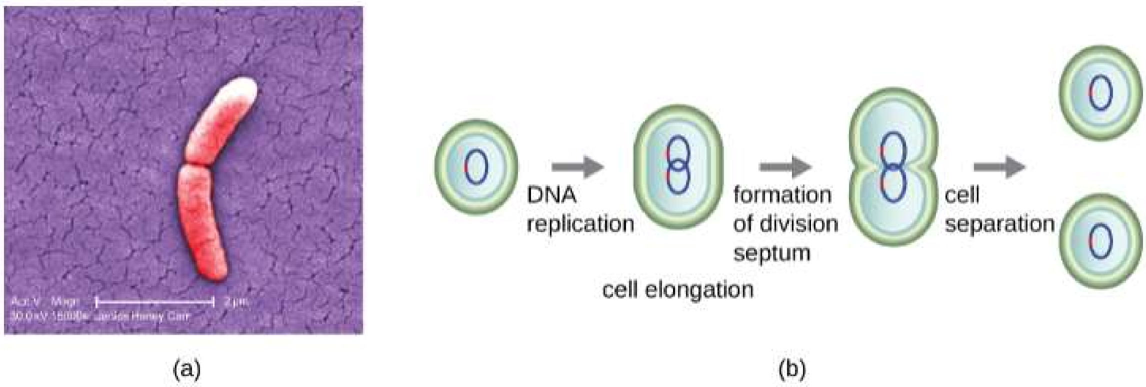
07- Microbial Growth and Nutrition (Instructor: Şeref Tağı)

The most common mechanism of cell replication in bacteria is a process called binary fission, which is shownd below. Before dividing, the cell grows and increases its number of cellular components. Next, the replication of DNA starts at a location on the circular chromosome called the origin of replication, where the chromosome is attached to the inner cell membrane. Replication continues in opposite directions along the chromosome until the terminus is reached.



(a) The electron micrograph depicts two cells of Salmonella typhimurium after a binary fission event. (b) Binary fission in bacteria starts with the replication of DNA as the cell elongates. A division septum forms in the center of the cell. Two daughter cells of similar size form and separate, each receiving a copy of the original chromosome. (credit a: modification of work by Centers for Disease Control and Prevention) (Download for free at https://openstax.org/details/books/microbiology)

For each microorganism, there is a set of conditions (both physical and chemical) under which it can survive. Many factors combine to create these conditions. Within the range of conditions that a microbe can survive, there is a narrower range that is optimal for growth.

Physical requirements

Microbes have a variety of physical requirements for growth, including temperature, pH, and water stress.

Temperature:

Microbes can be separated into groups based on the range of temperatures at which they can survive. At the edges of each range, microbes can usually survive but not thrive, whereas the perfect conditions for growth are usually somewhere in the middle. There is also a lot of gray area between these groups because not all microbes in each group are the same. For instance, some psychrophiles can survive at 0°C but prefer 15°C, and others prefer 30°C, bringing them almost into the mesophile group.

The various groups of microbes based on their physical requirements:

Psychrophiles are microbes that can grow at 0°C. Some are inhibited at higher temperatures, preferring to live in cold climates, whereas others can survive in conditions above 20°C. This latter group are called psychrotrophs because they prefer colder temperatures but can live just fine in higher ones. The range for psychropiles is –10°C to 20°C, with an optimum at about 10°C. The range for psychrotrophs is from 0°C to 40°C with an optimum of about 20°C.

Mesophiles like it best between 25°C and 40°C but can survive between 10°C and 50°C. Microbes that live within animals grow optimally at a temperature that matches that of their host. For instance, microbes that live in the human body grow between 34 and 37°C, which is body temperature.

Thermophiles can tolerate temperatures up to 70°C and like it best between 50°C and 60°C. This group contains a subset considered hyperthermophilic, or extreme heat loving. All the known microorganisms in this category are archaea and some can even grow in temperatures above 120°C, deep in the sea where the pressure stops water from boiling at that temperature.

pH: Another physical growth condition important to microorganisms is pH. The pH is the measure of how acidic or alkaline a solution is, with values from 0 to 14. Acidic environments include acid mine drainage, iron lakes, and the jar of pickles in your cupboard, with ranges between 1 and 6. Neutral pH is around 7. Alkaline, or basic pH, is 8 to 14. Most bacteria prefer a pH range of 6.5 to 7.5, whereas fungi can grow in more acidic conditions, preferring pH 5 to

6. Some bacteria and archaea are acididophilic (acid loving); they grow in conditions far too acidic for other species.

Water stress

The last physical condition to consider is water stress, either from the concentration of solutes in the microbe's surroundings or from drying. As more solutes such as salts or sugar are dissolved in water, the concentration of water to solutes goes down. A microbial cell is permeable to water, so if the concentration of water is lower outside the cell than inside the cell, water will move out in order to balance the inside and outside solutions.

