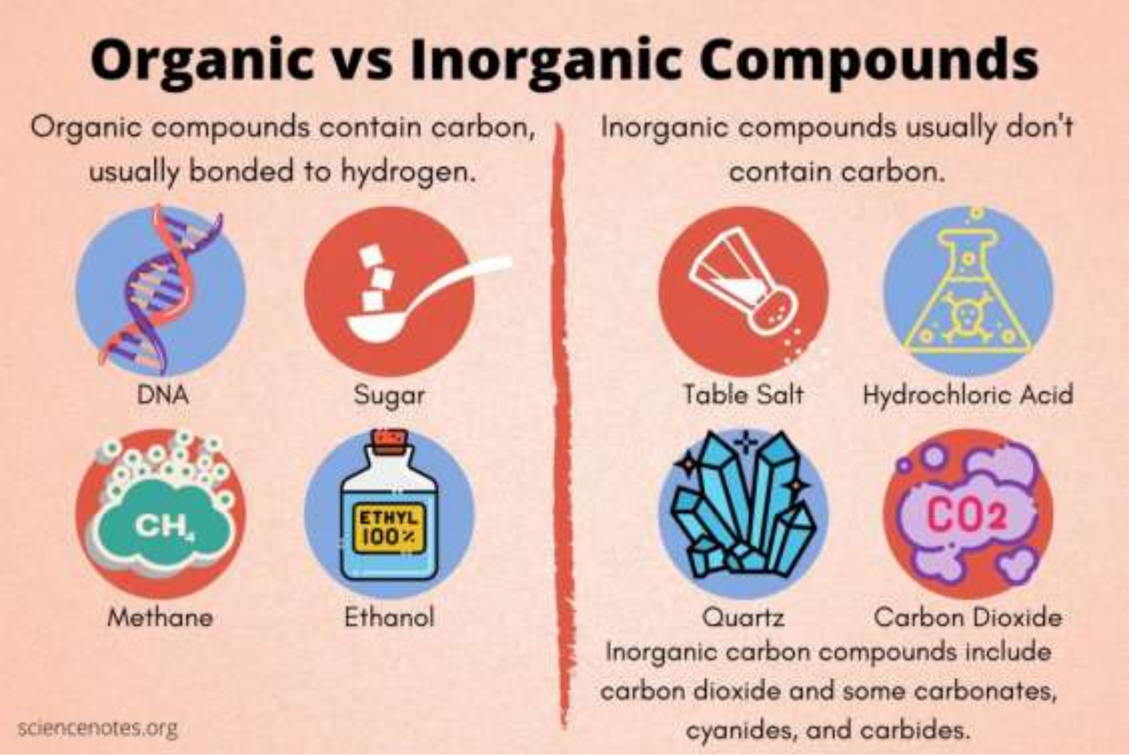
UNIT - 5

NUTRITION ,NUTRITIONAL TYPES AND GROWTH OF BACTERIA

NUTRIENTS :

- Nutrients are essential substances that organisms need to survive, grow, and carry out basic biological functions.
- Nutrients can be broadly classified into **organic** and **inorganic** based on their chemical composition.



Organic Nutrients :

These nutrients contain carbon and are primarily derived from living organisms. They are complex molecules that play key roles in biological functions.

1. **Carbohydrates**
   1. **Function**: Provide energy to the body.
   2. **Sources**: Bread, rice, fruits, vegetables, and cereals.
2. **Proteins**
   1. **Function**: Essential for growth, repair, and maintenance of body tissues.
   2. **Sources**: Meat, fish, eggs, legumes, nuts, and dairy.
3. **Lipids (Fats and Oils)**
   1. **Function**: Provide energy, insulation, and essential fatty acids.
   2. **Sources**: Butter, oil, avocados, nuts, and seeds.
4. **Vitamins**
   1. **Function**: Support various biochemical processes, including immunity, vision, and metabolism.
   2. **Sources**: Fruits, vegetables, fish, and dairy (e.g., Vitamin C in citrus fruits, Vitamin A in carrots).

Inorganic Nutrients

These nutrients do not contain carbon and are usually derived from non-living sources such as soil, water, and air. They play structural and regulatory roles in the body.

