

CH 27

Bacteria & Archaea

Contributing factors to Prokaryotic success

Earth's first organisms were likely prokaryotes.

Most prokaryotes are unicellular, although some species form colonies.

Most prokaryotic cells are 0.5–5 μm , much smaller than the 10–100 μm of many eukaryotic cells.

Prokaryotic cells have a variety of shapes.

The three most common shapes are spheres (cocci), rods (bacilli), and spirals.

Cell-Surface Structures

An important feature of nearly all prokaryotic cells is their cell wall, which maintains cell shape, protects the cell, and prevents it from bursting in a hypotonic environment.

Eukaryote cell walls are made of cellulose or chitin.

Bacterial cell walls contain peptidoglycan, a network of sugar polymers cross-linked by polypeptides.

Archaea contain polysaccharides and proteins but lack peptidoglycan.

Scientists use the Gram stain to classify bacteria by cell wall composition.

Gram-positive bacteria have simpler walls with a large amount of peptidoglycan.

Gram-negative bacteria have less peptidoglycan and an outer membrane that can be toxic.

Motility

In a heterogeneous environment, many bacteria exhibit taxis, the ability to move toward or away from a stimulus.

Chemotaxis is the movement toward or away from a chemical stimulus.

Most motile bacteria propel themselves by flagella scattered about the surface or concentrated at one or both ends.

Flagella of bacteria, archaea, and eukaryotes are composed of different proteins and likely evolved independently.

Oscillatoria VIDEO

Flagella VIDEO

Origins of Bacteria Flagella

Bacterial flagella are composed of a motor, hook, and filament.

Many of the flagella's proteins are modified versions of proteins that perform other tasks in bacteria.

Flagella likely evolved as existing proteins were added to an ancestral secretory system.

This is an example of exaptation, where existing structures take on new functions through descent with modification.

Internal Organization

Prokaryotic cells usually lack complex compartmentalization.
Some prokaryotes do have specialized membranes that perform metabolic functions.
These are usually infoldings of the plasma membrane.

The chromosome is not surrounded by a membrane; it is located in the nucleoid region.
Some species of bacteria also have smaller rings of DNA called plasmids.

There are some differences between prokaryotes and eukaryotes in DNA replication, transcription, and translation.
These allow people to use some antibiotics to inhibit bacterial growth without harming themselves.

Reproduction & Adaptation

Prokaryotes reproduce quickly by binary fission and can divide every 1–3 hours.

Key features of prokaryotic reproduction:

They are small

They reproduce by binary fission

They have short generation times

Many prokaryotes form metabolically inactive endospores, which can remain viable in harsh conditions for centuries.

Their short generation time allows prokaryotes to evolve quickly.

For example, adaptive evolution in a bacterial colony was documented in a lab over 8 years

Prokaryotes are not “primitive” but are highly evolved.

Rapid reproduction, mutation, and genetic recombination promote genetic diversity in prokaryotes

Prokaryotes have considerable genetic variation.

Three factors contribute to this genetic diversity:

Rapid reproduction

Mutation

Genetic recombination

Rapid Reproduction & Mutation

Prokaryotes reproduce by binary fission, and offspring cells are generally identical.

Mutation rates during binary fission are low, but because of rapid reproduction, mutations can accumulate rapidly in a population.

High diversity from mutations allows for rapid evolution.

Genetic Recombination

Genetic recombination, the combining of DNA from two sources, contributes to diversity.

Prokaryotic DNA from different individuals can be brought together by transformation, transduction, and conjugation.

Movement of genes among individuals from different species is called horizontal gene transfer.

Transformation & Transduction

A prokaryotic cell can take up and incorporate foreign DNA from the surrounding environment in a process called transformation.

Transduction is the movement of genes between bacteria by bacteriophages (viruses that infect bacteria).

Conjugation & Plasmids

Conjugation is the process where genetic material is transferred between prokaryotic cells.

In bacteria, the DNA transfer is one way.

A donor cell attaches to a recipient by a pilus, pulls it closer, and transfers DNA.

A piece of DNA called the F factor is required for the production of pili.

F Factor as a Plasmid

Cells containing the F plasmid function as DNA donors during conjugation.

Cells without the F factor function as DNA recipients during conjugation.

The F factor is transferable during conjugation.

Prokaryotes can be categorized by how they obtain energy and carbon.

Phototrophs obtain energy from light

Chemotrophs obtain energy from chemicals

Autotrophs require CO₂ as a carbon source

Heterotrophs require an organic nutrient to make organic compounds

Role of Oxygen in Metabolism

Prokaryotic metabolism varies with respect to O₂

Obligate aerobes require O₂ for cellular respiration

Obligate anaerobes are poisoned by O₂ and use fermentation or anaerobic respiration

Facultative anaerobes can survive with or without O₂

Nitrogen Metabolism

Nitrogen is essential for the production of amino acids and nucleic acids.

Prokaryotes can metabolize nitrogen in a variety of ways.

In nitrogen fixation, some prokaryotes convert atmospheric nitrogen (N₂) to ammonia (NH₃).

Archaea

Archaea share certain traits with bacteria and other traits with eukaryotes.

Some archaea live in extreme environments and are called extremophiles.

Extreme halophiles live in highly saline environments.

Extreme thermophiles thrive in very hot environments.

Methanogens live in swamps and marshes and produce methane as a waste product.

Methanogens are strict anaerobes and are poisoned by O₂.

In recent years, genetic prospecting has revealed many new groups of archaea.

Some of these may offer clues to the early evolution of life on Earth.

Prokaryotes play crucial roles in the biosphere

Prokaryotes are so important that if they were to disappear the prospects for any other life surviving would be dim.

Prokaryotes play a major role in the recycling of chemical elements between the living and nonliving components of ecosystems.

Chemoheterotrophic prokaryotes function as decomposers, breaking down dead organisms and waste products.

Prokaryotes can sometimes increase the availability of nitrogen, phosphorus, and potassium for plant growth.

Ecological Interactions

In mutualism, both symbiotic organisms benefit.

In commensalism, one organism benefits while neither harming nor helping the other in any significant way.

In parasitism, an organism called a parasite harms but does not kill its host.

Parasites that cause disease are called pathogens.

Beneficial & Harmful Impacts

Mutualistic Bacteria

Human intestines are home to about 500–1,000 species of bacteria

Many of these are mutualists and break down food that is undigested by our intestines

Pathogenic Bacteria

Prokaryotes cause about half of all human diseases

For example, Lyme disease is caused by a bacterium and carried by ticks