Growth curves of micro-organisms

- Bacteria divide by **Binary Fission**.
- This is a form of **asexual reproduction**.
- Under ideal conditions it can take place every 20 minutes!
- In this way huge numbers of bacteria can be produced very rapidly.

- Because of this we use a special scale called the logarithmic scale to represent their numbers.

- In a logarithmic scale each division represents a unit increase in the value of x in the term 10^x.

- **Thus:**

$10^0 = 0$

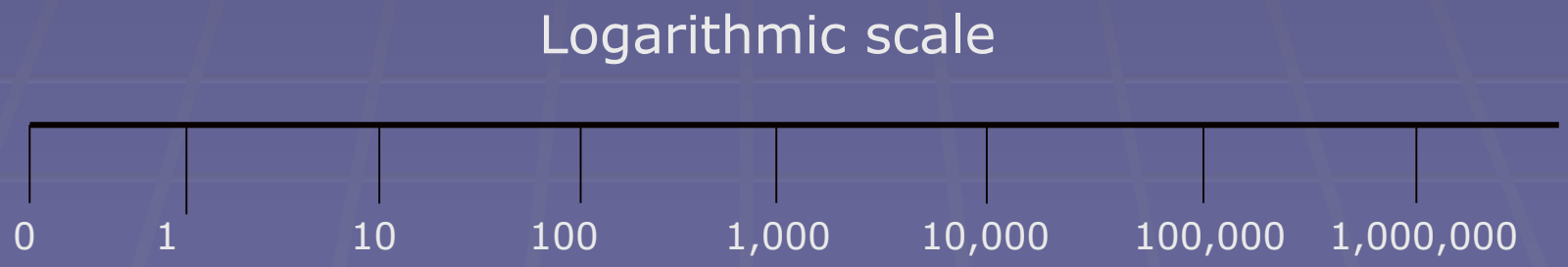
$10^1 = 10$

$10^2 = 100$

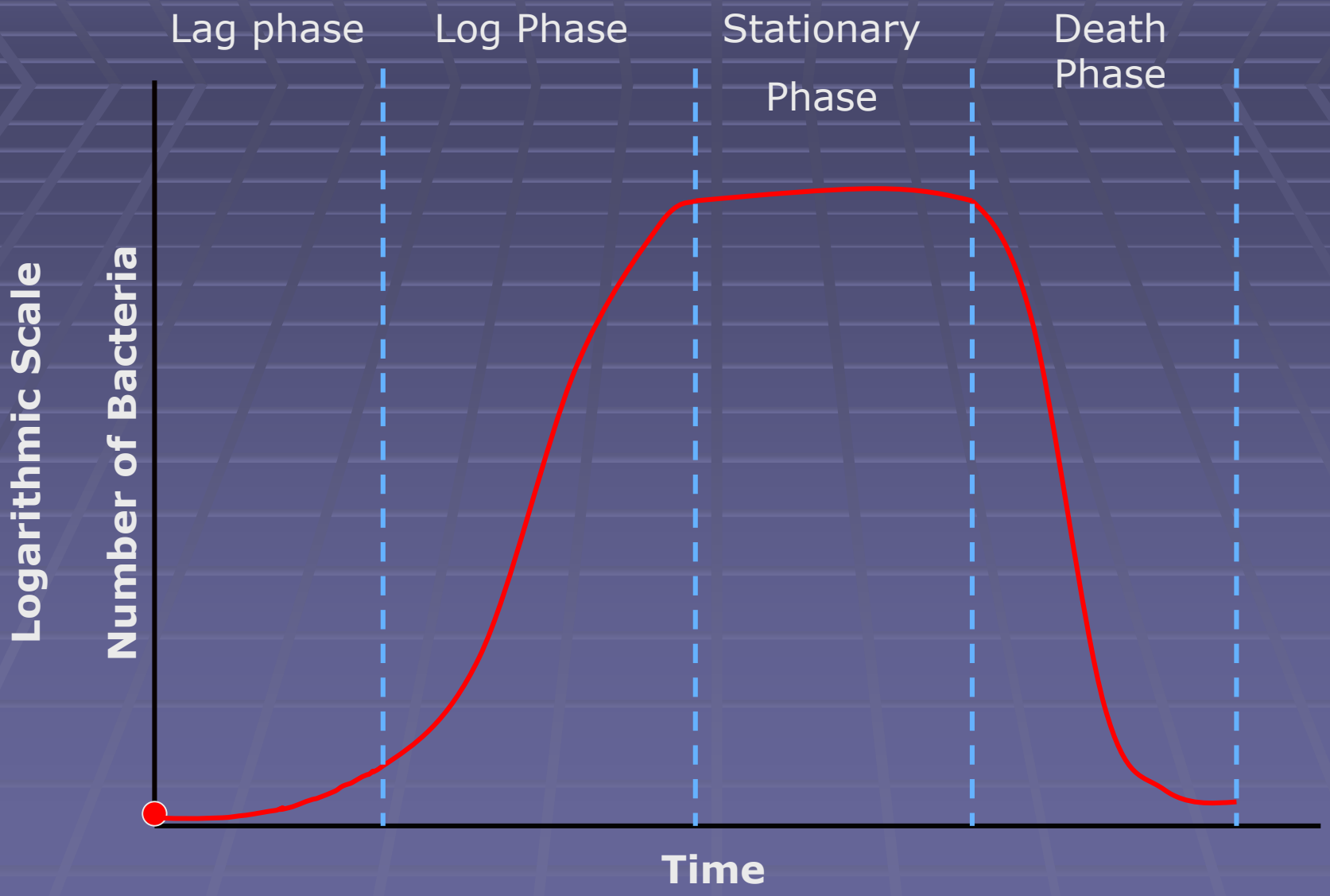
$10^3 = 1000$

$10^4 = 10{,}000$

$10^5 = 100{,}000$ etc



Growth curve for Bacteria



The Lag Phase

- After inoculation there is normally a brief period of adaptation by the cells to the new conditions.
- Bacteria are producing the enzymes necessary to digest the nutrients.
- The rate of growth begins to increase towards the end of this phase.

The Log (Logarithmic / Exponential) phase

- There is a rapid period of growth during this phase due to the fact that:
- Bacteria have developed the necessary enzymes and there are plenty of nutrients.
- There are few waste products being produced.
- The rate of cell division is currently at its maximum with the number of bacteria doubling as often as every 20 minutes.

Limitation of log or exponential phase

- Exhaustion of nutrition
- Accumulation of toxic metabolites end products
- Rise in cell density
- Change in PH

[Log phase is the time when cells are most active metabolically and is preferred for industrial purpose]

The Stationary Phase

- The rate of growth levels stop during this period.
- This is because:
  - The nutrients are becoming used up.
  - The amount of waste produced by the bacteria themselves is increasing.
  - The rate at which new cells are produced is equal to the rate at which other cells are dying.

The Death (Decline) Phase

During this phase more bacteria are dying than are being produced. This is because:

- Very few nutrients are left.
- Many bacteria are poisoned by the waste produced by such large numbers
- Finally, after certain time period all the cells die and culture becomes sterile.

Association of Growth and Cell Changes

- Lag Phase- maximum cell size towards end of phage
- Log Phase- cells are smaller and stain uniformly
- Stationary Phase- cells are Gram variable and irregular staining due to presence of intracellular granules, Sporulation occurs
- Decline Phase- involution forms are common

Batch and Continuous Flow Culture

A bioreactor is a vessel in which biological reactions take place

Food processing

- Modern bio-processing methods involve the use of bacteria (and other organisms) to produce a wide range of products.
- These include dairy products e.g. yoghurts and cheeses, artificial sweeteners, flavourings, vitamins and alcohol products such as wines and beers.

