Physiology of Bacteria

By

Dr. Marwa Kadhim

Growth may be defined as an increase in cellular constituents. It leads to a rise in cell number when microorganisms reproduce by processes like budding or binary fission.

Phases of bacterial growth curve

The bacterial growth curve can be divided into four major phases: lag phase, exponential or log (logarithmic) phase, stationary phase and decline phase. These phases reflect the physiologic state of the organisms in the culture at that particular time.

1. **Lag phase:** When microorganisms are introduced into fresh culture medium, usually no immediate increase in cell number occurs, and therefore this period is called the **lag phase**. After inoculation, there is an increase in cell size at a time when little are no cell division is occurring. During this time, however, the cells are not dormant. This initial period is the time required for adaptation to the new environment, during which the necessary enzymes and metabolic intermediates are built up in adequate quantities for multiplication to proceed.

2. Log (logarithmic) or exponential phase:

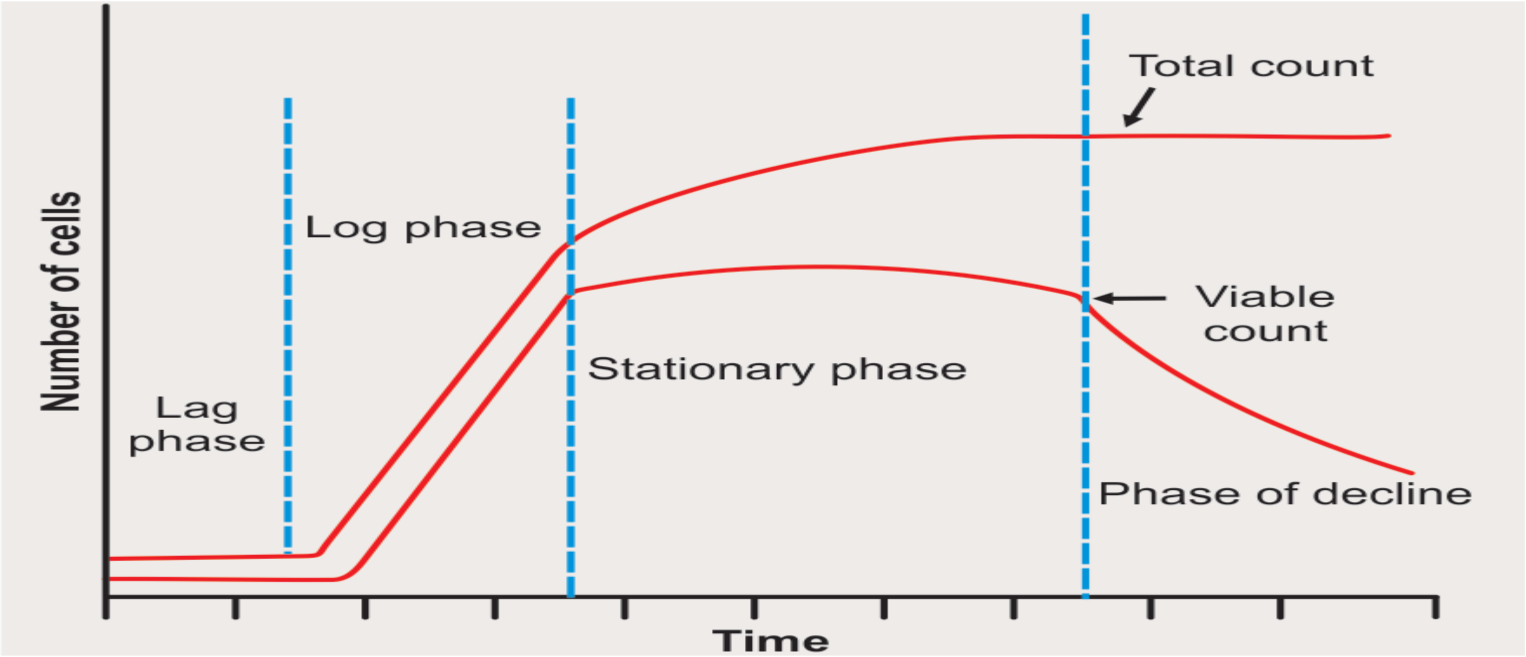
Following the lag phase, the cells start dividing and their numbers increase exponentially or by geometric progression with time. If the logarithm of the viable count is plotted against time, a straight line will be obtained.

3. Stationary phase:

After a varying period of exponential growth, cell division stops due to depletion of nutrients and accumulation of toxic products. Eventually growth slows down, and the total bacterial cell number reaches a maximum and stabilizes. The number of progeny cells formed is just enough to replace the number of cells that die. The growth curve becomes horizontal. The viable count remains stationary as an equilibrium exists between the dying cells and the newly formed cells.

