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DEPARTMENT OF BOTANY

STUDY NOTES

SBOTCT 1101

Viruses, Bacteria and Algae

B.Sc. Botany, I Year (Semester I)

Major Core Theory Course | 2 Credits | 30 Hours

Unit 1: Viruses • Unit 2: Bacteria

Prepared as a study aid for students; please also refer to the prescribed textbooks and reference books.

BY

Dr Narsingh

Course Information

Item	Details
Programme / Class	B.Sc. Botany, I Year (Semester I) – Major Core Theory Course
Course Code	SBOTCT 1101
Title	Viruses, Bacteria and Algae
Credits / Hours	2 Credits 30 Hours total
Pre-requisite	Primary training in biology at higher secondary level (CBSE / ICSE / HSC) and basic knowledge of plant science

Course Objectives

1. To study and impart knowledge about the occurrence, distribution, structure and life history of Viruses, Bacteria and Algae.
2. To instil an appreciation for the diversity of life forms and the structural organisation within plant bodies that allows plants to develop and live as integrated organisms in diverse environments.

Course Outcomes

1. Students understand the morphology, structure and evolution of organisms like Viruses, Bacteria and Algae.
2. Students are able to differentiate between various groups of Viruses, Bacteria and Algae.
3. Students learn the importance of Viruses, Bacteria and Algae for human beings.

Curriculum Details (Units covered in these notes)

Unit	Title	Topics	Hrs
1.0	VIRUSES	1.1 Introduction, brief history and general characters of viruses. 1.2 Classification of viruses (on the basis of host); general introduction with special reference to the structure of TMV and T4, viroids and prions. 1.3 Transmission of viruses; economic importance of viruses. 1.4 Study of Yellow Vein Mosaic of Bhendi.	07
2.0	BACTERIA	2.1 Introduction, general characters and classification; general characteristics and types of mycoplasma. 2.2 Forms of bacteria, ultrastructure of bacterial cell and flagellation. 2.3 Reproduction in bacteria – asexual (binary fission) and sexual (conjugation).	08

Note

These notes cover Unit 1 (Viruses) and Unit 2 (Bacteria) exactly as listed in the curriculum details. The Algae unit of the course is not included in this booklet.

Recommended Books

- Dubey, R. C. and Maheshwari, D. K. (2007). A Textbook of Microbiology. S. Chand & Co., New Delhi.
- Power and Dagainwala (1994). General Microbiology. Himalayan Publishing House, Bombay.
- Sharma, P. D. (1992). Microbiology. Rastogi & Co., Meerut.
- Mehrotra, R. S. (1994). Plant Pathology. Tata McGraw Hill, Delhi; Pandey, B. P. (1982). A Textbook of Plant Pathology. S. Chand & Co.
- Staley, J. T. et al. (1991). Bergey's Manual of Systematic Bacteriology, Vol. I–IV. Williams & Wilkins, London.
- Smith, K. M. (1957). A Textbook of Plant Virus Diseases; Cooper, J. I. (1995). Viruses and the Environment, 2nd ed.
- Singh, R. S. (1990). Plant Diseases, 6th ed. Oxford & IBH; Rangaswamy, G. (1972). Diseases of Crop Plants in India. Prentice Hall of India.
- Bendre and Kumar (1997). A Textbook of Practical Botany, Vol. I; Pandey, B. P. (2019). Modern Practical Botany, Vol. I. S. Chand.

How to use these notes

1. Read the units in order; topic numbers (1.1, 1.2 ...) match the university curriculum.
2. Learn definitions, diagrams and comparison tables — these are the commonly asked short and long questions.
3. Practise drawing the labelled diagrams (TMV, T4 phage, bacterial cell, flagellation, conjugation) as they carry good marks.
4. Use the Question Bank, MCQs and Glossary at the end for revision.

UNIT 1: VIRUSES

1.1 Introduction, Brief History and General Characters of Viruses

Introduction

The word **virus** is a Latin word meaning "poison" or "venom". Viruses are ultramicroscopic, non-cellular, infectious particles that can multiply only inside the living cells of a host (plant, animal, bacterium or fungus). They occupy a borderline position between the living and non-living worlds: outside a host they are inert, crystallisable particles, but inside a host cell they take over its machinery and multiply. Viruses cause many serious diseases of plants, animals and humans; the science that deals with their study is called **Virology**.

Brief history of virology

Year	Scientist	Contribution
1796	Edward Jenner	Developed the smallpox vaccine using cowpox material.
1885	Louis Pasteur	Prepared the rabies vaccine; used the term "virus" for infectious agents.
1886	Adolf Mayer	Showed that the mosaic disease of tobacco was infectious – transmissible by sap; named it "tobacco mosaic disease".
1892	D. J. Ivanowsky	Showed that sap of diseased tobacco remained infectious after passing through a bacteria-proof (Chamberland) filter – the first evidence of a filterable virus.
1898	M. W. Beijerinck	Confirmed filterability; called the agent "contagium vivum fluidum" (a contagious living fluid).
1898	Loeffler and Frosch	Demonstrated the first animal virus – foot-and-mouth disease virus.
1915–17	Twort and d'Herelle	Discovered viruses that infect bacteria – bacteriophages.
1935	W. M. Stanley	Crystallised TMV, showing it could be crystallised like a chemical (Nobel Prize 1946).
1937	Bawden and Pirie	Showed that TMV contains nucleic acid (RNA) along with protein.
1939	Kausche, Pfankuch and Ruska	First saw TMV particles under the electron microscope.
1956	Gierer and Schramm	Proved that the RNA alone of TMV is infectious.
1971	T. O. Diener	Discovered viroids (potato spindle tuber viroid).
1982	S. B. Prusiner	Proposed prions as proteinaceous infectious particles.

General characters of viruses

- **Size:** extremely small, ultramicroscopic (about 20–300 nm); visible only under an electron microscope; pass through bacteria-proof filters.
- **Non-cellular:** no cell wall, plasma membrane, cytoplasm or organelles; they have a protein coat (capsid) enclosing the nucleic acid.
- **Nucleic acid:** the genetic material is either DNA or RNA, never both (single or double stranded).

- **Obligate intracellular parasites:** multiply only within living host cells; they cannot be cultured on ordinary artificial media.
- **No independent metabolism:** they lack their own enzymes for energy production and protein synthesis; they depend on the host ribosomes and enzymes.
- **Crystallisable:** many viruses can be crystallised and stored for years without losing infectivity.
- **Do not grow or divide:** they are assembled from components made in the host cell (replication), not by binary fission.
- **Mutation:** viruses undergo mutations and can change their host range and virulence.
- **Host specificity:** each virus infects a particular type of host and often a specific tissue.
- **Not affected by antibiotics** (acting on bacteria), but sensitive to interferons and antiviral drugs.

Are viruses living or non-living?

Non-living characters: crystallisable, no cellular structure, no metabolism or growth outside the host, inert outside host.

Living characters: possess nucleic acid (genetic material), reproduce inside host cells, mutate, show heredity and evolution, cause diseases.

Conclusion: viruses are considered to be at the border between the living and non-living; they are best described as "obligate parasites that are active only inside a host".

Virus versus bacteria – a comparison

Feature	Virus	Bacterium
Cellular organisation	Non-cellular (virion)	Cellular, prokaryotic
Size	20–300 nm	0.2–10 µm
Genetic material	Either DNA or RNA	DNA (with RNA also present)
Ribosomes and enzymes	Absent	Present (70S ribosomes)
Growth on culture media	No – needs living host cells	Yes (most bacteria)
Reproduction	Replication inside host cell	Binary fission
Effect of antibiotics	Not affected	Affected (most)
Crystallisation	Possible	Not possible

Replication of viruses – an overview

Viruses cannot multiply on their own. The steps of virus multiplication in a host cell are common to most viruses:

1. **Attachment (adsorption):** the virion attaches to specific receptors on the host cell surface.
2. **Penetration:** the virion or its nucleic acid enters the host cell (injection in phages; endocytosis or fusion in animal viruses; through wounds in plants).

