Chapter 5
Microbial Nutrition

Nutrients:

- *A supply of raw materials needed by organisms to obtain energy and construct cellular components.*
- *Substances used in biosynthesis and energy production, a requirement for microbial growth.*

Common Nutrient Requirement:

- *Over 95% of the microbial cell dry weight composition is composed of the following major elements:*
  - ***Carbon***
  - ***Oxygen***
  - ***Hydrogen***
  - ***Nitrogen***
  - ***Sulfur***
  - ***Phosphorus***
  - ***Potassium***
  - ***Calcium***
  - ***Magnesium***
  - ***Iron***

Macronutrients

These are referred to as *Macroelements or Macronutrients:* ***required by MO in relatively large amounts.***

- ***C, O, H, N, S, and P*** are components of Carbohydrates, lipids, proteins, and nucleic acids.
- ***K, Ca, Mg, and Fe*** *are cations and play a variety of roles.*
  - **K** required for activity by a number of enzymes, some involved in protein synthesis
  - ***Ca*** *contributes to the heat resistant endospore*
  - ***Mg*** *serves as a cofactor for many enzymes*
    Complexes with ATP
    Stabilizes ribosomes and cell membranes
  - ***Fe*** *is part of the cythchromes*
    A cofactor for enzymes and electron-carrying proteins

Micronutrients (trace elements)

Required by all organisms and the following are needed by most cells.

- ***Manganese (Mn^{2+})***
  Aids many enzymes catalyzing the transfer of phosphate groups.

- ***Zinc (Zn^{2+})***
  Present at active site of some enzymes , also involved in the association of regulatory and catalytic subunits in E.coli

- ***Cobalt (Co^{2+})***
  A component o f vitamin B_{12}

- ***Molybdenum (Mo^{2+})***
  Is required for Nitrogen fixation

- ***Nickel***
- ***Copper***

  - *Cells require such small amounts that they can obtain these trace elements from contaminants in water, glassware, and regular media components for growth.*
  - ***Micronutrients** are ubiquitous in nature*
    - *Normally part of enzymes and cofactors*
    - *Aid in catalysis of reactions*
    - *Maintenance of protein structure*

  - *MO requires a balanced mixture of nutrients. If an essential nutrient is in short supply, microbial growth will be limited regardless of the concentration of other nutrients.*

Requirements for Carbon, Hydrogen, and Oxygen

- *Microorganisms can also be classified by the manner in which they incorporate external compounds into cellular material. This process is called **assimilation**.*

- *All living organisms must be supplied the following elements, in a form which can be assimilated and metabolized*

  - *The requirement for C, H, and O often are satisfied together.*

Carbon:

- *Accounts of 50% of the dry weight of a bacterial cell*
- *Needed for the skeleton or backbone for all organic molecules.*
- *Molecules serving as a carbon source normally also contribute both O & H atoms.*
- *Organic nutrients are almost always* ***reduced - have electrons that can be donated to other molecules – they can serve as energy sources.***
- *The more reduced organic molecules – the higher their energy content.* ***Lipids have higher energy content than COH (carbohydrates)***

CO_2

- *Does not supply H or energy*
- *Its oxidized and lacks H*
- *Probably all MO can fix* **CO_2** *(reduce it and incorporate it into organic molecules)*

Autotrophs:

- *Use CO_2 as their sole or principal source of carbon*
- *Many mo and most carry out photosynthesis and use light as their energy source.*
- *Some oxidize inorganic molecules and derive energy from electron transfers*
- *Green plants are classified as* ***photoautotrophs***

Heterotrophs:

- *Use more reduced complex molecules like glucose for a supply of carbon because the reduction of CO2 is a very energy expensive process.*
- *Therefore many mos can not use CO2 as the sole C source.*
- *Most heterotrophs* ***use organic compounds as a sources of carbon and energy.***
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  EXAMPLE: glycolytic pathway produces carbon skeleton for use in biosynthesis and also releases energy as ATP and NADH.

