Bacterial Growth and Metabolism

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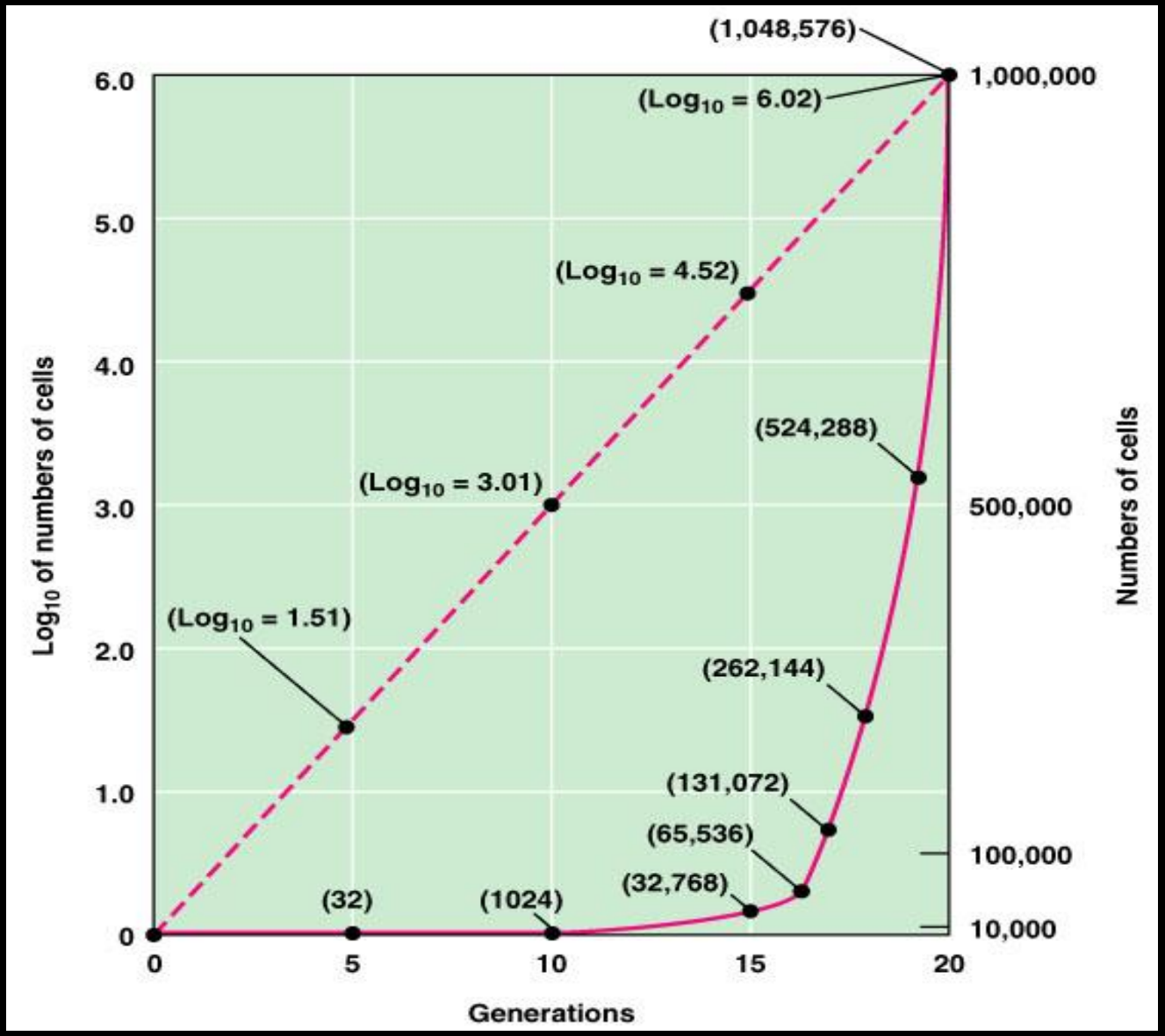
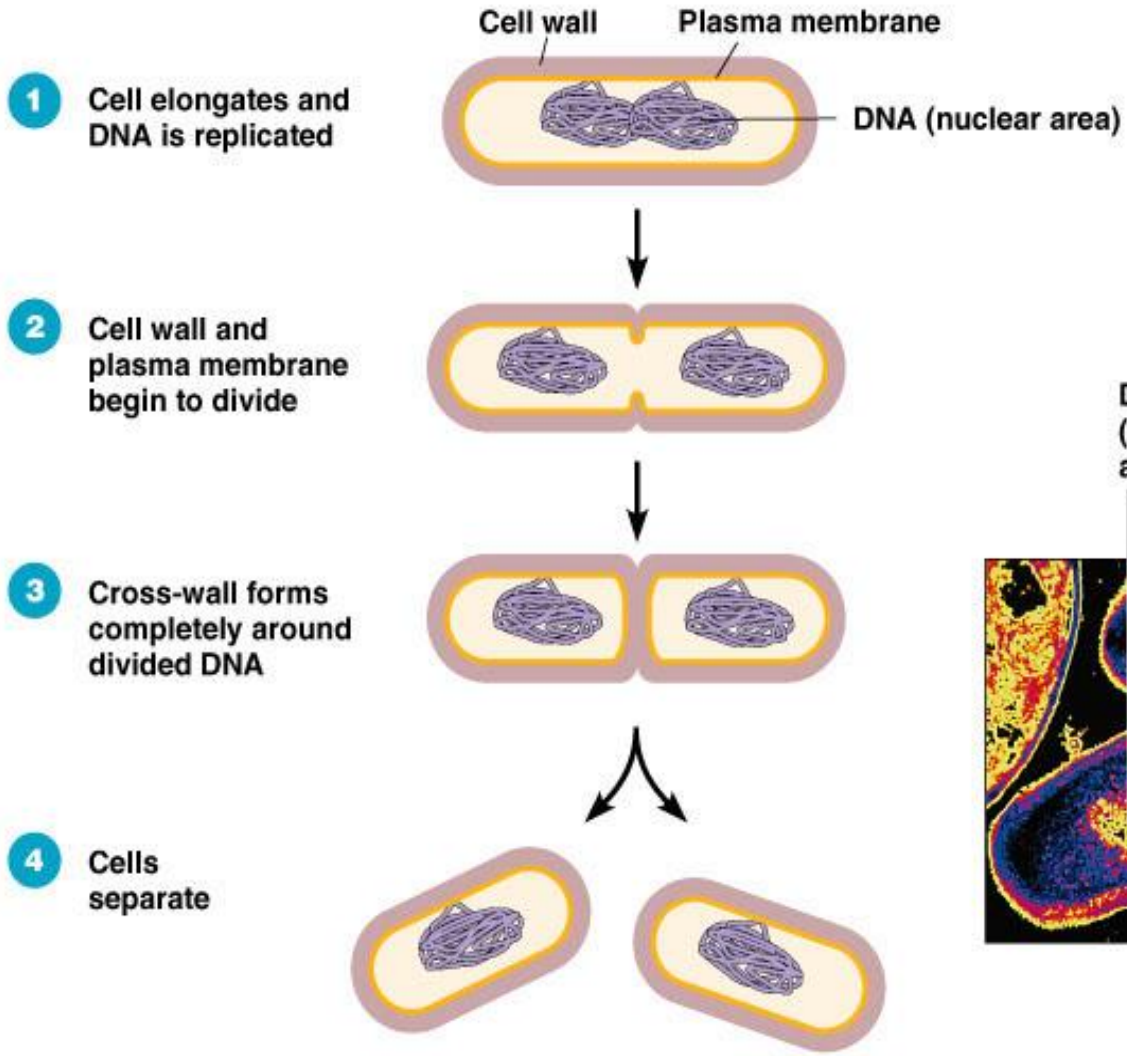
Growth of Microbes

