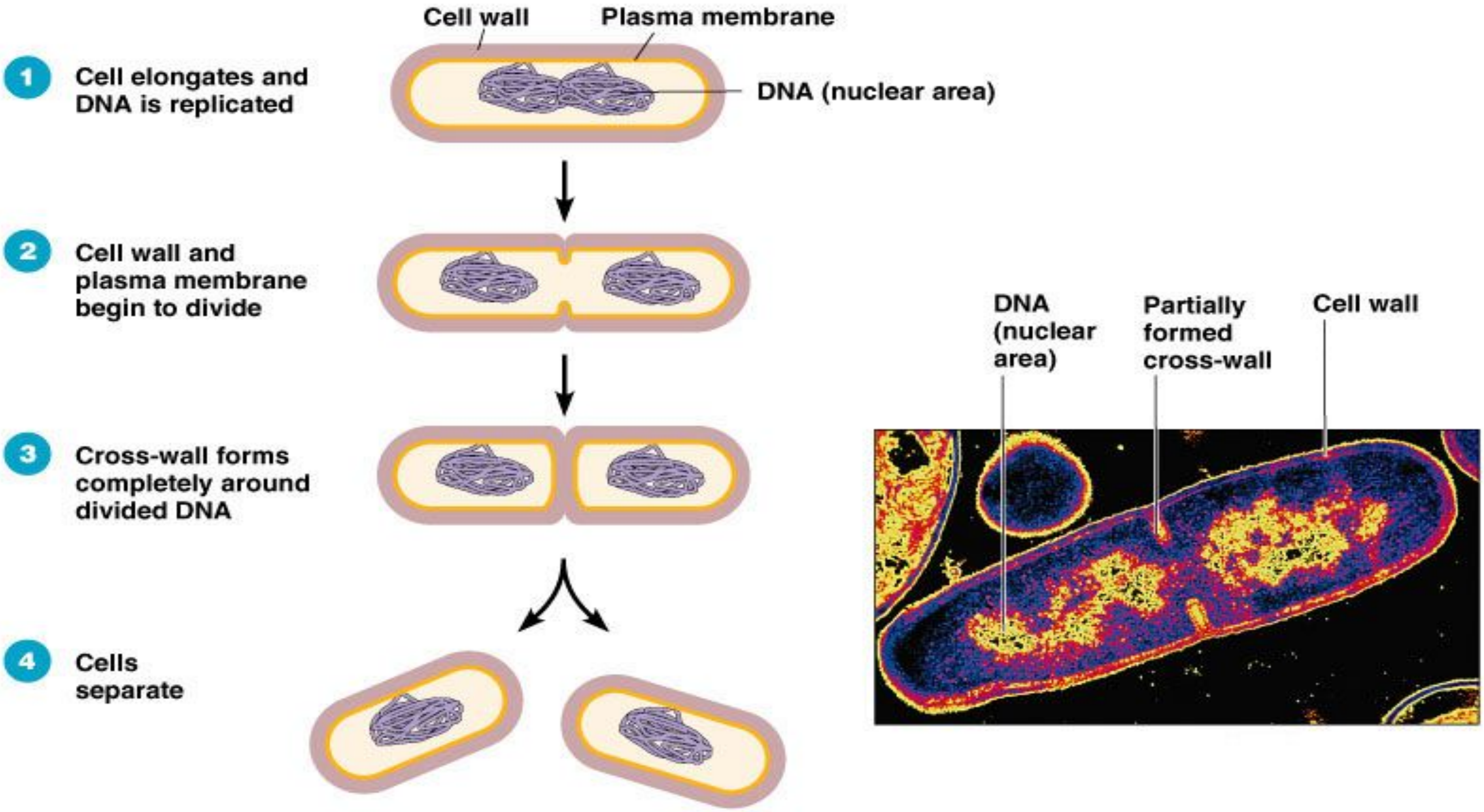
Bacterial Growth and Metabolism

Lecture 2

Growth Of Microbes

- 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
- Bacteria grow to produce **identical offspring**, which cannot be distinguished as

