Lecture 8

Microbial Nutrition, Ecology, and Growth

Microbial Nutrition

Nutrition – process by which chemical substances (nutrients) are acquired from the environment and used in cellular activities

Essential nutrients – must be provided to an organism

Two categories of essential nutrients:

- **Macronutrients** – required in large quantities; play principal roles in cell structure and metabolism
  - Proteins, carbohydrates
- **Micronutrients** or **trace elements** – required in small amounts; involved in enzyme function and maintenance of protein structure
  - Manganese, zinc, nickel

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Nutrients

- **Organic nutrients** – contain carbon and hydrogen atoms and are usually the products of living things
  - Methane (CH_4), carbohydrates, lipids, proteins, and nucleic acids
- **Inorganic nutrients** – atom or molecule that contains a combination of atoms other than carbon and hydrogen
  - Metals and their salts (magnesium sulfate, ferric nitrate, sodium phosphate), gases (oxygen, carbon dioxide) and water

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Chemical

Analysis of Cell Contents

70% water/Proteins/96% of cell is composed of 6 elements:

Carbon/Hydrogen/Oxygen/Phosphorous/Sulfur/Nitrogen

Sources of Essential Nutrients

- Carbon sources
- **Heterotroph** – must obtain carbon in an organic form made by other living organisms such as proteins, carbohydrates, lipids, and nucleic acids
- **Autotroph** – an organism that uses CO_2, an inorganic gas as its carbon source
  - Not nutritionally dependent on other living things

Growth Factors: Essential Organic Nutrients

- Organic compounds that cannot be synthesized by an organism because they lack the genetic and metabolic mechanisms to synthesize them
- **Growth factors** must be provided as a nutrient
  - Essential amino acids, vitamins

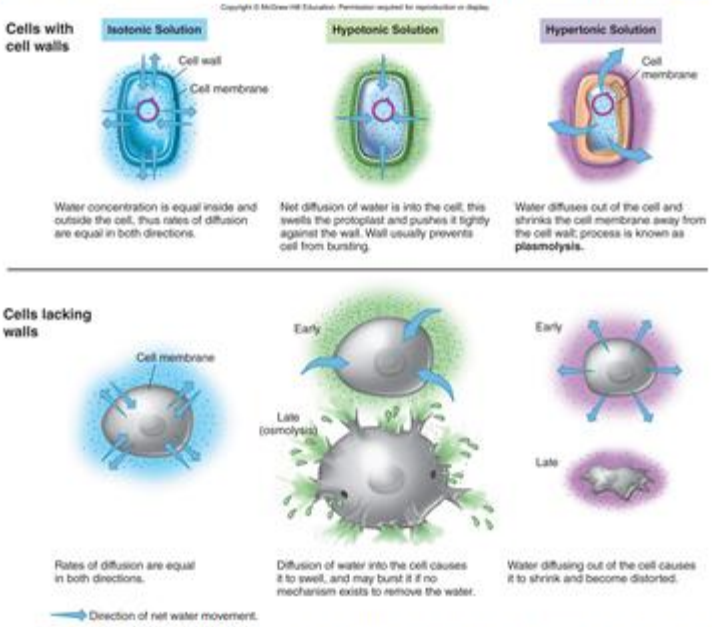
Nutritional Types

- Main determinants of nutritional type are:
  - Carbon source – heterotroph, autotroph
  - Energy source
    - **Chemotroph** – gain energy from chemical compounds
    - **Phototrophs** – gain energy through photosynthesis

