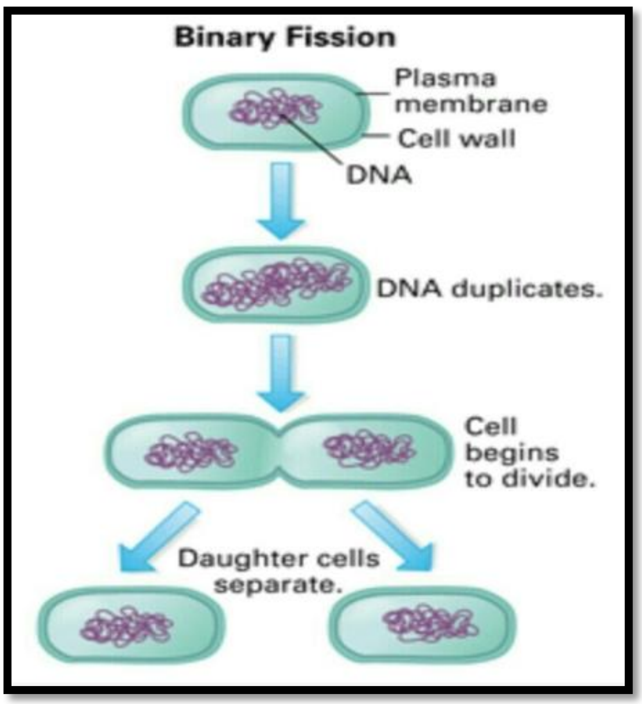
Microbial growth

Bacterial growth is defined as **an increase in cell numbers rather than an increase in cell size**. The process by which bacterial cells divide to reproduce themselves is known as **binary fission**.

Cell Division

The division of a bacterial cell occurs mainly through **binary fission** or **transverse fission**; **binary** means that one cell becomes two, and transverse refers to the division level forming across the width of the cell. During binary fission, the parent cell enlarges, duplicates its chromosome, and forms a central transverse septum that divides the cell into two daughter cells. This process is repeated at intervals by each new daughter cell in turn, and with each successive round of division, the population increases.



The time taken from cell formation to cell division is called **the generation time** (also defined as the time taken for the cell count to double).

- When bacteria are inoculated into a liquid medium, there are four distinct phases to a population's growth curve; **lag, log, stationary, and death.**

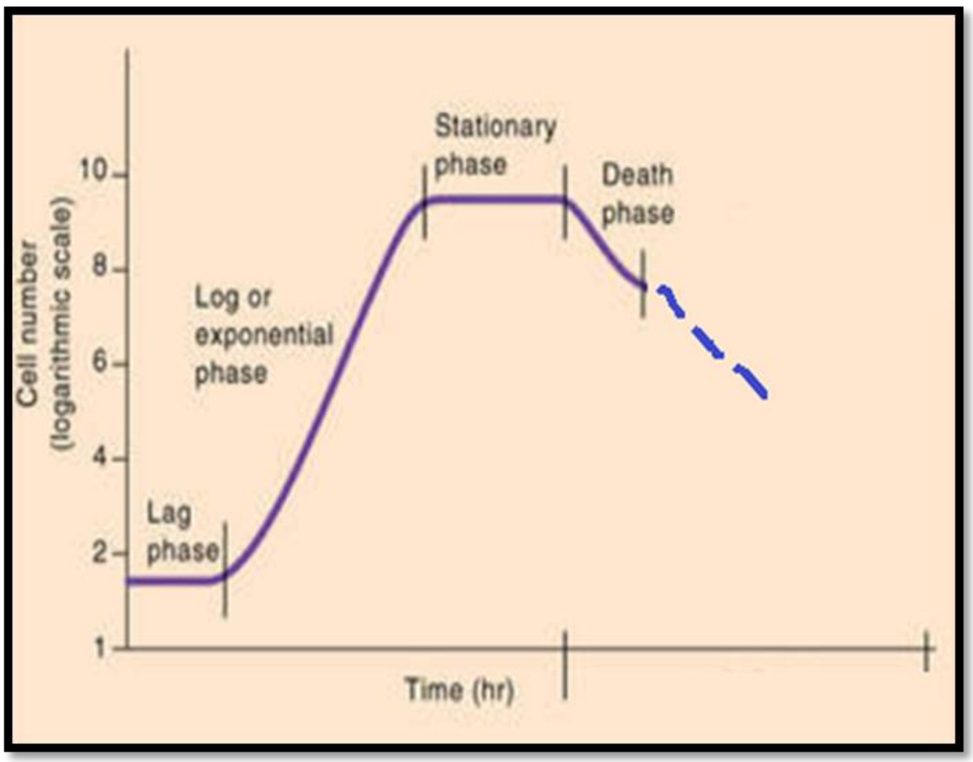
1-Lag phase: the cells are adjusting to their new environment, and most cells do not reproduce immediately, instead, actively synthesize enzymes to utilize nutrients in the medium.