3. **Uncoating:** the capsid is removed and the nucleic acid is released.
4. **Synthesis (biosynthesis):** the viral genome is replicated and viral proteins are made using the host's ribosomes, enzymes and energy.
5. **Assembly (maturation):** new nucleic acid and capsid proteins are assembled into virions.
6. **Release:** by lysis of the host cell or by budding through the membrane.

1.2 Classification of Viruses (on the basis of Host); Structure of TMV and T4; Viroids and Prions

General structure of a virus

A complete, infectious virus particle is called a **virion**. Its basic components are:

- **Core:** the genome (DNA or RNA) in the centre.
- **Capsid:** a protein coat that surrounds the nucleic acid, made up of repeating protein subunits called **capsomeres**. The capsid with the enclosed nucleic acid is called the **nucleocapsid**.
- **Envelope (in some viruses):** an outer lipoprotein membrane derived from the host cell membrane (e.g., influenza virus, HIV). Viruses without it are called naked viruses (e.g., TMV, T4).
- **Symmetry of the capsid:** helical (TMV), icosahedral (adenovirus, polio virus) or complex (T4 bacteriophage, which has an icosahedral head and a helical tail).

Classification on the basis of host

Group	Host	Genetic material	Examples
Plant viruses	Higher plants	Mostly ssRNA (a few DNA)	Tobacco mosaic virus (TMV), Cucumber mosaic virus, Bhendi yellow vein mosaic virus, Potato virus X, Banana bunchy top virus
Animal (and human) viruses	Vertebrates and invertebrates	DNA or RNA	Polio, rabies, influenza, hepatitis, HIV, SARS-CoV-2, smallpox virus, foot-and-mouth disease virus
Bacterial viruses (bacteriophages)	Bacteria	Mostly dsDNA	T-even phages (T2, T4, T6), lambda (λ) phage, ϕ X174
Other viruses	Insects, fungi (mycoviruses), algae and cyanobacteria (cyanophages)	DNA or RNA	Baculoviruses of insects, cyanophages

(Viruses are also classified by the type of nucleic acid – DNA/RNA, single/double stranded – and by capsid symmetry, and the modern system of Baltimore classifies them by the mode of mRNA synthesis.)

Structure of Tobacco Mosaic Virus (TMV)

TMV causes the mosaic disease of tobacco and other plants of the family Solanaceae. It is the first virus to be crystallised and is the best-studied plant virus.

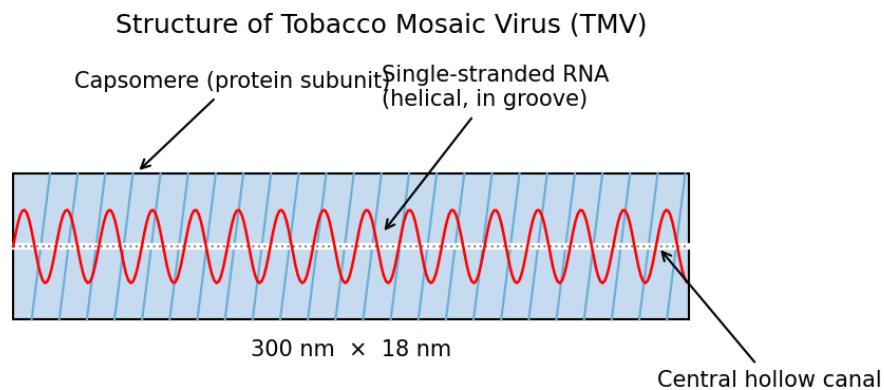


Fig. 1.1: Structure of TMV (rod-shaped, helical symmetry)

- **Shape and size:** rigid, straight rod-shaped (rod = bacilliform) particle about **300 nm long and 18 nm in diameter**; helical symmetry; naked virus.
- **Capsid:** made of about **2130 identical protein subunits (capsomeres)**, each with 158 amino acids, arranged helically in about 130 turns around the central axis, with about 16–17 subunits per turn.
- **Genome:** a single-stranded, positive-sense RNA of about **6400 nucleotides**, lying in a groove on the inner side of the protein helix, about 4 nm from the axis; each protein subunit binds three nucleotides.
- **Central canal:** a hollow canal about 4 nm in diameter runs along the length of the rod.
- **Infectivity:** the RNA is the infective part; protein protects it. Separated and reconstituted RNA and protein can form infectious virions again (Fraenkel-Conrat).
- **Symptoms:** mottling (light and dark green mosaic) of leaves, curling, stunted growth and reduced yield. Transmitted by sap (mechanical contact).

Structure of T4 Bacteriophage

T4 is one of the T-even phages that infect the bacterium *Escherichia coli*. It is a tadpole-shaped virus with a complex symmetry and is made up of the following parts.

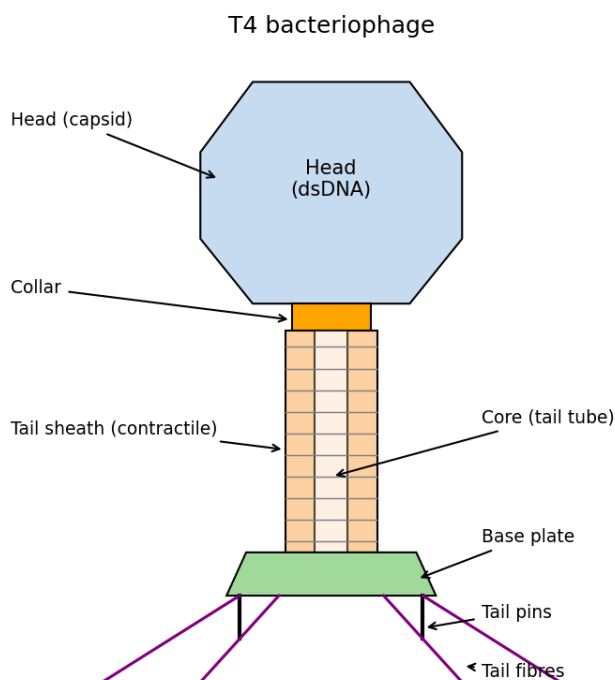


Fig. 1.2: Structure of T4 bacteriophage

- **Head:** an elongated icosahedral (hexagonal in section) capsid about 100 nm × 80 nm, made of protein capsomeres, enclosing a **linear double-stranded DNA** of about 170 kb (about 170,000 base pairs).
- **Collar:** a short neck between head and tail.
- **Tail:** a hollow **core (tube)** surrounded by a contractile **sheath** (about 24 rings of protein subunits). The tail is about 100 nm long.
- **Base plate:** a hexagonal plate at the end of the tail, bearing six **tail pins (spikes)** and six long, jointed **tail fibres** used for attachment to the bacterial receptors.
- **Lytic life cycle (brief):** adsorption of tail fibres to the host cell wall → contraction of the sheath and penetration of the DNA through the core into the cell (the empty head stays outside) → host DNA degraded, phage DNA replicates and phage proteins are made → assembly of new phages → lysis of the host cell and release of about 100–200 new phages. The whole cycle takes about 20–30 minutes.