Transport: Movement of Chemicals Across the Cell Membrane

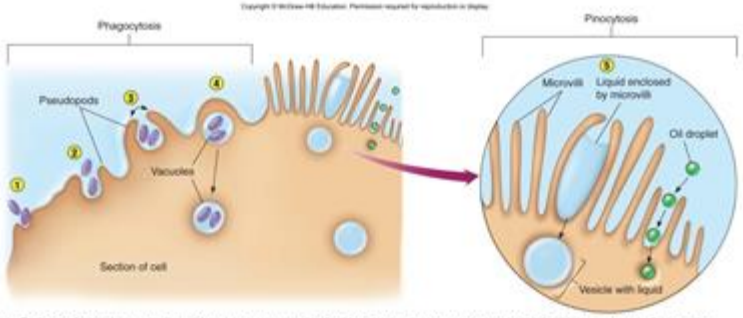
- **Passive transport** – does not require energy; substances exist in a gradient and move from areas of higher concentration toward areas of lower concentration
  - Diffusion
  - Osmosis – diffusion of water
  - Facilitated diffusion – requires a carrier
- **Active transport** – requires energy and carrier proteins; gradient independent
  - Active transport
  - Group translocation – transported molecule chemically altered
  - Bulk transport – endocytosis, exocytosis, pinocytosis

Response to solutions of different osmotic content



Endocytosis: Eating and Drinking by Cells

- **Endocytosis**: bringing substances into the cell through a vesicle or phagosome
  - **Phagocytosis** ingests substances or cells
  - **Pinocytosis** ingests liquids



(c) **Endocytosis.** With phagocytosis, solid particles are engulfed by flexible cell extensions or pseudopods (1,000X). (5) With pinocytosis, fluids and/or dissolved substances are enclosed in vesicles by very fine protrusions called microvilli (3,000X). Oil droplets fuse with the membrane and are released directly into (1-4) the cell.

Summary of Transport Processes

TABLE 7.3 Summary of Transport Processes in Cells

General Process	Nature of Transport	Examples	Description	Qualities
Passive 	Energy expenditure by the cell is not required. Substances exist in a gradient and move from areas of higher concentration toward areas of lower concentration in the gradient.	Diffusion osmosis	A fundamental property of atoms and molecules that exist in a state of random motion	Nonspecific Brownian movement Movement of small uncharged molecules across membranes
		Facilitated diffusion	Molecule binds to a carrier protein in membrane and is carried across to other side.	Molecule specific; transports both ways Transports sugars, amino acids, water
Active 	Energy expenditure is required. Molecules need not exist in a gradient. Rate of transport is increased. Transport may occur against a concentration gradient.	Carrier-mediated active transport	Atoms or molecules are pumped into or out of the cell by specialized receptors; driven by ATP or other high-energy molecules	Transports simple sugars, amino acids, inorganic ions (Na^+, K^+)
		Group translocation	Molecule is moved across membrane and simultaneously converted to a metabolically useful substance.	Alternate system for transporting nutrients (sugars, amino acids)
		Bulk transport	Mass transport of large particles, cells, and liquids by engulfment and vesicle formation	Process is endocytosis; examples are phagocytosis and pinocytosis

Environmental Factors That Influence Microbes

- Niche: totality of adaptations organisms make to their habitat
- Environmental factors affect the function of metabolic enzymes
- Factors include:
  - Temperature
  - Oxygen requirements
  - pH
  - Osmotic pressure
  - Barometric pressure

3 Cardinal Temperatures

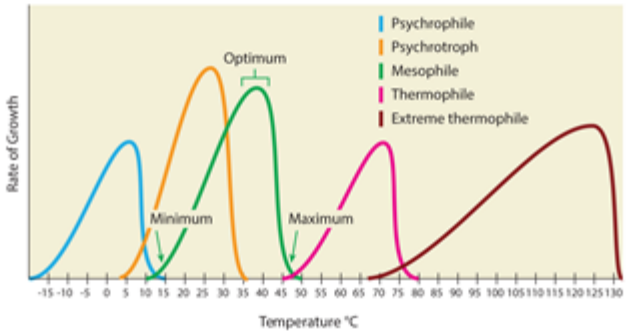
- **Minimum temperature** – lowest temperature that permits a microbe's growth and metabolism
- **Maximum temperature** – highest temperature that permits a microbe's growth and metabolism
- **Optimum temperature** – promotes the fastest rate of growth and metabolism

