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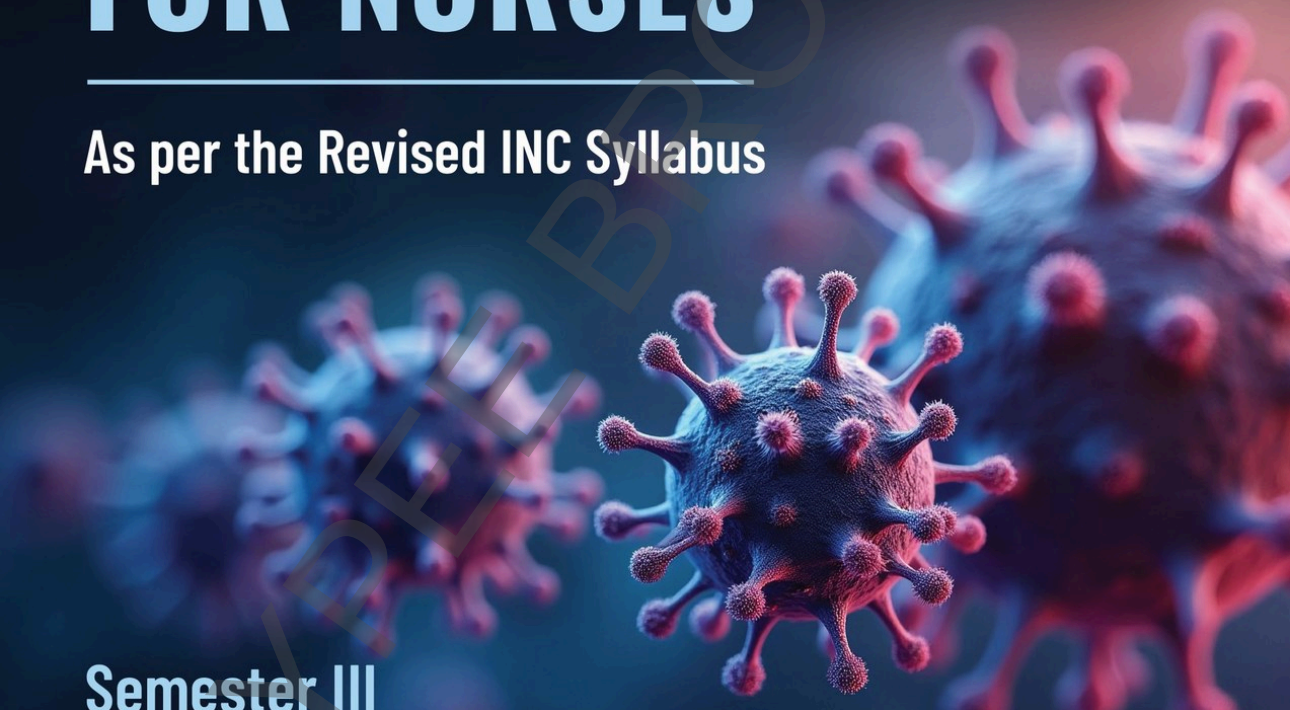
APPLIED MICROBIOLOGY, INFECTION CONTROL AND SAFETY FOR NURSES

As per the Revised INC Syllabus



Semester III



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Dipak Sethi

Foreword
Jyoti Sarin

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UNIT 3

Pathogenic Organisms

At the end of the unit the student will able to learn about:

- Bacterial cell
- Structure and morphology of bacteria
- Classification of bacteria
- Bacterial growth
- Factors influencing bacterial growth
- Viral morphology
- Methods of cultivation of viruses
- Morphology of fungi
- Classification of fungi
- Physiology of fungi
- Parasites
- Types of parasites
- Chain of infection
- Types of transmission
- Modes of transmission
- Insect, vectors, rodents

Key Terms

- **Capsid:** The outer protein shell of a virus
- **Envelope:** An enclosing structure or cover, such as a membrane
- **Filamentous:** Having the form of threads or filaments
- **Carrier:** A person or animal that harbors a specific infectious agent in the absence of symptoms and signs of a disease and serves as a potential source of infection.
- **Commensalism:** Kind of relationship in which one organism, the commensal is benefited whereas; the host is not harmed or even helped.
- **Infectious:** Infectious diseases, also known as transmissible diseases or communicable diseases, comprise clinically evident illness resulting from the infection, presence, and growth of pathogenic biological agents in an individual host organism.
- **Pathogen:** Any organism or substance, especially a microorganism, capable of causing disease, such as bacteria, viruses, protozoa, or fungi. Microorganisms are not considered to be pathogenic until they have reached a population size that is large enough to cause disease.
- **Contagious:** Person, having a disease that can be transmitted to another person by touch.
- **Vectors:** Vectors are arthropods or other invertebrates which transmit infection by inoculation into or through the skin or mucous membrane by biting or by deposit of infective materials on the skin or on food or other objects.

INTRODUCTION

Infectious diseases have plagued humanity for centuries. In ancient times, they were often thought to be divine punishments inflicted on wrongdoers. Hippocrates, regarded as the Father of Medicine, recognized that environmental factors—such as air, winds, water, climate, diet, soil, and human behavior—could influence health and lead to disease.

Varro (117–26 BC) proposed an early germ theory, suggesting that disease might be caused by invisible, mobile particles inhaled through the mouth and nose. Later, in the 1500s, Fracastorius theorized that living agents (which he called "germs") were responsible for contagious diseases and could be spread by direct contact with infected individuals or

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indirectly through objects. However, due to the lack of experimental tools, he couldn't provide concrete evidence.

The Father of Microbiology, Antony van Leeuwenhoek (1632–1723), was the first to observe and describe microorganisms, which he referred to as "animalcules," using a simple single-lens microscope. He accurately documented various bacterial shapes, although he did not investigate their origins. Meanwhile, other scientists sought explanations for the spontaneous generation of life from decaying matter, stagnant water, and fermenting substances.

TAXONOMY

Taxonomy is the scientific study of the classification of organisms. It involves organizing species into distinct groups or categories, which may or may not reflect evolutionary relationships. Classification focuses on:

1. Developing criteria to identify and assign organisms to specific categories (determining what belongs where).
2. Dividing organisms into appropriate taxonomic groups, such as determining when a single species should be split into two or more based on distinct differences.

BACTERIAL CELL

General Property:

a. Typical prokaryotic cell
b. Contain both DNA and RNA
c. Most grow in artificial media
d. Replicate by binary fission
e. Almost all contain rigid cell wall
f. Sensitive to antimicrobial agent

Structure of Bacteria (Fig. 3.1)

Bacterial Structure is Considered at Three Levels

1. Cell envelope proper: Cell wall and cell membrane.

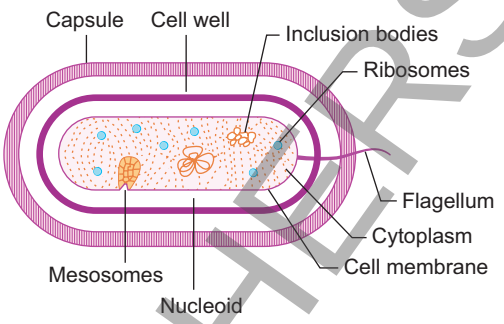

Fig. 3.1: Structure of bacteria.

2. Cellular element enclosed with in the cell envelope: Mesosomes, ribosomes, nuclear apparatus, polyamies and cytoplasmic granules.
3. Cellular element external to the cell envelope: Flagellum, Pilus and Glycocalyx.

1. Cell envelope

a. Cell wall: Multi layered structure and constitutes about 20% of the bacterial dry weight. Average thickness is 0.15-0.5 µm. Young and rapidly growing bacteria have thin cell wall but old and slowly dividing bacteria have thick cell wall. It is composed of N-acetyl Muramic acid and N-acetyl Glucosamine back bones cross linked with peptide chain and Pentaglycine Bridge **(Fig. 3.2** and **Table 3.1)**.

Components of cell wall of Gram negative bacteria

1. Peptidoglycan
2. Lipoprotein
3. Phospholipid
4. Lipopolysaccharide

Components of cell wall of Gram-positive bacteria

1. Peptidoglycan
2. Teichoic acid

Functions of cell wall

1. Provides shape to the bacterium
2. Gives rigidity to the organism
3. Protects from environment
4. Provides staining characteristics to the bacterium

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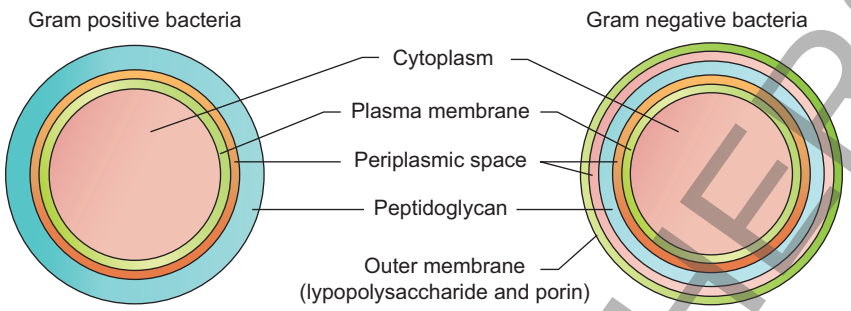

Fig. 3.2: Cell wall of gram positive and negative bacteria.