Feature	TMV	T4 Phage
Host	Plants (tobacco and other Solanaceae)	Bacterium Escherichia coli
Shape	Rod-shaped, helical	Tadpole-shaped, complex
Nucleic acid	ssRNA (≈ 6400 nucleotides)	dsDNA (≈ 170 kb)
Size	300 × 18 nm	Head ≈ 100 × 80 nm; tail ≈ 100 nm
Capsid	≈ 2130 identical protein subunits	Head and tail proteins; contractile sheath
Entry into host	Through wounds (sap transmission)	Injection of DNA through the tail

Lytic and lysogenic cycles of bacteriophages

Bacteriophages show two kinds of life cycle:

Feature	Lytic (virulent) cycle	Lysogenic (temperate) cycle
Phage example	T4 phage	Lambda (λ) phage
Phage DNA	Remains free and replicates immediately	Integrates into the host chromosome as a **prophage**
Host cell	Destroyed (lysed) after multiplication	Survives and divides, the prophage is passed to daughter cells
Release of new phages	Within 20–30 minutes	Only after induction (e.g., by UV light), when the prophage excises and enters the lytic cycle
Result	Death of bacterium	Lysogeny; may change the characters of the host (lysogenic conversion)

Symptoms of plant virus diseases (general)

- **Mosaic:** patches of light and dark green on leaves (TMV, cucumber mosaic).
- **Vein clearing / vein banding:** loss of green colour in veins (yellow vein mosaic).
- **Leaf curl and distortion:** rolling, crinkling, puckering or reduced leaf size (tomato leaf curl, papaya leaf curl).
- **Stunting:** reduced growth of the whole plant, shortening of internodes (bunchy top of banana).
- **Necrosis:** death of tissues – necrotic spots or streaks (potato virus Y, tobacco necrosis virus).
- **Ring spots:** circular chlorotic or necrotic rings on leaves and fruits (papaya ring spot).
- **Colour breaking:** streaked flowers (tulip breaking).
- Symptoms vary with the virus strain, the host variety, age, temperature and light. Control is through resistant varieties, healthy planting material, vector control, rogueing and quarantine because no chemical cures virus-infected plants.

Important facts about viruses at a glance

Point	Fact
Study of viruses	Virology
First plant virus discovered / crystallised	TMV (Mayer 1886 – Ivanowsky 1892 – Stanley 1935)
First animal virus	Foot-and-mouth disease virus (Loeffler and Frosch, 1898)
Largest and smallest plant infectious agents	Viruses (rods, spheres) – smallest are viroids
Viral genome of TMV	Single-stranded RNA ($\approx$ 6400 nucleotides)
Viral genome of T4	Double-stranded DNA ($\approx$ 170 kb)

Point	Fact
Instrument to see viruses	Electron microscope
Antiviral substance produced by host cells	Interferon

Viroids

Viroids are the smallest known infectious agents of plants, discovered by **T. O. Diener (1971)** as the cause of the potato spindle tuber disease (PSTV).

- They consist of a **short, naked, single-stranded, covalently closed circular RNA** of only about 246–400 nucleotides; they have **no protein coat (no capsid)**.
- The RNA is highly base-paired, forming a rod-like structure; it does not code for any protein, so it depends entirely on host enzymes for replication.
- They cause diseases such as potato spindle tuber, citrus exocortis, coconut cadang-cadang and chrysanthemum stunt.
- They are transmitted by sap, vegetative propagation, seeds and pollen; they spread by contaminated tools.

Prions

Prions (**proteinaceous infectious particles**) were proposed by **Stanley B. Prusiner (1982; Nobel Prize 1997)**. They are infectious agents made only of **protein**, with **no nucleic acid**.

- The normal cellular prion protein (PrP^c , rich in α -helices) is converted by contact with the abnormal form (PrP^{Sc} , rich in β -sheets) into the misfolded infectious form, which accumulates in the brain.
- They cause fatal neurodegenerative diseases: **scrapie** in sheep, **bovine spongiform encephalopathy (BSE, "mad cow disease")** in cattle, and **kuru and Creutzfeldt–Jakob disease (CJD)** in humans.
- Prions are extremely resistant to heat, ultraviolet light and disinfectants.

Feature	Virus	Viroid	Prion
Genetic material	DNA or RNA	Naked circular ssRNA	None (protein only)
Protein coat	Present (capsid)	Absent	The infectious agent itself is a protein
Host	All organisms	Plants	Mammals (animals, humans)
Example	TMV, T4, HIV	PSTV	Scrapie, BSE, CJD

1.3 Transmission of Viruses; Economic Importance of Viruses

Transmission of plant viruses

Plant viruses cannot enter through intact cell walls; they enter through wounds or are introduced by vectors. The main modes of transmission are:

Mode	Description	Examples
Mechanical (sap) transmission	Contact of healthy plants with infected sap through wounds, by hands, tools, leaf rubbing, animals	TMV, Potato virus X
Vegetative propagation	Through cuttings, tubers, bulbs, grafts and budding from infected plants	Potato viruses, citrus tristeza, banana viruses
Seed and pollen	Virus present in the embryo or pollen of infected plants	Bean common mosaic, barley stripe mosaic
Insect vectors	Aphids, whiteflies, leafhoppers, thrips, beetles carry virus while feeding (non-persistent, semi-persistent or persistent transmission)	Bhendi yellow vein mosaic (whitefly), Cucumber mosaic (aphids), rice tungro (leafhoppers)
Nematodes and fungi	Soil nematodes and fungi (e.g., <i>Olpidium</i> , <i>Polymyxa</i>) carry virus in the soil	Tobacco rattle virus, tomato ringspot virus
Parasitic plants	Dodder (<i>Cuscuta</i>) forms a bridge between plants	Several mosaic viruses

Transmission of animal and human viruses

- **Direct contact** (touch, sexual contact, blood), **droplets** from coughing or sneezing (influenza, common cold, COVID-19).
- **Contaminated food and water** (polio, hepatitis A).
- **Vectors:** mosquitoes (dengue, chikungunya), animal bites (rabies).
- **Mother to child** across the placenta or during birth (HIV, rubella).
- **Blood transfusion and contaminated needles** (hepatitis B, HIV).

Economic importance of viruses

A. Harmful effects

- **Plant diseases:** mosaics, leaf curl, bunchy top and yellowing cause huge crop losses – TMV (tobacco), Yellow vein mosaic of bhendi, papaya ring spot, banana bunchy top, citrus tristeza, tomato leaf curl, sugarcane mosaic.
- **Human diseases:** smallpox, polio, rabies, measles, mumps, influenza, hepatitis, dengue, AIDS (HIV) and COVID-19.
- **Animal diseases:** foot-and-mouth disease of cattle, rinderpest, and bird flu in poultry.
- Viruses cause loss of crops, livestock and human productivity and require expensive control measures.

B. Beneficial effects

- **Vaccines:** inactivated or attenuated viruses are used for vaccines against polio, smallpox, rabies, measles, hepatitis B and others.
- **Genetic engineering:** viruses and phages (e.g., lambda phage, SV40) are used as **vectors** for gene cloning and gene therapy; transduction is used for transferring genes between bacteria.
- **Biological control:** the myxoma virus controlled rabbit populations in Australia; **baculoviruses** (NPV, granulosis virus) are used to control insect pests such as *Helicoverpa*.
- **Phage therapy:** bacteriophages can be used against antibiotic-resistant bacteria; phage typing is used to identify bacterial strains.
- **Research tools:** viruses (TMV, phages) have been used as models to study molecular biology – DNA as genetic material (Hershey–Chase), gene expression and replication.
- **Ornamental value:** the "breaking" of tulip flower colour (streaked flowers) is caused by a virus.

Quick revision – Unit 1 (sections 1.1–1.3)

- Virus = non-cellular obligate parasite; DNA **or** RNA; protein capsid; crystallisable; 20–300 nm.
- History: Mayer (1886) → Ivanowsky (1892) → Beijerinck (1898) → Stanley (1935) → Bawden and Pirie (1937).
- Classification by host: plant, animal, bacterial (phage) viruses.
- TMV: rod 300 × 18 nm, 2130 subunits, ssRNA. T4: head + contractile tail + base plate, dsDNA.
- Viroid = naked circular ssRNA; Prion = infectious protein.
- Plant virus transmission: sap, vegetative parts, seed, insects (aphids, whiteflies), nematodes, fungi, dodder.
- Importance: harmful (diseases) and useful (vaccines, vectors, biocontrol, phage therapy).

