells are approximately one order of magnitude larger, ranging in size from 5 to 20 micrometers in diameter, with an average size of 20 micrometers.

The bacteria come in a number of distinct shapes as well. Common shapes include spherical (coccus), cylindrical (rod), and spiral forms (spirilla). While bacteria are generally regarded as unicellular organisms, there are also examples of bacteria that exist as multicellular colonies, aggregates, or filaments. In addition, bacteria can aggregate on surfaces. Called biofilms, these assemblages can consist of a single species or communities of microorganisms that can participate in metabolic cooperation.

Origin of Bacteria

It is not known whether the ancestor of bacteria originated on Earth or elsewhere. Some scientists believe that a life form existed extraterrestrially in the Martian meteorite ALH84001. Whether primitive life originated on Earth or elsewhere, current consensus is that bacteria were present on Earth 3.8 billion years ago.

Colored transmission electron micrograph of the rod-shaped E.coli bacteria, showing its long flagellae.

Diversity

Bacteria show an incredible range of metabolic diversity. Some bacteria can get their energy from light (these are referred to as phototrophic organisms), organic compounds (organotrophic), orinorganic compounds such as hydrogen (H_2), sulfur compounds (H_2S), inorganic nitrogen compounds or ferrous iron compounds (chemolithotrophic). Some bacteria can make all of their organic compounds by fixing carbon (autotrophic), while others need to break down organic compounds to provide a carbon source (heterotrophic). Many bacteria are

capable of fixing atmospheric nitrogen as a nitrogen source, in addition to organic and inorganic sources of nitrogen. Because of this metabolic diversity, bacteria play an important role in biogeochemical cycles such as the carbon, nitrogen, and phosphorous cycles.

This metabolic diversity also permits them to occupy a wide range of habitats. Bacteria can thrive in extremes of temperature, pH , salt, pressure, or toxic substances. Some bacteria can survive these conditions by spore formation, while other bacteria are able to multiply under extreme conditions. The most primitive bacteria extant today are theromophiles, leading to the consensus view that life arose under extreme conditions. Within and between these extremes, bacteria are found in marine, aquatic, terrestrial and subterranean environments. There are bacteria that are obligate aerobes and some that are obligate anaerobes , and many that fall somewhere in between.

In recent years, highly conserved genes such as the gene coding for the small subunit ribosomal RNA have been used as principal taxonomic characters. As bacteria evolve over time the sequence of this molecule changes, allowing taxonomic relationships between bacteria to be discerned.

Many divisions exist within the Bacteria. An example of this diversity is the subdivision α-proteobacteria, whose members are more diverse from each other than are plants from animals. More recently, full genome sequencing has revealed that genes can move between cells and even between species. Thus, bacterial genomes are in constant flux driven by gene acquisition from other species as well as evolutionary forces. The known bacterial tree of life is remarkable, but as 99 percent of bacterial life remains uncultured, this tree will undoubtedly expand greatly over time.

Associations

While most bacteria are free living at some point of their life cycles, many bacteria are capable of living in close associations with other organisms, including eukaryotes. Some of these so-called symbiotic associations are so highly evolved as to be obligate, while other associations are facultative, meaning the symbiotic partners can live apart from each other. In some symbioses, the eukaryotic host provides a highly specialized structure within which the bacteria reside, such as the nitrogen-fixing root nodules found on leguminous plants, such as clover, or the rumen possessed by some herbivorous mammals. Looser symbiotic associations exist where the host provides no specialized structure for the symbiotic bacteria. Organisms that populate the root zone of plants can provide growth benefits; these bacteria are in turn making use of plant products exuded though the roots.

There are also bacteria that are very harmful or even fatal to eukaryotic hosts. An example of this is *Yersinia pestis,* causative agent of the bubonic plague. Not all associations between bacteria and their eukaryotic hosts have such a drastic result. Many bacteria exist in relatively benign associations with their hosts, such as the *Escherichia coli* bacteria in the human large intestine. Some resident bacteria can become pathogenic under certain circumstances. These opportunisticpathogens can cause serious infection in hosts whose defenses are compromised by age or previous illness.

Some association can be very intimate, occurring on the intracellular level. It is generally accepted that the eukaryotic chloroplasts and mitochondria arose from associations between bacteria and other cells. These organelles are similar in size to bacteria and contain remnants of bacterial genomes.

Chlamydia

General Characteristics

The chlamydia, which are incorrectly called the PLT viruses or Bedsonia or basophilic viruses, are bacteria which are obligate intracellular parasites of higher animals (mammals and birds). The members of this group share a unique development cycle, a common morphology and a common family antigen. They are not transmitted by arthropods. These organisms are termed basophilic because they take up the Giemsa stain (i.e., they stain blue). They are gram-negative, non-motile and multiply in the cytoplasm of the host cell. These organisms generally parasitize epithelial cells. The methods used to study them are, in the main, those of the virologist rather than the bacteriologist. Furthermore, the clinical features, pathogenesis, pathology and epidemiology of chlamydial infections are similar to those of viral infections.

Taxonomy

The chlamydia fall into two main ecological groups. In the first group, are the agents causing trachoma, inclusion conjunctivitis, and lymphogranuloma venereum, which seem to infect man only. In the second group, are those agents transmitted to man as zoonotic infections. About 100 species of birds are naturally infected with chlamydia. This includes 71 species of parrots as well as finches, pigeons, chickens, ducks, turkeys and seabirds. The chlamydia are thought to have evolved in the following way:

Gram-negative cocci
Facultative intracellular parasites of mammals

↓

Protochlamydiae
Gram-negative cocci
Obligate intracellular parasites
Host range restricted to rodents
Restricted virulence (compact inclusions)
Folates synthesized (sulfonamide susceptible)
Glycogen synthesized and deposited in inclusions

Subgroup A	Subgroup B
↓	↓
Mammalian parasites	Primarily bird parasites
Compact inclusions	Diffuse inclusions
Glycogen synthesized	Glycogen not synthesized

Folates synthesized	Folates not synthesized
Sensitive to D-cycloserine	Resistant to D-cycloserine
Restricted host range	Broadening of host range
↓	↓
Chlamydia trachomatis	*Chlamydia psittaci*
Seven strains which are probably distinct species	Ten strains which are probably distinct species

Chlamydia pneumoniae
Only one serotype has been identified

Morphology and Structure

The chlamydial cell is roughly spherical and measures between 0.3 and 1.0 u in diameter, according to the stage of development. Both the small and the large cell types contain complete cell walls which are similar to the cell walls of gram-negative bacteria.

Under the cell wall lies a separate cytoplasmic membrane made up of large amounts of lipid. The DNA occurs as an irregular mass in the cytoplasm. There is no nuclear membrane. Ribosomes can be seen throughout the cytoplasm. The cells contain no capsule or flagella.

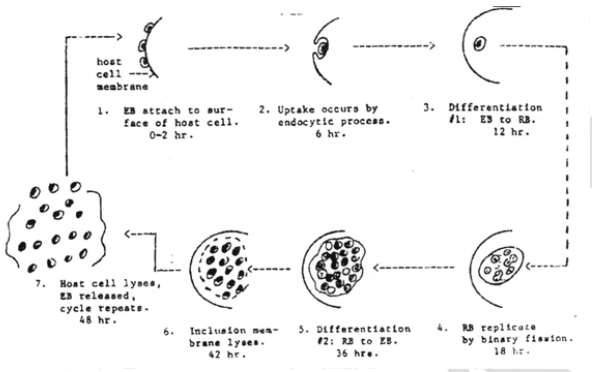
Metabolism

There are no detectable flavoproteins or cytochromes. It appears that the basis of the obligate intracellular parasitism is due to a lack of ATP-generating ability and the need to obtain ATP from the host cell. The cells can synthesize DNA, RNA and protein.

Growth and multiplication

Chlamydia pass through a series of developmental forms while multiplying by binary fission. This is termed the "developmental cycle." Two morphologically different developmental forms with a continuous gradation of intermediates between them can be recognized. One is a small cell about 0.3 u in diameter, with an electron-dense nucleoid. The other is a large cell, 0.5 to 1.0 u in diameter without a dense center.

There appears to be no significant difference in morphology or developmental cycle among the various chlamydia, and a single generalized description applies to all. The development cycle may be regarded as an orderly alternation of the small and large cell type. It is initiated by the highly infectious small cell which is taken into the host cell by phagocytosis. The engulfed small cell retains its morphological integrity in vacuoles bound by membrane derived from the surface of the host cell, and there is no eclipse (period in which the parasite loses the infectious ability). Instead, without loss of individuality, the small cell is reorganized into a large cell which is the vegetative multiplying form of these organisms. Then, still within the membrane-bound vacuole, the large cell grows in size and multiplies by repeated binary fission. The developmental cycle is completed by the reorganization of most of the large cells into small ones which are then available for infection of new host cells. The time required for completion of a cycle varies from 24-48 hours, depending on the particular host/parasite system involved.



Characteristics of the elementary and reticulate bodies of Chlamydia can be found in the table below.

ELEMENTARY BODY (EB)	**RETICULATE BODY (RB)**
Size 0.3 um	Size 0.5 - 1.0 um
RNA:DNA content = 1.1	RNA:DNA content = 3.1
Infectious	Not infectious
Adapted for extracellular survival	Adapted for intracellular growth
Hemagglutinin present	Hemagglutinin absent
Induces endocytosis	Does not induce endocytosis
Metabolically inactive	Metabolically active

Pathogenicity

Subgroup A organisms primarily infect the mucous membranes of the eye or the genitourinary tract of humans. Subgroup B organisms, although primarily parasites of birds, can be transmitted to man where they cause a lung infection.

The mechanism by which chlamydia cause disease or injure cells is unknown. Chlamydial infections of mucous membranes cause damage to tissues deep in the epithelial layer; for example, in trachoma, scarring of the tarsal plate occurs frequently. There is some evidence that a toxin is produced.

Chlamydia has on its surface, a peptide that resembles one in heart myosin. The peptide, when displayed by antigen-presenting cells, can trigger T-cells that attack both *Chlamydia*and heart cells, thus causing heart muscle inflammation (myocarditis). This autoimmune reaction also plays a role in the formation of the artery-clogging plaques of atherosclerosis.

Rickettsia

General Features

The rickettsia are bacteria which are obligate intracellular parasites. They are considered a separate group of bacteria because they have the common feature of being spread by arthropod vectors (lice, fleas, mites and ticks). The cells are extremely small (0.25 u in diameter) rod-shaped, coccoid and often pleomorphic microorganisms which have typical bacterial cell walls, no flagella, are gram-negative and multiply via binary fission only inside host cells. They occur singly, in pairs, or in strands. Most species are found only in the cytoplasm of host cells, but those which cause spotted fevers multiply in nuclei as well as in cytoplasm. In the laboratory, they may be cultivated in living tissues such as embryonated chicken eggs or vertebrate cell cultures.

The family Rickettsiaceae is taxonomically divided into three genera:

1. *Rickettsia* (11 species)--obligate intracellular parasites which do not multiply within vacuoles and do not parasitize white blood cells.

2. *Ehrlichia* (2 species) - obligate intracellular parasites which do not multiply within vacuoles but do parasitize white blood cells.

3. *Coxiella* (1 species)--obligate intracellular parasite which grows preferentially in vacuoles of host cells.

4. *Baartonella* (3 species)--intracellular parasite which attacks the red blood cell.

Structure

The structure of the typical rickettsia is very similar to that of Gram-negative bacteria. The typical envelope consists of three major layers: an innermost cytoplasmic membrane, a thin electron dense rigid cell wall and an outer layer. The outer layer resembles typical membranes in its chemical composition and its trilaminar appearance. The cell wall is chemically similar to that of Gram-negative bacteria in that it contains diaminopimelic acid and lacks teichoic acid. Intracytoplasmic invaginations of the plasma membrane (mesosomes) and ribosomes are also seen. There are no discrete nuclear structures.

Metabolism

In dilute buffered salt solutions, isolated rickettsia are unstable, losing both metabolic activity and infectivity for animal cells. If, however, the medium is enriched with potassium, serum albumin and sucrose, the isolated organisms can survive for many hours. If ATP is added to the solution, the organisms metabolize and consume oxygen. The basis for the obligate parasitism of these cells is that they require the rich cytoplasm to stabilize an unusually permeable cell membrane.

The rickettsia have many of the metabolic capabilities of bacteria, but require an exogenous supply of cofactors to express these capabilities. The response to exogenous cofactors implies an unusually permeable cytoplasmic membrane.

Growth and Multiplication

Rickettsia normally multiply by transverse binary fission. Under poor nutritional conditions, the rickettsia cease dividing and grow into long filamentous forms, which subsequently undergo rapid and multiple division into the typical short rod forms when fresh nutrient is added. Immediately after division, the rickettsia engage in extensive movements through the cytoplasm of the cell. *C. burnetii* differs from other rickettsia in that it is enclosed in a persistent vacuole during growth and division. Six to ten daughter cells will form within a host cell before the cell ruptures and releases them.

Pathogenicity

In their arthropod vectors, the rickettsia multiply in the epithelium of the intestinal tract; they are excreted in the feces, but occasionally gain access to the arthropods salivary glands. They are transmitted to man, via the arthropod saliva, through a bite. In their mammalian host, they are found principally in the endothelium of the small blood vessels, particularly in those of the brain, skin and heart. Hyperplasia of endothelial cells and localized thrombus formation lead to obstruction of blood flow, with escape of RBC's into the surrounding tissue. Inflammatory cells also accumulate about affected segments of blood vessels. This angiitis appears to account for some of the more prominent clinical manifestations, such as petechial rash, stupor and terminal shock. Death is ascribed to damage of endothelial cells, resulting in leakage of plasma, decrease in blood volume, and shock.

It is assumed that the observed clinical manifestations of a rickettsial infection are due to production of an endotoxin, although this endotoxin is quite different in physiological effects from that produced by members of the Enterobacteriaceae. This is inferred, although the toxin has not been isolated, from these facts:

1. IV-injected rickettsia cause rapid death in experimental animals.

2. UV-irradiation of rickettsia diminished their infectivity without reducing toxicity.

3. The use of anti-rickettsial drugs does not prevent rapid death in experimental animals.

4. Antiserum specific for cell wall antigens of the rickettsia prevents the toxic effect.

Chemotherapy

The drugs of choice for the treatment of rickettsial diseases are chloramphenicol and tetracycline. Each of these is highly toxic, especially in children, and must be used with care. The sulfonamides stimulate rickettsial growth and thus are contraindicated in the treatment of these diseases.

Mycoplasma

General Characteristics

The mycoplasmas are essentially bacteria lacking a rigid cell wall during their entire life cycle, although they are also much smaller than bacteria. The first organism of this type was associated with pleuropneumonia of cattle, and was originally called the pleuropneumonia organism (PPO). Since that time, a number of organisms with similar morphological characteristics and cultural properties have been isolated. These are commonly referred to as pleuropneumonia-like organisms or PPLO. A certain group of mycoplasmas produce extremely tiny colonies on agar plates, and are called the T-strains.

Some bacteria readily give rise spontaneously to variants that can replicate in the form of small filterable protoplasmic elements with defective or absent cell walls. These organisms, called L-forms, can also be formed by many species when cell wall synthesis is impaired by antibiotic treatment or high salt concentration. These organisms differ from mycoplasma in that they contain a rigid cell wall, at least at one stage of their life cycle and contain no sterols in their cytoplasmic membrane.

These organisms are the smallest known free-living organisms. Because of the absence of cell walls, they do not stain with the Gram stain, and they are more pleomorphic and plastic than eubacteria. With Giemsa stain, they appear as tiny pleomorphic cocci, short rods, short spirals, and sometimes as hollow ring forms. Their diameter ranges from 0.15 u to 0.30 u.

Most mycoplasmas require a rich medium containing a sterol and serum proteins for growth. Despite the lack of a cell wall, they do not require a medium of very high osmotic pressure. On solid media, they form minute, transparent colonies. When viewed under low-power magnification, the colony looks like a fried egg. The different strains vary in their growth rate and may take from two days to several weeks to form a colony.

Structure

The cell is enclosed by a limiting membrane which is more similar to that of animal cells than that of bacterial cells because of sterols present in the membrane. The cytoplasm contains ribosomes, but lacks mesosomes. There is no nuclear membrane. In some strains, amorphous material on the outer surface of the membrane suggests the existence of a capsule.

Metabolism

The parasitic mycoplasmas have truncated respiratory systems, lacking quinones and cytochromes. Another indication for the simplicity of the electron transport chain is the finding that the reduced nicotinamide adenine dinucleotide (NADH) oxidase activity is cytoplasmic. Complex electron transport chains are usually membrane bound, since they depend on the spatial organization of their components. Ruling out oxidative phosphorylation as an ATP-generating system leaves only two proven ways of ATP generation, both based on substrate level phosphorylation. The major source for ATP is the arginine dihydrolase pathway.

arginine deaminase
Arginine + H_2O ----------> citrulline + NH_3

ornithine carbamoyltransferase
Citrulline+inorganic orthophosphate----------->ornithine+carbamoylPO

carbamate kinase
Carbamoyl PO_4 + ADP ----------> ATP + CO_2 + NH_3

Another mechanism for ATP generation is:

phosphate acetyltransferase
Acetyl CoA + inorganic orthophosphate ----------> acetyl PO_4 + CoA

acetate kinase
Acetyl PO_4+ ADP ----------> Acetate + ATP

Acetyl CoA is produced by oxidative decarboxylation of pyruvate.

A few species derive their energy from the degradation of glucose or the hydrolysis of urea. All species synthesize DNA, RNA, lipids and proteins. However, it is not known if they can synthesize amino acids. Those species that require sterols incorporate these sterols (mainly cholesterol) into the cell membrane up to concentrations of 65%.

Multiplication

In the absence of a rigid cell wall, the pattern of replication is quite different from that of typical bacteria, whose division starts with the formation of a well-defined septum. Though the mechanism of division in mycoplasmas is controversial, sequential microscopic observation suggests that new elementary particles arise by fragmentation of filamentous cells containing several discrete DNA components.

Pathogenesis

M. pneumoniae is an extracellular pathogen that adheres to the respiratory epithelium by a specialized terminal protein attachment factor. This adherence protein interacts specifically with neuraminic acid residues on the epithelial cell surface. Ciliastasis occurs following attachment and then destruction of the superficial layer of epithelial cells. Destruction is due to release of hydrogen peroxide and superoxide anion.

Archaebacteria (Extremophiles)

General features

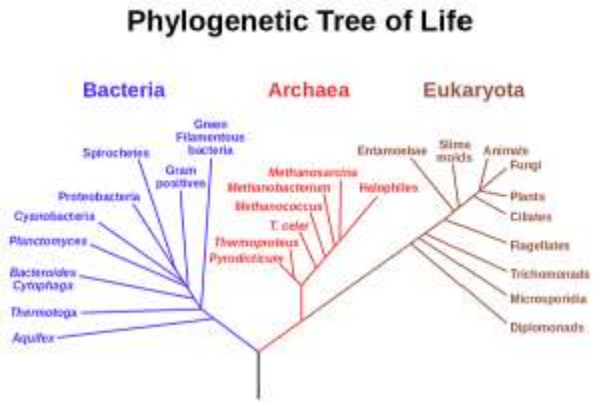
Archaebacteria are a type of single-cell organism which are so different from other modern life-forms that they have challenged the way scientists classify life.

Until the advent of sophisticated genetic and molecular biology studies allowed scientists to see the major biochemical differences between archaebacteria and “normal” bacteria, both were considered to be part of the same kingdom of single-celled organisms. “Kingdoms,” a way of organizing life forms based on their cell structure, traditionally included Animalia, Planitia, Fungi, Protista (for single-celled eukaryotes), and Monera (which was once considered to hold all forms of prokaryotes).

However, genetic and biochemical studies of bacteria soon showed that one class of prokaryotes was very different from “modern” bacteria, and indeed from all other modern life forms. Eventually named “archaebacteria” from “archae” for “ancient,” these unique cells are thought to be modern descendants of a very ancient lineage of bacteria that evolved around sulfur-rich deep sea vents.

Sophisticated genetic and biochemical analysis has led to a new “phylogenetic tree of life,” which makes use of the concept of “domains” to describe divisions of life that are bigger and more basic than that of “kingdom.”

The most modern version of this system shows all eukaryotes – animals, plants, fungi, and protists – constituting the domain of “Eukaryota,” while the more common and modern branching of bacteria constitutes “Prokarya,” and archaebacteria constitute their own domain altogether – the domain of “Archaea.”



The discovery of Archaea and its unique differences is exciting for scientists, because it's believed that archaebacteria's unique biochemistry might give us insight into the workings of very ancient life. Some scientists propose that the archaebacteria Thermoplasma may in fact be ancestors of the nuclei of our own eukaryotic cells, which are believed to have developed through the process of endosymbiosis.

Another remarkable trait of archaebacteria is their ability to survive in extreme environments, including very salty, very acidic, and very hot surroundings. Archaebacteria have been recorded surviving temperatures as high as 190° Fahrenheit, which is only twenty-two degrees shy of the boiling point of water, and acidities as high as 0.9 pH.

Archaebacteria have even challenged scientist's ideas about how to define a species, since they practice a lot of horizontal gene transfer – where genes are transferred from one individual to another during their lifetimes – making it difficult to determine how closely different cells are related, or even if archaebacteria cells have the sort of stable combinations of traits that scientists typically use to define a species.

The domain of Archaea include both aerobic and anaerobic species, and can be found living in common environments such as soil as well as in extreme environments.

So what biochemical characteristics make scientists so excited about archaebacteria? Well…

Archaebacteria Characteristics

Archaebacteria have a number of characteristics not seen in more "modern" cell types. These include:

1. Unique cell membrane chemistry.

Archaebacteria have cell membranes made of ether-linked phospholipids, while bacteria and eukaryotes both make their cell membranes out of ester-linked phospholipids

Archaebacteria use a sugar that is similar to, but not not the same as, the peptidoglycan sugar used in bacteria cell membranes.

2. Unique gene transcription.
Archaebacteria have a single, round chromosome like bacteria, but their gene transcription is similar to that which occurs in the nuclei of eukaryotic cells.

This leads to the strange situation that most genes involving most life functions, such as production of th e cell membrane, are more closely shared by Eukarya and Bacteria – but genes involved in the process of gene transcription are most closely shared by Eukarya and Archaea.

This has led some scientists to propose that eukaryotic cells arose from a fusion of archaebacteria with bacteria, possibly when an archaebacteria began living endosymbiotically inside a bacterial cell.

Other scientists believe that eukaryotes descended directly from archaebacteria, based on the findings of archaebacteria species, *Lokiarcheota*, which contains some found only in eukaryotes, which in eukaryotes code for genes with uniquely eukaryotic abilities.
It is thought that *Lokiarcheota* may be a transitional form between Archaea and Eukaryota.
3. Only archaebacteria are capable of methanogenesis – a form of anaerobic respiration that produces methane.
Archaebacteria who use other forms of cellular respiration also exist, but methane-producing cells are not found in Bacteria or Eukarya.
4. Differences in ribosomal RNA that suggest they diverged from both Bacteria and Eukarya at a point in the distant past

Types of Archaebacteria

There are three main types of archaebacteria. These are classified based on their phylogenetic relationship (how closely related they are to each other), and members of each type tend to have certain characteristics. The major types are:

1. **Crenarchaeota** – *Crenarchaeota* are extremely heat-tolerant.
They have special proteins and other biochemistry that can continue to function at temperatures as high as 230° Fahrenheit! Many *Chrenarchaeota* can also survive in very acidic environments.
Many species of *Crenarchaeota* have been discovered living in hot springs and around deep sea vents, where water has been superheated by magma beneath the Earth's surface.
One theory of the origin of life suggests that life may have originally started around deep sea vents, where high temperatures and unusual chemistries could have led to the formation of the first cells.

