Microbial Growth in Response to Nutrition and Energy

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Principal source of Carbon

- Microorganisms can be classified as either heterotrophs or autotrophs with respect to their preferred source of carbon.
- **Autotrophs can organisms that use CO2 as their** sole or principal source of carbon.
  - Many microorganisms are autotrophic, and most of these carry out photosynthesis and use light as their energy source.
  - Some autotrophs oxidize inorganic molecules and derive energy from electron transfers.

Principal source of Carbon: Heterotrophs

- The reduction of CO2 is a very energy-expensive process.
- Thus many microorganisms cannot use CO2 as their sole carbon source but must rely on the presence of more reduced, complex molecules such as glucose for a supply of carbon.
- Organisms that use reduced, preformed organic molecules as carbon sources are **heterotrophs (these preformed molecules normally come from** other organisms).
- Most heterotrophs use reduced organic compounds as sources of both carbon and energy.
- For example, the glycolytic pathway produces carbon skeletons for use in biosynthesis and also releases energy as ATP and NADH.

Source of Energy

- There are only two sources of energy available to organisms:
  - (1) light energy,
  - (2) the energy derived from oxidizing organic or inorganic molecules.
- **Phototrophs** use light as their energy source
- **Chemotrophs** obtain energy from the oxidation of chemical compounds (either organic or inorganic).

Source of Electron

- Microorganisms also have only two sources for electrons.
- **Lithotrophs (i.e., "rock-eaters") use reduced inorganic** substances as their electron source,
- Whereas **organotrophs extract** electrons from organic compounds.

Table 5.1 Sources of Carbon, Energy, and Electrons

Carbon Sources	
Autotrophs	CO_2 sole or principal biosynthetic carbon source (*pp. 207–8*)[a]
Heterotrophs	Reduced, preformed, organic molecules from other organisms (*chapters 9 and 10*)
Energy Sources	
Phototrophs	Light (*pp. 195–201*)
Chemotrophs	Oxidation of organic or inorganic compounds (*chapter 9*)
Electron Sources	
Lithotrophs	Reduced inorganic molecules (*pp. 193–94*)
Organotrophs	Organic molecules (*chapter 9*)

[a]For each category, the location of material describing the participating metabolic pathways is given within the parentheses.

Nutritional classes

- Despite the great metabolic diversity seen in microorganisms, most may be placed in one of four nutritional classes based on their primary sources of carbon, energy, and electrons (**table 5.2).**
- The large majority of microorganisms thus far studied are either
  - photolithotrophic autotrophs or
  - chemoorganotrophic heterotrophs.
- **Photolithotrophic autotrophs (often called photoautotrophs or** photolithoautotrophs) use light energy and have CO2 as their carbon source.
- Eucaryotic algae and cyanobacteria employ water as the electron donor and release oxygen.
- Purple and green sulfur bacteria cannot oxidize water but extract electrons from inorganic donors like hydrogen, hydrogen sulfide, and elemental sulfur.

- **Chemoorganotrophic heterotrophs (often called chemoheterotrophs,** chemoorganoheterotrophs, or even heterotrophs) use organic compounds as sources of energy, hydrogen, electrons, and carbon.
- Frequently the same organic nutrient will satisfy all these requirements.
- It should be noted that essentially all pathogenic microorganisms are chemoheterotrophs.

- Some purple and green bacteria are photosynthetic and use organic matter as their electron donor and carbon source.
- These **photoorganotrophic heterotrophs** (photoorganoheterotrophs) are common inhabitants of polluted lakes and streams.
- The fourth group, the **chemolithotrophic autotrophs (chemolithoautotrophs),** oxidizes reduced inorganic compounds such as iron, nitrogen, or sulfur molecules to derive both energy and electrons for biosynthesis.
- Carbon dioxide is the carbon source.
- Chemolithotrophs contribute greatly to the chemical transformations of elements (e.g., the conversion of ammonia to nitrate or sulfur to sulfate) that continually occur in the ecosystem.

Table 5.2 Major Nutritional Types of Microorganisms

Major Nutritional Types[a]	Sources of Energy, Hydrogen/Electrons, and Carbon	Representative Microorganisms
Photolithotrophic autotrophy (Photolithoautotrophy)	Light energy Inorganic hydrogen/electron (H/e^-) donor CO_2 carbon source	Algae Purple and green sulfur bacteria Cyanobacteria
Photoorganotrophic heterotrophy (Photoorganoheterotrophy)	Light energy Organic H/e^- donor Organic carbon source (CO_2 may also be used)	Purple nonsulfur bacteria Green nonsulfur bacteria
Chemolithotrophic autotrophy (Chemolithoautotrophy)	Chemical energy source (inorganic) Inorganic H/e^- donor CO_2 carbon source	Sulfur-oxidizing bacteria Hydrogen bacteria Nitrifying bacteria Iron-oxidizing bacteria
Chemoorganotrophic heterotrophy (Chemoorganoheterotrophy)	Chemical energy source (organic) Organic H/e^- donor Organic carbon source	Protozoa Fungi Most nonphotosynthetic bacteria (including most pathogens)

[a]Bacteria in other nutritional categories have been found. The categories are defined in terms of energy, electron, and carbon sources. Condensed versions of these names are given in parentheses.

- Although a particular species usually belongs in only one of the four nutritional classes, some show great metabolic flexibility and alter their metabolic patterns in response to environmental changes.
- Bacteria such as *Beggiatoa* that rely on inorganic energy sources and organic (or sometimes CO2) carbon sources.
- These microbes are sometimes called **mixotrophic because they combine** chemolithoautotrophic and heterotrophic metabolic processes.
- This sort of flexibility seems complex and confusing, yet it gives its possessor a definite advantage if environmental conditions frequently change.