

# Bacterial metabolism and growth

## Nutrition

- For optimal growth and multiplication, bacteria requires **nutrients**, such as **water**, **energy**, **carbon**, **nitrogen** and some **inorganic** salts.
- Bacteria also require various **environmental** factors for growth in **optimum** concentration. These include **Oxygen/Carbon** dioxide, **pH**, **temperature** and **light**
- All bacteria need some form of the element Carbon, H, O<sub>2</sub>, S, P, and N for growth.
- Special elements such as K, Ca, Fe, Mn, Mg, Co, Cu, Z, Ur are needed by **certain** bacteria.

# Nutrition ... Cont'd

- Some have specific **vitamin**, and **growth** factor requirements and others need **organic** substances secreted by **other** microorganisms during their growth.
- In most case, bacteria need **small amount of salt** concentration to grow.
  - **Halophytes** are bacteria which need **high** concentration of salt for their growth.

# 1. Nutrient requirement

- Depending on their **nutritional requirement** **bacteria** can be **classified**
  - **Autotrophs:** - are free-living, **non-pathogenic** bacteria, most of which can use **carbon** dioxide as their **carbon** source.
    - The energy needed for their metabolism can be obtained from
      - (a). **Sunlight-photoautotrophs** and
      - (b) inorganic compounds by **oxidation-chemoautotrophs**
  - **Heterotrophs** are generally **parasitic** bacteria which require **more complex organic compounds** than carbon dioxide as their source of carbon and energy, e.g. **sugar**

## 2. Temperature requirement

- Most pathogenic bacteria grow best at an **optimum** temperature of **37°C**.
- Optimum temperature is the temperature at which **growth occur best**.
- Based on temperature requirement, microorganisms can be **broadly classified into**
- **Psycrophylic**- are those bacteria, which grow in the range of **-5 to 20°C**
- **Mesophilic**- are those bacteria, which grow at 20-45°C and show optimum growth at 37°C.
- **Thermophilic** – are those organisms which prefer high temperature (50-80°C)
- **Hyperthermophilic**-Those which grow at a temperature of above 80°C, Some of them grow even at **250°C**

### 3. Oxygen requirement

The need of oxygen for particular bacterium **reflects** its mechanism to meet the **requirement** of energy. On the basis of this requirement, bacteria have been divided in to:

- **Obligate Anaerobes** -these grow **only** in the environment devoid of oxygen
  - e.g. *clostridium*
- **Facultative aerobes**- these can grow **under both aerobic and anaerobic** conditions, e.g. enterobacteriaceae
- **Obligate aerobes**- these **cannot** grow **unless oxygen** is present in the medium, e.g. pseudomonas
- **Microaerophilic**- these organisms can grow under conditions with **low oxygen tension** e.g. *clostridium titani*.
- **Aerotolerant anaerobes** - These bacteria **oxidize** nutrient substrates without using elemental **oxygen**. Unlike obligate anaerobes, they can tolerate the presence of oxygen.

## 4. pH requirement

Most pathogenic bacteria require a pH of 7.2-7.6 for their optimal growth. Based on pH requirement bacteria can be classified as

- **Neutrophilic**:- bacteria grow best at neutral pH (pH=7)
  - Most pathogenic micro-organism best grow at neutral pH (pH=7)
- **Acidophilic**
  - Bacterial grow best at acidic pH (pH<7)
  - E.g. Lactobacilli, fungi and yeast
- **Alkalophilic**
  - Bacterial grow best at Alkaline pH (pH>7)
  - E.g. Vibrio cholerae grow at a pH of 8.6

# Bacterial Metabolism

- bacterial metabolism involves all the **cellular processes** required for the **survival** and **replication** of the organism.
- It refers to **all of the chemical reactions** occurring within a cell, including the production of energy, intermediate products, and end products.
- A **metabolite** is any molecules that are a nutrient (energy source), intermediary product, or end product in a metabolic reaction.
- Most biochemical reactions fall into two categories: **Catabolism** and **Anabolism**.

## **Heterotrophic Metabolism**

- the biologic oxidation of organic compounds, such as glucose, to yield ATP and simpler organic (or inorganic) compounds, which are needed by the bacterial cell for biosynthetic or assimilatory reactions.

## **Autotrophy**

- a unique form of metabolism found only in bacteria.
- Inorganic compounds are oxidized directly (without using sunlight) to yield energy (e.g.,  $\text{NH}_3$ ,  $\text{NO}_2^-$ ,  $\text{S}_2$ , and  $\text{Fe}^{2+}$ ).

## **Respiration**

- a type of heterotrophic metabolism that uses oxygen and in which 38 moles of ATP are derived from the oxidation of 1 mole of glucose, yielding 380,000 cal. (An additional 308,000 cal is lost as heat.)

## **Fermentation**

- another type of heterotrophic metabolism,
- an organic compound rather than oxygen is the terminal electron (or hydrogen) acceptor.
- Less energy is generated from this incomplete form of glucose oxidation, but the process supports anaerobic growth.

## **Bacterial Photosynthesis**

- a light-dependent, anaerobic mode of metabolism.
- Carbon dioxide is reduced to glucose, which is used for both biosynthesis and energy production.

# **Metabolic pathways**

**Krebs Cycle**

**Glyoxylate Cycle**

**The Nitrogen Cycle**

**Electron Transport and Oxidative  
Phosphorylation**

# Bacterial growth

- Bacteria divide by binary fission.
- When a bacterial cell reaches a **certain** size, it divides to form two daughter cells.
- **Nuclear** division precedes **cell** division and, therefore, in a growing population, many cell carrying two nuclear bodies can be found.