Oxygen and Hydrogen

- Cells must also be provided a source of oxygen (which accounts for 20% of the dry weight) as well as hydrogen (8%)
- These are generally obtained by assimilation of organic compounds or from HOH Gaseous O_2, and H_2 are not assimilated
- Oxygen is required for aerobic respiration, where it serves as the terminal electron acceptor in the electron transport chain

Nutritional Types of Microorganisms

*Besides C, H, and O, all organisms require sources of **energy and electrons** for growth to take place.*

Two sources of energy available to organisms:

(1). *Light energy*

- ***Phototrophs** uses light at their energy source*

(2). *Energy obtained from oxidizing organic or inorganic molecules*

- ***Chemotrophs** obtain energy from the oxidation of chemical cmpds. **(fermentation and respiration)***

Two sources of electrons available to organisms:

(1). ***Lithotrophs (rock eaters)***

- *Uses reduced inorganic molecules as their electron source*

(2). ***Organotrophs***

- *Extract electrons in the form of hydrogen from reduced organic compounds*

<u>Four (4) Major Nutritional Types of Microorganisms</u>

*Large majority of MO are **Photolithotrophic autotrophs** or **Chemoorganotrophic heterotrophs***

(1) Photolithotrophic autotrophs:

- *Called photoautotrophs or photolithoautotrophs*
- *Use light energy and have CO_2 as their carbon source*

  ***Eucaryotic algae** and **cyanobacteria** employ water as the electron donor and release oxygen*

(2) Chemoorganotrophic heterotrophs:

- *Called chemoheterotrophs, chemoorganpheterotrophs, or heterotrophs*
- *Use organic compounds as sources of energy, hydrogen, electrons, and carbon.*
- *Essentially all pathogenic mo are chemoheterotrophs*

Fewer MO are ***Photoorganotrophic heterotrophs or Chemolithotrophicautotrophs***

(3) Photoorganotrophic heterotrophs:

- *Called Photoorganoheterotrophs*
- *Common inhabitants of polluted lakes and streams*
- *Some purple and green bacteria are photosynthetic and use organic matter as a electron donor and carbon source*

(4). Chemolithotrophic autotrophs

- *Called chemolithoautotrophs*
- *Oxidizes reduced inorganic cmpds such as iron, nitrogen, or sulfur molecules to derive both energy and electrons for biosynthesis.*
- *CO2 is the carbon source*

Mixotrophic:

- *Another nutritional classification*
- *Some species show great metabolic flexibility and alter their metabolic patterns in response to environmental conditions*
- *They combine* ***chemolithoautotrophic and heterotrophic*** *metabolic processes.*
- ***Example:***
  Purple nonsulfur bacteria act as photoorganotrophic heterotrophs in the absence of oxygen but oxidize organic molecules and function chemotrophically at normal oxygen levels.

Requirements for Nitrogen, Phosphorus, and Sulfur

Microorganisms must be able to incorporate large quantities of N, P and S.

Nitrogen

- Nitrogen accounts for 14% of the cell dry weight which can be supplied through organic or inorganic compounds.
- Nitrogen is needed for the synthesis of:
  - Amino acids
  - Purines (used in the synthesis of ATP, DNA. RNA)
  - Pyrimidines (used in the synthesis of ATP, DNA, RNA)
  - Some Carbohydrates
  - Lipids

- Enzyme Cofactor (non-protein component of an enzyme, it is required for catalytic activity)

Some cells use inorganic compounds as a nitrogen source

- *Ammonium (NH_4^+) assimilation*
- *Nitrate (NO_3^-) and Nitrite (NO_2^-) assimilation*
- *Fixation of Nitrogen gas (N_2)*

Phosphorous

- Elemental phosphorous comprises only 3% of the dry weight.
- Once again, microorganisms can utilize both organic and inorganic forms such as PO_4^{3-}
- Present in
  - nucleic acids
  - phospholipids
  - nucleotides (ATP)
  - several cofactors
  - some proteins & other cell components
- Low phosphate levels limit microbial growth in many acquatic environments

Sulfur

- 1% of the dry weight of a cell is Sulfur
- Needed for the synthesis of amino acids: cysteine and methionine
  Some carbohydrates, biotin and thiamine (vitamins)
- Inorganic sulfur can be assimilated as Sulfate (SO_4^{2-}), Sulfide (S^0) or Sulfur (S^{2-})

