CSIR NET Life Science Unit 2

Microbial Physiology

Growth Yield and Characteristics, and Strategies of Cell Division

Growth:

- Increasement of number and size of any cell is known as growth, in which cell replicate and divides into two daughter cell and in microbes like bacteria the most common mean of reproduction is binary fission in which one cell divides and produces two daughter cells. In this, bacterial population increase by geometric progression, for example, if we start from single bacterium growth happens like:

$$2- 2^2- 2^3 -2^4 \text{-------} 2^n$$

Where n= number of generations

- And after each generation, assume that no cell death happens; microbial population doubles, if total population denoted by N at the end of the given time period it is expressed as:

$$N=1*2^n$$

- However, under practical conditions number of microbes as initial or starting is denoted as N0

so, the equation will be $N=N0*2^n$

after taking the log $\log_{10}N=\log_{10}N0+n\log 2$

$$n=\log_{10}N-\log_{10}N0/\log_{10}2$$

after putting the value of $\log_{10} 2$ in the equation

$$n=\log_{10}N-\log_{10}N0/0.301$$

$$n=3.3(\log_{10}N-\log_{10}N0)$$

so, by this equation number of generations can be calculated.

- The generation time which is defined as the time required by a population to get doubled, denoted as g can be calculated by:

$$g=t/n$$

where, t=particular time interval

and during exponential growth, per hour growth of bacteria termed growth rate (R):

$$R=n/t$$

Growth Curve:

For examination of the growth pattern of microorganisms, a small number of viable bacterial cells were placed in a closed vessel. The vessel contains food supply and suitable environmental conditions for microbial growth in which growth takes place and after a certain time, growth reaches its characteristic size and cell division occurs.

The growth rate follows a pattern which is represented by a curve known as the growth curve.

