Environmental Limits on Microbial Growth

- Temperature
- pH
- Osmolarity
- Oxygen
- Pressure
Changes in Temperature

- Growth rate increases with temperature
- Proteins denature if temperature too high

  - Microbial proteins adapted to temperature range:
    - Psychrophiles  
      - Cold: 0°C–20°C
    - Mesophiles  
      - 12°C–45°C
    - Thermophiles  
      - 40°C–80°C
    - Extreme thermophiles  
      - 65°C–113°C
Response to Temperature

- Heat shock response
  - Occurs at high end of temperature range
  - “Emergency” proteins produced
  - Help keep proteins from denaturing
  - Induced by many stressful conditions
    - Heat
    - High salt concentrations
    - Arid conditions
Variations in Pressure

- **Barophiles**
  - Adapted to high pressures
  - Up to 1,000 atm

- **Barotolerant organisms**
  - Grow at high, but not very high pressure

- **Barosensitive organisms**
  - Die at high pressure
    - Most “typical” bacteria, all mammals
Changes in Water Activity

- Solute changes raise osmolarity
- High osmolarity reduces available water
- Osmotic pressure can burst membranes
  - Low osmotic pressure outside cell
    - Mechanosensitive channels relieve stress
    - Release cell contents
  - High osmotic pressure outside cell
    - Cells synthesize osmolytes
    - Increase internal osmolarity
Changes in Water Activity

- Halophiles
- Require high concentration of NaCl
  - 2–4 M (10x seawater)
  - Live in salt seas
Changes in pH

- Enzymes only work in narrow pH range
  - Amino acids must have correct charges
    - pH levels alter concentration of $H^+$
- Bacteria regulate internal pH
  - When environment is in similar pH range
- Weak acids can pass through membranes
  - Disrupt cell pH homeostasis, kills cells
  - Good food preservatives
Changes in pH

- Neutralophiles
  - Grow at pH 5–8
  - Include bacteria in gut

- Acidophiles
  - Grow at pH 0–5
    - Some grow in stomach acid
    - Some in sulfuric acid springs

- Alkalophiles
  - Grow at pH 9–11
    - Found in soda lakes
Oxygen as Electron Acceptor

- **Aerobes**—O$_2$ is ultimate electron acceptor
  - Very strong electron acceptor
  - Can oxidize, damage proteins

- **Anaerobes**
  - Reactive oxygen species (ROS) produced
    - Oxidize, damage proteins

- **Microaerophiles**
  - Can tolerate low levels of O$_2$
    - Catalase inactivates ROS
Other Electron Acceptors

- Anaerobes pass electrons to different ultimate electron acceptors
  - Anaerobic respiration
    - Inorganic electron acceptors
      - Nitrate nitrite, thiosulfate
  - Fermentation
    - Organic electron acceptors
- Thrive in anaerobic environments
  - Early Earth, deep water, lower gut
Nutrient Deprivation, Starvation

- Lack of nutrients slows cell metabolism
  - Stimulates stress responses
  - Cells spread farther
  - Sporulation

- Oligotrophs
  - Most microbes
  - Efficiently absorb N$_2$, PO$_4$ from nutrient-poor environments
    - Many nutrients at low environmental levels
Controlling Microbial Growth

- Microbes die at logarithmic rate
- **D-value** = time to kill 90% of cells
  - 2 D-values = time to kill 99% of cells
- Antimicrobial agents decrease D-value
  - Kills cells faster
Physical Agents—Temperature

- Pasteurization
  - 63°C for 30 minutes

- Flash pasteurization
  - 72°C for 15 seconds
  - Pasteurization treatments do NOT kill all cells
    - Pasteurized food spoils eventually
    - Leaves food tasting normal

- UHT—Ultra-high temperature
  - 150°C for 3 seconds
    - Sterilizes—all bacteria killed
      - Used for creamers
Physical Agents
—Temperature + Pressure

- Autoclave = steam cooker
  - 121°C, 15 psi (2 atm) for 20 minutes
  - Kills all bacteria
  - Kills endospores
    - *Clostridium botulinum*
      - Botulism
    - *Bacillus anthracis*
      - Anthrax
Physical Agents—Other Methods

- Cold temperature—refrigeration
  - Slows growth, does not kill all bacteria

- Freezing

- Irradiation
  - UV, X-rays, γ-rays

- Filtration
Chemical Agents

- Disinfectants
  - Kill all microbes
  - Destroys eukaryotic cells as well
    - Cannot be used inside patients
  - Bleach (chlorine), Betadyne (iodine)
  - Soap
  - Detergents
Chemical Agents

- Antibiotics
  - Selectively kills microbes
    - May not work on all species
  - Has minimal effect on eukaryotic cells
    - Can be used inside patients
  - Interferes with bacterial-specific enzymes
    - Cell wall synthesis
    - Bacterial ribosome
**Penicillin**

- Many derivatives
- Blocks cell wall synthesis
- Growing bacteria lyse
  - Slow-growing bacteria take longer to die

Weakening cell wall
Biological Agents

- Probiotics
  - “Good” bacteria
  - Displace disease organisms from tissues

- Bacteriophages
  - “Phages”
  - Viruses that attack bacteria
  - Do not harm eukaryotes