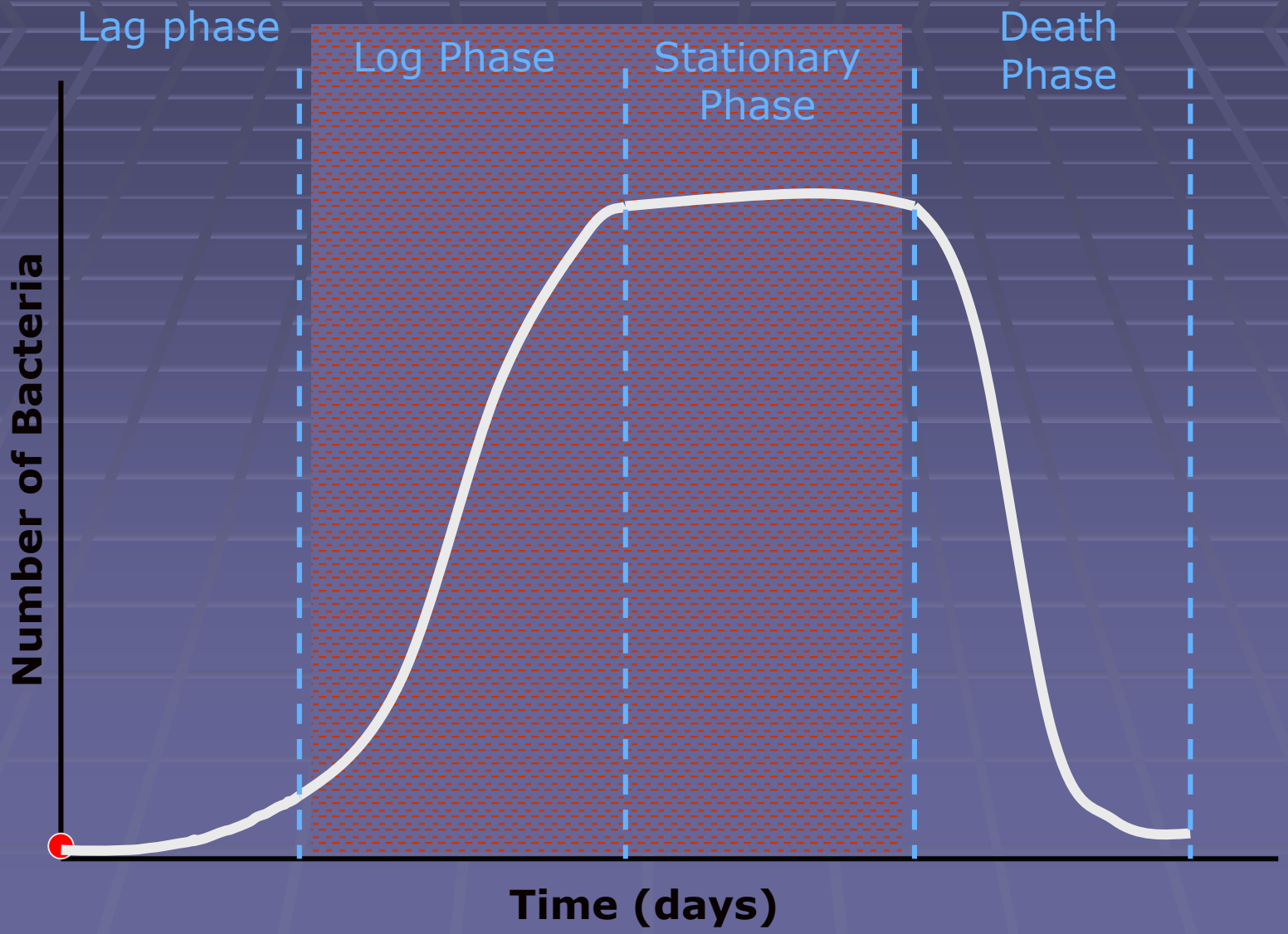
Food processing

- There are two main methods of food processing:
- Batch culture
- Continuous culture

