MICROBIAL NUTRITION & GROWTH

Chapter 6

Microbiology – CCV

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GROWTH REQUIREMENTS

- **Microbial Growth**
  - **Increase in a population** of microbes
  - Due to **reproduction** of individual microbes
  - Results in discrete colony or biofilm
    - **Colony** — aggregation of cells arising from single parent cell
    - **Biofilm** — collection of microbes living on a surface in a complex community

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GROWTH REQUIREMENTS

- Organisms use a variety of **nutrients** for their energy needs and to build organic molecules and cellular structures
- Most common nutrients contain necessary elements such as carbon, oxygen, nitrogen, and hydrogen
- Microbes obtain nutrients from variety of sources

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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - Sources of carbon, energy, and electrons
    - Organisms classified into two groups based on **source of carbon**
      - **Autotrophs**—use inorganic carbon (ie carbon dioxide)
      - **Heterotrophs**—use catabolic process to obtain carbon from outside source
    - Organisms classified into two groups based on **source of energy**
      - **Chemotrophs**—acquire energy from redox reactions
      - **Phototrophs**—acquire energy from light

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FIGURE 6.1 FOUR BASIC GROUPS OF ORGANISMS BASED ON THEIR CARBON AND ENERGY SOURCES.

Carbon source	Energy source: Light (*photo-*)	Energy source: Chemical compounds (*chemo-*)
Carbon dioxide (*auto-*)	***Photoautotrophs*** • Plants, algae, and cyanobacteria use H_2O as an electron source to reduce CO_2, producing O_2 as a by-product • Green sulfur bacteria and purple sulfur bacteria use H_2S as an electron source; they do not produce O_2	***Chemoautotrophs*** • Hydrogen, sulfur, and nitrifying bacteria, some archaea
Organic compounds (*hetero-*)	***Photoheterotrophs*** • Green nonsulfur bacteria and purple nonsulfur bacteria, some archaea	***Chemoheterotrophs*** • Aerobic respiration: most animals, fungi, and protozoa, and many bacteria • Anaerobic respiration: some animals, protozoa, bacteria, and archaea • Fermentation: some bacteria, yeasts, and archaea

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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - Sources of carbon, energy, and electrons
    - Organisms classified into two groups based on **source of electrons**
      - **Organotrophs** — heterotrophs acquire electrons from same organic molecules that provide them carbon
      - **Lithotrophs** — autrotrophs acquire electrons from inorganic molecules

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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - **Oxygen requirements**
    - Oxygen is essential for **obligate aerobes**
    - Oxygen is deadly for **obligate anaerobes**
    - How can this be true?
      - Toxic forms of oxygen are highly reactive and excellent oxidizing agents
      - Resulting oxidation causes irreparable damage to cells

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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - **Oxygen requirements**
    - **Aerobes**—oxygen is necessary
    - **Anaerobes**—oxygen is toxic
    - **Facultative anaerobes**—organisms can live with or without oxygen
    - **Aerotolerant anaerobes**--organisms which prefer anaerobic conditions but can tolerate exposure to low levels of oxygen
    - **Microaerophiles**—organisms that require low levels of oxygen

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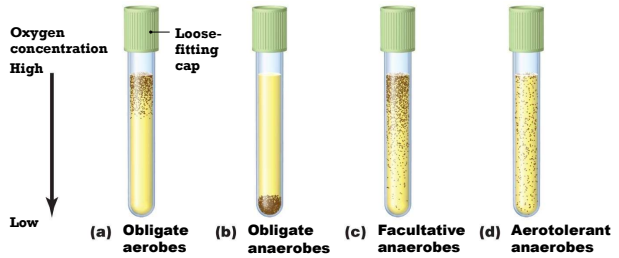
FIGURE 6.3 USING A LIQUID THIOGLYCOLLATE GROWTH MEDIUM TO IDENTIFY THE OXYGEN REQUIREMENTS OF ORGANISMS.