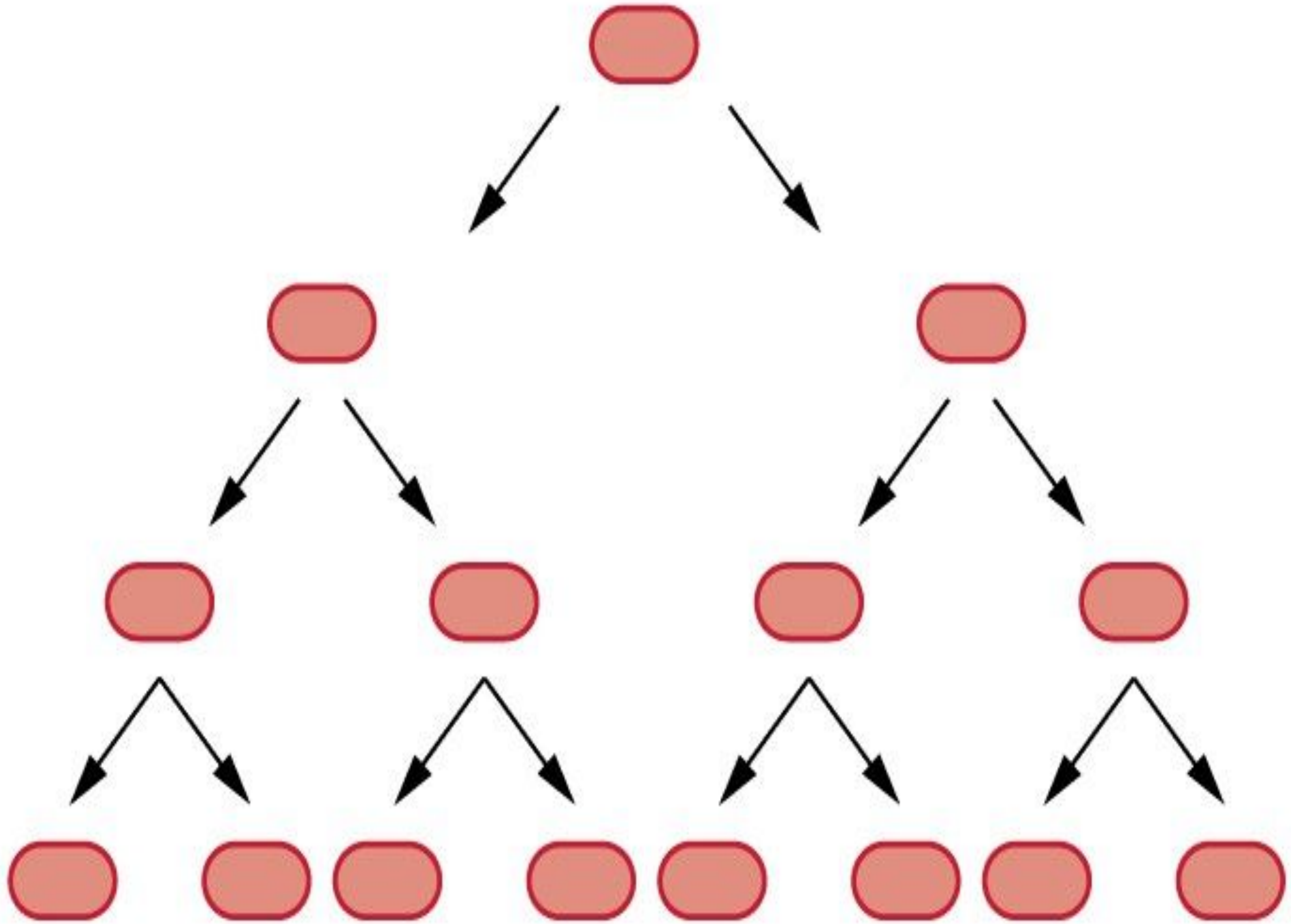


(a) A diagram of the sequence of cell division.

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

Generation time

- Generation time: is the time that bacteria takes for a single cell to grow and divide.
- Average for bacteria is 1-3 hours
- *Escherichia coli*: 20 minutes ..... 20 generations (7 hours), one cell becomes 1million cells.

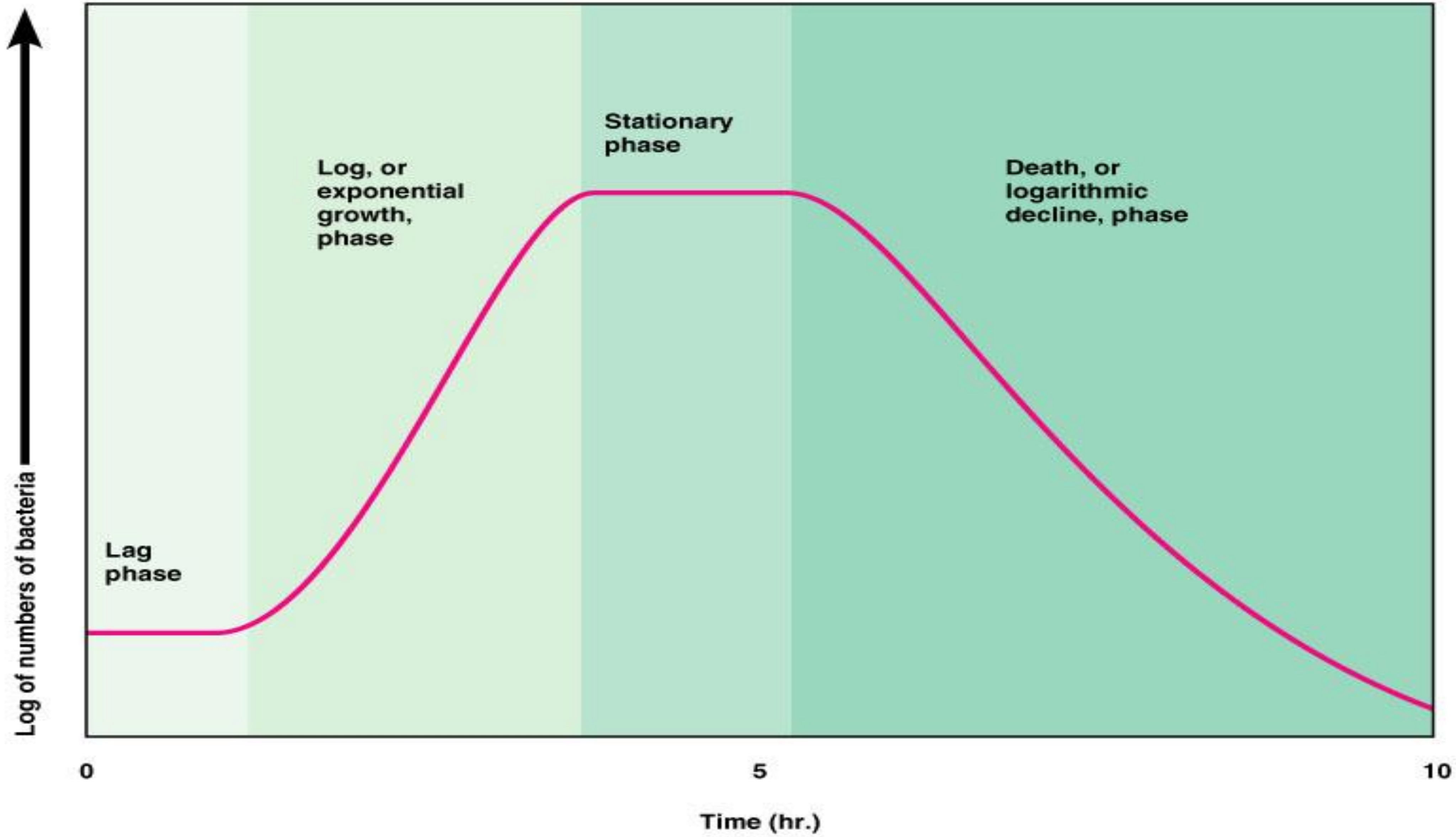
Number of generations (*n*)	Number of cells	Each division adds two new cells
0	1	
1	2	
2	4	
3	8	