- Microbial growth: Microbes grow via binary fission, resulting in exponential increases in numbers
- Bacterial “growth” means an increase in the number of cells, not an increase in cell size.
- One cell becomes colony of millions of cells

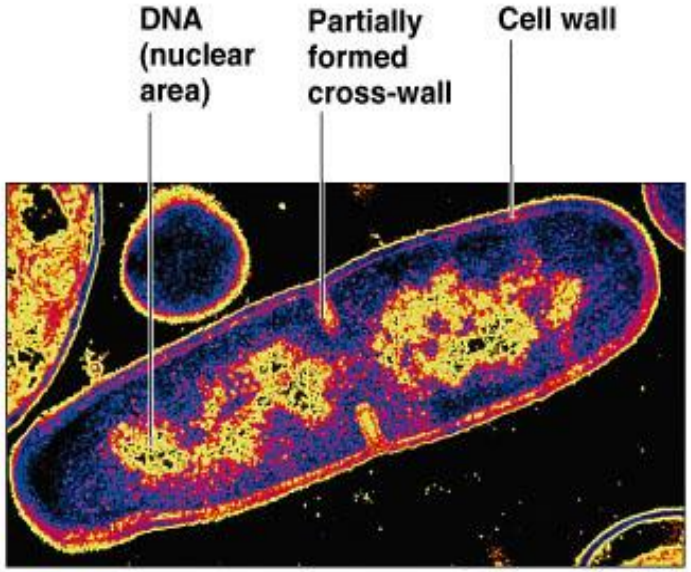

(1,048,576)
1,000,000
(Log10 = 6.02)
6.0
5.0
(Log10 = 4.52)
4.0
(524,288)
(Log10 = 3.01)
3.0
500,000
(Log10 = 1.51)
2.0
(262,144)
1.0
(131,072)
(65,536)
100,000
(32,768)
(32)
(1024)
0
10,000
0
5
10
15
20
Generations
Log10 of numbers of cells
Numbers of cells

- Bacteria grow by binary fission to produce identical offspring, which cannot be distinguished as a parent or offspring