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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - **Nitrogen requirements**
    - Anabolism often ceases because of insufficient nitrogen (rate-limiting)
    - Nitrogen acquired from organic and inorganic nutrients
    - All cells recycle nitrogen from amino acids and nucleotides
    - Nitrogen fixation by certain bacteria is essential to life on Earth

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GROWTH REQUIREMENTS

- **Nutrients: Chemical and Energy Requirements**
  - **Other chemical requirements**
    - Phosphorus
    - Sulfur
    - Trace elements
      - Required only in small amounts
    - Growth factors
      - Necessary organic chemicals that cannot be synthesized by certain organisms

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TABLE 6.1 Some Growth Factors of Microorganisms and Their Functions

Growth Factor	Function
Amino acids	Components of proteins
Cholesterol	Used by mycoplasmas (bacteria) for cell membranes
Heme	Functional portion of cytochromes in electron transport system
NADH	Electron carrier
Niacin (nicotinic acid, vitamin B_3)	Precursor of NAD^+ and $NADP^+$
Pantothenic acid (vitamin B_5)	Component of coenzyme A
Para-aminobenzoic acid (PABA)	Precursor of folic acid, which is involved in metabolism of one-carbon compounds and nucleic acid synthesis
Purines, pyrimidines	Components of nucleic acids
Pyridoxine (vitamin B_6)	Utilized in transamination synthe-ses of amino acids
Riboflavin (vitamin B_2)	Precursor of FAD
Thiamine (vitamin B_1)	Utilized in some decarboxylation reactions

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GROWTH REQUIREMENTS

- **Physical Requirements**
  - **Temperature**
    - Temperature affects three-dimensional structure of proteins
    - **Lipid-containing membranes** of cells and organelles are temperature sensitive
      - If too low, membranes become rigid and fragile
      - If too high, membranes become too fluid

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FIGURE 6.4 THE EFFECTS OF TEMPERATURE ON MICROBIAL GROWTH.

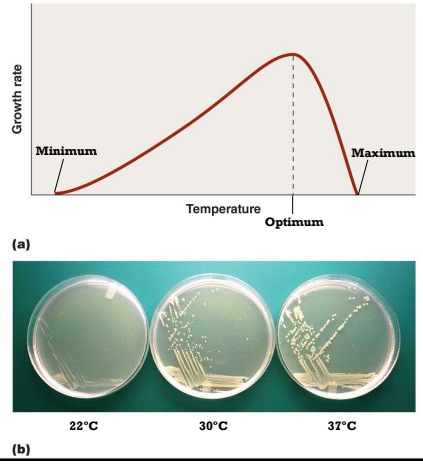

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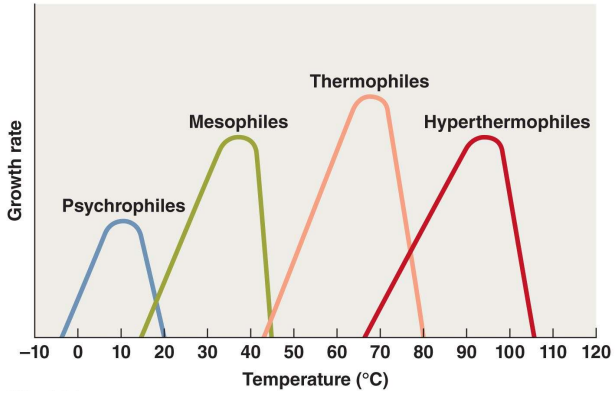
FIGURE 6.5 FOUR CATEGORIES OF MICROBES BASED ON TEMPERATURE RANGES FOR GROWTH.



