Factors Affecting Bacterial Growth

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Bacterial requirements for growth

PHYSICAL OR ENVIRONMENTAL FACTORS

- oxygen (presence or absence)
- Temperature
- pH
- osmotic pressure
- moisture
- radiation

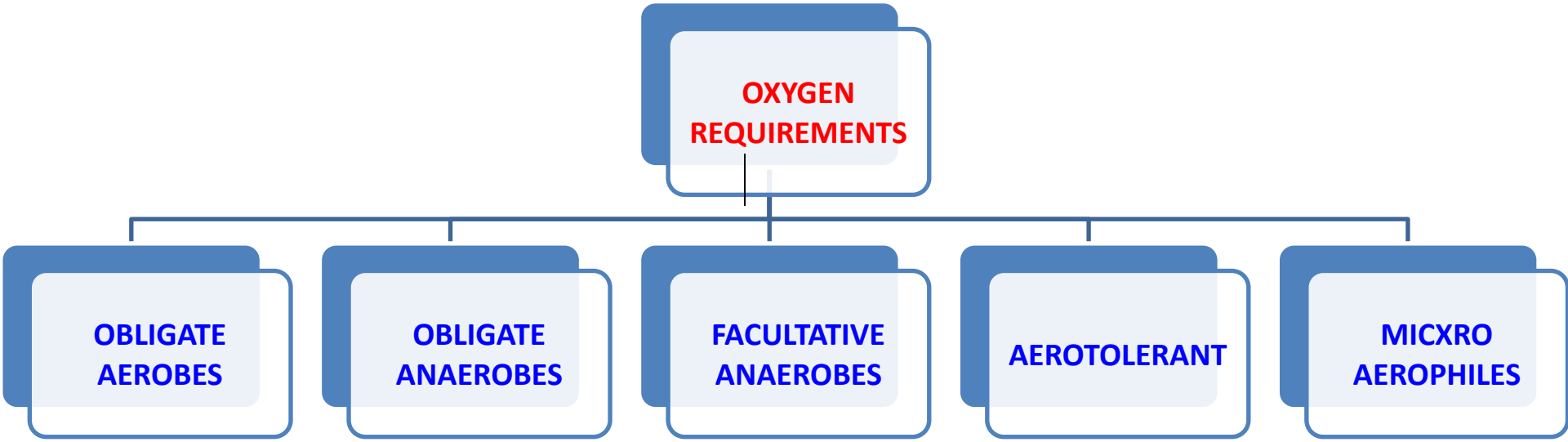
Bacterial requirements for growth

CHEMICAL OR NUTRITIONAL FACTORS

- carbon
- nitrogen
- phosphorous
- sulphur
- metal ions
- trace elements
- vitamins
- growth factors

PHYSICAL
OR
ENVIRONMENTAL FACTORS

OXYGEN


OXYGEN REQUIREMENTS
OBLIGATE AEROBES
OBLIGATE ANAEROBES
FACULTATIVE ANAEROBES
AEROTOLERANT
MICXRO AEROPHILES

- **Obligate aerobes are organisms that grow only in the presence of oxygen. They obtain their energy through aerobic respiration.**

- **Obligate anaerobes are organisms that grow only in the absence of oxygen and, in fact, are often inhibited or killed by its presence. They obtain their energy through anaerobic respiration or fermentation.**

- **Facultative anaerobes are organisms that grow with or without oxygen, but generally better with oxygen. They obtain their energy through aerobic respiration if oxygen is present, but use fermentation or anaerobic respiration if it is absent. Most pathogenic bacteria are facultative anaerobes.**

- **Aerotolerant anaerobes do not use oxygen to transform energy but can tolerate and grow in its presence. They obtain energy only by fermentation and are also known as obligate fermenters.**

- **Microaerophiles are organisms that require a low concentration of oxygen (2% to 10%) for growth, but higher concentrations are inhibitory. They obtain their energy through aerobic respiration. .**

OXYGEN REACTIVITY

- **Oxygen is a very reactive molecule and is a potent cellular poison unless a cell has a mechanisms to enzymatically inactivate it.**
- **Various reactive oxygen radicals (ROS) are invariably generated by cells in the presence of O_2.**
- **These ROS are H_2O_2 (peroxide), superoxide (O_2^-), singlet oxygen (O^-), peroxide anions and hydroxyl radicals (OH^-).**