Binary Fission



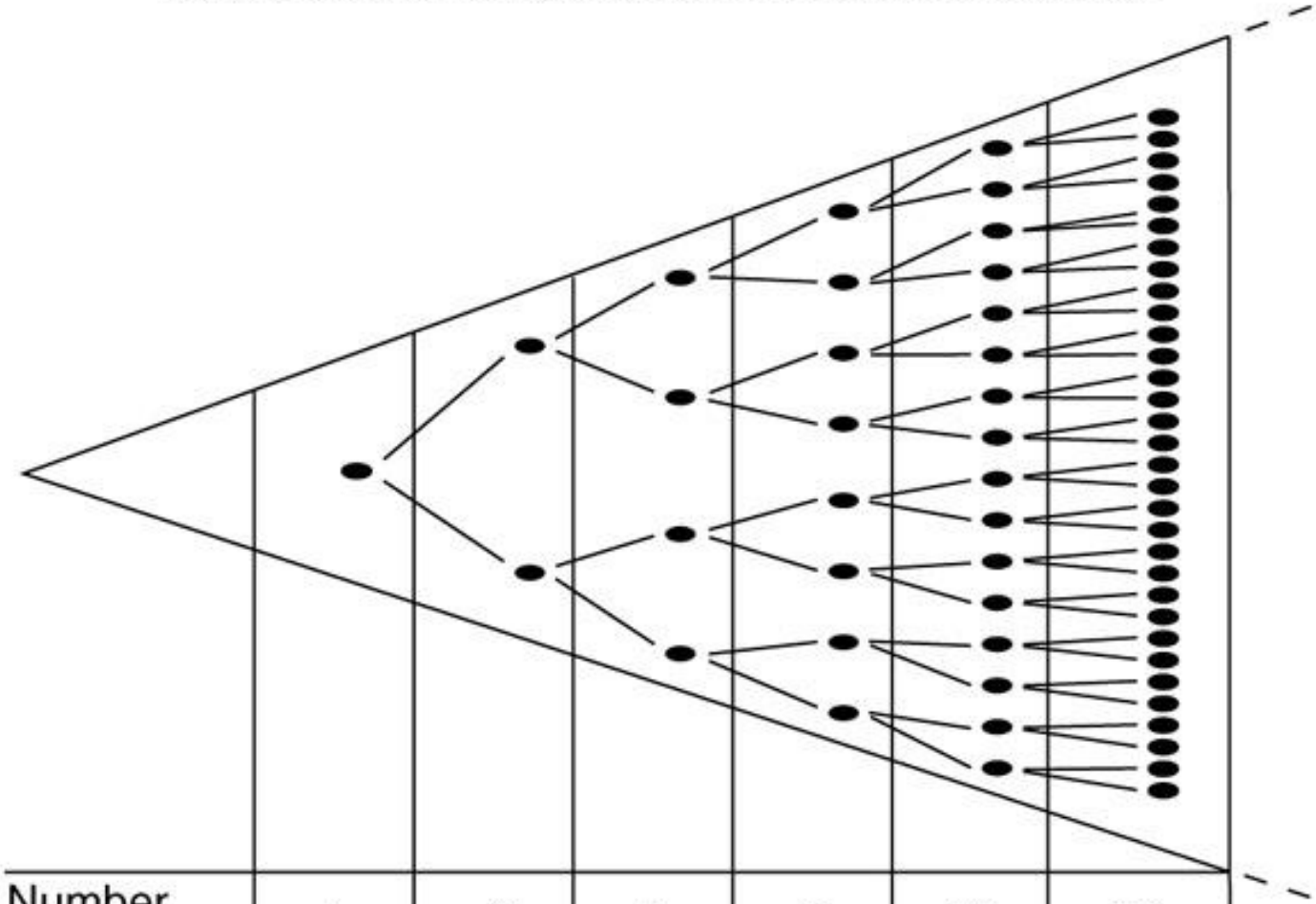
(a) A diagram of the sequence of cell division.



(b) A thin section of a cell of *Bacillus licheniformis* starting to divide.

Generation Time

- Generation time; is the time it takes for a single cell to grow and divide
- Average for bacteria is 1-3 hours
- ***Escherichia coli***: 20 minutes……20 generations (7 hours), 1 cell becomes 1 million cells!
- ***Mycobacterium*** much slower: (12-24h)



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)

(a)