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GROWTH REQUIREMENTS

- **Physical Requirements**
  - **pH**
    - Organisms are sensitive to changes in acidity
    - **Neutrophiles** grow best in a narrow range around neutral pH
    - **Acidophiles** grow best in acidic habitats
      - Many microbes produce acidic waste products that can accumulate and inhibit their growth
    - **Alkalinophiles** live in alkaline soils and water

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GROWTH REQUIREMENTS

- **Physical Requirements**
  - **Physical effects of water**
    - Microbes require water to dissolve enzymes and nutrients
    - Water is important reactant in many metabolic reactions
    - Most cells die in absence of water
      - Some have cell walls that retain water
      - Endospores and cysts cease most metabolic activity
    - Two physical effects of water
      - Osmotic pressure
      - Hydrostatic pressure

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GROWTH REQUIREMENTS

- **Physical Requirements**
  - Physical effects of water
    - **Osmotic pressure**
      - Pressure exerted on a semipermeable membrane by a solution containing solutes that cannot freely cross membrane
      - **Hypotonic solutions** have lower solute concentrations
        - Cell placed in hypotonic solution swells
      - **Hypertonic solutions** have greater solute concentrations
        - Cell placed in hypertonic solution shrivels
      - Restricts organisms to certain environments
        - Obligate and facultative halophiles

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GROWTH REQUIREMENTS

- **Physical Requirements**
  - Physical effects of water
    - **Hydrostatic pressure**
      - Water exerts pressure in proportion to its depth
      - **Barophiles** live under extreme pressure
        - Their membranes and enzymes depend on pressure to maintain their three-dimensional, functional shape

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GROWTH REQUIREMENTS

- **Associations and Biofilms**
  - Organisms live in association with different species
    - **Antagonistic relationships** — a microbe harms another organism
    - **Synergistic relationships** — members of an association receive benefits that exceed those that would result if each lived by itself
    - **Symbiotic relationships** — organisms become interdependent and rarely live outside the relationship

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GROWTH REQUIREMENTS

- **Associations and Biofilms**
  - **Biofilms**
    - Complex relationships among numerous microorganisms
    - Form on surfaces, medical devices, mucous membranes of digestive system
      - Form as a result of **quorum sensing**
    - Many microorganisms more harmful as part of a biofilm
    - Dental plaque is a biofilm that can lead to cavities
    - Scientists seeking ways to prevent biofilm formation

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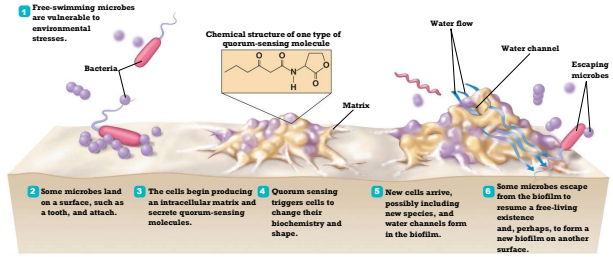
FIGURE 6.7 BIOFILM DEVELOPMENT.



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CULTURING MICROORGANISMS

- Inoculum introduced into nutrients called ***media***
  - Inocula obtained from various sources
    1) Environmental specimens
    2) Clinical specimens
    3) Stored specimens
- **Culture**
  - Act of cultivating microorganisms or the microorganisms that are cultivated

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FIGURE 6.8 CHARACTERISTICS OF BACTERIAL COLONIES.

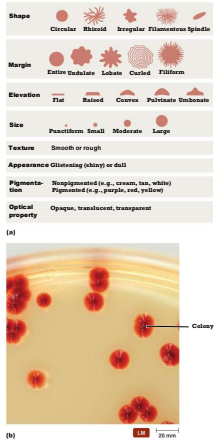

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TABLE 6.2 Clinical Specimens and the Methods Used to Collect Them