Phases of Growth:

Four main growth phases

1. **Lag phase**
2. **Log (Exponential) phase**
3. **Stationary phase**
4. **Decline phase**

1. **The lag phase**, during which vigorous metabolic activity occurs but cells **do not divide**. This can last for a few minutes up to many hours.
2. **The log phase** is when **rapid cell division** occurs.
3. **The stationary phase** occurs when nutrient depletion or toxic products cause growth to slow until the number of new cells produced balances the number of cells that die.
4. **The death phase**, which is marked by a decline in the number of viable bacteria.


Log of numbers of bacteria
Lag phase
Log, or exponential growth, phase
Stationary phase
Death, or logarithmic decline, phase
0
5
10
Time (hr.)

Requirements for Growth

Bacteria must obtain or synthesize amino acid, carbohydrates and lipids build up the cell.

1- Nutrient

2- Temperature

3- Oxygen

4- pH

5- Osmotic Pressure

Nutrients

- Carbon sources
- Nitrogen sources
- Inorganic salt and trace elements
- Growth factor
- Water

B-Depend on how the organisms obtains reducing equivalents used either in energy conversation or in biosynthesis 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
- **Chemo-litho-autotrophs:** obtain energy from chemical compounds ,red, equiv., from inorganic compounds and carbon from CO_2 e.g. knallgas bacteria.

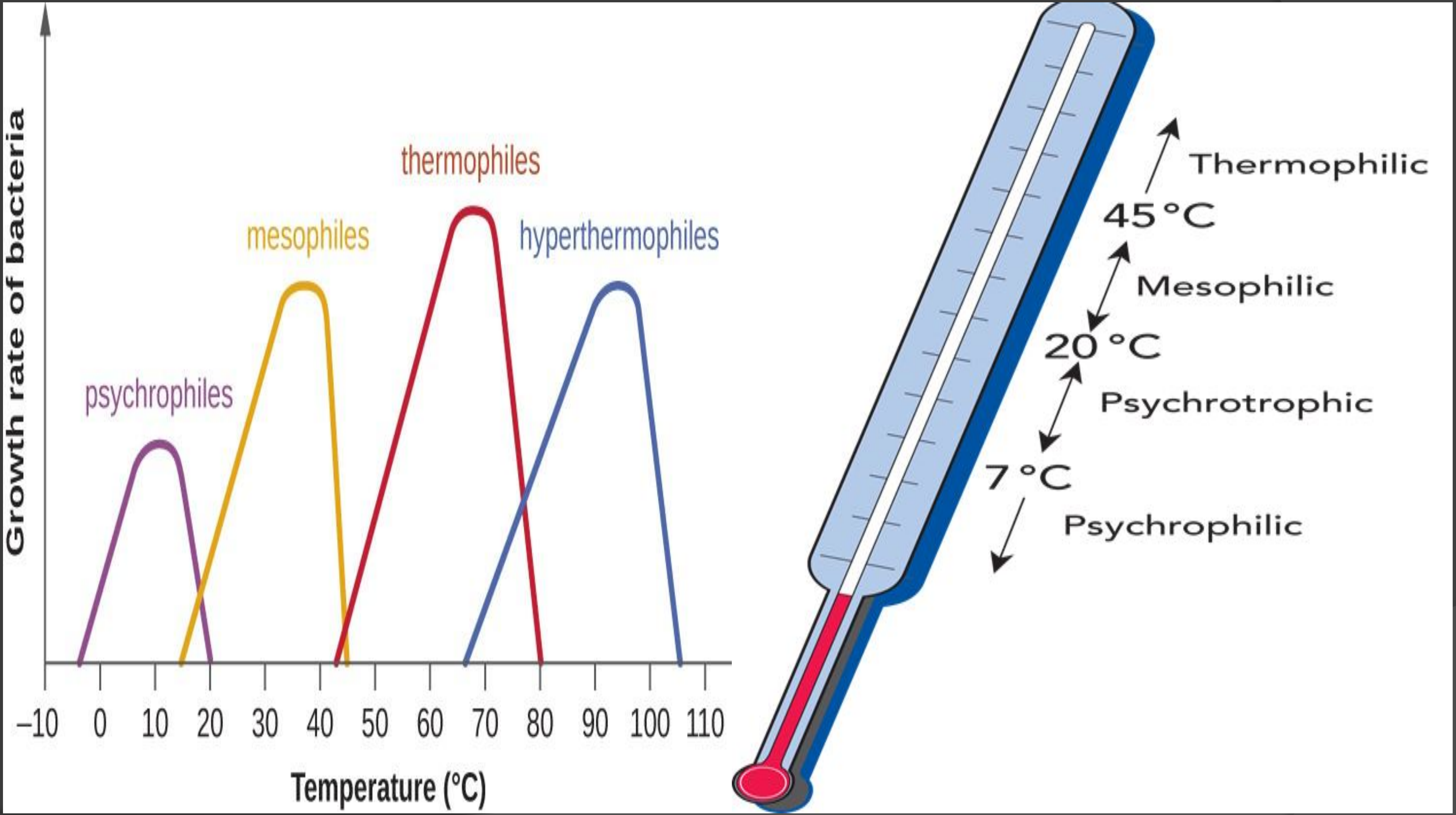
- **Photo-litho-autotrophs:** obtain energy from light, using reducing equivalents from inorganic compounds and carbon from the fixation of CO_2 e.g. *Cyanobacteria* .
- **Chemo-litho-heterotrophs:** obtain energy and red. eq from inorganic compounds, but cannot fix CO_2 e.g. *Nitrobacter* spp.
- **Chem-organo-heterotrophs:** obtain energy, carbon and reducing equivalents from organic compounds e.g. most bacteria e.g. *Escherichia*