Frequently asked 2.5-mark questions (with answers) – Unit 1

Question	Answer
Why are viruses called obligate parasites?	They can multiply only within living host cells, using the host's machinery.
What is a virion?	A complete, infectious virus particle with nucleic acid and capsid.
Why do antibiotics not work on viruses?	Viruses have no cell wall or their own metabolism; antibiotics target bacterial structures and enzymes.
What is the role of the tail fibres in T4?	They recognise and attach to receptors on the <i>E. coli</i> cell wall.
Name the vector of YVMV.	Whitefly (<i>Bemisia tabaci</i>).

Question	Answer
What is a prophage?	Phage DNA integrated into the bacterial chromosome during the lysogenic cycle.

1.4 Study of Yellow Vein Mosaic of Bhendi (Okra)

Yellow Vein Mosaic Disease (YVMD) is the most destructive disease of bhendi (okra, *Abelmoschus esculentus*) in India. It was first reported from Bombay (Maharashtra) by **Kulkarni in 1924**.

Aspect	Details
Disease	Yellow Vein Mosaic of Bhendi (Okra yellow vein mosaic / Bhendi yellow vein mosaic disease)
Causal organism	Bhendi yellow vein mosaic virus (BYVMV), a begomovirus of the family Geminiviridae (single-stranded DNA, twinned/geminate particles)
Vector	Whitefly, <i>Bemisia tabaci</i> (persistent transmission)
Host	Bhendi (okra); also certain weeds and other malvaceous plants act as reservoirs
Losses	Yield loss ranges from about 30–90 % depending on the stage at which the plant is infected

Symptoms

- Characteristic **yellowing of the veins and veinlets** in a network pattern, while the intervening leaf tissue remains green – hence the name "yellow vein mosaic".
- In severe cases the **whole leaf turns yellow or creamy white**, with reduced size and curling.
- Infected plants are **stunted**, with shortened internodes and poor branching.
- Fruits are **small, deformed, yellowish-green and hard** (fibrous), unfit for marketing; very early infection results in almost no fruit.

Disease cycle (spread)

- The virus survives in perennial hosts, weeds and volunteer bhendi plants and in off-season plants.
- Whiteflies feed on infected plants, acquire the virus and transmit it to healthy plants in the new crop; the virus multiplies in the vector and in the host.
- The disease is **not transmitted by seed or by sap contact**; it spreads only by the whitefly vector (and by grafting). Warm weather favours whitefly multiplication and the rapid spread of the disease.

Control measures

- **Use of resistant / tolerant varieties:** e.g., **Parbhani Kranti** (a resistant variety released from Parbhani, Maharashtra), Arka Anamika and Arka Abhay.
- **Rogueing:** early removal and destruction of infected plants and weed hosts.
- **Vector control:** spraying systemic insecticides (e.g., imidacloprid) or neem-based formulations against whiteflies; use of yellow sticky traps.
- **Cultural practices:** timely sowing, avoiding overlapping crops of bhendi, growing barrier crops (maize, sorghum) around the field.
- Use of virus-free healthy planting material and clean cultivation.

Short answer questions – Unit 1

1. Define virus. Why are viruses called obligate parasites?
2. Write the contributions of Ivanowsky, Beijerinck and Stanley in virology.
3. What are bacteriophages? Name their parts.
4. What is a viroid? How is it different from a virus?
5. What are prions? Name two prion diseases.
6. Describe symptoms and control of Yellow Vein Mosaic of Bhendi.

UNIT 2: BACTERIA

2.1 Introduction, General Characters and Classification; Mycoplasma

Introduction

Bacteria are microscopic, unicellular, **prokaryotic** organisms found almost everywhere – in soil, water, air, on and inside the bodies of plants and animals, and even in extreme environments such as hot springs and polar ice. The study of bacteria is called **Bacteriology**. **Anton van Leeuwenhoek (1676)** was the first to observe bacteria with his simple microscope (calling them "animalcules"); **Ehrenberg (1829)** introduced the name "bacterium"; **Louis Pasteur** and **Robert Koch** established the germ theory of disease, and Koch's postulates (1876) linked specific bacteria with specific diseases.

General characters of bacteria

- **Prokaryotic:** no well-organised nucleus (no nuclear membrane) and no membrane-bound organelles such as mitochondria, plastids, ER or Golgi apparatus.
- **Size:** generally 0.2–10 μm (average 1–2 μm); the shape is constant for a species.
- **Cell wall:** rigid, made of **peptidoglycan (murein)**, which gives shape and protection.
- **Genetic material:** single circular double-stranded DNA in the **nucleoid**; extra-chromosomal circular DNA called **plasmids** may be present.
- **Ribosomes:** 70S type (50S + 30S subunits).
- **Nutrition:** autotrophic (photosynthetic or chemosynthetic) or heterotrophic (saprophytic, parasitic, symbiotic).
- **Respiration:** aerobic, anaerobic or facultative.
- **Motility:** by flagella in many; non-motile in others.
- **Reproduction:** mainly asexual by binary fission; genetic recombination occurs by conjugation, transformation and transduction.
- Under adverse conditions some form resistant **endospores**.

Classification of bacteria

Bacteria were first classified by **Cohn (1872)** on the basis of shape. Today, they are classified by many characters: shape, flagellation, Gram reaction, nutrition, oxygen requirement and, in modern systems, nucleic acid (16S rRNA) sequences. **Bergey's Manual of Systematic Bacteriology** is the standard reference for bacterial classification. In its older (1984) edition bacteria were placed in the kingdom **Prokaryotae**, divided into four divisions:

Division	Characters	Examples
Gracilicutes	Gram-negative bacteria with a thin cell wall (cyanobacteria, spirochaetes, many rods and cocci)	Escherichia coli, Rhizobium, Pseudomonas, Nostoc
Firmicutes	Gram-positive bacteria with a thick cell wall	Bacillus, Clostridium, Staphylococcus, Streptococcus
Tenericutes	Bacteria that lack a cell wall (mycoplasmas)	Mycoplasma, Spiroplasma
Mendosicutes	Archaeobacteria with unusual cell-wall chemistry	Methanogens, halophiles, thermoacidophiles

Practical (common) classification on different bases:

Basis	Types
Shape	Cocci, bacilli, spirilla, vibrios, filamentous
Flagella	Atrichous, monotrichous, lophotrichous, amphitrichous, peritrichous
Gram staining	Gram-positive (violet) and Gram-negative (pink/red)
Nutrition	Autotrophs (photo-, chemo-) and heterotrophs (saprophytes, parasites)
Oxygen requirement	Obligate aerobes, obligate anaerobes, facultative anaerobes, microaerophiles

Koch's postulates

Robert Koch (1876–1884) proposed four conditions to prove that a specific microbe causes a specific disease:

1. The organism must be present in every case of the disease and absent in healthy individuals.
2. It must be isolated from the diseased host and grown in pure culture.
3. The pure culture, when inoculated into a healthy susceptible host, must produce the same disease.
4. The organism must be re-isolated from the experimentally infected host and shown to be the same.

Exceptions: viruses and some bacteria cannot be grown on artificial media.

Beneficial and harmful roles of bacteria (brief)

- **Beneficial:** nitrogen fixation (Rhizobium, Azotobacter), decomposition and nutrient recycling, curd and cheese making (Lactobacillus), antibiotics (Streptomyces), vitamins, genetic engineering (E. coli), sewage treatment.
- **Harmful:** plant diseases (bacterial blight of rice, citrus canker, bacterial wilt), human diseases (cholera, typhoid, tuberculosis, tetanus), food spoilage and denitrification.

Mycoplasma – general characteristics

Mycoplasmas are the **smallest free-living prokaryotes** that can reproduce on their own. They were first isolated by **Nocard and Roux (1898)** from cattle suffering from pleuropneumonia, and were therefore called **PPLO** (Pleuro-Pneumonia-Like Organisms). The term "Mycoplasma" was introduced by Nowak (1929). They belong to the class Mollicutes ("soft skin"). Plant-infecting mycoplasma-like organisms are now called **phytoplasmas**.