2. **Euryarchaeota** are able to survive in very salty habitats. They are also able to produce methane, which no other life f orm on Earth is able to do!

Euryarchaeota are the only form of life known to be able to perform cellular respiration using carbon as their electron acceptor.
This gives them an important ecological niche because the breakdown of complex carbon compounds into the simple molecule of methane is the final step in the decomposition of most life forms. Without methanogens, the Earth's carbon cycle would be impaired.
Wherever methane gas is produced by life, *Euryarchaeota* are responsible.
Methanogen archaebacteria can be found in marshes and wetlands, where they are responsible for "swamp gas" and part of the marsh's distinctive smell, and in the stomachs of ruminants such as cows, where they break down sugars found in grass that are undigestible to eukaryotes by themselves. Some methanogens live in the human gut and assist us in the same way.

They can also be found in deep sea sediments, where they produce pockets of methane beneath the ocean floor.

3. **Korarchaeota** are the least-understood, and thought to be the oldest lineage of archaebacteria. This makes them possibly the oldest surviving organisms on Earth!
Korarchaeota can be found in hydrothermal environments much like *Crenarchaeota*. However, *Korarchaeota* have many genes found in both *Crenarchaeota* and *Euryarcheaota*, and also genes which are different from both groups. To scientists, this suggests that both other types of archaebacteria may have descended from a common ancestor similar to *Korarchaeota*.
Korarchaeota are rare in nature, perhaps because other, newer forms of life are better adapted to survive in modern environments than they are. Still, *Korearchaeota* can be found in hot springs, around deep sea vents.

Examples of Archaebacteria

Lokiarcheota

Lokiarcheota is a hyperthermophile discovered at the deep sea vent called Loki's Castle, which some scientists think has unique evolutionary significance.
It has a highly unique genome, consisting of roughly 26% proteins that are known to be found in other archaebacteria, 29% proteins that are known to be found in bacteria, 32% genes that do not correspond to any known protein, and – 3.3% genes that correspond to those only found in eukaryotes.

The eukaryotic genes are particularly exciting for scientists, because they are genes that appear to code for proteins that eukaryotes use to actively control the shape of their cell, including proteins for cytoskeletons, the motor protein actin, and several proteins that in eukaryotes are involved in changing cell membrane shape.

Some of these genes are involved in phagocytosis, which is exciting because the process of phagocytosis could have been used by eukaryotic ancestors to "swallow" other cells – which may have gone on to become endosymbiotes, leading to the endosymbiotic relationships between eukaryotic cells and their mitochondria, chloroplasts, and nuclei.

Lokiarchaeota's unique genome makes it possibly our closest relative among prokaryotes, and possibly a transitional form in the extremely important jump from prokaryotic to eukaryotic life, which made the evolution

of the animal, plant, fungi, and protist kingdoms possible. Scientists think that Lokiarchaeota and ourselves probably shared a common ancestor around 2 billion years ago.
It is unknown whether this means that eukaryotes likely evolved around deep sea vents, or whether *Lokiarchaeota's* relatives may once have been common in other environments before they were outcompeted and driven to extinction by their more advanced descendants, the eukaryotes.

Methanobrevibacter Smithii

Methanobrevibacter smithii is a methane-producing archaebacteria that lives in the human gut. This member of *Euryarchaeota* helps us to break down complex plant sugars and extract extra energy from the food we eat.
The microorganisms in our guts – including members of *Euryarchaeota* – also have a complex relationship with our health. While some studies show that many people with obesity and colon cancer have above-average levels of *Euryarchaeota* in their guts, *Euryarchaeota* also help people who don't have enough food to produce more energy, and some types of these archaebacteria appear to protect against colon cancer.

Application of bacteria

Industry
A large number of saprophytic bacteria are employed in the manufacture of various industrial products.

(a) Butter making industry:
Saprophytic bacteria such as Lacto bacilli popularly known as starters make the milk sour and produce various flavours. These bacteria are largely employed in butter industry for ripening milk and producing flavours in butter.

(b) Cheese making industry:
Bacteria are employed in this industry. First the casein of milk is coagulated and then it is ripened by certain bacteria. Bacteria make the case in spongy, soft and give it characteristic taste and flavour.

Pasteurization:
Heating milk at 62°C for 30 minutes or at 71°C for 15 seconds.

(c) Vinegar making industry:
Bacillus aceti convert the sugar solution into vinegar.

(d) Alcohol and acetone manufacture:
Butyl alcohol and acetone are manufactured by the action of bacteria on molasses.

(e) Tobacco curing:

Crude dry tobacco leaves pass through curing and ripening processes before they are ready for use. Bacteria are employed in both these processes and the peculiar taste and smell in the tobacco is due to the bacterial activity. For this purpose molasses and alcohol are added to tobacco.

(f) Tea curing:
Crude tea leaves are acted upon by certain bacteria. The process is known as curing, which is employed to impart a peculiar taste and flavour to the leaves. For this purpose alcohol is added to tea leaves.

(g) Leather tanning:
The hides and skins after drying, salting and clearing are steeped in fluids containing specific bacteria. The process of fermentation goes on for some time and then they are transferred to tan-pits and are further allowed to be fermented. This whole process is known as tanning and the bacteria employed in the process are obtained from cowdung and the excreta of dogs and poultry.

(h) Fibre retting:
Retting is the process of separating fibres from-the plant tissues. Bacteria are employed in this industry, which cause decay of the softer tissues and render fibres easily separable mechanically. Fibres of flax, hemp, jute, coconut and other fibrous plants are obtained by immersing the specific plant organs in stagnant pond water where bacteria develop and cause retting.

(i) The sewage work:
In order to remove solid and semi-solid constituents of sewage it is allowed to putrify. Putrifying bacteria are allowed to act upon sewage under anaerobic conditions. It gets decayed and liquefied. It is now filtered and the liquid is either drained out to the river or used as manure in fields. For this purpose, in the soak pits the horse dung is filled up.

(J) Ensilage:
It is the process of preserving green fodder in pits. Certain bacteria help in the preservation of fodder.

(k) Medicines:
Antitoxins are the chemical substances produced in the host tissues in response to the attack of parasitic bacteria. Different vaccines and serums now prepared from these antitoxins are used in the treatment of specific ailments. The antibiotics such as streptomycin, aureomycin, Chloromycetin, etc., are obtained from certain actinomycetous bacteria.

Environment and food
(a) Ammonifying bacteria:
Bacillus subtilis, B. mycoides, B. ramosus, etc., act upon the dead animal and plant tissues and decompose their complex organic compounds like proteins into ammonium compounds. They are also known as putrefying bacteria.

(b) Nitrifying bacteria:
Nitrosomonas oxidise the ammonium compounds into nitrites in presence of free oxygen and Nitrobacter oxidise nitrites into nitrates in the presence of free oxygen. Thus ammonifying and nitrifying bacteria increase the

amount of nitrogenous compounds in the soil. Dead plants, animals and dung, etc., are converted into humus by the action of putrefying bacteria. This humus itself acts as fertilizer for plants.

(c) Nitrogen fixing bacteria:
They are Azotobacter, Clostridium and Rhizobium spp. They fix free nitrogen of the soil and make it available to the plants. The first two bacteria live freely in soil and fix the atmospheric nitrogen in the form of nitrogenous compounds in the soil. The third one is a symbiotic type.

They live in the root nodules of leguminous plants, take the free atmospheric nitrogen and fix it within its tissues. These bacteria enable plants to grow in soil where no nitrogenous fertilizers are available. The leguminous plants make the soil rich in nitrogen, and therefore used as green manures.

Nitrogen fixation:
The phenomenon of nitrogen fixation takes place by special type of bacteria which fix free atmospheric nitrogen gas into ammonia by means of symbiosis with leguminous plants. The bacteria taking part in this process are Rhizobium leguminosarum (Rhizobiaceae) which live in soil. These bacteria produce IAA (Indol-Acetic Acid) due to which the root hairs curl. These rod-like bacteria penetrate through the tip of the root hair forming a continuous 'infection thread' that enters the cortical region within twenty-four hours.

During its passage through the root hair, the infection thread gets surrounded by a cellulose wall. This wall is secreted by the host as a reaction to the infection. The infection thread ramifies in the cortical region and the bacterial rods are released in the cytoplasm of the cells which are stimulated.

These cells enlarge and multiply to form the characteristic nodules all over the root system. On the outside, the root nodule possesses a cortical layer which is followed by an actively proliferating meristematical region, then the vascular system enclosing in the centre the bacterial zone possessing abundantly the branched rods of Rhizobium leguminosarum.

These bacteria absorb atmospheric nitrogen and make it available to the host plant in the form of ammonia which is being converted into nitrates. In turn, the bacteria get shelter and carbohydrate-nutrition from the leguminous plant. On the death and decay of root nodules the rhizobia are again set free in the soil; the decomposition of roots adds nitrates into the soil thus increasing fertility of the soil.

Azotobacter is also found in the soil; this fixes the nitrogen gas of the atmosphere in the presence of carbohydrates. This fixation of free nitrogen from the atmosphere through ammonia into free nitrates and again their conversion into ammonia and free nitrogen takes place by means of nitrifying and denitrifying bacteria, along with other organisms. This process is termed nitrogen cycle.

POSSIBLE QUESTIONS

UNIT-I

PART-A (20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B (2 MARKS)

1. Write a short note about pasteurization
2. Give a list of Anton von Leeuwenhoek contributions
3. What is binomial nomenclature?
4. Describe the spontaneous generation vs. biogenesis

PART-C (8 MARKS)

1. Give a detail about development of various microbiological techniques
2. Describe the role of microorganisms in fermentation
3. Write about the goldern era of microbiology
4. Distinguish between prokaryotic and eukaryotic microorganisms
5. Give a detail about Whittaker's and Carl Woese's classification

S.No	**Unit - IV**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	Answer
1	When S.typhi is grown in Wilson and Blair medium, containing sulphite, the bacterial colonies become due to reduction of sulphite.	Black	Green	Pink	Yellow	**Black**
2	Mac Conkey's agar is a _____ medium	Selective	Differential	Both a and b	Enrichment	**Both a and b**
3	_____ is a transport medium	Mac Conkey	Blood agar	Stuart's Media	Nutrient agar	**Stuart's Media**
4	In Mac conkey's Medium, lactose fermenters produce _____ colonies.	Pink	Yellow	Black	Green	**Pink**
5	Assay medium is also known as _____	Selective media	Complex media	Production media	Indicator media	**Production media**
6	Assay medium is used to estimate the quantity of	Oxygen	Vitamins	Gas	Bacteria	**Vitamins**
7	Petri dishes were invented by	Robert Koch	Louis Pasteur	Richard Petri	Burnet	**Richard Petri**
8	Culture media can be solidified by the addition of	Blood	Agar	Sugar	Peptone	**Agar**
9	The function of agar in culture medium is	Carbon source	Nitrogen source	Buffering agent	Solidifying agent	**Solidifying agent**

10	Crystal violet inhibit the growth of _____ bacteria	Aerobic	Anaerobic	Gram positive	Gram negative	**Gram positive**
11	The differential medium used for isolation of Escherichia coli.	Mac conkey agar	Eosin methylene blue agar	Nutrient agar	Stuart's medium	**Eosin methylene blue agar**
12	Anaerobic bacteria can be isolated by pour plate technique using a medium containing a reducing agent such as	Methylene blue	Thioglycolate	Palladium	Serum	**Thioglycolate**
13	Cultures of organism that are maintained in the laboratory for stud and reference are Called ----------	Stab culture	Stock culture	Broth culture	Mixed culture	**Stock culture**
14	Media that contain some ingredients of unknown chemical composition are	Defined media	Synthetic media	Complex media	Natural media	**Complex media**
15	Solidifying used other than agar is	Thio glycollate	Silica gel	Soya meal	Casein	**Silica gel**
16	_____ is an enriched media	Nutrient agar	Tryptic soy agar	Blood agar	Macconkey agar	**Blood agar**
17	All of the following are true about agar except it	liquefies at 100°C	is a polysaccharide derived from a red alga	Solidifies at approximately 40°C	is metabolized by many bacteria	**is metabolized by many bacteria**

18	For photolithotrophic autotroph; in addition to light, _____would be most essential to maintaining its growth	a continual supply of abundant oxygen	a nutrient medium containing glucose	a source of CO_2	a source of O_2	**a source of CO_2**
19	For chemolithotrophic autotroph; _____ would be most essential to maintaining growth of the organism	a nutrient medium containing glucose	nutrient medium containing glucose	a source of reduced inorganic compound such as NH4	a source of carbon compounds	**a source of reduced inorganic compound such as NH4**
20	Which of the following uses radiant energy as their energy source?	Chemotrop h	Lithotroph	Autotroph	Phototroph	**Phototroph**
21	Addition of blood to a culture medium only is an example of a _____	Differential media	Chemically defined media	Simple media	Selective media	**Differential media**

22	Vitamins are _____	the building blocks of proteins	a part of an enzyme cofactor	used for transfer of energy and information within the cell	a major energy source for bacteria	**a part of an enzyme cofactor**
23	Addition of salt to a culture medium is an example of a	Differential media	Chemically defined media	Simple media	Selective media	**Selective media**
24	_____ consists of a population of only one species of micro organism, all derived from a single parent micro organism.	Pure Culture	Inoculum	Mixed Culture	Broth Culture	**Pure Culture**
25	Agar was suggested as a substitute for gelatin in pure culture technique by	Robert Koch	Mrs. W. Hesse	Joseph Lister	Louis Pasteur	**Mrs. W. Hesse**
26	Agar, is a polysaccharide derived from _____ species	Microspore	Spirochete	gelidium	Mycoplasma	**gelidium**
27	Pure culture technique is used to	Isolate bacteria	Obtain sufficient growth for tests	Maintain stock cultures	Decontaminate	**Isolate bacteria**
28	Inoculation loops are usually made of	Plastic	Rubber	Nichrome	Steel	**Nichrome**

29	Mac Conkey's agar is a _____ medium	Selective	Differential	Both a and b	Enrichment	**Both a and b**
30	_____ is a transport medium	Mac Conkey	Blood agar	Stuart's Media	Nutrient agar	**Stuart's Media**
31	In Mac conkey's Medium, lactose fermenters produce _____ colonies.	Pink	Yellow	Black	Green	**Pink**
32	Petri dishes were invented by	Robert Koch	Louis Pasteur	Richard Petri	Burnet	**Richard Petri**
33	Culture media can be solidified by the addition of	Blood	Agar	Sugar	Peptone	**Agar**
34	The function of agar in culture medium is	Carbon source	Nitrogen source	Buffering agent	Solidifying agent	**Solidifying agent**
35	The differential medium used for isolation of Escherichia coli.	Mac conkey agar	Eosin methylene blue agar	Nutrient agar	Stuart's medium	**Eosin methylene blue agar**
36	Solidifying used other than agar is	Thio glycollate	Silica gel	Soya meal	Casein	**Silica gel**
37	_____ is an enriched media	Nutrient agar	Tryptic soy agar	Blood agar	Macconkey agar	**Blood agar**

38	All of the following are true about agar except it	liquefies at 100°C	is a polysaccharide derived from a red alga	Solidifies at approximately 40°C	is metabolized by many bacteria	**is metabolized by many bacteria**
39	Endospores were first discovered by	Tyndall	Pasteur	Robert Koch	Ferdinand Cohn	**Ferdinand Cohn**
40	The principle of pour plate technique is _____ of the culture in the tubes of liquefied or melted agar.	Dilution	Reduction	Concentration	Fraction	**Dilution**
41	_____ is considered as Father of Modern Microbiology	Fanny Hesse	Rous	Louis Pasteur	Twort.	**Louis Pasteur**
42	The role of microorganisms in the fixation of atmospheric nitrogen was first stated by	Beijerinck and Metchnihoff	Winogradsky and Beijerinck	Winogradsky and Pasteur	Pasteur and Koch	**Winogradsky and Beijerinck**
43	Cell theory was proposed by	Schleiden and Schwann	Schleiden and Robert	Robert Hooke	Leeuwenhock	**Robert Hooke**
44	Who discovered the penicillin	Alexander Flemming	Alexander Francis	Leewenhoek	Roberthook	**Alexander Flemming**

45	Who proposed one- gene-one –enzyme hypothesis	Avery	Stanley	Beadle and Tatum	Leader berg	**Beadle and Tatum**
46	Who showed that lacticacid fermentation is due to a micro organism?	Robert koch	Robert hook	Louis pasture	Francisco redi	**Louis pasture**
47	Who were the first to introduce the idea ofusing cotton plugs for pluging microbial culture tubes	Franz sehulze & Theodar schwan	George Schroeder & Theodar von Dush	Beadle&Tatum	Robert koch	**George Schroeder & Theodar von Dush**
48	_____ was the first to observe and report microorganisms.	Watson, Crick	Wasserman	Leeuwen hoek	Robert hook	**Leeuwen hoek**
49	Germ theory of disease was proved by _____	Robert Hook	Robert Koch	Louis Pasteur	Leeuwen hoek	**Robert Koch**
50	_____ provide the germ theory of fermentation	Fanny Hesse	Jaco Henle	Pasteur	Leeuwen hoek	**Pasteur**
51	To disprove spontaneous generation theory Pasteur did an experiment in _____ flask.	Round	Swan neck	Narrow	Broad	**Swan neck**
52	_____ for the first time proved that a bacterium was the cause of animal disease.	Robert Koch	Fanny Hesse	Wasserman	Richard	**Robert Koch**
53	Concept of aseptic technique was developed by _____	Robert Koch	Leeuwen hoek	Jaco Henk	Lister	**Lister**

54	Tubercle bacilli were first isolated by _____	Boardet	Robert Koch	Ehrlich	Twort	**Robert Koch**
55	Complement fixation test for Syphilis was introduced by _____	Wasserman	Fleming	Ricketts	Bordet	**Wasserman**
56	Vaccination againt Rabies was first introduced by _____	Ricketts	Louis Pasteur	Bordet	Ehrtich	**Louis Pasteur**
57	Filament synthesis is an excellent example of	self assembly	Mutualism	Parasitism	Commensalism	**self assembly**
58	The inclusion bodies of procaryotic cells are present in the .	plasma membrane	cytoplasmic matrix	nucleus	ribosomes	**cytoplasmic matrix**
59	is needed for peptidoglycan synthesis.	lactose	mannitol	glucose	sucrose	**glucose**
60	are present in many cyanobacteria, nitrifying bacteria and thiobacilli	carboxyzomes	nitrates	pigment	pili	**carboxyzomes**

UNIT- V

SYLLABUS

Algae, Fungi and Protozoa

History of phycology; general characteristics of algae including occurrence, thallus organization, algae cell ultra structure, pigments, flagella, eyespot food reserves and vegetative, asexual and sexual reproduction. Applications of Algae in agriculture, industry, environment and food. Historical developments in the field of Mycology, significant contributions of eminent mycologists. General characteristics of fungi including habitat, distribution, nutritional requirements, fungal cell ultra-structure, thallus organization and aggregation, fungal wall structure and synthesis, asexual reproduction, sexual reproduction, heterokaryosis, heterothallism and parasexual mechanism. Economic Importance of Fungi in Agriculture, environment, Industry, medicine, food, biodeterioration, mycotoxins. General characteristics with special reference to Amoeba.

Algae

History of Phycology

The history of phycology is the history of the scientific study of algae. Human interest in plants as food goes back into the origins of the species and knowledge of algae can be traced back more than two thousand years. However, only in the last three hundred years has that knowledge evolved into a rapidly developing science.

The study of botany goes back into pre-history as plants were the food of people from the beginning of the human race. The first attempts at plant cultivation are believed to have been made shortly before 10,000 BC in Western Asia (Morton, 1981) and the first references to algae are to be found in early Chinese literature. Records as far back as 3000 BC indicate that algae were used by the emperor of China as food (Huisman, 2000 p. 13). The use of *Porphyra* in China dates back to at least A.D. 533–44 (Mumford and Miura, 1988), there are also references in Roman and Greek literature. The Greek word for algae was "Phycos" whilst in Roman times the name became *Fucus*. There are early references to the use of algae for manure. The first coralline algae to be recognized as living organisms were probably *Corallina*, by Pliny the Elder in the 1st century AD (Irvine and Chamberlain, 1994 p. 11).

The classification of plants suffered many changes since Theophrastus (372–287 B.C.) and Aristotle (384–322 B.C.) grouped them as "trees", "shrubs" and "herbs" (Smith, 1955 p. 1).

Little is known of botany during the Middle Ages — it was the Dark Ages of botany.

The development of the study of phycology runs in a pattern comparable with, and parallel to, other biological fields but at a different rate. After the invention of the printing-press in the 15th century (with the publication of the first printed book: Gutenberg's *Bible* of 1488) education enabled people to read and knowledge to spread.

Exploration of the world and the advance of knowledge

Written accounts of the algae of South Africa were made by the Portuguese explorers of the 15th and 16th centuries, however it is not clear to which species reference was being made (Huisman, 2000 p. 7).

Linnaeus's "sexual system" (Linnaeus, 1754) in which he grouped plants according to the number of stamens and carpels in their flowers, although wholly artificial was advantageous in that a newly discovered plant could be fitted in amongst those already known. He divided the plant kingdom into 25 classes, one of which was the Cryptogamia — plants with "concealed reproductive organs" (see above) (Smith, 1955). Linnaeus accepted 14 genera of algae of which only four, Conferva, *Ulva, Fucus* and *Chara,* contained organisms now regarded as algae (Dixon, 1973 p. 231). As a consequence of the great increase in the number of species the artificiality of the Linnaean system was appreciated so that during the 18th Century and early 19th Century considerable numbers of new genera were described. J.V.F.Lamouroux in 1813 was the first to separate the groups on the basis of colour, however this was not taken up by other botanists and it was Harvey who, in 1836, divided the algae into four major divisions solely on the basis of their pigmentation: Rhodospermae (red algae), Melanospermae (brown algae), Chlorospermae (green algae) and Diatomaceae (Dixon,1973 p. 232).

In 1883 and 1897 Schmitz separated the Rhodophyceae into two main groups. The first contained the Bangiales and the second the Nemoniales, Cryptonemiales, Gigartinales and Rhodymeniales (Newton, 1931). The Rhodophyta are now arranged in the Orders: Porphyridiales, Goniotrichales, Erythropeltidales, Bangiales, Acrochaetiales, Colaconematales, Palmariales, Ahnfeltiales, Nemaliales, Gelidiales, Gracilariales, Bonnemaisoniales, Cryptonemiales, Hildenbrandiales, Corallinales, Gigartinales, Plocamiales, Rhodymeniales and Ceramiales. The Chlorophyta are arranged in the Orders: Chlorococcales, Microsporales, Chaetophorales, Phaeophilales, Ulvales, Prasiolales, Acrosiphoniales, Cladiphorales, Bryopsidales, Chlorocystidales, Klebsormidiales and Ulotrichales. The Heterokontophyta: Sphacelariales, Dictyotales, Ectocarpales, Ralfsiales, Utleriales, Sporochniales, Tilopteridales, Desmarestiales, Laminariales and the Fucales (Hardy and Guiry, 2006).

Recently (1990s) The Kingdom: Protoctista has been recommended,[55] however, this has not been accepted by many authors.