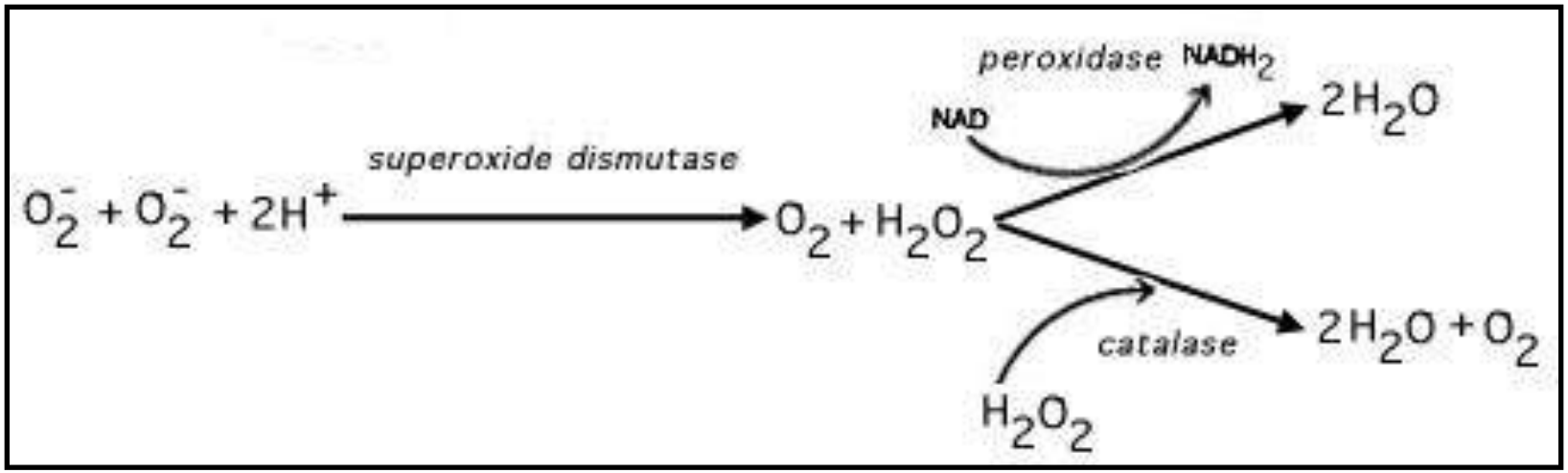
OXYGEN DETOXIFICATION

- All organisms which can live in the presence of O_2 (whether or not they utilize it in their metabolism) contain enzyme superoxide dismutase, which destroys superoxide (O_2^-) ion.

- Nearly all organisms also contain the enzyme catalase, which decomposes H_2O_2.

- Some organisms decompose H_2O_2 by means of peroxidase enzymes which derive electrons from $NADH_2$ to reduce peroxide to H_2O.

The action of superoxide dismutase, catalase and peroxidase enzymes on toxic oxygen radicals



Distribution of superoxide dismutase, catalase and peroxidase in prokaryotes with different O_2 tolerances.