Depending on the species, chemical, and physical conditions of the medium, the lag phase can last less than an hour or for days.

2- Log phase: the bacteria synthesize the necessary chemicals for conducting metabolism in their new environment, rapid chromosome replication, growth, and reproduction. This phase is called **the log phase** because the population increases logarithmically, and the reproductive rate reaches a constant as DNA and protein syntheses are maximized.

3-Stationary phase: the rate of reproduction decreases, as the nutrients are depleted, and waste is accumulated. The number of dying cells equals the number of cells being produced. The size of the population becomes stationary, and the metabolic rate declines.

4-Death phase: some cells remain alive and continue metabolizing and reproducing, but the number of dying cells exceeds the number of new cells produced.



Growth curve

Microbial metabolism is all of the chemical reactions in an organism, which can be divided into two major classes of reactions; **catabolism** and **anabolism**. A series of such reactions are called **pathways.**

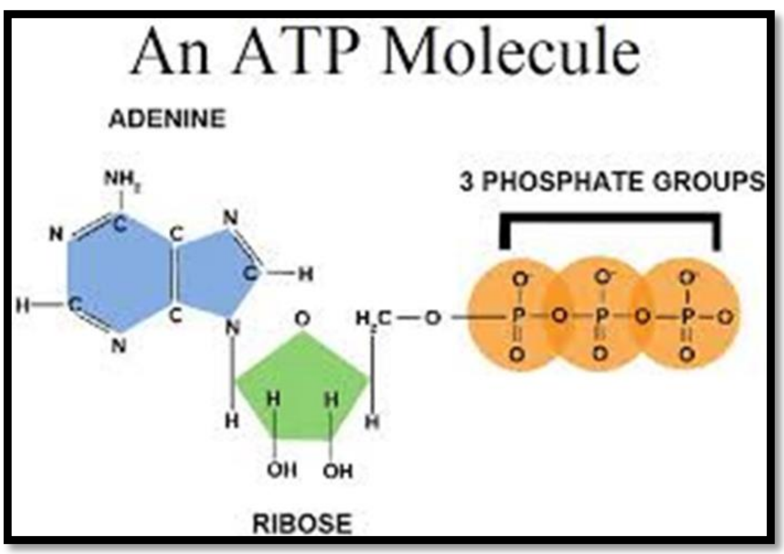
- **Catabolic pathway:** breaking down the larger molecules into smaller products, like breakdown lipids into glycerol and fatty acids. Thus release energy, that is, catabolic pathways are ***exergonic***. Cells store some of this released energy in the bonds of ATP, though much of the energy is lost as heat. Catabolic pathways also resulted in the production of numerous smaller molecules, some of which are **precursor metabolites of anabolism.**

- **Anabolic pathway:** is synthesizes large molecules from the smaller products of catabolism, and thus requires more energy than they release, that is, the anabolic pathway is ***endergonic*** because the building of anything requires energy. This energy comes from ATP molecules produced during catabolism. Like the synthesis of lipids for cell membranes from glycerol and fatty acid.