Batch Culture

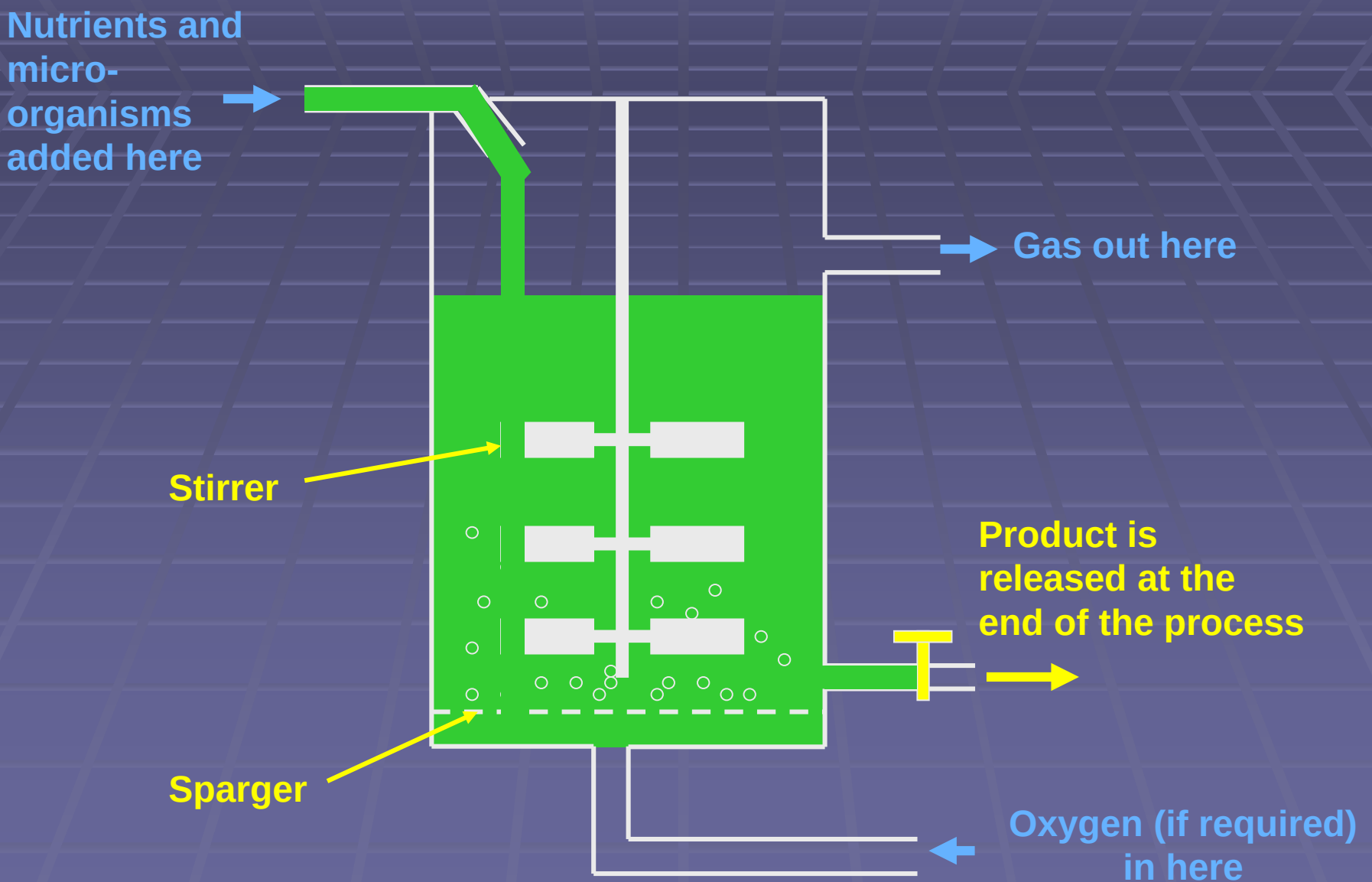
- In batch food processing a fixed amount of sterile nutrient is added to the micro-organisms in the bioreactor.
- The micro-organisms go through the stages of a typical growth curve
- i.e. The Lag, Log, Stationary and Death stages
- Although the reaction may be stopped before the death stage as very little product will be formed at this stage.

In Batch Processing most of the product is formed during the stages highlighted below



- At the end of production the bioreactor is cleared out. The product is separated from the rest of the solution and is purified.
- The bioreactor is cleaned and re-sterilised.
- The process can then be repeated.