Inorganic ions and metals together account for 4% of the cells dry weight

- *These are required to maintain osmotic balance, serve as cofactors for enzymes, and are required to maintain the integrity of several macromolecular structures such as the cell membrane and ribosomes.*

Growth Factors

- *MO grow and reproduce when necessary minerals and sources of energy, C, N, P, and S are supplied, making it necessary for the for the cell to synthesize all needed cell components.*

- *Many MO lack one or more essential enzymes, making it impossible to synthesize necessary cell components.*
- ***Growth Factors:***
  - *Organic cmpds required bc they are essential cell components or precursors of such components and cannot be synthesized by the organism.*
  - ***Three Major Classes of Growth Factors***

(1). Amino Acids

- *Needed for protein synthesis*

(2). Purines and Pyrimidines

- *Needed for nucleic acids synthesis*

(3). Vitamins

- *Small organic molecules that usually make up all or part of enzyme cofactors and only a small amount sustain growth Page 99.   Bonus Question*

Uptake of Nutrients by Cell

- *In order for an organism to utilize a nutrient, it must be able to move that compound across the cell membrane.*

- *These compounds cross the membrane by a process known as simple diffusion where the flux, or movement to either side, is proportional to the concentration on the entering side. Therefore the net rate of transfer is proportional to the concentration difference between the two sides. These properties also apply to the movement of large molecules by diffusion across the outer membrane through pores.*

- *Molecules larger than glycerol, and all charged molecules (including H+) require specific transport systems that facilitate transmembrane flux.*

Microorganism Different Transport Mechanism

1. *Facilitated Diffusion*
2. *Active Transport*
3. *Group Translocation*

Passive Diffusion

- *The cytoplasmic membrane serves as a permeability barrier to most molecules. It is permeable to H_2O, O_2, CO_2, and small uncharged molecules up to the size of glycerol which can cross the plasma membrane by* ***passive diffusion.***

Passive Diffusion**:** *called diffusion*

- *Process which molecules move from a region of higher concentration to one of lower concentration*
- *The rate of passive diffusion is dependent upon the size of the concentration gradient between a cells interior and exterior.*

Facilitated Diffusion (Passive Carrier-Mediated Systems)

- *A carrier protein facilitates the diffusion process of larger molecules, ions, and polar substances across the membrane*
- ***Proteases****: carrier protein embedded in the plasma membrane that greatly increases the rate of diffusion across the selectively permeable plasma membrane.*

The rate of facilitated diffusion increases with the concentration gradient much more rapidly and at lower concentrations of the diffusing molecule than that of passive diffusion.

Look at figure 5.1:

Diffusion rate levels off above a specific gradient value because the carrier is saturated.

- ***Saturated:*** Carrier protein is binding and transporting as many solute molecules as possible
- Carrier proteins have a ***specificity for the substance to be transported***
  - Each carrier is ***selective*** and will transport only closely related solutes.
  - A ***concentration gradient*** spanning the membrane drives the movement of molecules and ***NO metabolic energy imput in required.***

Overview of Facilitated Diffusion

- *Mechanism is driven by concentration gradients (higher concentration gradient outside the cell, therefore moving inside the cell to a lower concentration)*

Carrier protein complex spans the membrane
After the solute molecule binds to the outside
Carrier may change conformation and release molecule in the cell interior
The carrier changes back to its original shape, ready to pick up another molecule

Effect:
Lipid-insoluble molecule can enter the cell in response to its concentration gradient.

Remember this process is concentration gradient sensitive and can be reversed. If the solute's concentration is greater inside the cell, it will move outward.

Facilitated diffusion does not seem to be important in procaryotes bc nutrients concentrations often are lower outside the cell, so FD cannot be used.

Glycerol is transported by facilitated diffusion in: (Examples)

- *E.coli*
- *Salmonella typhimurium*
- *Pseudomonas*
- *Bacillus*

***Much more prominent in eukaryotic cells where it is used to transport a variety of sugars and amino acids*.**