Microorganisms

Chapter 8: INTRODUCTION TO MICRO-ORGANISMS

Learning Objectives: Upon completion of this chapter, students should be able to:

- Define microorganisms and state their general characteristics.
- Classify different types of microorganisms (bacteria, fungi, viruses, protozoa, algae).
- Describe the structure of common microorganisms (e.g., bacterium, yeast, *Amoeba*).
- Discuss the beneficial roles of microorganisms in nature and industry.
- Explain the harmful effects of microorganisms, including disease causation.
- Outline methods of controlling harmful microorganisms.

8.1 Definition and General Characteristics of Microorganisms

- **Definition:** Microorganisms (or microbes) are microscopic living organisms, either single-celled (unicellular) or multi-cellular, that are too small to be seen individually with the naked eye. They require a microscope for observation.
- **General Characteristics:**
    - **Ubiquitous:** Found almost everywhere – in air, water, soil, on and within living organisms, even in extreme environments (hot springs, deep sea vents).
    - **Diverse:** Exhibit immense diversity in form, structure, metabolism, and ecology.
    - **Rapid Reproduction:** Many reproduce very quickly (e.g., bacteria by binary fission), leading to rapid population growth.
    - **Metabolically Versatile:** Can utilize a wide range of energy sources and perform diverse chemical reactions.
    - **Often Unicellular:** Many are single-celled, though some exist as colonies or simple multicellular forms.
    - **Crucial Roles:** Play essential roles in nutrient cycling, decomposition, disease, and industrial processes.

8.2 Classification of Microorganisms

Microorganisms are broadly classified into several major groups:

1. **Bacteria (Singular: Bacterium):**
    - **Characteristics:** Unicellular prokaryotes (lack a true nucleus and membrane-bound organelles).

- **Structure:** Cell wall, cell membrane, cytoplasm, genetic material (nucleoid region, plasmids), ribosomes, sometimes flagella for movement.
- **Shapes:** Cocci (spherical), Bacilli (rod-shaped), Spirilla (spiral), Vibrios (comma-shaped).
- **Nutrition:** Autotrophic (photosynthetic or chemosynthetic) or heterotrophic (saprophytic or parasitic).
- **Reproduction:** Asexually, primarily by binary fission.
- **Importance:** Decomposers, nitrogen fixers, probiotics, industrial uses (food production, pharmaceuticals), disease-causing (pathogens).

2. **Fungi (Singular: Fungus):**
   - **Characteristics:** Eukaryotic (have a true nucleus and organelles), can be unicellular (yeasts) or multicellular (moulds, mushrooms). Cell walls made of chitin.
   - **Structure (Moulds):** Consist of filamentous structures called hyphae, forming a mycelium. Produce spores for reproduction.
   - **Nutrition:** Heterotrophic (saprophytic – absorbing nutrients from dead organic matter, or parasitic – absorbing from living hosts).
   - **Importance:** Decomposers, food (mushrooms, yeast for bread/beer), antibiotics (penicillin), plant/animal diseases.
3. **Viruses (Singular: Virus):**
   - **Characteristics:** Non-cellular, obligate intracellular parasites (can only reproduce inside living host cells). Extremely small.
   - **Structure:** Genetic material (DNA or RNA) enclosed in a protein coat (capsid). Some have an outer lipid envelope.
   - **Reproduction:** Replicate by taking over host cell machinery.
   - **Importance:** Cause a wide range of diseases in plants, animals, and bacteria (bacteriophages). Not considered truly "living" by some due to their reliance on host cells.
4. **Protozoa (Singular: Protozoan):**
   - **Characteristics:** Unicellular eukaryotes, often motile.
   - **Structure:** Diverse shapes often lack cell walls. Possess organelles like nucleus, contractile vacuole, food vacuoles.
   - **Movement:** Amoeboid movement (pseudopods), flagella, cilia.
   - **Nutrition:** Heterotrophic (ingest food particles, some are parasitic).
   - **Importance:** Important in aquatic food webs, some cause diseases (e.g., malaria by *Plasmodium*, amoebic dysentery by *Entamoeba*).
5. **Algae (Singular: Alga):**
   - **Characteristics:** Diverse group of photosynthetic eukaryotes. Can be unicellular or multicellular (though simple, not differentiated into true roots, stems, leaves like plants).
   - **Structure:** Contain chlorophyll and other pigments. Range from microscopic single cells to large seaweeds.
   - **Nutrition:** Autotrophic (photosynthesis).
   - **Importance:** Major producers in aquatic ecosystems (base of food webs), produce oxygen, some used as food or in industrial products (agar, carrageenan), can cause algal blooms (harmful).