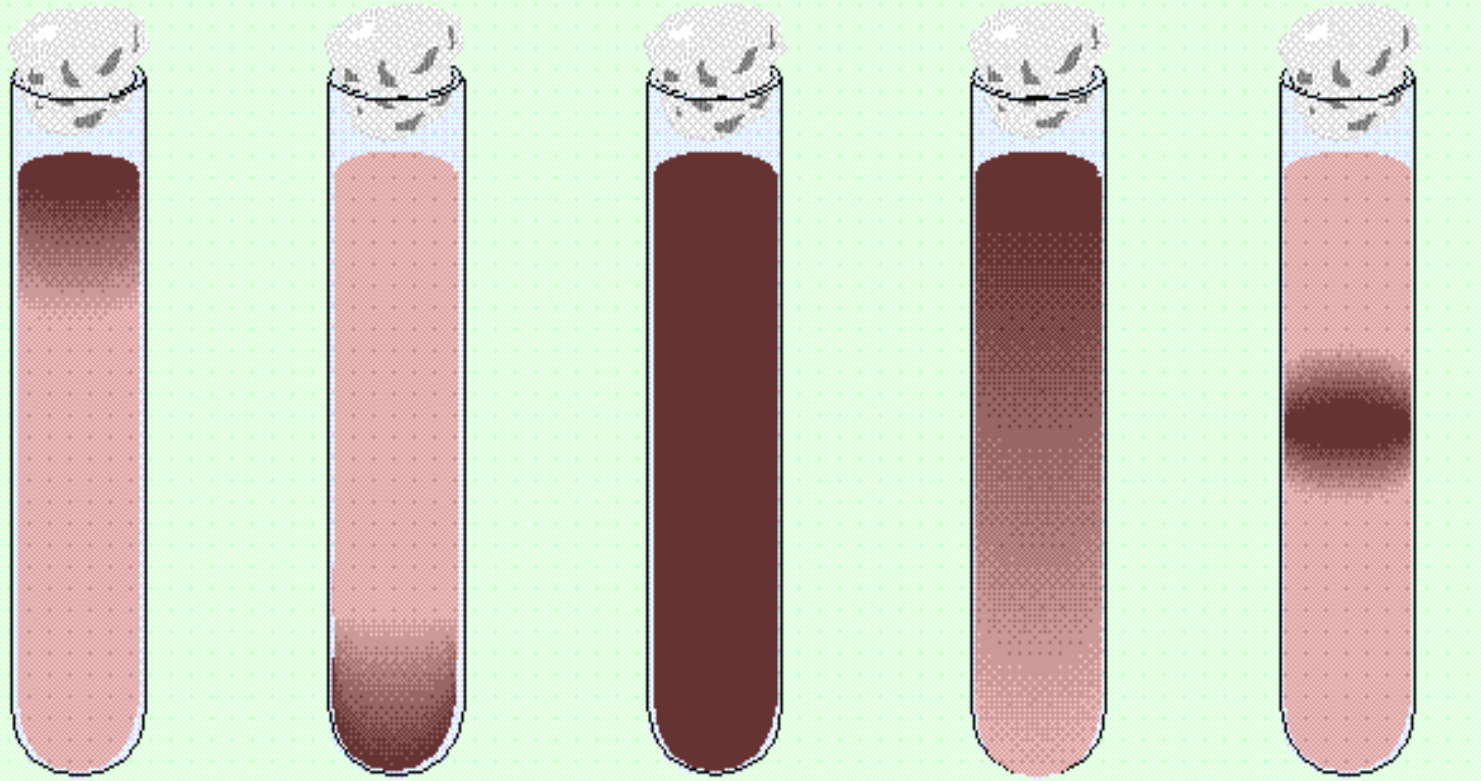
Group	Superoxide dismutase	Catalase	Peroxidase
Obligate aerobes and most facultative anaerobes (e.g. Enterics)	+	+	-
Most aerotolerant anaerobes (e.g. Streptococci)	+	-	+
Obligate anaerobes (e.g. Clostridia)	-	-	-

Terms used to describe O_2 Relations of Microorganisms

Group	Aerobic	Anaerobic	O_2 Effect
Obligate aerobe	Growth	No growth	Required (utilized for aerobic respiration)
Obligate anaerobe	No growth	Growth	Toxic
Facultative anaerobe (Facultative aerobe)	Growth	Growth	Preferentially utilized when available

Microaerophile	**Growth if level not too high**	**No growth**	**Required but at levels below 0.2 atm**
Aerotolerant anaerobe	**Growth**	**Growth**	**Not required and not utilized**

Growth of different physiological groups of bacteria in agar tubes in response to atmospheric oxygen.



