Origin of Prokaryotes

In 1862, Pasteur disproved the spontaneous-generation theory but left open a question: How did life begin? Miller's synthesis is a possible answer, or it may be the seeding of organic molecules by meteorites from outer space, or a God event that started life. It is generally held that the first organisms were formed around four billion years ago, with the earliest forms being simple molecular groupings that somehow gained the ability to metabolize and reproduce. It is also held that these simple molecular arrangements formed from existing inorganic substances—life from nonlife!

RNA World

RNA World describes the hypothetical time of the earliest life-forms when genes were simply strands of RNA. It is interesting to note that only nucleic acids have the ability to replicate and store genetic information, one of the fundamental characteristics of life. Referencing that certain prokaryotes and viruses do not contain DNA, but reproduce solely with RNA, it is also believed that the earliest life-forms were nucleic acids that simulated RNA in structure and function. Laboratory experiments confirmed that nucleotide monomers can spontaneously join to form gene-like structures composed of RNA segments. They can also create the complementary strand of RNA.

The strands of RNA were then available to serve as a template to bind amino acids together into polypeptides. Most long molecules, such as proteins, respond to the surface tension of water in an aquatic environment to spontaneously form circles and rings, called *microspheres*. These nonliving microspheres appear to function as a cell membrane. They have been shown to grow by adding monomers and divide as they become too large, and also demonstrate some selective permeability by allowing water-soluble substances to pass while prohibiting fat-soluble transport. Scientists hypothesize that these early rings may have surrounded RNA segments of genes to form a cooperative alliance. *Coacervates* are droplets of organic molecules that include amino acids and sugars. Both coacervates and microspheres spontaneously form into spheres under certain conditions. These conditions are thought to be similar to early Earth, such as a hot surface (a sunbaked or geologically heated rock, for instance). The heat provides the energy for the dehydration synthesis, which joins basic units together to make more complex molecules. Note that genes were not required!

Chemiautotrophic Prokaryotes and the Heterotroph Hypothesis

The advancements in prokaryote complexity may have evolved from a more efficient acquisition of food. Based on studies of archaebacteria, scientists theorize that the earliest prokaryotes absorbed energy from extracellular reactions to power the formation of ATP within the cell. These *chemiautotrophic* cells probably used carbon dioxide as the carbon source and the energy of ATP to construct larger and more complex molecules. Another theory, called the *heterotroph hypothesis*, suggests that the aquatic environment was full of organic molecules, including ATP, which were then absorbed into the cell for cellular functions. The first heterotrophs could have survived easily on the supposed soup of organic molecules in their consumptive environment. However, at some point the heterotrophs would inevitably exhaust their food supply and the autotrophic system would replace the heterotrophs and become established as the dominant life-form. In both cases, the presence of enzymes is necessary, and their origin is not fully understood.

Today prokaryotes are found everywhere life exists on Earth and greatly outnumber all eukaryotes combined. Prokaryotes contribute as decomposers and recyclers to such an extent that without them, eukaryotes would die off. However, prokaryotes could survive without eukaryotes as they have already demonstrated for about two billion years!

Prokaryote Evolution: Bacteria and Archaea

Prokaryotes are mostly bacteria, and their advancements led to more complex living organisms. It has been suggested that the diverse nature of bacteria and archaebacteria resulted from this evolution. As bacteria modified structures to expand their territory and tolerance, they changed into newer species of bacteria with diverse structures and functions. Due to their uniqueness, bacteria are classified in their own kingdom!

Advancements in the structure and function of prokaryotes continued to the juncture where two separate types are now identifiable: bacteria and archaea.

Bacteria and Cyanobacteria

Bacteria are the most common and well studied because they are the easiest to find and have historically been the source of many human maladies, such as bubonic plague, tuberculosis, and cholera, and the source of much advancement such as cheese, recombinant DNA, and intestinal flora, which aids in digestion and nutrient production.

Even today, anabaena, a typical cyanobacteria, blooms in nutrient overloaded aquatic environments to produce a telltale blue-green color. Environmentalists use anabaena blooms as an indicator of environmental quality.

Bacteria appear to be simpler than archaea because they do not possess certain advanced structures typical in archaea, such as the complex RNA polymerase, the presence of interons, and branched carbon chains in lipid membranes, as well as some internal membranes. However, they do possess a cell membrane and have definite life functions. They exist alone or in colonies, in a variety of shapes, and some can endure unfavorable conditions by forming a protective *endospore* around the cell, which allows the cell to remain viable and dormant until favorable conditions arrive. Bacteria and archaea do possess whiplike flagella for movement.

Cyanobacteria, also known as blue-green algae, are intriguing organisms because they contain photosynthetic capabilities and are thought to be responsible for changing the prehistoric environment to an oxygen atmosphere.

Microfossil cyanobacteria estimated to be 3.5 billion years old were discovered in Australia. Their hypothesized oxygen production likely also created the protective ozone layer.

Archaea

Archaea have structures such as tRNA nucleotide sequences and RNA polymerase that are more closely related to eukaryotes than bacteria. They have adapted complex protein, carbohydrate, and lipid molecules that allow them to live and reproduce in the harshest environments where nothing else will live. In fact, archaea are so different from bacteria that they are also classified in their own kingdom, separate from all other organisms! Many species are autotrophic and obtain energy through the chemosynthesis of carbon dioxide instead of the photosynthesis of carbon dioxide. Because of their extreme lifestyle, they do not have the history of scientific investigation that bacteria have generated, although they contain the solutions for expanding the genetic territory of other helpful microorganisms. For example, archaebacteria thrive in the hot springs in Yellowstone National Park where the water temperature is measured at 194°F (90°C).