Type or Location of Specimen	Collection Method
Skin, accessible membrane (including eye, outer ear, nose, throat, vagina, cervix, urethra) or open wounds	Sterile swab brushed across the surface; care should be taken not to contact neighboring tissues
Blood	Needle aspiration from vein; antico-agulants are included in the specimen transfer tube
Cerebrospinal fluid	Needle aspiration from subarachnoid space of spinal column
Stomach	Intubation, which involves inserting a tube into the stomach, often via a nostril
Urine	In aseptic collection, a catheter is in-serted into the bladder through the ure-thra; in the "clean catch" method, initial urination washes the urethra, and the specimen is midstream urine
Lungs	Collection of sputum either dislodged by coughing or acquired via a catheter
Diseased tissue	Surgical removal (biopsy)

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CULTURING MICROORGANISMS

- **Obtaining Pure Cultures**
  - Pure cultures are composed of cells arising from a single progenitor
    - Progenitor is termed a ***colony-forming unit (CFU)***
  - **Aseptic technique** prevents contamination of sterile substances or objects
  - Two common **isolation techniques**
    1) Streak plates
    2) Pour plates

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FIGURE 6.9 THE STREAK-PLATE METHOD OF ISOLATION.

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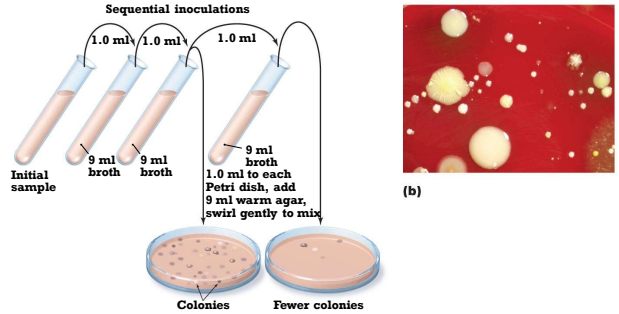
FIGURE 6.10 THE POUR-PLATE METHOD OF ISOLATION.



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CULTURING MICROORGANISMS

- **Obtaining Pure Cultures**
  - Other isolation techniques
    - Some fungi are isolated with streak and pour plates
    - Protozoa and motile unicellular algae are isolated through dilution of broth cultures
    - Can individually pick single cell of some large microorganisms and use to establish a culture

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CULTURING MICROORGANISMS

- **Culture Media**
  - **Nutrient broth** is common medium
  - **Agar** is a common addition to many media
    - Complex polysaccharide derived from certain red algae
    - Produces a solid surface for colonial growth
    - Most microbes cannot digest agar

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CULTURING MICROORGANISMS

- **Culture Media**
  - Six types of general culture media
    - Defined media
    - Complex media
    - Selective media
    - Differential media
    - Anaerobic media
    - Transport media

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CULTURING MICROORGANISMS

- **Culture Media**
  - **Defined media**
    - Medium in which the exact chemical composition is known
    - Fastidious organisms require the addition of a large number of growth factors

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CULTURING MICROORGANISMS

- **Culture Media**
  - **Complex media**
    - Exact chemical composition is unknown
    - Contain nutrients released by partial digestion of yeast, beef, soy, or proteins
    - Support growth of wide variety of microorganisms
    - Used to culture organisms with unknown nutritional needs

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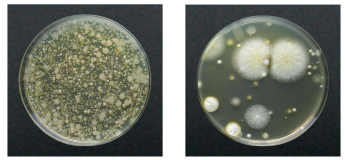
CULTURING MICROORGANISMS

Culture Media

- **Selective media**
  - Contain substances that either favor the growth of particular microorganisms or inhibit the growth of unwanted ones
  - A medium can become a selective medium when a single crucial nutrient is left out of it
  - Used to culture organisms with known nutritional needs

Selective Medium (@ right) favoring fungal growth but inhibiting bacterial growth



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CULTURING MICROORGANISMS

Differential Media

- Formulated to differentiate different types of bacteria in a sample based on key characteristics of behavior in the medium
- Ex: *Streptococcus pyogenes, Streptococcus pneumoniae, and Enterococcus faecalis* in sample at right