Bioreactor for Batch Culture



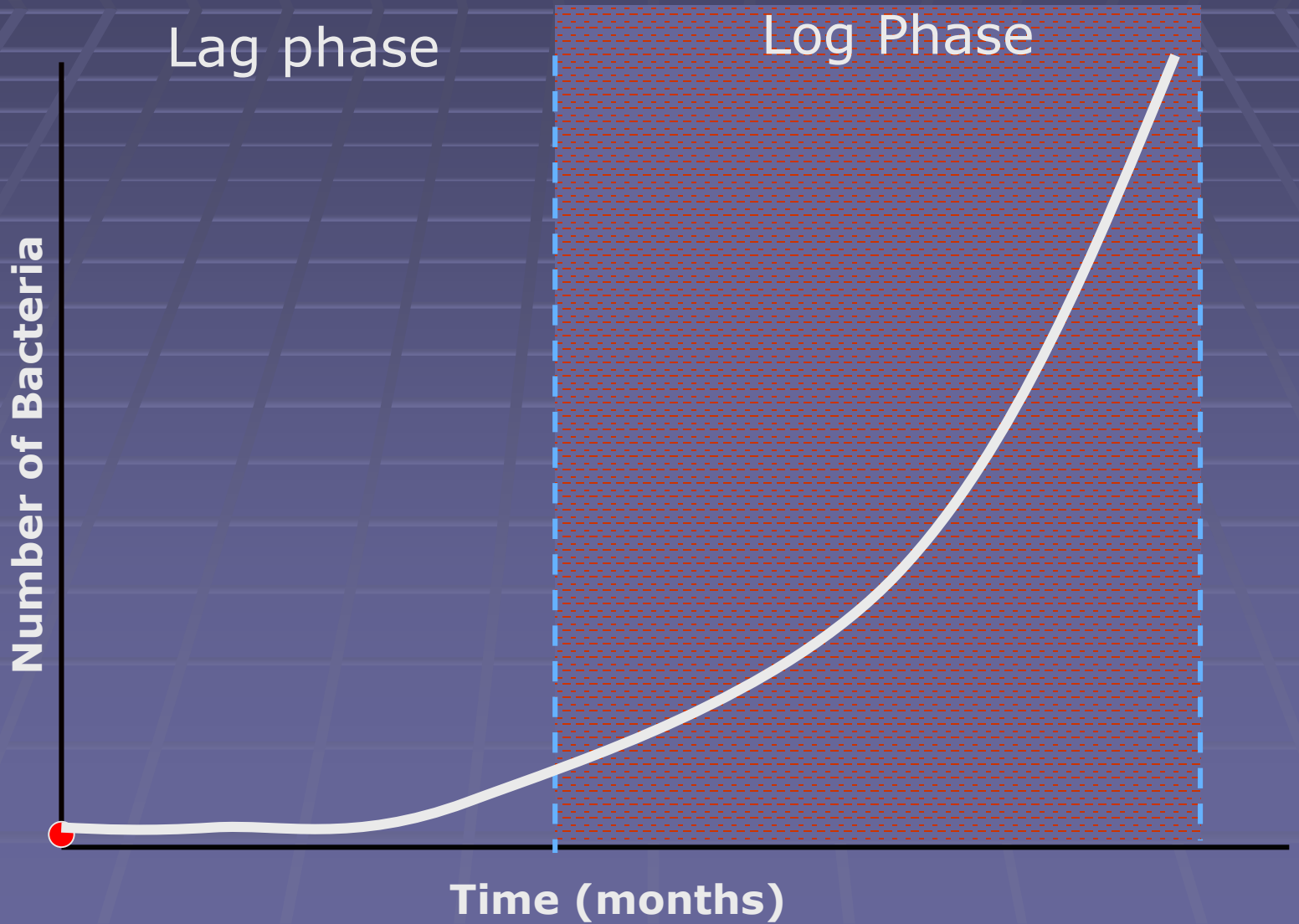
Continuous Culture

- In continuous culture nutrients are continuously fed into the bioreactor.
- At the same time the culture medium (containing some micro-organisms) is continually withdrawn.
- In this method of food processing micro-organisms are maintained in the Log phase of growth and the process can continue uninterrupted for weeks, even months.

Continuous flow food processing

- In continuous flow bioreactors factors such as temperature, pH, rate of stirring, concentration of nutrients, oxygen and waste products are constantly monitored in order to maintain growth in the Log phase and therefore produce the maximum yield.

In Continuous culture most of the product is formed during the stage highlighted below



Bioreactor for Continuous Culture