- **No cell wall**; they are bounded only by a triple-layered **plasma membrane** that contains sterols – so they are pleomorphic (variable in shape: spherical, pear-shaped, filamentous, ring-like).
- **Size**: very small, about 0.1–0.25 μm ; they pass through bacterial filters.
- **Genome**: a very small, circular dsDNA (the smallest genome among prokaryotes); ribosomes are 70S.
- **Colonies** on solid medium look like a "**fried egg**" (dense centre, lighter periphery).
- They are **resistant to penicillin** (which acts on the cell wall) but are sensitive to tetracycline.
- Most are **parasitic** or pathogenic; some are saprophytic. They reproduce by binary fission, budding and fragmentation.

Types of mycoplasma

Type	Characters / Diseases
Mycoplasma	Sterol-requiring parasites; <i>Mycoplasma pneumoniae</i> causes atypical pneumonia in humans; <i>M. mycoides</i> causes pleuropneumonia in cattle
Ureaplasma	Hydrolyse urea; <i>Ureaplasma urealyticum</i> infects the urogenital tract of humans
Acholeplasma	Do not require sterols; saprophytic or parasitic, found in animals and plants
Spiroplasma	Helical, motile forms; cause citrus stubborn disease and corn stunt
Phytoplasma (MLOs)	Plant pathogens in phloem, transmitted by leafhoppers; cause sandalwood spike, little leaf of brinjal, grassy shoot of sugarcane, witches' broom and aster yellows

2.2 Forms of Bacteria, Ultrastructure of Bacterial Cell and Flagellation

Forms (shapes) of bacteria

Based on the shape of the cell, bacteria are broadly divided into the following types:

Form	Shape	Arrangements / Examples
Coccus	Spherical or oval	Micrococcus (single); Diplococcus (pairs); Streptococcus (chains); Tetrad/Sarcina (4 or cubical packets of 8); Staphylococcus (grape-like clusters)
Bacillus	Rod-shaped	Single Bacillus; Diplobacillus (pairs); Streptobacillus (chains); <i>Bacillus subtilis</i> , <i>E. coli</i>
Vibrio	Comma-shaped curved rods	<i>Vibrio cholerae</i> (cholera)

Form	Shape	Arrangements / Examples
Spirillum	Rigid, spiral (corkscrew) form	Spirillum volutans
Spirochaete	Flexible, spirally coiled	Treponema pallidum (syphilis)
Filamentous / branching	Thread-like	Actinomycetes (Streptomyces); Beggiatoa
Pleomorphic / others	Variable, stalked, square	Mycoplasma; Caulobacter (stalked)

Forms of bacteria

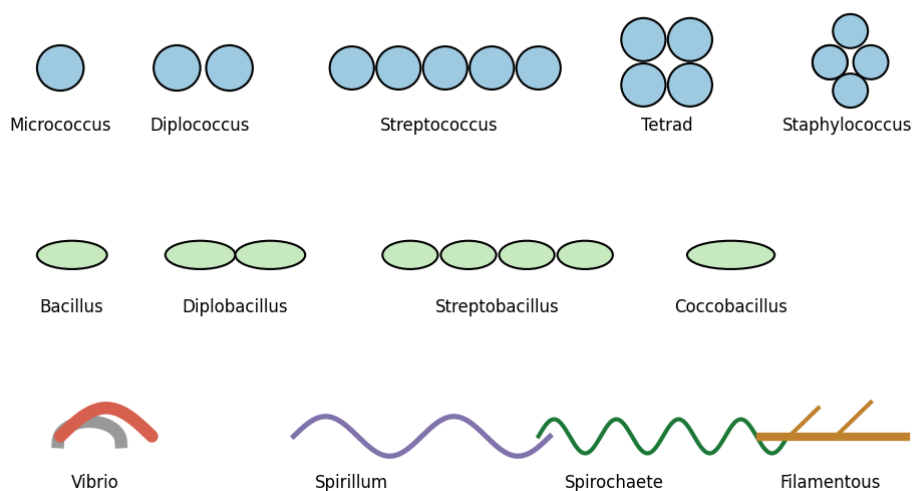


Fig. 2.1: Forms of bacteria

Ultrastructure of a bacterial cell

The structure of a bacterial cell as revealed by the electron microscope consists of the following parts (from outside to inside):

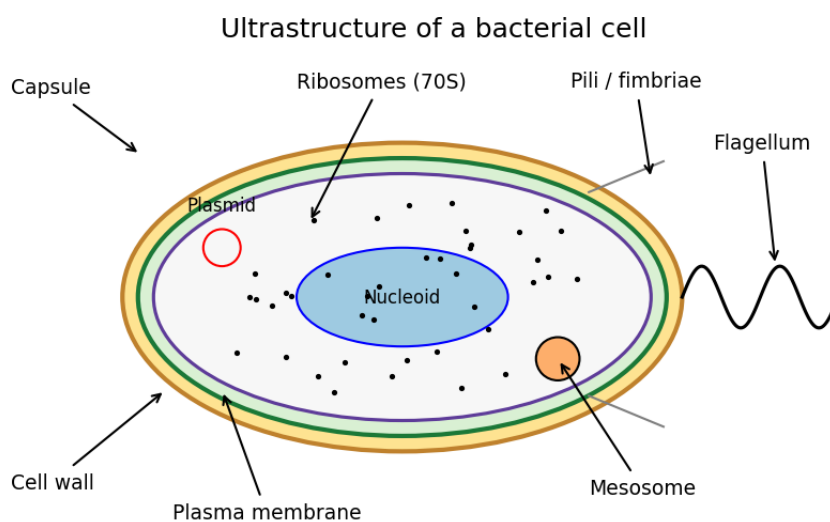


Fig. 2.2: Ultrastructure of a typical bacterial cell

- **Capsule / slime layer:** a gelatinous layer of polysaccharide (sometimes polypeptide) outside the cell wall. A thick, firmly attached layer is a capsule; a thin loose layer is a slime layer. It protects from desiccation and phagocytosis and helps in attachment and virulence.

- **Cell wall:** rigid layer (10–25 nm) made of **peptidoglycan** (N-acetylglucosamine, N-acetylmuramic acid and short peptides). It gives shape and protects the cell against osmotic lysis.
- **Plasma membrane:** a lipoprotein bilayer beneath the wall; selectively permeable and the site of respiratory enzymes, transport and cell-wall synthesis.
- **Mesosomes:** invaginations of the plasma membrane in the form of vesicles or tubules; involved in respiration, DNA replication and septum formation during cell division.
- **Cytoplasm:** a dense fluid with enzymes, 70S ribosomes (sites of protein synthesis) and various inclusions; no ER, mitochondria or Golgi.
- **Nucleoid:** a single, circular, naked double-stranded DNA molecule (not enclosed by a membrane); **plasmids** are small extra-chromosomal DNA circles that may carry genes for antibiotic resistance and fertility.
- **Inclusion bodies:** reserve materials – volutin (metachromatic) granules, glycogen, poly- β -hydroxybutyrate (PHB), sulphur granules, gas vacuoles.
- **Flagella:** thin, long, helical appendages for locomotion.
- **Pili (fimbriae):** short, hair-like protein filaments for attachment; the **sex pilus** is used in conjugation.
- **Endospores:** highly resistant, dormant structures formed by some bacteria (Bacillus, Clostridium) under unfavourable conditions.

Gram staining procedure

1. Make a thin smear of bacteria on a glass slide, air-dry and heat-fix it.
2. Flood with **crystal violet** (primary stain) for 1 minute; wash with water.
3. Apply **Gram's iodine** (mordant) for 1 minute; wash.
4. Decolourise with **alcohol (or acetone)** for a few seconds; wash immediately.
5. Counterstain with **safranin** for 30–60 seconds; wash, blot dry and observe under the oil-immersion lens.