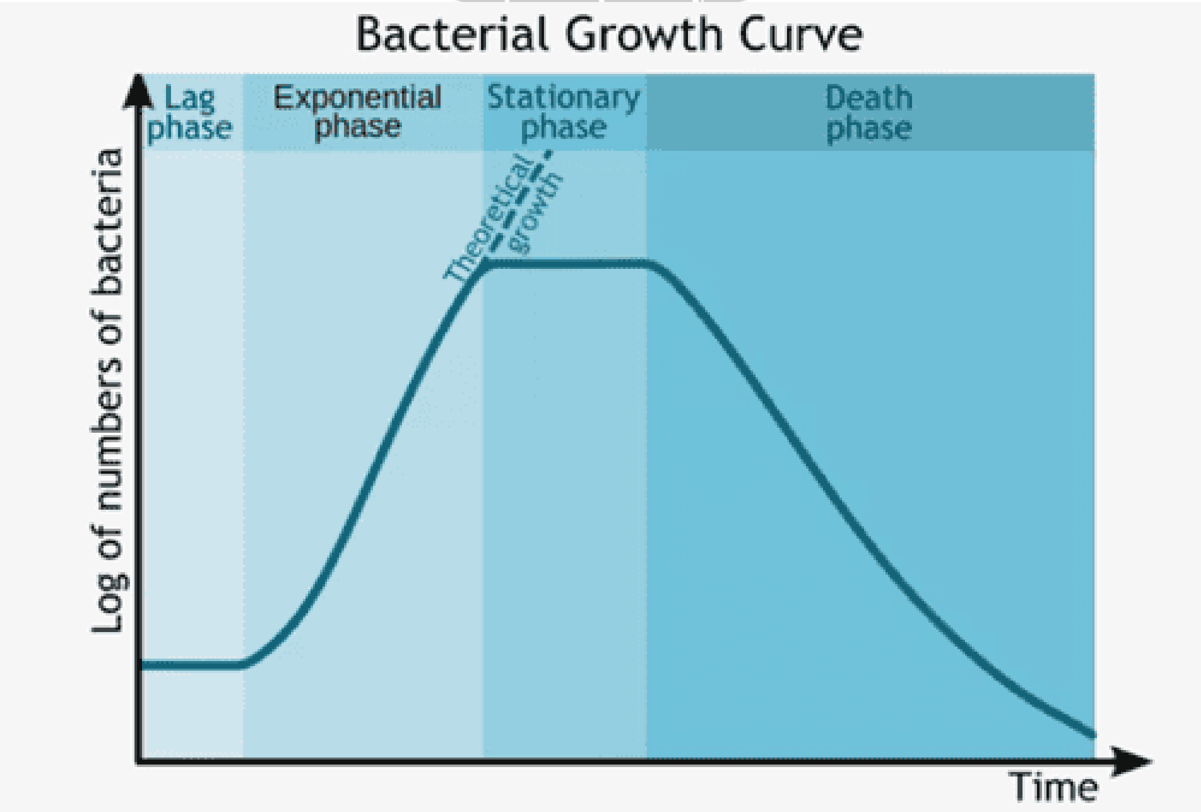

Fig. Bacterial Growth Curve

Four phases are observed in the bacterial growth curve, a number of live cells in bacterial population within a period of time is represented by the growth curve of bacteria:

1. **Lag Phase**- In this phase, cellular activity happens, but no growth is observed. In this stage, cells take nutrition from the medium and synthesize proteins and other molecules which is necessary for the replication process so that cell increase in size, but no division occurs so no change in number is seen in this phase.
2. **Log Phase /Exponential Phase**- This phase comes after lag phase. Currently, bacterial cells are dividing by binary fission and the number of cells double at the end of each generation time, i.e., growth proceeds in a logarithmic way. In this phase, the metabolic activity of each cell is very high. All components and substances necessary for growth are generated; synthesis of primary metabolite occurs in this phase. Proteins for bacterial cell synthesis and also protein and substance synthesis which require in transcription and translation are also generated.
3. **Stationary Phase**- After log phase, cell enters in stationary phase. At this stage of growth, depletion of available nutrition from media starts and accumulation of waste products begins. Bacterial growth reaches it plateau wherein the number of dividing cells equals to a number of dead cell, so no overall growth is observed. Competition for nutrients increase and cell becomes metabolically inactive. Production of secondary metabolites occurs in this phase. In this phase endospore-forming bacteria produce spores.
4. **Death Phase/Decline Phase**- When the availability of nutrients is very less and the accumulation of waste products increase, the number of dead cells continuously increase. In this phase, dead cell numbers increase exponentially so sharp decline is being observed in growth curve in this stage.

Growth Yield:

The defined increment of microbial cell biomass by the utilization of a particular amount of substrate is defined as growth yield.

The maximum specific growth rate is Um= Y.K.

Where Y= maximum yield coefficient K= Kinetic coefficient it depends on the environmental condition.

Growth Rate:

The rate of growth is expressed by Monad equation.

The total rate of microbial growth,

$$dx/dt=Um\ XS/Ks + S$$

where, Um=maximum specific growth

X=Concentration of microorganism

S=Substrate concentration

Ks=substrate concentration at one half of maximum growth rate

And the rate of substrate utilization is calculated by:

$$Ds/dt=k\ Xs\ /Ks+\ S$$

Here, K=maximum specific substrate utilization rate

Strategies of Cell Division:

Binary fission is the commonest method of division of bacteria. Some bacterial species also have some alternative method of division like budding, fragmentation etc. all alternative methods of division need cell division.