8.3 Structure of Common Microorganisms

- **A. Bacterium (e.g., *Escherichia coli* - a typical rod-shaped bacterium):**
    - **Cell Wall:** Rigid outer layer, provides shape and protection (made of peptidoglycan).
    - **Cell Membrane:** Controls what enters and leaves the cell.
    - **Cytoplasm:** Jelly-like substance filling the cell, where metabolic reactions occur.
    - **Nucleoid Region:** Area containing the main circular chromosome (DNA) – *no true nucleus*.
    - **Plasmids:** Small, extra-chromosomal circles of DNA, often carrying genes for antibiotic resistance.
    - **Ribosomes:** Sites of protein synthesis.
    - **Flagella (optional):** Long, whip-like appendages for locomotion.
    - **Pili/Fimbriae (optional):** Hair-like appendages for attachment to surfaces.
    - **Capsule (optional):** Sticky outer layer for protection and adhesion.
- **B. Yeast (*Saccharomyces cerevisiae* - a common unicellular fungus):**
    - **Cell Wall:** Rigid outer layer, made of chitin.
    - **Cell Membrane:** Controls passage of substances.
    - **Cytoplasm:** Contains organelles.
    - **Nucleus:** Contains genetic material (eukaryotic).
    - **Vacuole:** Storage and waste removal.
    - **Mitochondria:** Sites of aerobic respiration.
    - **Bud Scar:** Mark left after budding (asexual reproduction).
- **C. *Amoeba* (a typical protozoan):**
    - **Cell Membrane:** Flexible outer boundary.
    - **Cytoplasm:** Divided into outer ectoplasm (clear, jelly-like) and inner endoplasm (granular).
    - **Nucleus:** Controls cell activities.
    - **Contractile Vacuole:** Pumps out excess water to maintain osmotic balance.
    - **Food Vacuole:** Forms around ingested food particles for digestion.
    - **Pseudopods ("false feet"):** Temporary cytoplasmic extensions used for locomotion (amoeboid movement) and engulfing food (phagocytosis).

8.4 Beneficial Roles of Microorganisms

Microorganisms are indispensable for life on Earth and have numerous applications.

- **A. In Nature:**
    1. **Decomposition/Nutrient Cycling:**
        - **Decomposers:** Bacteria and fungi break down dead organic matter, animal waste, and pollutants, releasing nutrients (carbon, nitrogen, phosphorus) back into the environment (soil, water, atmosphere). This makes nutrients available for producers.
        - **Detoxification:** Some microbes can break down toxic substances.
    2. **Nitrogen Cycle:**
        - **Nitrogen Fixation:** Nitrogen-fixing bacteria (e.g., *Rhizobium* in legume root nodules, *Azotobacter* in soil) convert atmospheric nitrogen (N_2) into usable forms (ammonia/nitrates) for plants.

        - **Nitrification:** Nitrifying bacteria convert ammonia to nitrites and then nitrates.
        - **Denitrification:** Denitrifying bacteria return nitrogen gas to the atmosphere.
    3. **Photosynthesis:** Algae and cyanobacteria are major producers of oxygen and form the base of aquatic food chains.
    4. **Digestion in Animals:** Symbiotic bacteria in the guts of herbivores (e.g., cows, termites) digest cellulose, allowing them to extract nutrients from plant material.
    5. **Bioremediation:** Using microorganisms to clean up environmental pollutants (e.g., oil spills, contaminated soil).
- **B. In Industry and Medicine:**
    1. **Food Production:**
        - **Yeast:** Used in bread making (fermentation produces CO_2 for rising) and brewing (fermentation produces alcohol in beer/wine).
        - **Bacteria:** Used in making yogurt, cheese, vinegar, sauerkraut, and pickles (fermentation processes).
    2. **Antibiotics:** Many antibiotics (e.g., penicillin from *Penicillium* fungus, streptomycin from *Streptomyces* bacteria) are produced by microorganisms to kill or inhibit the growth of other harmful microbes.
    3. **Vaccine Production:** Some vaccines are produced using weakened or inactivated microbes, or parts of microbes.
    4. **Enzyme Production:** Microbes produce enzymes used in detergents, food processing, and biotechnology.
    5. **Vitamins:** Some vitamins (e.g., Vitamin B12) are produced commercially using microbial fermentation.
    6. **Biogas Production:** Anaerobic bacteria break down organic waste to produce methane (biogas), a renewable energy source.
    7. **Genetic Engineering:** Microbes (especially bacteria like *E. coli*) are extensively used as "factories" to produce insulin, hormones, and other recombinant proteins.

