FDE 330
FOOD BIOTECHNOLOGY

Microbial Growth

What is microbial growth?

- **Microbial growth** can be defined as an orderly increase in cellular components, resulting in cell enlargement and eventually leading to cell division.

- This definition is not strictly accurate as it implies that a consequence of growth is always an increase in cell numbers. However, under certain conditions growth can occur without cell division, for example, when cells are synthesizing storage compounds, e.g. glycogen or poly β-hydroxybutyrate. In this situation the cell numbers remain constant, but the concentration of biomass continues to increase. This is also true for coenocytic organisms, such as some fungi, that are not divided into separate cells. Their growth results only in increased size.

What is microbial growth?

- What is Microbial growth?
- involves an increase in the number of cells rather than in the size of individual cells.

- 2 levels of growth:

1. A cell synthesizes new components, increase its size
2. Increase number of cells in the population

- increase in cellular constituents that may result in:
  - increase in cell number
    - e.g., when microorganisms reproduce by budding or binary fission
  - increase in cell size
    - e.g., some microorganisms have nuclear divisions that are not accompanied by cell divisions

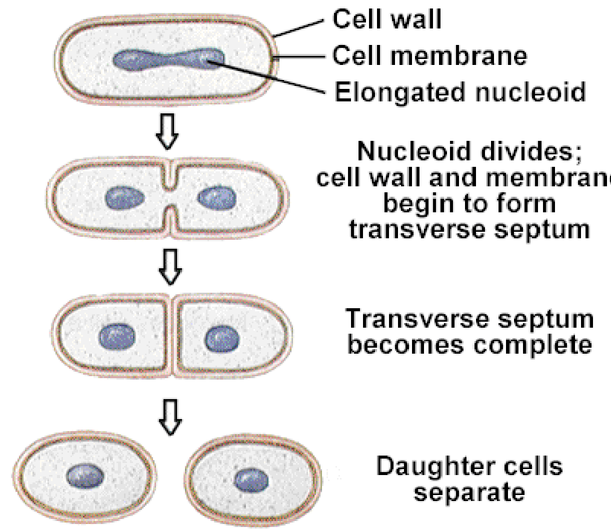
Generation time (Doubling time)

- Each time a cell divides is called a **generation** and the time taken for the cell to divide is referred to as the **generation time**.

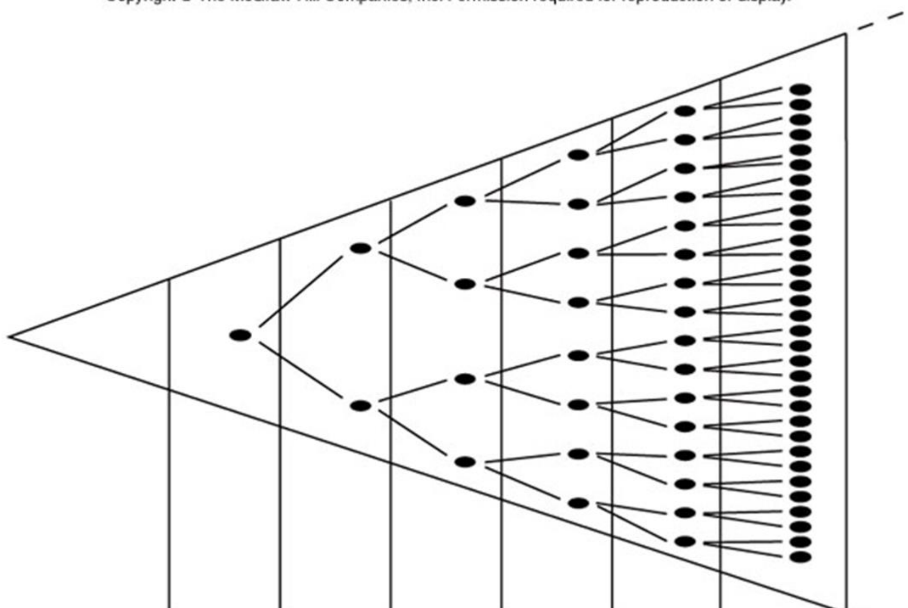
- The generation time or doubling time (t_d) is the time required for a microbial population to double.