3 Temperature Adaptation Groups

Psychrophiles – optimum temperature below 15°C; capable of growth at 0°C

Mesophiles – optimum temperature 20°-40°C; most human pathogens

Thermophiles – optimum temperature greater than 45°C



Gas Requirements

Oxygen

- As oxygen is utilized it is transformed into several toxic products:
  - Singlet oxygen ($^1O_2$), superoxide ion (O_2^-), peroxide (H_2O_2), and hydroxyl radicals (OH^-)
- Most cells have developed enzymes that neutralize these chemicals:
  - Superoxide dismutase, catalase
- If a microbe is not capable of dealing with toxic oxygen, it is forced to live in oxygen free habitats

Categories of Oxygen Requirement

- **Aerobe** – utilizes oxygen and can detoxify it
- **Obligate aerobe** – cannot grow without oxygen
- **Facultative anaerobe** – utilizes oxygen but can also grow in its absence
- **Microaerophilic** – requires only a small amount of oxygen
- **Anaerobe** – does not utilize oxygen
- **Obligate anaerobe** – lacks the enzymes to detoxify oxygen so cannot survive in an oxygen environment
- **Aerotolerant anaerobes** – do not utilize oxygen but can survive and grow in its presence

Culturing by Oxygen Requirement

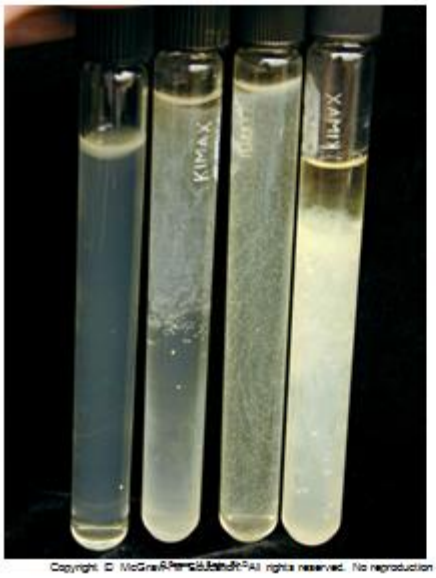


Photo by Keith Weller, USDA/ARS

Carbon Dioxide Requirement

All microbes require some carbon dioxide in their metabolism

- **Capnophile** – grows best at higher CO_2 tensions than normally present in the atmosphere

Courtesy of BD Becton, Dickinson and Company

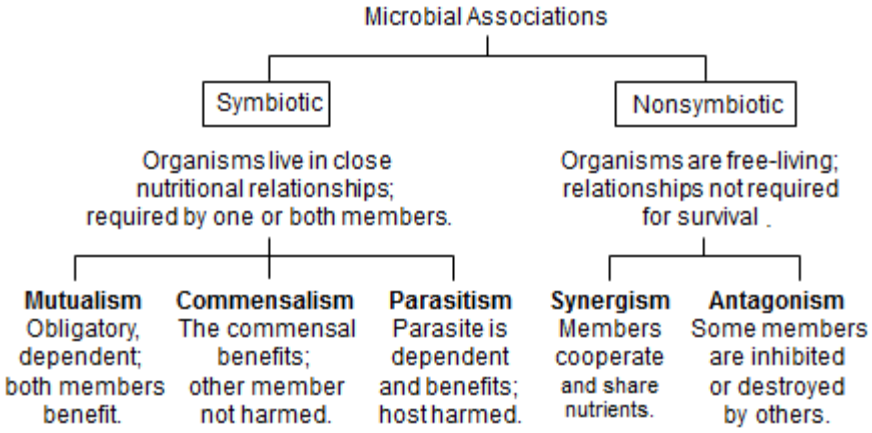
Effects of pH

- Majority of microorganisms grow at a pH between 6 and 8 (**neutrophiles**)
- **Acidophiles** – grow at extreme acid pH
- **Alkalinophiles** – grow at extreme alkaline pH

Osmotic Pressure

- Most microbes exist under hypotonic or isotonic conditions
- **Halophiles** – require a high concentration of salt
- **Osmotolerant** – do not require high concentration of solute but can tolerate it when it occurs
- **Barophiles** – can survive under extreme pressure and will rupture if exposed to normal atmospheric pressure

