# Classification of Microbes Based on Nutritional types and Energy Source

# Macronutrients

- Analysis of microbial cell composition shows that over 95% of cell dry weight is made up of a few major elements: carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, potassium, calcium, magnesium, and iron.
- These are called **macroelements** or macronutrients because they are required by microorganisms in relatively large amounts.
- The first six (C, O, H, N, S, and P) are components of carbohydrates, lipids, proteins, and nucleic acids.
- The remaining four macroelements exist in the cell as cations and play a variety of roles. For example, potassium (K) is required for activity by a number of enzymes, including some of those involved in protein synthesis.
- Calcium ($Ca^{2+}$), among other functions, contributes to the heat resistance of bacterial endospores.
- Magnesium ($Mg^{2+}$) serves as a cofactor for many enzymes, complexes with ATP, and stabilizes ribosomes and cell membranes.
- Iron ($Fe^{2+}$ and $Fe^{3+}$) is a part of cytochromes and a cofactor for enzymes and electron-carrying proteins.

# Micronutrients or Trace elements

- All organisms, including microorganisms, require several **micronutrients** or **trace elements** besides macroelements.
- The micronutrients—manganese, zinc, cobalt, molybdenum, nickel, and copper—are needed by most cells.
- However, cells require such small amounts that contaminants in water, glassware, and regular media components often are adequate for growth.
- Micronutrients are normally a part of enzymes and cofactors, and they aid in the catalysis of reactions and maintenance of protein structure.
- Molybdenum ($Mo^{2+}$) is required for nitrogen fixation, and cobalt ($Co^{2+}$) is a component of vitamin B12.

# Electron sources

- Organic nutrients are almost always reduced and have electrons that they can donate to other molecules, they also can serve as energy sources.
- Indeed, the more reduced organic molecules are, the higher their energy content.
- Electron transfers release energy when the electrons move from reduced donors with more negative reduction potentials to oxidized electron acceptors with more positive potentials.

# Nutritional Types of Microorganisms

- Microorganisms can be classified as either heterotrophs or autotrophs with respect to their preferred source of carbon.
  - **Autotrophs** can 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.
  - The reduction of CO2 is a very energy-expensive process. Thus many microorganisms cannot use $CO_2$ as their sole carbon source but must rely on the presence of more reduced, complex molecules like glucose.
  - Organisms that use reduced, preformed organic molecules as carbon sources are **heterotrophs.**

# Energy and Electron source

- There are only two sources of energy available to organisms:
  - (1) light energy, and
  - (2) the energy derived from oxidizing organic or inorganic molecules.
- **Phototrophs:** The organisms that can utilize light as an energy source are known as phototrophs. These bacteria gain energy from light.
- **Chemotrophs** obtain energy from the oxidation of chemical compounds (either organic or inorganic).
- Microorganisms also have only two sources for electrons.
- **Lithotrophs** (i.e., “rock-eaters”) use reduced inorganic substances as their electron source.
- **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. *Source: Prescot*

# Microorganisms may be placed in one of four nutritional classes based on their primary sources of carbon, energy, and electrons

- 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.