5. Contains receptor sites for phages/ complements
6. Site of action of antibody and colicin
7. Contains toxic components to host

Bacteria with defective cell walls, Bacteria without cell wall can be induced by growth in the presence of antibiotics and a hypertonic environment to prevent lysis. They are of three types:

1. **Protoplasts:** Derived from Gram-positive bacteria and totally lacking cell walls; unstable and osmotically fragile; produced artificially by lysozyme and hypertonic medium: require hypertonic conditions for maintenance.
2. **Spheroplast:** Derived from Gram-negative bacteria, retain some residual but non-functional cell wall material, osmotically fragile, produced by growth with penicillin and must be maintained in hypertonic medium.
3. **L- forms:** Cell wall-deficient forms of bacteria usually produced in the laboratory but sometimes spontaneously formed in the body of patients treated with penicillin; more stable than protoplasts or spheroplasts, they can replicate in ordinary media.

b. Cell membrane: Also named as cell membrane or cytoplasmic membrane It is a delicate trilaminar unit membrane. It accounts for 30% of the dry weight of bacterial cell. It is composed of 60% protein, 20-30% lipids and 10-20% carbohydrate.

Function of cell membrane

1. Regulates the transport of nutrients and waste products into and out of the cell.
2. Synthesis of cell wall components
3. Assists DNA replication
4. Secrets proteins
5. Carries on electron transport system
6. Captures energy in the form of ATP

2. Cellular element enclosed with in the cell envelope

a. Mesosomes: Convoluted invagination of cytoplasmic membrane often at sites of septum formation. It is involved in DNA segregation during cell division and respiratory enzyme activity.

b. Ribosomes: Cytoplasmic particles which are the sites of protein synthesis. It is composed of RNA (70%) and proteins (30%) and constitutes 90% of the RNA and 40% of the total protein **(Fig. 3.3)**.

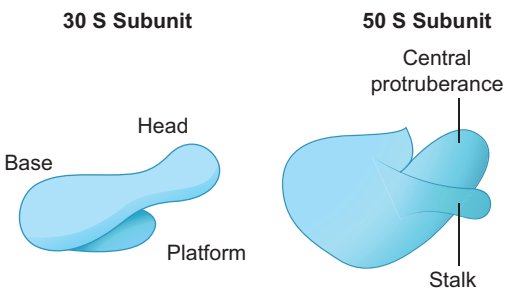

Fig. 3.3: Ribosomes

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c. Polyamines: It is found in association with bacterial DNA, ribosomes and cell membrane.

d. Cytoplasmic granules: It represents accumulated food reserves.

e. Nuclear apparatus: Well defined nucleus and nuclear membrane, discrete chromosome and mitotic apparatus are not present in bacteria; so nuclear region of bacteria is named as nuclear body, nuclear apparatus and nucleoid **(Fig. 3.4)**.

3. Cellular element external to the cell envelope

a. Flagellum: It is the organ of locomotion in bacterial cell and consists of three parts. These are, the filament, the hook and the basal body. The basal body and hook are embedded in the cell surface while the filament is free on the surface of bacterial cell **(Fig. 3.5)**.

b. Pili (fimbriae): It is hair like structure composed of protein (pilin) **(Fig. 3.6)**.

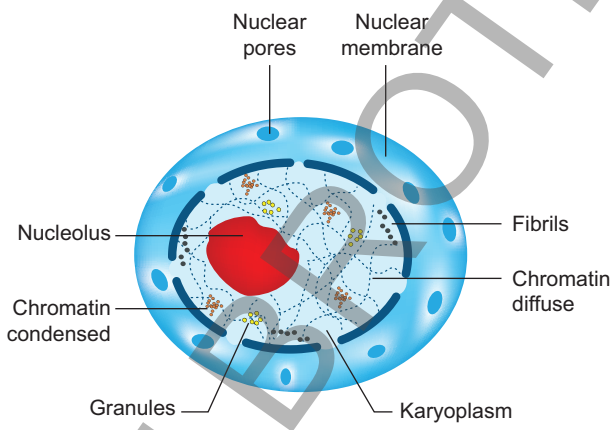

Fig. 3.4: Nuclear apparatus.

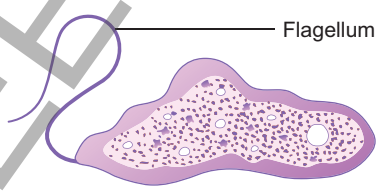

Fig. 3.5: Flagellum.

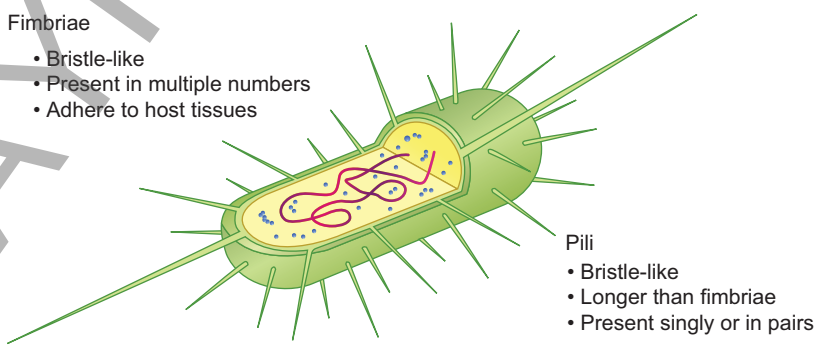

Fig. 3.6: Pili (fimbriae).

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TABLE 3.1: Cellular components and functions.

Level	*Components*	*Functions*
1. Cell Envelope	Cell wall, Cell membrane	Protection, shape, permeability, energy processes
2. Internal Structures	Mesosomes, ribosomes, nucleoid, polyamines, granules	Metabolism, replication, protein synthesis, storage
3. External Structures	Flagella, Pili, Glyc ocalyx	Motility, adhesion, protection

Classification of Bacteria

Bacterial Classification Depends on the Following Characteristics

1. Morphology and arrangement
2. Staining
3. Cultural characteristics
4. Biochemical reactions
5. Antigenic structure
6. Base composition of bacterial DNA

1. Morphology and staining of bacteria are the commonly used characteristics to classify bacteria.

When observed under a light microscope, bacteria exhibit a variety of shapes and arrangements, which help in their identification and classification. These morphological types include **(Fig. 3.7)**:

a. Cocci *(Singular: Coccus)*
   - *Shape:* Spherical or oval
   - *Size:* Approximately 0.5–1.0 µm in diameter
   - *Arrangements:*
     - Monococci – single cocci
     - Diplococci – in pairs
     - Streptococci – in chains
     - Staphylococci – in irregular clusters (grape-like)
     - Tetrads – groups of four
     - Sarcinae – cubic arrangement of eight cocci

b. Bacilli *(Singular: Bacillus)*
   - *Shape:* Rod-shaped; can have rounded, tapered, square, or swollen ends
   - *Size:* Around 1–10 µm in length and 0.3–1.0 µm in width
   - *Arrangements:*
     - Single bacilli
     - Diplobacilli – in pairs
     - Streptobacilli – in chains
     - Palisades – side-by-side or angular arrangements
   - *Examples: Bacillus anthracis, escherichia coli*

c. Coccobacilli *(Singular: Coccobacillus)*
   - *Shape:* Short rods that resemble cocci
   - Intermediate form between cocci and bacilli
   - **Examples:** *Haemophilus influenzae, Acinetobacter spp.*

d. Spiral Forms
   - *Shape:* Helically twisted or curved
   - *Types:*
     - Spirilla – rigid spiral bacteria with external flagella
       - Example: *Spirillum minus*
     - Spirochetes – flexible spiral bacteria with internal flagella (axial filaments)
       - **Example:** *Treponema pallidum, Borrelia burgdorferi*
   - *Movement:* Typically motile with corkscrew-like motion

2. Bacterial staining is the process of applying dyes (stains) to bacterial cells to color otherwise transparent structures, making them visible under a microscope. This helps in the detection, identification, and study of microorganisms.

