Characteristics of life

- Organization
- Homeostasis
- Reproduction and heredity
- Growth and development
- Metabolism
- Interactions with environment
- Adaptation
Kingdoms Eubacteria and Archaeabacteria

Bacteria at tip of a pin
Organization

- Most are unicellular; some eubacteria form colonies
- No nucleus; no organelles, some w/specialized membranes
- Common shapes are spheres (cocci), rods (bacilli), and helices (spirilla and spirochetes)
- Size: 1-5 µm; largest one 0.75 mm
Bacteria colonies
Membranes in bacteria
bacilli

cocci

spirilla
Marine bacterium *Thiomargarita namibiensis*
Homeostasis

• Cell wall
  – Material: Peptidoglycan in eubacteria; no peptidoglycan in archaeabacteria (like eukaryotes)
  – Amount of peptidoglycan defines Gram stain. Large amount Gram-positive; low amount Gram-negative

• Capsule
• Pili
• Flagella
• Endospore
Bacilli with pili
Diagram of flagella
An anthrax endospore
Reproduction and heredity

• Single circle of DNA; no histones associated to DNA in eubacteria but they are observed in archaeabacteria as in eukaryotes; some prokaryotes have plasmids; DNA replication similar to eukaryotes
• No sexual reproduction; not known in archaea
• Binary fission; no mitosis or meiosis
• Gene transfer through:
  – Transformation
  – Conjugation
  – Transduction
• Mutation: main source of genetic variation
Conjugation between two bacteria cells
Growth and development

• In prokaryotes, the word growth mainly applies to multiplication of cells and increase in population size
• Generation times of 1-3 hours; some of 20 minutes
Metabolism

Classification based on energy and carbon sources

- **Photoautotrophs**: they use light as energy and CO2 as carbon source; e.g. cyanobacteria; in prokaryotes and photosynthetic eukaryotes
- **Chemoautotrophs**: use energy from inorganic chemicals and CO2 as carbon source; e.g. nitrifying bacteria; only in prokaryotes
- **Photoheterotrophs**: use light as energy and organic compounds as carbon source; e.g. *Heliobacteria*; only in some prokaryotes
- **Chemoheterotrophs**: use organic molecules as energy and carbon source; e.g. *Eschericia coli*; widely found in bacteria and eukaryotes
Metabolism cont.

• Prokaryotes vary on their use of O₂ for cellular respiration (degradation of organic compounds in cell to generate ATP)
  – Obligate aerobes. Only use O₂
  – Facultative aerobes. Can use O₂ or engage in fermentation
  – Obligate anaerobes. Are poisoned by O₂. Engage in fermentation or anaerobic respiration (cellular respiration powered by inorganic chemicals other than O₂)
Ecology

• Highly abundant: *Prochlorococcus* found at 70,000-200,000 cells ml⁻¹ of seawater
• Ubiquitous: up to 1500 m below Earth’s surface, in oceans from the surface to depths of 10,000 m; temperature range: 0-110°C
• Highly diverse: in human mouth up to 500 spp
• Conditions for optimal growth (T, pH, salt concentrations, nutrient sources) vary across spp
  – Most spp are highly specialized: *Lactobacillus*, methanogens, extreme halophiles, extreme thermophiles
  – Some species are generalists: *Escherichia coli*, nitrogen fixing cyanobacteria
Extreme halophiles
Ecology cont.

• Competition is high among bacteria spp. They use antibiotic to inhibit growth of other spp

• Symbiotic with many species from other taxa (domains)
  – Mutualism: nitrogen fixing bacteria, *Rhizobium*
  – Comensalism: bacteria living on human skin
  – Parasitism: Pathogens like *Streptococcus pneumoniae*, *Clostridium botulinum*, *Salmonella*
Bioluminescence caused by chemical reaction of symbiotic bacteria
Adaptation

• High capacity for adaptation to new environments
  – Mutation can be rapidly propagated through offspring since generation times are quite fast
  – Populations can adapt quickly to novel environments through natural selection
Importance

• Prokaryotes are indispensable links in the recycling of chemical elements in ecosystems
• Cause of human diseases
• Used in bioremediation
• Metabolic factories for commercial products
• Great systems for molecular and biochemical research
## Phylogeny of prokaryotes

### Domain Bacteria

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<th>Alpha</th>
<th>Beta</th>
<th>Gamma</th>
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### Domain Archaea

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### Domain Eukarya

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