Bacteria and Archaea: The Prokaryotic Domains

Structure of a Prokaryotic Cell

Prokaryotic cells have a simple interior organization compared to Eukaryotes.
- True nucleus lacking
- Cytoskeleton lacking—support from rigid cell wall
- Membrane-bound organelles lacking (in most)

Endosymbiotic Theory

Nitrogen cycle

Mycobacterium tuberculosis
Color-enhanced images show rod-shaped bacterium responsible for tuberculosis (Raven et al. 2002)
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structure and function
origins, evolution and diversity
ecological function and relationships

1. Prokaryote Phylogeny
Genome of the Archaeon

*Methanococcus jannaschii* was sequenced in 1996. Sequencing of *M. jannaschii* confirmed Carl Woese’s long-standing hypothesis that life traces back to three main lineages, one of which (Archaea) includes prokaryotes that share a more recent common ancestry with eukaryotes than with the prokaryotic “true bacteria.”

Prokaryotic Structure and Function
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Sizes of viruses, bacteria and eukaryotes compared Most bacteria are 1-5 um diameter (most Eukaryotic cells are 10-100 um)

Cyanobacteria 10 um dia.
E. coli 1X2 um
Mycoplasma 0.3-0.8 um dia.
Bacteriophage 0.07X 0.2 um
Viroid 0.01 X 0.3 um
Lymphocyte 10 um dia.

Paramecium 30X 75 um

Largest known prokaryote is the marine bacterium Thiomargarita namibensis; bright white cell in upper left, about .75 mm dia., attached to two dead ones. Fruitfly in picture for size comparison.

Bacterial Form

Three shapes are especially common among bacteria – spheres, rods and spirals

Most are unicellular, some aggregate transiently, some form permanent aggregations of identical cells; some show division of labor between two or more specialized cell times
Scanning electron micrograph of a colony of streptomycetes, one of the actinomycetes. The actinomycetes have a much more complicated morphology than most other bacteria. (Keaton and Gould 1993)

- Most bacterial cell walls contain peptidoglycan (lacking in Archaea)
- Gram staining is an important technique for identifying bacterial; cells stain differentially based on structure and composition of walls
- Pathogenesis is related to cell wall structure and composition
- Many antibiotics act by preventing formation of cell walls, by inhibiting synthesis of cross-links in peptidoglycan
- Many prokaryotes produce capsules that function in adherence and protection
- Many prokaryotes have surface appendages called pili that are function in adherence

The exterior surfaces of Prokaryotes. Almost all prokaryotes have a cell wall, and in most that wall contains peptidoglycan — polymers of modified sugars that are cross-linked by short polypeptides.
Mechanisms of Motility  Many bacteria are motile. Flagellar action is the most common, but not the only mechanism, for generating movement.
• Prokaryotic flagella
• Flagella-like helical filaments
• Growing gelatinous threads

Motility Behavior
• Kinesis
• Taxis

Spirillum volutans  Borrelia burgdorferi

Aquaspirillum sinosum

Lyme disease symptoms, and the disease vector – a tick

Electron micrograph of E. coli showing long helical flagella.
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Bacteria swim by rotating their flagella.

Vibrio cholerae (pathogen responsible for cholera); the unsheathed core visible at top of photo is composed of a single crystal of the protein flagellin.

In intact flagella, core is surrounded by a flexible sheath. Rotary motion of the motor creates a kind of rotary motion when organism swims.

Bacteria swim by rotating their flagella.

Exensive folded photosynthetic membranes are visible in Prochloron cell. The single, circular DNA molecule is located in the clear area in the central region of the cell.

Cellular and Genomic Organization The organization of cellular components, including the genome, differs substantially between prokaryotes and eukaryotes
Prokaryote Reproduction and Population Growth  Prokaryote populations grow and adapt rapidly, through asexual reproduction as well as mechanisms involving gene transfer.

Dormancy and Endosporulation Some bacteria form highly resistant spores under harsh environmental conditions.

Antibiotic synthesis Some prokaryotes (and protists and fungi) synthesize and release antibiotic chemicals that inhibit growth of other microbes.

Adaptations to Harsh Environmental Conditions: Some bacteria are capable of dormancy, endosporulation and antibiotic synthesis.