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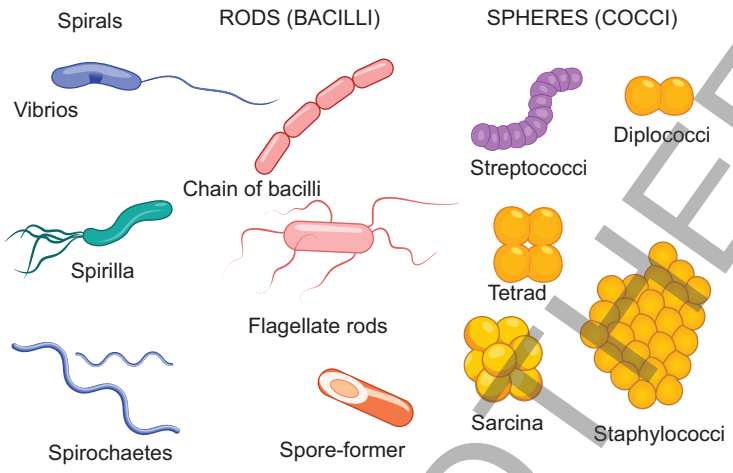

Fig. 3.7: Morphology of Bacteria.

Purpose of staining:

- To selectively color microorganisms or their components.
- To differentiate between different types of bacteria or cellular parts.
- To observe bacterial morphology, arrangement, and structural details.

Mechanism:

- Staining depends on physical and chemical interactions such as capillary osmosis, solubility, adsorption, and absorption.
- The cell wall composition of bacteria affects how they take up stains, resulting in different colors.
- Due to the acidic nature of the nucleus, it has a stronger affinity for basic dyes (cationic stains).
- The cytoplasm, being acidic, prefers acidic dyes (anionic stains).

Types of chemical affinities in staining:

The attraction between stains and bacterial cells occurs through several types of bonds/ interactions:

- Hydrophobic bonding
- Reagent-cell interaction
- Reagent-reagent interaction
- Ionic bonding
- Hydrogen bonding
- Covalent bonding

Types of staining procedures:

1. Progressive staining
   - Stains microbial cells directly with a dye for an exact time until the desired coloration is achieved.
   - *Example:* Simple staining with methylene blue.
2. Regressive staining
   - First, cells are over-stained to cover all structures, then excess stain is selectively removed (decolorized) to reveal contrast.
   - *Example:* Gram staining (primary stain is removed selectively).
3. Differentiation
   - The process of selectively removing excess stain from certain parts to create contrast.
   - This happens during regressive staining to highlight specific bacterial structures.
4. Simple staining method
   - Uses a single dye to color all bacterial cells uniformly.
   - Mainly used to observe morphology (shape and size) and arrangement of bacteria.
   - *Example dyes:* Methylene blue, crystal violet.

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5. Gram staining method
   – Developed by Christian Gram.
   – Differentiates bacteria into two groups based on their cell wall properties:
     - Gram-positive bacteria retain the primary stain (crystal violet) and appear purple.
     - Gram-negative bacteria lose the primary stain during decolorization and take up the counterstain (safranin), appearing pink/red.
   – This difference is due to the thickness and composition of the bacterial cell wall.

BACTERIAL GROWTH

Bacterial growth is the orderly increase in all cellular components of a bacterial cell, resulting in an increase in biomass.

Mechanism of Bacterial Population Growth

- **Relation to reproduction:**
  Growth is synchronous with bacterial cell reproduction—as cells grow, they eventually divide.
- **Growth process:**
  Bacteria take in nutrients from their environment and incorporate these nutrients into cellular components, increasing cell size and mass.
- **Cell division:**
  After growth, the bacterial cell divides into two equal daughter cells, effectively doubling the number of cells.
- **Generation time:**
  This is the time required for the bacterial population to double in number.

Bacterial Growth Phases

The pattern in cell numbers exhibited by bacterial population obtained after inoculation of a bacterium into a new culture medium. The normal bacterial growth curve has four phases.

Phases of Bacterial Growth (Fig. 3.8)

When bacteria grow in a closed system (like a culture tube or flask), their growth occurs in a series of distinct phases:

1. **Lag phase:**
   – Bacteria adapt to the new environment.
   – Little or no cell division occurs.
   – Metabolic activity is high as cells synthesize enzymes and prepare for growth.
2. **Log (exponential) phase:**
   – Bacteria multiply at the fastest rate.
   – Cells divide by binary fission, doubling their number at a constant rate.
   – This phase is characterized by **exponential growth**.
   – Cells are metabolically active and most susceptible to antibiotics.
3. **Stationary phase:**
   – Growth rate slows down and stabilizes.
   – The number of new cells equals the number of dying cells.
   – Nutrients become limited and waste products accumulate.
   – Some cells may start producing spores or secondary metabolites.
4. **Death (decline) phase:**
   – Nutrients are depleted and toxic wastes build up.
   – The number of dying cells exceeds the number of new cells.
   – The population declines exponentially.

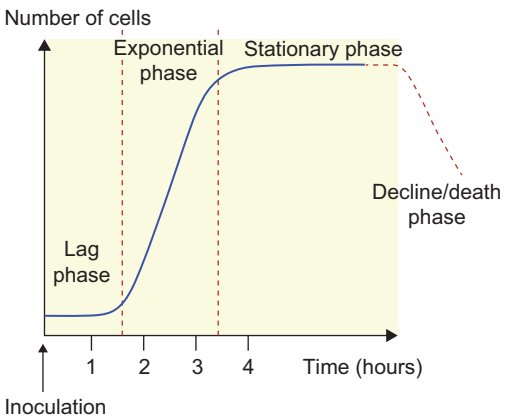

Fig. 3.8: Bacterial growth curve.

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Factors Influencing Bacterial Growth

1. Nutritional factors
   - Bacteria require nutrients such as carbon, nitrogen, sulfur, phosphorus, minerals, vitamins, and water for growth.
   - The type and availability of nutrients affect the growth rate and population size.
2. Temperature
   - Each bacterial species has an optimum temperature for growth.
   - Categories based on temperature preference:
     - Psychrophiles: Grow best at low temperatures (0-15°C).
     - Mesophiles: Grow best at moderate temperatures (20-45°C); includes most human pathogens.
     - Thermophiles: Grow best at high temperatures (45-80°C).
     - Hyperthermophiles: Thrive at extremely high temperatures (>80°C).
3. pH
   - Most bacteria prefer neutral pH (6.5-7.5).
   - Acidophiles thrive in acidic environments (pH < 5).
   - Alkaliphiles thrive in alkaline conditions (pH > 9).
4. Oxygen availability
   - Based on oxygen requirement, bacteria are classified as:
     - Obligate aerobes: Require oxygen.
     - Facultative anaerobes: Can grow with or without oxygen.
     - Obligate anaerobes: Cannot tolerate oxygen.
     - Microaerophiles: Require low oxygen levels.
     - Aerotolerant anaerobes: Don't use oxygen but can tolerate its presence.
5. Moisture
   - Water is essential for bacterial metabolism.
   - Lack of moisture inhibits growth; desiccation can kill bacteria.
6. Osmotic pressure
   - High salt or sugar concentrations can create hypertonic environments causing plasmolysis.
   - Some bacteria, called halophiles, require high salt concentrations.
7. Light
   - Some bacteria require light (photosynthetic bacteria).
   - Others are inhibited or killed by intense light or UV radiation.
8. Pressure
   - Barophiles or piezophiles can grow under high pressure (e.g., deep-sea bacteria).

VIRAL MORPHOLOGY

Viruses: Structure and Characteristics

Viruses are acellular organisms, meaning they are not composed of cells and lack most of the structures found in living cells, such as organelles, ribosomes, and a plasma membrane. As a result, viruses are obligate intracellular parasites that rely entirely on a host cell's machinery for replication.

A complete virus particle, known as a virion, typically consists of three main components:

1. **Nucleic acid core:**
   - Contains the virus's genetic material, which may be either DNA or RNA (but never both), and can be single-stranded or double-stranded.
2. **Capsid:**
   - A protective protein coat that surrounds the nucleic acid.
   - Made up of protein subunits called capsomeres, which assemble to form the overall shape of the virus (helical, icosahedral, complex, etc.).
3. **Envelope (optional):**
   - Many viruses possess an outer lipid envelope derived from the host cell

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membrane, embedded with viral proteins and glycoproteins.
  - This envelope helps in host cell recognition and entry.

Some viruses also contain enzymes or accessory proteins needed for their replication cycle (e.g., reverse transcriptase in retroviruses).

Major Structural Types

The morphology of viruses is highly diverse and is a key characteristic for classification into families. Major structural types include **(Fig. 3.9)**:

- Helical
- Icosahedral
- Complex (e.g., bacteriophages with a head-tail structure)

Interestingly, there is no direct correlation between the complexity of a virus and the complexity of its host. For example, bacteriophages, which infect simple prokaryotes like bacteria, often have intricately structured virions, more complex than those of some viruses infecting higher organisms.