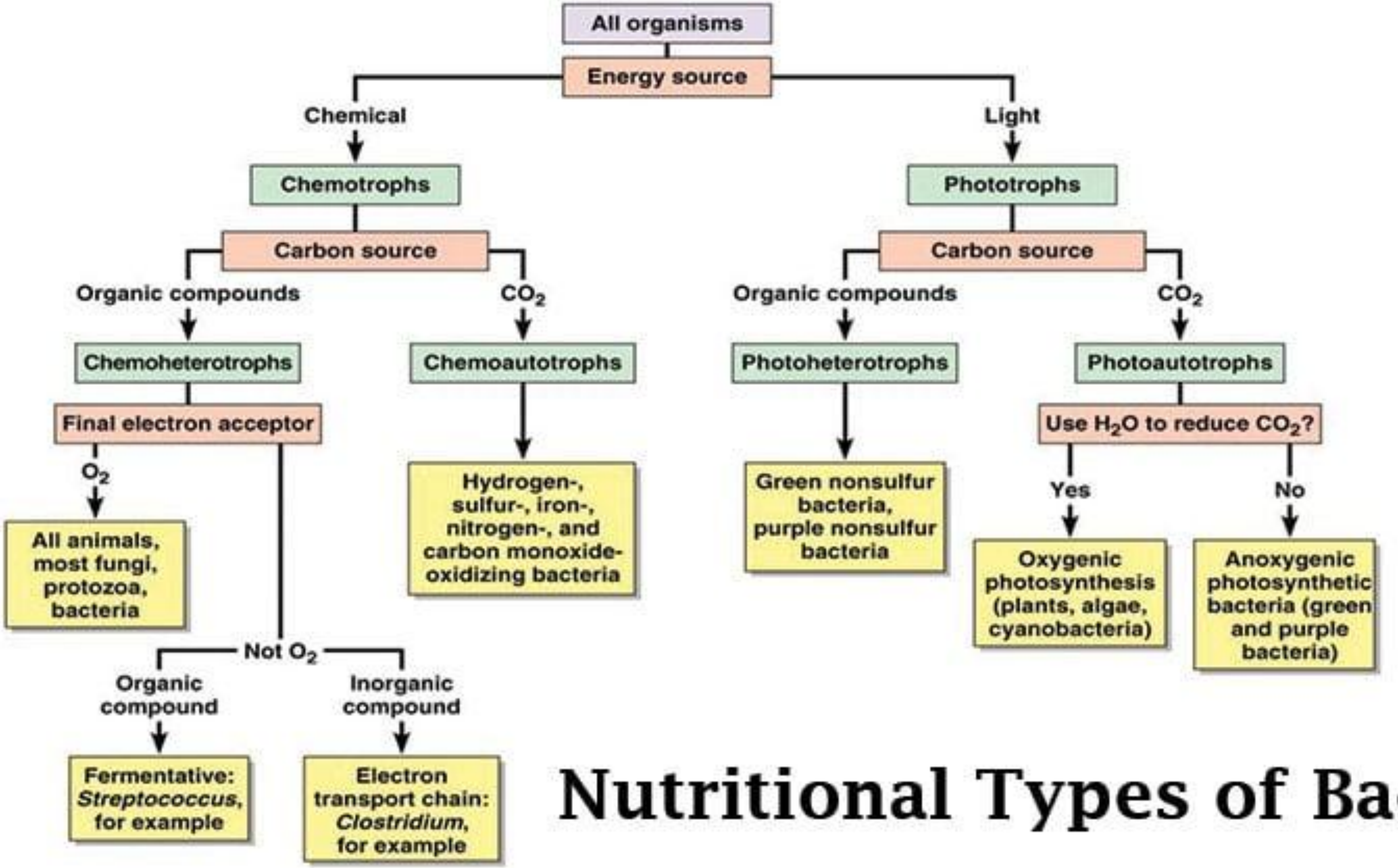
# Microorganisms may be placed in one of four nutritional classes based on their primary sources of carbon, energy, and electrons

- **Photoorganotrophic heterotrophs** (photoorganoheterotrophs) are common inhabitants of polluted lakes and streams.
- Eg. Some purple and green bacteria are photosynthetic and use organic matter as their electron donor and carbon source.
- **Chemolithotrophic autotrophs** (chemolithoautotrophs), **,** the fourth group, 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<br>Inorganic hydrogen/electron ($H/e^-$) donor<br>$CO_2$ carbon source | Algae<br>Purple and green sulfur bacteria<br>Cyanobacteria |
| Photoorganotrophic heterotrophy (Photoorganoheterotrophy) | Light energy<br>Organic $H/e^-$ donor<br>Organic carbon source ($CO_2$ may also be used) | Purple nonsulfur bacteria<br>Green nonsulfur bacteria |
| Chemolithotrophic autotrophy (Chemolithoautotrophy) | Chemical energy source (inorganic)<br>Inorganic $H/e^-$ donor<br>$CO_2$ carbon source | Sulfur-oxidizing bacteria<br>Hydrogen bacteria<br>Nitrifying bacteria<br>Iron-oxidizing bacteria |
| Chemoorganotrophic heterotrophy (Chemoorganoheterotrophy) | Chemical energy source (organic)<br>Organic $H/e^-$ donor<br>Organic carbon source | Protozoa<br>Fungi<br>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.




# Nutritional Types of Bacteria

# Mixotrophs

- 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.
- For example, many purple nonsulfur bacteria act as photoorganotrophic heterotrophs in the absence of oxygen but oxidize organic molecules and function chemotrophically at normal oxygen levels.
- When oxygen is low, photosynthesis and oxidative metabolism may function simultaneously.
- Another example is provided by bacteria such as *Beggiatoa* that rely on inorganic energy sources and organic (or sometimes $CO_2$) carbon sources.
- These microbes are sometimes called **mixotrophic** because they combine chemolithoautotrophic and heterotrophic metabolic processes.