1. **Minerals**
   1. **Examples**:
      1. **Macro minerals**: Calcium, phosphorus, magnesium, potassium, sodium.
      2. **Trace Minerals**: Iron, zinc, iodine, selenium.
   2. **Function**: Bone health, nerve function, muscle contraction, and enzyme activity.
   3. **Sources**: Dairy, leafy greens, nuts, seafood, and fortified foods.
2. **Water**
   1. **Function**: Essential for hydration, temperature regulation, and transportation of nutrients and waste.
   2. **Sources**: Drinking water, fruits, and vegetables

Nutritional classification of microorganism

- ❖Microorganisms can be classified into nutritional classes based on how they satisfy the requirements of carbon, energy and electrons for their growth and nutrition. Based on the carbon source, microorganisms are able to utilize, they are classified into Autotrophs and Heterotrophs.
- ❖**Based on Carbon Source**

Microorganisms can utilize either inorganic carbon (like CO_2) or organic carbon as a source.

1. **Autotrophs**: Use carbon dioxide (CO_2) as their carbon source.

   Example: Cyanobacteria, Nitrosomonas.

2. **Heterotrophs**: Use organic carbon (e.g., carbohydrates, lipids, or proteins) as their carbon source.

   Example: Escherichia coli, Saccharomyces cerevisiae.

❖ **Based on Electron Donor (for Chemotrophs)**

1. **Lithotrophs**: Use inorganic electron donors (e.g., H_2, NH_3, H_2S).
Example: Sulfur bacteria.

2. **Organotrophs**: Use organic electron donors.
Example: Most heterotrophic bacteria.

❖ **Based on Energy Source**

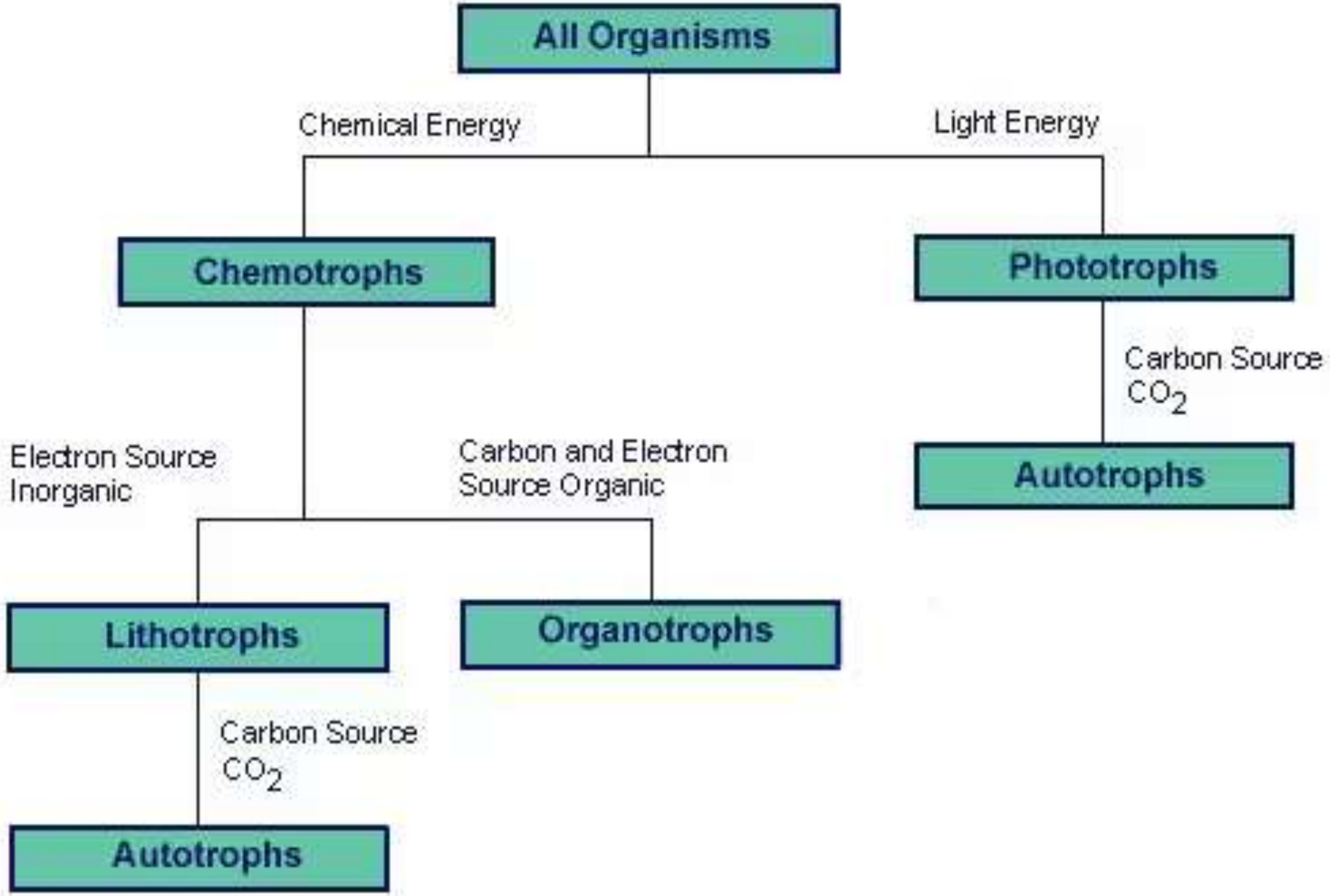
Microorganisms can use either light or chemical compounds as their energy source.