Gram-positive cells appear **violet/purple**; Gram-negative cells appear **pink/red**.

Structure of cell wall: Gram-positive vs Gram-negative

The Gram staining technique (Hans Christian Gram, 1884) separates bacteria into two groups on the basis of cell-wall chemistry: Gram-positive bacteria retain the crystal violet–iodine complex (violet),

while Gram-negative bacteria lose it on decolourisation and take up the counterstain safranin (pink/red).

Feature	Gram-positive	Gram-negative
Peptidoglycan layer	Thick (20–80 nm), multilayered	Thin (2–3 nm), single layer
Outer membrane	Absent	Present (with lipopolysaccharide, LPS)
Teichoic acids	Present	Absent
Periplasmic space	Narrow or absent	Distinct
Lipid content	Low	High
Sensitivity to penicillin	More sensitive	Less sensitive
Examples	Bacillus, Staphylococcus, Streptococcus	E. coli, Salmonella, Pseudomonas

Flagellation

The **flagellum** (plural: flagella) is a long, thin, helical proteinaceous appendage (about 20 nm thick and 5–20 μm long) responsible for the swimming movement of bacteria. It has three parts: the **filament** (made of the protein **flagellin**), the **hook**, and the **basal body** (a rod with rings anchored in the cell wall and membrane; it acts like a rotary motor driven by proton flow). The arrangement of flagella on the cell surface is called **flagellation**.

Type	Arrangement	Example
Atrichous	No flagella	Lactobacillus, Corynebacterium
Monotrichous	A single flagellum at one pole	Vibrio cholerae, Pseudomonas aeruginosa
Lophotrichous	A tuft of flagella at one (or both) poles	Pseudomonas fluorescens, Spirillum
Amphitrichous	One flagellum at each of the two poles	Alcaligenes faecalis
Peritrichous	Flagella distributed all over the surface	E. coli, Salmonella typhi, Proteus

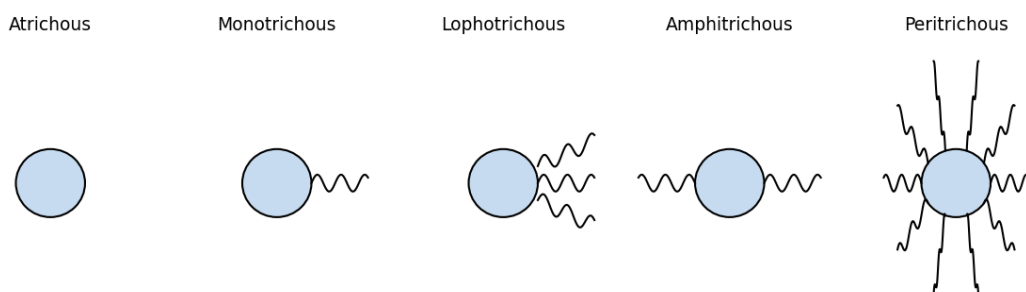


Fig. 2.3: Types of flagellation in bacteria

Endospores

Some Gram-positive bacteria (Bacillus, Clostridium) form a thick-walled, highly resistant, dormant structure called an **endospore** inside the cell when nutrients become scarce. It contains the DNA, a little cytoplasm and calcium dipicolinate, and is surrounded by a thick cortex and spore coats.

Endospores withstand boiling, drying, radiation and disinfectants for years and germinate into a vegetative cell when conditions improve. Endospore formation is a survival mechanism and **not** a method of reproduction because one cell forms only one spore.

Comparison: Gram-positive and Gram-negative flagellated, capsulated forms (summary of structures)

Structure	Chemical nature	Function
Capsule	Polysaccharide / polypeptide	Protection, virulence, attachment
Cell wall	Peptidoglycan	Shape and protection
Plasma membrane	Lipoprotein	Transport, respiration, selective permeability
Mesosome	Membrane invaginations	Respiration, cell division
Ribosome (70S)	rRNA + protein	Protein synthesis
Nucleoid	Circular dsDNA	Heredity
Plasmid	Small circular DNA	Antibiotic resistance, fertility
Flagellum	Flagellin protein	Motility
Pili	Pilin protein	Attachment; conjugation (sex pilus)
Endospore	DNA + dipicolinate + coats	Survival

Bacterial growth curve

When bacteria are inoculated into a fresh liquid medium and counted at intervals, the population passes through four phases:

Phase	Features
Lag phase	Cells adjust to the new medium; enzymes are synthesised; little or no division.
Log (exponential) phase	Cells divide at a constant, maximum rate; number doubles every generation time.
Stationary phase	Nutrients are depleted and wastes accumulate; rate of cell division equals rate of cell death.
Decline (death) phase	Death rate exceeds division rate; the population falls.

2.3 Reproduction in Bacteria

Bacteria reproduce mainly by **asexual methods**, and show **sexual-like** (genetic recombination) processes; true sexual reproduction with gametes and zygote formation is absent.

A. Asexual reproduction: Binary fission

Binary fission is the most common method of multiplication. A mature bacterial cell divides transversely into two equal daughter cells. Steps:

1. The cell grows and its **chromosome (DNA) replicates** – the replication starts at the point of attachment of the DNA to the plasma membrane (mesosome).
2. The cell elongates and the two chromosomes move apart, each attached to the membrane.
3. The plasma membrane and cell wall grow inward from the sides, forming a **transverse septum** (cross-wall) in the middle.
4. The septum completes, and the cell separates into **two identical daughter cells**, each with a copy of the DNA.

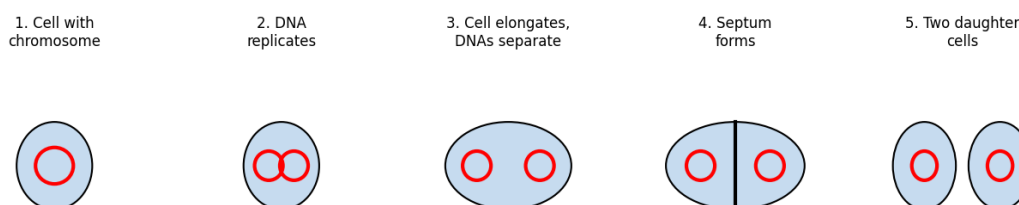


Fig. 2.4: Binary fission in bacteria

- Under favourable conditions the time taken for one division (**generation time**) is about **20 minutes in E. coli**; hence one cell can produce millions of cells in 7–8 hours.
- Bacterial growth in a culture shows four phases: lag, log (exponential), stationary and death (decline).
- **Other asexual methods:** budding (Rhodomicrobium), fragmentation of filaments (actinomycetes), and formation of conidia (Streptomyces). Endospores are resistant structures for survival, not for multiplication.

Solved Numerical 1

Q. One bacterium divides every 20 minutes. How many cells are produced in 2 hours?

Sol. Number of generations = $120 / 20 = 6$. Cells = $2^6 = 64$ cells.

B. Sexual reproduction (genetic recombination): Conjugation

Conjugation was discovered by **Joshua Lederberg and Edward Tatum (1946)** in *Escherichia coli* K-12. It is the transfer of genetic material (DNA) from a **donor (male) cell** to a **recipient (female) cell** through direct physical contact by means of a **conjugation tube (sex pilus)**.