## **Generation time or population doubling time.**

- The interval of time between **two** cell division, or the time required for a bacterium to give **rise** to two **daughter** cells under optimum conditions
- The generation time of bacteria ranges from as little as **20** minutes for E-coli to more than **20** hrs for Mycobacterium tuberculosis.
- The generation time varies not only with the **species** but also with the amount of **nutrients**, the **temperature**, the pH, and other environmental factors.

# Bacterial growth curve

- The growth cycle of **bacteria** has **four** major phases.
- If a small number of bacteria are inoculated into a **liquid nutrient** medium and the bacteria are counted at frequent interval, the typical phase of a standard growth curve can be demonstrated.

## The Lag Phase

- this phase is of **short** duration in which bacteria **adapt** themselves to **new** environment in such away that the bacterial machinery brings itself in conformity with the **nutrition** available.
- This is a period of **active** macro molecular **synthesis** like DNA, RNA, various enzymes and other structural components
- **It is the preparation time for reproduction**

## The log, logarithmic, or exponential phase

- During this phase, the population can double approximately every 30 **minutes** with fast growing bacteria
- It has limited duration

# Bacterial growth curve ...Cont'd

## Stationary Phase

- There is almost a balance between the bacterial reproduction and **bacterial death**

## The death/decline phase

- Due to depletion of **nutrients** and **accumulation** of toxic end products the number of bacteria **dying** is much more than those **dividing** and hence there is gradual decline in the total number of organism.
- There is drastic decline in **viable** cells.
- to maintain a culture in **exponential, steady-state** (balanced) growth for long periods is to use a device in which **fresh medium is continuously added but the total volume of culture is held constant by an overflow tube.**
- E.g:-**chemosta,turbidostat**

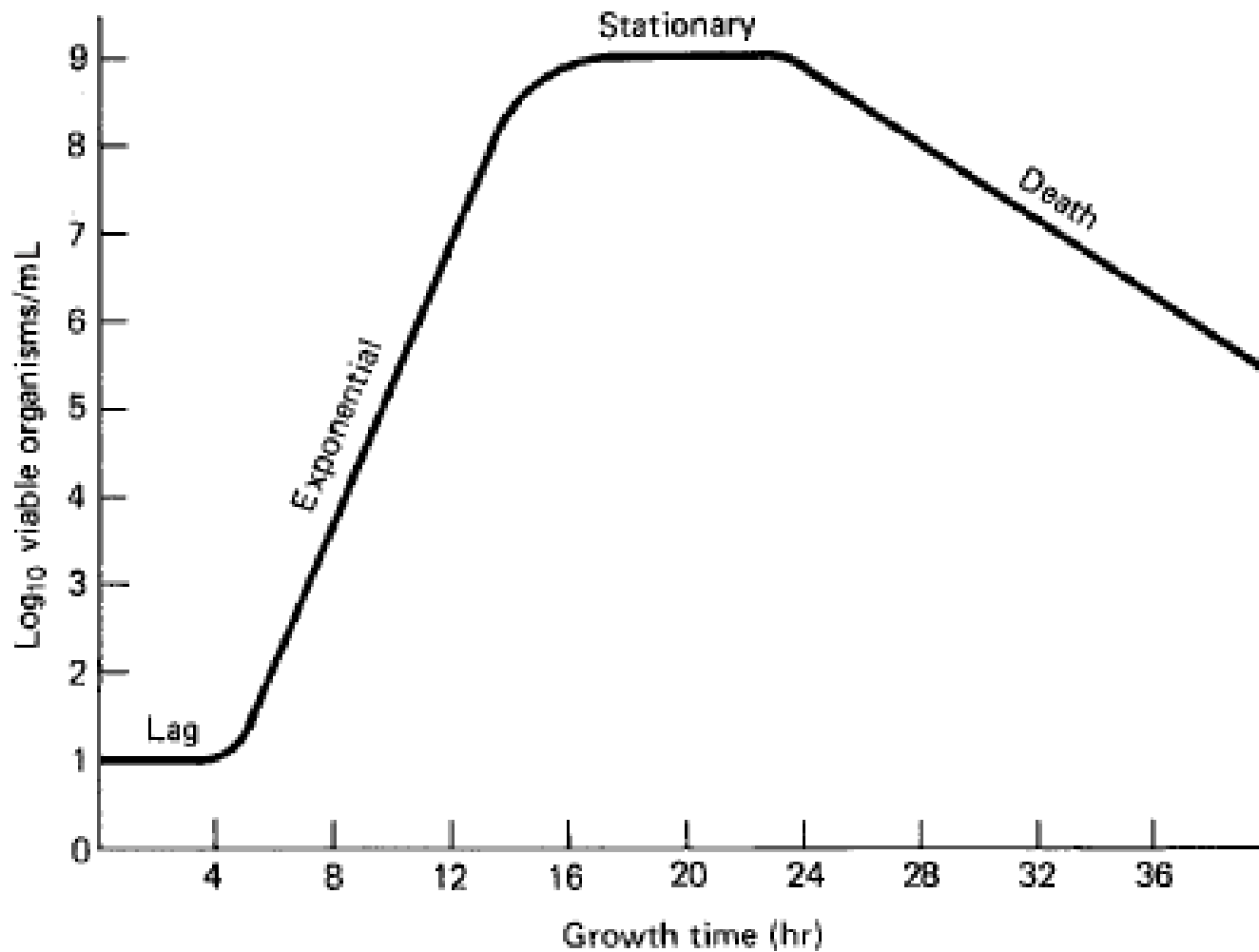


**Fig. Bacterial growth curve**