1. **Phototrophs**: Use light as an energy source.

Example: Cyanobacteria, green sulfur bacteria.

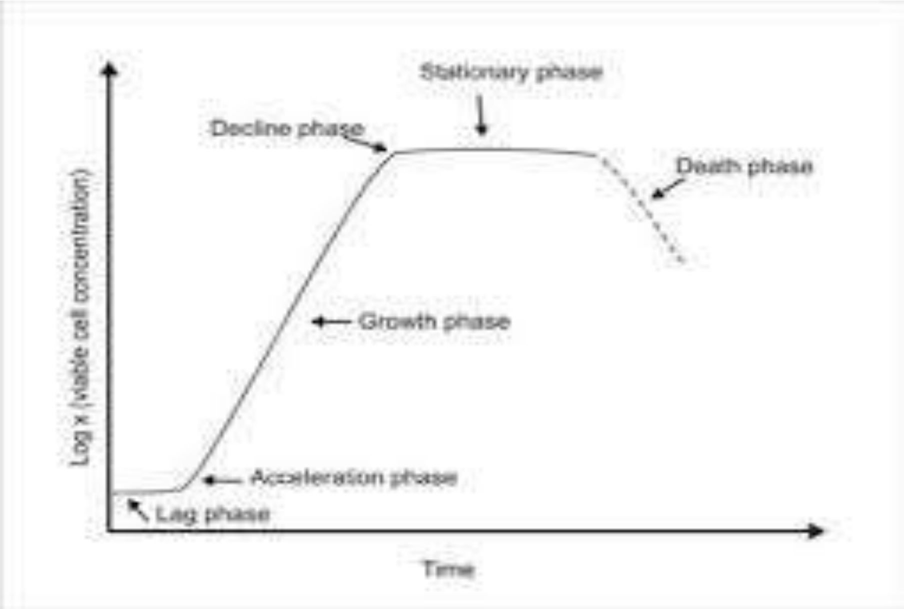
2. **Chemotrophs**: Use chemical compounds as an energy source.

- **Chemoorganotrophs**: Use organic compounds like glucose.
  Example: Most bacteria, fungi.
- **Chemolithotrophs**: Use inorganic compounds like ammonia, hydrogen sulfide, or ferrous iron.
  Example: Nitrosomonas, Thiobacillus.


All Organisms
Chemical Energy
Light Energy
Chemotrophs
Phototrophs
Carbon Source
CO_2
Electron Source
Inorganic
Carbon and Electron
Source Organic
Autotrophs
Lithotrophs
Organotrophs
Carbon Source
CO_2
Autotrophs

GROWTH PHASE :

- The **growth phases** of microorganisms refer to the different stages of population growth when they are cultured in a closed system (batch culture). These phases are typically observed when microorganisms are grown in a nutrient-rich medium under controlled conditions.
- Growth phase kinetics is the study of how the rate of cell growth changes over time. It's a type of autocatalytic reaction, which means that the rate of growth is proportional to the concentration of cells.
- The **growth phases** and the related **kinetics** of microbial growth can be studied in different systems, including **asynchronous** and **synchronous cultures**, as well as in **batch** and **continuous cultures**.



1. Growth Kinetics

- Growth kinetics refers to the rate of microbial growth and how it changes over time. It involves analyzing:
- **Specific growth rate (μ):** The rate of increase in cell population per unit time.
- **Doubling time (td):** The time it takes for the cell population to double.
- **Yield coefficient (Y):** The efficiency of converting nutrients into biomass.
- In the exponential phase, microbial growth follows this equation: Nt=N0·eμtN_t = N_0 \cdot e^{\mu t}Nt=N0·eμt Where:
- NtN_tNt: Cell number at time ttt.
- N0N_0N0: Initial cell number.
- μ\muμ: Specific growth rate.
- ttt: Time.