Morphology (Fig. 3.10)

- Viruses come in many shapes and sizes, but these are consistent and distinct for each viral family. All virions have a nucleic acid genome covered by a protective layer of proteins, called a capsid.
- The capsid is made up of protein subunits called capsomeres. Some viral capsids are simple polyhedral "spheres".
- whereas others are quite complex in structure.
- The shapes of viruses are classified into four groups: filamentous, isometric, enveloped, and head and tail.
- Filamentous viruses are long and cylindrical.
- Many plant viruses are filamentous, including TMV.
- Isometric viruses have shapes that are roughly spherical, such as poliovirus or herpesviruses.
- Enveloped viruses have membranes surrounding capsids.
- Animal viruses, such as HIV, are frequently enveloped.

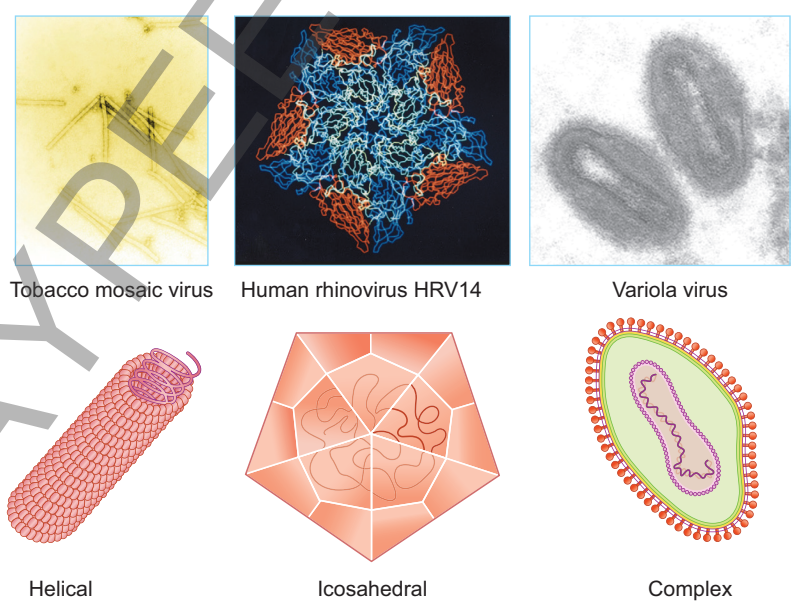

Fig. 3.9: Structural types of viruses.

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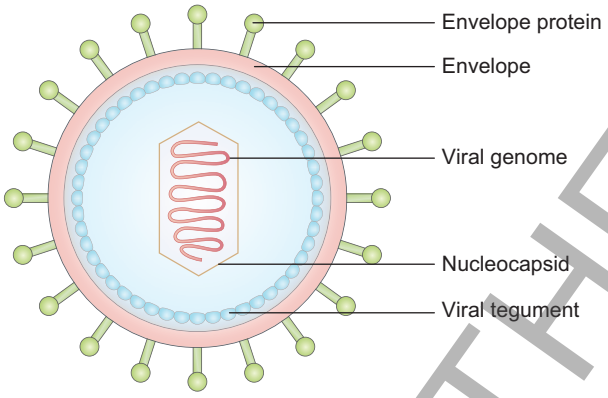

Fig. 3.10: Morphology of viruses.

- Head and tail viruses infect bacteria and have a head that is similar to icosahedral viruses and a tail shape like filamentous viruses.

1. **Helical symmetry:** There are several viruses that have helical morphology. These viruses are made up of identical protein subunits or promoters that are formed into a helical shape around the DNA. Typically, this class of protein subunits creates a solid nucleocapsid. Furthermore, the helical shape gives the filaments elasticity. By using an electron microscope, the morphology of these viruses may be examined. Additionally, the helical nucleocapsid is distinguished by its length, breadth, number of promoters per helical turn, and pitch. The tobacco mosaic virus is the most frequent kind of helical virus. In addition, the Sendai virus is believed to have a helical shape.
2. **Icosahedral symmetry:** The icosahedron is a form of polyhedron having twenty equilateral triangular faces and twelve vertices. The stiff structure offers genome protection. Examples of viruses with an icosahedral structure include papovavirus, picornavirus, adenovirus, togavirus, and others.
3. **RNA virus genome:** Approximately 70% of viruses use RNA as their genome. According to many studies, RNA viruses have greater mutation rates than DNA viruses owing to mistakes in the enzyme involved in RNA replication. The genome may be either single-stranded RNA (ss-RNA) or double-stranded RNA within the capsid (ds RNA). Aside from this, the strands may be whole or broken. In the case of ss-RNA, the RNA strand may either operate as a sense or antisense strand. Since the sense strand may operate as mRNA, it can directly contribute to the creation of viral proteins. While complementary to its mRNA, the antisense strand has no translational activity. Several reovirus species possess fragmented ds-RNA, with each fragment connected to its corresponding strand. On the other hand, the retrovirus genome has two ss-RNA strands that are the same and have reverse transcriptase attached to them.
4. **DNA virus genome:** Double-stranded linear DNA (ds DNA) is mostly found as the genome of DNA viruses. Papovaviruses are an exception, since their DNA genome is circular. In addition, single-strand DNA viruses (ss DNA) are also present in parvovirus family members. The

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members of the circovirus family have circular single-stranded DNA (ss DNA).

Viral Classification

Initial virus classification was based primarily on morphology (shape, size, and capsid structure). However, as molecular techniques advanced, classification criteria expanded to include:

- The type of nucleic acid: DNA or RNA
- The strand nature: Single-stranded (ss) or double-stranded (ds)
- Whether the genome is linear or circular
- The presence or absence of an envelope

This modern classification is more reflective of viral replication strategies and genetic makeup, which are essential for understanding virus behavior and pathogenicity.

Methods of Cultivation of Viruses (Table 3.2 and Fig. 3.11)

Viruses cannot grow on artificial media as they are obligate intracellular parasites. They require living cells to replicate. There are three primary methods used to cultivate viruses:

1. **Animal inoculation (In Vivo)**
   - Involves injecting the virus into live animals (e.g., mice, rabbits, monkeys).
   - Common for studying pathogenicity, immune responses, or isolating certain viruses.
   - *Advantages:*
     - Natural environment for viral replication.
     - Useful for studying host-virus interactions and symptomatology.
   - *Disadvantages:*
     - Expensive and time-consuming.
     - Ethical concerns.
     - Not all viruses infect animals.
2. **Embryonated egg inoculation**
   - Fertile chicken eggs (usually 7–12 days old) are inoculated with the virus into various parts:
     - Chorioallantoic membrane (CAM) – for poxviruses.
     - Allantoic cavity – for influenza virus.
     - Amniotic cavity – for mumps or influenza viruses.
     - Yolk sac – for some arboviruses.
   - *Advantages:*
     - Cost-effective.
     - Sterile, controlled environment.
     - Commonly used for vaccine production (e.g., influenza vaccine).
   - *Disadvantages:*
     - Limited to viruses that grow well in eggs.
     - Not suitable for all types of viruses.
3. **Cell culture (In Vitro)**

This is the most commonly used method today.

Types of cell cultures:

- *Primary cell culture:*
  - Derived directly from tissues (e.g., monkey kidney).
  - Can only divide a few times.
  - Closely resembles the original tissue.
- *Diploid cell line:*
  - Can divide up to 50 times (e.g., human embryonic lung cells).
  - Used for virus isolation and vaccine preparation.
- *Continuous cell line:*
  - Immortal cells (e.g., HeLa, Vero).
  - Used in research and diagnostics.
  - Can be subcultured indefinitely.

Observations:

- *Cytopathic effect (CPE):* Structural changes in host cells (e.g., rounding, lysis).
- *Hemadsorption:* Adsorption of red blood cells on virus-infected cells (e.g., influenza).
- *Plaque formation:* Clear zones indicating virus-induced cell death.