Phases of Growth

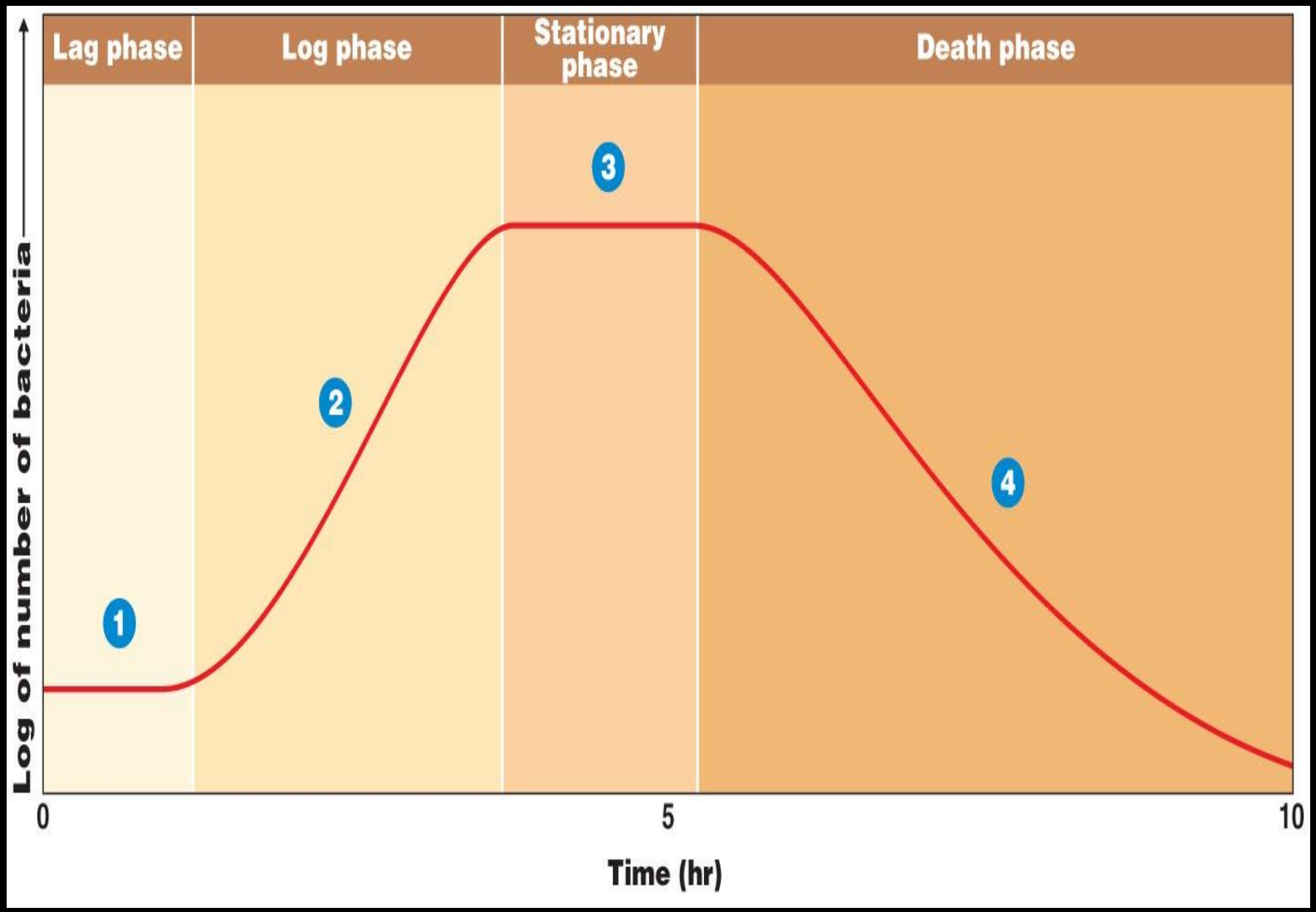
Four main growth phases

-Lag phase

-Exponential (Log) phase

-Stationary phase (Post-exponential)

-Decline phase


Lag phase
Log phase
Stationary phase
Death phase
1
2
3
4
Log of number of bacteria
0
5
10
Time (hr)

Lag phase (adaptation)

- The cells are believed to be preparing for the growth , the number of cells present appears to remain constant in Lag phase

Exponential (Log) phase

- There is increase in cell number then becomes detectable and its rate accelerates higher.

Stationary phase

- Eventually growth slows down, the total bacterial cell number reaches to a maximum and stabilizes

Decline phase (the death phase)

- Death of cells is due to nutrient exhaustion and accumulation of detrimental end-products

- **Media for bacterial growth**

•For identification of bacteria, a culture is obtained by growing the organisms on artificial culture media.

Types of culture media

- Simple media
- Enriched media
- Selective media
- Differential media


BIGSTOCK

a. Simple media

- Contain basic nutrients for bacterial growth like broth with peptone, e. g. Nutrient broth

b. Enriched media

- Enriched by some substances like: Blood & Serum, e.g. Blood agar, Chocolate agar

c. Selective media

- Contain substances such as bile salts or antibiotics that inhibit the growth of some organisms but have little or no effect on the required organism.

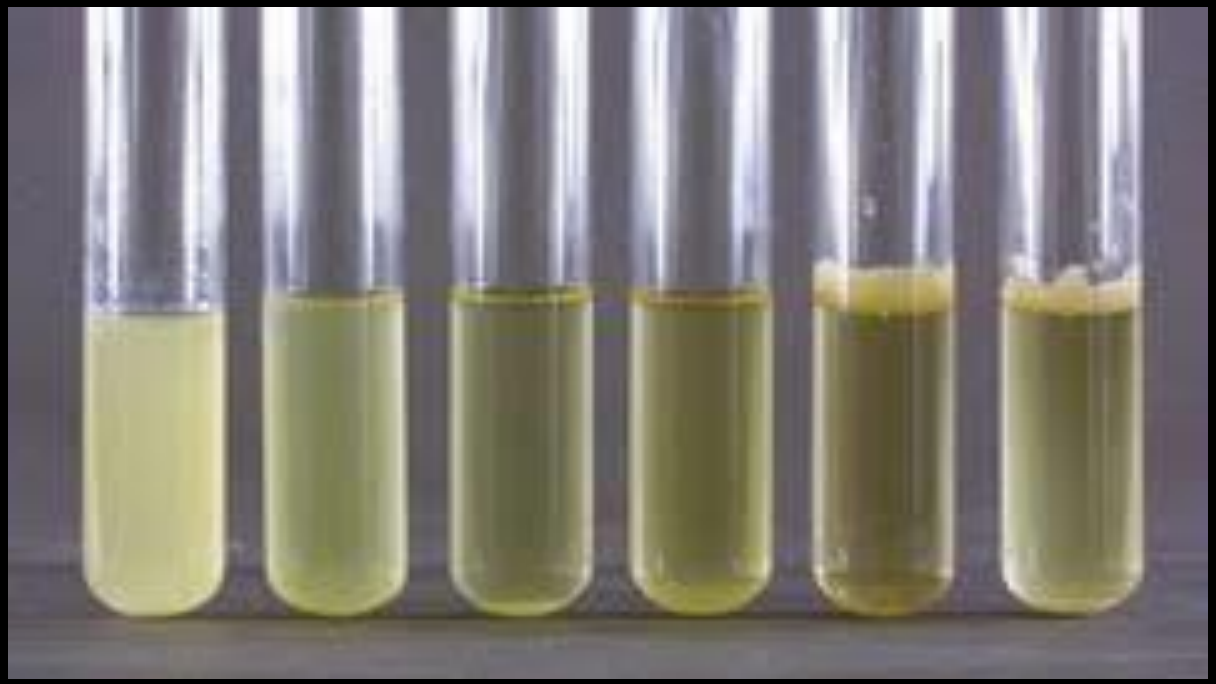
- e. g. Salmonella Shigella agar.

