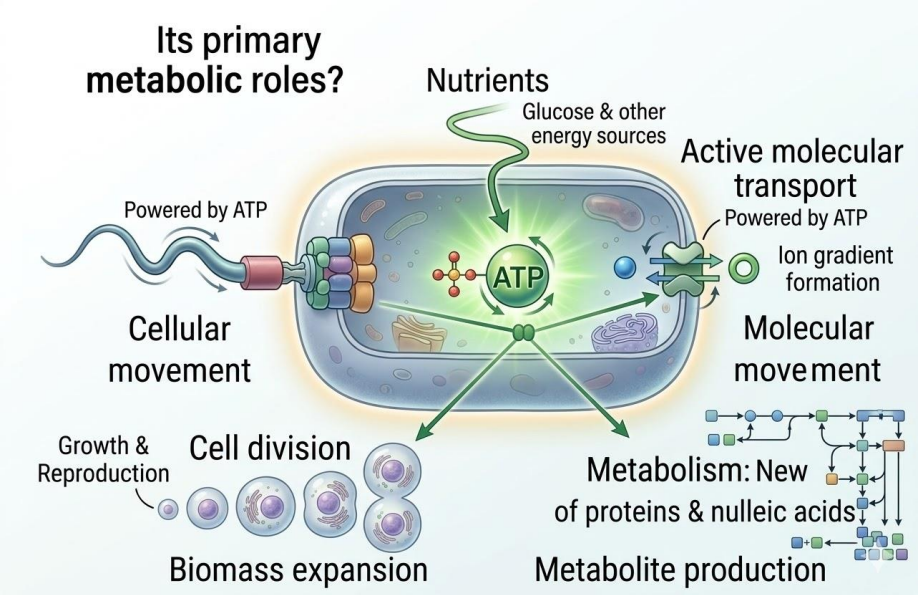
BACTERIAL NUTRITION

NUTRITION

Nutrition must be satisfied by two types of substances: elemental substances, which are the structural materials of the cell (carbon, nitrogen, minerals, etc.), and energy-providing substances that allow the cell to synthesize its own components.

To study nutrition, we will analyze the elemental and energy needs necessary for bacterial growth, as well as the physicochemical factors that condition it.



A - Energy and Elemental Requirements

B - Specific Needs – Growth Factors

C - Physical Factors

A – Energy and Elemental Requirements

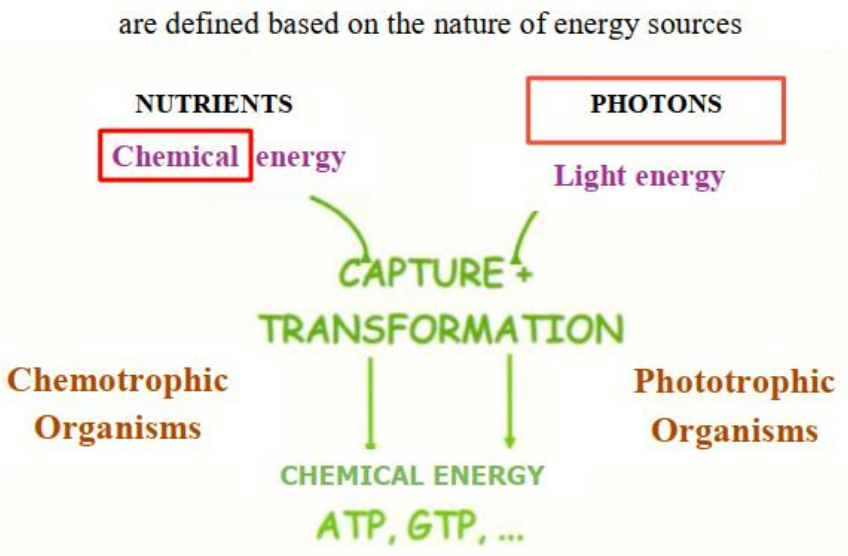
Bacteria multiply by using nutrients present in the culture media.