8.5 Harmful Effects of Microorganisms (Pathogens)

Many microorganisms are pathogens, meaning they can cause diseases in humans, animals, and plants.

- **Disease Causation (Examples):**
    - **Bacteria:** Tuberculosis, cholera, typhoid, pneumonia, tetanus, food poisoning (e.g., *Salmonella*).
    - **Viruses:** Influenza (flu), common cold, measles, mumps, rubella, HIV/AIDS, COVID-19, chickenpox.
    - **Fungi:** Ringworm, athlete's foot, candidiasis (thrush), plant diseases (e.g., rusts, blights).
    - **Protozoa:** Malaria (*Plasmodium*), amoebic dysentery (*Entamoeba*), sleeping sickness (*Trypanosoma*).
    - **Algae:** Harmful algal blooms (red tides) can produce toxins that contaminate seafood and harm marine life and humans.
- **Mechanism of Harm:**
    - **Toxin Production:** Releasing harmful chemicals (exotoxins, endotoxins).
    - **Direct Cell Damage:** Invading and destroying host cells.
    - **Host Response:** Triggering an excessive or harmful immune response from the host.

    - **Resource Depletion:** Consuming host nutrients.
- **Spoilage of Food:** Microorganisms (bacteria, fungi) cause food to spoil by breaking down its components, leading to changes in taste, smell, texture, and appearance. They can also produce toxins in spoiled food.

8.6 Control of Harmful Microorganisms

Controlling harmful microbes is essential in medicine, public health, and food preservation.

- **A. In Humans (Disease Prevention and Treatment):**
    1. **Hygiene:**
        - **Personal Hygiene:** Handwashing, bathing, proper dental care.
        - **Environmental Hygiene:** Clean water supply, proper sewage disposal, waste management.
    2. **Sterilization and Disinfection:**
        - **Sterilization:** Complete destruction of all microorganisms (including spores) on surfaces or in materials (e.g., heat sterilization in autoclaves for medical instruments).
        - **Disinfection:** Reduction of pathogenic microorganisms to a safe level (e.g., disinfectants on surfaces, antiseptics on living tissue).
    3. **Vaccination:** Introducing weakened or inactivated pathogens (or parts of them) to stimulate the immune system to produce antibodies, providing immunity against future infections.
    4. **Antibiotics:** Medications (from microbes or synthetic) that kill or inhibit the growth of bacteria. *Note: Ineffective against viruses.*
    5. **Antivirals:** Drugs that target specific viral processes to inhibit their replication.
    6. **Antifungals:** Medications to treat fungal infections.
    7. **Vector Control:** Eliminating or controlling disease-carrying organisms (vectors) like mosquitoes (e.g., spraying insecticides, removing breeding grounds).
- **B. In Food Preservation:**
    1. **Refrigeration:** Low temperatures slow down microbial growth.
    2. **Freezing:** Stops microbial growth and enzyme activity.
    3. **Heating (Pasteurization/Sterilization):**
        - **Pasteurization:** Mild heat treatment to reduce pathogenic microbes and spoilage organisms (e.g., milk, juice).
        - **Sterilization (Canning):** High heat treatment to kill all microbes and spores for long-term storage.
    4. **Drying/Dehydration:** Removes water, inhibiting microbial growth.
    5. **Salting/Sugaring:** Creates a hypertonic environment, drawing water out of microbes through osmosis.
    6. **Pickling/Acidification:** Lowering pH (e.g., with vinegar) inhibits microbial growth.
    7. **Smoking:** Chemicals in smoke act as preservatives.
    8. **Chemical Preservatives:** Adding food-grade chemicals to inhibit microbial growth (e.g., benzoates, nitrites).
    9. **Vacuum Packaging/Modified Atmosphere Packaging (MAP):** Removing oxygen or altering gas composition to inhibit aerobic spoilage organisms.