"BACTERIAL NUTRIYION & GROWTH"

THE COMMON NUTRIENT REQUIREMENTS Of BACTERIA .

Microbiologists use the term growth to indicate an increase in a population of microbes rather than an increase in size. Microbial growth depends on the metabolism of nutrients, and results in the formation of a discrete colony, an aggregation of cells arising from a single parent cell .

- A nutrient is any chemical required for growth of microbial populations. The most important of these are compounds containing carbon, oxygen, nitrogen, and hydrogen . Nutrients Chemical and Energy Requirements that all cells require three things to conduct metabolism , a carbon source, a source of energy, and a source of electrons or hydrogen atoms.

- Organisms can be categorized into one of four groups based on their source of carbon and their use of either chemicals or light as a source of energy :-

- **Photoautotrophs** use carbon dioxide as a carbon source and light energy from the environment to make their own food.

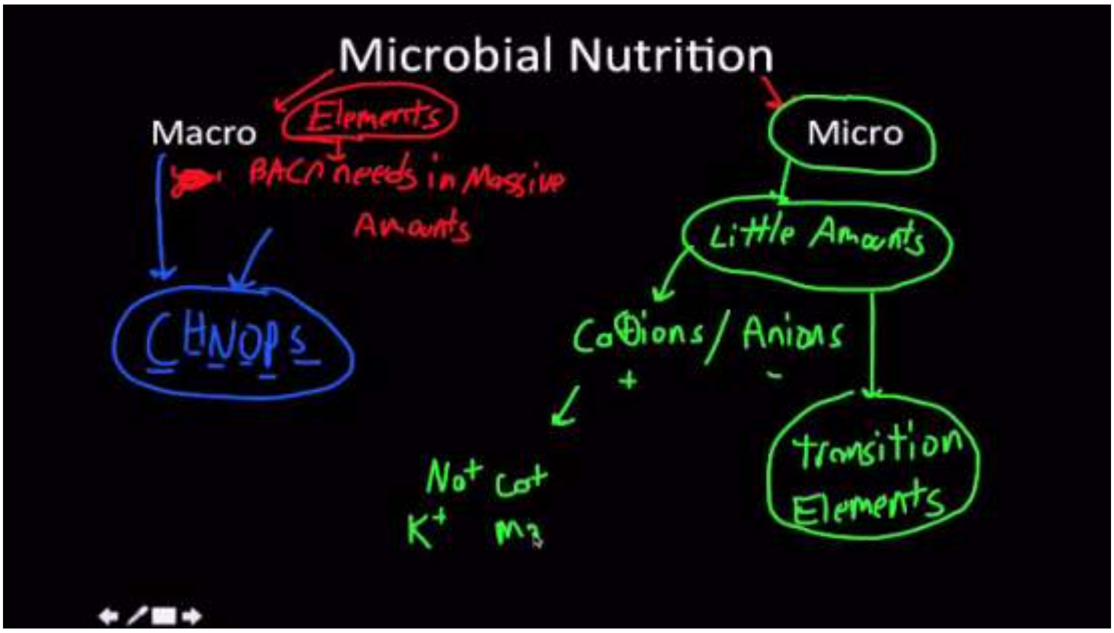
- **Chemoautotrophs** use carbon dioxide as a carbon source but catabolize organic molecules for energy .

- **Photoheterotrophs** are photosynthetic organisms that acquire energy from light and acquire nutrients via catabolism of organic compounds.

- **Chemoheterotrophs** use organic compounds for both energy and carbon. In addition, organotrophs acquire electrons from organic sources, where as Lithotrophs acquire electrons from inorganic sources.

- For growth and nutrition of bacteria, the minimum nutritional requirements are water, a source of carbon, a source of nitrogen and some inorganic salts. Water is the vehicle of entry of all nutrients into the cell and for the elimination of waste products.

- 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 and Play principle roles in cell structure and metabolism , include Proteins (source of amino acids) and Carbohydrates . 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 (Ca2),** among other functions, contributes to the heat resistance of bacterial endospores.

Magnesium (Mg2) serves as a cofactor for many enzymes, complexes with ATP, and stabilizes Ribosome's and cell membranes . **Iron (Fe2 and Fe3)** is a part of Cytochromes and a cofactor for enzymes and electron-carrying proteins.

In addition to macroelements, all microorganisms require several nutrients in small amounts . These are called **Micronutrients** or **Trace elements** **like Minerals .** The micronutrients are Manganese, Zinc, Cobalt, Molybdenum, Nickel, and Copper are needed by most cells.
However, cells require such small amounts that contaminants from water, glassware, and regular media components often are suitable for growth .