4. Decline or death phase:

The death phase is the period when the population decreases due to cell death. Cell death may also be caused by autolysis besides nutrient deprivation and build-up of toxic wastes.



Fig(1) : Bacterial growth curve. The viable count shows lag, log, stationary and decline phases. In the total count, the phase of decline is not evident

Bacterial Nutrition

The minimum nutritional requirements for growth and multiplication of bacteria are water, a source of carbon, a source of nitrogen and some inorganic salts. The water content of bacterial cells can vary from 75 to 90% of the total weight and is the vehicle for the entry of all cells and for the elimination of all waste products. It participates in the metabolic reactions and also forms an integral part of the protoplasm.

Categories of Requirements for Microbial Growth

The requirements for microbial growth can be divided into two main categories: (A) Chemical and (B) Physical.

A. **Chemical requirements:** Chemical requirements include sources of carbon, nitrogen, sulfur, phosphorus, trace elements, oxygen, and organic growth factors.

1. Major Elements (Macroelements orMacronutrients)

These include carbon, oxygen, hydrogen, nitrogen, sulfur, phosphorus, potassium, magnesium, calcium, and iron. Carbon is the structural back bone of living matter; it is needed for all the organic compounds that make up a living cell.

i. **Autotrophs:** Organisms that can use inorganic carbon in the form of carbon dioxide as their carbon source are called autotrophs (auto means self). They are soil are of no medical importance.

ii. **Heterotrophs:** Organisms that use organic carbon are called heterotrophs (hetero—different; troph—nourishment). They are unable to utilize carbon dioxide as the sole source of carbon and use reduced, preformed organic molecules as carbon sources.

2. Trace Elements: Some elements, termed as trace elements or micronutrients, are required in very minute quantities by all cells. They include cobalt, zinc, copper, molybdenum and manganese.

3. Growth Factors: Some bacteria require certain organic compounds in minute quantities known as growth factors or bacterial vitamins. Growth factors are called 'essential' when growth does not occur in their absence, or 'accessory' when they enhance growth without being absolutely necessary for it.

B. Physical Factors Influencing Microbial Growth

1. **Temperature:**

Optimum temperature: Each bacterial species has an optimal temperature for growth and a temperature range above and below which growth is blocked. The temperature at which growth occurs best is known as the **'optimum temperature'**. Bacteria are divided into three groups on the basis of temperature ranges through which they grow:

i. **Mesophilic:** Bacteria which grow between 10°C and 45°C, with optimal growth between 20 and 40°C.

Examples: *Escherichia coli*, *Neisseria gonorrhoeae*.

ii. **Psychrophlic:** Psychrophilic bacteria (cold-loving) are organisms that grow between 5 and 30°C, optimum at 10 to 20°C.

Examples: *Bacillus psychrophilus.*

iii. **Thermophilic:** Thermophiles (heat-loving) have growth range of 25–80°C, optimum at 50–60°C.

Examples: Some thermophiles (like *Bacillus stearothermophiles*) form spores that are exceptionally thermotolerant.

2. **Oxygen:** Based on their O_2 requirements, prokaryotes can be separated into aerobes and anaerobes.

A. **Aerobic bacteria:** Require oxygen for growth and may be:

i. **Obligate aerobes:** These have an absolute or obligate requirement for oxygen (O_2), like the *cholera vibrio.*

e.g. *Pseudomonas*, *Mycobacterium*

ii. **Facultative anaerobes:** These are ordinarily aerobic but can also grow in the absence of oxygen, though less abundantly. Most bacteria of medical importance are facultative anaerobes.

e.g. *Escherichia*, *Enterococcus*

iii. **Microaerophilic organisms:** These grow best at low oxygen tension (~5%), e.g. ***Campylobacter* spp**.

B. **Anaerobic bacteria:** Grow in absence of oxygen.

Obligate anaerobes: These may even die on exposure to oxygen, e.g. *Clostridium tetani.*

3. **Carbon dioxide:** All bacteria require small amount of carbon dioxide for growth. Some organisms such as ***Brucella abortus*** require much higher levels of carbon dioxide (5–10%) for growth, especially on fresh isolation (**capnophilic bacteria**), e.g. *pneumococci* and *gonococci*.

4. **Moisture and drying:** Moisture is very essential for the growth of the bacteria. However, the effect of drying varies in different species.

5. **pH:** Most pathogenic bacteria grow best at a neutral or slightly alkaline pH (7.2–7.6). Some acidophilic bacteria such as lactobacilli grow under acidic conditions while cholera vibrio grow at high degrees of alkalinity (well above pH 8).

6. **Light:** Darkness provides a favorable condition for growth and viability of bacteria. Bacteria are sensitive to ultraviolet light and other radiations.

7. **Osmotic effect:** Tolerance to osmotic variation— bacteria are more tolerant to osmotic variation.