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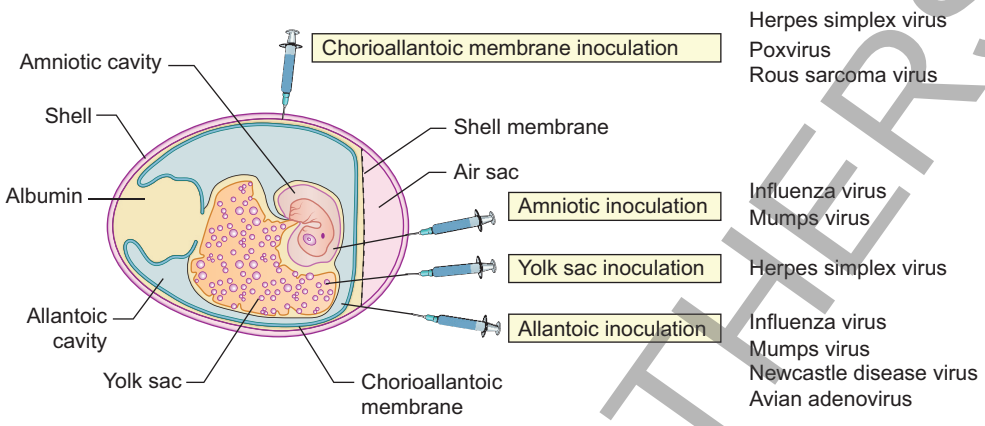

Fig. 3.11: Technique of cultivation of viruses.

TABLE 3.2: Methods of virus cultivation.

Method	*Main Use*	*Advantage*	*Limitation*
Animal Inoculation	Pathogenicity studies	Natural environment for replication	Ethical issues, not suitable for all viruses
Embryonated Eggs	Vaccine production, isolation	Cost-effective, sterile	Limited virus types
Cell Culture	Isolation, diagnostics, research	Controlled, reproducible, scalable	Requires expertise and equipment

Virion Size, Visualization, and Classification

Virions, or individual virus particles, typically range in size from 20 to 250 nanometers in diameter. These particles represent the infectious form of a virus when it is outside the host cell. Compared to bacteria—which are approximately 100 times larger—viruses are too small to be seen with a light microscope, with the exception of the large poxvirus virions.

The structure of viruses remained largely unknown until the invention of the electron microscope in the late 1930s, which allowed scientists to first observe the tobacco mosaic virus (TMV) in detail. Since then, electron microscopy has been instrumental in virology:

- Scanning Electron Microscopy (SEM) reveals the surface structure of virions in three dimensions.
- Transmission Electron Microscopy (TEM) provides detailed images of internal structures, allowing visualization of the nucleic acid and capsid organization.

These advanced imaging techniques have enabled scientists to identify and classify viruses infecting all domains of life, from animals and plants to fungi, bacteria, and archaea.

FUNGI

Introduction: Fungi – Structure, Classification, and Nutrition

Compared to prokaryotes such as prions, viruses, and bacteria, fungi are more evolutionarily advanced microorganisms. They are classified as eukaryotes due to the presence of:

- A nuclear membrane
- Plasma membrane sterols
- A diploid number of chromosomes

This genetic complexity allows for morphological diversity, contributing to the speciation and structural complexity seen in fungi.

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Taxonomic Classification

Fungi belong to a distinct biological kingdom, Kingdom Fungi, separate from:

- Plants
- Animals
- Protists
- Bacteria

Organisms in this kingdom include

- Yeasts
- Molds
- Mushrooms

The true fungi are referred to as Eumycota (or Eumycetes), forming a monophyletic group—i.e., they all descend from a common ancestor. They are distinct from structurally similar but unrelated groups such as:

- Myxomycetes (slime molds)
- Oomycetes (water molds)

Mycology

The scientific study of fungi is known as mycology. Historically, mycology was considered a subdiscipline of botany, but genetic research now shows that fungi are more closely related to animals than to plants.

Cell Structure and Organization

Fungi are eukaryotic organisms with a well-defined nucleus and membrane-bound organelles. The fungal cell wall is a key distinguishing feature.

Cell wall composition

- Primarily composed of chitin (a polymer of N-acetylglucosamine) and β-glucans.
- Unlike plants (which have cellulose) and bacteria (which have peptidoglycan), fungal cell walls contain chitin.
- In some primitive fungi (e.g., certain Chytrids), small amounts of cellulose may also be present, but this is not typical.
- Other components may include glycoproteins, mannans, and lipids depending on the species.

Morphology of Fungi

Fungi display diverse morphological forms, ranging from unicellular yeasts to multicellular filamentous molds and complex fruiting bodies like mushrooms. Their morphology is key to their classification, reproduction, and ecological roles.

1. **Major morphological forms**
   - **a. Yeasts**
     - Unicellular fungi.
     - Generally oval or round in shape.
     - Reproduce asexually by budding or fission.
     - Common examples: Saccharomyces cerevisiae, Cryptococcus neoformans.
   - **b. Molds (hyphal/filamentous fungi) (Fig. 3.12)**
     - Multicellular, composed of hyphae (thread-like filaments).



Fig. 3.12: Molds.

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- Hyphae collectively form a mycelium.
- Grow by elongation at the hyphal tip.
- Examples: Aspergillus, Penicillium, Rhizopus.

2. **Hyphal structure and growth (Fig. 3.13)**
- Fungi grow using thread-like structures called hyphae.
- These hyphae form an interconnected network known as a mycelium.
- The mycelium penetrates the substrate (e.g., wood, cheese, soil, or flesh).
- Filamentous growth provides:
  - A large surface area-to-volume ratio
  - Efficient nutrient absorption
- Although this exposes fungi to dehydration and ion imbalances, most fungi grow in moist environments, which mitigates these risks.

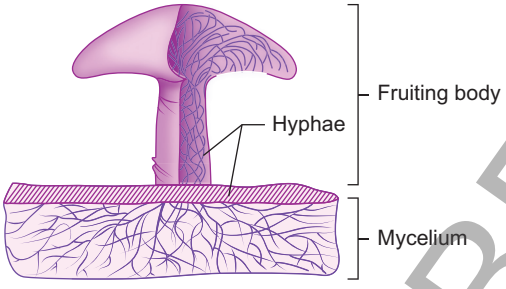

Fig. 3.13: Structure of fungus.

3. Hyphae types (Fig. 3.14)

Based on the presence of septa:

- **Septate hyphae:**
  - Divided by cross walls called septa.
  - Each compartment typically contains one or more nuclei.
  - Found in most fungi, e.g., Aspergillus.
  - Some septate fungi form clamp connections, structures that help in nuclear distribution during cell division.
- **Coenocytic (aseptate) hyphae:**
  - Lack septa, forming a continuous cytoplasmic mass with many nuclei.
  - Found in lower fungi, e.g., Rhizopus (a zygomycete).
- **Based on function:**
  - *Vegetative hyphae:* Absorb nutrients and grow into the substrate.

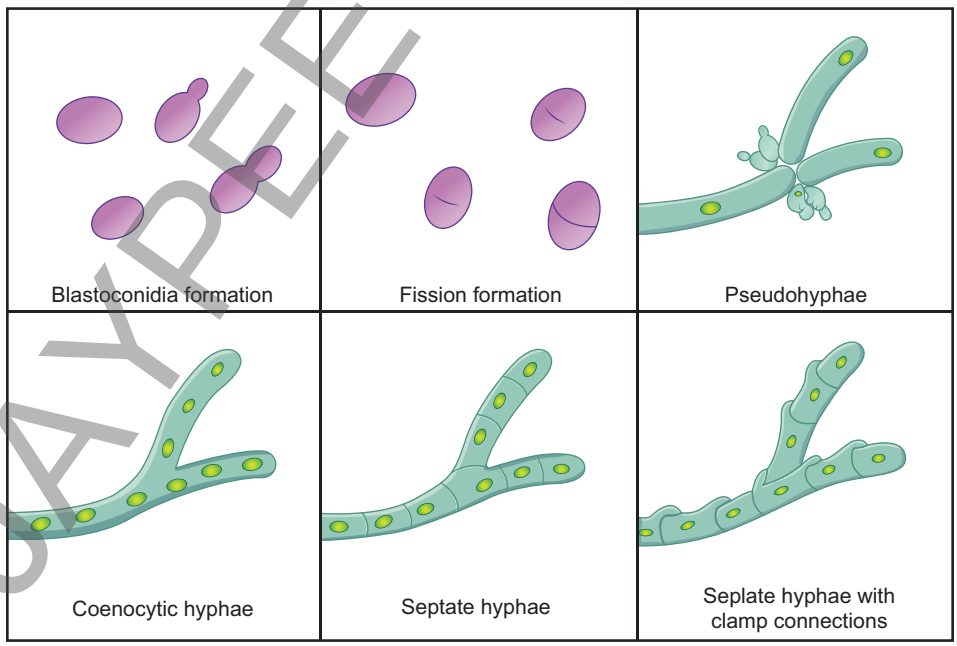

Fig. 3.14: Types of hyphae in fungus.

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- *Reproductive hyphae:* Give rise to reproductive structures like spores.
- *Rhizoidal hyphae:* Anchor the fungus to the substrate.

4. Mycelium

- A network of hyphae that forms the body of a mold.
- Can be aerial (above the surface) or substrate (within the surface).
- Responsible for nutrient absorption and growth.