(L.= beta-hemolysis, middle = alpha-hemolysis, R = gamma-hemolysis)

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CULTURING MICROORGANISMS

- **Culture Media**
  - **Enrichment media**
    - Use of a selective medium to increase the numbers of a chosen microbe to observable levels
    - May require a series of cultures to enrich for the desired microbe
    - Cold enrichment used to enrich a culture with cold-tolerant species

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CULTURING MICROORGANISMS

- **Culture Media**
  - **Anaerobic media**
    - Obligate anaerobes must be cultured in the absence of free oxygen
    - Reducing media contain compounds that combine with free oxygen and remove it from the medium
    - Petri plates are incubated in anaerobic culture vessels
      - Sealable containers that contain reducing chemicals

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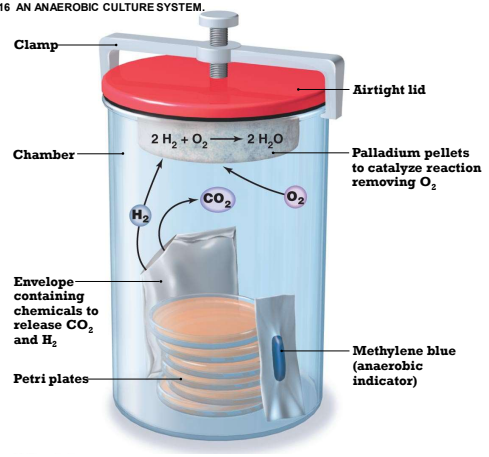
FIGURE 6.16 AN ANAEROBIC CULTURE SYSTEM.



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CULTURING MICROORGANISMS

- **Culture Media**
  - **Transport media**
    - Used by clinical personnel to ensure clinical specimens are not contaminated and to protect people from infection
    - Rapid transport of samples is important

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CULTURING MICROORGANISMS

- **Special Culture Techniques**
  - **Techniques developed for culturing microorganisms**
    - **Animal and cell culture**
      - Used when artificial media are inadequate
      - Required for growth of viruses and other obligate intracellular parasites

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BACTERIAL GROWTH

View the Study Area Video in Mastering Microbiology:

Study Area→Micro Animations→Microbial Nutrition & Growth→Bacterial Growth Overview

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BINARY FISSON

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Study Area→Micro Animations→Microbial Nutrition & Growth→Binary Fission

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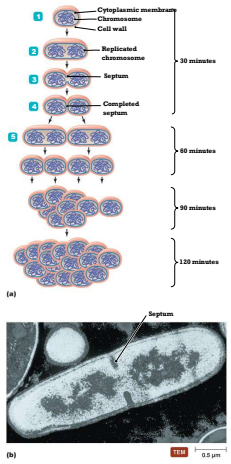
FIGURE 6.17 BINARY FISSION.



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GROWTH OF MICROBIAL POPULATIONS

- **Generation Time**
  - Time required for a bacterial cell to grow and divide
  - Dependent on chemical and physical conditions

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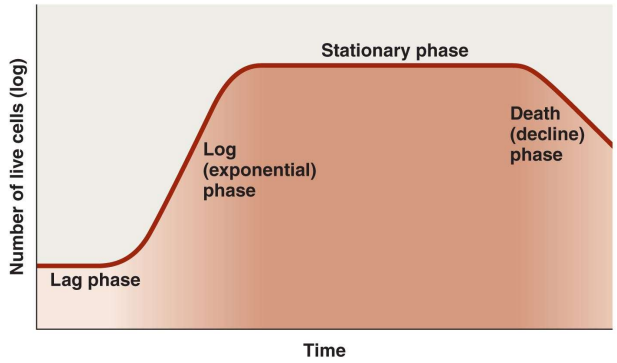
FIGURE 6.20 A TYPICAL MICROBIAL GROWTH CURVE.



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BACTERIAL GROWTH CURVE

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