General Characters of Algae including Occurrence

Algae are eukaryotic organisms that have no roots, stems, or leaves but do have chlorophyll and other pigments for carrying out photosynthesis. Algae can be multicellular or unicellular. Most algae grow permanently submerged, and are either attached (benthos) or free-floating (plankton). In fresh waters the algae of the benthos grow on stones, twigs, and larger aquatics, while the benthic seaweeds are nearly all lithophytes (i.e., fixed to rocks) . Few algae (Chara, Caulerpa) can obtain a foothold in loose sand or mud, and a rock on a sandy beach often stands covered with vegetation like an oasis in a desert. Members of the benthos may become detached from their substratum and float freely, like the tangles of filamentous algae found in ponds, or the seaweed Sargassum, innumerable plants of which drift into the North Atlantic from the Gulf of Mexico and the Caribbean sea and thus give rise to the Sargasso sea. Unattached species of Fucus are not uncommon in salt marshes, but most seaweeds are doomed when torn away from their substratum. In rivers too all algal growth, other than the plankton, is attached, either encrusting rocks and pebbles (Myxophyceae, the red Hildenbrandtia)

or forming long tresses trailing out with the current (Cladophora, Ulothrix, various red algae). All benthic forms bear numerous epiphytes and their dense tangles usually harbour a wealth of smaller algae and animal life.

Thallus organization, algae cell structure, pigments, flagella, eyespot food reserves

Chlamydomonas, a member of green algae (chlorophyceae) is found almost in all places. It is simple, motile, unicellular, fresh water alga. Its ultrastructure can be divided into following parts (Fig. 1, 2):

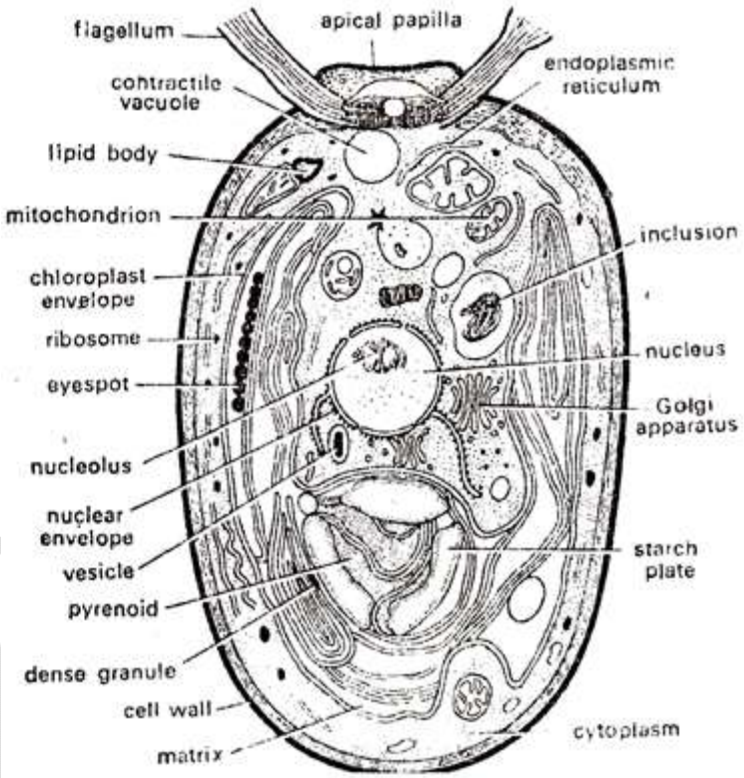


Fig. 1. *Chlamydomonas.* Ultrastructure of eukaryotic cell.

Cell Wall of Eukaryotic Algal Cell:

The cell is bounded by a thin, cellulose cell wall. Cellulose layer is finely striated with parallel cellulose fibrils (Fig. 1). In many species there is a pectose layer external to it which dissolves in water and forms a mucilaginous pectin layer. According to Roberts et. al. (1972), Hills (1973) the cell wall in C. Reinhardt consists of seven layers.

Plasma Lemma of Eukaryotic Algal Cell:

It is present just below the cell wall and consists of two opaque layers which remain separated by less opaque zone (Fig. 1).

Protoplast of Eukaryotic Algal Cell:

It is bounded by plasma lemma. It is differentiated into cytoplasm, nucleus, chloroplast with one or more pyrenoids, mitochondria, Golgi bodies, two contractile vacuoles, a red eye spot and two flagella.

Chloroplast of Eukaryotic Algal Cell:

In majority of the species of Chlamydomonas, cytoplasm contains of a single, massive cup shaped chloroplast which almost fills the oral or pear shaped body of the cell. It is surrounded by a double-layered unit membrane. It bears number of photosynthetic lamellae (disc or thylakoids).

The lamellae are lippo-proteinaceous in nature and remain dispersed in a homogeneous granular matrix (stroma). About 3-7 thylakoids bodies fuse to form grana like bodies. Matrix also contains ribosomes, plastoglobuli, microtubules and many crystals like bodies.

Flagella of Eukaryotic Algal Cell:

The anterior part of thallus bears two flagella. Both the flagella are whiplash or acronematic type, equal in size. Each flagellum originates from a basal granule or blepharoplast and comes out through a fine canal in cell wall. It shows a typical 9+ 2 arrangement. Fibrils remain surrounded by a peripheral fibril. According to Ringo (1907), 2 central ones are singlet fibrils and 9 peripheral ones are doublet fibrils (Fig. 2).

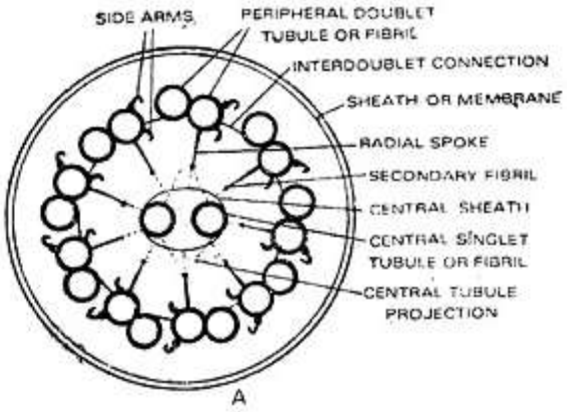


Fig. 2. Ultrastructure of flagellum of *Chlamydomonas*.

Stigma or Eyespot of Eukaryotic Algal Cell:

The anterior side of the chloroplast contains a tiny spot of orange or reddish colour called stigma or eyespot. It is photoreceptive organ concerned with the direction of the movement of flagella. The eye spot is made of curved pigmented plate. The plate contains 2-3 parallel rows of droplets or granules containing carotenoids (Fig. 3).

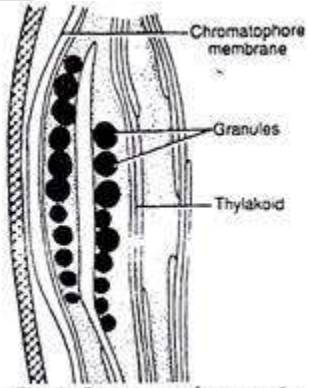


Fig. 3. Structure of eyespot.

The other structures such as mitochondria, Golgi bodies, endoplasmic reticulum and nucleus are also bounded by double-layered unit membrane.

Ultrastructure of Cyanobacterial Cell:

The cell exhibits a typical prokaryotic structure. It can be differentiated into two parts:

1. Outer cellular covering

2. Cytoplasm

1. Outer Cellular Covering of Cyanobacterial Cell:

It can be differentiated into following parts:

A. Slime layer or Mucilaginous sheath:

Presence of mucilaginous sheath is the characteristic feature of cyanobacteria. It consists of fibrils reticulately arranged within the matrix to give a homogeneous appearance (Fig. 4 A). Fibrils are made up of peptic acids and mucopolysaccharides. It retains the absorbed water and protects the cell against dessication.

B. Cell Wall:

It is present between the slime layer and plasma membrane. It is a rigid and complex structure and resembles the cell wall of bacteria. It is made of four layers. Carr and Whitton (1973) named all these four layers as L I, L II, L III and L IV (Fig. 4 A).

L I is a transparent space and occurs between the L II and plasmembrane. L II and L III are mucopolymer, made up of alanine, glucosamine, peptidoglycan, muramic acid, glutamic acid and α-diaminopimelic acid. The L IV is undulating, wavy and made of liposaccharides and proteins.

C. Plasma Membrane:

It is present below the cell wall. It is made up of protein-lipid-protein layers. The cytoplasmic membrane and its invaginations are the sites of biochemical functions, normally associated with the membrane bounded structures like mitochondria, endoplasmic reticulum and Golgi bodies of the eukaryotic cells.

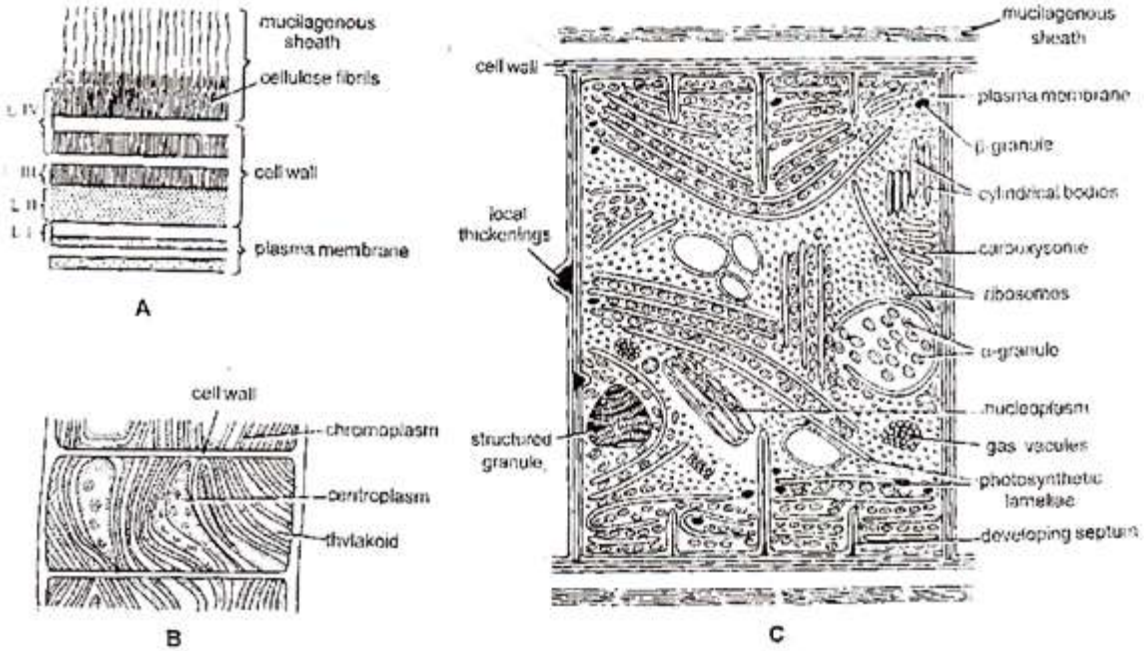


Fig. 4. (A–C). Cyanobacteria. Cell structure. A. Cell structure as seen under light microscope, B. Cell wall as seen under electron microscope, C. Ultrastructure of a cell.

2. Cytoplasm of Cyanobacterial Cell:

It is differentiated into two regions (Fig. 4B):

(1) Chromoplasm

(2) Centroplasm

(1) Chromoplasm:

It is the outer or peripheral pigmented region. This region consists of flattened vesicle like structures called thylakoids or photosynthetic lamellae. These lamellae contain chlorophyll V, carotenoids and three phycobilins—C-phycocyanin, allophycocyanin and C-phycoerythrin.

Photosynthetic lamellae are arranged in parallel rows close to the periphery of the cell or they are distributed irregularly throughout the cell. In between the lamellae, occur certain granules of 400 A° diameter. These granules contain phycobilin pigment and are called cyanosomes y or phycobilisomes.

(2) Centroplasm:

It is the inner or central colourless region. It is often called nucleoid or incipient nucleus. It consists of DNA fibrils. DNA is not surrounded with protein materials (histones). Like bacteria, small circular DNA segments occur in addition to nucleoid. These are known as plasmids or transposons. 70S ribosomes are also present in this region (Fig. 4 C).

Cytoplasmic Inclusions:

The membrane bound organelles such as the plastids, endoplasmic reticulum, vacuoles, mitochondria and the dictyosomes are absent. However, the chromoplasm contains a large number of inclusions.

These are ribosomes, a granules, (3 granules, structural granules, polyhedral bodies, gas vacuoles and vacuoles like inclusions (Fig. 4 C). α granules are also called mitochondrion granules and are said to be the region of storage. β granules are thought to be equivalent to cyanophycin (cyanophycean) granules.

Structural granules are considered as modified β or cyanophycean granules. Polyhedral bodies are also found in the central region. They are associated with the genetic material but their function is unknown.

In some cyanobacteria e.g., Oscillatoria, gas filled vacuoles (pseudo vacuoles) are present in the peripheral part of the cell. A gas vacuole is made up of a large number of units called vesicles. Gas vacuoles provide a buoyancy regulating mechanism.

Vegetative, asexual and sexual reproduction

In this type, any vegetative part of the thallus develops into new individual. It does not involve any spore formation and there is no alternation of generations. It is the most common method of reproduction in algae.

The vegetative reproduction in algae is of the following types:

a. Cell division or fission:

It is the simplest method of reproduction. The unicellular forms of algae commonly reproduce by this simple process, often called binary fission as found in Chlamydomonas, Synechococcus (Fig. 3.16A), diatoms etc. In this method the vegetative cell divides mitotically into two daughter cells, those finally behave as new individual.

b. Fragmentation:

In this method, the multicellular filamentous thallus breaks into many-celled fragments, each of which gives rise to a new individual. The fragmentation may be accidental or by the formation of separation discs or by some other mechanical force or injury. It is found in Spirogyra, Ulothrix, Oedo- gonium, Zygnema, Cylindospermum (Fig. 3.16B) etc.

c. Hormogonia:

This method of vegetative reproduction is found in blue-green algae. The trichomes of blue-green algae break up within the sheath into many-celled segments called hormogonia or hormogones. They remain delimited by the formation of heterocysts, separation discs or necridia or by the death and decay of intercalary cells of the trichome. Hormogonia are commonly found in Nostoc, Oscillatoria, Cylindosporium etc.

d. Formation of Adventitious Branches:

Adventitious branches are formed in different large thalloid algae, which, when detached from the plant body, develop into new individuals (e.g., Fucus, Dictyota). Protonema-like adventitious branches are formed from the internodes of Chara, stolons of Cladophora glomareta etc.

e. Bulbils:

Tuber-like outgrowths are developed due to storage of food at the tip of rhizoids and on the lower nodes of Chara, called bulbils (Fig. 3.16C). After detachment from the plant body, bulbils grow into new plants.

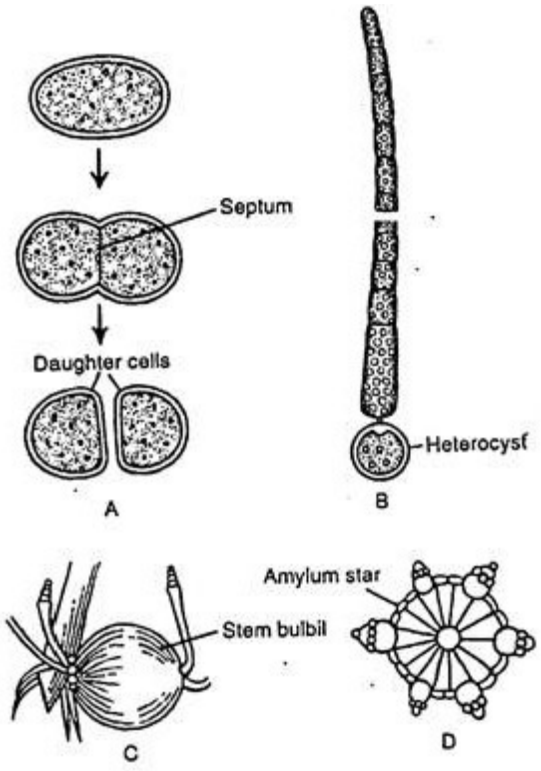


Fig. 3.16 : Vegetative reproduction in algae : A. Cell division (*Synechococcus* sp.) B. Fragmentation of filament (*Cylindrospermum* sp.) C. Stem bulbil (*Chara* sp.) and D. Amylum star (*Chara* sp.)

f. Amylum stars:

Star-shaped aggregation of starch containing cells develops on the lower nodes of Chara. These structures are called amylum stars (Fig. 3.16D). When detached from the plant body, they grow into new plants.

g. Budding:

In Protosiphon bud-like structures are formed due to proliferation of vesicles delimited from the parental body by a septum, which, after detachment, grow into a new plant.

Mode # 2. Asexual Reproduction:

Asexual reproduction involves the formation of certain type of spores — either naked or newly walled. It is a process of rejuvenation of the protoplast without any sexual fusion. Each and every spore germinates into a new plant. In this method, there is no alternation of generations.

The asexual spores may be of various types:

a. Zoospores:

These are motile naked spores provided with two, four or many flagella and called as bi-, quadri- or multiflagellate zoospores, respectively. Biflagellate zoospores are found in Chlamydomonas, Ulothrix (Fig. 3.17A) Ectocarpus etc., quadriflagellate zoospores are found in Ulothrix (Fig. 3.17B) and multiflagellate zoospores are found in Oedogonium (Fig. 3.17C).

But the multinucleate and multiflagellate zoospores as found in Vaucheria (Fig. 3.17D) are called synzoospores. Each zoospore has a chloroplast and an eye spot. The zoospores may be either haploid or diploid.

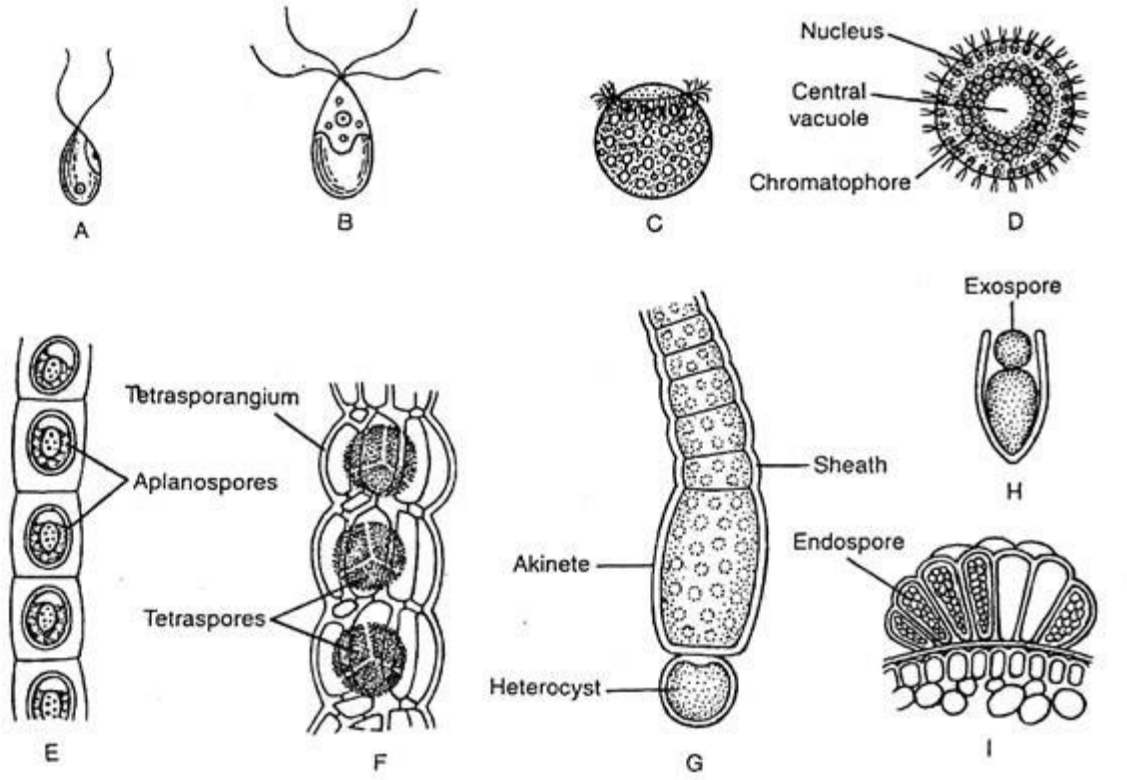


Fig. 3.17 : Asexual spores in algae : A. Biflagellate microzoospore, and B. Quadriflagellate microzoospore of *Ulothrix* sp., C. Multiflagellate zoospore of *Oedogonium* sp., D. Synzoospore of *Vaucheria* sp., E. Aplanospores of *Ulothrix* sp., F. Tetraspores of *Polysiphonia* sp., G. Akinete of *Gloeotrichia* sp., H. Exospore of *Chamaesiphon incrustans*, and I. Endospores of *Dermocarpa prasina*

They are formed within the zoosporangium. There may be single zoospore (e.g., Oedogonium) or many zoospores (e.g., Cladophora) per zoosporangium. Zoospores are either haploid or diploid depending on the nature of plant body, gametophytic or sporophytic on which it develops.

The zoospores are liberated either by the disintegration of the zoosporangial wall or by the formation of an apical pore on the zoosporangium. After liberation the zoospores swim for a while, then withdraw their flagella, encyst and ultimately germinate into new plants.

b. Aplanospores:

Aplanospores are non- motile spores. These spores are formed either singly or its protoplast may divide to form many aplanospores inside sporangium during unfavourable conditions, especially in drought (e.g., Ulothrix (f ig. 3.17E), Microspora). The aplanospores may also be formed in certain algae of semiaquatic habitat.

When they appear identical to the parent cell, they are referred to as autospores (e.g., Scenedesmus, Chlorella etc.). Aplanospores with thickened wall and abundant food reserve are known as hypnospores (e.g., Pediastram, Sphaerella etc.).

They are formed to overcome prolonged period of desiccation. With the onset of favourable condition the hypnospores either directly germinate into a new individual or their protoplasts may form zoospores. Due to deposition of haematochrome pigment in their walls, the hypnospores of Chlamydomonas nivalis are red in colour.

c. Tetraspores:

Diploid plants of some algae (e.g., Polysiphonia, Fig. 3.17F) produce a special type of haploid aplanospores, called tetraspores, formed within tetrasporangium. The diploid nucleus of a tetrasporangium divides meiotically to form four haploid nuclei which — with little amount of protoplasm — are developed into four tetraspores. After liberation the tetraspores germinate to form male and female gametophytes.

d. Akinetes:

The vegetative cells of certain filamentous algae develop into elongated thick-walled spore-like structures with abundant food reserves, called akinetes (e.g., Gloeotrichia, Fig. 3.17G). They can tide over the unfavourable conditions. With the onset of favourable condition they germinate into new individuals.

e. Exospores:

In some algae, spores are regularly cut off at the exposed distal end of the protoplast in basipetal succession, called exospores. These spores aggregate in groups and develop new colonies, e.g., Chamaesiphon (Fig. 3.17H).

f. Endospores:

These are small spores formed by the divisions of the mother protoplast. They are also called conidia or gonidia. They are set free after the dissolution of mother wail. Without taking rest, the spores germinate directly and develop into a new plant, e.g., Dermocarpa (Fig. 3.17 I).

Mode # 3. Sexual Reproduction:

All algae except the members of the class Cyanophyceae reproduce sexually. During sexual reproduction gametes fuse to form zygote (Fig. 3.18). The new genetic set up can develop by the fusion of gametes coming from the different parents.