5. Dimorphism

- Dimorphism is the ability of certain fungi to exist in two morphological forms—yeast and hyphae—depending on environmental conditions (e.g., temperature, CO_2 concentration).
- Yeast form in host tissues (typically at 37°C).
- Mycelial (mold) form in the environment (typically at 25°C).
- Examples: Histoplasma capsulatum, Blastomyces dermatitidis, Coccidioides immitis.
- Few fungi exhibit true dimorphism. Most exist predominantly in the hyphal form.

6. Fruiting bodies (in higher fungi)

- Complex multicellular structures that produce sexual spores.
- Seen in mushrooms, puffballs, and bracket fungi.
- Includes:
  - Pileus (cap)
  - Stipe (stalk)
  - Gills or pores under the cap containing spore-producing cells.

7. Spores

- Produced for reproduction and dispersal.
- Asexual spores (e.g., conidia, sporangiospores).
- Sexual spores (e.g., zygospores, ascospores, basidiospores).

Physiology of Fungi

Fungal physiology deals with the metabolic activities, growth mechanisms, and environmental interactions of fungi. Unlike plants, fungi lack chlorophyll and are non-photosynthetic; they rely on organic matter for nutrition and have distinct mechanisms for nutrient absorption and energy production.

1. Nutritional mode

Fungi are heterotrophic organisms, meaning they obtain nutrients by absorbing organic matter from their surroundings. They are categorized as:

- **Saprophytes:** Decompose dead organic material (e.g., Penicillium, Rhizopus).
  - *Obligate saprophytes:* Remain saprophytic throughout their life.
  - *Facultative saprophytes:* Parasites that have adapted to saprophytic nutrition.
- **Parasites:** Derive nutrients from living hosts, often causing disease (e.g., Candida albicans).
  - *Obligate parasites:* Survive only on a living host.
  - *Facultative parasites:* Saprophytes that have adapted to live parasitically.
- **Symbionts:**
  - *Mycorrhizae:* Mutualistic association with plant roots.
  - *Lichens:* Symbiosis between fungi and algae/cyanobacteria.

2. Enzyme production and nutrient absorption

- Fungi secrete extracellular enzymes (e.g., proteases, cellulases, amylases) to break down complex organic molecules.
- The digested products are absorbed across the fungal cell wall by diffusion or active transport.
- The extensive surface area of hyphae enhances nutrient absorption.

3. Growth requirements

- **Carbon source:** Glucose, sucrose, starch.
- **Nitrogen source:** Ammonia, nitrates, amino acids.

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- **Minerals:** Phosphates, potassium, magnesium, iron, zinc, and sulfur.
- **Water:** Essential for enzymatic activity and growth.
- **pH:** Fungi generally prefer acidic environments (pH 4–6).
- **Temperature:** Most fungi grow well at 25–30°C (mesophilic). Pathogenic fungi grow at 37°C.

4. Respiration

- Most fungi are aerobic and require oxygen.
- Some yeasts (e.g., Saccharomyces cerevisiae) are facultative anaerobes – they can undergo fermentation in the absence of oxygen, producing ethanol and CO_2.
- Energy is derived from glycolysis, Krebs cycle, and oxidative phosphorylation in aerobic conditions.

5. Reproduction

Fungi reproduce both asexually and sexually:

- **Asexual reproduction:**
  - Budding (yeasts)
  - Spore formation (e.g., conidia, sporangiospores)
  - Fragmentation of hyphae
- **Sexual reproduction (involving fusion of nuclei):**
  - Zygospores, Ascospores, Basidiospores (depending on fungal group)

6. Metabolite production

Fungi produce various primary and secondary metabolites:

- **Primary metabolites:** Ethanol, organic acids (citric acid, gluconic acid).
- **Secondary metabolites:** Antibiotics (penicillin, cephalosporin), toxins (aflatoxins), pigments, and enzymes.

7. Stress tolerance and survival

- Fungi can survive in low-moisture, low pH, and high osmotic pressure environments.
- Some can form dormant spores that resist desiccation, heat, and UV light.

8. Osmoregulation

- Fungi regulate their internal water balance using compatible solutes (like glycerol).
- This helps maintain turgor pressure and cellular integrity in hypertonic environments.

Classification of Fungi (Table 3.3)

Fungi are classified primarily based on their reproductive structures, particularly their sexual spores. They belong to the Kingdom Fungi (Eumycota) and are broadly divided into five major phyla:

1. Phylum zygomycota (zygomycetes)

- **Reproduction:** Asexual spores (sporangiospores); sexual spores (zygospores).
- **Hyphae:** Coenocytic (non-septate).
- **Examples:** Rhizopus stolonifer (bread mold), Mucor spp.
- **Habitat:** Soil, decaying organic matter.
- **Importance:** Some are used industrially, others cause spoilage or opportunistic infections.

2. Phylum ascomycota (ascomycetes – sac fungi)

- **Reproduction:**
  - *Asexual spores:* Conidia.
  - *Sexual spores:* Ascospores formed inside sac-like structures called asci.
- **Hyphae:** Septate.
- **Examples:** Aspergillus spp., Penicillium spp., Saccharomyces cerevisiae (yeast), Candida albicans (opportunistic pathogen).
- **Importance:** Antibiotic production (e.g., penicillin), baking and brewing, human disease.

3. Phylum basidiomycota (basidiomycetes – club fungi)

- **Reproduction:**
  - *Sexual spores:* Basidiospores produced on club-shaped structures called basidia.
  - Asexual reproduction is less common.

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- **Hyphae:** Septate with clamp connections.
- **Examples:** Agaricus bisporus (edible mushroom), Cryptococcus neoformans (pathogenic yeast), Rusts and smuts (plant pathogens).
- **Importance:** Edible mushrooms, plant pathogens, medical relevance.

4. Phylum chytridiomycota (chytridiomycetes)

- **Reproduction:**
  - Produce motile zoospores with flagella (unique among fungi).
  - Both sexual and asexual reproduction.
- **Hyphae:** Mostly unicellular or simple multicellular.
- **Examples:** Batrachochytrium dendrobatidis (infects amphibians).
- **Habitat:** Aquatic or moist environments.
- **Importance:** Ecological role in aquatic systems; some are parasites.

5. Phylum glomeromycota

- **Reproduction:** No known sexual spores; reproduce asexually via large spores.
- **Hyphae:** Coenocytic.
- **Examples:** Arbuscular mycorrhizal fungi (e.g., Glomus spp.).
- **Importance:** Form symbiotic relationships with plant roots (mycorrhizae); essential for nutrient uptake in plants.

6. Fungi imperfecti (deuteromycota)

- **Definition:** A group for fungi where sexual reproduction is unknown.
- **Reproduction:** Only asexual via conidia.
- **Examples:** Alternaria, Fusarium, Trichophyton spp.
- **Importance:** Includes many medically important fungi and plant pathogens.

Note: Many of these fungi are now reclassified under Ascomycota or Basidiomycota after molecular analysis.

PARASITES

Parasites belong to a diverse group of eukaryotic organisms, meaning their cells contain a true nucleus and other membrane-bound organelles. This distinguishes them from bacteria and viruses, which lack a nucleus. Generally, parasites are larger than bacteria, though some environmentally resistant forms can be quite small. Parasites may reproduce

TABLE 3.3: Classification of fungi.

Phylum	*Sexual Spores*	*Hyphae*	*Examples*	*Key Feature*
Zygomycota	Zygospores	Coenocytic	*Rhizopus*, *Mucor*	Bread mold, opportunistic infections
Ascomycota	Ascospores (in asci)	Septate	*Aspergillus*, *Penicillium*, *Yeast*	Antibiotic producers, yeast, pathogens
Basidiomycota	Basidiospores	Septate w/ clamps	*Mushrooms*, *Cryptococcus*	Mushroom formation, plant pathogens
Chytridiomycota	Zoospores (flagellated)	Simple/Unicellular	*Batrachochytrium*	Aquatic fungi, motile spores
Glomeromycota	None (asexual)	Coenocytic	*Glomus* spp.	Mycorrhizal fungi
Deuteromycota	None (asexual only)	Septate	*Trichophyton*, *Alternaria*	Includes many human pathogens

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only inside their hosts or sometimes freely in the environment. They can be unicellular, like Giardia, or multicellular, such as parasitic worms.

A parasite is an animal or plant that lives on or inside another organism, called the host, deriving food and nutrients at the host's expense and often causing harm. This harm can lead to stress, illness, or even death of the host.

- **Endoparasites:** Live inside the host's body. For example, tapeworms reside in the intestines of their hosts.
- **Ectoparasites:** Live on the external surface of the host. Head lice are a common example.