One way bacteria have developed to deal with bad conditions is to transform themselves into endospores. The **endospore** is a dormant form of the original bacterial cell surrounded by a tough coating that makes it resistant to drying, as well as toxic compounds in its environment.

Chemical requirements

Unlike the physical requirements where a specific range or concentration is necessary for optimum growth, the chemical requirements just need to be present in the environment and a microbe will use what it needs. Microbes use compounds containing the following elements and vitamins to make everything in the cell including membranes, proteins, and nucleic acids:

Carbon: Carbon is necessary for all life. In the microbial world, chemoorganotrophs get their carbon from organic matter, whereas chemoautotrophs get it from carbon dioxide in the atmosphere.

Nitrogen, sulfur, and phosphorus: Nitrogen, sulfur, and phosphorus are necessary for protein and nucleic acid biosynthesis. Most microbes get these elements by degrading proteins and nucleic acids, but some capture nitrogen from nitrogen gas or ammonia or get sulfur from other ions in the environment.

Trace elements: Trace elements such as iron, copper, molybdenum, and zinc are needed as cofactors for enzymes and must be obtained, in tiny amounts, from the environment.

Vitamins and amino acids: Unlike humans, microbes can make vitamins, which also act as enzyme cofactors. Some microbes, however, lack the ability to make one or several vitamins and have to get them from their environment. The same is true of amino acids and these along with the vitamins needed are called growth factors. Although most bacteria can make all the amino acids they need, some can't quite make them all; these bacteria are called auxotrophs.

Oxygen: The presence of oxygen affects a few different aspects of microbial growth . Different microbes respond differently to oxygen. The term obligate refers to the absolute need for something, whereas the term facultative means that they can function in conditions that are not their preferred conditions.

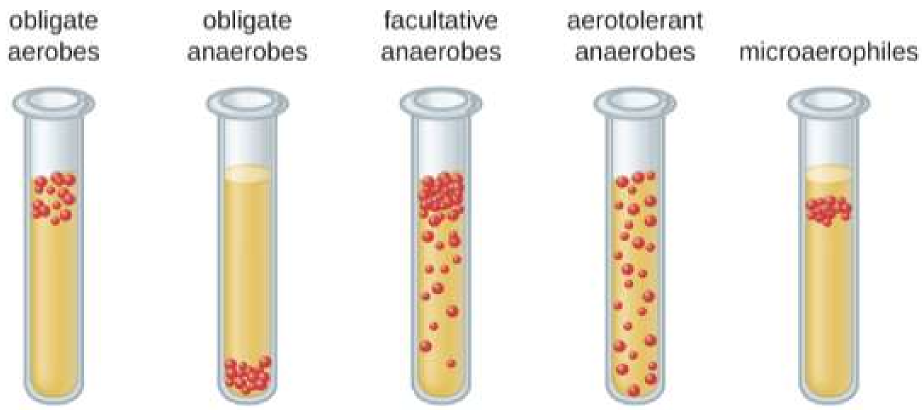


Diagram of bacterial cell distribution in thioglycolate tubes according to their oxygen requirements (https://openstax.org/details/books/microbiology)

Aerobes use oxygen in their metabolism as the terminal electron acceptor for the electron transport chain in respiration.Different aerobes can grow in a range of oxygen concentrations for example:

Some microbes, simply called **aerobes**, grow well at full oxygen levels (about 21 percent in air).

Microaerophiles prefer to grow in conditions where the concentration of oxygen is very low.

Facultative aerobes either grow either in the presence or the absence of oxygen. When oxygen is present these organism use it during respiration and when oxygen isn't present they use other pathways for their metabolism.

Anaerobes don't use oxygen for their metabolism but instead these type of microbes use fermentation or anaerobic respiration. Different anaerobes respond differently to oxygen in their environment:

Obligate anaerobes are either inhibited or killed by oxygen. They live in environments that are devoid of all oxygen, like aquatic sediments or the colon of animals.

Aerotolerant anaerobes essentially ignore oxygen in their environment and can grow well in it's presence or absence. Because they lack the citric acid cycle and/or an electron transport chain, they don't switch to aerobic respiration when oxygen is present.

Culturing Microorganisms and Culture Media

The culture medium used for a particular microbe must contain all the chemical requirements for that organism, as well as have the right pH and solute concentration and be incubated at the right temperature and oxygen conditions. Here are some of the different kinds of culture media.

Chemically defined media are those where the concentration of all the components within it are known. Often, chemically defined media are used to study specific aspects of microbial growth and metabolism.