Aerobic

Anaerobic

Aerotolerant

Facultative anaerobic

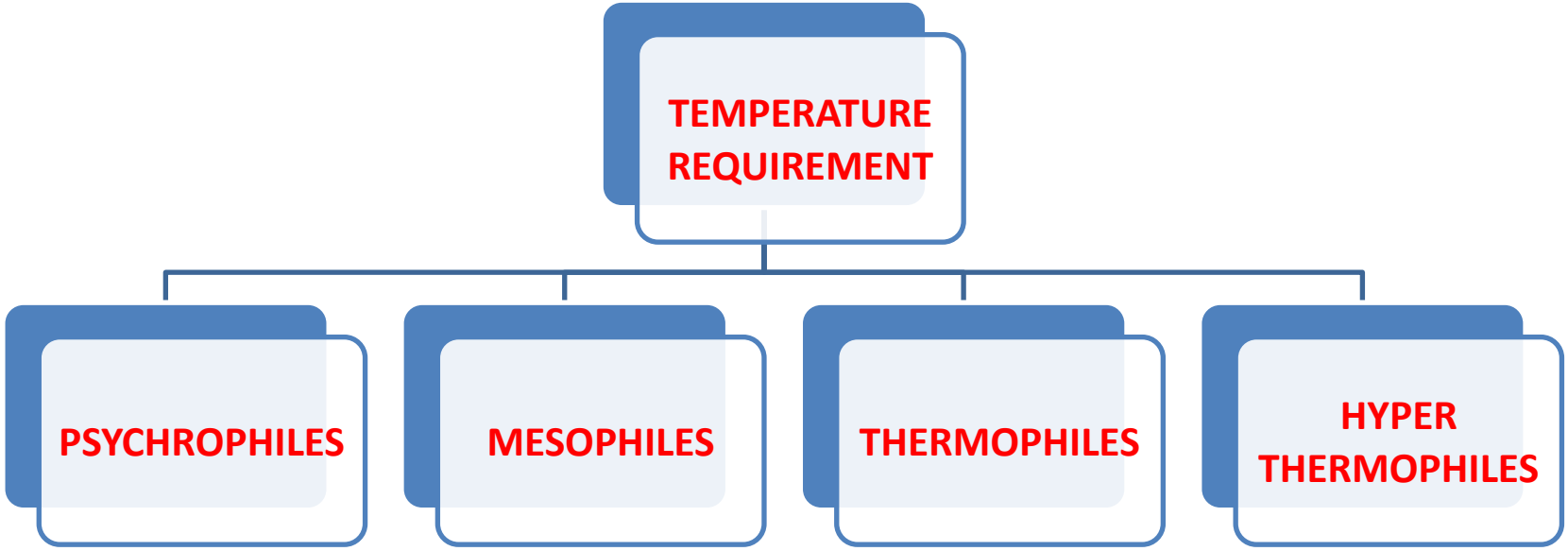
Microaerobic

Capnophiles

- **A small amount of CO_2 is required by all organisms for growth, which is provided by metabolism.**

- **Some organisms requires relatively high concentrations of carbon dioxide (1-5%) for their optimum growth, particularly for primary isolation; these are known as capnophiles, e.g., *Brucella abortus***

TEMPERATURE



Bacteria have a minimum, optimum, and maximum temperature for growth and can be divided into following groups based on their **optimum growth temperature** (temperature at which an organism grows best):

- **Psychrophiles** are cold-loving bacteria. Their optimum growth temperature is between -5°and 15°C with maximum up to 20°C. They are usually found in the Arctic and Antarctic regions and in streams fed by glaciers.

- **Mesophiles** are bacteria that grow best at moderate temperatures. Their optimum growth temperature is between 25° and 40°C with maximum below 45°C. Most bacteria are mesophilic and include common soil bacteria and **PATHOGENS**.

- **Thermophiles** are heat-loving bacteria. Their optimum growth temperature is between 45° and 70°C and are commonly found in hot springs and in compost heaps, e.g. *Bacillus stearothermophilus*

- **Hyperthermophiles** - grow at very high temperatures. Their optimum growth temperature is between 70° and 110°C. They are usually members of the *Archae* and are found growing near hydrothermal vents at great depths in the ocean, e.g. *Sulfolobus acidocaldarium*

- **Obligate psychrophiles –** are unable to grow above 20ºC.

- **Facultative psychrophiles -** are able to grow above 20ºC, but not in mesophilic range.

- **Psychrotroph -** A variant of a psychrophile which can grow at temperature in the range of mesophiles

- **Thermoduric** - Mesophilic organisms that can survive brief exposures to relatively high temperatures are termed thermoduric.

TEMPERATURE TOLERANCE

- **Psychrophilic bacteria are adapted to their cool environment due to high concentration of unsaturated fatty acids in their plasma membranes.**

- **Thermophilic bacteria adapted to their hot environment due to high concentration of highly saturated fatty acids in their plasma membranes.**