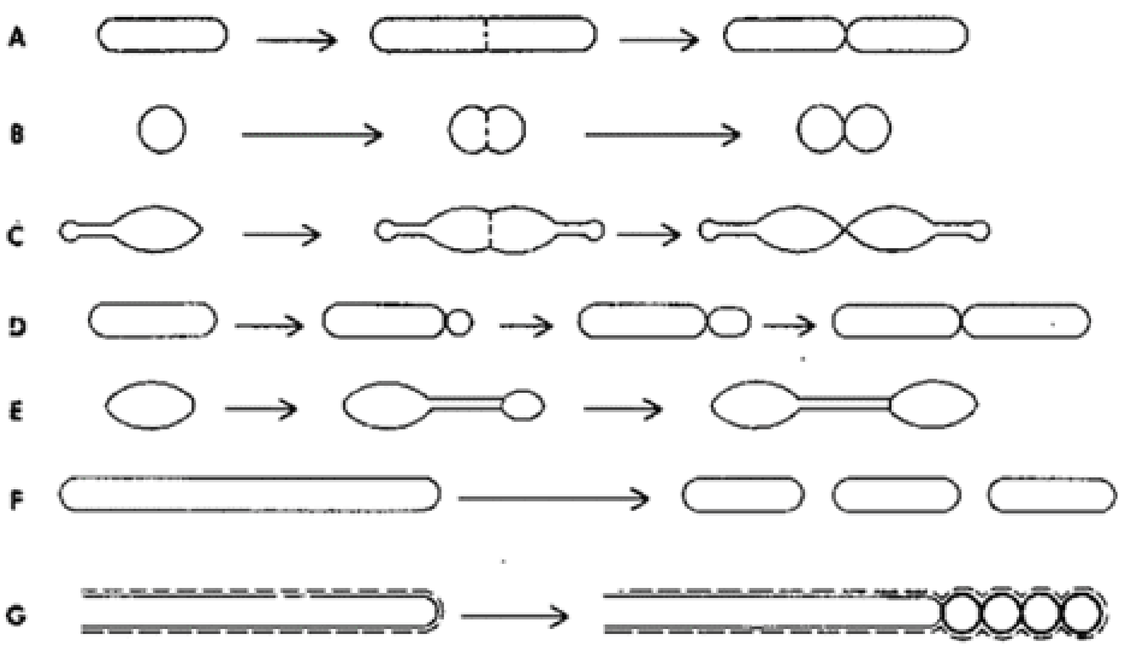

Figure 7-1. Schematic drawing of modes of cell division in various bacteria. Transverse binary fission occurs in *Bacillus subtilis* (A), *Streptococcus faecalis* (B), and the prosthecate bacterium *Prosthecobacter fusiformis* (C); in the latter species the small round area at the tip of each prostheca is a holdfast—a means of attachment to surfaces. Budding occurs in *Rhodopseudomonas acidophila* (D) and *Hyphomicrobium vulgare* (E); in the latter species the mother cell produces a prostheca on which a terminal bud forms; this bud develops into a daughter cell. (F) Fragmentation occurs in the filamentous cells of a *Nocardia* species. (G) Formation of conidiospores by a *Streptomyces* species. A hypha that gives rise to spores is covered by a sheath (represented here by a dashed line); septation occurs at the hyphal tip to produce a chain of conidiospores still enclosed by the sheath.

Different Mode of Cell Division:

1. **Budding -** some bacteria like *Rhodopseudomonas acidophila*, divided by the process of budding. In this a small bud develops at one end of cell that eventually enlarges and develops into a new cell and gets separated from the parent cell. In some bacteria, this bud also develops at the end of prostheca.
2. **Fragmentation** -bacteria those produce extensive filamentous growth, for example, *Nocardia sp*. reproduces by this method. The filament broke into small bacillary and coccoid cells, which give rise to new cell.
3. **Conidiospore -** Some genus like *Streptomyces* and other related bacteria, produces spores by developing cross wall at the tip of hypha and each spore gives rise to new organism.
4. **Binary fission** -

