

Microbial Nutrition and Ecology

Lecture 9

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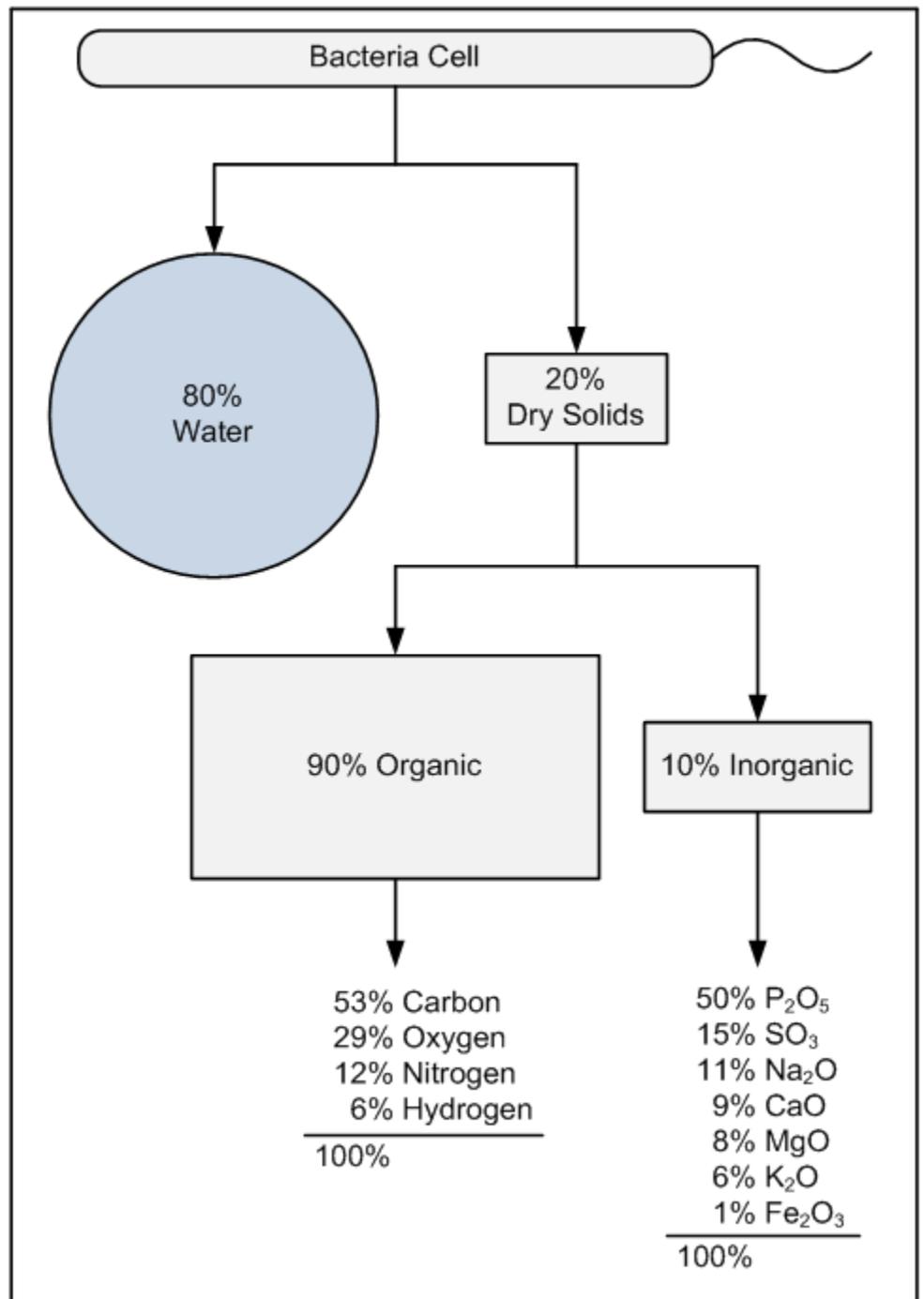
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Microbial Nutrition