1. Energy Sources

Bacteria must find in their environment the substances necessary for their energy and for cellular synthesis. Depending on the **type of energy used**, two types of bacteria are recognized:

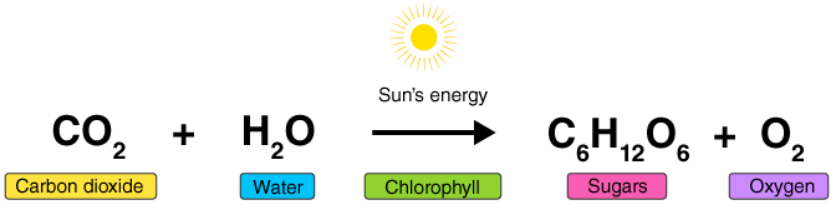
- **Phototrophs** (use light)
- **Chemotrophs** (use chemical substances)

Trophic types :

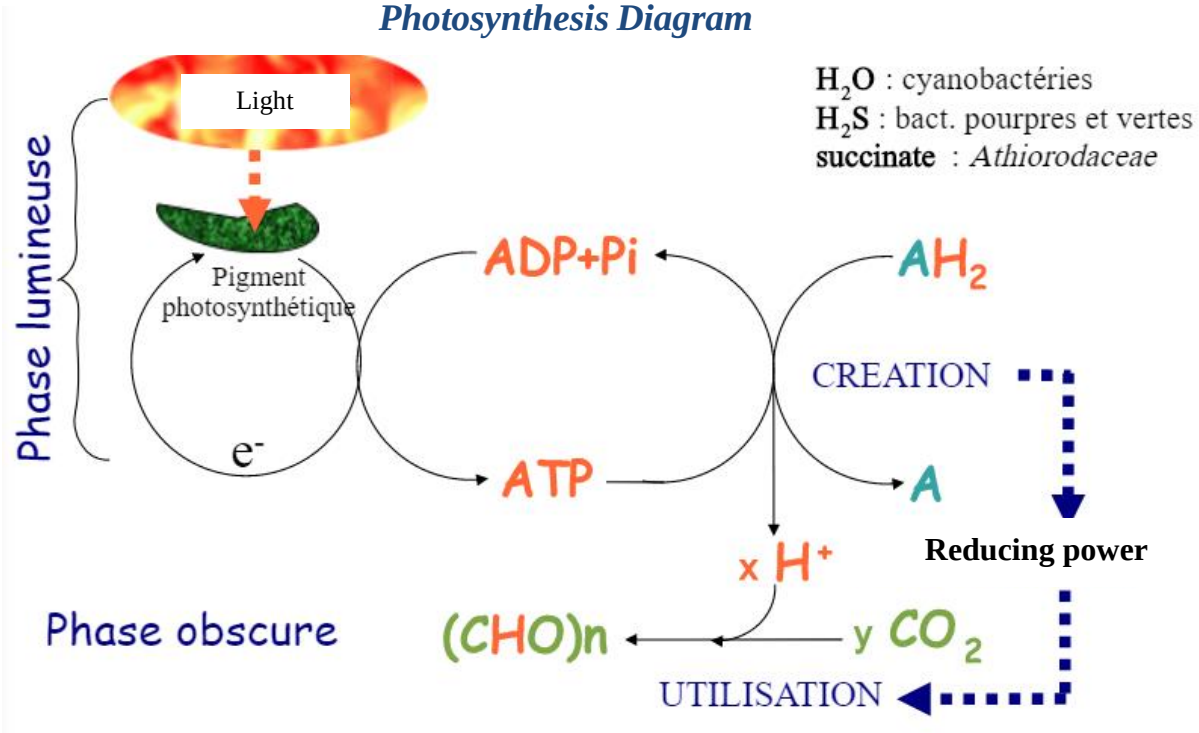


1/ Phototrophic Bacteria

Phototrophic bacteria use light energy for photosynthesis (ATP synthesis from ADP and inorganic phosphate).



Photosynthesis Diagram



Types : Bacterial phototrophy can rely on either inorganic or organic compounds as **electron sources**:

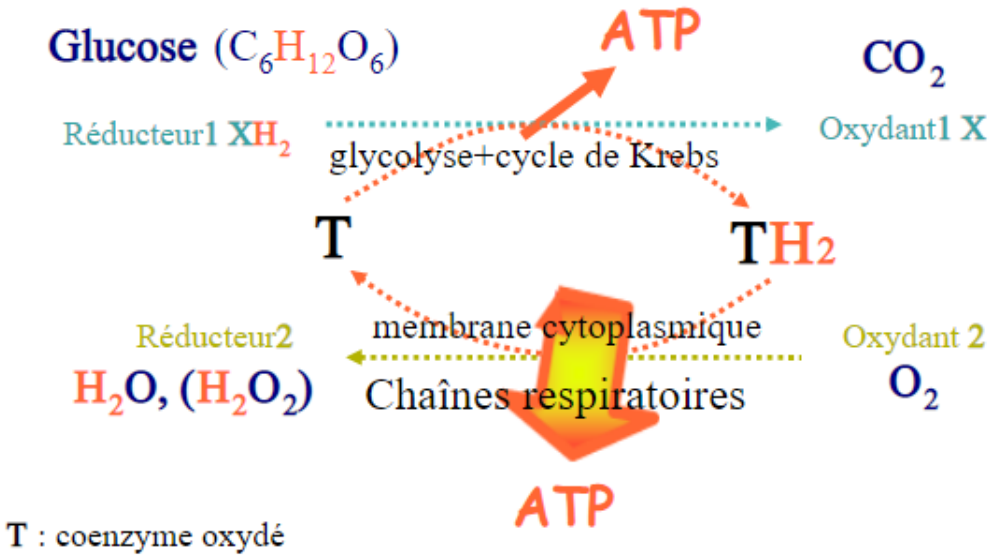
- **Photolithotrophs**: bacteria capable of developing in purely mineral media. Its use inorganic compounds (e.g., purple sulfur bacteria : *Thiorhodaceae*).
- **Photoorganotrophs**: use organic compounds (e.g., non-sulfur purple bacteria : *Athiorhodaceae*).

2/ Chemotrophic Bacteria

Chemotrophic bacteria derive their energy from inorganic or organic compounds.

Energy released during chemical oxidation-reduction reactions

Nutrients: they are reducing substances

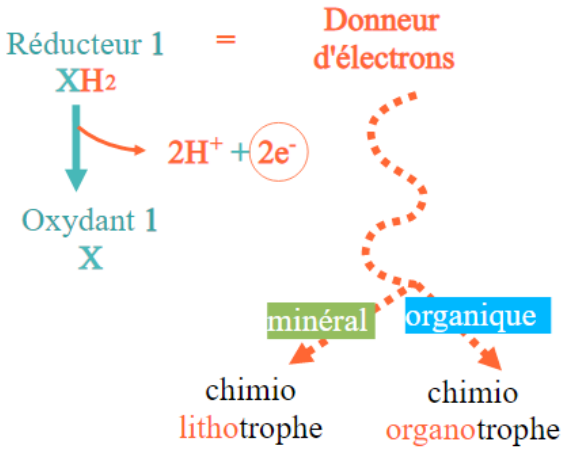


Reducing (reducer) ----------Oxidizing (oxidant)

Types (the nature of reducer1):

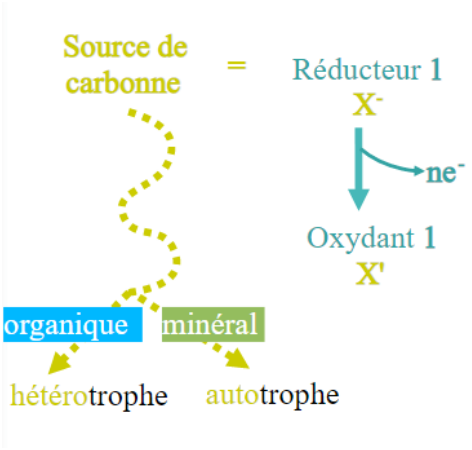
They use electron donors and acceptors: inorganic compounds or organic compounds.

- **Chemolithotrophs**: use inorganic compounds.
- **Chemoorganotrophs**: use organic compounds (majority of medically important bacteria).