8. **Mechanical and sonic stresses:** In spite of tough walls of bacteria, they may be ruptured by mechanical stress such as grinding or vigorous shaking with glass beads.

Bacterial Reproduction

Bacteria divide by **binary fission** where individual cells enlarge and divide to yield two progeny of approximately equal size. Nuclear division precedes cell division.

a)A young cell at early phase of cycle

b) A parent cell prepares for division by enlarging its cell wall, cell membrane, and overall volume.

(c) The septum begins to grow inward as the chromosomes move toward opposite ends of the cell. Other cytoplasmic components are distributed to the two developing cells.

d) The septum is synthesized completely through the cell center, and the cell membrane patches itself so that there are two separate cell chambers.

(e) At this point, the daughter cells are divided. Some species separate completely as shown here, while others remain attached, forming chains, doublets, or other cellular arrangements.

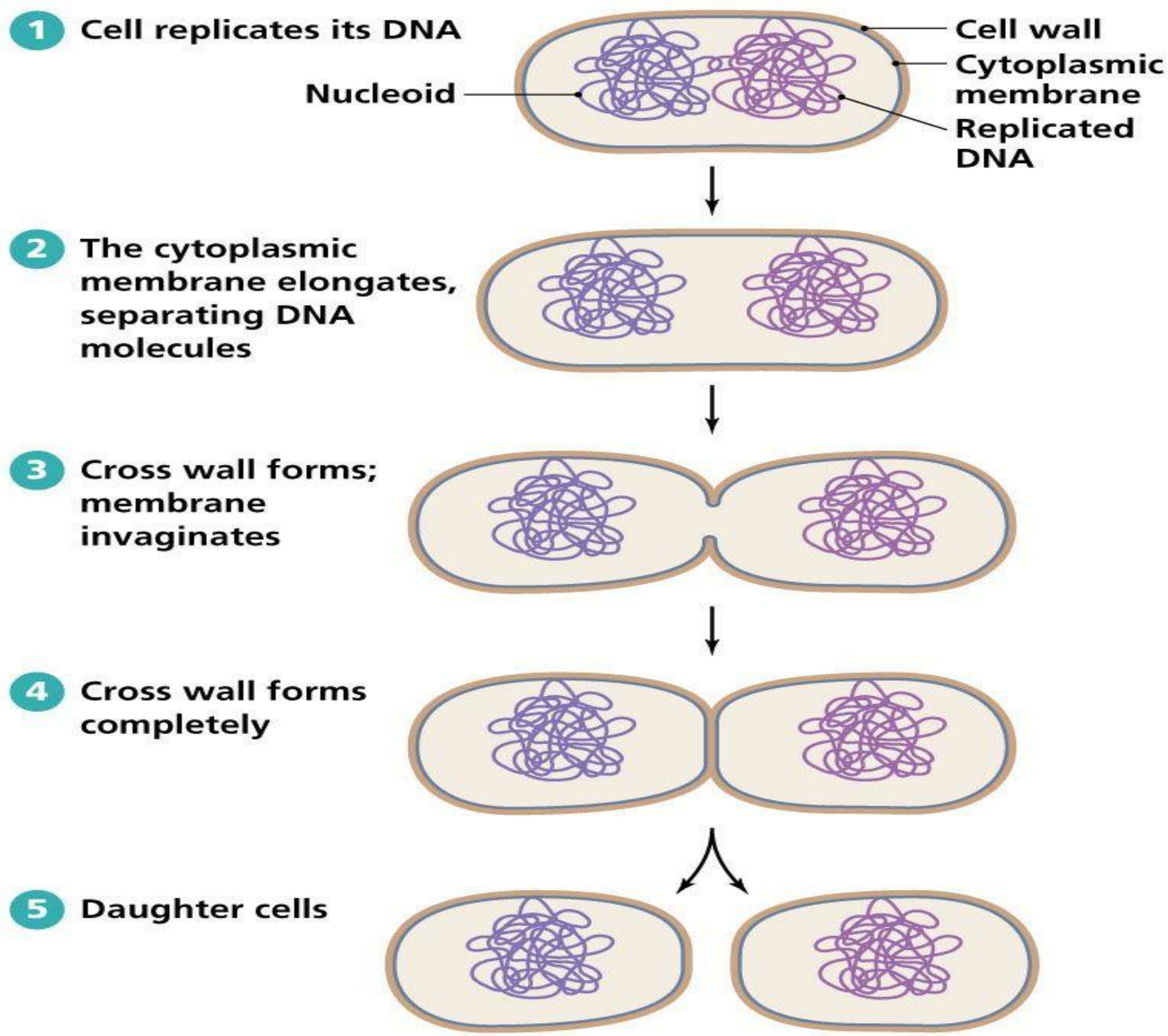


Figure (2): Binary Fission.