ATP production and energy storage

- During catabolism, organisms release energy from nutrients that can be then concentrated and stored in high-energy phosphate bonds of ATP molecules. This happens through a general process called **Phosphorylation.** In which inorganic phosphate [PO_4^{2-}] is added to a substrate.

  Ex: Cells phosphorylate ADP to form ATP



Phosphorylation of ADP to ATP is mediated by three specific ways:

1- ***Substrate-level phosphorylation***: This involves the transfer of phosphate to ADP from another phosphorylated organic compound.

2- ***Oxidation phosphorylation***: energy from redox (**oxidation-reduction**) reactions of respiration is used to attach inorganic phosphate to ADP.

3- ***Photophosphorylation***: in which light energy is used to phosphorylate ADP with inorganic phosphate.

Carbohydrate catabolism:

- Many organisms oxidize carbohydrates as their primary energy source for anabolic reactions. They use glucose most commonly, other sugars, amino acids, and fat, which convert them to glucose.

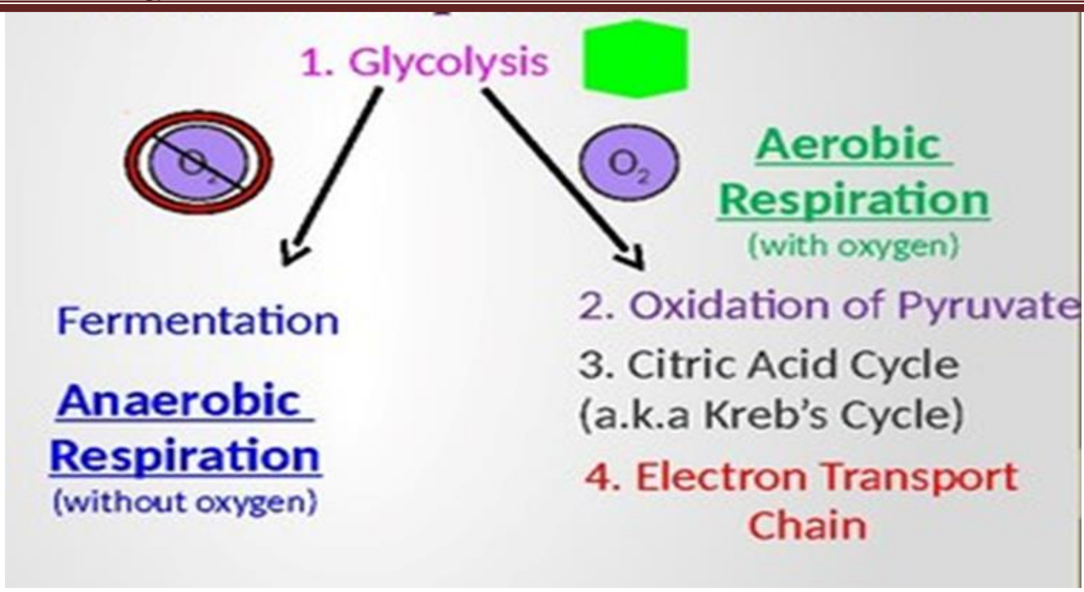
***Glucose can be catabolised via one of two processes:**

1- Cellular respiration: is an energy-generating process that occurs in the plasma membrane of bacteria resulting in the complete breakdown of **glucose to carbon dioxide and water**.

This process uses **oxygen, nitrate, or sulfate** to break down nutrients to generate a cell's energy. If **oxygen** is used, it is called **aerobic cellular respiration**. If oxygen is not used, it is called **anaerobic cellular respiration**. In the process of breaking down nutrients such as glucose, carbon dioxide, and water are generated. Carbon dioxide and water are waste products of aerobic cellular respiration.