d. Differential media

- Differential shows up as visible changes, variations in colony size or in media color, or in the formation of gas bubbles or precipitates, e.g. MacConkey agar

Methods used to measure microbial growth

- Count colonies on plate (counts live cells)
- Microscopic counts
- Flow cytometry
- Turbidity



Requirements for Growth

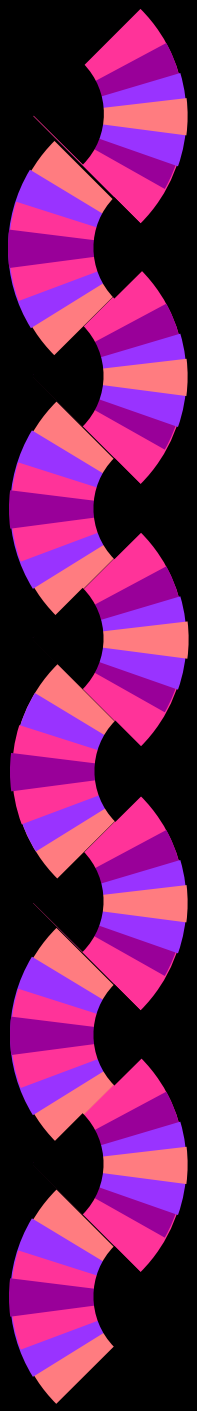
- Bacteria must obtain or synthesize Amino acids, Carbohydrates & Lipids => build up the cell.

Requirement of growth included:

1. Nutrients
2. Temperature
3. Oxygen
4. pH (**potential of hydrogen**)
5. Osmotic pressure

- Growth requirements & metabolic by-products

=> Classify different bacteria.



1. Nutrient

-Carbon sources

-Nitrogen sources

-Inorganic salts and trace elements

-Growth factors

-Water

Nutritional types of bacteria

A. Depend on how the organism obtains carbon for synthesizing cell mass divided into:

- **autotrophic** – carbon is obtained from carbon dioxide (CO_2)
- **heterotrophic** – carbon is obtained from organic compounds
- **mixotrophic** – carbon is obtained from both organic compounds and CO_2

B. Depend on how the organism obtains reducing equivalents used either in energy conservation or in biosynthetic reactions:

- **lithotrophic** – red. equiv. are obtained from inorganic compounds
- **organotrophic** – red. equiv. are obtained from organic compounds

C. Depend on how the organism obtains energy for living and growing:

- **chemotrophic** – energy is obtained from chemical compounds
- **phototrophic** – energy is obtained from light

chemolithoautotrophs obtain energy from chemical compounds, red. eque. from inorganic compounds and carbon from CO_2 . e.g.: Knallgas-bacteria

photolithoautotrophs obtain energy from light, reducing equivalents from inorganic compounds and carbon from CO_2. e.g.: Cyanobacteria

chemolithoheterotrophs obtain energy chemical compounds and red. eq from inorganic compounds, carbon by organic compounds . e.g.: *Nitrobacter* spp

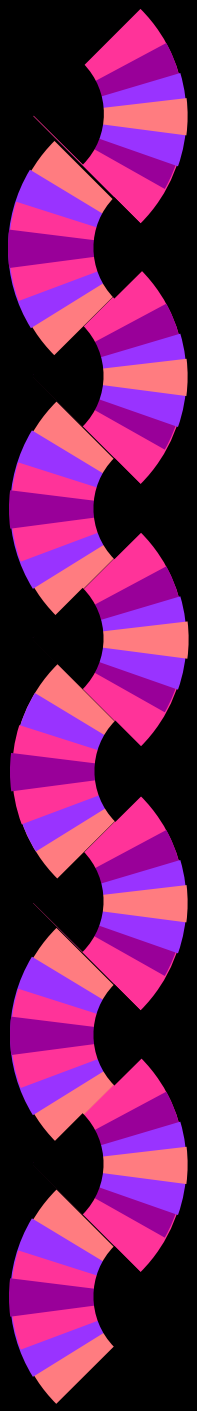
chemoorganoheterotrophs obtain energy, carbon, and reducing equivalents from organic compounds. e.g.: most bacteria, e. g. *Escherichia coli*

2.Temperature

- Psychrophiles: cold-loving, can grow at 0 C.
- Mesophiles: moderate temperature-loving (Most bacteria)

- Include most pathogens.
- Best growth between 25 to 40 C.
- Optimum temperature commonly 37C.
- Many have adapted to live in the bodies of human.