Micronutrients are normally a part of enzymes and cofactors, and they aid in the catalysis of reactions and maintenance of protein structure.

For example, **Zinc (Zn2)** is present at the active site of some enzymes but can also be involved in the association of regulatory and catalytic subunits **. Manganese (Mn2)** aid many enzymes that catalyze the transfer of phosphate groups. **Molybdenum (Mo2)** is required for nitrogen fixation, and **Cobalt (Co2)** is a component of vitamin B12 .

Element	Source	Function
Carbon	Organic Compounds or CO_2	Main role of cellular material .
Oxygen	H_2O, organic compounds, CO_2, and O_2	Constituent of cell material and Cell water ; O_2 is electron acceptor in aerobic respiration.
Nitrogen	NH_3, NO_3, organic compounds, N_2	Constituent of amino acids, nucleic acids nucleotides , and coenzymes .
Hydrogen	H_2O, organic compounds, H_2	Main constituent of organic compounds and cell water
Phosphorus	inorganic phosphates (PO_4)	Constituent of nucleic acids, nucleotides, phospholipids, LPS, Teichoic acids
Sulfur	SO_4, H_2S, S^o, organic sulfur compounds	Constituent of cysteine, methionine, glutathione, several coenzymes
Potassium	Potassium salts	Main cellular inorganic and Cofactor for certain enzymes .
Magnesium	Magnesium salts	Inorganic cellular , Cofactor for certain enzymatic reactions .
Calcium	Calcium salts	Inorganic cellular , Cofactor for certain enzymes and a component of endospores .
Iron	Iron salts	Component of Cytochromes and iron-proteins and a cofactor for some enzymatic reactions .

GROWTH FACTORS .

Some microorganisms have the enzymes and biochemical pathways needed to synthesize all cell components using minerals and sources of energy , carbon , nitrogen, phosphorus, and sulfur.

Other microorganisms lack one or more of the enzymes needed to manufacture indispensable compounds . Therefore they must obtain these constituents from the environment . Organic compounds that are essential cell components or major of such components but cannot be synthesized by the organism are called **growth factors .**

There are three major classes of growth factors :-
(1) amino acids
(2) purines and pyrimidines for nucleic acid synthesis .
(3) vitamins. Amino acids are needed for protein synthesis .

Vitamins are small organic molecules that usually make up all or part of enzyme cofactors and are needed in only very small amounts to sustain growth.

Mechanisms of nutrient uptake by bacteria.

1 - Passive Diffusion – Often called simple diffusion, is a process in which molecules from a region of higher concentration to one of lower concentration. Only very small molecules like H_2O and CO_2 (non-polar) can move across by passive diffusion.

2 - Facilitated Diffusion – Diffusion involving carrier proteins (permeases) . Rate of diffusion increases with the concentration gradient. Major intrinsic proteins (MIPs) facilitate diffusion of small polar molecules. Glycerol is transported by facilitated diffusion in bacteria.

3- Osmosis – Movement of solvent molecules through a selectively permeable membrane from a region of higher to lower concentration

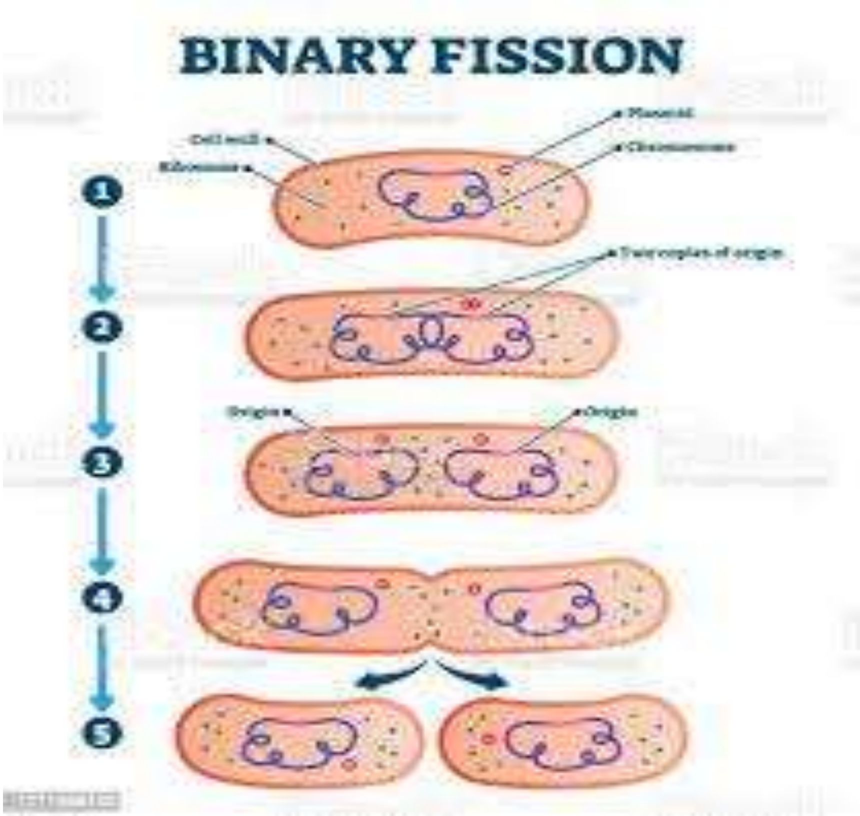
- Isotonic solution – When the concentration of both the solution on either sides of a semipermeable membrane are same .
- Hypotonic solution – When external environment of the membrane has higher concentration than the internal environment of the cell .
- Hypertonic solution – When external environment of the membrane has lower concentration than the internal environment of the cell .