The purpose of respiration is to provide the cell with the appropriate molecules for creating energy in the form of adenosine triphosphate, ATP.

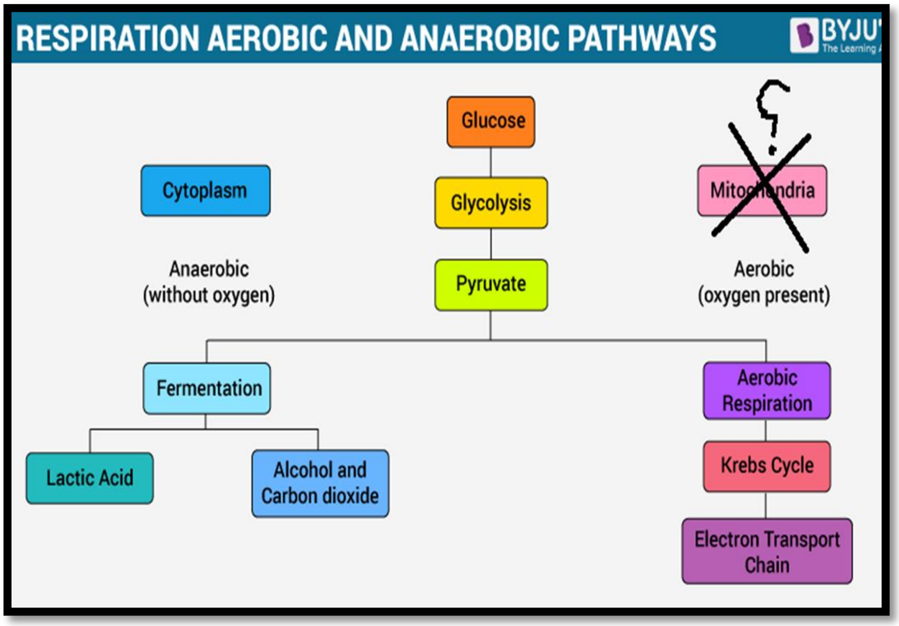
2- **Fermentation**: is a metabolic process that consumes sugar in the absence of oxygen, which results in organic waste products. The products are organic acids, gases, or alcohol. In microorganisms, fermentation is the primary means of producing adenosine triphosphate (ATP) by the degradation of organic nutrients anaerobically.



Both **cellular respiration and fermentation** start with ***glycolysis***, **a process that catabolizes a single molecule of glucose to two molecules of pyruvic acid or (pyruvate), and results in a small amount of ATP production.**

-Respiration is continued via **the Kreps cycle and the electron transport chain**, which results in a significant amount of ATP.

-Fermentation: involved the conversion of pyruvic acid into other organic compounds and much less ATP production.



Fermentation	Cell Respiration
– Produces little ATP (only 2 ATP through glycolysis)	– Produces massive amounts of ATP (~38 ATP)
– Does not need O_2	– Needs O_2
– Thought to have evolved first.	– Thought to have evolved after fermentation.
– Final e^- acceptor is pyurvate	– Final e^- acceptor is O_2