Common parasites causing human diseases include protozoa, helminths, and arthropods. Some well-known examples are:

- **Protozoa:** Unicellular organisms like Plasmodium (causes malaria), Giardia, and Cryptosporidium.
- **Helminths:** Multicellular parasitic worms such as tapeworms and roundworms.
- **Arthropods:** Parasites like mosquitoes, lice, and ticks, which may also act as vectors for other diseases.

Diseases caused by parasites are significant health concerns worldwide, especially in developing countries. For instance, Plasmodium species, responsible for malaria, cause major illness and mortality. Waterborne parasites such as Giardia and Cryptosporidium are common culprits in parasitic infections linked to contaminated water.

Classification of Parasites (Fig. 3.16)

1. **Protozoa: Protozoa** are single-celled, eukaryotic microorganisms characterized by membrane-bound organelles and a distinct nucleus. They typically inhabit aquatic or moist environments and lack filamentous structures. Most protozoa that infect humans are smaller than 50 micrometers. Over 11,000 species of parasitic protozoa have been identified. These organisms can replicate within a host, enabling rapid proliferation and potentially leading to serious illness and tissue damage. Transmission primarily occurs via the fecal-oral route, often through contaminated water, food, or direct person-to-person contact. Additionally, some protozoa are vector-borne and are transmitted through the bites of blood-feeding arthropods such as mosquitoes and ticks. In such cases, the vector introduces the protozoa directly

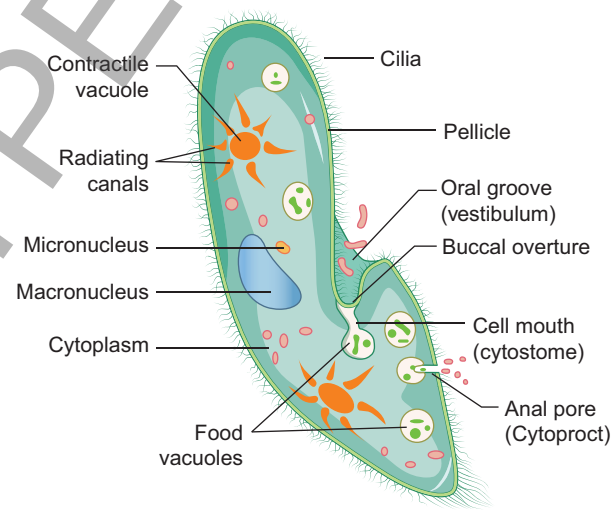

Fig. 3.15: Protozoa.

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into the host's bloodstream. Protozoa exhibit a range of motility. While some are non-motile, others move using structures such as **cilia**, **flagella**, or through **amoeboid** motion **(Fig. 3.15)**.

2. **Helminthes and insects:** Helminths are parasitic worms broadly classified into two major groups: roundworms (Phylum *Nematoda*) and flatworms (Phylum *Platyhelminthes*), which includes both tapeworms (Class *Cestoda*) and flukes (Class *Trematoda*). These organisms are multicellular and possess well-developed organ systems. However, in parasitic forms, certain systems—such as the digestive, locomotive, and nervous systems—may be reduced or simplified due to their specialized lifestyle within a host. Reproductive strategies vary among helminths. Some are monoecious (hermaphroditic), having both male and female reproductive organs in a single individual, while others are dioecious, with separate sexes. Helminths can enter the human body through multiple routes: ingestion of contaminated food or water, skin penetration (e.g., larvae in soil or water), or via transmission by a vector organism.
3. **Ectoparasites:** Ectoparasites are small organisms that live on the outside of the body. These include ticks, fleas, and lice.

Life Cycles of Parasites (Fig. 3.17)

Parasites typically have complex life cycles that may involve one or more hosts and include both asexual and sexual reproduction stages. These life cycles can be categorized into two broad types:

1. **Direct life cycle (Monoxenous)**
   - Involves only one host.
   - The parasite completes its entire development and reproductive cycle within a single host organism.
   - Transmission usually occurs via ingestion of infective stages (e.g., eggs or cysts) from contaminated food, water, or surfaces.

   Example: *Enterobius vermicularis* (pinworm) – spreads through ingestion of eggs.
2. **Indirect life cycle (Heteroxenous)**
   - Involves two or more hosts: a definitive host (where sexual reproduction occurs) and one or more intermediate hosts (where asexual reproduction or larval development occurs).
   - Transmission can involve vectors, such as insects, or ingestion of intermediate hosts.

   Example:
   - *Plasmodium spp.* (malaria parasite): Mosquito (vector and definitive host) → Human (intermediate host).
   - *Taenia solium* (pork tapeworm): Human (definitive host) → Pig (intermediate host).

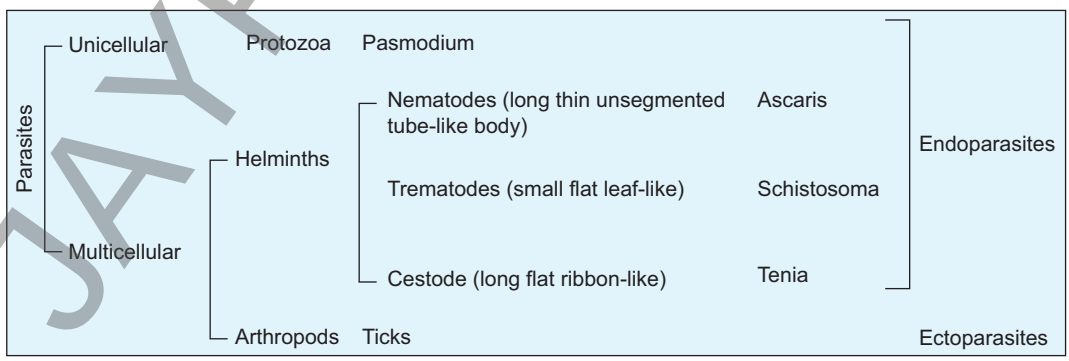

Fig. 3.16: Classification of parasites.

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Common Life Cycle Stages

1. **Egg**—The starting point for many helminths, shed in feces or urine.
2. **Larva**—An immature stage that may migrate through body tissues or require an intermediate host.
3. **Cyst/Oocyst**—A dormant, infective stage found in protozoa, enabling survival in harsh conditions.
4. **Trophozoite**—The active, feeding stage of protozoa (e.g., in *Entamoeba histolytica*).
5. **Adult**—The mature, reproductive stage found in the definitive host.

Transmission Routes

- **Fecal-oral:** Contaminated water/food (e.g., *Giardia*, *Ascaris*).
- **Skin penetration:** Larvae enter through skin (e.g., *Schistosoma*).
- **Vector-borne:** Transmitted via bites from mosquitoes, ticks, etc. (e.g., *Plasmodium*, *Trypanosoma*).
- **Consumption of undercooked meat:** Hosts ingest cysts or larvae (e.g., *Trichinella*, *Taenia*).

Types of Protozoa

1. Giardia Duodenalis

Giardia duodenalis is a flagellated protozoan parasite that causes giardiasis, an intestinal infection. Transmission occurs primarily through ingestion of infective cysts, which are excreted in the feces of infected individuals

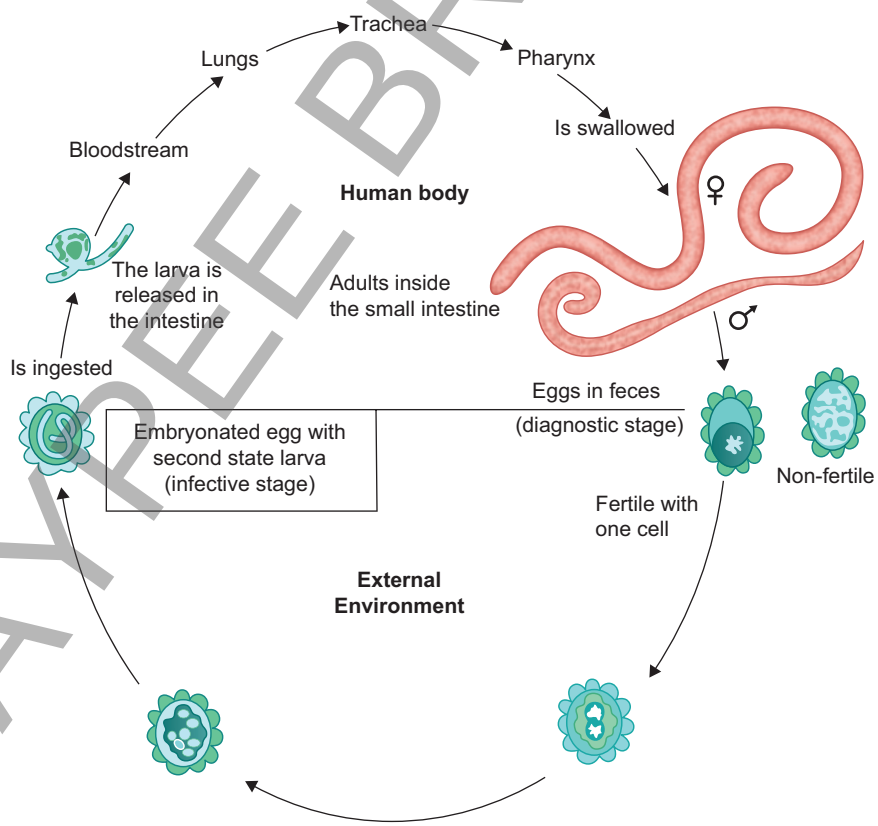

Fig. 3.17: Life cycle of parasite.