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 animals

- **Thermophiles:** heat loving.

- Optimum growth between 50-80c
- Many cannot grow below 45c
- Adapted to live in sunlit soil and hot springs.

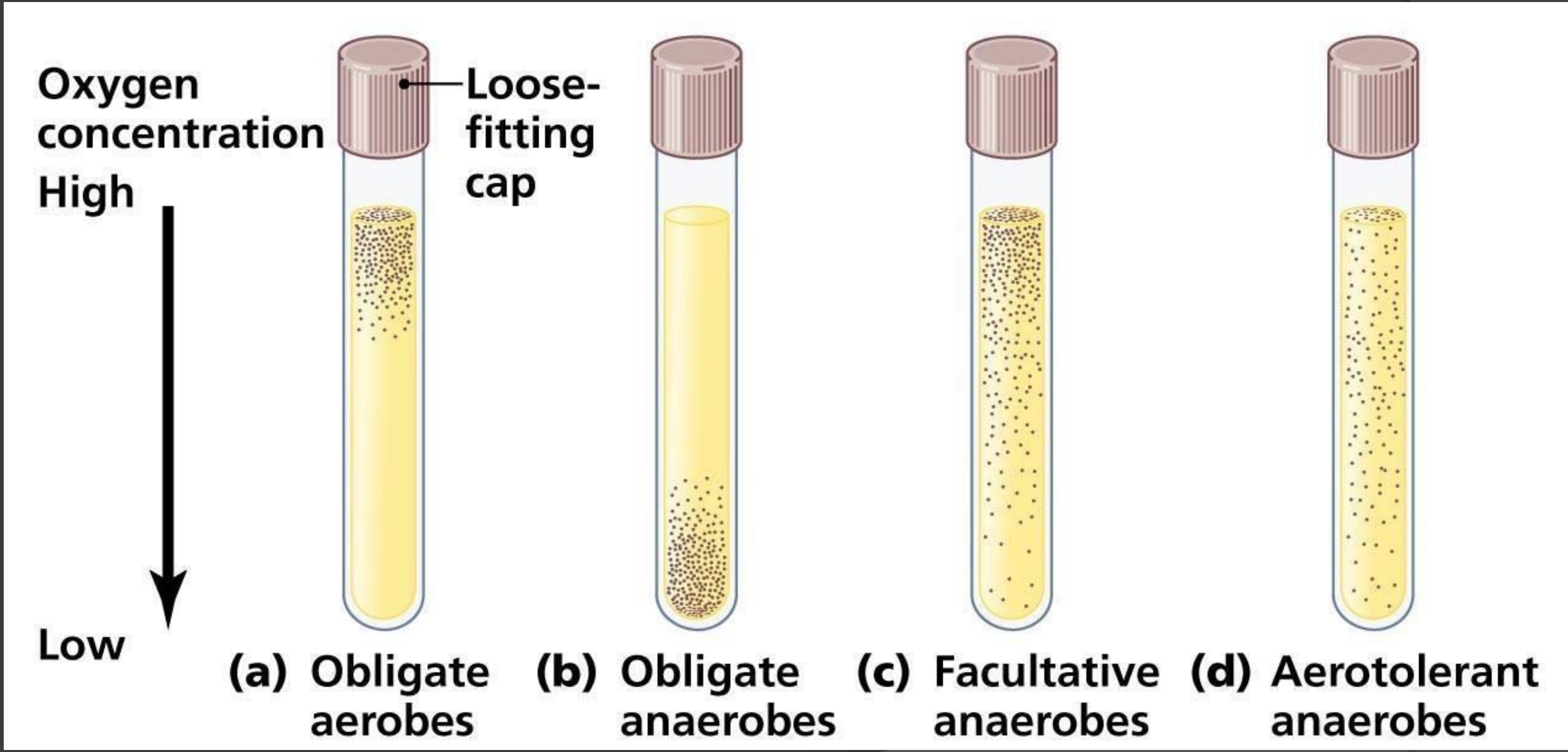

Growth rate of bacteria
psychrophiles
mesophiles
thermophiles
hyperthermophiles
−10 0 10 20 30 40 50 60 70 80 90 100 110
Temperature (°C)
Thermophilic
45 °C
Mesophilic
20 °C
Psychrotrophic
7 °C
Psychrophilic

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.