- **Often thermophiles have a high G + C content in their DNA**

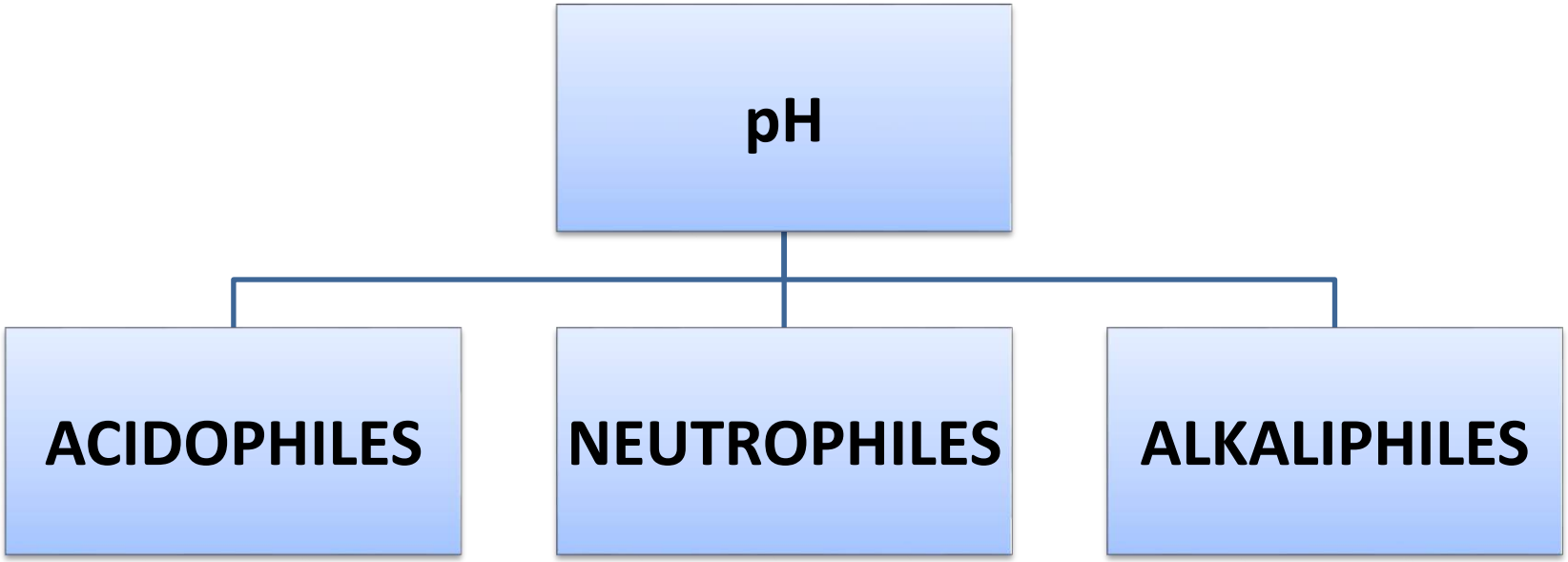
- **The membranes of hyperthermophiles are composed of repeating subunits of the C5 compound, phytane, which help them to live in superheated environments.**

Terms used to describe microorganisms in relation to temperature requirements for growth

Group	Minimum	Optimum	Maximum	Comments
Psychrophile	Below 0	10-15	Below 20	Grow best at relatively low T
Psychrotroph	0	15-20	Above 25	Able to grow at low T but prefer moderate T
Mesophile	10-15	25-40	Below 45	Most bacteria especially those living in association with warm-blooded animals

Thermoduric	**10-15**	**30-40**	**45-60**	**Mesophiles that can survive brief exposures to relatively high temperatures**
Thermophile	**45**	**50-70**	**Above 100 ºC (boiling)**	**Shows wide variation in optimum and maximum T**
Hyperthermophile	**70**	**80-110**	**Above 121**	**occurring in hot springs or deep sea vents in mid- ocean ridges**

pH



Microorganisms can be placed in one of the following groups based on their optimum pH requirements:

- **Acidophiles - Organisms whose optimum pH is moderately to highly acidic, usually 5.5. Several genera of Archaea, including *Sulfolobus* and *Thermoplasma*, are obligate acidophiles.**
  Among eukaryotes, many fungi are acidophiles.

- **Neutrophiles - Organisms whose optimum pH is 7± 1.5 with a range of 5 to 8, e.g. *Staphylococcus aureus* (7.0-7.5), *E. coli* (6.0-7.0)**

- **Alkaliphiles - Organisms whose optimum pH is usually above 8.0, e.g. *Nitrobacter***

WATER AVAILABILITY

- **Water is the solvent in which the molecules of life are dissolved, and the availability of water is, therefore, a critical factor that affects the growth of all cells.**
- **The availability of water for a cell depends upon its presence in the atmosphere (relative humidity) or its presence in solution (water activity).**
- **Microorganisms live over a range of Aw from 1.0 to 0.7.**
- **The concept of lowering water activity in order to prevent bacterial growth is the basis for preservation of foods by drying (in sunlight or by evaporation) or by addition of high concentrations of salt or sugar.**
- **Xerophiles - Organisms which live in dry environments (made dry by lack of water).**

OSMOTIC PRESSURE

Most bacteria require an isotonic environment or a hypotonic environment for optimum growth.

