Microbial nutrition

Microbiology I

Microbial Nutrition

- To obtain energy and construct new cellular components, organisms, must have a supply of raw materials or nutrients.

- **Nutrients** – are substances used in biosynthesis and energy production, and therefore are required for microbial growth.

Nutrient Requirements:

- Microbial cell composition shows that 95% of cell dry weight is made up of a few major elements: Carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorous, potassium, calcium, magnesium and iron.

Nutrients can be classified into two groups:
1. Macronutrients and 2. Micronutrients

Macronutrients:

- Carbon
- Oxygen
- Hydrogen
- Nitrogen
- Sulfur
- Phosphorous
- Potassium
- Calcium
- Magnesium
- Iron

Micronutrients:

- Manganese
- Zinc
- Cobalt
- Molybdenum
- Nickel
- Copper

Macronutrients or macro elements:

- These are required by microorganisms in relatively large amounts.
- Carbon, oxygen, hydrogen, nitrogen, sulfurs and phosphorous are components of carbohydrates, lipids, proteins and nucleic acids.

- The remaining four macro elements (K, Ca, Mg and Fe) exist in the cell as cations.

- **K^+** - is required for the activity by a number of enzymes, including those involved in protein synthesis.
- **Ca^{2+}** - contributes to the heat resistance of bacterial endospores. 15% of spore contains dipicolinic acid and calcium.
- **Mg^{2+}** - serves as a cofactor for many enzymes, complexes with ATP and stabilizes ribosomes and cell membranes.
- **Fe^{2+}** and **Fe^{3+}** - part of cytochromes and a cofactor for enzymes and electron-carrying proteins.

Sources of Macronutrients

ELEMENT	POSSIBLE SOURCES
Carbon (C)	CO_2 / Organic Compounds
Hydrogen (H)	H_2O / Organic Compounds
Oxygen (O)	O_2 / H_2O / Organic Compounds
Nitrogen (N)	NH^3 / NO^{3-} / N_2 / organic N compounds
Sulphur (S)	H2S / $SO4^{2-}$ / organic S compounds
Phosphorus (P)	$PO4^{3-}$

Micronutrients or Trace elements:

- They are required in minute quantities.
- These are manganese, zinc, cobalt, molybdenum, nickel and copper.
- These are normally part of enzymes and cofactors, and they aid in the catalysis of reactions and maintenance of protein structure.

- **Zn^{2+}** - is present at the active site of some enzymes
- It is also involved in the association of regulatory and catalytic subunits in *E.coli* aspartate carbomoyl transferase.

- **Mn^{2+}** - aids many enzymes catalyzing the transfer of phosphate groups.
- **Mo^{2+}** - required for nitrogen fixation.
- **Co^{2+}** - is a component of Vitamin B12.

Requirements for carbon, hydrogen and oxygen:

- The requirements for carbon, hydrogen, and oxygen often are satisfied together.

- **Carbon:** is needed for the skeleton or backbone of all organic molecules.

- Molecules serving as carbon sources normally also contribute both oxygen and hydrogen atoms. (Ex. **Carbohydrates and lipids**).

- One important carbon source that does not supply hydrogen or energy is **CO_2**.

- **Autotrophs** – can use CO_2 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 transfer

- **Heterotrophs** – are organisms that use reduced pre-formed organic molecules as carbon sources.

- Ex. Glycolytic pathway produces carbon skeleton for use in biosynthesis and also releases energy as ATP and NADH.

Nutritional types of microorganisms:

- In addition to Carbon, hydrogen and oxygen all organisms require sources of energy and electrons for growth.

Carbon sources:

- Autotrophs - **CO_2** sole or principal biosynthetic carbon source
- Heterotrophs – reduced, **preformed** organic molecules from other organisms.

Energy sources:

- Phototrophs – use **light** as their energy source.
- Chemotrophs – obtain energy from the oxidation of **chemical** compounds (either organic or in organic)

Electron sources:

- Lithotrophs – use reduced **inorganic** substances as their electron source.
- Organotrophs – extract electrons from **organic** compounds.

- There are **four major** nutritional classes based on their **primary sources** of carbon, energy and electrons:

1. Photoautotrophs
2. Photoheterotrophs
3. Chemoautotrophs
4. Chemoheterotrophs

Table 6.2: Nutritional classes of Microorganisms

Nutritional class	Energy/Electron/Carbon source	Organisms
Photoautotrophs	Light energy Inorganic e^- donor CO_2	Cyanobacteria, Purple and Green sulphur Bacteria
Photoheterotrophs	Light energy Organic e^- donor Organic carbon source	Purple and Green Nonsulfur bacteria
Chemoautotrophs	Inorganic chemical compounds as energy source Inorganic e^- donor CO_2	Nitrifying bacteria, Iron bacteria
Chemoheterotrophs	Organic compounds as energy, electron and carbon source.	Most pathogenic bacteria, fungi and protozoa.

Photoautotrophs:

- Source of energy – light energy
- Source of electrons – Inorganic hydrogen/ electron
- Carbon source - CO_2
- Example: Algae, purple and green sulfur bacteria and cyanobacteria.

Photoheterotrophs:

- Source of energy – light energy
- Source of electrons – organic hydrogen/ electron
- Carbon source –organic carbon sources (CO2 may also be used)
- Example: Purple and green nonsulfur bacteria (common inhabitants of lakes and streams).

Chemoautotrophs:

- Source of energy – Chemical energy source (inorganic)
- Source of electrons – Inorganic hydrogen/ electron donor
- Carbon source - CO_2
- Example: Sulfur-oxidizing bacteria, hydrogen bacteria, nitrifying bacteria, iron-oxidizing bacteria.

Chemoheterotrophs:

- Source of energy – Chemical energy source (organic)
- Source of electrons – Inorganic hydrogen/ electron donor
- Carbon source – organic carbon source
- Example: Protozoan, fungi, most non-photosynthetic bacteria (including most pathogens)

Requirements for nitrogen, phosphorous and sulfur:

- **Nitrogen** is needed for the synthesis of amino acids, purines, pyramidines, some carbohydrates and lipids, enzyme cofactors and other substances.

- Most phototrophs and many nonphotosynthetic microorganisms reduce nitrate to **ammonia (NH_3)** and incorporate the ammonia in assimilatory nitrate reduction.

- A variety of bacteria like many Cyanobacteria and *Rhizobiium* can reduce and assimilate atmospheric nitrogen using the nitrogenase systems.

- **Phosphorous** is present in nucleic acids, phospholipids, ATP, several cofactors, some proteins and other cell components.

- All microorganisms use inorganic phosphate as their phosphorous source and incorporate it directly.

- **Sulfur** is needed for the synthesis of substances like the amino acids cysteine and methionine, some carbohydrates, biotin and thiamine.

- Most of them use sulfate as a source of sulfur and reduce it by assimilatory sulfate reduction.

- Few microbes require a reduced form of sulfur such as cysteine.

Growth factors:

- Many microorganisms have the enzymes and pathways necessary to synthesize all cell components.

- Many lack one or more **enzymes** and hence require organic compounds because they are essential cell components or precursors of such components and cannot be synthesized by the organisms are called **growth factors**.

There are three major classes of growth factors :

1. **Amino acids** – needed for protein synthesis.
2. **Purines** and **Pyramidines** – for nucleic acid synthesis
3. **Vitamins** – small organic molecules that usually make up all or part of enzyme cofactors, and only very small amounts sustain growth.