Oxygen concentration
High
Low
Loose-fitting cap
(a) Obligate aerobes
(b) Obligate anaerobes
(c) Facultative anaerobes
(d) Aerotolerant anaerobes

4. pH

Organisms can be classified as:

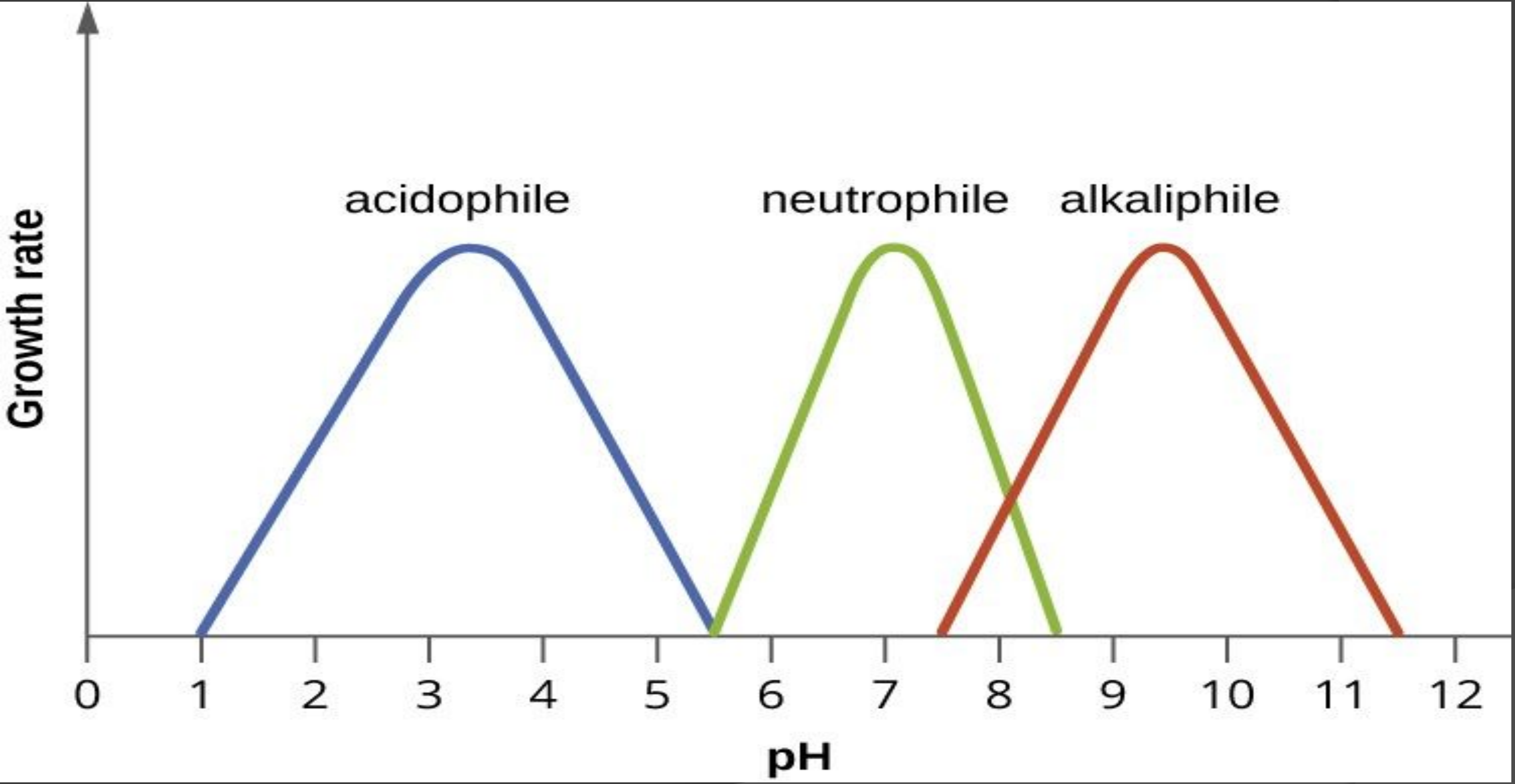
1. Acidophiles: acid loving

Grow at very low pH (0.1 to 5.4) (many fungi).

2. Neutrophiles :

Growth at pH 5.4 to 8.5

Includes most human pathogens.