Nutrition – process by which chemical substances (nutrients) are acquired from the environment and used in cellular activities

Essential nutrients – must be provided to an organism

Chemical Analysis of Cell Contents



Two categories of essential nutrients:

A. Macroelements (Macronutrients)

- **Over 95% of cell dry weight** is made up of a few major elements:
C, O, H, N, S, P, K, Ca, Mg, Fe
- Required by microorganisms in **relatively large amounts**.
- **Roles of Major Macroelements**
 - **C, O, H, N, S, P** → Components of carbohydrates, lipids, proteins, and nucleic acids.
 - **K⁺** → Required for enzyme activity and protein synthesis.
 - **Ca²⁺** → Contributes to heat resistance of bacterial endospores.
 - **Mg²⁺** → Acts as a **cofactor** for enzymes, forms complexes with ATP, and stabilizes ribosomes and membranes.
 - **Fe²⁺ / Fe³⁺** → Part of **cytochromes** and acts as a **cofactor** for enzymes and electron-carrier proteins.

Two categories of essential nutrients:

B. Micronutrients (Trace Elements)

- Required by microorganisms in very small amounts.
 - Include: Mn, Zn, Co, Mo, Ni, Cu
- **General Characteristics**
 - Often obtained from contaminants in water, glassware, and media.
 - Usually do not limit growth in natural environments.
 - Function as enzyme cofactors aiding in catalysis and protein structure maintenance.
- **Example**
 - **Zn²⁺** → Present at the active site of some enzymes; also involved in regulation and catalytic subunit association.

Nutrients

- **Organic nutrients** – contain **carbon** and **hydrogen** atoms and are usually the products of living things
 - Methane (CH₄), carbohydrates, lipids, proteins, and nucleic acids
- **Inorganic nutrients** – atom or molecule that contains a combination of atoms other than carbon and hydrogen
 - Metals and their salts (magnesium sulfate, ferric nitrate, sodium phosphate), gases (oxygen, carbon dioxide) and water

Requirements for Carbon, Hydrogen, Oxygen, and Electrons

•All organisms require:

- **Carbon** – forms the skeleton/backbone of organic molecules.
- **Hydrogen and Oxygen** – essential elements found in organic compounds.
- **Electrons** – required for two main reasons:
 1. **Energy generation:**
 - Electrons move through electron transport chains and other redox (oxidation–reduction) reactions.
 - This movement provides energy for cellular work.
 2. **Biosynthesis:**
 - Electrons are needed to reduce molecules during biosynthetic processes (e.g., reducing CO₂ to form organic molecules).

Nutritional Types of Microorganisms

- The need for **carbon**, **energy**, and **electrons** defines how microorganisms are nutritionally classified.
- Microorganisms are classified based on:
 1. **Carbon source** → autotrophs or heterotrophs
 2. **Energy source** → phototrophs or chemotrophs
 3. **Electron source** → lithotrophs or organotrophs

Classified of Mos based on:

1. Carbon sources

➤ Heterotroph

- Use **reduced, organic molecules** as their carbon source.
- Can also obtain **hydrogen, oxygen, and electrons** from the same organic molecules.
- Because these molecules contain electrons usable in redox reactions, carbon sources also serve as **energy sources**.
- **Example: Lipids** have a higher energy content than **carbohydrates**.

▪ Parasitic

➤ Autotroph

- An organism that uses CO_2 , an inorganic gas as its carbon source.
- Must obtain **energy** from other sources (e.g., **light** or **reduced inorganic molecules**) because CO_2 alone cannot supply energy.
- CO_2 is the **most oxidized form of carbon**, lacks hydrogen, and cannot donate electrons.
- **Called Saprophytic (air, soil) and non medical important.**

Types of Microbial Carbon Use

- **Bacterial omnivores:**
 - Can use many types of carbon sources.
- **Fastidious microbes:**
 - Can use only a few specific carbon compounds.
- **Methylotrophic bacteria:**
 - Metabolize **one-carbon molecules** such as:
 - Methane
 - Methanol
 - Carbon monoxide
 - Formic acid
- **Parasitic genus *Leptospira*:**
 - Uses **only long-chain fatty acids** as major carbon and energy sources.