4 - Active Transport – Transport of solute molecules to higher concentration with the input of metabolic energy.

Bacterial growth .

Growth of bacterial cultures is defined as an increase in the number of bacteria in a population rather than in the size of individual cells. The growth of a bacterial population occurs in a geometric or exponential manner , with each division cycle (generation), one cell gives rise to 2 cells, then 4 cells, then 8 cells, then 16, then 32, and others.

Bacteria are prokaryotic organisms that most commonly replicate by the asexual process of **Binary Fission**. These microbes reproduce rapidly at an exponential rate under favorable conditions. When grown in culture, a predictable pattern of growth in a bacterial population occurs. This pattern can be graphically represented as the number of living cells in a population over time and is known as a **bacterial growth curve**. Bacterial growth cycles in a growth curve consist of four phases : lag Phase , exponential (log) , stationary , and death .

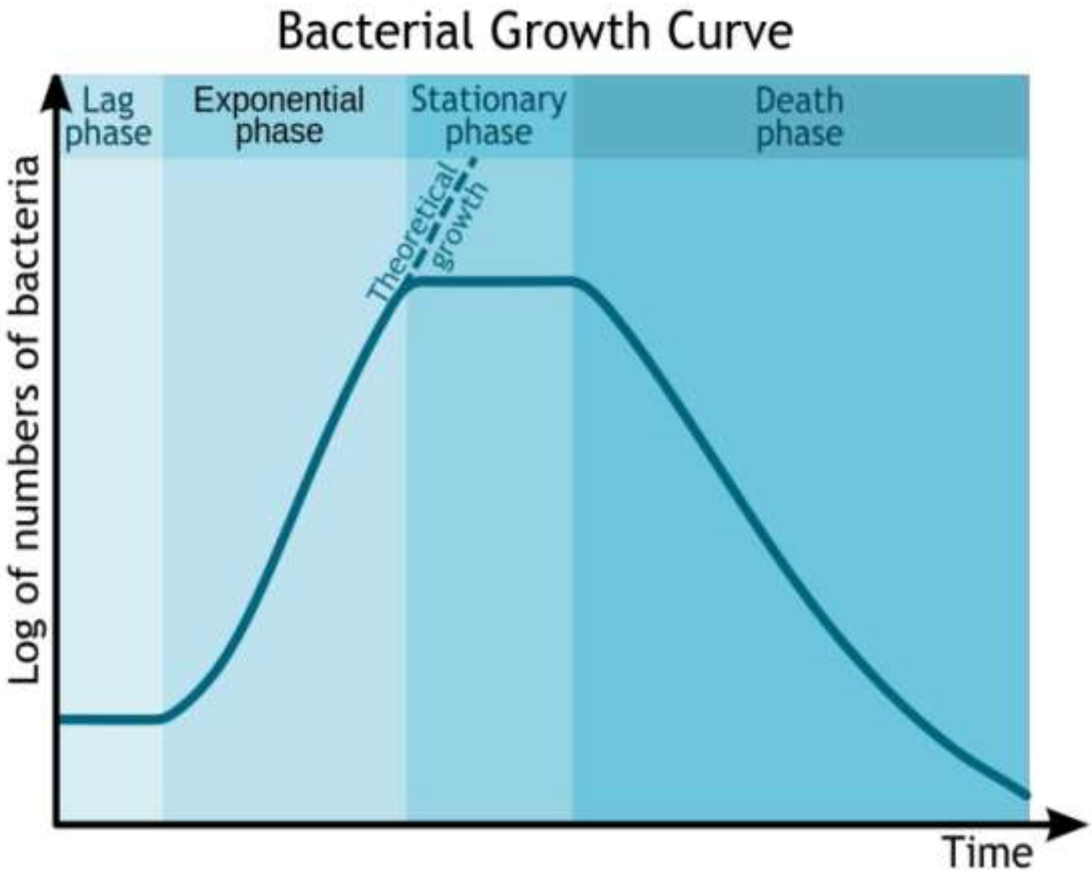


- Growth involves increase in cell mass and number of ribosome's , duplication of the bacterial chromosome, synthesis of new cell wall and plasma membrane , partitioning of the two chromosomes, septum formation , and cell division . The growth of microorganism can be measured by :-