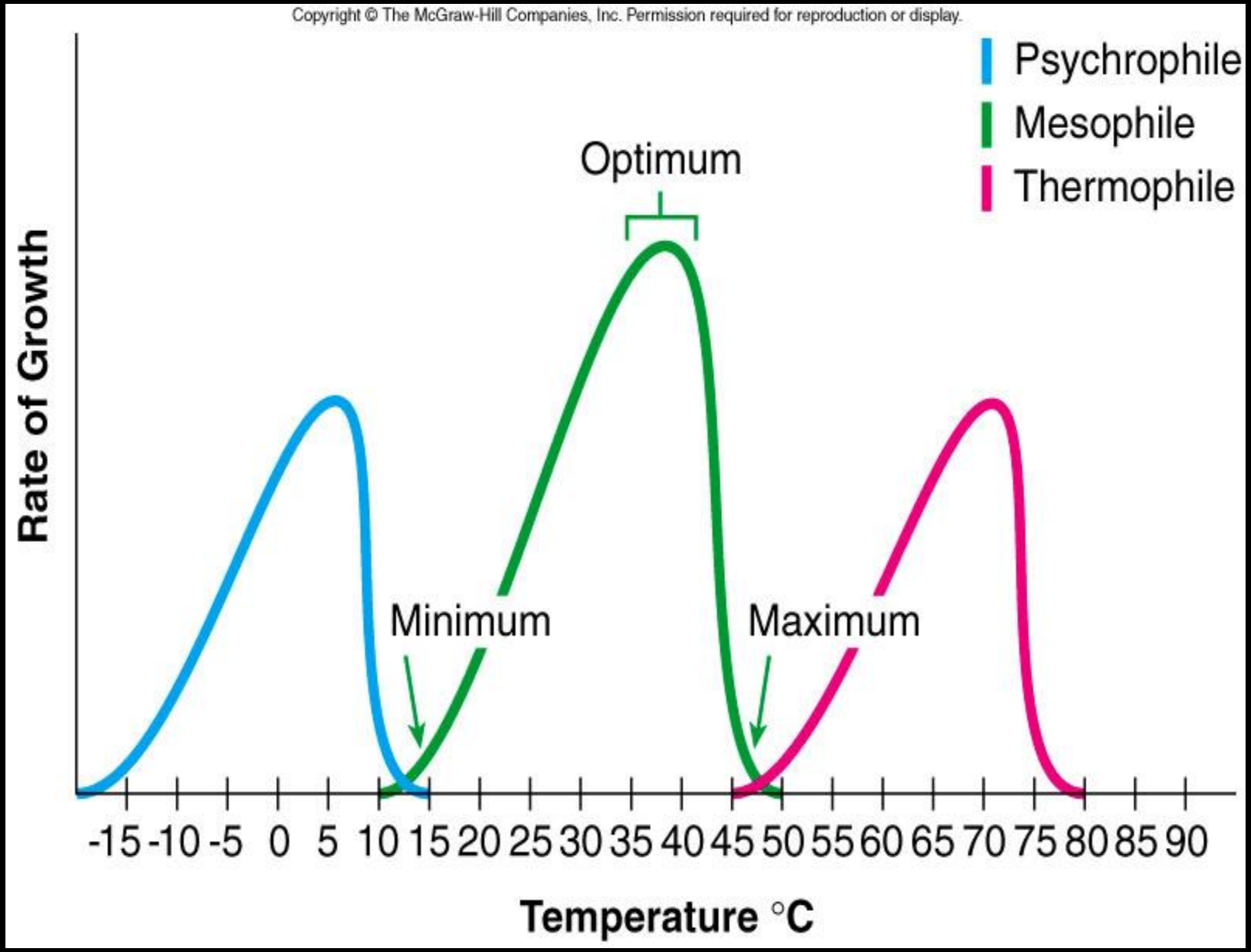
- Thermophiles: heat-loving



- Optimum growth between 50 to 80 C.

- Many cannot grow below 45 C.

-Adapted to live in sunlit soil and hot springs.