acidophile
neutrophile
alkaliphile
Growth rate
0
1
2
3
4
5
6
7
8
9
10
11
12
pH

3. Alkaliphiles: "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.

5- Osmatic Pressure

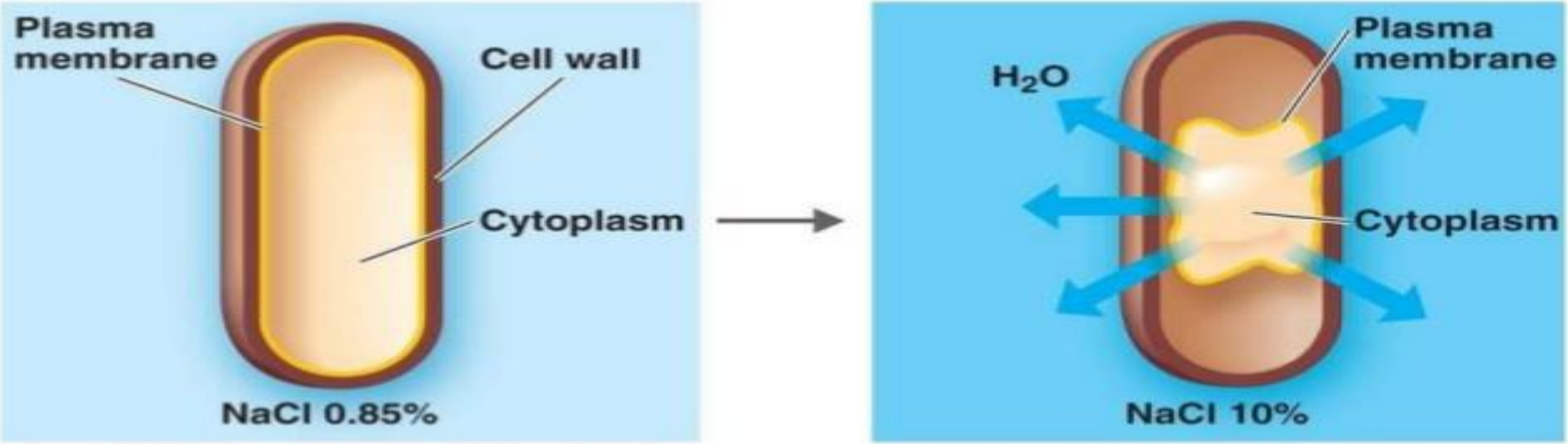
Cells are 80-90% water.

1.Hypertonic solutions: high osmotic pressure removes water from cell, causing shrinkage of cell membrane (plasmolysis).

2. Hypotonic solutions: low osmotic pressure causes water to enter the cell.

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

Plasmolysis



(a) Normal cell in isotonic solution. Under these conditions, the solute concentration in the cell is equivalent to a solute concentration of 0.85% sodium chloride (NaCl). See Figure 4.18.

(b) Plasmolyzed cell in hypertonic solution. If the concentration of solutes such as NaCl is higher in the surrounding medium than in the cell (the environment is hypertonic), water tends to leave the cell. Growth of the cell is inhibited.

Microbial metabolism

Microbial metabolism

- Is the by which a microbe obtains the energy and nutrients, it needs to living and reproduce.
- Microbes use many different types of metabolic.
- Strategies, and species can often be differentiated from each other based on metabolic characteristics.
- All cell require the energy supply to survive

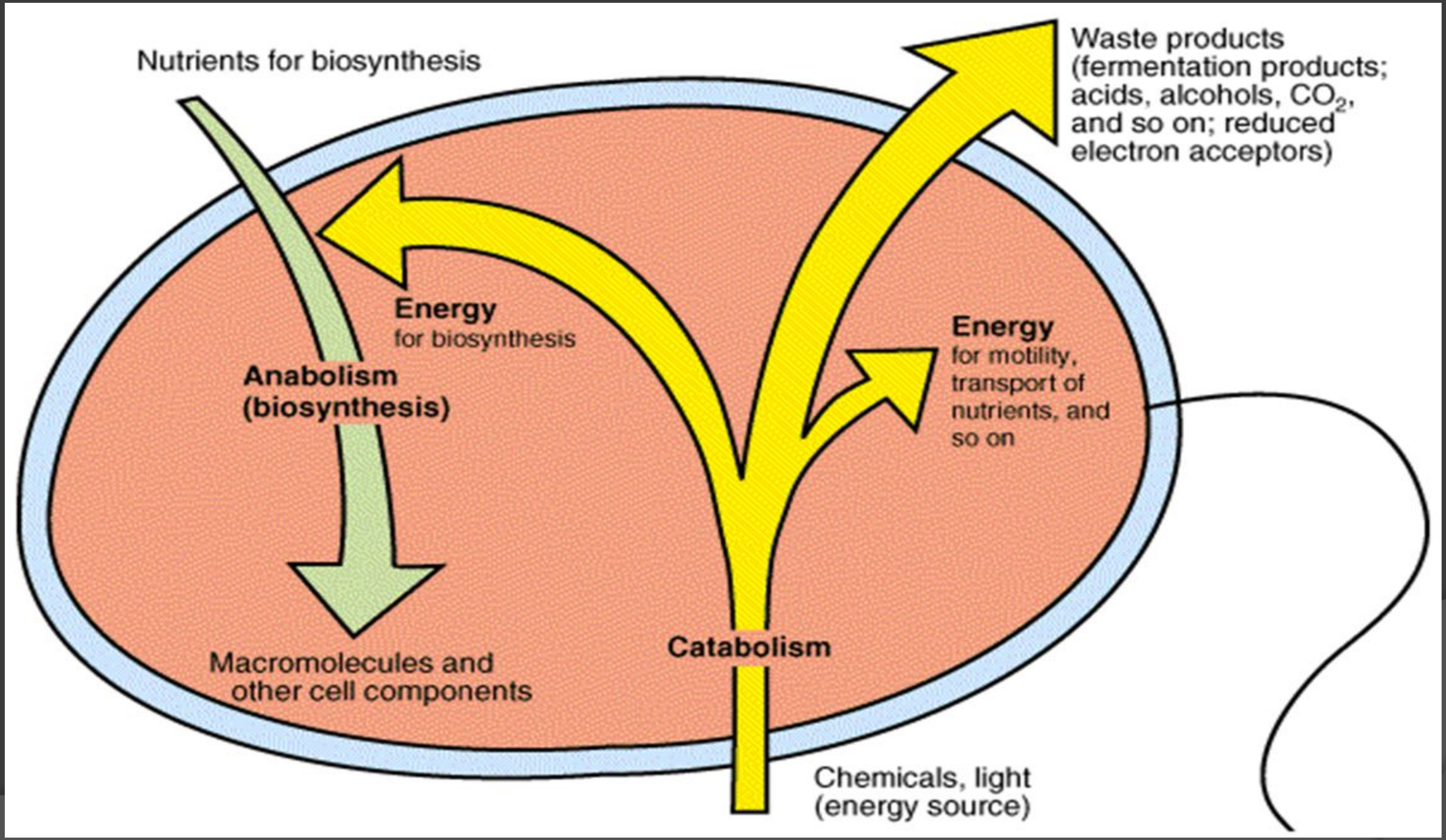
1- Anabolisms (Assimilation)

Assimilatory pathways for the formation of key intermediates and then to end products (cellular components.