1- increase in size but this a poor criterion of growth.
2- increase in the number of microorganism by either counting the number of living cells (viable count) or all cells (total count).
3- measurement of some component of cell structures such as protein or DNA as an indication of microbial increase (growth) or decrease (death).

Generation time (G) :- Is the time required for one complete cell division . Some microbes are able to divide as rapidly as once every 12 to 15 minutes, other require up to several hours, and a few very slow growing bacteria may require more than 24 hour per cell division .

Growth Curve:- When a fresh medium is inoculated with a given number of cells, and the population growth is monitored over a period of time, plotting the data will yield a **typical bacterial growth curve .** Four characteristic phases of the growth cycle are recognized .



Growth curve

- During lag phase, cells are recovering from a period of no growth and are making macromolecules in preparation for growth
- During log phase cultures are growing maximally
- Stationary phase occurs when nutrients are depleted and wastes accumulate (Growth rate = death rate)
- During death phase death rate is greater than growth rate

Phases of the Bacterial Growth Cycle .

1. Lag Phase.

This initial phase is characterized by cellular activity but not growth. A small group of cells are placed in a nutrient rich medium that allows them to synthesize proteins and other molecules necessary for replication. These cells increase in size, but no cell division occurs in the phase **.**

- Immediately after inoculation of the cells into fresh medium, the population remains temporarily unchanged. Although there is no apparent cell division occurring, the cells may be growing in volume or mass, synthesizing enzymes, proteins, RNA, etc., and increasing in metabolic activity. The length of the lag phase is apparently dependent on a wide variety of factors including the size of the inoculums ; time necessary to recover from physical damage or shock in the transfer ; time required for synthesis of essential coenzymes or division factors ; and time required for synthesis of new enzymes that are necessary to metabolize the substrates present in the medium .

2. Exponential (log) Phase .

After the lag phase, bacterial cells enter the exponential or log phase. This is the time when the cells are dividing by binary fission and doubling in numbers after each generation time. Metabolic activity is high as DNA, RNA, cell wall components, and other substances necessary for growth are generated for division .

The exponential phase of growth is a pattern of balanced growth where in all the cells are dividing regularly by binary fission, and are growing by geometric progression. The cells divide at a constant rate depending upon the composition of the growth medium and the conditions of incubation. The rate of exponential growth of a bacterial culture is expressed as **generation time**, also the **doubling time** of the bacterial population .

3. Stationary Phase.

The population growth experienced in the log phase begins to decline as the available nutrients become depleted and waste products start to accumulate. Bacterial cell growth reaches a plateau, or stationary phase, where the number of dividing cells equal the number of dying cells.

This results in no overall population growth. Under the less favorable conditions, competition for nutrients increases and the cells become less metabolically active .

Population growth is limited by one of three factors :-

1. Accumulation of toxic product and/ or exhaustion of available nutrients .
2. Accumulation of inhibitory metabolites or end products .
3. exhaustion of space, in this case called a lack of "biological space".

During the stationary phase, the number of new cell produce balance the number of that cell die resulting in steady state.

4. Death Phase.

As nutrients become less available and waste products increase, the number of dying cells continues to rise. In the death phase, the number of living cells decreases exponentially and population growth experiences a sharp decline. As dying cells lyse or break open, they spill their contents into the environment making these nutrients available to other bacteria.

During the death phase, the number of viable cells decreases geometrically (exponentially), essentially the reverse of growth during the log phase .

Growth of bacteria in an open environment, such as soil, water, or even the intestine generally does not follow the curve shown above, in these circumstances bacterial growth is most often continuous, so that the number of viable microorganisms remain fairly constant over long periods of time.

In Laboratory (in vitro) studies of bacterial growth in continuous culture have shown that the microorganisms grow exponentially in a condition of balanced growth, and the generation time is determined by the rate at which fresh nutrients are supplied to the culture. continuous culture is usually used by genetic engineering for synthesis of some wanted things like; insulin, vitamins, toxins, enzyme,……etc.