Conjugation in bacteria

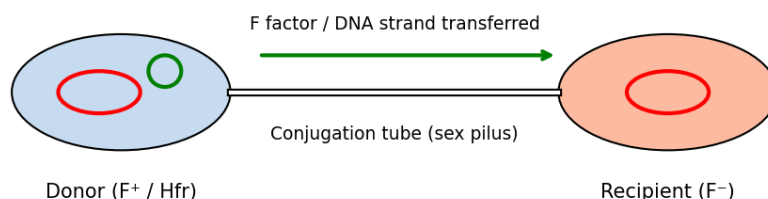


Fig. 2.5: Conjugation between F^+ (donor) and F^- (recipient) cells

- **Fertility factor (F factor):** a plasmid that carries genes for sex pilus formation and for transfer of DNA. Cells having it are **F^+ (donor)**; cells without it are **F^- (recipient)**.
- **Process:** the sex pilus of the F^+ cell attaches to the F^- cell and pulls the cells together; a conjugation bridge is formed. One strand of the F plasmid is nicked and is **transferred as a single strand** to the recipient (rolling-circle replication). The complementary strand is synthesised in both cells.
- **$F^+ \times F^-$:** the recipient becomes F^+ (the plasmid is transferred, but the chromosomal genes are usually not).
- **Hfr $\times F^-$:** in a high frequency of recombination (Hfr) strain the F factor is integrated into the chromosome, so chromosomal genes are transferred (the whole chromosome transfers only rarely); the recipient remains F^- but becomes recombinant.
- **F' cells:** carry an F factor with a piece of host DNA; transferred as in $F^+ \times F^-$.
- Recombination in the recipient produces cells with new combinations of genes (e.g., antibiotic resistance) – an important source of variation.

Cross	Donor transfers	Result in recipient
$F^+ \times F^-$	F plasmid (single strand)	F^- becomes F^+
Hfr $\times F^-$	Part of chromosome (with part of F)	Remains F^- , becomes recombinant
$F' \times F^-$	F factor + bit of host DNA	Becomes F' (partial diploid)

Other genetic recombination methods (for completeness)

- **Transformation:** uptake of naked DNA from the surroundings by a competent cell – shown by **Griffith (1928)** in *Streptococcus pneumoniae* and later by Avery, MacLeod and McCarty (1944).
- **Transduction:** transfer of bacterial DNA from one bacterium to another by a bacteriophage – discovered by **Zinder and Lederberg (1952)** in *Salmonella*.

Quick revision – Unit 2

- Bacteria: prokaryotic, unicellular, peptidoglycan wall, 70S ribosomes, circular DNA, plasmids.
- Mycoplasma: no cell wall, PPLO, fried-egg colonies, smallest free-living prokaryote; phytoplasmas cause plant diseases.
- Forms: coccus, bacillus, vibrio, spirillum, spirochaete, filamentous.
- Ultrastructure: capsule → cell wall → plasma membrane → cytoplasm with ribosomes → nucleoid; flagella and pili outside.
- Flagellation: atrichous, monotrichous, lophotrichous, amphitrichous, peritrichous.
- Reproduction: binary fission (asexual); conjugation ($F^+ \times F^-$, $Hfr \times F^-$) = sexual-like recombination.

Frequently asked 2.5-mark questions (with answers) – Unit 2

Question	Answer
Why are mycoplasmas pleomorphic?	They lack a rigid cell wall, so the cell can change shape.
What is a plasmid?	A small, circular, extra-chromosomal DNA that can replicate independently and carry genes such as antibiotic resistance.
Why is Gram-negative bacteria resistant to some antibiotics?	The outer membrane acts as a barrier against many drugs and dyes.
What is the role of the sex pilus?	It joins donor and recipient cells and forms the conjugation tube for DNA transfer.
What is generation time?	The time taken for a bacterial population to double (≈ 20 min for <i>E. coli</i>).
Are endospores a means of reproduction?	No, they are resistant resting structures; one cell makes only one spore.

Differentiate between: Gram-positive and Gram-negative; asexual and sexual reproduction; viruses and bacteria

Use the comparison tables given in sections 1.1–2.3 above (virus vs bacteria; Gram-positive vs Gram-negative; $F^+ \times F^-$ vs $Hfr \times F^-$).

Short answer questions – Unit 2

1. Define bacteria. Write any five general characters.
2. What are mycoplasmas? Mention their characters and types.
3. Describe the ultrastructure of a bacterial cell with a labelled diagram.
4. What is flagellation? Describe types with examples.

5. Describe binary fission in bacteria.
6. What is conjugation? Explain with a diagram.

Model Answers to Important Questions

Q. Describe the structure of TMV (5 marks)

TMV (Tobacco Mosaic Virus) is a rigid, rod-shaped plant virus about 300 nm in length and 18 nm in diameter. It has helical symmetry and is a naked virus. The capsid is composed of about 2130 identical protein subunits (capsomeres), each of 158 amino acids, arranged helically around a central hollow canal of about 4 nm. The genome is a single-stranded RNA of about 6400 nucleotides which is embedded in a groove of the protein helix, each subunit binding three nucleotides. The RNA is the infective part, while the protein coat protects it. TMV causes mosaic symptoms on tobacco, tomato and other Solanaceae and is transmitted mechanically by sap. (Draw Fig. 1.1.)

Q. Describe the structure of T4 bacteriophage (5 marks)

T4 is a tadpole-shaped bacteriophage of *Escherichia coli* with a complex symmetry. It has (i) an elongated icosahedral head of about 100×80 nm made of protein capsomeres and containing a linear double-stranded DNA of about 170 kb; (ii) a collar; (iii) a tail, consisting of a hollow core surrounded by a contractile sheath; and (iv) a hexagonal base plate with six tail pins and six long tail fibres which attach the phage to the host cell. During infection the sheath contracts and the DNA is injected through the core into the host cell. (Draw Fig. 1.2.)

Q. Explain the ultrastructure of a bacterial cell (5 marks)

A bacterial cell is prokaryotic. From outside to inside it has: a capsule or slime layer (polysaccharide, protective); a rigid cell wall of peptidoglycan which gives shape; a lipoprotein plasma membrane which is selectively permeable and bears the respiratory enzymes, and which forms vesicular invaginations called mesosomes; the cytoplasm which contains 70S ribosomes, inclusion bodies (volutin, glycogen, PHB) and no membrane-bound organelles; and a nucleoid which is a single circular dsDNA not enclosed by a nuclear membrane. Plasmids are present in many. Outside the cell, flagella provide locomotion and pili help in attachment and conjugation. (Draw Fig. 2.2.)

Q. Describe conjugation in bacteria (5 marks)

Conjugation is the transfer of DNA from a donor to a recipient cell by direct contact, discovered by Lederberg and Tatum (1946) in *E. coli*. The donor (F^+) carries a fertility factor plasmid that codes for the sex pilus. The pilus attaches to a recipient (F^-) cell and draws it close; a conjugation tube forms. One strand of the F plasmid is nicked and passes to the recipient, where the complementary strand is synthesised, making the recipient F^+ . In Hfr strains the F factor is integrated into the chromosome, so

chromosomal genes are transferred and recombine with the recipient's DNA, giving genetic variation. (Draw Fig. 2.5.)

Q. Write notes on Yellow Vein Mosaic of Bhendi (5 marks)

Yellow vein mosaic is the most serious viral disease of bhendi (*Abelmoschus esculentus*), first reported by Kulkarni (1924). The causal virus is Bhendi yellow vein mosaic virus (a begomovirus, family Geminiviridae, ssDNA) transmitted by the whitefly *Bemisia tabaci*. Symptoms are yellowing of veins and veinlets in a network, yellowing of the whole leaf in severe cases, stunted plants, and small, hard, yellowish fruits. Weeds and perennial hosts maintain the virus. Control: resistant varieties like Parbhani Kranti and Arka Anamika, roguing, systemic insecticides against whitefly, barrier crops and avoiding overlapping crops.

