17.2: Factors that Influence Bacterial Growth

Skills to Develop

1. Define the following:
   a. psychrophile
   b. psychrotroph
   c. mesophile
   d. thermophile
   e. obligate aerobe
   f. obligate anaerobe
   g. aerotolerant anaerobe
   h. facultative anaerobe

2. State the optimum pH range for most bacteria and compare this range with the optimum pH for fungi.

3. Define the following:
   a. phototroph
   b. chemotroph
   c. autotroph
   d. heterotroph
   e. fastidious

Physical requirements
a. Temperature

Bacteria have a minimum, optimum, and maximum temperature for growth and can be divided into 3 groups based on their optimum growth temperature:

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

2. Mesophiles are bacteria that grow best at moderate temperatures. Their optimum growth temperature is between 25°C and 45°C. Most bacteria are mesophilic and include common soil bacteria and bacteria that live in and on the body.

3. Thermophiles are heat-loving bacteria. Their optimum growth temperature is between 45°C and 70°C and are commonly found in hot springs and in compost heaps.

4. Hyperthermophiles are bacteria that grow at very high temperatures. Their optimum growth temperature is between 70°C and 110°C. They are usually members of the Archaea and are found growing near hydrothermal vents at great depths in the ocean.

b. Oxygen requirements

Bacteria show a great deal of variation in their requirements for gaseous oxygen. Most can be placed in one of the following groups:

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

2. Microaerophils 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.

3. 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.

4. Aerotolerant anaerobes, like obligate anaerobes, cannot use oxygen to transform energy but can grow in its presence. They obtain energy only by fermentation and are known as obligate fermenters.

5. 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 bacteria are facultative anaerobes.

c. pH

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

1. Neutrophiles grow best at a pH range of 5 to 8.
2. Acidophiles grow best at a pH below 5.5.

3. Alkaliphiles grow best at a pH above 8.5.

d. Osmosis

Osmosis is the diffusion of water across a membrane from an area of higher water concentration (lower solute concentration) to lower water concentration (higher solute concentration). Osmosis is powered by the potential energy of a concentration gradient and does not require the expenditure of metabolic energy. While water molecules are small enough to pass between the phospholipids in the cytoplasmic membrane, their transport can be enhanced by water transporting transport proteins known as aquaporins. The aquaporins form channels that span the cytoplasmic membrane and transport water in and out of the cytoplasm.

To understand osmosis, one must understand what is meant by a solution. A solution consists of a solute dissolved in a solvent. In terms of osmosis, solute refers to all the molecules or ions dissolved in the water (the solvent). When a solute such as sugar dissolves in water, it forms weak hydrogen bonds with water molecules. While free, unbound water molecules are small enough to pass through membrane pores, water molecules bound to solute are not (see Figure 4C and Figure 4D). Therefore, the higher the solute concentration, the lower the concentration of free water molecules capable of passing through the membrane.

A cell can find itself in one of three environments: isotonic, hypertonic, or hypotonic. (The prefixes iso-, hyper-, and hypo- refer to the solute concentration).

- In an isotonic environment (see Figure 5A), both the water and solute concentration are the same inside and outside the cell and water goes into and out of the cell at an equal rate.

  Flash animation showing osmosis in an isotonic environment.
  http5 version of animation for iPad showing osmosis in an isotonic environment.

- If the environment is hypertonic (see Figure 5B), the water concentration is greater inside the cell while the solute concentration is higher outside (the interior of the cell is hypotonic to the surrounding hypertonic environment). Water goes out of the cell.

  Flash animation showing osmosis in a hypertonic environment.
  html5 version of animation for iPad showing osmosis in a hypertonic environment.

- In an environment that is hypotonic (see Figure 5C), the water concentration is greater outside the cell and the solute concentration is higher inside (the interior of the cell is hypertonic to the hypotonic surroundings). Water goes into the cell.

  Flash animation showing osmosis in a hypotonic environment.
Most bacteria require an isotonic environment or a hypotonic environment for optimum growth. Organisms that can grow at relatively high salt concentration (up to 10%) are said to be osmotolerant. Those that require relatively high salt concentrations for growth, like some of the Archaea that require sodium chloride concentrations of 20% or higher halophiles.

**Nutritional requirements**

In addition to a proper physical environment, microorganisms also depend on an available source of chemical nutrients. Microorganisms are often grouped according to their energy source and their source of carbon.