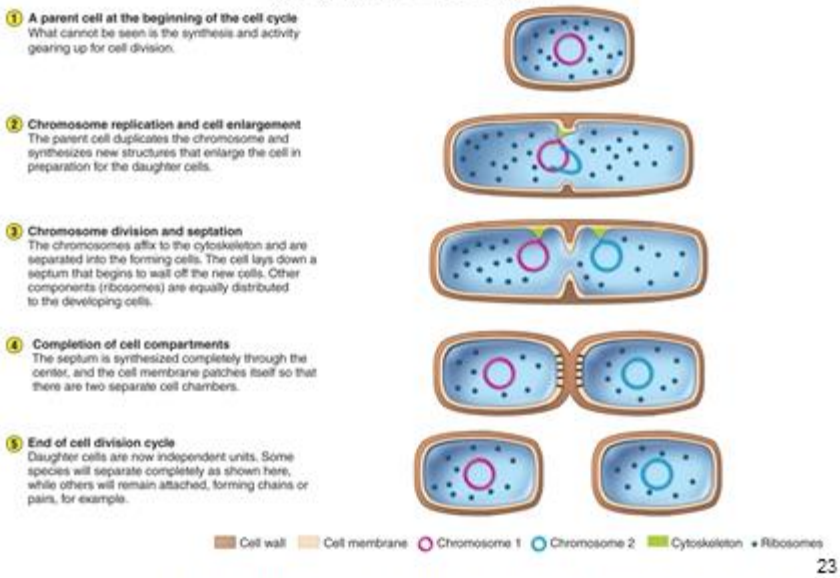
Ecological Associations Among Microorganisms



The Study of Microbial Growth

- Microbial growth occurs at two levels: growth at a cellular level with increase in size, and increase in population
- Division of bacterial cells occurs mainly through **binary fission** (transverse)
  - Parent cell enlarges, duplicates its chromosome, and forms a central transverse septum dividing the cell into two daughter cells

Binary Fission



Rate of Population Growth

- Time required for a complete fission cycle is called the **generation**, or **doubling** time
- Each new fission cycle increases the population by a factor of 2 – **exponential** growth
- Generation times vary from minutes to days

The Population Growth Curve

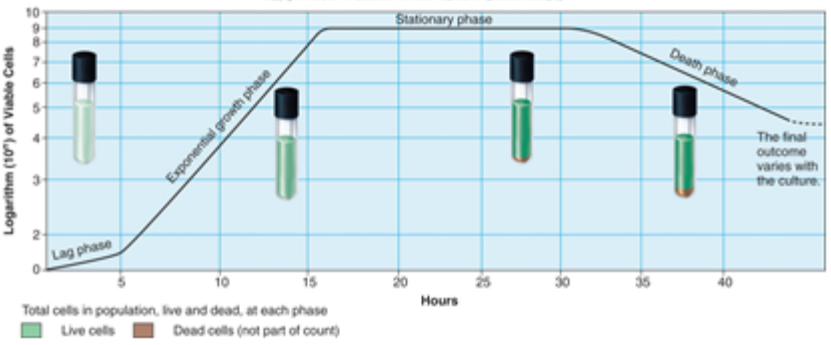
In laboratory studies, populations typically display a predictable pattern over time – **growth curve**

Stages in the normal growth curve:

1. **Lag phase** – "flat" period of adjustment, enlargement; little growth
2. **Exponential growth phase** – a period of maximum growth will continue as long as cells have adequate nutrients and a favorable environment.
3. **Stationary phase** – rate of cell growth equals rate of cell death caused by depleted nutrients and O_2, excretion of organic acids and pollutants.
4. **Death phase** – as limiting factors intensify, cells die exponentially

The Population Growth Curve

Stages in the normal growth curve



Methods of Analyzing Population Growth

- Turbidometry – most simple
- Degree of cloudiness, turbidity, reflects the relative population size

Methods of Analyzing Population Growth

- Enumeration of bacteria:
  - Viable colony count
  - Direct cell count – count all cells present; automated or manual

Methods of Analyzing Population Growth

Direct cell count – count all cells present; automated or manual