Complex media are those in which the concentration of nutrients is unknown. These media are used most commonly in microbiology labs because they work well to culture a variety of microorganisms. Complex media contain ingredients such as animal or plant products, for which the exact chemical ingredients are not known. They're often used to grow enough microbial biomass to be used for research.

Anaerobic growth media contains reducing agents that remove the oxygen dissolved in them.

Selective media are used to isolate particular microbes of interest. The idea behind selective media is to discourage or completely inhibit the growth of all but the microbe that you want to culture. This is accomplished through the use of additives that are harmful to all but the microbe of interest and conditions that favor the desired microbe, which then outgrows the rest.

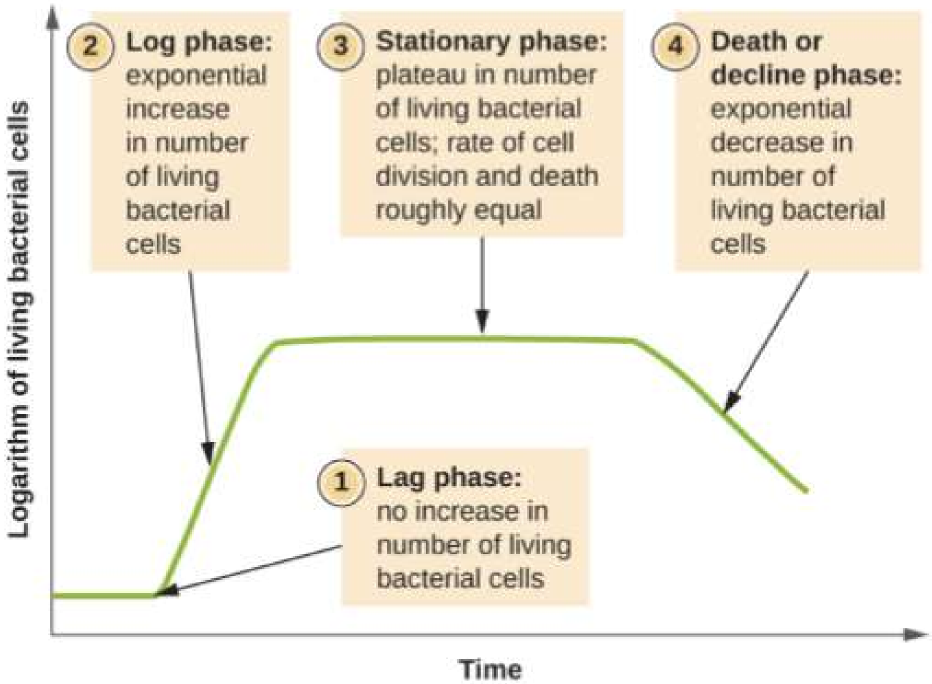
Enrichment media is a type of selective media specifically designed to encourage the growth of microbes that are either present in a sample in very small numbers or are easily outcompeted by the other microbes in the sample. If the microbes that you want to grow metabolize something rare, like phenol, it can be added as the sole carbon source and only allow microbes that degrade it to grow.

Differential media contains compounds that change color depending on the metabolism of the microbes present. An example of this is blood agar on which bacteria form halos around their colonies as they lyse (break open), red blood cells.

Each of these types of media can be used as a **liquid** or as a **solid**. To make the solid version of each medium, **agar** (a substance extracted from algae) is added to the medium and then it's heated (usually during sterilization). The mixture is poured into a container. Upon cooling, the agar sets the medium into a semisolid form on which microbial cultures can grow.

The Growth Curve

Microorganisms grown in closed culture (also known as a batch culture), in which no nutrients are added and most waste is not removed, follow a reproducible growth pattern referred to as the growth curve. An example of a batch culture in nature is a pond in which a small number of cells grow in a closed environment. The culture density is defined as the number of cells per unit volume. In a closed environment, the culture density is also a measure of the number of cells in the population. Infections of the body do not always follow the growth curve, but correlations can exist depending upon the site and type of infection. When the number of live cells is plotted against time, distinct phases can be observed in the curve.



The growth curve of a bacterial culture is represented by the logarithm of the number of live cells plotted as a function of time. The graph can be divided into four phases according to the slope, each of which matches events in the cell. The four phases are lag, log, stationary, and death. (https://openstax.org/details/books/microbiology, 02, 2020)

References:

1- Alcamo's Fundamentals of Microbiology, 2011, Ninth Edition (9 ed.) by Jeffrey C. Pommerville, Jones & Bartlett Publishers, Canada

2- "Download for free at https://openstax.org/details/books/microbiology."

3- Microbiology for Dummies,