2-Catabolism (Dissimilation)

Pathways that breakdown organic substrates (carbohydrates, lipids & proteins) to yield metabolic energy for growth and maintenance.

Overview of cell metabolism



Metabolism of Glucose

- Bacteria can produce energy from glucose. Glucose breakdown can be aerobic (using oxygen) or anaerobic (without oxygen).

1. Aerobic metabolism of glucose is known as glycolysis and respiration .

2. Anaerobic metabolism of glucose is also known as anaerobic glycolysis or fermentation.

1. **Aaerobic metabolism** of glucose is known as glycolysis and respiration.

- Three major metabolic pathways are used by bacteria to catabolize glucose:

1- Glycolysis (EMP pathway)
2- Tri-Carboxylic Acid (TCA) cycle
3- Pentose phosphate pathway.

Sources of metabolic energy:

- Respiration: Chemical reduction of an electron acceptor through a specific series of electron carries in the membrane. The electron acceptor is commonly O_2, but CO_2, SO_4^{-2}, and NO^{-}_3 are employed by some microorganisms.

- Fermentation: metabolic process in which the final electron acceptor is an organic compound.

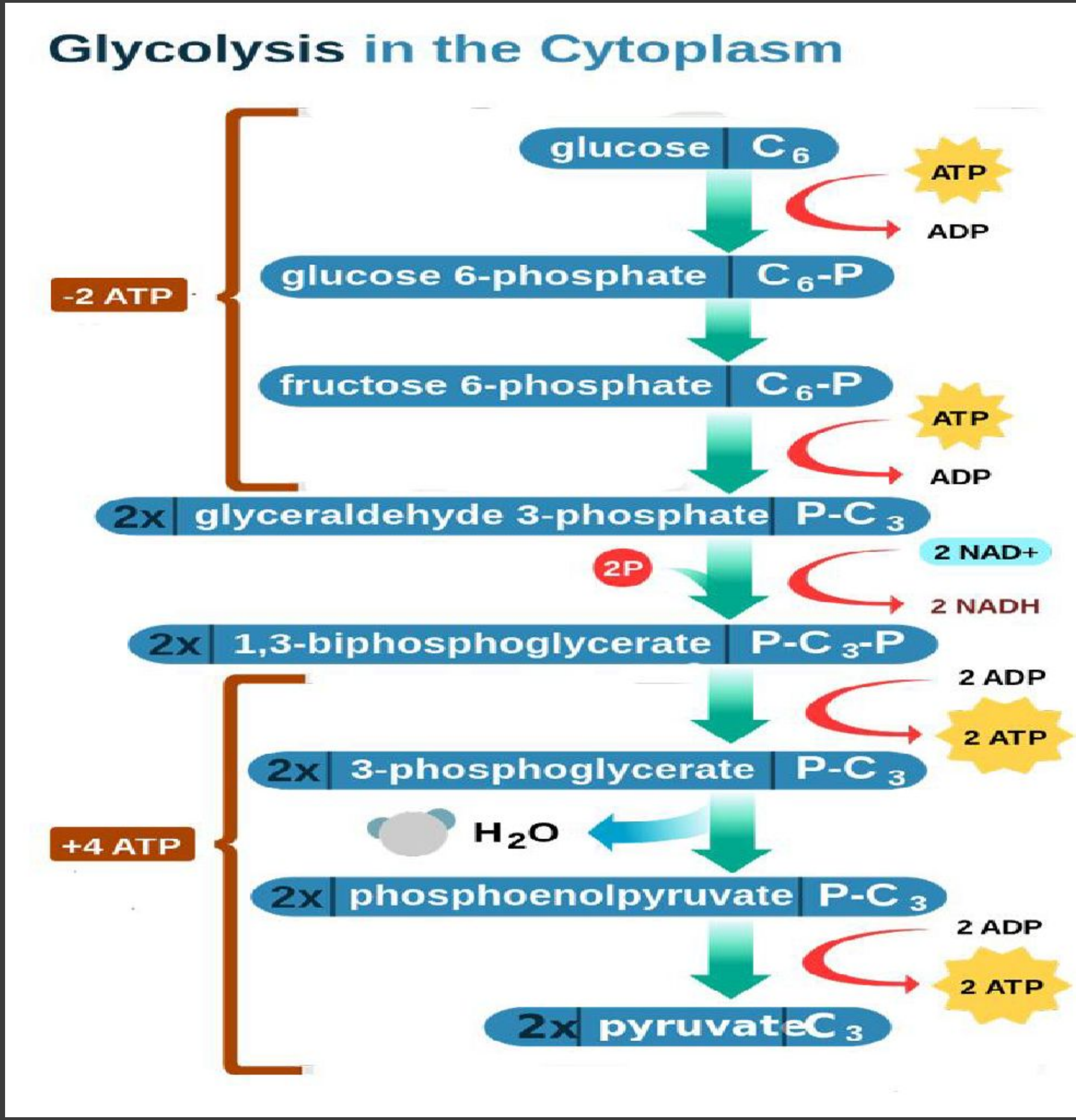
1. Glycolysis (Emden-Meyerhof-Parnas Pathway):

- A 10 step biochemical pathway where a glucose molecule (6C) is split into 2 molecules of pyruvate (3C).
- To begin the process 2 ATP must be invested. Energy released from reactions is captured in the form of 4 molecules of ATP molecules and high energy electrons are trapped in the reduction of 2

1- The most common pathway for bacteria in the catabolism of glucose.