3.Oxygen

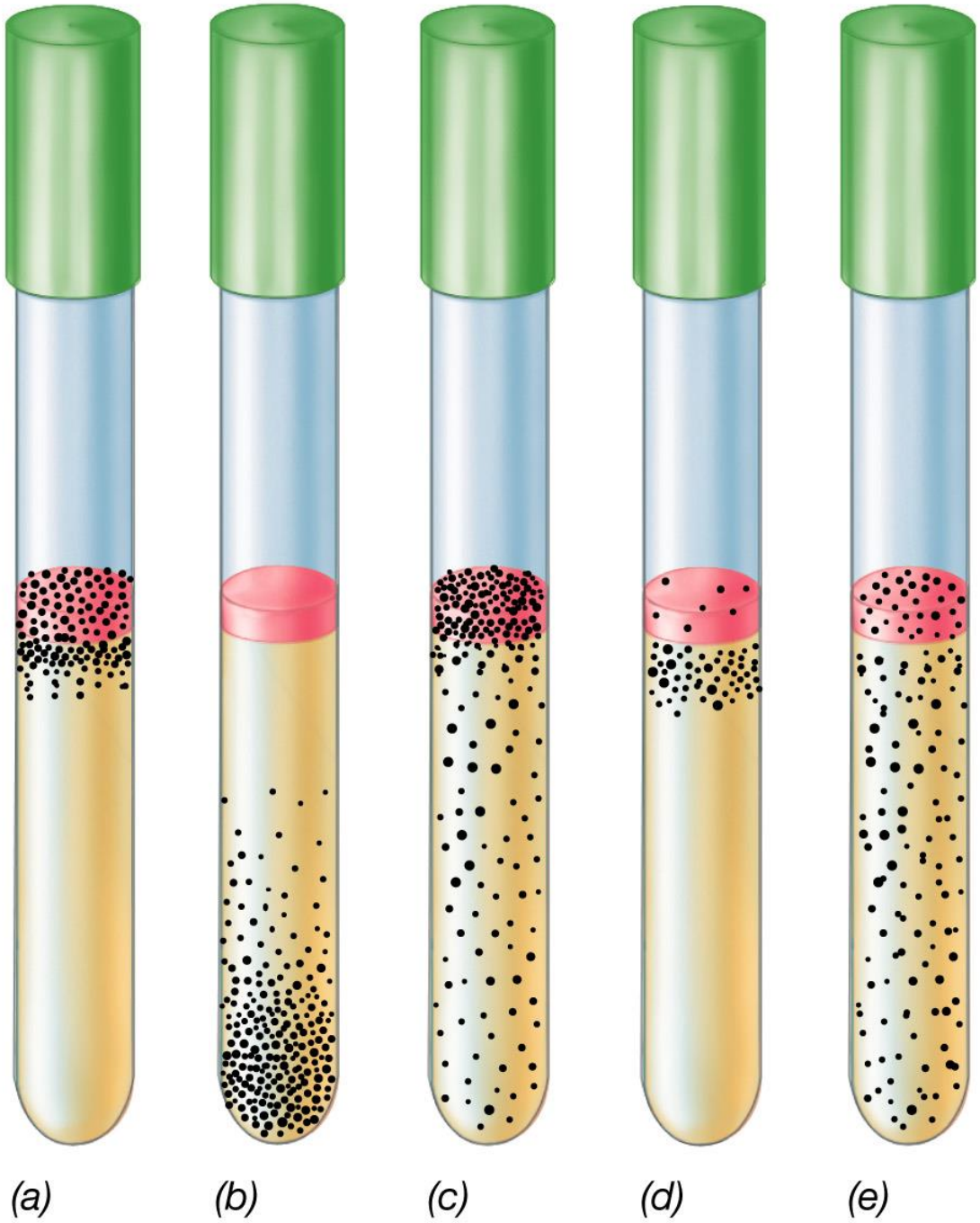
(a) Obligate aerobes – require O_2

(b) Obligate anaerobes – die in the presence of O_2

(c) Facultative anaerobes – can use O_2 but also grow without it

(d) Microaerophilic -requires lower oxygen to survive.

(e) Aerotolerant anaerobe: tolerate the presence of oxygen but does not require it for its growth


(a)
(b)
(c)
(d)
(e)

4. pH

Organisms can be classified as:

- **Acidophiles: "Acid loving".**
- Grow at very low pH (0.1 to 5.4) (many fungi).

- **Neutrophiles:**

- Grow at pH 5.4 to 8.5.
- Includes most human pathogens.

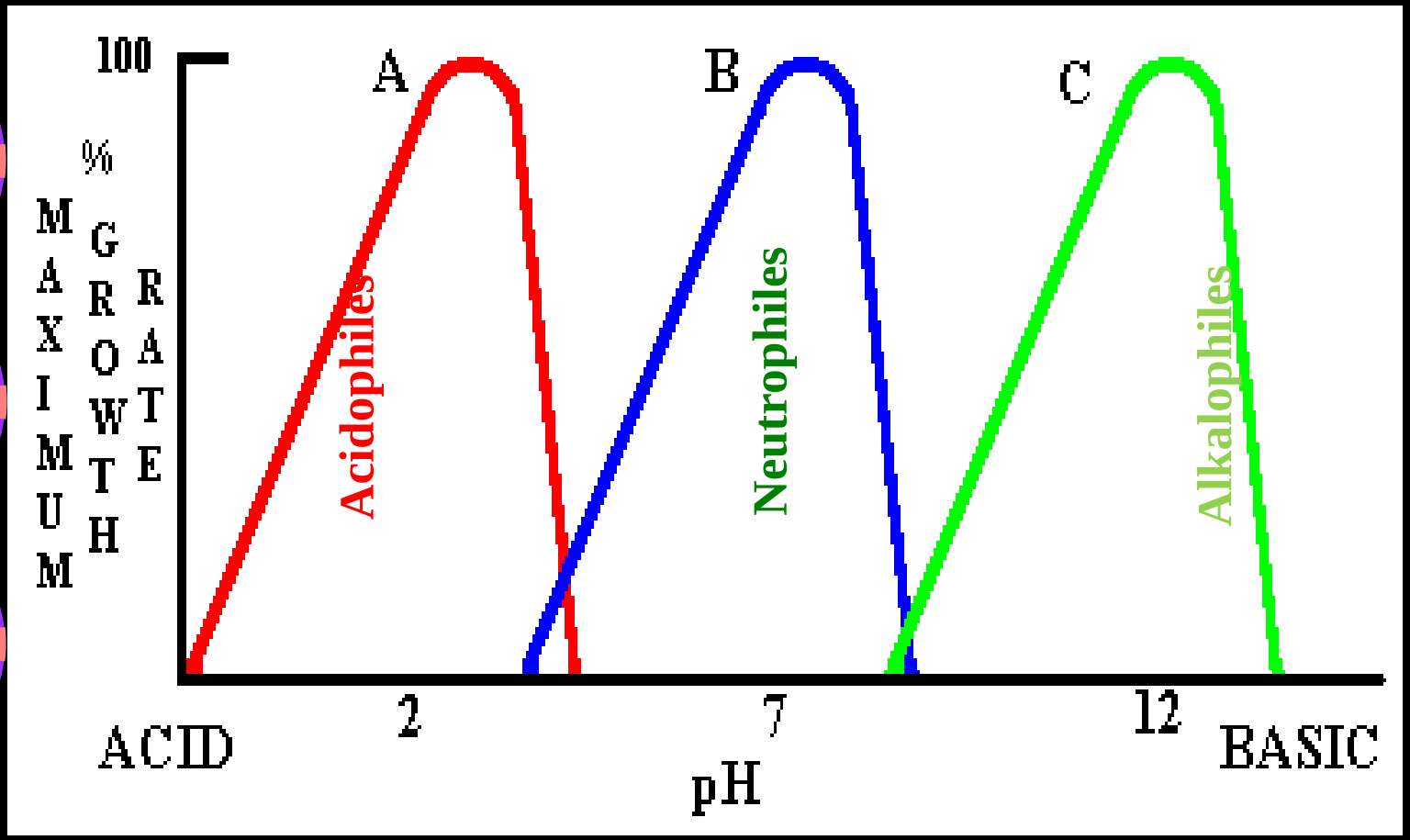
- **<u>Alkaliphiles</u>: “Alkali loving”.**