- **Osmophiles - organisms that are able to live in hypertonic environments high in salt or sugar.**

- **Osmotolerant - organisms that can tolerate salt concentration up to approximately 10%.**

Depending on the requirement of salt concentrations microorganisms are classified as follows:

- **Non-halophiles require less than 1% salt (***E. coli* or *Pseudomonas)*
- **mild halophiles require 1-6% salt**
- **moderate halophiles require 6-15% salt (***S. aureus*)
- **Extreme halophiles require 15-30% NaCl for growth** (archaea such as *Halococcus*).
- **Halotolerant - bacteria that are able to grow at moderate salt concentrations, even though they grow best in the absence of NaCl.**

CHEMICAL OR NUTRITIONAL FACTORS

NUTRITIONAL REQUIREMENTS

All living organisms are grouped into different nutritional groups according to their energy source, carbon source and hydrogen / electrons source.

Energy source

Phototrophs use light as the primary source of energy

Chemotrophs use chemical compounds as the primary source of energy

Carbon source

Autotrophs require only carbon dioxide as a carbon source. An autotroph can synthesize organic molecules from inorganic nutrients.

Heterotrophs require organic forms of carbon. A heterotroph cannot synthesize organic molecules from inorganic nutrients.

Hydrogen/Electron source

Lithotroph use inorganic substrates such as ammonium, nitrite, hydrogen sulfide or elementary hydrogen as a source of hydrogen/ electron donor

Organotroph use reduced organic compounds such as glucose and fatty acids as a source of hydrogen/ electron donor

Major nutritional types of prokaryotes

Nutritional Type	Energy Source	Carbon Source	Examples
Photoautotrophs	Light	CO_2	Cyanobacteria, some Purple and Green Bacteria
Photoheterotrophs	Light	Organic compounds	Some Purple and Green Bacteria
Chemoautotrophs or Lithotrophs (Lithoautotrophs)	Inorganic compounds, e.g. H_2, NH_3, NO_2, H_2S	CO_2	A few Bacteria and many Archaea
Chemoheterotrophs or Heterotrophs	Organic compounds	Organic compounds	Most Bacteria, some Archaea

Nutritional and Metabolic Diversity

PHOTOAUTOTROPHS

Photosynthetic organisms

Organic compounds produced from CO_2

They contain internal membranes with light-harvesting pigment system

cyanobacteria

CHEMOAUTOTROPHS

Obtain energy by oxidizing inorganic substances (H_2S, NH_3, Fe^{2+})

Organic compounds produced from CO_2

PHOTOHETEROTROPHS

Photosynthetic organisms

Organic compounds produced from carbon in organic form

CHEMOHETEROTROPHS

Obtain energy and carbon source by consumation of organic molecules

NUTRITIONAL FACTORS

- carbon
- nitrogen
- phosphorous
- sulphur
- metal ions
- trace elements
- vitamins
- growth factors

Major elements, their sources and functions in bacterial cells

Element	% of dry weight	Source	Function
Carbon	50	organic compounds or CO_2	Main constituent of cellular material
Oxygen	20	H_2O, organic compounds, CO_2, and O_2	Constituent of cell material and cell water; O_2 is electron acceptor in aerobic respiration
Nitrogen	14	NH_3, NO_3, organic compounds, N_2	Constituent of amino acids, nucleic acids nucleotides, and coenzymes

Hydrogen	**8**	**H_2O, organic compounds, H_2**	**Main constituent of organic compounds and cell water**
Phosphorus	**3**	**inorganic phosphates (PO_4)**	**Constituent of nucleic acids, nucleotides, phospholipids, LPS, teichoic acids**
Sulfur	**1**	**SO_4, H_2S, S^o, organic sulfur compounds**	**Constituent of cysteine, methionine, glutathione, several coenzymes**
Potassium	**1**	**Potassium salts**	**Main cellular inorganic cation, cofactor for enzymes**
Magnesium	**0.5**	**Magnesium salts**	**Inorganic cellular cation, cofactor for enzymes**
Calcium	**0.5**	**Calcium salts**	**Inorganic cellular cation, cofactor for certain enzymes, a component of endospores.**
Iron	**0.2**	**Iron salts**	**Component of cytochromes and certain nonheme iron-proteins, cofactor for some enzymes**

Growth factors

- **Growth factors are organic compounds such as amino acids, purines, pyrimidines, and vitamins that a cell must have for growth but cannot synthesize itself.**

- **Organisms having complex nutritional requirements and needing many growth factors are said to be fastidious.**