Taxonomy and Cell Structure/Function
Evidence of Life

- Stromatolites
- Isotope ratios
  - Limestone depleted of $^{12}\text{CO}_2$
- Microfossils

Filamentous Prokaryotes

Cyanobacteria

Algae
Microbial Taxonomy

- Hard to classify microbial species
  - Asexual reproduction
  - Horizontal gene transfer
    - Some genes can be copied to a recipient bacterium
      - Not entire genome
      - Sometimes transfers occur between species
    - Example: pathogenicity islands
      - Large set of genes present in some strains of a species
        - Absent in other strains
Taxonomic Identification

- Use metabolic, morphologic properties
  - Reflect genetic background
  - Growth substrates
  - Biochemical structure
    - Cell envelope—Gram stain

- Rapid pathogen identification
  - Multiple color tests
    - Results scored to give most probable species

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Microbial Divergence

- Mutation naturally occurs at each division
  - One mistake in a million base pairs
    - Higher if a mutagen is present
- Very rare mutations are favorable
  - Allow better survival of cell
    - Faster growth, higher reproduction rate
  - Or allow cell to attack competitors
    - Antibiotics made by bacteria
Three Domains of Life

Carl Woese
Molecular Clocks

- Assume mutations accumulate steadily
  - Constant rate per generation
- Sequence differences are proportional to number of generations since divergence
- Best to compare conserved sequences
  - Gene for small subunit rRNA
- Adjustments to rate
  - Conservation of sequences needed for function
Phylogenetic Trees

- Relate differences between sequences
  - To time since species divergence
- Assume fewest possible changes
  - “Maximum parsimony”

- Test trees via probability
  - “Maximum likelihood”
    - Tree most likely to give the observed sequences
Figure 3.53

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(a) Intermembrane space
Crista
Matrix
Inner membrane
Outer membrane

(b) © Keith Porter/Photo Researchers, Inc.

Scale: 0.1 µm
Figure 3.23

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(a) 

Flagellum
Pili

(b) 0.5 µm

Chromosome (DNA)
Ribosomes
Cytoplasm
Nucleoid
Cytoplasmic membrane
Cell wall
Capsule

The Bacterial Cell

- Cytoplasm surrounded by envelope
  - Cytoplasm contains DNA in nucleoid
- Envelope has lipid membrane boundary
  - Plus structural cell wall
Cell Membranes

- Made of lipid bilayer
  - Double layer of phospholipids
- Separate cytoplasm from outside world
- Proteins embedded in membrane
  - Anchor membranes to envelope
  - Sense the outside world
  - Transport materials into cell
Cell Transport

- Proton pumps push protons out of cell
  - Generates proton-motive force (PMF)
    - Osmotic force tries to push protons back into cell
    - Electrical force tries to push protons back into cell

- PMF is used to create ATP
  - ATP synthase uses PMF for energy
Cell Transport

- Transporters pass material into/out of cell
  - Passive transport follows gradient of material
- Pumps use energy
  - ATP or PMF
  - Move material against their gradient
- Passive diffusion lets small molecules into cell
The Bacterial Cell Wall

- Sacculus made of peptidoglycan
  - Sugar chains wrapped in circles around cell
    - “glyco” = “sweet”
  - Sugar chains linked to each other by short polymers of amino acids
    - amino acid = “peptide”

- polysaccharide (sugar) chains
- peptide (amino acid) crosslinks
The Gram-Positive Envelope

- Capsule (not all species)
  - Polysaccharide
- S Layer (not all species)
  - Made of protein
- Thick cell wall
  - 9-amino acid crosslinks in peptidoglycan
  - Teichoic acids for strength
- Thin periplasm
- Plasma membrane
The Gram-Negative Envelope

- Capsule (not all species)
  - Polysaccharide
- Outer Membrane
  - Lipopolysaccharide
    - In outer leaflet only
- Thin cell wall
  - 4-amino acid crosslinks in peptidoglycan
- Thick periplasm
- Plasma membrane
The Bacterial Nucleoid

- Single loop of double-stranded DNA
  - Single molecule of DNA
  - ~$4 \times 10^6$ bp in many bacteria
  - Compacted via supercoiling
- Attached to cell envelope
  - No membrane separates DNA from cytoplasm
- Replicates once for each cell division
Photosynthesis

- Cyanobacteria have thylakoids
  - Extensively folded inner membrane
  - Contain chlorophyll
  - Ancestors of chloroplasts
- Carboxysomes fix carbon
  - Use energy to make sugar
- Other bacterial photosynthetic pigments
  - Purple membranes in some
  - Phycobilisome proteins collect light energy
Storage Granules

- Intracellular deposits of material
  - Glycogen (sugar) for energy
  - PHB (fatty acid polymer) for energy
  - Polyphosphate to store material
  - Sulfur for disposal

Iridescent sulfur granules

Carboxysomes, lipid energy-storage granules
Cell Attachment

- Fimbriae and pili attach cells to surfaces
  - Thin filaments of protein “pilin”
- Stalks attach cells to surfaces
  - Extension of cell cytoplasm

- Secretion Systems attach cells to prey
  - Six types
    - Sex pilus is similar to type IV secretion system
  - Essential for bacterial pathogenicity
Cell Motility

- **Flagella**
  - Long, helical protein filaments
  - Attached at ends, or over whole cell

- **Flagella rotate to propel cell**
  - Base resembles type III secretion system
  - Proton passage drives rotation
    - Clockwise or counterclockwise
Chemotaxis

- Attractants cause counterclockwise rotation
  - Flagella bundle together
  - Push cell forward
    - “Run”

- Repellents cause clockwise rotation
  - Flagella fly apart together
    - “Tumble” = change of direction
Chemotaxis

- Runs + tumbles cause “random walk”
  - Receptors detect attractant concentrations
    - Sugars, amino acids
  - Attractant concentration increases and prolongs run
    - Biases random walk
    - Net movement of bacteria toward attractants