Examples (bacterial generation time):

- *Escherichia coli*: 20 minutes
- *Mycobacterium tuberculosis:* 18 hours

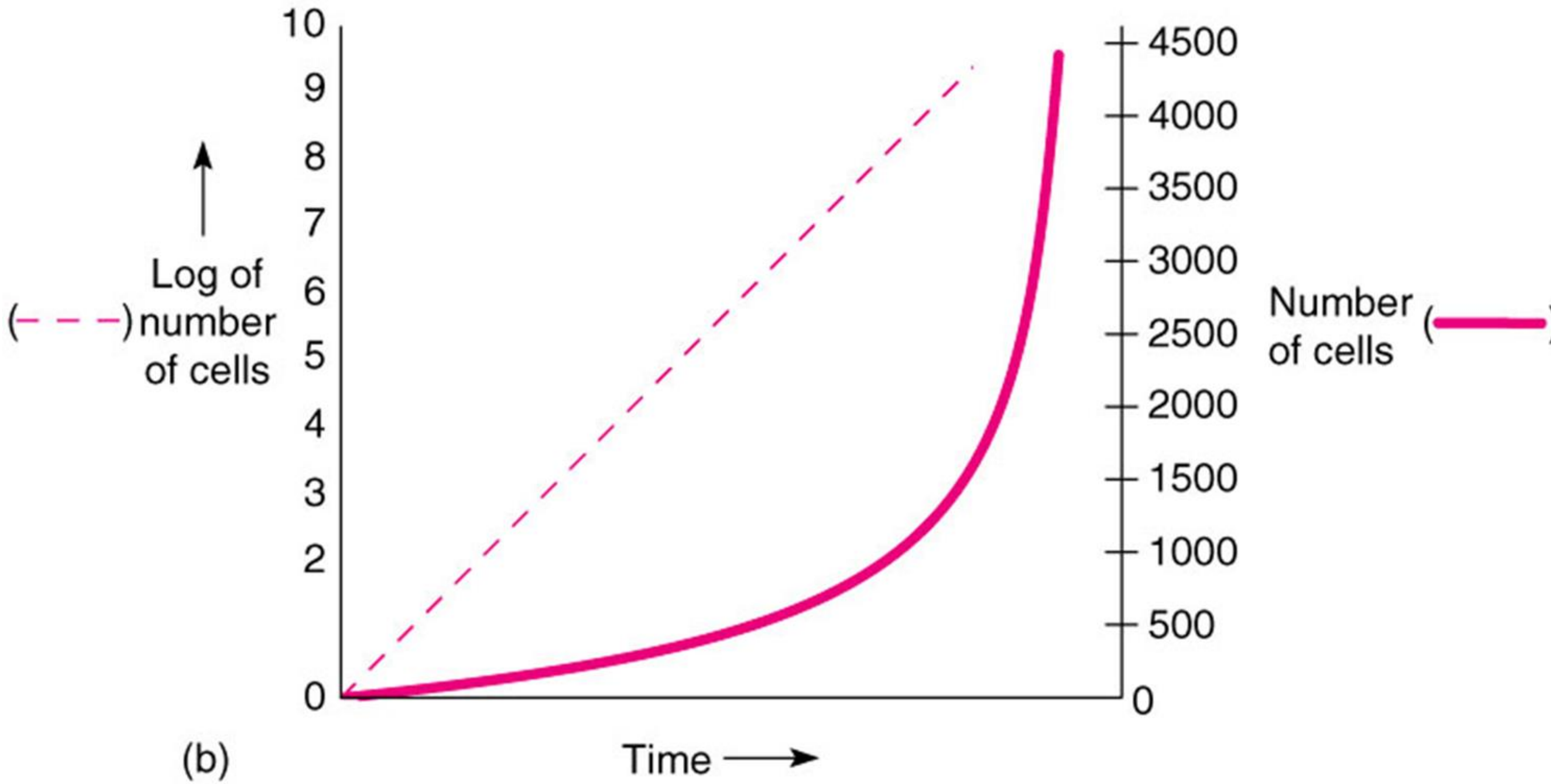


Bacteria undergo exponential growth.