2. Asynchronous Growth

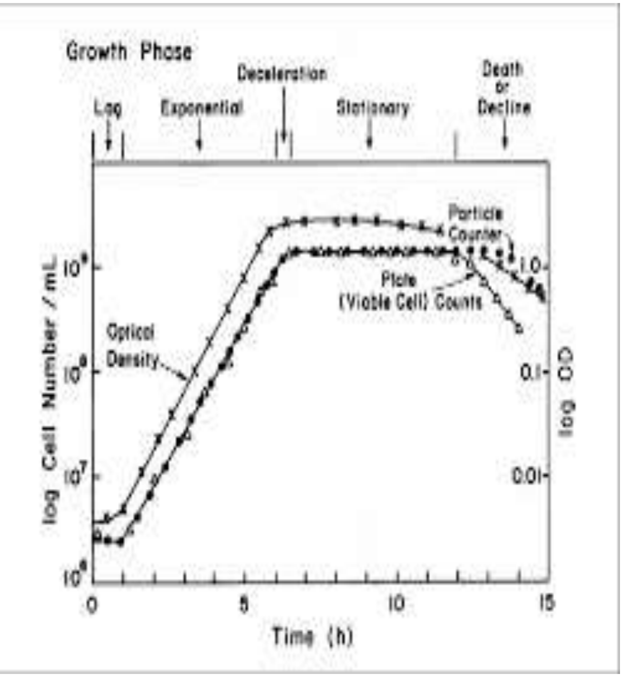
- **Definition**: In natural or typical cultures, microbial cells do not divide at the same time. Cells are at different stages of the cell cycle (asynchronous growth).
- **Key Features**:
  - Most common in batch cultures.
  - The population grows smoothly without sharp fluctuations in cell numbers.
  - Used in industrial applications where uniform, steady growth is desired.
- **Example**: A typical culture of *Escherichia coli* growing in a flask.

3. Synchronous Growth

- **Definition**: All cells in the culture divide simultaneously and are at the same stage of the cell cycle.
- **Key Features**:
    - Achieved through methods like nutrient starvation, temperature shocks, or size-based separation.
    - Growth occurs in stepwise bursts as all cells divide at the same time.
    - Useful for studying the cell cycle, gene expression, and metabolic regulation.
- **Challenges**: Difficult to maintain synchronization over long periods due to cell cycle variability.
- **Example**: Synchronization of *Chlamydomonas* cells for studying photosynthesis

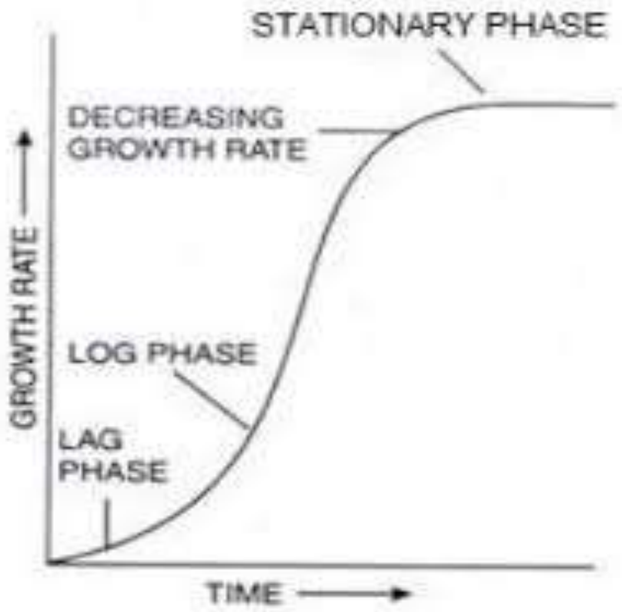
4. Batch Culture

- **Definition**: A closed system where microorganisms grow in a fixed volume of nutrient medium without adding fresh nutrients or removing waste during growth.
- **Key Features**:
  - Growth occurs in four distinct phases: **lag**, **log**, **stationary**, and **death**.
  - Nutrient depletion and waste accumulation limit growth.
  - Commonly used in laboratory studies and small-scale industrial processes.
- **Growth Kinetics**:
  - Growth is exponential during the log phase.
  - Stationary phase is marked by nutrient limitation and by-product inhibition.
- **Example**: Fermentation of *Saccharomyces cerevisiae* for ethanol production.