هذا الجدول اعلاه مطلوب

Growth requirements

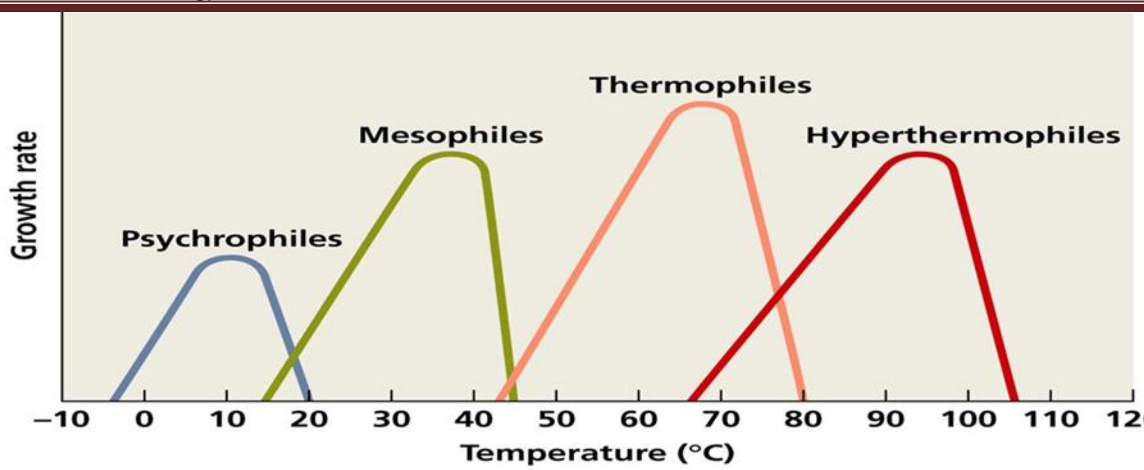
- Microorganisms' structure must have the proper PHYSICAL and CHEMICAL conditions for growth, In general, organisms use a variety of chemicals (nutrients) to get their energy needs, and to build organic and cellular molecules.

PHYSICAL REQUIREMENTS	CHEMICAL REQUIREMENTS
I. Temperature	1.oxygen
II. pH	2. carbon
III. Osmosis	3. nitrogen
	4. nutrients

PHYSICAL REQUIREMENTS

I. Temperature; (4 groups of microorganisms based on temperature)

1. **Psychorophiles**; usually grow at a temp. between 0 - 20 ^oC. like **algae, fungi, and bacteria and archaea**, live in snowfields, ice, and cold water. Non-pathogenic.
2. **Mesophiles;** usually grow at temperatures between 20 – 40 ^oC.
   Mesophiles include the common Human pathogens .
3. **Thermophiles**: capable of growth above 45 ^oC. in hot springs.
4. **Hyperthermophiles:** grow in water above 80^{o}C, such as Archaea.



Temperature: plays an important role in microbial life through its effect on **the three-dimensional configurations** of biological molecules (protein denaturation).
-In addition, lipid is temperature sensitive, as it is the main component of the membrane. If the temperature is too low, membranes become rigid and fragile; if the temperature is too high, the membranes become too fluid, and they cannot contain the cells and organelles.

Generally, an increase in temperature will increase enzyme activity. But if temperatures get too high, enzyme activity will diminish and the enzyme (the protein) will denature.

On the other hand, lowering temperature will decrease enzyme activity. At freezing, temperatures enzyme activity can stop. Repeated cycles of freezing and thawing can denature proteins. In addition, freezing causes water to expand and also form ice crystals, hence cells begin to rupture.

II. " pH": refers to the acidity or alkalinity of a solution.

pH: organisms are sensitive to changes in acidity because hydrogen ions and hydroxyl ions interfere with hydrogen bonding within proteins and nucleic acid.

1-Neutrophiles: most bacteria and protozoa that grow in a narrow range around the neutral pH (6.5-7.5) (the common Human pathogens).

1- **Acidophiles:** other bacteria and many fungi grow best in acidic habitats (pH 2-6).
2- **Alkalinophiles:** live in alkaline soil and water up to pH 11.5, such as ***Vibrio cholerae.***