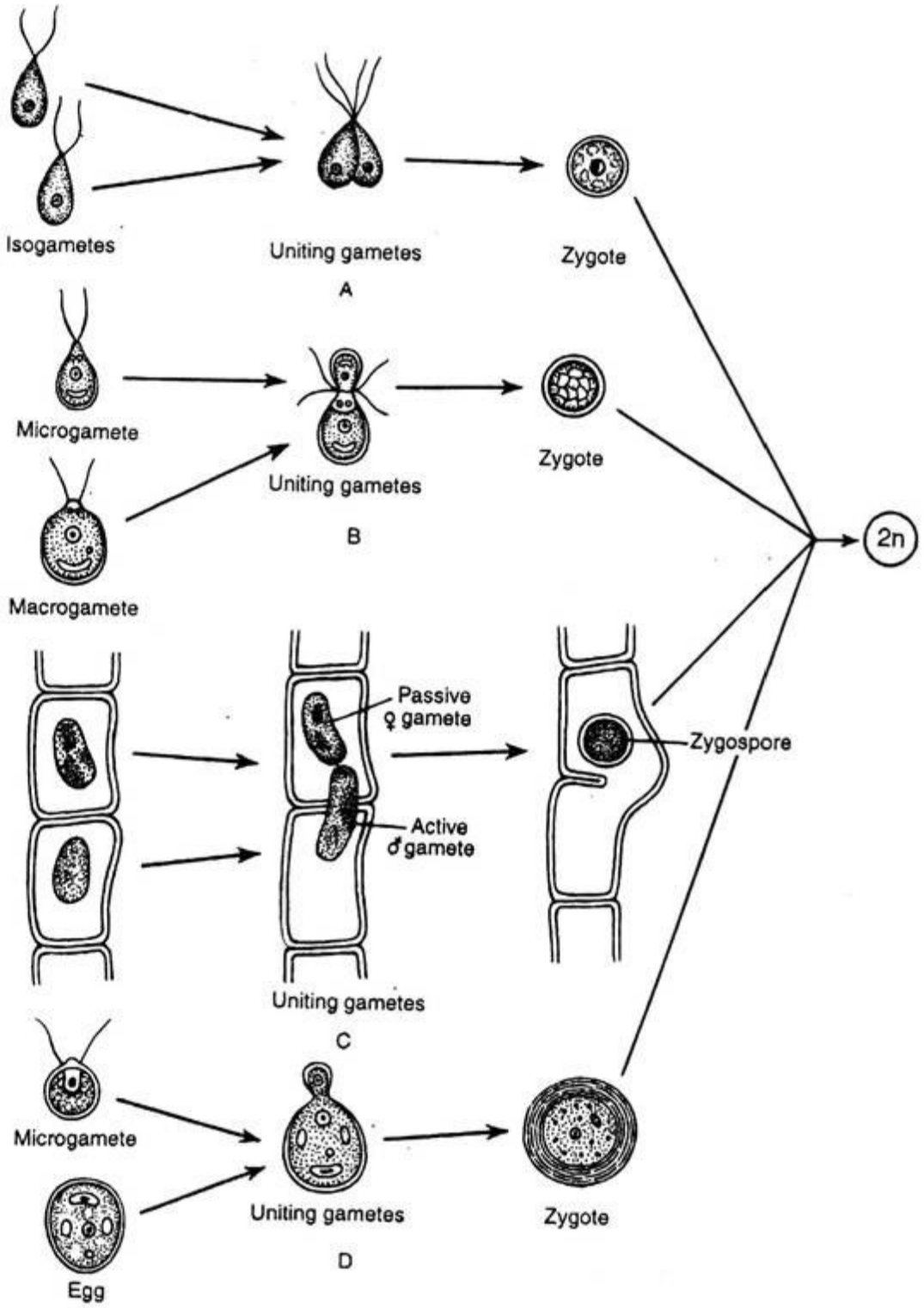


Fig. 3.18 : Types of sexual reproduction in algae : A. Isogamy in *Chlamydomonas* sp., B. Anisogamy in *Ectocarpus* sp. C. Physiological anisogamy in *Spirogyra* sp., and D. Oogamy in *Chlamydomonas* sp.

Depending on the structure, physiological behaviour and complexity of sex organs, sexual reproductions are of the following five types:

a. Autogamy:

In this process the fusing gametes are developed from the same mother cell and after fusion they form zygote. For the above, plant developed through autogamy does not show the introduction of any new characteristic, e.g., Diatom (Amphora normani).

b. Hologamy:

In some unicellular member the vegetative cells of different strains (+ and -) behave as gametes and after fusion they form zygote. It is an inefficient process considering the point of multiplication, but new genetic combi-nations are developed by this process, e.g., Chlamydomonas.

c. Isogamy:

It is the process of union, between two gametes which are morphologically and physiologically similar — after fusion they form zygote. The gametes are called isogametes. Usually they are flagellate, e.g., Chlamydomonas eugametos, Ulothrix etc.

d. Anisogamy:

In this process the uniting gametes are morphologically and physiologically different. The smaller and more active one is the microgamete (male), whereas the larger and less active one is the macrogamete (female), e.g., Chlamydomonas braunii.

Deviating from the typical anisogamy, when the uniting gametes show morphological similarity with physiological difference, it is called physiological anisogamy. e.g., Zygnema, Spirogyra etc.

e. Oogamy:

It is an advanced process where fertilisation takes place between a small motile (non-motile in Rhodo- phyceae) male gamete (sperm or antherozoides) with a large non-motile female gamete (egg or ovum). Male gametes develop within antheridium, whereas the female gamete within the oogonium, e.g., Oedogonium, Vaucheria, Chara, Laminaria, Sargassum, Polysiphonia, Batrachospermum etc.

Application of Algae

Algae with their increasing popularity due to their versatility are finding applications in many emerging spheres as nutritional supplement, fertilizer, pigment and stabilizing agents, neutraceutical, pharmaceutical and in medical fields.

Algae have been recognized as a rich energy source and thus have been utilized to produce many biofuels such as hydrogen, methane, bioethanol, biodiesel and many more. These renewable fuels produced are being termed as third generation fuels.

1. Agriculture

The sea weeds as fodder have been widely used in Norway, Sweden, Denmark, Scotland, America, China and New-Zealand. In Norway, Rhodymenia palmate has come to be known as 'Sheep's weed' since sheep are very fond of this particular alga. Laminaria saccharine, Ascophyllum sp., Sargassum sp. and Fucus sp., are equally liked by the catties.

The large Brown and Red algae are used as organic fertilizers, especially on land close to the sea. The weed is used either directly or as a seaweed meal. A concentrated extract of seaweed is also sold as a liquid fertilizer. Coralline algae Lithothamnioncalcareum and Lithophyllum sp. are used profusely for liming the soil. Similar is the use of Chara which becomes encrusted with calcium carbonate.

2. Industry

Many forms of marine algae, Phaeophyceae and Rhodophyceae, are highly valuable for certain commercial products, chiefly agar-agar, algin or alginic acid and carrageenin

3. Environment

Algae act as an important binding agent on the surface of the soil. Disturbed or burnt soils are soon covered with a growth of green and blue-green algae thus reducing the danger of erosion. The role of Cyanophycean members as a pioneer in colony formation and thus in soil formation is well known.

4. Food:

Algae have been in use as human food for centuries in various parts of the world, including Scotland, Ireland, Norway, Sweden, France, Germany, North and South America, China, and Japan. Algae are taken in several ways according to the choice and taste of the people. They may be taken as a salad, cooked with meat or eaten as vegetable, sprinkled with oatmeal or fried with meat.

FUNGI

Historical developments in the field of Mycology and Significant contributions of eminent mycologists

Beautifully coloured umbrella shaped mushrooms and toad stools growing on soils forming 'fairy rings' attracted Man from the very beginning. One finds references to fungi in Roman and Greek classics. Records of plant diseases could also be found in Vedas and the Bible.

Herbals or books containing descriptions of fungi were published by several authors like Clusius (1601) J. F. van Steerbeck (1675), Robert Hooke & others. The most famous work of their period was published by P. A. Micheli (1679- 1737) who included scientific descriptions and illustrations of many fungi know till then.

His famous book Nova plantarum genus was published in 1729. He experimentally proved that fungi originated from spores thus putting an end to the theory of fungal origin from decaying materials. He was much ahead of his time and thus has the honour of being referred to as Father of Mycology.

'Fairy Ring' on Soils

The number of species and genera discovered and described increased rapidly due to the diligently pursued researches by several renowned mycologists of that period. They included Persoon (1801), Fries (1821-32), DeBary (1831-1888), Saccardo (1845-1920), Sydow (1851- 1924) and others.

Soon it was proved beyond doubt that fungi caused diseases in plants, mycologists became interested in studying diseases of plants, animals and human beings. Cereal rusts, smuts warts etc. were observed and described by French, Italian, English and Russian mycologists.

The fact that yeasts were associated with fermentation announced independently by C. C. de la Tour (1836), T. Schwann (1837) and F.T. Kutzing (1837) opened new vistas in commercial exploitation of Fungi. Similarly, the discovery of penicillin by Alexander Fleming in 1928 initiated new avenues for therapeutic value of Fungi. Since then, a large number of fungi have been discovered to produce antibiotics.

Dangeard (1894) and Harper (1896-97) initiated Cytological Studies on Fungi while Dodge and Shear (1898) using Neurospora for genetical studies contributed to the laws of heredity, genetical control of enzyme and evolution of new improved varieties. Sexual reaction studies in Fungi were initiated by Blakeslee (1904) who discovered heterothallism in Fungi.

Mycological studies in India were initiated by Lt. Col. K.R. Kirtikar in late 19th Century who collected and identified fungi. In a real sense, studies on mycology and plant pathology in India began with the establishment of the then Imperial Agricultural Research Institute at Pusa (Bihar) and the arrival of Sir E.J. Butler as the first imperial Mycologists to the then Govt, of India in 1905.

It was mainly due to painstaking efforts of Butler that a firm foundation of mycology and Plant pathology was laid in this country. He authored a classic book **"Fungi and Diseases in Plants"** which is still used both by students and researchers. Because of his contributions Butler is aptly referred to as the Father of Indian Mycology.
Studies on isolation, collection and identification of both macro and micro fungi including parasitic fungi continued with more enthusiasm and several mycologists contributed in describing new fungi unknown to India. P. Bruhl and J. SenGupta (1927) compiled a checklist of Myxomycetes while H. Chaudhari (1947) and his coworkers compiled their work in the form of **"Handbook of Indian water moulds".**
Additions to the aquatic fungi were also made by S. N. Das Gupta and R. John (1953).

Parasitic fungi causing diseases of important crops received greater attention. B.N. Uppal and J.H. Weston (1936) made comprehensive studies of Sclerospora the cause of Green ear disease of Bajra.

Species of Pythium and Phytophthora causing diseases of rubber plants and palms received attention from S.L. Ajrekar and K.D. Rajulu (1931). In 1931 itself, M. Mitra recorded a new bunt or Kamal Bunt of wheat while a list of Indian Species and varieties of Aspergillus was published by U.N. Mohanty (1948).

B.B. Mundkur and M.J. Thirumalachar in 1952 published a consolidated list of Indian Ustilaginales. Earlier in 1947, Mundkur founded the Indian Phytopathological Society with S.R. Bose as its first president. K.C. Mehta and Coworkers (1940) studied the problem of the recurrence of the wheat rusts in plains of India.

Indian Mycological researches got an impetus with the establishment of the universities of Bombay, Madras and Calcutta. The then mycologists were purely plant pathologists who gave more importance to the listing and description of parasitic fungi causing diseases in plants.

In addition to mentioned above, the prominent names include K.D. Bagchee, T.S. Ramakrishnan, J.H. Mitter, K.J. Narsimhan, S.N. Das Gupta, R.N. Tandon, R. Prasad, T.S. Sadasivan, C.V. Subramaniam and others.

The mycologists who studied slime molds and soil fungi were B.S. Mehrotra (1952-1970) on Mucorales; B. Bakshi (1954) on Fungi from Himalayas, V. Agniothrudu (1954-68) slime molds and soil fungi from North and North East India; K. S. Bhargava (1968-80) on taxonomy of soil fungi; J. N. Rai (1961-83) on taxonomy of soil fungi from usar soils and Mangroves.

Ecological, physiological and Biochemical studies on fungi were also undertaken at different centres in the country. T. S. Sadasivan at Madras University initiated studies on ecology and physiology of Soil Fungi; S.N. Das Gupta at Lucknow University established a centre of studies on histopathology and deficiency disorders, A. Mahadevan at Madras University made significant contributions on physiology and biochemistry of fungi; at the University of Allahabad, R.K. Saksena initiated detailed studies on storage diseases of fruits and vegetables which were ably continued by R.N. Tandon. K.S. Bilgrami at Bhagalpur contributed on physiology and biochemistry of fungi especially the aflatoxins.

Studies on phyllosphere fungi were initiated by S. Sinha at Agra. J.N. Rai at Lucknow conducted Ecological studies on soil fungi especially those from usar soils. Other prominent mycologists who are engaged in studies on taxonomy, ecology and biochemistry of fungi include R.S. Dwivedi, B. Rai, K.G. Mukergi, RD. Sharma, H.C. Dube, S. Chandra, Kamal & A K Sinha.

Butler and Bisby (1931) published the first systematic account of Indian Fungi. Later several supplements were brought out by Mundkur (1938), Ramkrishnan and Subramanian (1952), Vasudeva (1977), and Bilgrami, Jamaluddin and Rizvi (1979).

Origin and phylogeny of Fungi:

The origin and evolutionary relationships of fungi are not definitely known. They are a matter of speculation and problem for future research for mycologists. Concerning their origin, the first and the traditional hypothesis regards algae as the ancestral stock. Some mycologists consider protozoa as the ancestral stock.

The supporters of the algal hypothesis hold that the fungi are degenerate algae which have lost their chlorophyll and thus have adapted themselves of a heterotrophic mode of nutrition. It is not difficult to believe it because certain flagellates under different conditions develop chlorophyll and prepare their own food or lose chlorophyll and live as saprobes.

The proponents of algal hypothesis are divided into two camps. Some suggest a monophyletic origin. They hold that with the exception of slime molds and some simplest fungi, all others, namely, Phycomycetes, Ascomycetes and Basidiomycetes represent one main evolutionary line of fungi evolved from an algal ancestor.

To view that all fungi have a common ancestry and arose in a monophyletic series appears untenable to most of the mycologists. They support the polyphyletic origin from the various groups of algae.

On the basis of multiple origins, the fungi are considered a heterogeneous aggregation, the Phycomycetes having evolved from one class of algae and Ascomycetes from another. The basidiomycetes are thought to have been evolved from the Ascomycetes.

The supporters of the algal origin of the Phycomycetes further belong to two opposite schools of thought. One favours algal origin from a siphonaceous ancestor belonging to the green algae and the other from a Xanthophycean ancestor such as Vaucheria. There are differences in metabolism and type of flagellation of the motile cells in the Phycomycetes and green algae (Table II).

TABLE – II

Green Algae	*Phycomycetes*
1. The reserve food in the green algae including even the saprophytic and parasitic species accumulates in the form of starch.	The reserve food in the Phycomycetes accumulates in the form of glycogen and not starch.
2. The motile cells in the green algae are usually biflagellate. The flagella are of equal length and of whiplash type. They are inserted at the anterior end.	The motile cells in some Phycomycetes are uni-flagellate and in others biflagellate. The single flagellum when inserted at the anterior end is of tinsel type and at the posterior end of it is whiplash type. Of the two flagella in the biflagellate cells, one is of tinsel type and the second of whiplash type.

In view of the above-mentioned differences in metabolism and type of flagellation in the two groups, the opponents of the chlorophycean origin of Phycomycetes consider this hypothesis untenable.

The advocates of the Xanthophycean origin of the Phycomycetes base their hypothesis on the resemblances of structure and reproduction between the Oogamous Phycomycetes (Oomycetes) and Oogamous yellow-green algae (Xanthophyceae) such as Vaucheria.

In both the somatic phase is a coenocytic, aseptate filamentous thallus. They have more or less an identical life cycle and oogamous sexual reproduction. There is similarity in the chemical composition of cell wall in both. This viewpoint of phycomycetean origin of fungi from Vaucheria-like ancestors was propounded by De Bary in 1881.

The name Phycomycetes of algal fungi emphasises this viewpoint. De Bary envisaged the origin of Saprolegnia-like oomycete from a vaucherial ancestor by loss of chlorophyll and change in the mode of nutrition. It further gave rise to the chytrids and to the Zygomycetes by retrogression.

Some mycologists led by Bessey (1942) advocated algal origin of fungi from the unicellular coccoid Xanthophyceae. This hypothesis is based on the similarity in structure, anterior position of flagella, and presence of cellulose in the cell wall and accumulation of reserve food in the form of glycogen in both the Phycomycetes and the coccoid ancestor.

The coccoid ancestor gave rise to the Phycomycetes along two divergent lines, one with anteriorly uniflagellate swarmers and the other with biflagellate swarmers. The opponents of this hypothesis point out to the occurrence of posteriorly uniflagellate swarmers and absence of cellulose in the cells of some uniflagellate Phycomycetes.

They argue that all the uniflagellate and biflagellate Phycomycetes have not evolved from a common ancestor. They are polyphyletic in their origin, some having evolved from an algal ancestor and the others from a protozoan (flagellate) ancestor.

Fischer and Dangeard advocate the protozoan (flagellate) ancestry of the Phycomycetes. To the modem mycologists, this hypothesis seems more probable. It is based on similar metabolism and type of flagellation in both the Phycomycetes and protozoans.

On the basis of this theory, the Phycomycetes have evolved from the flagellates via the chytrids. The uniflagellate forms arose from the uniflagellate protozoa and biflagellate forms evolved from the biflagellate protozoa. These non-mycelial forms, in turn, gave rise to the more advanced mycelial forms by progressive evolution.

Hawker (1967) suggests a polyphyletic origin of the lower fungi (Phycomycetes) from the aquatic flagellates along parallel lines. According to him, Chytridiales, Hyphochytridiomycetes and Plasmodiophoromycetes have originated from flagellates having appropriate types of flagella.

The Oomycetes which resemble certain filamentous algae in the composition (cellulose nature) of cell wall, form of sex organs, life cycle, and form of endoplasm and mitochondria may have evolved from an algal ancestor by the loss of chlorophyll.

Hawker suggests common ancestry for the chytrids and Zygomycetes at the flagellate level. The floridian origin of higher fungi based on the similarities between the reproductive organs does not survive critical examination.

To hold that different classes of fungi have an independent (polyphyletic) origin means there is no relationship between them. In that case, the classes of fungi should be raised to the status of divisions of phyla.

This view suffers from a drawback as how to explain the close similarities which exist between the different classes of fungi such as:

1. Similarity between the antheridia and oogonia of Phycomycetes and the sex organs of Ascomycetes.

2. Similar origin, physiology and phylogeny of the ascus and the basidium.

3. Similar nature, origin and development of conidia.

4. Similarity of the somatic phase (mycelium) differing, of course, in the magnitude of specialisation and differentiation.

The above-mentioned similarities indicate that the higher fungi have a common origin. The tendency among the Zygomycetes towards evolution of the conidium and protection of the zygote indicate an affinity with the Ascomycetes. Gaumann thus advocates that the Ascomycetes have evolved from the Zygomycetes.

Similar origin, physiology and phylogeny of the ascus and the basidium support the origin of the Basidiomycetes from the Ascomycetes. Saivle (1955) postulated a highly plausible theory of the origin of the Ascomycetes and Basidiomycetes from a Taphrinalike ancestor.

Burnett (1968) disapproves speculation of the phylogenetic trends based on the similarities between the reproductive parts and on the study of comparative morphology. According to him speculation based on **"this type of study can hardly be proved. Its plausibility cannot be subjected to scientific testing".**

General characters, habitat, distribution, nutritional requirements

The Kingdom Fungi includes some of the most important organisms, both in terms of their ecological and economic roles. By breaking down dead organic material, they continue the cycle of nutrients through ecosystems. In addition, most vascular plants could not grow without the symbiotic fungi, or mycorrhizae, that inhabit their roots and supply essential nutrients. Other fungi provide numerous drugs (such as penicillin and other antibiotics), foods like mushrooms, truffles and morels, and the bubbles in bread, champagne, and beer.

Fungi are heterotrophs. They are unable to manufacture their own food as photosynthetic organisms can and therefore depend on other organisms for their nutrition. Fungi obtain the carbon and energy necessary for their growth from dead or living organic substances through extracellular digestion typically by secreting enzymes into the environment and absorbing the nutrients produced. Over time, fungi have thrived in many different

conditions in aquatic and terrestrial environments. They live under snow, in very hot conditions, in sweet and salty water, in soil, on wood, excrements, dunes and sand beaches, on bryophytes, and many other places.

a).- Saprophytic. Saprophytic fungi feed on dead or decomposing organic material (sapros = putrefied and phyto = plant). They are the most common fungi and they are essential in the process of humification through fermentation and mineralization of plant remnants, (RAMBELLI, A. & BARTOLI, A., 1971). Fungi can decompose any type of natural organic material and, thanks to their intervention, close the cycle of organic material as this material is transformed into mineral elements that plants need. This cycle is essential in the maintenance of life.

Sometimes, the distinction between parasitic and saprophytic fungi is not obvious. Some fungi are even classified as semi saprophytic or semi parasitic; which means that they can be saprophytic or parasitic depending on the environmental conditions. An example is Kuehneromyces mutabilis , a very efficient fungus which becomes parasitic when it comes in contact with a fragile organism (such as a damaged tree trunk). b).- Parasites. Parasitic fungi live or colonise animals, plants and other fungi living on their expenses, inflict diseases or even death. Fungi represent 90% of plant parasites and destroy 15% of the world plant production every year. Thanks to the high number of enzymes, toxins and antibiotics that they produce, they are able to overcome the defences of the attacked organisms. c).- Symbiotic or mycorrhizal. The mycelium feeds on organic compounds in the soil substrate through decomposition or through particular associations with plants (trees, grasses, ferns, algae…). The relation between fungi and the plant roots constitute a particular type of symbiosis called mycorrhizal symbiosis.

Through mycorrhizal symbiosis the fungus obtains soluble sugars, from the plant roots; in exchange it enables the plant to increase the intake of some mineral elements (e.g. phosphorus) and its capacity to retain water. Chestnut mycorrhizal fungus One particular mycorrhizal species often associates with various plant species some species however are host specific. Sepultaria sunmeriana presents an example, it associates exclusively with cedar; Boletus elegans, associates with larch and the genus Leccinum associates with most birch species. Amanita muscaria is one of the non-host specific or “cosmopolitan” species. It can be found under a variety of trees including pines, birch, chestnut, cistus.

Nutrition

Unlike plants, which use carbon dioxide and light as sources of carbon and energy, respectively, fungi meet these two requirements by assimilating preformed organic matter; carbohydrates are generally the preferred carbon source. Fungi can readily absorb and metabolize a variety of soluble carbohydrates, such as glucose, xylose, sucrose, and fructose. Fungi are also characteristically well equipped to use insoluble carbohydrates such as starches, cellulose, and hemicelluloses, as well as very complex hydrocarbons such as lignin. Many fungi can also use proteins as a source of carbon and nitrogen. To use insoluble carbohydrates and proteins, fungi must first digest these polymers extracellularly. Saprotrophic fungi obtain their food from dead organic material; parasitic fungi do so by feeding on living organisms (usually plants), thus causing disease.

Fungi secure food through the action of enzymes (biological catalysts) secreted into the surface on which they are growing; the enzymes digest the food, which then is absorbed directly through the hyphal walls. Food must be in solution in order to enter the hyphae, and the entire mycelial surface of a fungus is capable of

absorbing materials dissolved in water. The rotting of fruits, such as peaches and citrus fruits in storage, demonstrates this phenomenon, in which the infected parts are softened by the action of the fungal enzymes. In brown rot of peaches, the softened area is somewhat larger than the actual area invaded by the hyphae: the periphery of the brown spot has been softened by enzymes that act ahead of the invading mycelium. Cheeses such as Brieand Camembert are matured by enzymes produced by the fungus *Penicillium camemberti*, which grows on the outer surface of some cheeses. Some fungi produce special rootlike hyphae, called rhizoids, which anchor the thallus to the growth surface and probably also absorb food. Many parasitic fungi are even more specialized in this respect, producing special absorptive organs called haustoria.