2. Carbon Sources

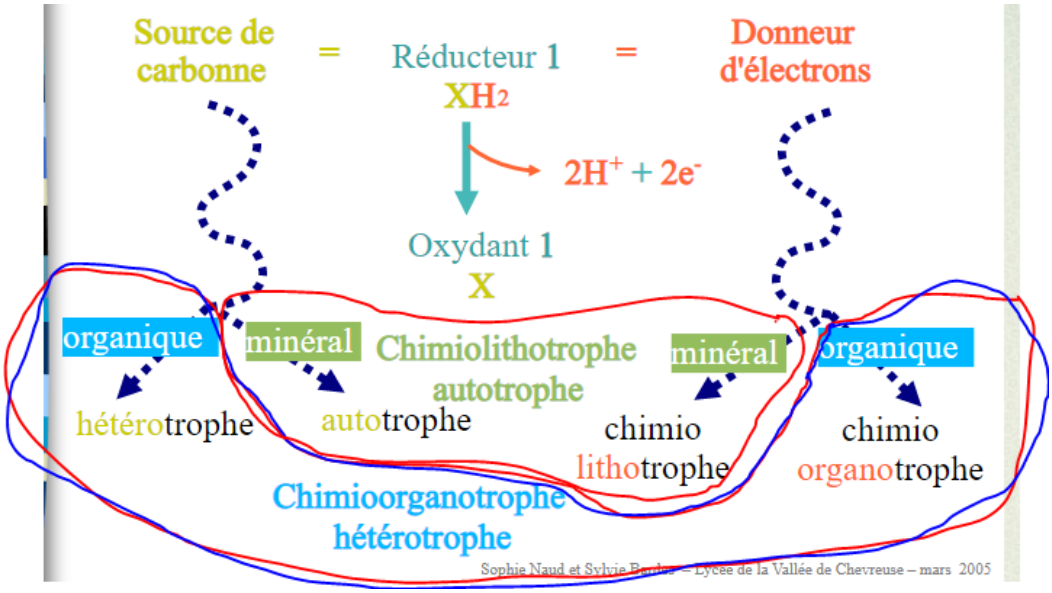
Carbon is one of the most abundant elements in bacterial cells. The simplest compound is carbon dioxide (CO_2), which can be used by bacteria in the synthesis of certain essential metabolites via carboxylation reactions.



- **Autotrophic bacteria** use CO_2 as their sole carbon source.

- **Heterotrophic bacteria** can use CO_2 facultatively but mainly degrade various hydrocarbon substances (alcohol, acetic acid, lactic acid, polysaccharides, and sugars).

Chemotrophs : the nature of reducer1



Nutritional Types of Microorganisms

Energy Source	Electron Source	Carbon Source	Nutritional Type
Light *Photo-*	Organic *-organo-*	Organic *-heterotroph*	Photoorganoheterotroph
		Carbon dioxide *-autotroph*	(no known organisms)
	Inorganic *-litho-*	Organic *-heterotroph*	(no known organisms)
		Carbon dioxide *-autotroph*	Photolithoautotroph
Chemical compounds *Chemo-*	Organic *-organo-*	Organic *-heterotroph*	Chemoorganoheterotroph
		Carbon dioxide *-autotroph*	(no known organisms)
	Inorganic *-litho-*	Organic *-heterotroph*	Chemolithoheterotroph
		Carbon dioxide *-autotroph*	Chemolithoautotroph

3. Nitrogen and Sulfur Needs

Bacteria need ***nitrogen***-containing substances to synthesize proteins. This nitrogen can come from direct *atmospheric nitrogen* (N_2) fixation or from incorporation of nitrogenous compounds (via deamination or transamination reactions).

Sulfur is incorporated in the form of *sulfate* or *organic sulfur compounds*.

4. Inorganic Requirements

Phosphorus is part of nucleic acids and many enzymatic reactions. It enables energy recovery, accumulation, and distribution within the bacterium, and is incorporated as inorganic phosphate.

5. Other Elements

Other elements play a role in bacterial metabolism (sodium, potassium, magnesium, chloride) and enzymatic reactions (calcium, iron, manganese, nickel, selenium, copper, cobalt, vitamins).

B – Specific Needs – Growth Factors

Growth factors are organic substances essential for growth that the bacterium cannot synthesize (amino acids, purine and pyrimidine bases, vitamins).

According to their needs, microorganisms are classified into two categories:

- **Prototrophs**: do not require growth factors; the usual elements are sufficient.
- **Auxotrophs**: require one or more growth factors. Some require only one, others many.

❖ The three main **categories** of growth factors are:

- Amino acids
- Purine and pyrimidine bases
- Vitamins

C – Physical Factors

Several physical factors influence nutrition. They may inhibit or promote it.

1. Temperature Effect

Bacteria can be classified by their optimal growth temperatures:

1) **Mesophiles**: prefer moderate temperatures (20–40°C). E.g., *Escherichia coli* grows optimally at human body temperature (~37°C).

2) **Thermophiles**: grow best between 45–65°C. E.g., *Thermus aquaticus* (45–70°C).
3) **Psychrophiles**: optimal growth around 0°C (optimum: 10–15°C).
4) **Psychrotrophs**: grow at refrigeration temperatures but multiply faster at 10–30°C. E.g., *Pseudomonas* (optimum similar to mesophiles).
5) **Hyperthermophiles** (e.g., Archaea): grow above 80°C.