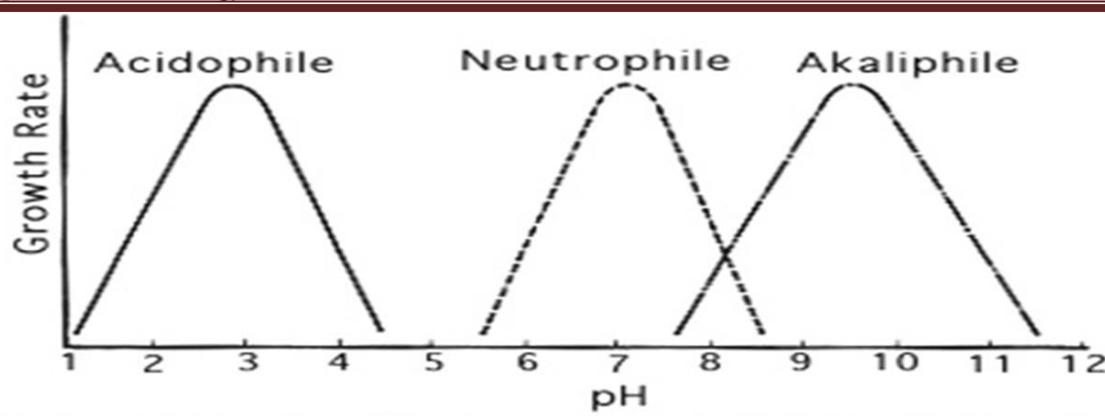


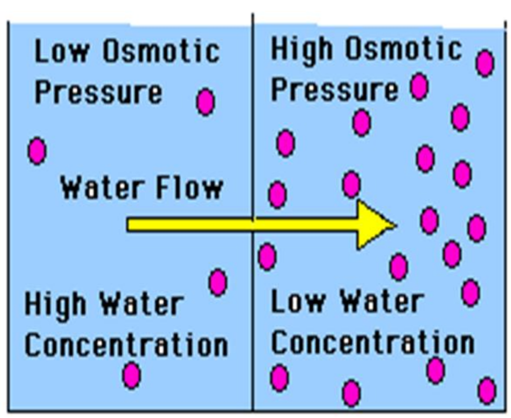
Figure 4. Growth rate vs pH for three environmental classes of procaryotes. Most free-living bacteria grow over a pH range of about three units. Note the symmetry of the curves below and above the optimum pH for growth.

Bacterial growth rates are greatly influenced by pH and are largely based on the nature of **proteins**. Changes in the external pH also might alter **the ionization of nutrient molecules** and thus reduce their availability to the organism.

When the external pH is low, the concentration of H^+ is greater outside than inside and H^+ will move into the cytoplasm which lowers internal pH. Drastic variations in cytoplasmic pH can harm bacteria by disrupting the plasma membrane or inhibiting the activity of enzymes and membrane transport proteins.

III . "Osmosis": is a process by which the molecules of a solvent pass from a solution of low concentration to a solution of high concentration through a semi-permeable membrane.

- **Osmotic pressure** is the amount of force applied to a solution that prevents solvent from moving across a semipermeable membrane.

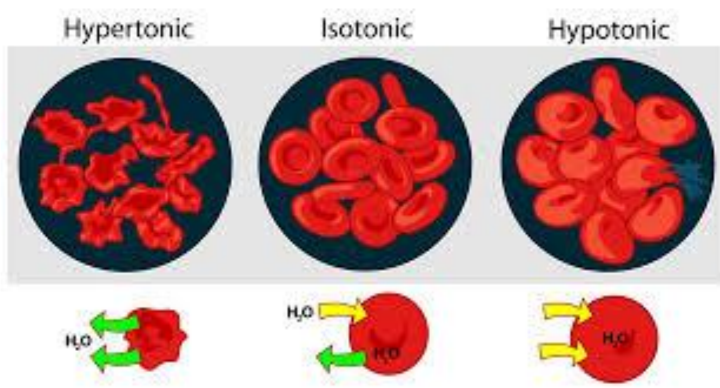


Types of osmotic pressure

There are three types of osmotic pressure: **isosmotic, hypoosmotic, and hyperosmotic.**

- **In isosmotic pressure**, the two solutions are divided by a semipermeable membrane and have the same solute concentration and therefore the same pressure.
- **In hypoosmotic pressure,** the solution inside a semipermeable membrane (e.g., a cell) has a lower solute concentration than the surrounding external solution (i.e., the internal solution is hypotonic), causing **outflux** of the solvent.
- **In hyperosmotic pressure,** the solution inside a semipermeable membrane has a higher solute concentration than the surrounding external solution (i.e., the internal solution is hypertonic), causing the **influx** of the solvent.