Fungal cell ultra-structure

In this article we will discuss about the structure of fungal cell. This will also help you to draw the structure and diagram of the fungal cell.

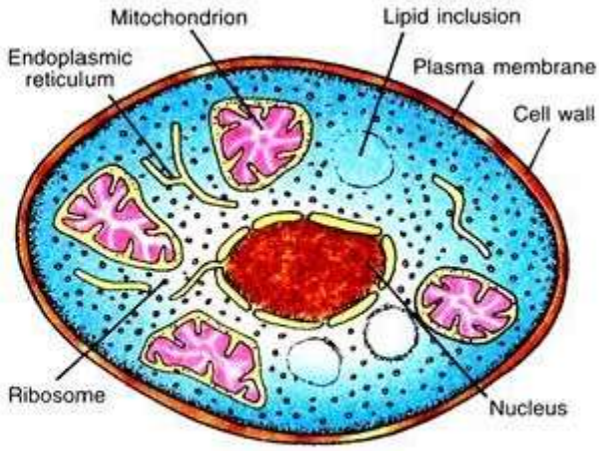


Fig. 1.8. *Fungi*. Fine structure of **Torula Yeast** cell based on an electron micrograph.

(a) The Cell Wall of the Fungal Cell:

The composition of cell wall is variable among the different groups of fungi or between the different species of the same group. In the majority of fungi, the wall lacks cellulose but contains a form of chitin known as the fungus cellulose which is strictly not identical with insect chitin.

The suggested formula for fungus chitin is $(C_{22}\ H_{54}\ N_{21})_n$. Electron microscope studies reveal that chitin occurs as elongated variously oriented microfibrillar units. These are laid down in layers and form the basis of the structural rigidity of fungal cell walls.

The microfibril layers generally run parallel to the surface. Associated with the microfibrillar components is the nonfibrillar material. The chief chemical constituents are various polysaccharides, but proteins, lipids besides other substances have also been reported.

In the lower fungi, the biflagellate Oomycetes are said to be distinct from all over fungi m the cellulose nature of the cell wall. De Bary reported true cellulose in Peronospora and Saprolegnia. Precise analysis of the cell wall of Phytophthora and Pythium by Bartnicki-Garcia (1966), Mitchell and Sabar (1968) has revealed that cellulose is a minority component or even absent altogether.

On the other hand, glucan predominates in their walls. Thus, the Oomycetes may be said to have cellulose in their cell walls but it may not be the predominant material. Chitin which had long been considered to be absent has recently been reported to be present even in the cell walls of some Oomycetes.

The basic structural constituent of the cell wall in the Zygomycetes and higher fungi (Ascomycetes and Basidiomycetes) is chitin. It is a polysaccharide based on the nitrogen containing sugar (glucosamine). It is probable that more or less closely associated with chitin in the cell wall are pectic materials, protein, lipids, cellulose, callose and minerals.

The clear evidence of such an association is, however, lacking. Burnet (1968) is of the opinion that insoluble B glucan forms the predominant structural material of the wall of Ascomycetes and Basi-diomycetes. In addition chitin may as well be present in appreciable amounts. In the yeasts and a few other Hemias- comycetideae chitin is absent. Their walls are mainly composed of micro-fibrils of mannan and B glucan.

Mannan is a polymer of hexose sugar mannose whereas glucan is polymer of glucose. Some investigators have reported the occurrence of lignin in several fungi It is doubtful whether this substance is chemically the same as the lignin of higher plants.

It is obvious that our present knowledge of the chemical composition of the cell wall of fungi is incomplete like the cellulose wall; the chitin wall of most fungi is permeable both to water and substances in true solution.

(b) The Protoplast in the Fungal Cell:

The living substance of the cell within the cell wall is the protoplast. It lacks the chloroplasts but is differentiated into the other usual cell parts such as plasma or cell membrane, vacuolated cytoplasm, cell organelles and one or more nuclei.

Cell Membrane:

It is a delicate, extremely thin, living membrane which closely invests the protoplast. The cell or plasma membrane is pressed against the cell or hyphal wall except for occasional invaginations in some regions. The Invagination is either in the form of an infolded convoluted pocket or a pouch enclosing granular or vesicular material.

Moore and Mc Lear (1961) named it lomasome. Actually the plasma membrane is the surface layer of the protoplast altered to perform special functions. It is differentially permeable and shows a typical tripartite structure under the electron microscope. There is an electron dense layer on either side of the less dense central region.

Cytoplasm:

Within the plasma membrane is the colorless cytoplasm in which sap-filled vacuoles may occur. In young hyphae and hyphal tips, the cytoplasm appears rather uniform and homogeneous. Immersed in the cytoplasm are structures known as the organelles and inclusions.

The organelles are living structures, each with a specific function. The inclusions are dead, have no specific function and thus are not essential to cell survival.

Amongst the cell organelles are included the endoplasmic reticulum, mitochondria, ribosomes, Golgi apparatus and vacuoles. Lomasomes which are membranous structures lying between the cell wall and plasma membrane are common. Examples of inclusions are the stored foods (glycogen, and oil drops) pigments and secretory granules.

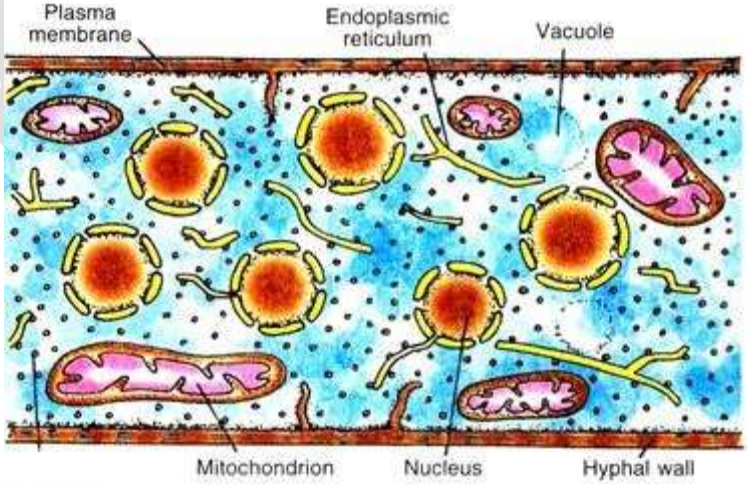


Fig. 1.9. *Fungi*. Fine structure of a hypha near the growing tip of *Mucor* based on an electron micrograph.

(i) Endoplasmic Reticulum:

The presence of endoplasmic reticulum in the fungal cytoplasm has been demonstrated by the use of electron micro-scope. It is composed of a system of membranes or microtubular structures usually beset with small granules which by some scientists are likened to the ribosomes. In many fungi, the endoplasmic reticulum is highly vesicular. Usually it is loose and more irregular than in the cells of green plants.

(ii) Mitochondria:

The cytoplasm contains small, usually spherical bodies known as the mitochondria. Each mitochondrion is enveloped by a double membrane. The inner membrane is infolded to form the cristae which are in the form of parallel flat plates or irregular tubules.

The cristae contain the same fluid that fills the space between the two membranes. The mitochondria function as the power house of the cell. There is no fundamental difference between the mitochondria of fungi and those of green plants. However, Hawker (1965) holds that the cristae of fungal mitochondria are fewer, flatter and more irregular than those of the green plants.

(iii) Golgi Apparatus (Dictyosomes):

With the exception of Oomycetes there is less certainty of the occurrence of structures similar to those of the golgi apparatus (dictyosomes) m fungi. Moore and Muhlethaler (1963) reported a golgi apparatus consisting of three flattened sacs surrounded by many bubble-like structures in Saccharomyces cells.

(iv) Vacuole:

The cytoplasm of young hyphae or fungal cells and hyphal tips lacks vacuoles. They appear further back or in the old cells. With age, they enlarge and show a tendency to coalesce and ultimately reduce the cytoplasm to thin lining layer immediately within the cell wall.

(v) Inclusions:

The cytoplasm contains various kinds of inclusions. Examples of stored foods are lipid globules, granules of glycogen, oils and the carbohydrate trehalose, proteinaceous material and volutin. The glycogen may occur in vacuoles.

There are no starch grains. Of the pigments, the fungi lack chlorophyll. Carotenoids are often conspicuous by their presence and may occur throughout the cytoplasm or concentrated in the lipid granules or distributed in the cell wall. The cytoplasm, in addition, secretes several kinds .of ferments, enzymes and organic acids.

Nucleus:

The cytoplasm in the individual cells contains one, two or more globose or ellipsoid nuclei which in the somatic portion are small and usually range from 1-2 or 3µ in diameter. They cannot be seen without special techniques.

Structurally the nucleus consists of:

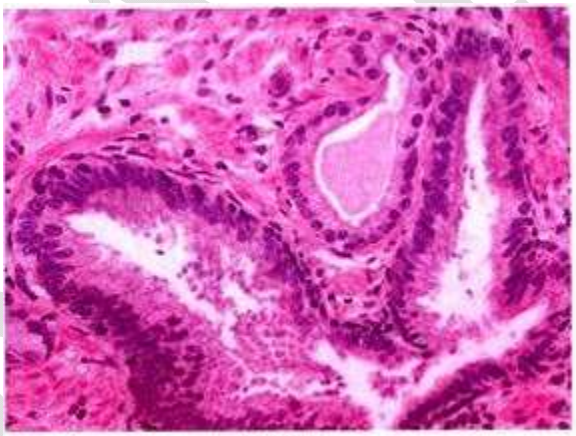
(i) A central, dense body with a clear area around it.

(ii) Chromatin strands, and

(iii) The whole structure surrounded by a definite nuclear, membrane.

The central body takes heavy iron haematoxylin stain and is usually Feulgen-negative. In electron micrographs, it appears as an amorphous or granular mass. Mycologists usually designate it as the nucleolus. Bakerspigel (1960) stated that it contains RNA. During nuclear division, the chromatin strands become organised into chromosomes which are extremely small and difficult to count.

Under the electron microscope, the nuclear membrane is seen to consist of inner and outer layers of electron dense material and the middle one of electron transparent substance. The nuclear membrane has pores. At certain points, the nuclear membrane is continuous with the endoplasmic reticulum.



Nucleolus.

Thallus organization and aggregation

The two main types of thallus found in fungi

The types are: 1. Unicellular Thallus 2. Filamentous Thallus.

Type # 1. Unicellular Thallus (Fig. 1.1):

In some of the lower fungi such as the chytrids, the thallus is more or less a spherical, single-celled structure (A). At the time of reproduction, it becomes a reproductive unit. The latter produces the asexual or sexual cells. Such fungi are called holocarpic. In them, the vegetative and reproductive stages do not occur together in the same thallus.

Plasmodiophora has a vegetative phase consisting of a naked, multi-nucleate, amoeboid mass of protoplasm (D). It is termed Plasmodium. The protoplast of the diploid Plasmodium cleaves to form the resting spores. The yeasts, which are related to the filamentous forms, also have a unicellular thallus (B). In the unicellular holocarpic forms (Synchytrium, Fig. 4-4D), the mycelium is absent.

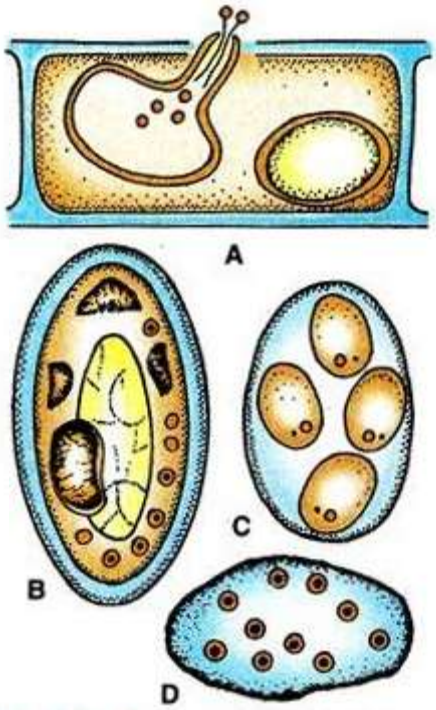


Fig. 1.1. (A—D). *Fungi*. Unicellular Holocarpic Thalli. A, *Olpidium endogenum* (holocarpic chytrid), two organisms within the algal host; B, Yeast, unicellular thallus; C, Reproductive phase of B; D, Diploid plasmodium of *Plasmodiophora*.

Type # 2. Filamentous Thallus (Fig. 1.2):

The vast majority of the fungi have a filamentous thallus. It originates through the germination of a spore. The spore germinates as it lands on a suitable substratum where other conditions of life are also favourable. In some species, the spore, on germination, produces only a short, tubular structure of limited growth.

It constitutes the thallus and is technically called a hypha. The spores of most of the fungi, however, give rise to a fluffy thallus consisting of a cottony mass of fine, branched filaments. These long, fine filaments are called the hyphae (sing, hypha). Some of these hyphae, at a certain stage of maturity, extend into the air and bear the reproductive bodies.

The rest spread over or within the substratum and continue the normal activities. Such fungi are called eucarpic. Collectively the hyphae comprise the vegetative body (thallus) of a fungus which is called the mycelium. The hypha is thus a structural unit of the mycelium. It consists of a thin, transparent wall filled or lined with a layer of cytoplasm.

The medium upon which the mycelium grows is known as substratum. The mycelium is the food procuring structure in the life cycle. It carries on the general activities of a plant cell such as absorption, digestion, respiration, excretion and growth but not photosynthesis. The hyphae constituting the mycelium branch, spread in all directions within or over the substratum to form a loose and ramifying network.

The hyphae are usually colourless particularly those embedded in the substratum. The aerial hyphae in some fungi become coloured. Black, orange, yellow, red, blue and brown are the usual tints. The colour is usually confined to the hyphal wall.

Even when the pigments are present in the protoplasmic contents, they do not form an integral part of the living matter. The pigments play no role in the physiology of the fungus. The growth in length takes place at the tips of the hyphae and is thus termed apical.

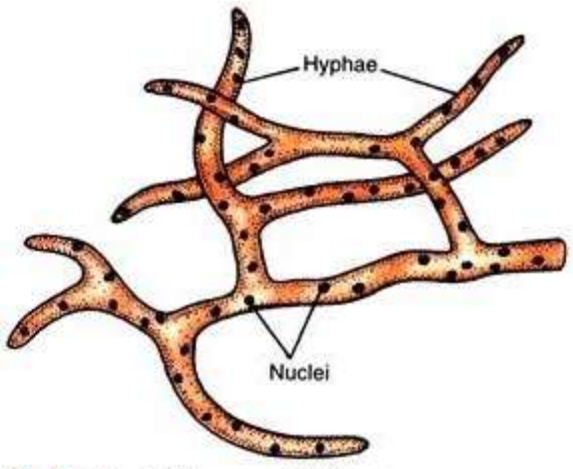


Fig.1.2 *Fungi*. Filamentous Thallus. Aseptate coenocytic mycelium.

Fungal wall structure and synthesis

The fungal cell wall is a dynamic organelle that functions in a number of important processes. It must provide the cell with sufficient mechanical strength to withstand changes in osmotic pressure imposed by the environment. Concurrently, the cell wall must retain adequate plasticity to allow for cell growth, cell division and the formation of a myriad of cell types during the life cycle of the fungus. In addition to maintaining cell shape and integrity in the face of environmental stress, the wall allows the fungal cell to interact with its surroundings. The cell wall mediates the adhesion of cells to one another and the substratum, and serves as a signaling center to activate signal transduction pathways within the cell. Disruptions of cell wall structure have a profound effect on the growth and morphology of the fungal cell, often rendering it susceptible to lysis and death. Given the vital role that the cell wall plays in fungal physiology, the cell wall has long been considered an excellent target for anti-fungal agents. Fungal cell walls are structurally unique and differ significantly from the cellulose-based plant cell wall. Fungal cell walls are comprised of glycoproteins and polysaccharides, mainly glucan and chitin. Additional minor cell wall components are present and vary amongst species of fungi. The glycoproteins present in the cell wall are extensively modified with both N- and O-linked carbohydrates and, in many instances, contain a glycosylphosphatidylinositol (GPI) anchor as well. The glucan component is predominately beta1,3-glucan, long linear chains of beta-1,3-linked glucose. Glucans having alternate linkages, such as beta-1,6-glucan, are found within some cell walls. Chitin is manufactured as chains of beta-1,4-linked N-acetylglucosamine residues and is typically less abundant than either the glycoprotein or glucan portions of the wall. The composition of the cell wall is subject to change and may vary within a single fungal isolate depending upon the conditions and stage of growth. The glycoprotein, glucan and chitin components are extensively cross-linked together to form a complex network, which forms the structural basis of the cell wall (Fig. 1). The formation and remodeling of the cell wall involves numerous biosynthetic pathways and the concerted actions of hundreds of gene products within the fungal cell. Mutational, genomic and proteomic analyses of model fungal systems, such as Saccharomyces cerevisiae, Schizosaccharomyces pombe, Candida albicans, Aspergillus fumigatus and Neurospora crassa, are beginning to elucidate the role of various pathways and individual proteins in the establishment of the cell wall (Fig. 2). The chitin component of the fungal cell wall Chitin, a long linear homopolymer of beta-1,4-linked N-acetylglucosamine, is considered to be a relatively minor, yet structurally important, component of the fungal cell wall. Chitin accounts for only 1–2% of the yeast cell wall by dry weight, whereas the cell walls of filamentous fungi, such as Neurospora and Aspergillus, are reported to contain 10–20% chitin. In both yeasts and filamentous fungi, chitin microfibrils are formed from inter-chain hydrogen bonding. These crystalline polymers have an enormous tensile strength and significantly contribute to the overall integrity of the cell wall. When chitin synthesis is disrupted, the wall becomes disordered and the fungal cell becomes malformed and osmotically unstable. The synthesis of chitin is mediated by chitin synthase, an integral membrane enzyme that catalyzes the transfer of Nacetylglucosamine from uridine diphosphate (UDP)-N-acetylglucosamine to a growing chitin chain. The elongation of the chitin polymers occurs via vectorial synthesis, so that the nascent chains are extruded through the plasma membrane as they are made. Hydrogen bonding between the newly formed polymers of chitin results in microfibril formation and subsequent crystallization of chitin in the extracellular space immediately adjacent to the plasma membrane.

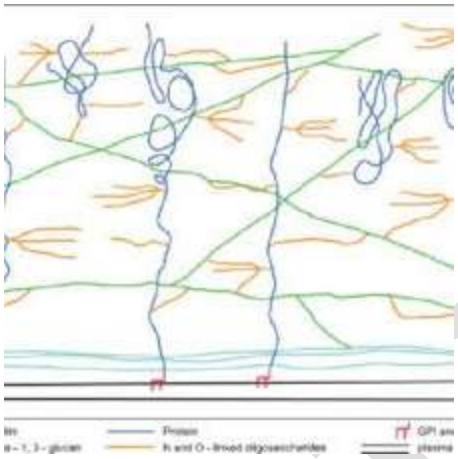


Figure 1. Representation of the fungal cell wall. The major components of the fungal cell wall are chitin, glucans and glycoproteins. Although species-specific variations exist, the cell wall components are thought to be arranged as shown. Most of the chitin is considered to be located near to the plasma membrane. The beta-1,3-glucan extends throughout the cell wall. The glycoproteins are extensively modified with N- and O-linked oligosaccharides. Many of the glycoproteins have GPI anchors, which tether them to the plasma membrane while other glycoproteins are secreted into the cell wall space. The proteins, glucans and chitin components are integrated into the wall by crosslinking the chitin, glucans, protein-associated oligosaccharides and GPI anchors together.

This process of chitin synthesis primarily occurs at sites of active growth and cell wall remodeling. For yeasts, this includes areas such as the bud tip during polarized growth and the bud neck during cytokinesis. In filamentous fungi, localized areas of cell wall synthesis occur at the hyphal apex, or growing tip. The specific roles of the chitin synthases of several fungi have been studied using both genetic and biochemical analyses. Saccharomyces cerevisiae has three chitin synthases, Chs1p, Chs2p and Chs3p. Chs1p functions in cell wall repair, replenishing chitin polymers lost during cytokinesis. Chs2p is required for the formation of the primary septum within the dividing yeast cell. The Chs3p chitin synthase is responsible for generating approximately 80–90% of the total cellular chitin. This includes the chitin ring formed during bud emergence, as well as the chitin that becomes covalently linked to the beta-1,3-glucan fraction of the cell wall. Mutants affected in the Chs3p chitin synthase have vastly reduced chitin levels and rates of growth, accompanied by defects in cell wall integrity. The simultaneous deletion of all three genes results in a lethal phenotype, demonstrating that chitin is an indispensable component of the cell wall of S. cerevisiae. A. fumigatus has seven chitin synthase-encoding genes designated as CHSA through CHSF. The genes encoding all seven chitin synthases of A. fumigatus have been cloned and disrupted. Null mutants for the CHSA, CHSB, CHSC and CHSF genes have no apparent phenotypic defect. Disruption of the CHSD gene results in a 20% reduction in the production of chitin, yet the mutants are morphologically indistinguishable from wild-type cells. CHSG mutants exhibit no apparent deficiency in the synthesis of chitin, but do have altered hyphal growth patterns. The CHSE gene product appears to be the most critical for cell wall biosynthesis. CHSE null mutants experience a 30% reduction in total chitin synthesis, which results in excessive hyphal swelling and alterations in conidiation. The ChsE enzyme is proposed to be involved in the majority of general, bulk chitin synthesis. A similar situation exists in N. crassa, where four specific chitin synthases have been identified and three additional isoenzymes are predicted to exist based upon an analysis of

its genome. Those chitin synthases that have been identified and characterized are encoded by the chs1, chs2, chs3 and chs4 genes. Mutants for each of these genes have been isolated and the genes differ with respect to their importance for morphology. Null mutations within chs1 result in only a modest reduction in the overall levels of chitin, yet yield mutants that grow slowly and produce swollen, bulbous hyphae. Disruptions in chs2 result in isolates that have normal gross morphologies and levels of cell wall chitin. The chs4 gene is thought to function in cell wall biosynthesis under environmental stress conditions. The chs3 gene of N. crassa is essential for survival, suggesting that the CHS3 enzyme may catalyze the majority of chitin synthesis under normal growth conditions. Because of the structural integrity that chitin provides the fungal cell, chitin synthesis has been considered an excellent target for anti-fungal agents. The best-known chitin synthesis inhibitors are the naturally occurring nikkomycins and polyoxins, as well as their synthetic derivatives. The nikkomycins and polyoxins are analogs of the chitin synthase substrate, UDP-N-acetylglucosamine, and function as competitive inhibitors for chitin synthase. However, treatments with nikkomycins and polyoxins have not proved effective in controlling mycoses. The nikkomycins and polyoxins are, however, often used in conjunction with other anti-fungal agents in treatment regimens. The ineffectiveness of nikkomycins and polyoxins is thought to be due to the limited uptake of the inhibitors into the cytoplasm of the fungal pathogen. Currently, fungicides that specifically target the chitin component of the cell wall have found limited use in therapeutic settings. The glucan component of the fungal cell wall Glucan is the major structural polysaccharide of the fungal cell wall, constituting approximately 50–60% of the wall by dry weight. Polymers of glucan are composed of repeating glucose residues that are assembled into chains through a variety of chemical linkages. In general, between 65% and 90% of the cell wall glucan is found to be beta-1,3-glucan, but other glucans, such as beta-1,6-, mixed beta-1,3- and beta1,4-, alpha-1,3-, and alpha-1,4-linked glucans, have been found in various fungal cell walls. The beta-1,3-glucan serves as the main structural constituent to which other cell wall components are covalently attached. As a result, the synthesis of beta-1,3-glucan is required for proper cell wall formation and the normal development of fungi. Initial studies examining the synthesis and composition of glucan were done in S. cerevisiae and Candida albicans. These studies demonstrated that yeast cell walls contain branched beta-1,3- and beta-1,6-glucans. Recent studies have shown that the cell walls of many filamentous fungi, including N. crassa and A. fumigatus, do not contain beta-1,6-glucan. Polymers of beta-1,3-glucan, like those of chitin, are generated by enzyme complexes associated with the plasma membrane and extruded into the extracellular space by means of vectorial synthesis. As with chitin, this mode of synthesis promotes the association of nascent glucan chains within the cell wall space and facilitates their integration into the cell wall. This integration occurs at points of active cell wall synthesis, and the glucan synthase complexes, similar to those generating chitin, are primarily localized to areas of cell growth and budding or branching. Glucan synthase catalyzes the formation of long linear chains of glucan, each composed of approximately 1,500 glucose residues connected via beta-1,3-linkages. Within each long glucan chain, the carbon-6 positions of approximately 40–50 glucose residues become sites at which additional beta-1,3-glucans are attached to generate a branched structure. The particular enzymes responsible for creating the branched structure within the cell wall space have not been identified. The branched glucans can then be cross-linked together and to chitin and mannoproteins to provide the cell wall with mechanical strength and integrity. The genes encoding the components of the beta-1,3- glucan synthase machinery were first identified in S. cerevisiae, which contains two known catalytic subunits and one regulatory protein. The S. cerevisiae FKS1 and FKS2 genes encode two functionally redundant catalytic subunits of the glucan synthase complex. Genetic analyses have

demonstrated the involvement of each in glucan synthesis and cell wall formation. Disruption of either the FKS1 or FKS2 gene yields mutants with slow growth rates and cell wall defects. The simultaneous deletion of FKS1 and FKS2 is lethal. This finding is consistent with the catalytic subunits having overlapping functions and illustrates the importance of beta-1,3-glucan production for yeast survival. Disruptions of the S. cerevisiae RHO1 gene, which encodes the Rho1 GTPase regulatory subunit, have demonstrated that it is essential for survival. Using the work from the yeast system as a model, the glucan synthase components of many filamentous fungi are now being identified. The FKS and RHO1 genes are highly conserved amongst fungi, and genome analyses have enabled the rapid identification of homologs in A. fumigatus and N. crassa. The A. fumigatus and N. crassa genomes each contain one catalytic subunit gene and one gene encoding a Rho1 GTPase regulatory subunit. The A. fumigatus FKS1 and RHO1 genes have been cloned and individually disrupted. Both genes are required for cell viability. The inhibition of beta-1,3-glucan synthesis has been extensively pursued as a means of disrupting wall formation and prevent fungal growth. A family of anti-fungal agents, known as the echinocandins, has been developed for clinical use. The echinocandins, which include caspofungin, micafungin and anidulafungin, are non-competitive inhibitors of the beta-1,3-glucan synthase complex. Although the exact mechanism of inhibition is not fully understood, the echinocandins are known to bind to the glucan synthase catalytic subunit. Treatment with the echinocandins results in cell swelling and lysis at areas of active cell wall synthesis and the echinocandins have emerged as a promising therapy for aspergillosis and candidiasis.

