# ABE 572
# Bioprocess Engineering

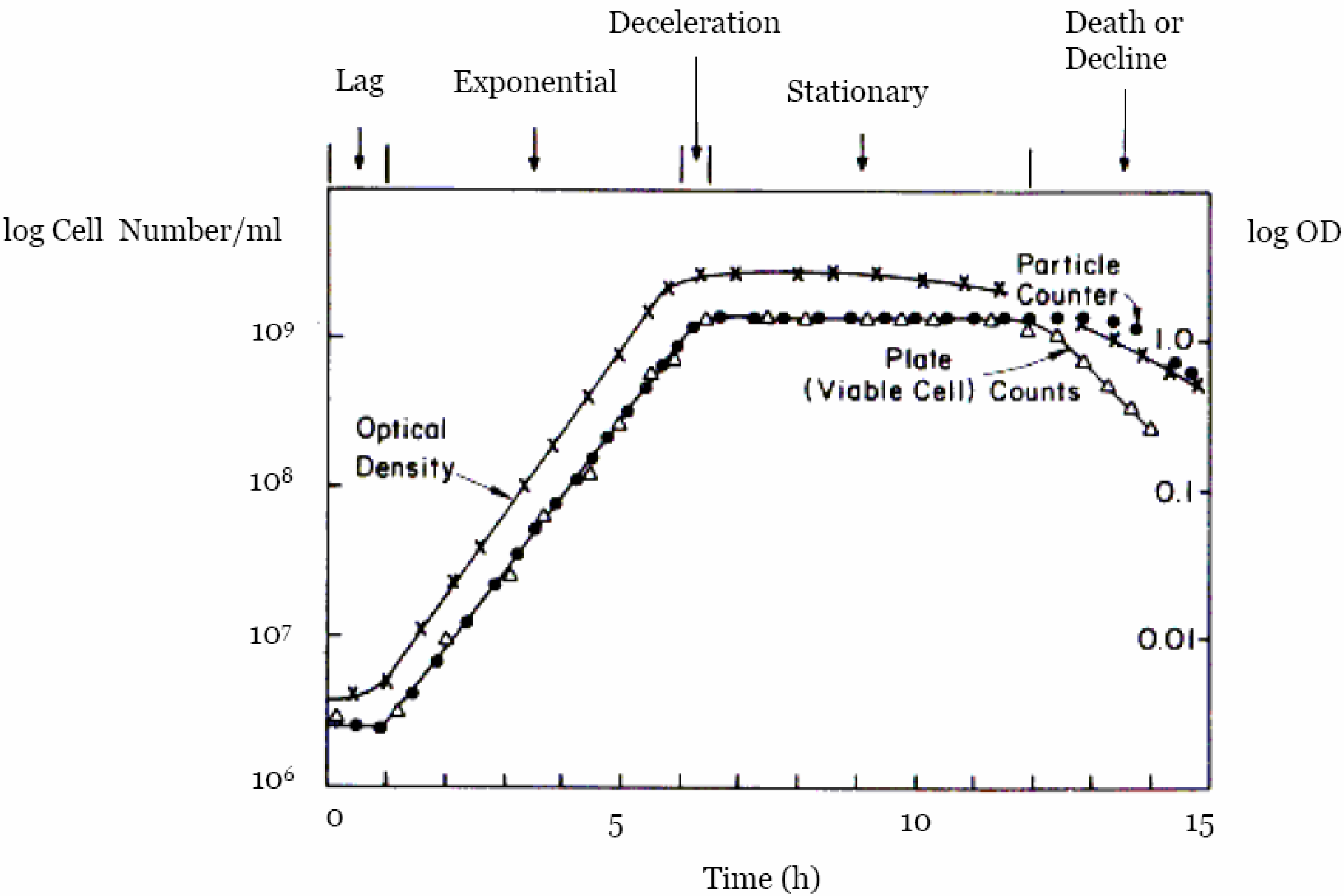
## Lecture 1: Cell Growth

# Phases of cell growth

Cell growth can be modelled with four different phases:

- **Lag phase**: Cells adapt themselves to growth conditions. It is the period where the individual bacteria are maturing and not yet able to divide.
- **Exponential phase** (log phase) is a period characterized by cell doubling. The number of new bacteria appearing per unit time is proportional to the present population.

- **Stationary phase** is often due to a growth-limiting factor such as the depletion of an essential nutrient, and/or the formation of an inhibitory product such as an organic acid. Stationary phase results from a situation in which growth rate and death rate are equal.
- At **death phase**, bacteria run out of nutrients and die.




Typical growth curve for a bacterial population. Note that the phase of growth (shown here for cell number) depends on the parameter used to monitor growth.

# Cell growth in bioreactor

Why use a bioreactor?

- control parameters: dissolved oxygen, temperature, pH
- increase scale of culture
- model industrial production system
- control growth rate (use chemostat)

If you want simply to produce a few cells, a simple flask and a controlled temperature shaker will do the job.

Substrates + Cells $\longrightarrow$ byproducts + more cells

$$\Sigma S + X \longrightarrow \Sigma S + nX$$

Specific Growth rate ( $\mu$ ) $\Rightarrow$

$$\mu = \frac{1}{X}\frac{dX}{dt}$$

also,

$$\mu = \frac{d \ln X}{dt}$$

Where $X$ is cell mass concentration (g/l), $t$ is time (h) and $\mu$ is specific growth rate ($h^{-1}$).

If μ is constant w.r.t., then rearranging previous equation and integrating, we get:

$$\int_{X_0}^{X} \frac{dX}{X} = \int_{0}^{t} \mu dt$$

or $$Ln\frac{X}{X_0} = \mu t$$

or $$X = X_0 e^{\mu t}$$

This equation applies only to the duration of the exponential growth phase, beyond which either substrate limitation or toxin accumulation become rate determining.

# Doubling Time

- It is the time required to double the quantity of biomass, that is growing exponentially.

- **X:** $X_0 \rightarrow 2X_0$ (The amount of biomass at the start must double)
  **t:** $0 \rightarrow td$ (Within a finite time, td, or doubling time)

$$\frac{X}{X_0} = e^{\mu t}$$

Substituting in $2X_0$ for $X$ and $td$ for $t$ *and* logging both sides

$$\frac{2X_0}{X_0} = e^{\mu t_d} \Rightarrow \ln 2 = \mu . td$$

, therefore

$$td = \frac{\ln 2}{\mu} = \frac{0.693}{\mu}$$

- Specific growth rate (μ) can be defined as any point during the growth cycle.

  During the exponential growth period is constant and at a maximum for that

  process under the specified conditions.

# Next lecture

- Chemostat
- Fed-Batch Reactor