- Grow at alkaline or high pH (7 to 12 or higher)

- *Vibrio cholerae -optimal pH 9.*

- Soil bacterium *Agrobacterium grows at pH 12.*

Most bacteria grow between pH 6.5 and 7.5

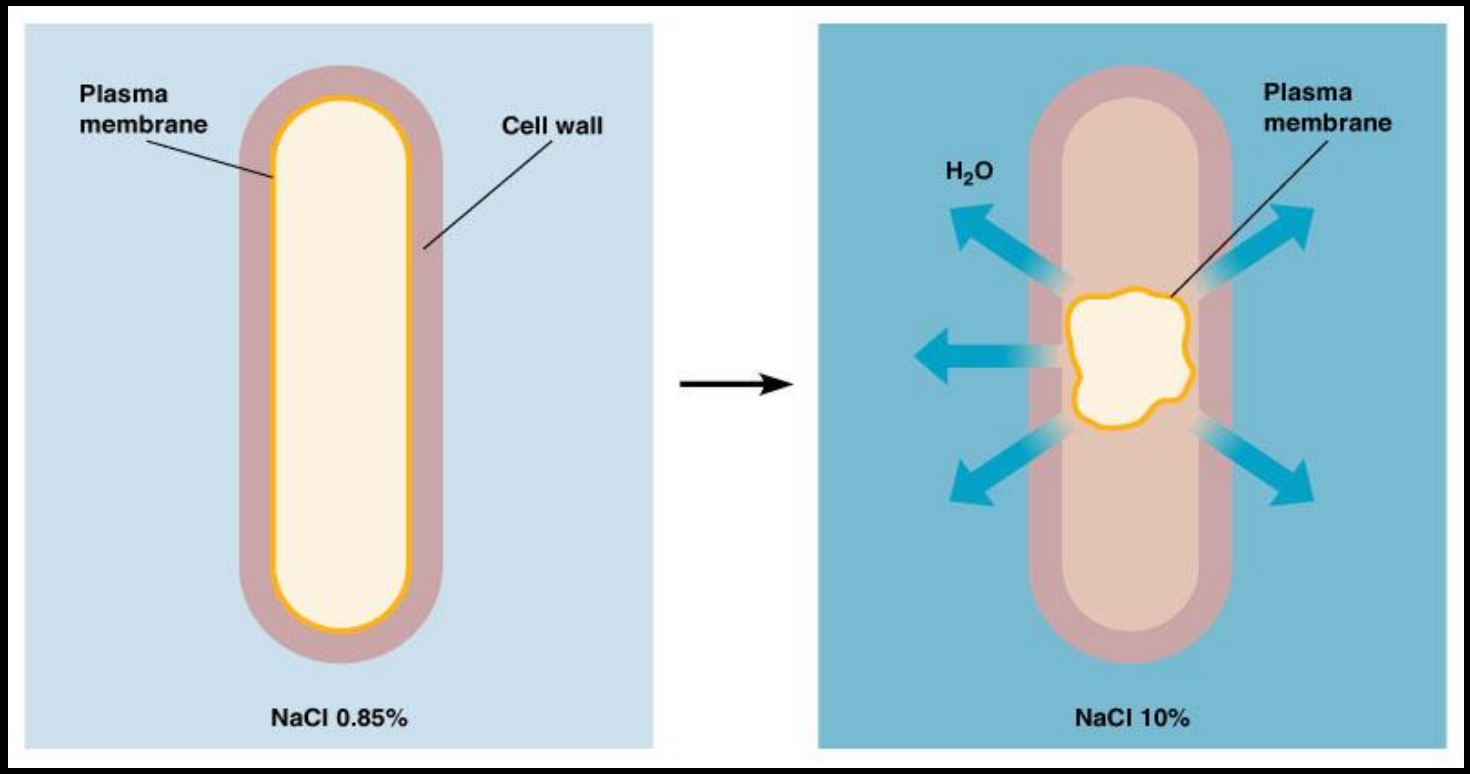


5. Osmotic Pressure

- Cells are composed of 80 to 90% water.

- **Hypertonic solutions:** High osmotic pressure removes water from cell, causing shrinkage of cell membrane (plasmolysis).
- **Hypotonic solutions:** Low osmotic pressure causes water to enter the cell.

- In most cases cell wall prevents excessive entry of water. Microbe may lyse or burst if cell wall is weak.


Plasma membrane
Cell wall
NaCl 0.85%
H_2O
Plasma membrane
NaCl 10%