Cells react differently in **hypotonic, isotonic, and hypertonic solutions.** In a hypotonic solution, water rushes into the cell causing it to expand or even burst. In an isotonic solution, there is no net flow of water, keeping the cell stable. In a hypertonic solution, water leaves the cell, causing it to shrivel. These reactions are due to the semipermeable nature of cell membranes and the concentration of solutes.



CHEMICAL REQUIREMENTS

1. **Oxygen:**

Aerobic or obligate aerobic oxygen serves as the final electron acceptor of electron transport chains, which produce most of the ATP…. e.g., Pseudomonas.

Facultative anaerobes; use oxygen if present, but can grow in its absence.. such as *E. coli*.

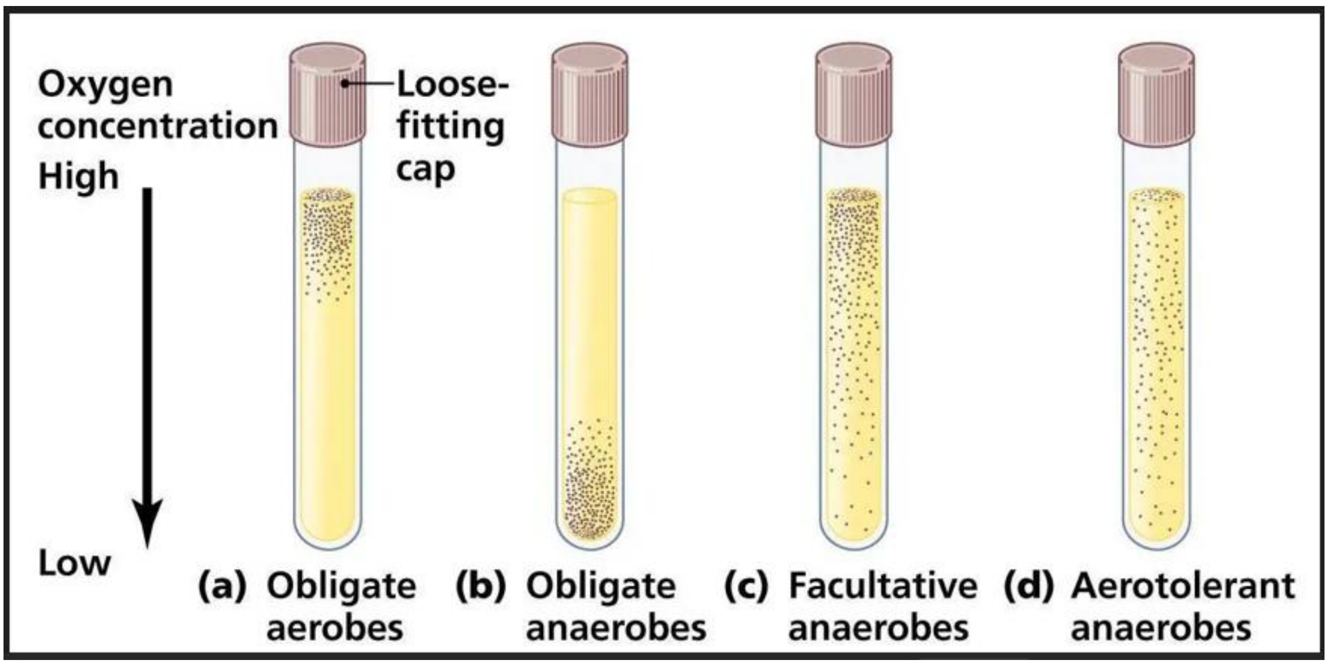
Anaerobic; organisms that do not use oxygen for energy. oxygen is a deadly poison.

