CHAPTER (3)

BACTERIAL GROWTH & PHYSIOLOGY

• Growth involves **increase in size & number** of organisms

• **In the laboratory, bacterial growth can be seen in one of two main forms:**

❶ Development of colonies	❷ Development of turbidity
Which are the **macroscopic products of 20-30 cell divisions** of **single bacterium** on **solid media**	Transformation of **clear fluid medium** to **turbid suspension**

Bacterial Reproduction

Bacterial multiplication takes place by simple binary fission:

❶ The cell **grows in size**, usually **elongates**
❷ The **bacterial chromosome** acts as **template** for **replication of another copy**
❸ Each **copy** becomes **attached to a mesosome** on **cytoplasmic membrane**
❹ **Protoplasm** becomes **divided into two equal parts** by **growth of transverse septum** from cytoplasmic membrane & cell wall

∗ In **some species**, this **septum splits the parent cell completely** into **two separate daughter cells**

∗ In **others**, the **cell walls of daughter cells** remain **continuous for some time after division** → giving the **characteristic arrangement**, e.g. pairs, clusters or chains

Generation time (doubling time):

∗ Time **between two successive divisions**
∗ It may be **as short as 13 min.** in ***Vibrio cholerae*** & may **reach 24 h. in *Mycobacterium tuberculosis***

Growth Requirements

In order to grow and divide, bacteria need the following growth requirements:

① Nutrients

According to the means by which a particular organism obtains energy & raw material to sustain its growth, bacteria are classified into:

① Autotrophs	② Heterotrophs
• They can **utilize simple inorganic materials** → e.g. CO_2 as a source of carbon & ammonium salts as a source of nitrogen	• These bacteria, on the other hand, **require organic sources carbon**
• They **can synthesize complex organic substances** from **simple inorganic materials**	• They **can not synthesize complex organic substances** from **simple inorganic sources**
• **Energy required for their metabolism** is predominantly **derived from light** or **simple chemical reactions**	
• Autotrophs are of **no or little medical importance**	• Most bacteria of **medical Importance** are **heterotrophic**

② Oxygen (O_2)

According to O_2 requirements, bacteria are classified into:

	Definition	Example
① Strict or obligate aerobes	Require **oxygen** for growth	***Pseudomonas aeruginosa***
② Strict or obligate anaerobes	Require complete **absence of oxygen**	***Bacteroides fragilis***
③ Facultative anaerobes	Generally grow **better in** presence of **O_2** but still are **able** to **grow in its absence**	***Staphylococci***, ***E. coli***, ... etc
④ Micro-aerophilic organisms	Require **reduced oxygen** level	***Campylobacter*** & ***Helicobacter***
⑤ Aerotolerant anaerobes	Have **anaerobic metabolism** → but can **tolerate presence of oxygen** because they possess superoxide dismutase	***Clostridium perfringens***

Respiration & energy production:

- Cellular respiration is **another name of glucose catabolism**
- When it takes place in **presence of oxygen** → it is called **aerobic cellular respiration**
- When it takes place in **absence of oxygen** → it is called **anaerobic cellular respiration**

① Aerobic cellular respiration	② Anaerobic cellular respiration
∗ **Glucose catabolism** under **aerobic** condition	∗ It occurs in **absence of oxygen**
∗ The **final electron acceptor** is **molecular O_2**	∗ The **final electron acceptor** is **inorganic molecule** as nitrate (NO_3), sulfate (SO_4^{-2}), or CO_2
∗ Results in production of energy = **38 ATP molecules**	∗ The net yield of **ATP molecules** is **less than** it is with aerobic cellular respiration → because nitrate, sulfate, and CO_2 are not as good at accepting electrons as oxygen
∗ During this type of respiration, **superoxide (O_2^-)** & **hydrogen peroxide (H_2O_2)** are formed → these molecules are **highly toxic**	
∗ To cope with this, **aerobic organisms** have **developed two enzymes** (**superoxide dismutase** & **catalase**) → which detoxify these molecules	∗ Compared to aerobes, **obligate anaerobes lack superoxide dismutase** & **catalase** → so they **can not grow in presence of O_2**

③ Fermentation

∗ It is **anaerobic process**, because it takes place in **absence of oxygen**

∗ It is **used by facultative anaerobes** when they **exist in environment that does not contain suitable inorganic final electron acceptor (NO_3, SO_4^{-2} or CO_2)**

∗ This is the **least efficient method of generating energy**

③ Carbon dioxide (CO_2)

- The **minute amount of CO_2** present **in air** is **sufficient for most bacteria**
- However, certain species require **higher concentrations (5-10%) of CO_2 for growth** (**capnophilic**) → e.g. ***Neisseria spp.*** & ***Brucella abortus***