**a. Energy source**

1. Phototrophs use radiant energy (light) as their primary energy source.
2. Chemotrophs use the oxidation and reduction of chemical compounds as their primary energy source.

**b. Carbon source**

Carbon is the structural backbone of the organic compounds that make up a living cell. Based on their source of carbon bacteria can be classified as autotrophs or heterotrophs.

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

Combining their nutritional patterns, all organisms in nature can be placed into one of four separate groups: photoautotrophs, photoheterotrophs, chemoautotrophs, and chemoheterotrophs.

1. Photoautotrophs use light as an energy source and carbon dioxide as their main carbon source. They include photosynthetic bacteria (green sulfur bacteria, purple sulfur bacteria, and cyanobacteria), algae, and green plants. Photoautotrophs transform carbon dioxide and water into carbohydrates and oxygen gas through photosynthesis.

Cyanobacteria, as well as algae and green plants, use hydrogen atoms from water to reduce carbon dioxide to form carbohydrates, and during this process oxygen gas is given off (an oxygenic process). Other photosynthetic bacteria (the green sulfur bacteria and purple sulfur bacteria) carry out an anoxygenic process, using sulfur, sulfur compounds or hydrogen gas to reduce carbon dioxide and form organic compounds.
2. Photoheterotrophs use light as an energy source but cannot convert carbon dioxide into energy. Instead they use organic compounds as a carbon source. They include the green nonsulfur bacteria and the purple nonsulfur bacteria.

3. Chemolithoautotrophs use inorganic compounds such as hydrogen sulfide, sulfur, ammonia, nitrites, hydrogen gas, or iron as an energy source and carbon dioxide as their main carbon source.

4. Chemoorganoheterotrophs use organic compounds as both an energy source and a carbon source. Saprophytes live on dead organic matter while parasites get their nutrients from a living host. Most bacteria, and all protozoans, fungi, and animals are chemoorganoheterotrophs.

c. Nitrogen source

Nitrogen is needed for the synthesis of such molecules as amino acids, DNA, RNA and ATP. Depending on the organism, nitrogen, nitrates, ammonia, or organic nitrogen compounds may be used as a nitrogen source.

d. Minerals

1. Sulfur

Sulfur is needed to synthesize sulfur-containing amino acids and certain vitamins. Depending on the organism, sulfates, hydrogen sulfide, or sulfur-containing amino acids may be used as a sulfur source.

2. Phosphorus

Phosphorus is needed to synthesize phospholipids, DNA, RNA, and ATP. Phosphate ions are the primary source of phosphorus.

3. Potassium, magnesium, and calcium

These are required for certain enzymes to function as well as additional functions.

4. Iron

Iron is a part of certain enzymes.

5. Trace elements

Trace elements are elements required in very minute amounts, and like potassium, magnesium, calcium, and iron, they usually function as cofactors in enzyme reactions. They include sodium, zinc, copper, molybdenum, manganese, and cobalt ions. Cofactors usually function as electron donors or electron acceptors during enzyme reactions.

e. Water
f. 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.

Summary

1. Bacteria have a minimum, optimum, and maximum temperature for growth and can be divided into 3 groups based on their optimum growth temperature: psychrophils, mesophils, thermophils, or hyperthermophils.
2. Bacteria show a great deal of variation in their requirements for gaseous oxygen. Most can be placed in one of the following groups: obligate aerobes, microaerophils, obligate anaerobes, aerotolerant anaerobes, or facultative anaerobes.
3. Microorganisms can be placed in one of the following groups based on their optimum pH requirements: neutrophiles, acidophiles, or alkaliphiles.
4. A bacterium's osmotic environment can affect bacterial growth.
5. Bacteria can be grouped according to their energy source as phototrophs or chemotrophs.
6. Bacteria can be grouped according to their carbon source as autotrophs or heterotrophs.
7. Combining their nutritional patterns, all organisms in nature can be placed into one of four separate groups: photoautotrophs, photoheterotrophs, chemoaototrophs, and chemoheterotrophs.
8. Bacteria also need a nitrogen source, various minerals, and water for growth.
9. Organisms having complex nutritional requirements and needing many growth factors are said to be fastidious.

Contributors

- Dr. Gary Kaiser (COMMUNITY COLLEGE OF BALTIMORE COUNTY, CATONSVILLE CAMPUS)