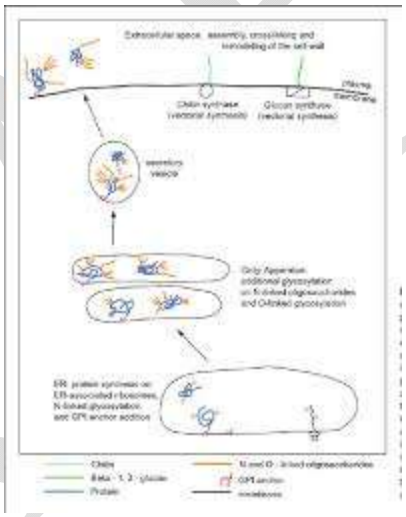


Figure 2. Cell wall biosynthesis. The glucan and chitin cell wall components are synthesized on the plasma membrane and extruded into the cell wall space during their synthesis. Glycoprotein synthesis begins in the endoplasmic reticulum with the cotranslational addition of N-linked oligosaccharides. GPI anchors are added to GPI-anchored proteins in the endoplasmic reticulum. In the Golgi apparatus, the glycosyltransferases further modify the proteins by the addition of sugars to generate O-linked oligosaccharides and to extend N-linked oligosaccharides. The glycoproteins are secreted into the cell wall space where they are integrated into the cell wall structure. The various components of the cell wall are cross-linked together in the cell wall space by cell-wall-associated glycosylhydrolases and glycosyltransferases.

1.3.3 Reproduction – asexual and sexual

1. Vegetative reproduction:

The most common method of vegetative reproduction is fragmentation. The hypha breaks up into small fragments accidentally or otherwise. Each fragment develops into a new individual. In the laboratory the 'hyphal tip method' is commonly used for inoculation of saprophytic fungus.

In addition to above-mentioned common method of vegetative reproduction the fungi reproduced vegetatively by other means, such as fission, budding, sclerotia, rhizomorphs, etc. In fission, the cell constricts in the centre and divides into two giving rise to new individuals.

The budding is commonly found in Saccharomyces. The buds arise from the protoplasm of the parent cells and ultimately become new individuals.

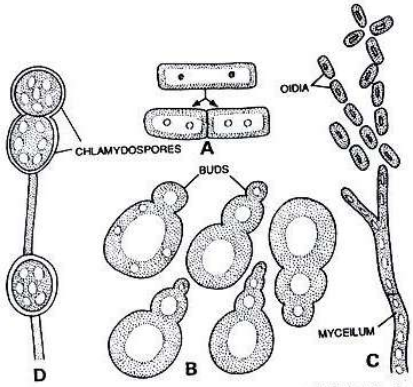


Fig. 8.14. Asexual reproduction, A, transverse cell division (fission); B, budding in yeast cell; C, hypha fragmenting into oidia or arthrospores in *Collybia conigena*; D, chlamydospore formation in *Fusarium*.

The sclerotia are resistant and perennating bodies. They survive for many years. Each sclerotium is cushion-like structure of compact mycelium. They give rise to new mycelia on the approach of favourable conditions.

As mentioned under the modified mycelium, the rope-like rhizomorphs are also resistant to unfavourable conditions and give rise to new mycelia even after several years on the approach of favourable conditions.

2. Asexual reproduction:

The asexual reproduction takes place by means of spores. Each spore may develop into a new individual. The spores may be produced asexually or sexually and thus named (a) asexual spores and (b) sexual spores. Under asexual reproduction, only asexual spores will be considered.

Asexual spores:

They are innumerable and produced on the diplont mycelium in Phycomycetes and Ascomycetes. In Basidio- mycetes they are produced on the diplont mycelium. The spores are of diverse type and borne upon special structures called the sporophores. These spores are produced asexually and called the asexual spores. Usually the spores are uninucleate and nonmotile but multinucleate and motile spores are also found.

The fungus producing more than one type of spores is called the pleomorphic or polymorphic. The spores produced inside the sporangia are termed the endogenous spores and the spores developing exogenously on the terminal ends of sporophores are called the exogenous spores.

Endogenous spores:

The endogenous spores are produced within the special spore producing cell the sporangium. The sporangia may be terminal or intercalary in their position. The sporophores which bear the sporangia on their apices are called the sporangiophores. They may be branched or unbranched.

The spores produced inside the sporangia are called the endospores or endogenous spores produced inside the sporangia are called the endospores or endogenous spores. They may be motile or non-motile. The motile spores are called the zoospores and the non-motile aplanospores. The zoospores are produced inside the zoosporangia. The protoplasm of the sporangium divides into uninucleate or multinucleate protoplasmic bits and each bit metamorphoses into a spore.

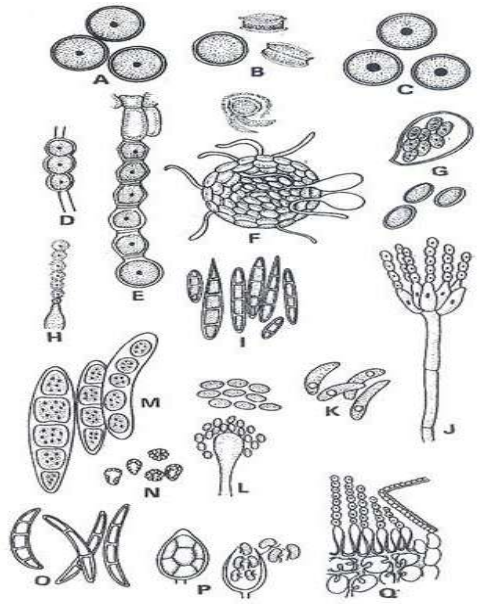


Fig. 8.15. The Fungi. Various types of spores. A, chlamydospores of *Ustilago hordei*; B, ascospores of *Aspergillus*; C, chlamydospores of *Ustilago tritici*; D, chlamydospores of *Fusarium*; E, ascospores of *Erysiphe*; F, cleistothecium of *Erysiphe*; G, ascus and ascospores of *Erysiphe*; H, conidia of *Aspergillus*; I, conidia of *Cercospora*; J, conidiophore and conidia of *Penicillium*; K, conidia of *Colletotrichum* sp; L, aplanospores of *Mucor*; M, conidia of *Helminthosporium*; N, aplanospores of *Rhizopus*; O, conidia of *Fusarium* sp; P, sporangium and zoospores of

The endogenously produced zoospores are uni or biflagellate. Each spore is without any cell wall, uninucleate and vacuolate. They can move with the help of their flagella. They are usually kidney-shaped or reniform and the flagella are inserted posteriorly or laterally on them. Such zoospores have been recorded from Albugo, Pythium, Phytophthora and many other lower fungi.

The aplanospores are non-motile, without flagella and formed inside the sporangia. They may be uni or multinucleate (e. g., Mucor, Rhizopus). These spores lack vacuoles and possess two layered cell walls. The outer thick layer is epispore or exospore which may be ornamented in many cases. The inner thin layer is endospore.

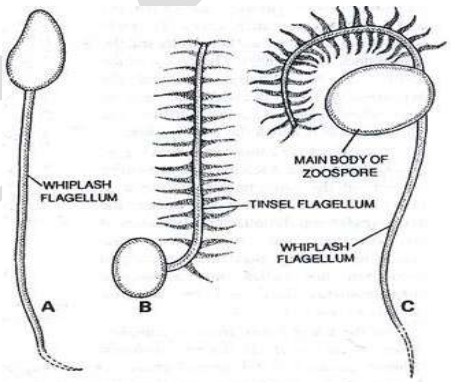


Fig. 8.16. Zoospores. A, posteriorly uniflagellate with a whiplash flagellum; B, anteriorly uniflagellate with a tinsel flagellum; C, biflagellate with an anterior tinsel and posterior whiplash flagellum.

Exogenous spores:

The spores producing externally or exogenously are either called the exogenous spores or conidia. They are produced externally on the branched or unbranched conidiophores. The condiophores may be septate or aseptate. The conidia borne upon the terminal apices of the conidiophores or the ends of the branches of the condiophores.

The conidia may be produced singly on each sterigma or in chains. The conidial chains may be basipetal to acropetal in succession. The conidia are diverse in their shape and size. They may be unicellular or multicellular, uninucleate or multinucleate. Different genera may be recognized only by the presence of various shaped and various coloured conidia. The conidia of Fungi Imperfecti are multicellular and variously shaped, whereas the conidia of Aspergillus and Penicillium are smoky green coloured and the fungi are called 'the blue-green molds'.

In other type of exospores, the sporophores develop in groups and form the specialized structure called the pustules, pycnia, aecidia, acervuli, and sporodochia. The pycnia are flask-shaped producing pycniospores in them. The acervuli are saucer- shaped widely open bodies having developed conidia in them on small conidiophores.

In mushrooms the sporophores are compactly arranged and form an umbrella-like fructification. The terminal expanded portion bears gills. In each gill there are hundreds of sporophores called the basidia bearing basidiospores. The sporophores (basidia) are arranged in hymenia.

3. Sexual reproduction:

A large number of fungi reproduce sexually. However, the members of Fungi Imperfecti, or 'Deuteromycetes' lack sexual reproduction.

Usually two phases are found in the life cycle of the plants. These phases are called haploid and diploid phases respectively. The haploid phase possesses the (n) number of chromosomes in the nucleus, whereas this number becomes (2n) in the diploid phase.

The gametes are always haploid (n) and by a sexual fusion they result in diploid (2n) sexual spores, such as zygospores, oospores, etc. To bring haploid (n) phase once again in the life cycle the reduction division (meiosis) takes place and the number of chromosomes becomes half.

The gametes taking part in sexual fusion may be morphologically or physiologically different. Such two gametes taking part in fusion are of opposite sexes or strains, which may be called male and female sex organs or plus and minus strains. When both the sex organs or strains occur on the same mycelicum, the fungus is said to

be monoecious or homothallic, and when the male and female sex organs or plus and minus strains occur separately on different mycelia the fungus is said to be dioecious or heterothallic.

The gametes taking part in fusion are usually formed in the cells of sacs called gametangia (singular-gametangium). The morphologically identical male and female gametes are called the isogametes. The morphologically dissimilar male and female gametes are called the heterogametes.

In such cases the male gametes are called the antherozoids and the female ones are the eggs. The fusion of the plasma of the gametes is called the plasmogamy, which is usually followed by the nuclear fusion, i.e., karyogamy. The whole process is called the fertilization.

Sometimes, in some of the fungi, e.g., Phycomycetes and Ascomycetes, the entire contents of the two gametangia fuse with each other, the process is called the gametangial copulation. In the members of Phycomycetes and Ascomycetes the gametangia taking part in gametangial copulation are called the antheridia (singular-antheridium) and the oogonia (singular-oogonium)

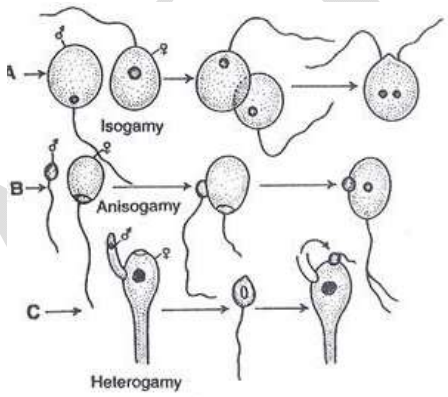


Fig. 8.17. Sexual reproduction in fungi. A, isogamy—as seen in *Synchytrium*; B, anisogamy—as seen in

In the lower fungi, there is complete fusion of the nuclei of the two different strained gametes in the sexual union, i.e., karyogamy, whereas in the higher fungi, i.e., Ascomycetes and Basidiomycetes, the fusion of the two nuclei of different strains is delayed and the pairs of the nuclei called the 'dicaryons' are formed. The mycelium having such pairs of nuclei is called the 'dicaryotic mycelium'. In the opposite cases where the mycelium possesses single haploid nucleus of either strain in each cell is called the monocaryotic mycelium. The most common methods of sexual reproduction are as follows:

i. Planogametic copulation:

This type of sexual reproduction involves the fusion of two naked gametes one or both of them are motile. The motile gametes are known as planogametes. The most primitive fungi produce insogamousplanogametes, e.g., Synchytrium, Plasmodiophorq etc. The anisogamousplanogametes are only found in the genus Allomyces of order Blastocladiales. In Monoblepharis (order Monoblepharidales) the unique

condition is present here the female gamete is non-motile whereas the male gamete is motile. The male gamete enters the oogonium and fertilizes the egg.

ii. Gametangial contact:

This method of reproduction is found in many lower fungi (class Phycomycetes). In this method two gametangia of opposite sex (oogonium and antheridium) come in contact and one or more gamete nuclei migrate from the male gametangium (antheridium) to the female gametangium (oogonium).

In no case the gametangia actually fuse. The male nuclei in some species enter the female gametangium through a pore developed by the dissolution of the wall of contact (e.g., in Aspergillus, Penicillium, etc.); in other species the male nuclei migrate through a fertilization tube (e.g., Phythium, Albugo, Peronospora, etc.). After the migration of the nuclei the antheridium eventually disintegrates but the oogonium continues its development in various ways.

iii. Gametangial copulation:

In this method of sexual reproduction the fusion of the entire contents of two contacting compatible gametangia takes place (e.g., Mucor, Rhizopus, Entomophthora, etc.)

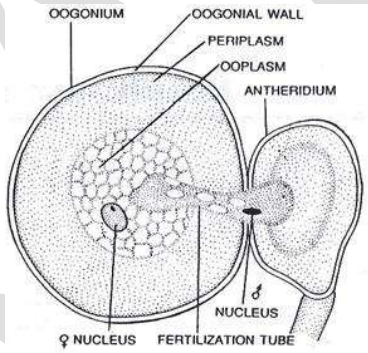


Fig. 8.18. Sexual reproduction. Gametangial contact by means of fertilization tube in *Pythium aphanidermatuam.*

iv. Spermatization:

The sexual reproduction in Neurospora (Class- Ascomycetes) and other fungi takes place by means of this method. The minute, uninucleate, spore-like male structures are known as spermatia. They are produced in several ways. The spermatia are carried by outer agencies to the receptive hyphae (trichogynes) of female gametangia, to which they become attached. A pore develops at the wall of contact and the contents of spermatium pass into the female gametangium through the receptive hypha.

v. Somatogamy:

The sex organs are not produced. The somatic cells take part in sexual fusion, e.g., Morchella, many higher fungi.

Heterokaryosis, heterothallism and parasexual mechanism

Heterokaryosis

- Heterokaryosis - co-existence of genetically- different nuclei in cytoplasm continuity with one another.
- Discovered by Hansen and Smith (1932) in Botrytis cinerea.
- Plays major role - variability and sexuality in fungi.

Formation of Heterokaryosis

Heterokaryotic condition arises by-

- Mutation
- Anastomosis
- Inclusion of dissimilar nuclei in spores after meiosis, in heterothallic fungi.

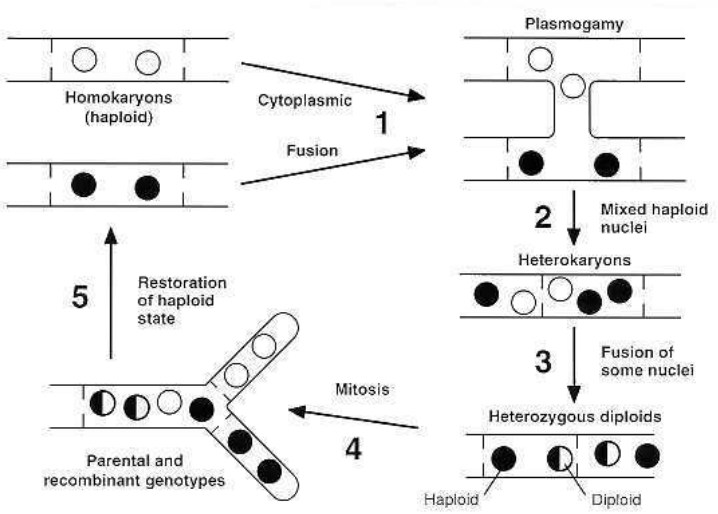
Mutation

A high frequency of mutation is characteristic of fungi - main source of variability.

Anastomosis (fusion of hyphae)- Fusion is mostly intra-specific. Nuclear migration from the point of fusion to the remainder of the mycelium takes place - heterokaryotic mycelium. **Example:** development of heterokaryon in basidiomycota.

Inclusion of dissimilar nuclei in spores after meiosis, in heterothallic fungi : Meiosis results in the production of genetically different nuclei sharing common cytoplasm. **Example:** Neurospora tetrasperma, Podospora anserine

On germination - give rise to a heterokaryotic thallus. In the asexul phase - occurs frequently in multinucleate spores.



Signification of Heterokaryosis:

- Substitute for heterozygosity and variability
- Heterokaryosis and pathogenicity- e.g. in rusts and smuts
- Origin of new race

- Initial step in Parasexual cycle

Establishment Of Heterokaryosis

- The presence of haploid nuclei of dissimilar genotypes in the same cytoplasm
- pre-requisite for recombination.
- Heterokaryosis is brought about by-

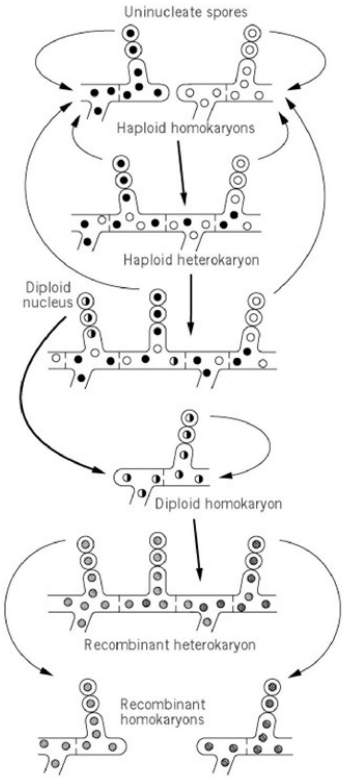
1. Mutation
2. Anastomosis
3. Inclusion of dissimilar nuclei in spores after meiosis, in heterothallic fungi.

Formation of Heterozygous Diploids

- Nuclear fusion in heterokaryotic somatic cells was first noted by Roper (1952) in Aspergillus nidulans.
- The nuclear fusion between dissimilar nuclei - the formation of heterozygous diploid nuclei or “zygotes”
- a rare event, occurring at the rate of one in a million.
- The heterozygous diploid nuclei - fairly stable
- The diploid colonies are recognized by-

1. higher DNA content of their nuclei
2. the bigger size of their conidia
3. certain phenotypic characteristics of their colony

- The prolonged diploid phase involving repeated nuclear divisions, enhances the chances of “mitotic crossing over”.



Occasional Mitotic Crossing Over During Multiplication Of Diploid Nuclei

- genetic recombination takes place.
- Penicllium chrysogenum and Aspergillus niger- mitotic crossing over is as frequent as during meiosis.
- In mitotic crossing over - exchange, or chiasmata formation - confined to a single chromosome pair out of the whole component of chromosomes.
- In meiosis, the crossing – over occurs simultaneously in all the chromosomes.
- splitting of chromosomes and segregation of strands is same in mitotic crossing over as it occurs in meiosis.

Occassional Haploidization Through Aneuploidy

- The diploid nuclei - haploid nuclei -gradual loss of chromosomes during successive mitotic division - haploidization.
- Meiosis is not involved.
- The haploidization occurs at a constant rate of 10- 3 per nuclear division - the result of aneuploidy.
- During mitotic division - non-disjunction of the chromatids of one chromosome pair - results in aneuploid nuclei (2N-N) or haploid.
- The aneuploids – unstable - the loss of chromosomes - favours the development of fully balanced haploid nuclei.

Parasexual Cycle in Fungi

Introduction

In some fungi, true sexual cycle comprising of nuclear fusion and meiosis is absent. These fungi derive the benefits of sexuality through a cycle known as Parasexual Cycle.

The Parasexual Cycle is defined as a cycle in which plasmogamy, karyogamy and meiosis (haploidisation) take place but not at a specified time or at specified points in the life-cycle of an organism.

Generally parasexual cycle occurs in those fungi in which true sexual cycle does not take place. The members of class Deuteromycetes (Deuteromycotina) in which sexual cycle does not occur, exhibit parasexual cycle generally.

Parasexual cycle was first discovered by Pontecarvo and Roper of University of Glasgow in 1952 in Aspergillus nidulans, the imperfect stage of Emericella nidulans.