④ Temperature

① Mesophiles	② Psychrophiles (Cold-loving)	③ Thermophiles (Heat-loving)
• Organisms **grow** within temperature range of **20-40°C** • **Pathogens** which replicate on or in human body are able to grow within this range with **optimum temperature of 37°C** which is the normal body temperature	Capable of growth at **refrigeration temperature (0-8°C)** → e.g. ***Flavobacterium spp.***	Grow best at **high temperature (> 60°C)** → e.g. ***Bacillus stearothermophilus***

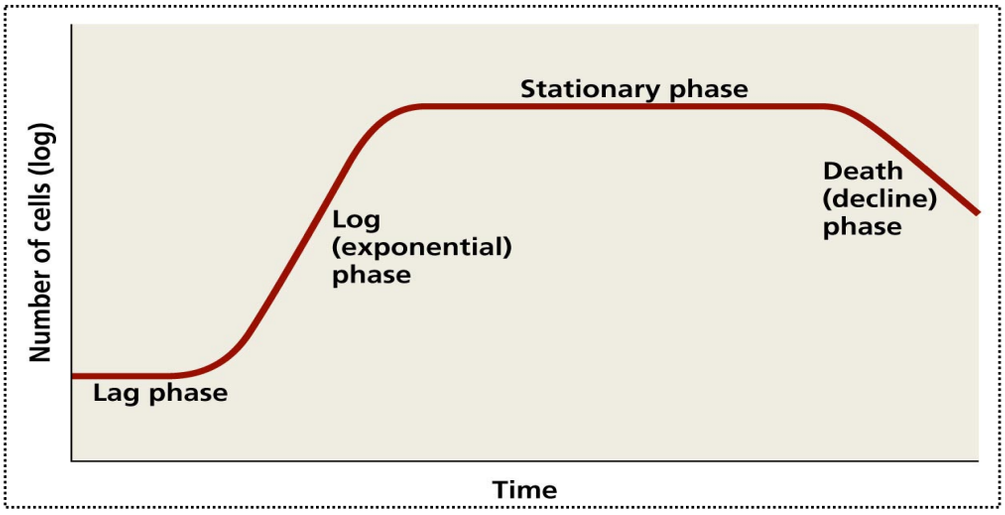
⑤ Hydrogen ion concentration (pH)

• **Most microorganisms** of **clinical significance grow best** in media whose pH is close to that of human body → (**pH = 7.2**)	• However, some M.Os grow better at **alkaline pH (8-9)** → such as ***V. cholerae***	• Others, prefer **acidic pH (4 or less)** → such as ***lactobacilli***

Growth Phases (Bacterial Growth Curve)

If small number of organism is placed in suitable fluid nutrient medium under appropriate physical & chemical conditions, then number of viable cells per milliliter is determined periodically, & plotted → characteristic growth curve with four phases is obtained:

① Lag phase	• Initial **number of bacterial** cells remains **constant** • During this period: ❶ **cells adapt to their new environment** ❷ **Enzymes & intermediates are formed** to permit growth
② Exponential (logarithmic) phase	• There is **marked increase in cell number** & its **rate is accelerated exponentially** with time giving **characteristic linear plot** on a **logarithmic scale** • In this phase, the **organism** shows **typical morphology**
③ Stationary phase	• **Exhaustion of nutrients** & **accumulation of toxic products** cause growth to decrease • There is **slow loss of cells through death** which is just **balanced by formation of new cells** through growth & division • **Number of viable bacteria remains constant**
④ Decline phase	• At the end of stationary phase, **death rate increases** & exceeds multiplication rate due to **nutrient exhaustion** & **accumulation of toxic metabolic end products** • The **number of viable bacteria decreases**



Test Yourself

1) What types of bacteria synthesize organic compounds from inorganic compounds?

a- Heterotrophs
b- Obligate anaerobes
c- Aerobes
d- Facultative anaerobes
e- Autotrophs

2) Which of the following best describes bacteria that lack catalases but not superoxide dismutase?

a- Obligate aerobe
b- Obligate anaerobe
c- Facultative anaerobe
d- Aerotolerant anaerobe
e- Microaerophilic

3) Capnophilic bacteria require:

a- Low concentration of O_2
b- High concentration of O_2
c- High concentration of CO_2
d- Alkaline pH
e- High temperature

4) What type of bacterium is most likely to cause spoilage of refrigerated foods?

a- Mesophilic
b- Thermopjilic
c- Psychrophilic
d- Capnophilic
e- Microaerophilic

5) Bacterial cell death is balanced by the formation of new cells in:

a- Lag phase
b- Exponential phase
c- Stationary phase
d- Decline phase
e- Log phase