Diagrams to practise

No.	Diagram	Important labels
1	TMV	Capsomeres, RNA, central canal
2	T4 bacteriophage	Head, DNA, collar, sheath, core, base plate, tail pins, tail fibres
3	Forms of bacteria	Cocci, bacilli, vibrio, spirillum, spirochaete
4	Bacterial cell	Capsule, cell wall, membrane, nucleoid, ribosomes, mesosome, flagellum, pili
5	Types of flagellation	Monotrichous, lophotrichous, amphitrichous, peritrichous
6	Binary fission	Stages 1–5
7	Conjugation	Donor, recipient, conjugation tube, F factor

Question Bank for Revision

Very short / one-line questions

- Who discovered viruses (filterable)? [Ivanowsky, 1892]
- Who crystallised TMV? [W. M. Stanley, 1935]
- Name the vector of Yellow Vein Mosaic of Bhendi. [Whitefly, *Bemisia tabaci*]
- What is a capsomere? [Protein subunit of the capsid]
- Who discovered viroids? [T. O. Diener, 1971]
- What is the Gram reaction of a bacterium with a thick peptidoglycan wall? [Gram-positive]
- Which structure in bacteria is used for conjugation? [Sex pilus]
- Which organisms are called PPLO? [Mycoplasmas]
- What is the shape of *Vibrio cholerae*? [Comma-shaped]
- Name the protein of the bacterial flagellum. [Flagellin]

Long questions (likely)

Unit	Questions
1	Describe the structure of TMV with a neat labelled diagram. / Describe the structure of T4 bacteriophage. / Write notes on viroids and prions. / Give the general characters of viruses and classify them on the basis of host. / Describe the modes of transmission of plant viruses. / Write about the economic importance of viruses. / Describe the symptoms, disease cycle and control of Yellow Vein Mosaic of Bhendi.
2	Write the general characters and classification of bacteria. / Write notes on mycoplasma and its types. / Describe forms of bacteria. / Describe the ultrastructure of a bacterial cell. / Describe the types of flagellation. / Describe binary fission and conjugation in bacteria.

Multiple choice questions

- The causal organism of tobacco mosaic is a: (a) Bacterium (b) Virus (c) Fungus (d) Mycoplasma.
[Ans: b]
- The genetic material of TMV is: (a) dsDNA (b) ssDNA (c) ssRNA (d) dsRNA. [Ans: c]
- The head of T4 phage contains: (a) ssRNA (b) dsDNA (c) protein only (d) ssDNA. [Ans: b]
- Viroids contain: (a) RNA without protein coat (b) DNA with protein coat (c) Only proteins (d) DNA and RNA. [Ans: a]
- Bhendi yellow vein mosaic is transmitted by: (a) Aphids (b) Whitefly (c) Seeds (d) Sap. [Ans: b]
- Which of the following lacks a cell wall? (a) *Bacillus* (b) *Mycoplasma* (c) *Vibrio* (d) *Spirillum*.
[Ans: b]

7. Flagella all over the surface of the bacterium is called: (a) Monotrichous (b) Lophotrichous (c) Amphitrichous (d) Peritrichous. [Ans: d]
8. The cell wall of bacteria is made of: (a) Cellulose (b) Chitin (c) Peptidoglycan (d) Pectin. [Ans: c]
9. Conjugation in bacteria was discovered by: (a) Griffith (b) Lederberg and Tatum (c) Zinder (d) Koch. [Ans: b]
10. Bacterial ribosomes are of the type: (a) 80S (b) 70S (c) 60S (d) 50S. [Ans: b]

Fill in the blanks

1. The study of viruses is called _____. [Virology]
2. The complete infective virus particle is called a _____. [virion]
3. TMV contains _____ as its genetic material. [ssRNA]
4. The tail of T4 phage has a contractile _____ around a hollow core. [sheath]
5. Viroids were discovered by _____ in 1971. [T. O. Diener]
6. Mad cow disease is caused by _____. [prions]
7. Bendi yellow vein mosaic is caused by a _____ virus. [begomovirus / geminivirus]
8. The cell wall of bacteria is made up of _____. [peptidoglycan]
9. A bacterium with a single flagellum at one pole is _____. [monotrichous]
10. Mycoplasma colonies look like a _____. [fried egg]
11. The transfer of DNA through the sex pilus is called _____. [conjugation]
12. Bacterial ribosomes are _____S. [70]

State True or False

1. Viruses can be grown on nutrient agar. [False]
2. A virus contains both DNA and RNA. [False – only one]
3. Prions contain nucleic acid. [False]
4. Bacteria are prokaryotic. [True]
5. Mycoplasmas are sensitive to penicillin. [False – no cell wall]
6. Gram-negative bacteria have an outer membrane. [True]
7. Binary fission is a sexual method of reproduction. [False]
8. Endospores are a method of multiplication in bacteria. [False]

9. Whitefly transmits the yellow vein mosaic virus of bhendi. [True]

10. The F⁻ cell is the donor in conjugation. [False – it is the recipient]

Match the following

Column A	Column B
1. Stanley	a. Crystallised TMV
2. Diener	b. Viroids
3. Prusiner	c. Prions
4. Lederberg and Tatum	d. Conjugation in E. coli
5. Nocard and Roux	e. First isolation of mycoplasma (PPLO)
6. Kulkarni	f. First report of yellow vein mosaic of bhendi
Answers	1-a, 2-b, 3-c, 4-d, 5-e, 6-f

Viva-voce / oral questions

- Why can viruses not be treated with antibiotics?
- Which part of the T4 phage enters the bacterial cell?
- What is the difference between a capsule and a slime layer?
- Why do mycoplasmas pass through bacterial filters?
- What is the importance of plasmids in genetic engineering?
- Why is vector control important in controlling plant virus diseases?

Scientists and their contributions – memory aid

Scientist	Contribution
Leeuwenhoek (1676)	First observed bacteria ("animalcules")
Jenner (1796)	Smallpox vaccine
Pasteur (1885)	Rabies vaccine; germ theory
Koch (1876–84)	Koch's postulates; pure culture methods
Gram (1884)	Gram staining
Mayer, Ivanowsky, Beijerinck	Discovery of the first virus (TMV)
Twort and d'Herelle	Bacteriophages
Griffith (1928)	Transformation in bacteria
Stanley (1935)	Crystallised TMV
Lederberg and Tatum (1946)	Conjugation in E. coli
Zinder and Lederberg (1952)	Transduction
Hershey and Chase (1952)	DNA is the genetic material (using phage T2)

Common mistakes to avoid in the examination

- Do not write that viruses have both DNA and RNA – a virus has only one.
- Do not call the viral capsid a "cell wall"; viruses are non-cellular.
- Do not say bacteria have a nucleus or mitochondria; they are prokaryotes with a nucleoid.
- Always label diagrams neatly and mention the magnification/size where relevant (TMV 300×18 nm).
- Write scientific names in italics (or underline them): *Escherichia coli*, *Bemisia tabaci*, *Abelmoschus esculentus*.
- For differences, always use a two-column table with at least five points.

Glossary of Key Terms

Term	Meaning
Virion	A complete, infectious virus particle.
Capsid / Capsomere	Protein coat of a virus / its individual protein subunits.
Nucleocapsid	Capsid together with the enclosed nucleic acid.
Bacteriophage	A virus that infects bacteria.
Viroid	Naked, circular ssRNA infectious agent of plants without a protein coat.
Prion	Infectious misfolded protein with no nucleic acid.
Vector	An organism (e.g., insect) that carries and transmits a pathogen.
Prokaryote	Organism without a membrane-bound nucleus and organelles.
Peptidoglycan	Polymer of sugars and amino acids forming the bacterial cell wall.
Nucleoid	Region of the bacterial cell containing the chromosome.
Plasmid	Small extra-chromosomal circular DNA in bacteria.
Flagellation	Arrangement of flagella on the bacterial cell.
Binary fission	Division of one cell into two equal daughter cells.
Conjugation	Transfer of DNA from donor to recipient bacterium through a sex pilus.
Mycoplasma (PPLO)	Smallest free-living prokaryote, lacking a cell wall.
Phytoplasma	Mycoplasma-like organism that infects plants.

— *Best wishes for your examination!* —