Number of cells	1	2	4	8	16	32
Number of generations		1	2	3	4	5
Exponential value		2^1 (2×1)	2^2 (2×2)	2^3 (2×2×2)	2^4 (2×2×2×2)	2^5 (2×2×2×2×2)

Plotting growth on graphs



Types of fermentations

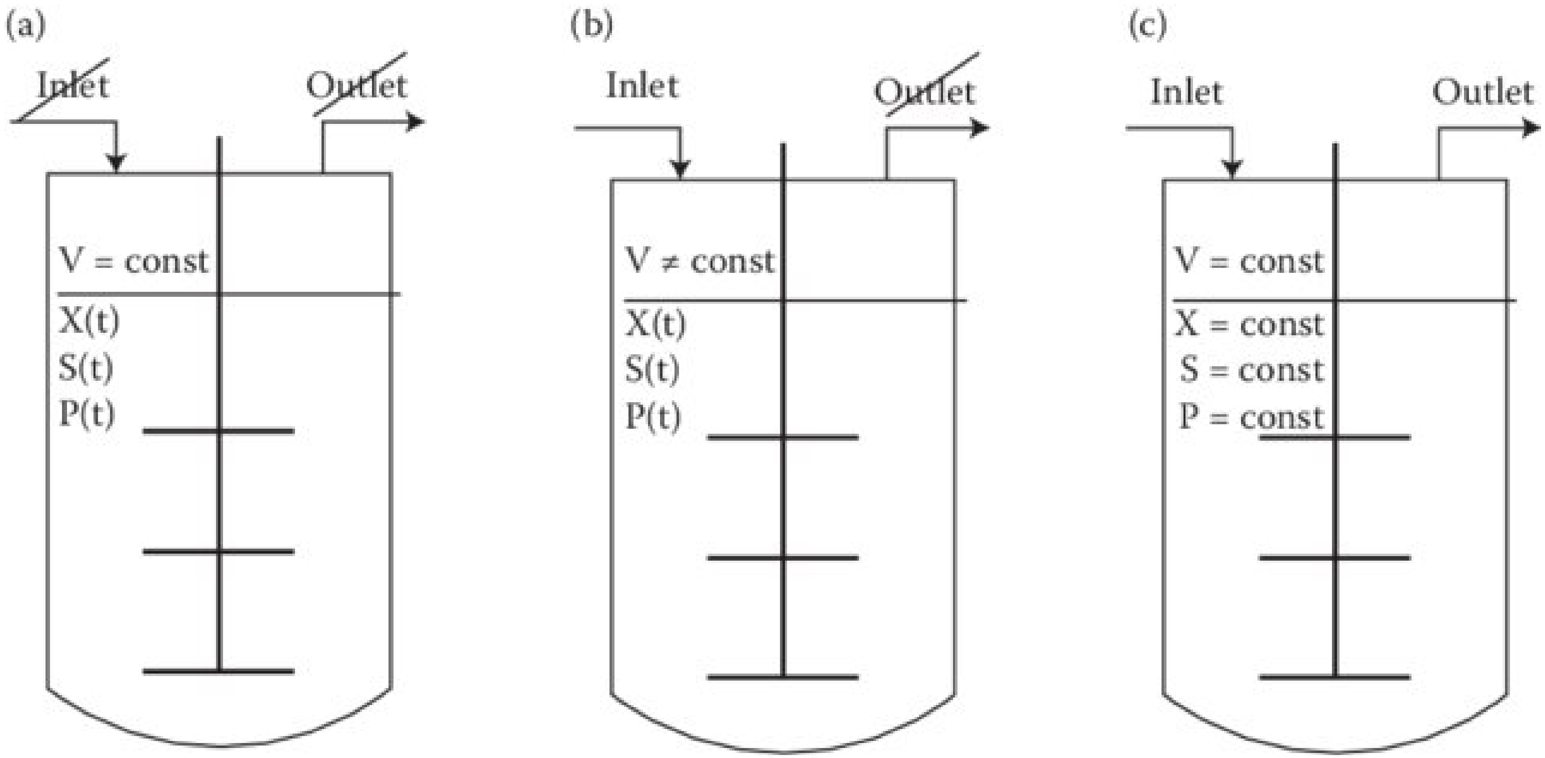
Fermentation processes can be classified into the following three categories.