Classified of Mos based on:

2. Energy Source

- **Phototrophs** → Use light as their energy source.
- **Chemotrophs** → Obtain energy from oxidation of chemical compounds (organic or inorganic).

3. Electron Sources

- **Lithotrophs (“rock-eaters”)** → Use reduced inorganic substances as electron donors.
- **Organotrophs** → Extract electrons from reduced organic compounds.

Sources of Carbon, Energy, and Electrons

| Category | Type | Source |
|------------------------|--------------|---|
| Carbon Source | Autotrophs | CO ₂ (sole/principal biosynthetic carbon source) |
| | Heterotrophs | Reduced, preformed organic molecules from other organisms |
| Energy Source | Phototrophs | Light |
| | Chemotrophs | Oxidation of organic or inorganic molecules |
| Electron Source | Lithotrophs | Reduced inorganic molecules |
| | Organotrophs | Organic molecules |

Nutritional Classification of Microorganisms

- Microorganisms can be grouped by their **sources of carbon, energy, and electrons** (see below table).
- Most belong to one of **five main nutritional types**.
- The majority are either:
 - **Photolithoautotrophic** autotrophs or
 - **Chemoorganoheterotrophic** heterotrophs.

Table 5.2

Major Nutritional Types of Microorganisms

| Nutritional Type | Carbon Source | Energy Source | Electron Source | Representative Microorganisms |
|--|--|--|--|---|
| Photolithoautotrophy (photolithotrophic autotrophy) | CO ₂ | Light | Inorganic e ⁻ donor | Purple and green sulfur bacteria, cyanobacteria |
| Photoorganoheterotrophy (photoorganotrophic heterotrophy) | Organic carbon, but CO ₂ may also be used | Light | Organic e ⁻ donor | Purple nonsulfur bacteria, green nonsulfur bacteria |
| Chemolithoautotrophy (chemolithotrophic autotrophy) | CO ₂ | Inorganic chemicals | Inorganic e ⁻ donor | Sulfur-oxidizing bacteria, hydrogen-oxidizing bacteria, methanogens, nitrifying bacteria, iron-oxidizing bacteria |
| Chemolithoheterotrophy or mixotrophy (chemolithotrophic heterotrophy) | Organic carbon, but CO ₂ may also be used | Inorganic chemicals | Inorganic e ⁻ donor | Some sulfur-oxidizing bacteria (e.g., <i>Beggiatoa</i>) |
| Chemoorganoheterotrophy (chemoorganotrophic heterotrophy) | Organic carbon | Organic chemicals often same as C source | Organic e ⁻ donor, often same as C source | Most nonphotosynthetic microbes, including most pathogens, fungi, many protists, and many archaea |

Metabolic Flexibility in Microorganisms

- Some species can **switch between nutritional modes** depending on environment.

Example: Purple nonsulfur bacteria

- Act as **photoorganotrophic heterotrophs** under anaerobic conditions.
 - Function as **chemoorganotrophs** under normal oxygen levels.
- This **metabolic flexibility** allows adaptation to changing conditions.

Growth Factors: Essential Organic Nutrients

- Some microorganisms can synthesize all required cell components from simple minerals and energy sources.
- Others **lack enzymes** needed to make certain essential compounds and must **obtain them from the environment**.
- These essential organic compounds that **cannot be synthesized**, but are **required for growth**, are called **growth factors**.

Classes of Growth Factors

1. Amino Acids

- Needed for **protein synthesis**.

2. Purines and Pyrimidines

- Required for **nucleic acid synthesis**.

3. Vitamins

- Small organic molecules acting as **enzyme cofactors**.
- Needed in **very small amounts** for growth.

Examples

- *Enterococcus faecalis* requires **eight different vitamins** for growth.
- *Haemophilus influenzae* requires **heme** (from hemoglobin or cytochromes).
- *Mycoplasmas* need **cholesterol** for membrane synthesis.