5. Continuous Culture

- **Definition**: An open system where fresh medium is continuously added, and culture broth (containing microorganisms and waste) is removed at the same rate.
- **Key Features**:
    - Maintains the culture in the exponential phase for extended periods.
    - Growth rate and cell density are controlled by the dilution rate and nutrient concentration.
    - Used for studying microbial physiology and large-scale industrial processes.
- **Types**:
    - **Chemostat**: Growth rate is controlled by limiting the nutrient concentration.
    - **Turbidostat**: Growth rate is controlled by maintaining a constant turbidity (cell density) using a feedback mechanism.
- **Growth Kinetics**:
    - Steady-state conditions are achieved when the growth rate equals the dilution rate.
    - Useful for producing secondary metabolites (e.g., antibiotics).
- **Example**: Continuous production of insulin by genetically engineered *E. coli*.



Sigmoid Growth Curve

Applications of Growth Systems

1. **Asynchronous Growth**:
   1. Used in natural and industrial systems where consistent growth is needed.
2. **Synchronous Growth**:
   1. Used in research to study specific stages of the microbial cell cycle.
3. **Batch Culture**:
   1. Common in traditional fermentation industries (e.g., beer, yogurt production).
4. **Continuous Culture**:
   1. Ideal for large-scale production of pharmaceuticals (e.g., antibiotics, enzymes) and biofuels.

Factors Affecting Growth Phases

1. **Nutrient availability**: The type and concentration of nutrients in the medium.
2. **Temperature**: Growth occurs at an organism's optimal temperature.
3. **pH**: Affects enzymatic activity and cell stability.
4. **Oxygen availability**: Essential for aerobic organisms but toxic to obligate anaerobes.
5. **Waste accumulation**: High levels of toxic by-products inhibit growth.

Measurement of growth ：

- Microbial growth can be measured using various methods depending on the type of organism, growth phase, and experimental requirements. The methods mentioned (**dry weight, wet weight, protein, Kjeldahl nitrogen, and chlorophyll**) are quantitative techniques used to estimate microbial biomass or growth. **1. Dry Weight**
- **Definition**: Measures the total biomass of microorganisms by drying the sample and weighing it.
- **Procedure**:
    - Collect the microbial culture by filtration or centrifugation.
    - Wash the biomass to remove residual medium.
    - Dry the sample in an oven at 60–100°C until a constant weight is achieved.
    - Weigh the dried biomass
    - **Applications**: Commonly used in fungal biomass estimation.

2. Wet Weight

- **Definition**: Measures the weight of the microbial culture without drying.
- **Procedure**:
  - Collect the microbial cells by centrifugation or filtration.
  - Remove excess liquid by blotting or draining.
  - Weigh the wet biomass.
- **Applications**: Used as a rapid preliminary method for estimating growth.

3. Protein Estimation

- **Definition**: Measures the total protein content in the microbial biomass, which correlates with cell growth.
- **Procedure**:
  - Lyse the cells to extract proteins (e.g., using sonication or chemical lysis).
  - Quantify protein using colorimetric assays:
    - **Bradford Assay**: Uses Coomassie Brilliant Blue dye.
    - **Lowry Assay**: Based on protein-copper complex reduction.
  - Measure absorbance using a spectrophotometer.
- **Applications**: Used in microbial physiology and metabolic studies.

Kjeldahl Nitrogen Estimation

- **Definition**: Measures total nitrogen content in the microbial biomass, which is proportional to protein content.
- **Procedure**:
  - Digest the microbial sample with concentrated sulfuric acid to convert nitrogen into ammonium.
  - Distill the ammonium and collect it in a receiver solution.
  - Titrate the ammonium solution to estimate nitrogen content.
  - **Applications**: Commonly used in food and agricultural industries to measure microbial growth in soil or fermentation processes.

5. Chlorophyll Estimation

- **Definition**: Measures chlorophyll content to estimate the growth of photosynthetic microorganisms (e.g., algae, cyanobacteria).
- **Procedure**:
  - Harvest the cells by centrifugation or filtration.
  - Extract chlorophyll using organic solvents like acetone, ethanol, or methanol.
  - Measure absorbance using a spectrophotometer at specific wavelengths (e.g., 663 nm and 645 nm for chlorophyll a and b, respectively).
  - **Applications**: Used in ecological studies and algae-based biotechnology (e.g., biofuel production)

Comparison of Methods

Method	Direct/Indirect	Sensitivity	Complexity	Applications
Dry Weight	Direct	Moderate	Moderate	Fungi, bacterial biomass
Wet Weight	Direct	Low	Simple	Preliminary biomass estimation
Protein	Indirect	High	Moderate	Metabolic and physiological studies
Kjeldahl	Indirect	High	High	Fermentation, soil microbiology
Chlorophyll	Indirect	High (for algae)	Moderate	Algal growth, photosynthesis studies