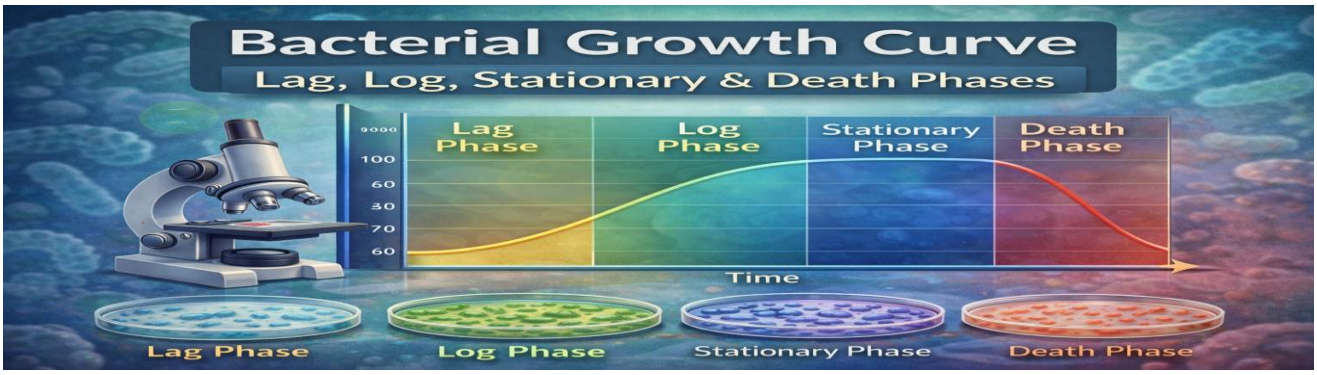
Bacterial Growth Curve



Understanding how bacteria grow is fundamental in microbiology. The **bacterial growth curve** explains how a bacterial population changes over time when cultured in a closed environment. This concept is essential for students, researchers, and professionals working in medical, industrial, and environmental microbiology.

When bacteria are grown in a liquid medium under laboratory conditions, they are typically cultured in a **batch system**. In this closed system, no fresh nutrients are added during incubation. As a result, nutrients gradually decrease while waste products accumulate. When the number of viable cells is plotted on a logarithmic scale against time, a characteristic four-phase growth pattern appears.

The bacterial growth curve consists of:

1. Lag Phase
2. Log (Exponential) Phase
3. Stationary Phase
4. Death Phase

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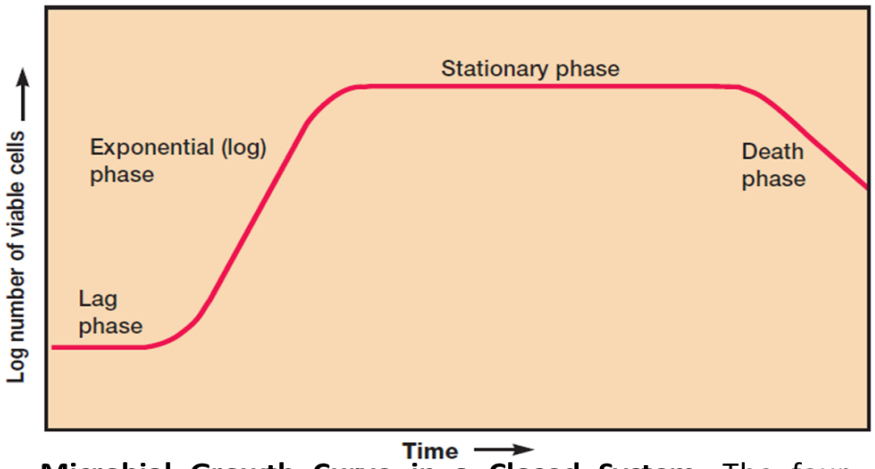
1. Lag Phase

The lag phase is the initial adjustment period after bacteria are introduced into a fresh medium. During this stage, there is no immediate increase in cell number.