1. Batch fermentation

2. Fed batch fermentation

3. Continuous culture fermentation

Inlet: Substrate
Outlet: Product



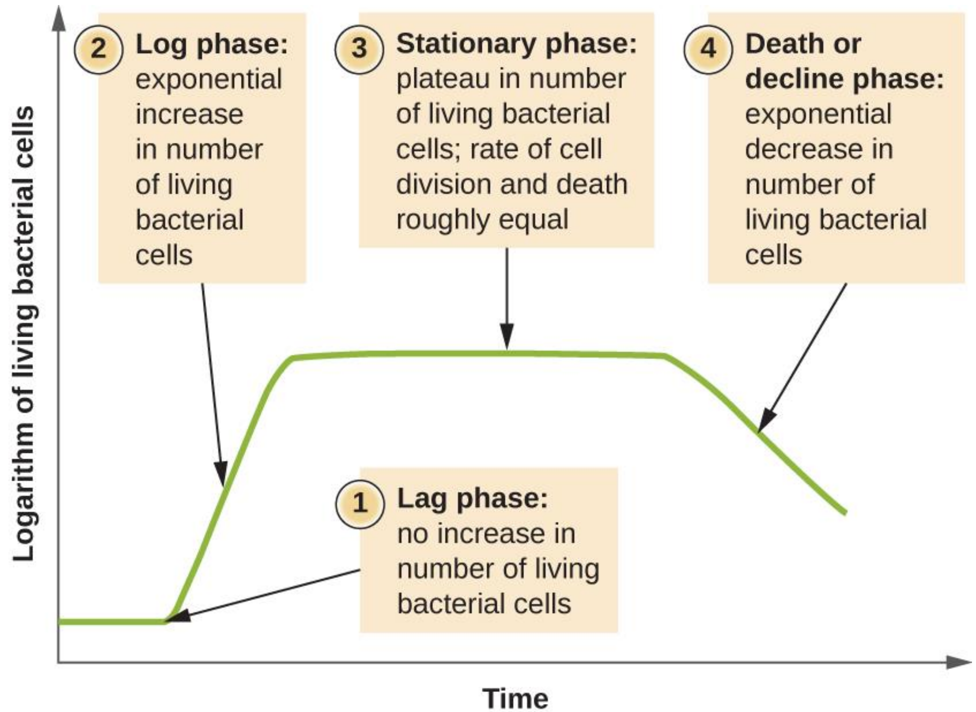
Simplified scheme of (a) batch, (b) fed-batch, and (c) continuous cultivation.

Microbial Growth Curve

The Growth Curve

Microorganisms grown in closed culture (also known as a batch culture), in which no nutrients are added and most waste is not removed, follow a reproducible growth pattern referred to as **the growth curve**.