Since then parasexual cycle has been discovered not only in several members of Deuteromycetes but also in fungi belonging to Ascomycetes and Basidiomycetes.

Steps Involved in Parasexual Cycle:

According to Pontecarvo (1958), parasexual cycle in A. nidulans involves the following steps:

(i) Formation of heterokaryotic mycelium

(ii) Fusion between two nuclei (Karyogamy)

(a) Fusion between like nuclei

(b) Fusion between unlike nuclei

(iii) Multiplication of diploid nuclei

(iv) Occasional Mitotic crossing over.

(v) Sorting out of diploid nuclei

(v) Occasional haploidisation of diploid nuclei, and

(vii) Sorting of new haploid strains.

A brief account of these steps are being presented below:

(i) Formation of heterokaryotic mycelium:

Heterokaryotic mycelium is formed in several ways. The most common is by the anastomosis of somatic hyphae of different genetic combinations.

The foreign nucleus or nuclei introduced into a mycelium multiplies and its progeny spreads through the mycelium rendering it heterokaryotic. Mutation in one or more nuclei of a homokaryotic mycelium also makes it heterokaryotic.

It happens in some of the fungi belonging to Ascomycetes. Still a third way is by the fusion of some of the nuclei and their subsequent multiplication and spread among the haploid nuclei. In this type of heterokaryotic mycelium a fixture of haploid and diploid nuclei occur.

(ii) Fusion between two nuclei (Karyogamy):

The fusion of nuclei in the mycelium has been demonstrated. The nucelar fusion may be of two types: (a) fusion between like nuclei and (b) fusion between unlike nuclei. The nuclear fusion results in the formation of homozygous or heterozygous diploid nucleus respectively.

If the genotype of unlike nuclei present in the heterokaryotic mycelium is A and B, then five types of nuclei can be formed by their fusion: two types of haploid nuclei (A and B), two types of homozygous diploid nuclei (AA and BB) and one type of heterozygous diploid nucleus (AB).

(iii) Multiplication of diploid nuclei:

The above mentioned five types of nuclei multiply at about the same rate but the diploid nuclei are present in much smaller number than the haploid nuclei. Portecarvo (1958) estimates a proportion of one diploid heterozygous nucleus to 1000 haploid nuclei.

(iv) Occasional mitotic crossing over:

During multiplication of diploid nuclei, mitotic crossing over may take place. This results in the formation of new gene combinations. These recombinations, which are dependent on the existence of heterokaryosis, give the fungus some of the advantages of sexuality within the parasexual cycle.

According to Pontecarvo's (1958) estimates, the amount of recombinations which may be expected to occur in an ascomycete through its parasexual cycle is 500 times smaller than through its sexual cycle.

However, in Penicillium chrysogenum and Aspergillus niger, diploidisation and mitotic crossing over occur more frequently indicating the importance of parasexual cycle in evolution of new strains.

(v) Sorting out of Diploid nuclei:

In those fungi which produce uninucleate conidia, sorting out of the diploid nucleus occurs by their incorporation into conidia which germinate to produce diploid mycelia. Diploid strains of several important imperfect fungi have been isolated.

Roper (1952) first synthesized and isolated diploid strains of Aspergillus nidulans. The conidia of diploid strains are somewhat larger than those of haploid strains.

(vi) Occasional haploidisation of the diploid nuclei:
Occasionally, some hyphae of diploid mycelium form haploid conidia which form haploid mycelia on germination. The formation of haploid conidia by diploid mycelium indicates that haploidisation occurs in some diploid nuclei.

(vii) Sorting of new haploid strains:
Some diploid nuclei undergo haploidisation in the mycelium and are sorted out by incorporation of haploid nuclei in the uninucleate conidia. Some of these haploid strains are genotypically different from their parents because of their mitotic recombinations.

Thus, after the parasexual cycle has operated for some time, the mycelium may contain the following types of nuclei:
(a) Haploid nuclei like those of both the parents,

(b) Haploid nuclei with various new genetic recombinations,

(c) Several types of diploid homozygous nuclei,and

(d) Several types of diploid heterozygous nuclei.

Significance of Parasexual Cycle:
Parasexual cycle is of importance in industrial processes. Several fungi which are used in various industrial processes belong to fungi imperfecti or Deuteromycetes and in these fungi only parasexual cycle operates.

New and better strains of these fungi are obtained by mutation through parasexual cycle. The strains of desirable characters can be developed through mitotic recombinations.

Parasexuality can also be applied in the analysis of genetic and physiological processes of perfect and imperfect fungi. Parasexual cycle has also been successfully employed in genetic control of pathogenicity and host-range in several species of Fusarium.

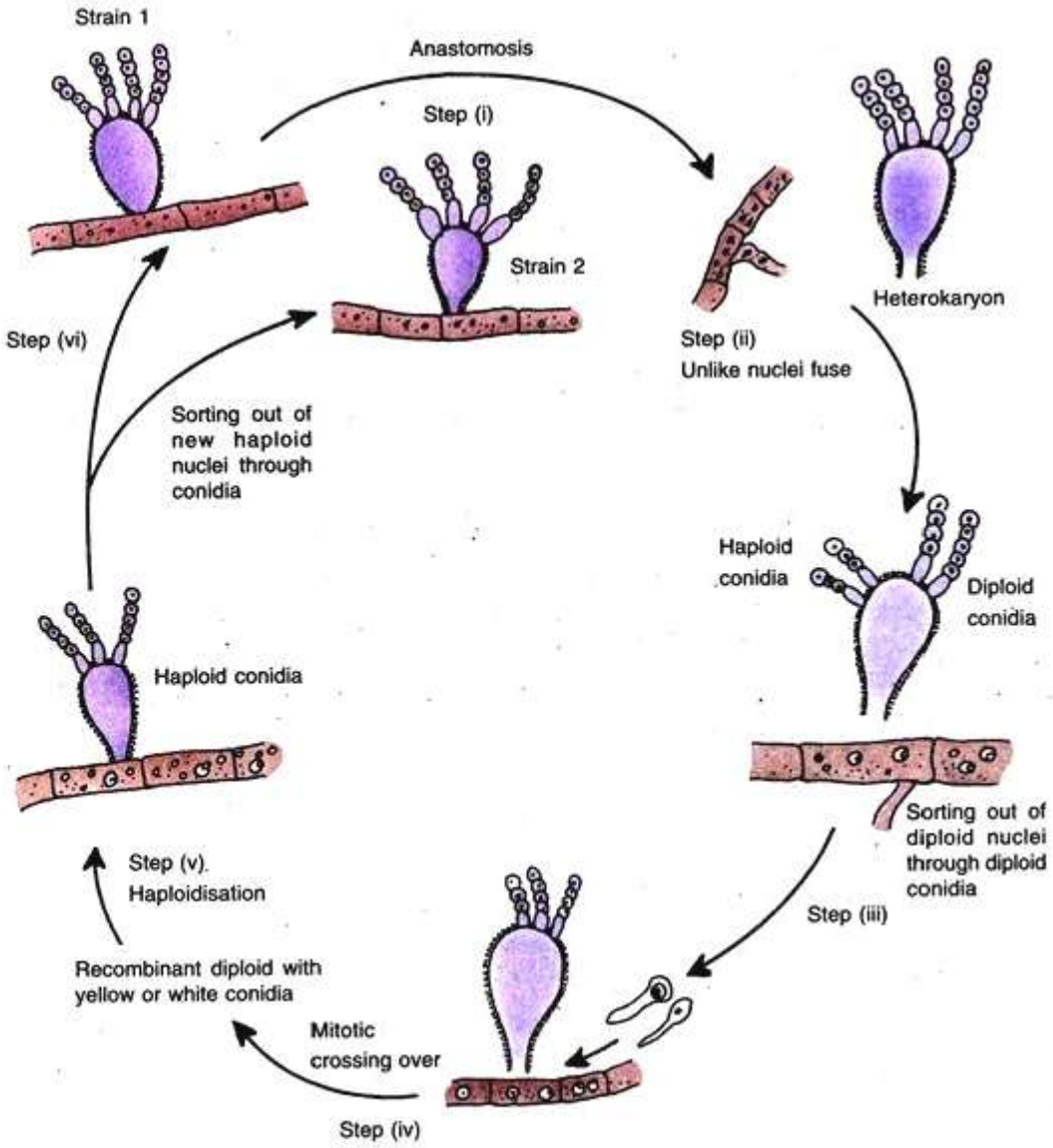


Fig. 17.10. Pontecarvo's (1958) idea of Parasexual cycle

Economic Importance of fungi

Fungi include hundreds of species which are of tremendous economic importance to man. In fact our lives are intimately linked with those of fungi. Hardly a day passes when we are not benefited or harmed directly or indirectly by these organisms.

They play an important role in medicine yielding antibiotics, in agriculture by maintaining the fertility of the soil and causing crop and fruit diseases, forming basis of many industries and as important means of food. Some of the fungi are important research tools in the study of fundamental biological processes.

Some of the fungi particularly molds and yeasts play a negative role by causing spoilage of stored goods such as foodstuffs, textiles, leather, rubber, plastic, timber and even glass.

Role of Fungi in Medicine:

Some fungi produce substances which help to cure diseases caused by the pathogenic microorganisms. These substances are called the antibiotics.

The term antibiotic, therefore, denotes an organic substance, produced by a microorganism, which inhibits the growth of certain other microorganisms. The most important antibiotics are produced by the moulds, actinomycetes or bacteria.

They are used to combat the evil effects of pathogenic bacteria and viruses. The use of antibiotics is not limited to disease treatment.

The addition to certain antibiotics in small amounts to the feed of slaughter animals promotes rapid growth and improves the quality of the meat products. Application of an antibiotic to surface of freshly killed poultry preserves the fresh-killed taste during long periods of refrigeration.

The discovery of antibiotic agents as drugs is comparatively a recent history. The role of fungi m producing antibiotic substances was first established by Sir Alexander Fleming in 1929.

He extracted the great antibiotic drug Penicillin from Penicillium notatum. It was the first antibiotic to be widely used. Penicillin is an organic substance lethal to microbes. It is far more effective than ordinary drugs and germicides.

It has no adverse effect on human protoplasm but kills bacteria especially gram-positive type. Penicillin is now produced on a commercial scale all over the world including India from the improved strains of P. notatum and P. chrysogenum.

There is a Penicillin factory at Pimpri in India. The success of penicillin as an antibiotic was later found to be limited. Naturally this led to further research for new antibiotics which would act on pathogenic bacteria and viruses not affected by penicillin.

This research resulted in the discovery of a number of other antibiotics. Of these, streptomycin is another.

Streptomycin is obtained from Streptomyces griseus. It is of great value in medicine. It destroys many organisms which are not killed by penicillin particularly the gram-negative organisms. A numbers of antibiotics have also been extracted from Aspergillus cultures.

However, these have not been proved so effective as penicillin. Some of the actinomycetes which are not considered to be true filamentous bacteria are the sources of many antibiotics such as chloromycetin, aureomycin, terramycin, etc.

They inhibit the growth of many pathogenic bacteria and are also used successfully in the treatment of various virus diseases. Many animal and human diseases which do not respond readily to other antibiotics are effectively cured by aureomycin.

The plasmodia of certain species of Myxogastres have been reported to yield soluble antibiotics. These check the growth of certain bacteria and yeasts in culture. The antibiotics play an important role to combat plant diseases as well.

Griseofulvin which is recovered from mycelium of Penicillium griseofulvum and many other species has antifungal properties. It acts on the hyphae by interfering with wall formation Consequently the hyphal tips curl and cease to grow.

When administered orally it is absorbed into the body where it accumulates in the keratinized tissues of the epidermis and hair. It is thus effective against fungal skin diseases such as ringworms and athlete’s foot disease.

Claviceps purpurea produces sclerotia in the ovaries of the flowers of grasses such as rye The sclerotium is called the ergot of rye. Ergot is used in veterinary and human medicine.

It contains a mixture of alkaloids which cause rapid and powerful contractions of the uterus. The medicine is thus used to control bleeding during child birth. Ergot is highly poisonous. A derivative of ergot known by the name of lysergic acid (LSD) is used in experimental psychiatry.

The giant puff ball Clavatia contains an anti-cancer substance calvacin. The eating of these fungi prevents stomach tumours.

Role of Fungi in Industry:

The industrial uses of fungi are many and varied. In fact the fungi form the basis of many important industries. There are a number of industrial processes in which the biochemical activities of certain fungi are harnessed to good account.

A brief sketch of some of the most important of these processes is given below:

(i) Alcoholic fermentation:

It is the basis of two important industries in India or rather all over the world. These are brewing and baking. Both are dependent on the fact that the fermentation of sugar solutions by yeasts produces ethyl alcohol and carbon dioxide.

In brewing or wine making industry alcohol is the important product. The other by-product which is carbon dioxide was formerly allowed to escape as a useless thing.

Now carbon dioxide is also considered a valuable by-product. It is collected, solidified and sold as **"dry ice".** In the baking or bread- making industry CO_2 is the useful product.

It serves two purposes:

(i) Causes the dough to rise.

(ii) Makes the bread light.

The other by-product, which is alcohol, is incidental. The yeasts secrete the enzyme complex called zymase which brings about conversion of sugar into alcohol. Many excellent yeast strains are now available.

The yeasts lack diastase. So they cannot break starch into sugar. There are a number of fungi popularly known as the moulds. They secrete a whole range of enzymes and thus bring about fermentation of complex carbohydrates.

In producing industrial alcohol moulds are employed as starters to bring about scarification of the starch. At the second stage yeast is employed to act on the sugar.

Although mould can complete the conversion to sugar but the yield is better if yeast is employed for the second stage. The moulds commonly used for purpose of scarification are Mucor racemosus.

M, rouxii and some species of Rhizopus. Aspergillus flavus is used in the production of African native beer.

(ii) Enzyme preparations:

Takamine on the basis of his intensive study of the enzymes produced by Aspergillus flavus-oryzae series has introduced in the market a few products of high enzymic activity. These are Digestin, Polyzime, Taka diastase, etc. They are used for dextrinization of starch and desiring of textiles.

Cultures of Aspergillus niger and A. oryzae on trays of moist, sterile bran yield a well-known amylase which contains two starch splitting components.

Invertase is extracted from Saccharoymces cerevisiae. It has many industrial uses. It hydrolyses sucrose to a mixture of glucose and fructose.

(iii) Preparation of organic acids:

The important organic acids produced commercially as the result of the biochemical activities of moulds are oxalic acid, citric acid, gluconic acid, gallic acid, fumaric acid, etc.

Oxalic acid is the fermentation product of Aspergillus niger. Citric acid is made by mould fermentation. Many species of Penicillium are used for the purpose. The acid is produced on a commercial scale and is cheaper than the acid made from the citrus fruits.

The gluconic acid is prepared from sugars. The moulds chiefly employed for this purpose are some species of Penicillium and Aspergillus.

Gallic acid is prepared on a commercial scale in Europe and America. The details of the method employed, however, are not known. It may be a modification of Calmete's process.

Calmette (1902) obtained the gallic acid as the fermentation product of an extract of tannin by Aspergillus gallomyces.

(iv) Gibberellins:

These are plant hormones produced by the fungus Gibberella fujikuroi which cause a disease of rice accompanied by abnormal elongation. Gibberellin is used to accelerate growth of several horticultural crops.

(v) Cheese Industry:

Certain fungi popularly known as the cheese moulds play an important role in the refining of cheese. They give cheese a characteristic texture and flavour.

The two chief kinds of mould refined cheese are:

(a) Camembert and Brie types. They are soft.

(b) Roquefort Gorgonzola and Stilton types. They are green or blue veined cheese. The moulds concerned are Penicillium camemberti and P. caseicolum in the first type and P. roqueforti in the second type.

(vi) Manufacture of Proteins:

As a supplement to the normal diet, some fungi particularly the yeasts are employed to synthesize proteins. The yeast (Saccharomyces cerevisiae and Candida utilis) contain high percentage of protein of great nutritive value.

They are grown with ammonia as the source of nitrogen and molasses as the source of carbon. The manufactured product is called Food Yeast. It contains 15% protein and B group of vitamins.

(vii) Vitamins:

The yeasts, are the best source of vitamin B complex. A number of preparations of high potency have been made from the dried yeast or yeast extracts and sold in the market.

A number of moulds and yeasts are utilised in the synthesis of Ergosterol which contains Vitamin D. Riboflavin—another vitamin useful both in human and animal food—is obtained from a filamentous yeast, Ashby gossypii.

(viii) A good many fungi synthesize fat from carbohydrates:

Endomyces vernalis, Penicillium javanicum and Oidium lactis have a high fat content. The microbiological production of fat is, however, too costly for use.

(ix) Antibiotics:

Certain fungi form an important basis of fermentation of Cocaobeans. Mention must also be made here of the use of Lichens in yielding certain dyes and reagents. An important substance is extracted from Roccella lichen.

It forms the basis of litmus paper which is used as an indicator to determine the acidity or alkalinity of a solution.

3. Role of Fungi in Agriculture:

The fungi play both a negative and a positive role in agriculture.

A. Negative Role:

They have a negative value because they are the causative agents of different diseases of our crop, fruit and other economic plants. These fungal diseases take a heavy toll and cause tremendous economic losses.

The modest estimate is that about 30 thousand different diseases (including bacterial and virus) attack the economic plants grown for food or commercial purposes.

The more important of these diseases are:

(i) Damping off disease:

The seedlings of almost every type of plant grown as a commercial crop such as tomatoes, com, cotton, mustard, peas, beans, tobacco, spinach, etc., are prone to this disease. It is caused by a species of Pythium.

(ii) The potato blight:

(Late blight of potatoes) is another destructive crop disease. It does a great damage to the potato tubers. A heavy attack of this disease in Ireland in 1845 destroyed the entire potato crop and caused so severe a famine that over a million Irish people migrated to U.S.A. Besides potatoes, it infects egg plants, tomatoes, etc.

(iii) Downy mildews of grapes:

It ruins the vine yards and thus causes heavy losses to the crop. When the disease was first introduced into France from U.S.A, it caused a havoc to the vine yards.

Almost all the French vine yards were destroyed before Bordeaux mixture, which proved an effective fungicide against this disease, was discovered.

(iv) Ergot disease of rye:

It is an important disease of a cereal crop—rye. It results in the formation of poisonous sclerotia in the rye kernel. It is called ergot of rye. Ergot is highly poisonous to man. Ergot poisoning causes hallucinations, insanity and finally death.

(v) Apple scab:

It is a serious disease of the apple crop. It lowers the quality as well as quantity of the fruit.

(vi) Brown rot of stone fruits:

It causes enormous losses in the fruit crop of apricots, cherries, plums and peaches.

(vii) Smut diseases of corn, wheat, oat and other cereal crops cause serious reduction in the yield and quality of grain.

(viii) Red rot disease of sugarcane:

It is a serious disease of sugarcane whose incidence has increased during the last few years, particularly in the northern parts of the country.

(ix) Rust diseases:

They attack our cereal crops and forest timber. Some of them such as black stem rust, yellow rust and orange rust are a serious threat to our wheat crop.

(x) Blackarm, Wilt and root rot of cotton:

These diseases of cotton, which is a very important commercial crop of our country, take a heavy toll of the crop every year.

(xi) Pore fungi:

They are the common wood rotters. They destroy timber and lumbar.

The above-mentioned diseases caused by fungi are thus responsible for a huge loss to our crop and other economic plants. The pathogenic fungi are always a nuisance to the agriculturists.

They affect the agricultural economy of our country seriously. The farmer and the Agriculture department must wage a constant war against them.

It will not be out of place if a brief mention is made here of some of the human diseases caused by the fungi. Some species of Aspergillus such as A. fumigatus, A. flavus, and A. niger are human pathogens.

They cause disease collectively known as aspergilloses such as aspergilloses of lungs, external ear, etc. Many parasitic Fungi Imperfecti live in the mucous membranes of throat, bronchi and lungs and cause infection of mouth and lungs.

A few fungi cause skin discoloration. Others (Trichophytoneae) are the causative agents of a disease known as athlete's foot. The well-known skin disease 'ring worm' and barber's itch are also fungal diseases.

Monilia—a member of the class Fungi Imperfecti—causes a throat or mouth disease known as thrush. A few fungi cause serious diseases of domestic animals. Some fungi produce diseases among annoying insects harmful to crop and thus help to destroy them and keep them in check.

TABLE 1

List of some important plant diseases caused by fungi

	Name of the disease	Pathogen
1.	Club root of Crucifers	*Plasmodiophora brassicae*
2.	Wart disease of potato	*Synchytrium endobioticum*
3.	Stem Rot of Papaya	*Pythium aphanidermatum*
4.	Damping off of seedlings	*Pythium sp.*
5.	Late blight of potato	*Phytophthora infestans*
6.	White rust of crucifers	*Albugo candida*
7.	Downy mildew of peas	*Peronospora pisi*
8.	Green ear disease of Bajra	*Sclerospora graminicola*
9.	Powdery mildew of peas	*Erysiphe polygoni*
10.	Powdery mildew of wheat	*Erysiphe graminis*
11.	Leaf curl of peaches	*Taphrina deformans*
12.	Stem gall of coriander	*Protomyces macrosporous*
13.	Ergot disease of rye	*Claviceps purpurea*
14.	Rust of wheat	*Puccinia graminis*
15.	Rust of pea	*Uromyces pisi*
16.	Rust of gram	*Uromyces ciceris-arieteni*
17.	Rust of Linseed	*Melampsora lini*
18.	Covered smut of barley	*Ustilago hordei*
19.	Loose smut of wheat	*Ustilago nuda*
20.	Bajra smut	*Tolyposporium penicillariae*
21.	Grain smut of Jowar	*Sphacelotheca sorghi*
22.	Bunt of wheat	*Tilletia tritici*
23.	Early blight of potato	*Alternaria solani*
24.	Wilt of pigeon pea	*Fusarium oxysporum*
25.	Red rot of sugarcane	*Colletotrichum falcatum*
26.	Tikka disease of groundnuts	*Cercospora personata*
27.	Stripe disease of barley	*Helminthosporium graminieum*

TABLE II

List of some common disease of human beings caused by fungi

Name of the disease	Pathogen
1. Aspergillosis	*Apsergillus flavus, A. niger*
2. Blastomycosis	*Blastomyces dermatidis*
3. Otomycosis	*Aspergillus fumigatus*
4. Neuritis	*Mucor pusillus*
5. Onychomycosis	*Trichophyton purpureum*
6. Candidiasis	*Candida albicans*
7. Histoplasmosis	*Histoplasma capsulatum*
8. Geotrichosis	*Geotrichum candidum*
9. Chromomycosis	*Cladosporium immitis*
10. Allergy	Spores of *Aspergillus, Chaeotomium etc*
11. Dermatomycosis	*Trichoderma viride*

TABLE III

List of some animal diseases caused by fungi.

Name of the disease	Pathogen
Penicillosis	Spp. of *Penicillium*
Aspergillosis	Spp. of *Aspergillus*
Athelete foot	*Tinea rubrum*
Ringwarm	*Trichophytom, Microsporum*
Mucomycosis	*Mucor, Rhizopus*

In addition to causing diseases in plants, human beings and domestic animals as described above, the fungi also play the following harmful roles:

(a) Destruction of timber:

Several fungi such as Polyporus, Serpula lacrymans, Fusarium negundi, Coniophora cerebella, Lentinus lapidens and Penicillium divaricatum cause destruction of valuable timbers by reducing the mechanical strength of the wood.

(b) Destruction of textiles:

Several fungi are able to grow on cotton and woolen textiles causing their destruction. These include spp. of Alternaria, Penicillum, Aspergillus, Mucor and Fusarium. Spp. of Stachybotrys causes destruction of cotton in storage. Chaetomium globosum is reported to cause greatest damage to textiles.