Concept Check:

If an organism is degrading large organic molecules to get both carbon and energy, it would be best described as a

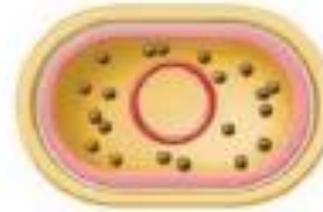
- A. Photoheterotroph
- B. Photoautotroph
- C. Chemoheterotroph
- D. Chemoautotroph

The Study of Microbial Growth

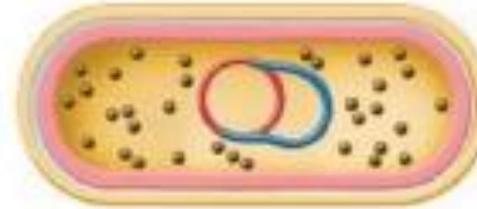
- Microbial growth occurs at two levels:
 1. Growth at a cellular level with increase in size
 2. Increase in population (Number).
- Bacteria and archaea reproduce asexually only (budding, fragmentation), while eukaryotic microbes sexual or asexual reproduction.
- Bacteria and archaea most commonly engage in a process known as **binary fission**, where a single cell splits into two equally sized cells.

binary fission

(a) A young cell at early phase of cycle



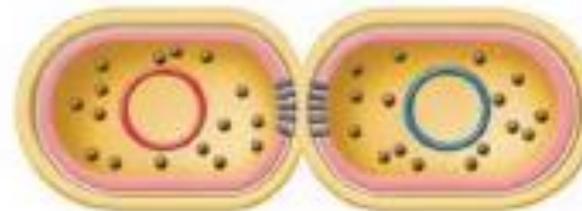
(b) A parent cell prepares for division by enlarging its cell wall, cell membrane, and overall volume.



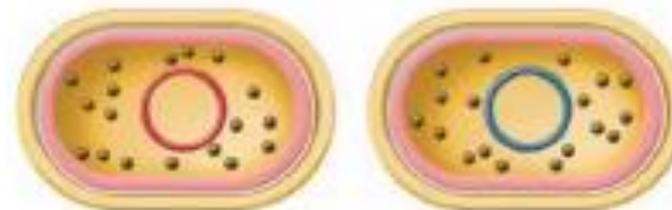
(c) The septum begins to grow inward as the chromosomes move toward opposite ends of the cell. Other cytoplasmic components are distributed to the two developing cells.



(d) The septum is synthesized completely through the cell center, and the cell membrane patches itself so that there are two separate cell chambers.



(e) At this point, the daughter cells are divided. Some species separate completely as shown here, while others remain attached, forming chains, doublets, or other cellular arrangements.



- Cell wall
- Cell membrane
- Chromosome 1
- Chromosome 2
- Ribosomes

Chromosome Replication and Partitioning in Prokaryotes

- ***Most** prokaryotic chromosomes are **circular**.
- Replication begins at a single, specific site called the **origin of replication (origin)** and ends at the **terminus**, located directly opposite the origin.
 - * such as certain species of *Borrelia* and *Streptomyces*
- **In *E. coli*:**
 - The **origin** and **terminus** are positioned at opposite ends of the cell.
 - During replication, proteins assemble to form the **replisome** at the origin.
 - Replication proceeds **bidirectionally** until the terminus is reached.

Chromosome Movement

- The **replisome** remains relatively stationary, while **DNA is pulled through it**.
- Newly formed **origins move toward opposite ends** of the cell.
- The chromosome is **organized and compacted** so it divides evenly.

Cytoskeletal Involvement

- Prokaryotes lack cytoskeletal structures, but have **actin-like proteins**.
- MreB protein**:
 - Analogous to eukaryotic **actin**.
 - Helps determine **cell shape** and **chromosome movement**.
 - **Polymerizes** to form a **spiral structure** around the inside periphery of the cell.
 - May help position newly replicated chromosomes.