Although cells are not dividing, they are highly active metabolically. They synthesize enzymes, ATP, ribosomes, and other essential components needed for growth. If the new medium differs

from the previous one, bacteria must produce new enzymes to utilize available nutrients. Injured or aged cells may also require time for repair.



Microbial Growth Curve in a Closed System. The four phases of the growth curve are lag phase, log phase, stationary phase and death phase

Ref: Willey, J. M., Sherwood, L., & Woolverton, C. J. (2011). Prescott's microbiology (Vol. 7). New York: McGraw-Hill.

The duration of the lag phase depends on:

- Age and condition of the inoculum
- Nutritional composition of the medium
- Environmental conditions such as temperature

Young, actively growing cells transferred to a similar medium show a very short lag phase. In contrast, old or stressed cultures display a longer adjustment period.

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2. Log (Exponential) Phase

The exponential phase is the period of rapid cell division. During this stage, bacteria multiply at their maximum possible rate under given conditions.

Cell numbers double at regular intervals, producing a steady, smooth upward curve when plotted on a logarithmic scale. The population is most uniform during this phase in terms of structure, metabolism, and chemical composition. For this reason, log-phase cells are commonly used in laboratory experiments.

This stage represents **balanced growth**, meaning all cellular components are produced proportionally.

Changes in Growth Conditions

When environmental conditions shift, bacteria may experience **unbalanced growth**.

- In a **shift-up** (poor to rich medium), cells first increase ribosome production, followed by enhanced protein and DNA synthesis. Eventually, the growth rate increases.
- In a **shift-down** (rich to poor medium), cells must synthesize enzymes required for biosynthesis. Cell size may decrease temporarily before stable growth resumes.

Effect of Nutrient Levels

The growth rate increases with nutrient concentration, but only up to a limit. Once transport systems are saturated, further increases in nutrients do not enhance growth. Final cell yield depends largely on the amount of the limiting nutrient present.

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3. Stationary Phase

As nutrients become scarce and waste products accumulate, bacterial growth slows and eventually stops. This stage is called the stationary phase.

During this phase:

- The number of living cells remains relatively constant.
- Cell division may equal cell death.
- Some cells remain metabolically active without dividing.

Why Does Stationary Phase Occur?

Several factors contribute:

- Depletion of essential nutrients
- Limited oxygen supply in aerobic cultures
- Accumulation of toxic metabolites
- High population density

For example, acid-producing bacteria can lower the pH of their medium, inhibiting further growth.

Survival During Starvation

Many bacteria adapt to nutrient limitation instead of forming spores. Adaptations may include:

- Reduced cell size
- DNA protection mechanisms
- Production of stress-response proteins
- Strengthening of the cell wall

These changes increase resistance to heat, oxidative stress, osmotic stress, and disinfectants. Some species can survive starvation for years. Interestingly, certain pathogens may become more virulent under nutrient-limited conditions.

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4. Death Phase

When environmental conditions become unfavorable, the number of viable cells begins to decline. This stage is known as the death phase.

Cell death often follows a logarithmic pattern, meaning a fixed percentage of the population dies per unit time. Even if total cell count appears constant, many cells may no longer be capable of reproduction.

In microbiology, a cell is considered dead when it permanently loses the ability to grow and divide in fresh medium.

The death curve may not always be smooth because some highly resistant cells survive longer than others.

Summary of the Bacterial Growth Curve

The bacterial growth curve in a batch culture follows four predictable stages:

- **Lag Phase** – Adaptation and preparation for division
- **Log Phase** – Rapid and balanced multiplication

- **Stationary Phase** – Growth stops due to limitations and stress
- **Death Phase** – Gradual decline in viable cells

A clear understanding of the bacterial growth curve is crucial in clinical microbiology, biotechnology, pharmaceutical production, food microbiology, and industrial fermentation processes.

Reference: Willey, J. M., Sherwood, L., & Woolverton, C. J. (2011). Prescott's microbiology (Vol. 7). New York: McGraw-Hill.