- In eubacteria and archaea, DNA is not enclosed as nucleus is found in specific location and known as nucleoid.
- Several proteins are associated with nucleoid which help to make it compact and organised. And plasma membrane of bacteria and archaea is also very organised with several proteins and enzymes.
- Bacterial DNA attaches with plasma membrane to start the replication (point known as origin). Due to structural arrangements, novel double strand DNA gets formed.
- Movement of origin point progress away from cell wall and attachment starts at the opposite end of cell.
- When replication occurs at same time, cell also grows physically by the synthesis of other component like carbohydrate and proteins, so that cell becomes elongated. And membrane grows and transport the chromosome towards the opposite pole of cell and after that cytoplasmic separation begins.
- A cytoskeletal protein called FtsZ form a ring which directs the partition formation. This ring triggers the accumulation of several proteins composing new cell wall material and gradually a septum is form in an elongated cell, between nucleoid and extended from periphery towards the centre of cell. And when the new cell wall forms, daughter cells separate and becomes two.

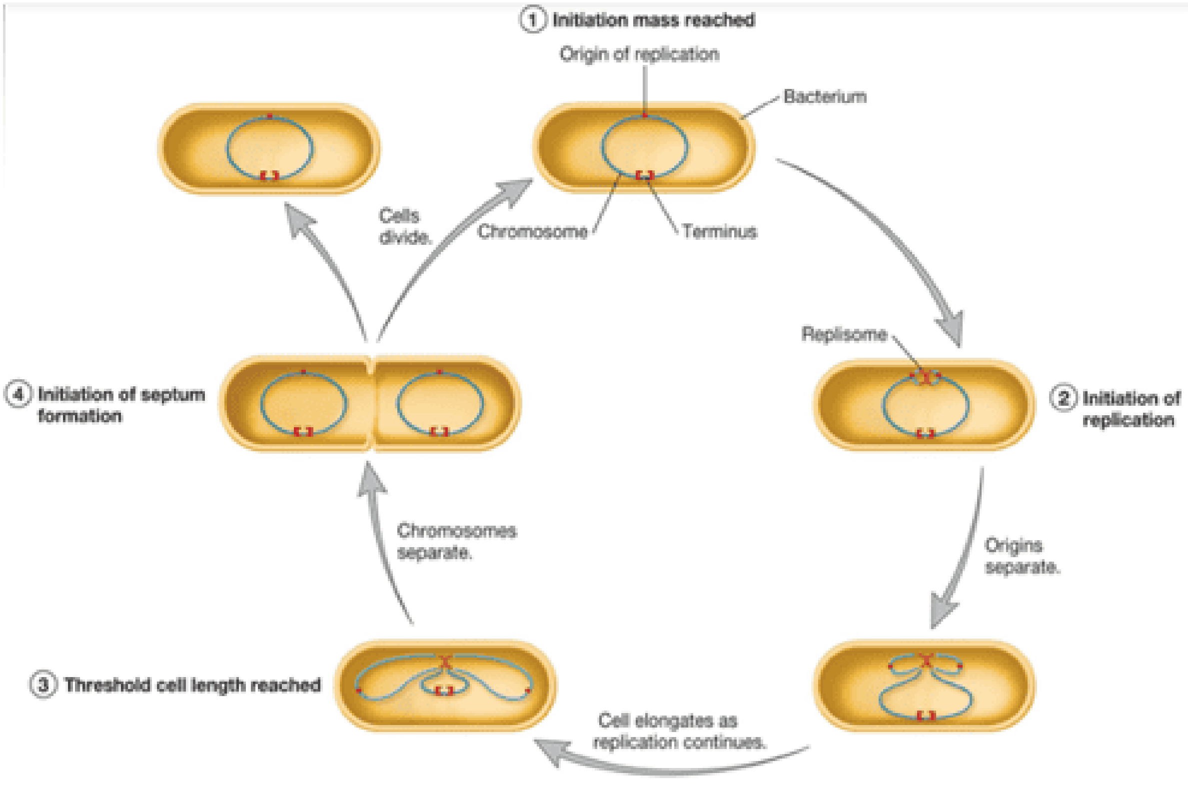

Fig. The process of binary fission