(c) Destruction of Paper:

Paper pulp wood is destroyed by the growth of Polyporus adustus, Polystictus hirsutus etc. several fungi such as species of Chaetomium, Aspergillus, Stachybotrys, Alternaria, Fusarium, Dematium, Mucor, Cladosporium etc. cause extensive damage to paper of books, newspapers and paper industry.

B. Positive Role of Fungi:

Some soil fungi are beneficial to agriculture because they maintain the fertility of the soil. Some saprophytic fungi particularly in acid soils where bacterial activity is at its minimum cause decay and decomposition of dead bodies of plants and their wastes taking up the complex organic compounds (cellulose and lignin) by secreting enzymes.

The enzymes convert the fatty carbohydrate and nitrogenous constituents into simpler compounds such as carbon dioxide, water, ammonia, hydrogen sulphide, etc.

Some of these return to the soil to form humus and the rest of the air from where they can again be used as raw material for food synthesis. There are fungi in the soil which produce more ammonia from proteins than the ammonifying bacteria.

Besides, many saprophytic fungi of decay maintain the never ending cycle of carbon dioxide which is a most important raw material for plant photosynthesis in nature.

They also bring about rot, decay and decomposition of animal and plant remains releasing plant nutrients in a form available to green plants as food. The soil fungi utilize many inorganic salts.

These are prevented from being lost from the soil by leaching. Some fungi form mycorrhizal association with the roots of certain plants and help them in their nutrition.

Such plants will grow satisfactorily only when the mycelium of the appropriate fungal partner is present in the soil. The fertile soil contains twice as much living fungus cell material as the material from bacteria and other soil microorganisms.

Giberrrelin produced by Gibberella fujikuroi is used as growth hormone accelerating plant growth.

Many insect pests can be controlled by the growth of fungi such as Empusa sepulchrasis, Metarrhizium anisopliae, Cordyceps melothac etc.

Some common fungal inhabitants of the soil help to combat diseases caused by soil borne fungi. Trichoderma lignorum and Gliocladium fimbriatum are found in damp soils. They have an inhibitory effect on the growth of the mycelium of Pythium.

They serve to suppress fungi causing the damping off disease of the seedlings and thereby influence favourably the growth of crops.

Drechsler (1937) reported that there are some predacious fungi (Fig. 17.1 A-C) in the soil. They trap and destroy the nematodes (eel worms). Some species of these predatory soil fungi form loops on the mycelium (A). These loops act as nooses.

They tighten and strangle the nematodes as they try to pass through (B). The mycelium later sends out special hyphae (C) to absorb nutrition from the captive. Some
predatory soil fungi produce conidia which are sticky.

As the nematodes pass through the soil the stickly conidia stick to their bodies. There the conidia germinate to produce hyphae which penetrate into the tissues of the host and absorb nourishment.

At the National Botanical Research Institute, Lucknow and at several other national institutes, fungi are being tested as biopesticides especially as nematicides and as fungicides.

An important fungus being used as nematicide is Beauveria bassiana against borers, thrips, and aphids. Trichoderma viride and T. harzianum are other examples which are used against a large number of soil-borne pathogens.

4. Role of Fungi as Food and as Food Producers:

Many species of fungi are edible, about 2000 species of them have been reported from all over the world. Of these, about 200 are said to occur in the Western Himalayas.

Many edible fungi are of great economic value as food. They are regarded as delicacies of the table. There are said to be over 200 species of edible fungi.

The fructifications of some fungi such as the field mushroom Agaricus campestris (dhingri), Podaxon podaxis (Khumb), the honey coloured mushrooms, the fairy ring mushrooms, the puff balls (Lycoperdon and Clavatia), morels (Morchella, guchhi), and truffles are edible.

The content of available food in them is not high but they supply vitamins and are valuable as appetisers. Yeasts and some filamentous fungi are valuable sources of vitamins of the B-complex.

A few of the mushrooms are fatally poisonous, some cause only discomfort. To the former category belong Amanita.

The fungi are also important as producers of foodstuffs. Certain species of Penicillium are active in the refining of certain kind of cheeses. Some fungi, such as red bread mold, Neurospora sitophila and others, complete their sexual life cycle in a few days and thus make ideal organisms for the study of the laws of heredity.

The slime molds (Physarum polycephalum) are now widely used in research. P. polycephalum has proved an excellent experimental organism for the study of DNA synthesis, meiotic cycle and the mechanism of protoplasmic streaming.

Many fungi are responsible for spoilage of food stuffs. Penicillium digitatum causes rotting of citrus fruits. Milk and milk products are spoiled and made unfit for human use due to the growth of several fungi such as Mucor, Aspergillus, Penicillium, Oidium and Fusarium Mucor mucedo and spp. of Aspergillus grow on bread and spoil it. Oidium lactis develops the fishy odour of butter causing damage to the butter.

In tropical conditions, many fungi such as Mucor sp., Penicillium, Neurospora, Fusarium, Aspergillus etc., grow on meat causing sufficient spoilage.

Aflatoxins the most potent carcinogenic agent-are produced by Aspergillus flavus, A. fumigatus, A. parasiticus and Penicillium islandicum on dried foods and groundnut meal.

Aflatoxins are reported to bind with DNA and prevent its transcription arresting protein synthesis. These are responsible for liver cancer in animals and human beings.

Mushroom toxins are produced by several poisonous mushrooms. These cause diarrhoea vomiting, liver damage, complete unconsciousness etc. Mushroom toxins are commonly produced by Amanita phalloides, spp. of Helvella and some species of Inocybe.

Ergot toxins produced by Claviceps purpurea contain poisonous alkaloids like ergotamine, ergometrimine, ergocrystinine, ergocrystinine and ergonovin. These cause diarrhoea, abdominal pain, vomiting and psychiatric disturbances.

Mycotoxins

Mycotoxins can have an impact on economics by causing losses in farm animals or giving rise to difficulties in their management, or by rendering a commodity unacceptable in national or international trade, because it does not conform with national criteria laid down for maximum tolerated levels of certain mycotoxins. The formation of mycotoxins in human food or animal feeds can occur as a result of postharvest sp materials badly stored, or preharvest as a result of invasion of a crop plant by a mycotoxigenic mould which may have a pathogenic or

symbiotic relationship with the plant. There is at least one situation (facial eczema of sheep) in which a mycotoxin (sporidesmin) is produced in the field but on dead plant litter rather than in the living plant.

Given sufficient economic resources there should be no problem in controlling the postharvest formation of mycotoxins in storage, but in tropical developing countries these resources may not be available and problems do still occur. The formation of mycotoxins in the field may be far more difficult to control and may require quite radical changes in agricultural practice.

Biodeterioration

Biodeterioration is a terminology used to describe any undesirable change in the properties of a material caused by the vital activities of organisms.

Fungal growth requires suitable temperature, moisture and air (oxygen). Fungi are heterotrophs that acquire nutrients by absorption. They secrete hydrolytic enzymes (exoenzymes) and acids to decompose complex molecules into simpler ones that can be absorbed and used as nutrients. Hence, they are believed to be potential contributors to biodeterioration of different kinds of materials containing cellulose, silicate mineral (mica and orthoclase), iron and magnesium-bearing minerals (biotite, olivine, pyroxene) etc.

Fungi cause biodeterioration to many materials including:

- building materials
- animal feeds
- electrical equipment
- food including meat, fruits and grains
- fuel including jet fuel
- glass and optical equipments
- gunpowder
- leather
- monuments
- paint
- paper
- tobacco etc.

How are Fungi involved in biodeterioration?

The rate of biodeterioration depend on prevailing environmental conditions and the fungus involved. There are different mechanisms of biodegradation. These include microbial corrosion, hydrocarbon degradation and biodegradation of cellulose.
Aspergillus *niger*, *Chaetomium globosum*, Scopulariopsis *brevicaulis*, Trichoderma*koningii*, Trichothecium *roseum*

and *Eurotium chevalieri* are cellulolytic fungi. Their efficiency to degradate cellulosic (cellulose containing) materials is due to their ability to produce large amounts of cellulase enzymes.

Stachybotrys *chartarum* is a common fungus growing on paper (such as that covering gypsum wallboard) in damp buildings.

Some fungi cause blue stain and soft rot of wood, discolouration and loss of strength of cotton materials. Many fungi spoil food in storage. Aspergillus flavus grows on peanuts and many other substrates, producing a mycotoxin called aflatoxin, which contaminate food and causes liver damage. Fusarium *graminearum* grows on feed corn and produces the mycotoxin zearalenone that causes oestrogenic syndrome in animals.

Through the action of excreted oxalic and citric acids fungi can deteriorate marble, limestone, granite and basalt. Several species of fungi are involved in biodeterioration of stone monuments in different countries. Some of these fungi are *Aspergillus elegans*, *Aspergillus flavus*, Aspergillus nidulans, Aspergillus niger, Aspergillus versicolor, Alternaria sp, Cladosporium *cladosporioides*, Cladosporium sphaerospermum, Cunninghamella *echinulata*, Curvularia *lunata*, *Fusarium roseum*, Gliocladium *virens*, Penicillium *crustosum*, *Penicillium glabrum*, *Penicillium chrysogenum* (=*Penicillium notatum*), Rhizopus *arrhizus*.

Biodeterioration is a problem worldwide. Several control measures have been applied to prevent the biodeterioration. These include use of fungicides, biological control, prevention of biodeterioration by control of environmental conditions, periodic cleaning of dirt, dust and spores, and use of radiation.

PROTOZOA

General characteristics

General Characteristics of phylum Protozoa

1. **Kingdom:** Protista
2. They are known as acellular or non-cellular organism. A protozoan body consists of only mass of protoplasm, so they are called acellular or non-cellular animals.
3. **Habitat:** mostly aquatic, either free living or parasitic or commensal

4. **Grade of organization:** protoplasmic grade of organization. Single cell performs all the vital activities thus the single cell acts like a whole body.
5. Body of protozoa is either naked or covered by a pellicle.
6. **Locomotion:** Locomotory organ are pseudopodia (false foot) or cilia or absent.
7. **Nutrition:** Nutrition are holophytic (like plant) or holozoic (like animal) or saprophytic or parasitic.
8. **Digestion:** digestion is intracellular, occurs in food vacuoles.
9. **Respiration:** through the body surface.
10. **Osmoregulation:** Contractile vacuoles helps in osmoregulation.
11. **Reproduction:**

- Asexually reproduction is through binary fission or budding.
- Sexual reproduction is by syngamy conjugation.

Classification of Protozoa:

Phylum protozoa is classified into four classes on the basis of locomotary organs

Class 1 Rhizopoda

- **Locomotary organ:**
- Mostly free living, some are parasitic
- **Reproduction:** asexually by binary fission and sexually by syngamy.
- No conjugation.
- Examples: *Amoeba, Entamoeba*

Class 2 Mastigophora/ Flagellata

- Locomotory organ: Flagella
- Free living or parasite.
- Body covered with cellulose, chitin or silica.
- Reproduction: A sexual reproduction by longitudinal fission.
- No conjugation.
- Examples: *Giardia, Euglena, Trypanosoma*

Class 3 Sporozoa

- Locomotory organ: Absent
- Exclusively endoparasites
- Contractile vacuoles is absent
- Body covered with pellicle.
- Reproduction: Asexual reproduction by fission and Sexual reproduction by spores
- Examples: *Plasmodium, Monocystis*

Class 4 Ciliata

- locomotary organ: Cillia
- Body covered by pellicle.
- Reproduction: Asexual reproduction by binary fission. Sexual reproduction by conjugation.
- Nuclei two types i.e. macronucleus and micronucleus.
- Examples: *Paramecium*, *Voricella, Blantidium*

Amoeba

Amoeba, also spelled as Ameba, is a genus that belongs to protozoa, which are unicellular eukaryotes (organisms with membrane-bound cell organelles). The name Amoeba is derived from the Greek word *amoibe*, which means change. There are many species, of which the most extensively studied is *Amoeba proteus*. Majority of the species are very minute and are not visible to the naked eye. In spite of its small size, the genomic content is several times more than the human genome. The species A. dubia consists of about 370 billion base pairs; whereas, human genome has about 3 billion base pairs.

The Amoeba (plural Amoebae or Amoebas) is found in terrestrial as well as aquatic habitats. In fact, it can thrive in nearly all types of habitat. Some are parasitic in nature, thereby causing harm in humans and animals. As of date, six parasitic species are identified which cause mild to severe ailments in humans. Hence, this unicellular eukaryotic organism is widely studied in microbiology. Let's discuss in brief about the characteristic features of the Amoeba.

A cell membrane encloses the cytoplasm and cell organelles of Amoeba. Since there is no cell wall, its cellular structure is not definite. It can exhibit in any form, based on the surrounding condition. It possesses pseudopodia for locomotion and feeding purposes. The pseudopods are extensions of the cytoplasm. Amoeba engulfs food by

means of phagocytosis, meaning it encircles bacteria or other smaller protists, and secretes digestive enzymes into the vacuole. Digestion of food particles takes place in the vacuole with the help of enzymatic actions.

An Amoeba can have more than two nuclei in the cell. Similar to other protozoans, it reproduces asexually either by mitosis or cytokinesis. Under forceful division of Amoeba, the portion that contains nucleus survives, while the portions without nucleus die. When the organism is exposed to lethal environment, it turns into a dormant form, known as the Amoebic cyst. It continues to remain in the cyst form until it encounters normal environmental conditions.

Amoebae are extremely sensitive to stimuli, which is evident from shrinkage or expansion of the cells, depending on the surrounding condition. As for maintaining the osmotic pressure inside the cells, the vacuoles are responsible for the same. When an Amoeba is kept in a hypertonic saline solution (concentrated), the cell shrinks and prevents entry of salt. On the contrary, when it is exposed to hypotonic freshwater, Amoeba cell expands and swells.

Coming to the taxonomy of this organism, it is often vague and confusing since Amoeba lacks characteristic morphological features. It is also partly due to the fact that many other species of protists resemble this unicellular eukaryote in their anatomy and behavior. One of the distinctive features that distinguishes marine Amoeba from that of the freshwater species is the lack of contractile vacuoles and their enzymes. Let's take a look at how Amoeba is classified scientifically.

Domain: *Eukaryota*
Kingdom: *Amoebozoa*
Phylum: *Tubulinea*
Order: *Tubulinida*
Family: *Amoebidae*
Genus: *Amoeba*
Species: *proteus*, *animalcule*, *dubia*, *animalcule*, etc.

Scientific studies are ongoing to classify Amoeba by using small subunit ribosomal RNA (SSU rRNA) genes. As Amoeba is one of the simplest forms of eukaryotic organisms on Earth, it is often considered as a representative organism in the process of evolution. Also, it is extensively studied in cell research in order to determine the relation between the cytoplasm and the nucleus of the cell.

POSSIBLE QUESTIONS

UNIT-I

PART-A (20 MARKS)

(Q.NO 1 TO 20 Online Examination)

PART-B (2 MARKS)

1. Write a short note about pasteurization
2. Give a list of Anton von Leeuwenhoek contributions
3. What is binomial nomenclature?
4. Describe the spontaneous generation vs. biogenesis

PART-C (8 MARKS)

1. Give a detail about development of various microbiological techniques
2. Describe the role of microorganisms in fermentation
3. Write about the goldern era of microbiology
4. Distinguish between prokaryotic and eukaryotic microorganisms
5. Give a detail about Whittaker's and Carl Woese's classification

S.No	**Unit - V**	**Option 1**	**Option 2**	**Option 3**	**Option 4**	Answer
1	Freeze drying is otherwise called as	Lyophilization	Tyndallisation	Drying	Air drying	**Lyophilization**
2	Nitrogen storage is otherwise called as	Lyophilization	Cryopreservation	Sterilization	Tyndallisation	**Cryopreservation**
3	MTCC is located at	Ranchi	Delhi	Chandighar	Coimbatore	**Chandighar**
4	The substance used in preservation of anaerobic cultures in slant is	Glycol	Alcohol	Liquid paraffin	Tween 80	**Liquid paraffin**
5	Cryopreservation is _____	Heating in liquid nitrogen	Freezing in liquid nitrogen	Drying in liquid nitrogen	Steaming in liquid nitrogen	**Freezing in liquid nitrogen**
6	In Cryopreservation, the microorganisms of culture are rapidly frozen in liquid nitrogen at_____	-72°C	-86°C	-196°C	-96°C	**-196°C**
7	The stabilizing agents used in cryopreservation is _____	Glycerol	Phenol	Terpenol	Lysol	**Glycerol**

8	_____that prevent the formation of ice crystals and promote cell survival.	Glycerol	Phenol	Terpenol	Lysol	**Glycerol**
9	Lyophilization is otherwiseknown as _____(Freeze-Drying)	Freeze etching	Freeze drying	Freeze shadowing	Freeze liquid nitrogen	**Freeze drying**
10	In Lyophilization, the culture is rapidly frozen at _____	-196°C	-86°C	-70°C	-96°C	**-70°C**
11	The metabolic activities of microbial cells are stopped in lyophilization method by_____	dry dehydration	vacuum dehydration	Spray dehydration	Dry heat dehydration	**vacuum dehydration**
12	Lyophilized or freeze-dried pure cultures sealed and stored in the dark at_____	1°C	8°C	7°C	4°C	**4°C**
13	_____ method is the most frequently used technique by culture collection centres.	Lyophilization	Cryopreservation	Sterilization	Tyndallisation	**Lyophilization**
14	In oil overlaying method paraffin oil is used in specific gravity of _____.	0.743 -0.780	0.801-0.825	0.901-0.925	0.865-0.890	**0.865-0.890**

15	Oil overlaying method is first used by _____.	Brell	Bacon	Dulaney	Nakayama.	**Brell**
16	Bacterial species are preserved by oil overlaying method for _____.	10-15 years	15-20 years	5-10 years	5 years.	**15-20 years**
17	Freezing mixture used in lyophilization is _____.	Ice and methanol	Ice and alcohol	Only dry ice	Nitrogen and ice	**Ice and alcohol**
18	Nitrogen storage is also called as _____.	Freezing	Cooling	Cryogenic storage	Lyophilization	**Cryogenic storage**
19	Fungal species are stored by _____.	Freezing	Soil cultures	Nitrogen storage	Silica gel cultures	**Soil cultures**
20	Lyophilization is first used by _____.	N.Appert	Davis	Alexander	Pepler	**Alexander**
21	The specific gravity of British Pharmacopoeia Medicinal Paraffin oil is_____ .	0.665	0.865	0.965	0.765	**0.865**
22	Agar slants with cultures when covered with sterile mineral oil will prevent _____	Dressing	Heating	Drying	Freezing	**Drying**

23	Crowded plate technique is used to isolate organism producing _____	Enzyme	Aminoacids	Antibiotics	Toxin	**Toxin**
24	Culture grown on agar slopes are stored in a refrigerator at _____	10ºC	5ºC	1ºC	0ºC	**10ºC**
25	Cryoprotective agent is _____	10% Glycerol	20% Glycerol	30% Glycerol	40% Glycerol	**10% Glycerol**
26	Storage at Liquid nitrogen reduces _____ activity of microorganisms.	cationic	metabolic	enzymatic	proliferative	**cationic**
27	Temperature at which microorganisms are stored using liquid nitrogen is _____	–20º	–200º	–196º	-350º	**–196º**
28	Freeze drying method is otherwise known as _____	Dehydrated storage	Glycerol Storage	Liquid nitrogen storage	Lyophilization	**Lyophilization**
29	An example for protective medium is _____	Water	Skimmed Milk	Butter	Sewage	**Sewage**
30	N_2 storage is otherwise known as _____ storage.	Dry	Pyrogenic	Sand	Cryogenic	**Dry**

31	NCTC is _____	National Collection of Type Cultures	North Collection of Type Cultures	National Cultures Type Collection	North Cultures Type Collection	**North Cultures Type Collection**
32	IFO is located at _____	America	Italy	Korea	Japan	**Italy**
33	ATCC is _____	American Type Collection Cultures	African Type Collection Cultures	American Type Culture Collection	African Type Culture Collection	**American Type Culture Collection**
34	The function of paraffin is to prevent ----------	Dehydration	Decarboxylation	Loss of viability	Hydroxylation	**Dehydration**
35	Freeze drying was first introduced by ----------	Alexanander & Raper	Raper & Pasteur	both a& b	Alexander & Pasteur	**Alexanander & Raper**
36	In lyophilization special type of flask is used which named as ----------	Conical flask	plastic flask	dewar flask.	Swan neck flask	**dewar flask.**
37	Vial is made up of ----------	.Aluminium	Asbestose	Copper	steel	**Asbestose**
38	The bacterial suspension are kept in lyophilizer in ----------	Glass tube.	Petriplates	Ampoule	plastic tube	**Ampoule**

39	Dewar flask containg the mixture of ----------	dry ice & alcohol	Ethanol &H2O	dry ice & H2O	methanol & formaldehyde.	**dry ice & alcohol**
40	Lyophilization process was successfully done in year ----------	1946	1948	1942	1947	**1942**
41	A chemical that absorbes O2 is ----------	salicylic acid	.aldehyde	farmaldehyde	alkaline pyrogallol.	**alkaline pyrogallol.**
42	Catalyst used in Mcintyosh jar is ----------	palladium	copper rod	iron rod	pallanised asbestose	**pallanised asbestose**
43	Indicator used in the gas pak system is ----------	phenol red	oxidized methylene blue	reduced methylene blue	bromophenol blue	**reduced methylene blue**
44	Lyophilization cause ---------- of culture.	drying	heating	sublimation	breaking	**sublimation**
45	The vials with cell suspension frozen at ----------	-55to -78c	-60to -78c	-65to -78c	-70to -78c	**-60to -78c**
46	Cultivation of anaerobes by ----------	nutrient medium	differential medium	Robertsons cooked meat medium	blood agar medium	**Robertsons cooked meat medium**

47	In lyophilization the vials are scaled off under ----------	open tube	water contains flask	pressure	vaccum.	**vaccum.**
48	In mineral overlaying method allow the diffusion of ----------	gases	cells	minerals	.colony	**gases**
49	The first preservation technique used by the microbiologist is ----------	preservation under oil	preservation in soil	lyophilizatio n	serial transfer	**serial transfer**
50	Which is the preservation process successful for algae	Lyophilizatio n	glycerol storage	serial transfer	cryopreservatio n	**serial transfer**
51	Who introduced the concept of preservation in distilled water	Taylor	wheaton	castellani	Martine	**castellani**
52	Preservation of culture in distilled water is mainly used for the conservation of ----------	Bacteria	Algae	fungai	protozoa	**fungai**
53	----------is used for the conservation of non sporulating strains	preservation under oil	preservation in soil	serial transfer	cryopreservatio n	**preservation under oil**

54	The mineral oil which used for preservation of culture have a specific gravity of -------	0.3 to 0.5	1.3 to 1.5	.0.3 to 1	0.8 to 0.9	**0.8 to 0.9**
55	The culture preserved in mineral oil preserved at a temperature of ----------	10˚C	50˚C	-4˚C	5˚C	**10˚C**
56	The most commonly used natural cryopreservative agents are ----------	Glucose	Lactose	soy bean oil	skim milk	**skim milk**
57	Moisture indicator consisting of filterpaper strips used in freeze drying is impregnated with ----------	Cacl2	Cocl2	Zncl2	.Kcl	**Cocl2**
58	Which organism is successfully maintained over silica gel ?	Neurospora	Dermatophytes	.Aspergillus	Penicillium.	**Neurospora**
59	Preserved culture over silica gel is at a temperature of about ----------	. 20˚C	. 10˚C	15˚C	. 25˚C	**. 25˚C**
60	The temperature to thaw samples rapidly at ----------	. 50˚C	.20˚C	37˚C	52˚C	**37˚C**