2- reaction occur under both aerobic and anaerobic condition .

3- One glucose=> 2 ATP 2 NADH 2 Pyruvate.



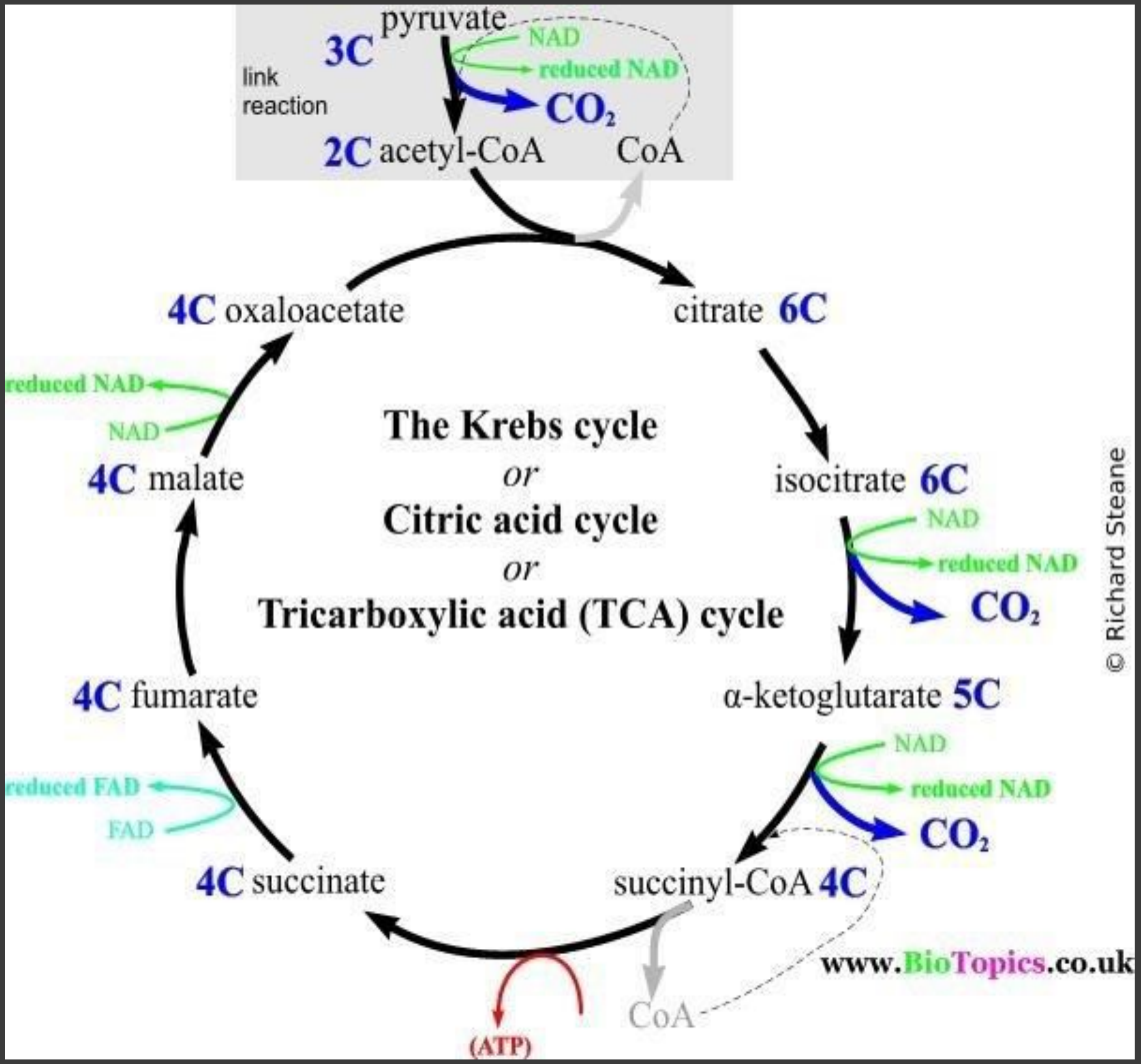
2. Krebs Cycle

- A **9 step** biochemical pathway that converts all of the remaining carbons from the original glucose into **CO2** and yield **1 ATP** and traps high energy electrons in 3 NADH and 1 FADH per CO-A .

1- Pyruvate => Acetyl-CoA
1X NADH=>3ATP

2- TCA cycle: 3 x NADH=> 3 x 3 ATP 1 x FADH2=>1 x 2 ATP 1 x GTP=>1 x ATP

3- NADH & FADH2 go to electro transport chain.



3. The Pentose phosphate pathway (also called the hexose monophosphate shunt):

- Is a biochemical pathway parallel to glycolysis that generates NADPH and Pentoses (5-carbon sugars).

Functions:

1. Provides various sugars as precursors of biosynthesis and NADPH for use in biosynthesis.

2. The various sugars may be shunted back to glycolytic pathway.