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and can remain viable in the environment (soil or water) for several weeks **(Fig. 3.18)**.

Transmission and risk factors

- Infection occurs upon ingestion of as few as 10 cysts, commonly via contaminated water or food.
- At-risk populations include:
- Children (especially in daycare settings),
- Men who have sex with men,
- Institutionalized individuals (e.g., those with mental illness).

Predisposing factors increasing susceptibility include:

- Blood type A,
- Achlorhydria,
- Chronic pancreatitis,
- Malnutrition,
- Cannabis use,
- Immunodeficiencies (e.g., selective IgA deficiency, hypogammaglobulinemia).

Life cycle

- Cysts are ingested and pass through the stomach.
- Excystation occurs in the small intestine (within ~30 minutes), where each cyst releases two trophozoites.
- Trophozoites attach to the epithelial lining of the jejunum and duodenum using a ventral adhesive disc and surface adhesins. This attachment is critical to prevent their removal by intestinal peristalsis.
- Multiplication occurs via binary fission.
- Trophozoites may be present in diarrheal stools during acute infection, although they do not survive long outside the body.
- Encystation begins in the colon, especially under adverse conditions (e.g., dehydration, exposure to bile salts).

Key steps include:

- Flagellar retraction,
- Cytoplasmic condensation,
- Cyst wall formation.

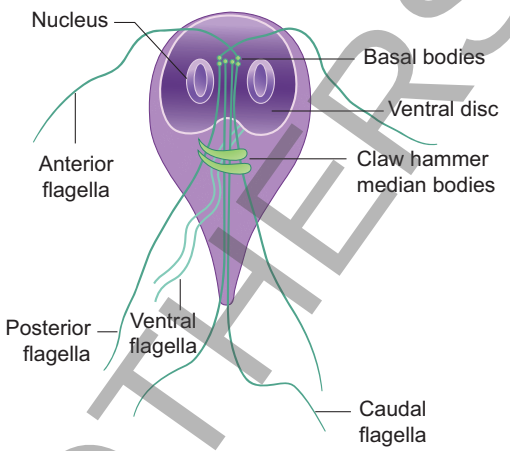

Fig. 3.18: Giardia duodenalis.

Factors promoting encystation

- Presence of conjugated bile salts,
- Alkaline pH,
- Cholesterol depletion in the intestinal environment.

Types of Helminths

2. Strongyloides Stercoralis

Strongyloides stercoralis, commonly known as the threadworm, is a parasitic roundworm (nematode) that causes strongyloidiasis. It is the smallest human-infecting nematode and is notable for its ability to cause autoinfection, allowing chronic infections that may persist for decades **(Fig. 3.19)**.

Morphology and habitat

- The parasitic female is thin, semi-transparent, and colorless, measuring approximately 2.5 mm in length and 0.05 mm in width.
- It resides embedded in the mucosal epithelium of the proximal small intestine (mainly the duodenum and jejunum).
- In contrast, the free-living female measures about 1 mm in length and 80 µm in width.

Anatomical features

- The anterior end features a mouth with three small lips.

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- The esophagus occupies the anterior one-third of the body and is cylindrical.
- The posterior two-thirds contains the intestines, and the anus is situated along the mid-ventral surface.
- The posterior end is sharply pointed.

Reproductive system

- The parasitic female is oviparous, containing:
- Two uteri,
- A single vagina,
- A vulva located at the junction of the middle and posterior third of the body.
- The uterus typically contains oval, clear, thin-walled eggs measuring approximately 50 µm by 30 µm.
- A single female can lay up to 50 eggs per day.

Infection and persistence: Although individual worms live for only 3–4 months, the infection can persist for years due to autoinfection, where larvae develop into infective forms within the host and re-enter the body without exiting.

3. Ascaris Lumbricoides

Ascaris lumbricoides is a large intestinal roundworm that causes ascariasis. Infection occurs when a person ingests embryonated eggs containing infective second-stage rhabditiform larvae, usually through contaminated food or water **(Fig. 3.20)**.

Infection and larval migration

- After ingestion, the eggs hatch in the small intestine under the influence of digestive enzymes.
- The released second-stage larvae (juveniles) are about 0.2–0.3 mm in length and 13–15 µm in diameter. They resemble the adult worm structurally but lack developed reproductive organs.
- Instead of maturing in the intestine, the larvae penetrate the intestinal wall, enter the mesenteric circulation, and travel via the hepatic portal vein to the liver.
- From the liver, they migrate to the right side of the heart through the postcaval (inferior vena cava) vein and are then pumped to the lungs via the pulmonary artery.
- Pulmonary Phase: In the lungs, larvae rupture capillaries and enter the alveoli, where they remain for a few days, grow in size, and molt twice:
- From second-stage to third-stage larvae, Then to the fourth-stage larvae, which grow to about 2–3 mm in length.
- Re-entry into the Intestine

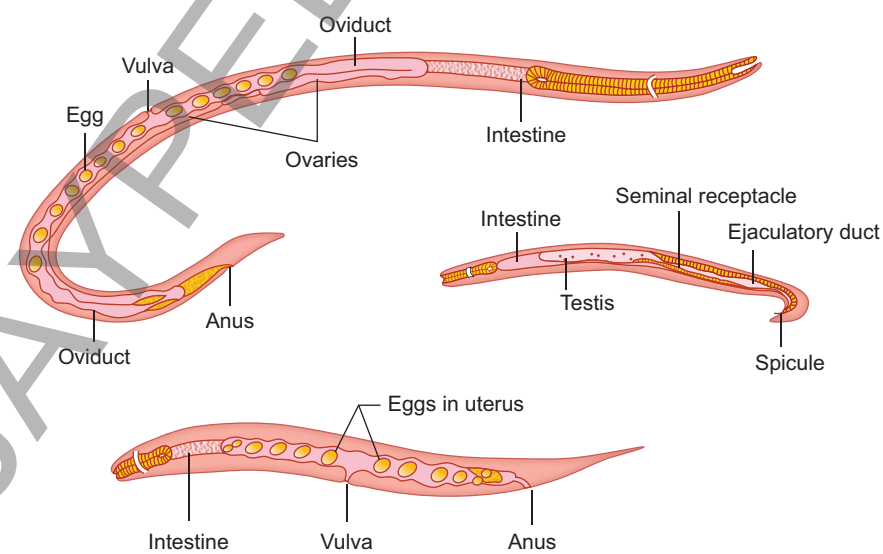

Fig. 3.19: Strongyloides stercoralis.

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APPLIED MICROBIOLOGY, INFECTION CONTROL AND SAFETY FOR NURSES

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The book aims to bridge the gap between theoretical microbiological knowledge and clinical nursing practice. It explains microorganisms and infectious processes in a manner that enables nursing students to understand how infections develop, how they spread, and how nurses can effectively prevent their transmission.

Salient Features

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- **Nursing-focused approach:** Microbiology concepts are explained with direct relevance to nursing practice, patient care, infection prevention, and clinical procedures.
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Dipak Sethi PhD Nursing is an accomplished academician, researcher, author, and nursing education professional currently serving as the Dean, College of Nursing, Noida International University (NIU), Noida, Uttar Pradesh, India, and as the Central IQAC Secretary at NIU. With a strong commitment to academic excellence, research, innovation, and quality assurance in nursing education, he has made significant contributions to teaching, research, and institutional development. He has contributed as Principal Investigator to 32 Scopus-indexed publications and has been associated with 8 patents as a primary investigator. He has also authored 15 books published by M/s Jaypee Brothers Medical Publishers (P) Ltd and has contributed to externally funded research, including two ICMR-sanctioned projects on DNA sequencing, along with an intramural research project on cervical cancer at NIU. His professional engagements include membership with QCI, Maharashtra, and international academic association as a visiting faculty member at Thumbay University of Medical Sciences, Ajman, UAE. Through his academic leadership, research initiatives, publications, and commitment to quality improvement, Dr Sethi continues to contribute to the advancement of nursing education and evidence-based healthcare practice.

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