2. pH

The environmental pH (hydrogen ion concentration [H+]) ranges from 0.5 (acid soils) to 10.5 (alkaline lake waters).

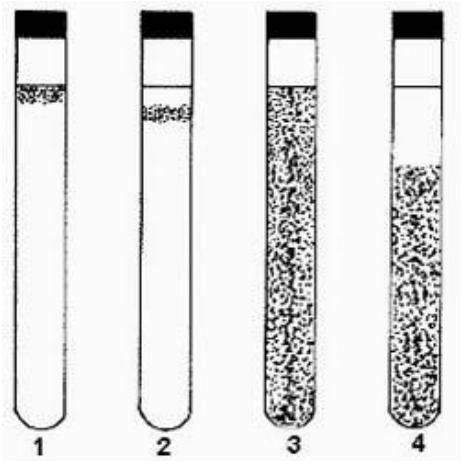
Pathogenic bacteria or those linked to human ecosystems typically grow in neutral or slightly alkaline media.

Bacterial types by pH preference:

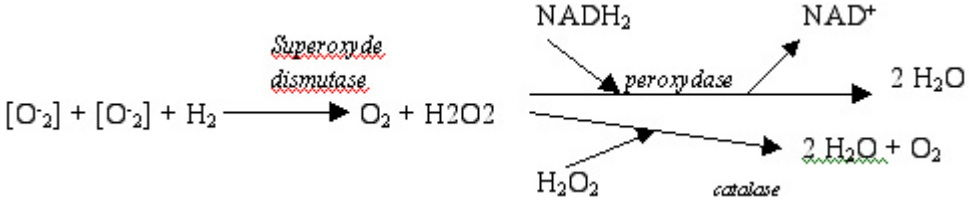
1) **Neutrophiles**: grow between pH 5.5 and 8.5, optimal around 7. Includes most medically relevant bacteria.
2) **Alkaliphiles**: prefer alkaline pH. E.g., *Pseudomonas* and *Vibrio* – require special culture media.
3) **Acidophiles**: grow better in acidic environments. E.g., *Lactobacillus* (optimal pH near 6).

3. Gaseous Requirements

Several bacterial classes exist based on their oxygen needs:



1) **Strict aerobes**: grow only in the presence of air. Their main energy source is respiration; oxygen is the terminal electron acceptor, reduced to water (*Pseudomonas, Acinetobacter, Neisseria*).
2) **Microaerophiles**: grow better or only when the oxygen partial pressure is lower than air (*Campylobacter, Mycobacteriaceae*).
3) **Facultative aero-anaerobic bacteria**: grow with or without air. Includes many medically important bacteria (*Escherichia, Salmonella, Streptococcus, Staphylococcus*). Energy is obtained from substrate oxidation and fermentation.
4) **Strict anaerobes**: grow only in the absence of oxygen, which is often toxic. Must be cultured in a reducing atmosphere. All energy comes from fermentation (*Bacteroides, Fusobacterium, Clostridium*). Oxygen toxicity results from superoxide radical production, which these bacteria cannot neutralize (due to lack of superoxide dismutase, catalase, or peroxidase enzymes).



4. Osmotic Pressure Effect

Osmotic pressure is directly proportional to the total concentration of ions and molecules in solution.

1) **Isotonic medium**: concentration equal inside and outside the cell.
2) **Hypotonic medium**: lower concentration outside.
3) **Hypertonic medium**: higher concentration outside.

Most bacteria tolerate ionic concentration variations well due to their rigid cell walls.

5. Effect of Free Water (Water Activity – Aw)

The availability of water in the environment or substances affects bacterial growth.

- Water activity (Aw) influences bacterial growth and is inversely proportional to osmotic pressure.
- Aw decreases with increased concentrations of dissolved **salts** or **sugars**.

Presence of salts :

- **Halophilic bacteria** require salt (NaCl) to grow. Concentration ranges from:
  - Mild halophiles: 1–6% NaCl
  - Extreme halophiles (e.g., *Halobacterium*): to 15–30% NaCl
- **Halotolerant bacteria** (e.g., *Staphylococcus aureus*) can grow with salt but do not require it.

Presence of sugars **:** Sugars and Water Stress Adaptation

- **Osmophilic bacteria** : require high sugar concentrations to grow.
- **Osmotolerant bacteria** : can grow in the presence of sugar but do not require it.

Xerophilic bacteria : can grow in dry environments with very low water availability.