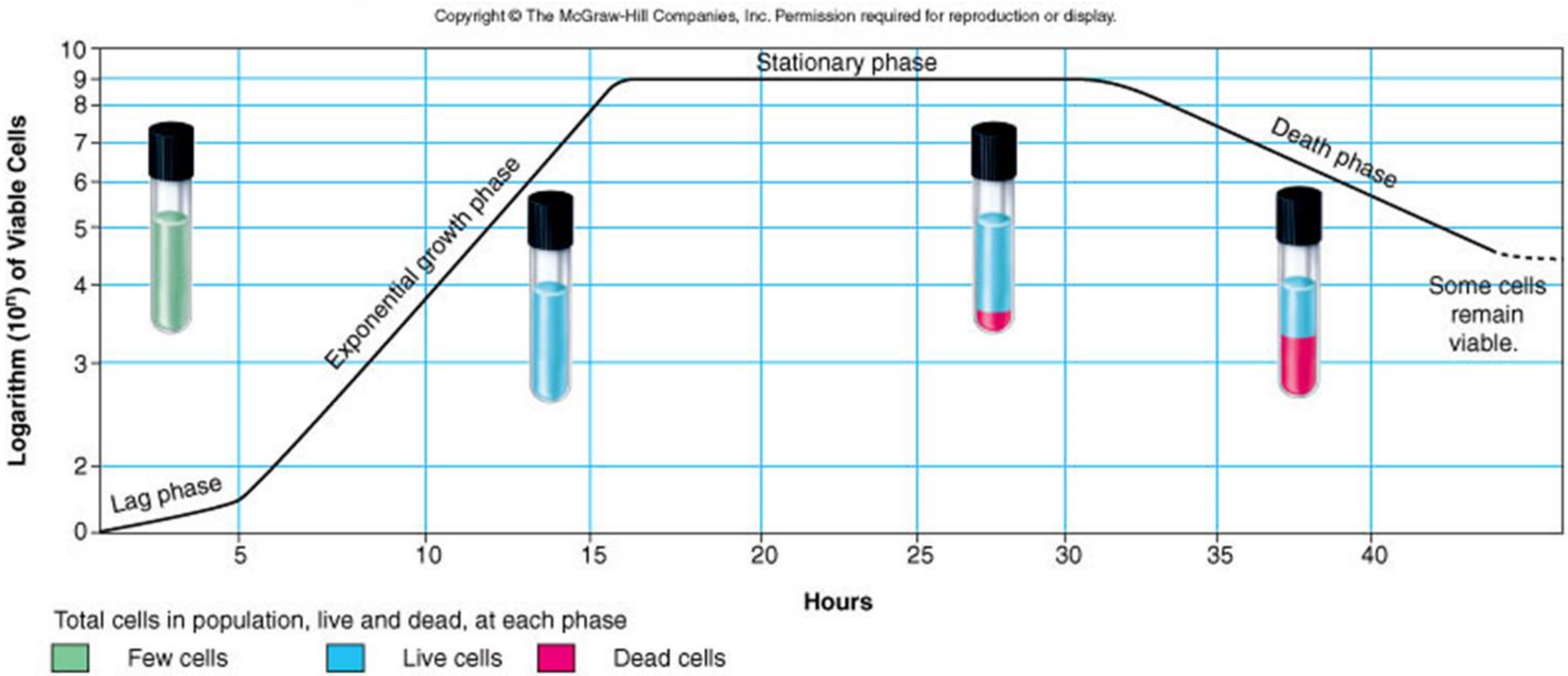
When the number of live cells is plotted against time, **four distinct growth phases** (the lag phase, the exponential or log phase, the stationary phase, and the death or decline phase) can be observed in the curve.



There are four basic phases of growth:

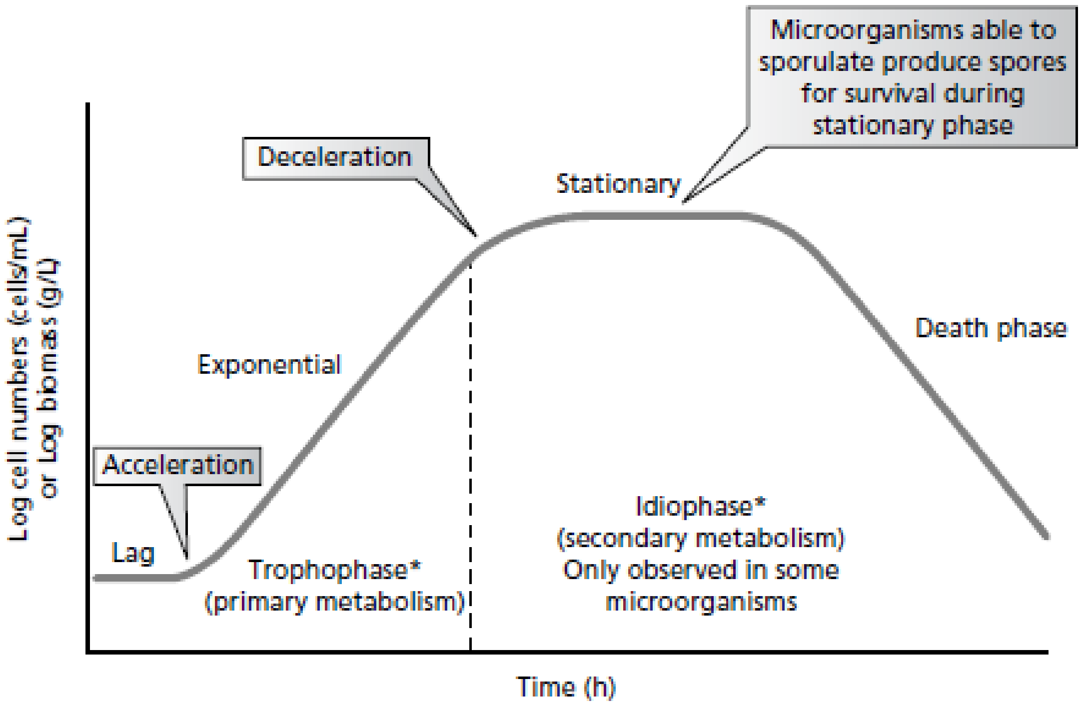
1. **Lag phase**
2. **Log phase**
3. **Stationary phase**
4. **Decline phase**

Stages in Bacterial Growth



- When a few bacteria are inoculated into a liquid growth medium, it is possible to plot a <u>bacterial growth curve</u> that shows the growth of cells over time.
- There are four basic phases of growth: **1-the lag**, **2-log (exponential)**, **3-stationary**, and **4-death phases**.

Microbial Growth Curve



Growth of a microorganism in a batch culture

During batch fermentations the populations of microorganisms goes through several distinct growth phases:

1. Lag
2. Acceleration
3. Exponential Growth
4. Deceleration
5. Stationary
6. Death

Microbial Growth Kinetics

- **Growth kinetics**; describe the growth and product formation of microorganisms with mathematical equations.

- This includes not only active cell growth, but also the activities of cells in stationary or death phase.

- Because many commercially important fermentation products occur after cell growth is completed.

- In some industrial productions, the enzymes released after the cell dies perform the necessary biotransformation and provide product formation.

Microbial Growth Kinetics

- Mathematically, the exponential growth can be described by 2 methods;
  - One is related to biomass (X)
  - The other is related to cell numbers (N)

Microbial Growth Kinetics

- $$\frac{dX}{dt} = \mu X$$

- $$\frac{dN}{dt} = \mu_n N$$

X : Concentration of biomass (g/L)

N: Cell number (cells/mL)

t : Time (h)

μ : Specific growth rate (per hour) (h^{-1}) (cell mass)

μ_n : Specific growth rate (per hour) (h^{-1}) (cell number)

1. The first equation shows the increase in cell mass over time.

2. The second equation shows the increase in cell number over time.

Microbial Growth Kinetics

Taking the integral of this equation, we have;

$$\int_{x1}^{x2} \frac{dX}{X} = \int_{t1}^{t2} \mu \, dt$$

Microbial Growth Kinetics

When $X_2 = 2X_1$;

Δt; $(t_2 - t_1) = t_d$, so it shows **the doubling time** and from here;

$$t_d = \frac{ln(X_2/X_1)}{\mu} = \ ln\,\frac{2}{\mu} = \frac{0,693}{\mu}$$

Problem-1

The biomass concentration values measured from the samples withdrawn from the culture medium of a microorganism at certain intervals are given as follows. Calculate the maximum specific growth rate of the microorganism.