Obligate anaerobes; are unable to use oxygen for growth and are usually harmed by it. They are unable to produce the enzyme superoxide dismutase (SOD) to neutralize superoxide free radicals

Aerotolerant; organisms that cannot use oxygen for growth but tolerate oxygen by having some of the enzymes that detoxify oxygen's poisonous forms (superoxide radicals and peroxide anion). Ex; lactobacilli that transform cucumber into pickles.(

Microaerophilic; organisms that require oxygen concentrations at lower levels than those found in air, 2-10 %, have a limited ability to detoxify hydrogen peroxide and superoxide radicals, such as ***Helicobacter pylori***.

Capnophilic (or carbon dioxide–loving): organisms require an increased concentration of carbon dioxide (5% – 10%) and approximately 15% oxygen. This condition can be achieved by a candle jar (3% carbon dioxide) or carbon dioxide incubator, jar, or bag. such as *Haemophilus influenzae*, *Neisseria gonorrhea*.



2. Carbon;

Virtually all chemical substances in microorganisms contain carbon in some form. About 50% of bacteria's dry weight is carbon.

Both **chemoautotrophic** and **photoautotrophic** microorganisms obtain their energy and produce their nutrients from simple inorganic compounds. Ex **carbon dioxide.**

3. **Nitrogen:**

Nitrogen is acquired from organic and inorganic nutrients and used in the synthesis of **proteins, amino acids, DNA, and RNA .**

Bacteria that obtain nitrogen directly from the atmosphere are called **nitrogen-fixing bacteria.** Ex Rhizobium, and Azotobacteria, are both found in soil.

4. **Nutrients:**

- In general, organisms use a variety of chemicals (nutrients) to get their energy needs, and to build organic molecules and cellular

- The most common nutrients are compounds containing necessary elements such as **carbon, oxygen, nitrogen, and hydrogen.**
- Microbes obtain nutrients from a variety of sources in their environment, so that, organisms can be categorized **into two broad groups based on their source of carbon:**

- ***Autotrophs*:** (self-feeder) organisms that synthesize food from inorganic compounds. Ex. Some bacteria; make organic compounds from CO_2 from the same organism.
- ***Heterotrophs:*** (other feeders) organisms that preformed organic carbon compounds from another organism. Ex. All animals, most bacteria, and all pathogenic bacteria.

- **Organisms can be also grouped according to whether they use chemicals or light as a source of energy for cellular process anabolism, intracellular transport, and motility:**

- ***Chemotrophs:*** organisms that acquire energy from redox reactions involving inorganic and organic chemicals via either aerobic respiration, anaerobic respiration, or fermentation.
- ***Phototrophs*:** organisms that use light as their energy source.

*** So, organisms can be classified into four groups according to their carbon and energy source:**

- **Photoautotrophs**
- **Photoheterotrophs**
- **Chemoautotrophs**
- **Chemoheterotrophs**

Nutritional types of microorganisms

Major nutritional type	Sources of energy, hydrogen/electrons, and carbon	Representative microorganisms
Photoautotroph (Photolithotroph)	Light energy, inorganic hydrogen/electron(H/e^-) donor, CO_2 carbon source	Algae, Purple and green bacteria, Cyanobacteria
Photoheterotroph (Photoorganotroph)	Light energy, inorganic H/e^- donor, Organic carbon source	Purple nonsulfur bacteria, Green sulfur bacteria
Chemoautotroph (Chemolithotroph)	Chemical energy source (inorganic), Inorganic H/e^- donor, CO_2 carbon source	Sulfur-oxdizing bacteria, Hydrogen bacteria, Nitrifying bacteria
Chemoheterotroph (Chenoorganotroph)	Chemical energy source (organic), Organic H/e^- donor, Organic carbon source	Most bacteria, fungi, protozoa