Time (hour)	2	4	6	8	10	12	14	16	18	20
X (g/L)	0,95	1,063	1,513	2,010	2,313	2,550	2,750	2,906	3,060	3,068

Microbial Growth Kinetics

The growth of microorganisms in the logarithmic phase is exponential and given by the following equations.

$N = N_o e^{\mu t}$

or

$X = X_o e^{\mu t}$

Here, N_0 or X_0 indicates the initial cell concentration in the medium, and N or X indicates the microorganism concentration at any time t.

Microbial Growth Kinetics

Taking the natural logarithm of this equation;

$$ln N = ln N_o + (\mu\, t)$$

or

$$ln \frac{N}{N_0} = \mu\, t$$

the above equations are obtained, similar to the equation given before.

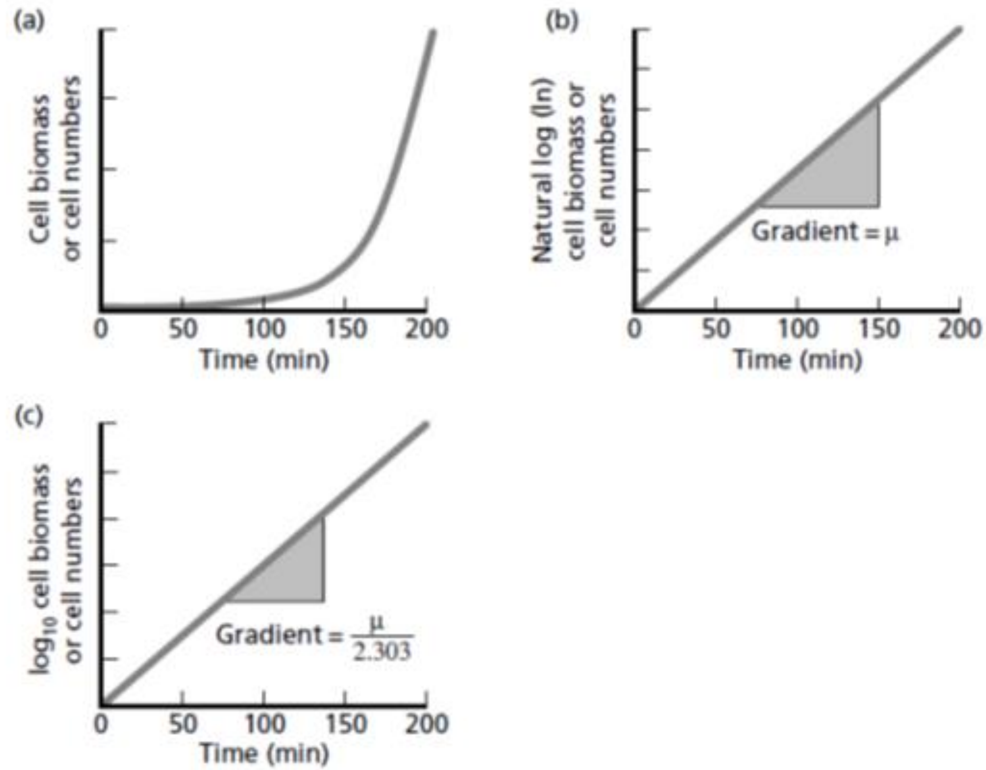


Fig. 2.2 Exponential growth of a unicellular microorganism with a doubling time of 20 min (a) arithmetic plot, (b) semilog plot using natural logarithms and (c) semilog plot using logarithms to the base 10 (μ = specific growth rate).

a) When a graph is plotted of cell biomass against time, the product is a curve with a constantly increasing slope.
b) For cells in exponential phase, a plot of natural log of biomass concentration against time, a semilog plot, should yield a straight line with the slope (gradient) equal to **μ**.
c) When plotting log10 values instead of the natural log, the gradient of the semilog plot is equal to **μ/2.303**.